REPORT OF THE EXPERT PANEL ON A DECLARED COMMERCIAL FISHING ACTIVITY:

FINAL (SMALL PELAGIC FISHERY) DECLARATION 2012

October 2014

Letter of Transmittal to the Minister

Dear Minister

I am pleased to present the report of the Expert Panel to Assess a Declared Commercial Fishing Activity (*Final (Small Pelagic Fishery) Declaration 2012*).

The report assesses and advises on:

1. the likely nature and extent of direct interactions of the Declared Commercial Fishing Activity with species protected under the *Environment Protection and Biodiversity Conservation Act* (EPBC Act), particularly seals and dolphins
2. the potential for any localised depletion of target species (arising from the Declared Commercial Fishing Activity) to result in adverse impacts to the Commonwealth marine environment, including the target species' predators protected under the EPBC Act
3. actions that could be taken by operators of the Declared Commercial Fishing Activity or relevant regulatory authorities to avoid, reduce and mitigate adverse environmental impacts of the activity
4. monitoring or scientific research that would reduce any uncertainties about the potential for adverse environmental impacts resulting from the Declared Commercial Fishing Activity.

The panel's advice on these issues was informed by consultation with national and international experts in the relevant fields, by targeted, commissioned research and by broader stakeholder consultation.

The panel members hope that this report will assist your assessment of the environmental impacts of the Declared Commercial Fishing Activity and help inform future government decision making on the Small Pelagic Fishery.

Mary Lack
Chair
Expert Panel on a Declared Commercial Fishing Activity

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Acknowledgements

The panel extends its sincere thanks to the members of the secretariat, Mr Nathan Hanna, Ms Genine Sutton and Dr Candace McBride of the Sustainable Fisheries Section, and to Ms Carolyn Armstrong of the Environmental Resources Information Network, in the Department of the Environment. The panel appreciates and values the time and effort of the experts, researchers, fishing industry members, government agencies and advisory bodies, conservation groups, Indigenous groups and recreational fishing organisations that provided advice, data and views to inform its assessment.

Executive summary

Background

The *Final (Small Pelagic Fishery) Declaration 2012* (the Declaration), prohibited large-scale mid-water trawl operations in the Small Pelagic Fishery (SPF) for up to two years while an expert panel (the panel) undertook an assessment of the potential for the Declared Commercial Fishing Activity (DCFA) to cause adverse environmental impacts.

The panel has assessed the direct impacts of the DCFA on species protected under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act), particularly seals and dolphins, and the adverse impacts of any localised depletion of SPF target species, caused by the DCFA, on the Commonwealth marine environment, including on the target species' predators protected under the EPBC Act. Based on that assessment, advice has been provided on actions that could be taken to avoid, reduce and mitigate any adverse environmental impacts, and scientific research and monitoring that could reduce uncertainties about those impacts. A synthesis of the panel's assessment and advice is presented in Chapter 7 and an overview of the key outcomes is provided below.

The DCFA

The DCFA is a commercial fishing activity which:

a. is in the area of the Small Pelagic Fishery

b. uses the mid-water trawl method

c. uses a vessel which is greater than 130 metres (m) in length, has an on-board fish processing facility and has storage capacity for fish or fish products in excess of 2000 tonnes.

A primary consideration in the panel's assessment was the likely pattern of fishing of the DCFA. The species targeted, the area and times of year fished and the intensity of that fishing will all have a large bearing on the nature and extent of interactions with protected species and those species that might be adversely affected by localised depletion arising from the DCFA.

A key characteristic of the DCFA is the ability to stay at sea for an extended period and, therefore, the potential to fish more extensively, spatially and temporally, in the SPF area than previous mid-water trawl operations in the fishery. The fishing plan of the DCFA in terms of species composition, the spatial/temporal pattern of fishing and the intensity of fishing, will be dictated by prevailing environmental and economic conditions. It was not possible for the panel to predict this fishing plan in detail but the panel considered that the DCFA would most likely focus its fishing effort on the shelf and slope areas of the SPF where the target species are predominantly distributed. The panel considered it likely that the DCFA would fish these areas more extensively and might fish in slightly deeper water off the shelf than previous mid-water trawl operations in the SPF.

As a result, the panel considered that historical data on direct interactions with protected species or the absence of data that showed any adverse impacts on these species from localised depletion by historical fishing, did not necessarily inform the likely nature and extent of potential direct or indirect impacts of the DCFA on protected species or the Commonwealth marine environment.

Assessment of direct interactions with protected species

There are 241 species protected under the EPBC Act that occur in the SPF area including pinnipeds (seals), cetaceans, dugong (possible but unlikely), seabirds, turtles, seasnakes, sharks and rays, syngnathids and other teleost fishes. The panel focussed its assessment on species considered at increased risk of interactions from mid-water trawling which included three species of pinnipeds (Australian fur seal *Arctocephalus pusillus doriferus,* New Zealand fur seal *A. forsteri* and Australian sea lion *Neophoca cinerea*), 21 cetacean species, and seabirds as a group. Some common themes with respect to the likely nature and extent of direct interactions by the DCFA with these species are apparent across the taxa:

- It is inevitable that the DCFA would have direct interactions with protected species of pinnipeds, cetaceans and seabirds and some interactions will result in mortalities regardless of the adoption of the best available mitigation and management measures; however, there remains uncertainty about the extent of those interactions.
- It is possible to identify the likely nature of the interactions and the species that are more likely to interact or are more vulnerable to interactions.
- There remains considerable uncertainty about the level of direct interactions that would result in an adverse environmental impact on pinnipeds, cetaceans and seabirds, but there are opportunities for research and monitoring that could reduce the uncertainties associated with the DCFA's interaction with protected species.
- Some progress has been made, domestically and internationally, on measures to manage the risks of direct interactions between fishing operations and seals and dolphins, but mitigation measures for marine mammals need further development and testing before they could be applied with confidence.
- Substantial progress has been made on measures to manage the risks associated with direct interactions of fishing operations with seabirds.
- Management and mitigation measures, individually and as a package, require testing and refinement to ensure their operation is optimised in the context of the fishery, the protected species, the vessel, its gear and the fishing plan.
- One hundred per cent observer coverage of all fishing operations and bycatch mitigation devices is paramount.

Assessment and advice on localised depletion

The panel interpreted localised depletion as a spatial and temporal reduction in the abundance of a targeted fish species that results from fishing. The central issue for the panel's assessment was whether the fishing activity of the DCFA could be concentrated enough, both spatially and temporally, to cause a localised depletion of SPF target species sufficient to cause adverse environmental impacts to the Commonwealth marine environment including the target species' predators. The panel assessed the potential impact of localised depletion on the target species and on protected species of central place foragers (CPF) that prey on SPF target species. The key points arising from the assessment are:

- The target species of the SPF are susceptible to capture but also have characteristics that are likely to reduce the temporal and spatial extent of localised depletion.
- The available evidence does not suggest that past extensive fishing activity for jack mackerel *Trachurus declivis* in the area of the SPF has significantly affected reproductive capacity or caused impacts on genetic diversity in that stock; nor does available evidence suggest an impact on age or size structure of the other SPF target species.
- The dependency on near-colony prey resources at certain locations and times increases the vulnerability of protected species of CPFs to localised depletion of SPF target species, and the nature and extent of the impact will depend on the spatial and temporal scale of the depletion.
- Very few studies anywhere in the world have linked reduced foraging and reproductive performance of CPFs to the impacts of fishing, and even fewer to localised depletion. Active management of the potential impacts of localised depletion on CPF species is rare.
- The available data suggest that the CPF species at greatest risk from localised depletion in the SPF are the Australian

fur seal, New Zealand fur seal, Australasian gannet *Morus serrator*, short-tailed shearwater *Ardenna tenuirostris*, little penguin *Eudyptula minor*, crested tern *Thalasseus bergii* and shy albatross *Thalassarche cauta* and that key foraging areas for these species within the SPF are Bass Strait, Tasmania and South Australia.

- There remains uncertainty about the importance of SPF target species to other CPF predators, because diet information is poor or unavailable.
- The ecosystem modelling studies available indicate that the SPF target species are not as influential in the southern Australian ecosystem compared to small pelagic species in other more productive global upwelling systems that support much larger biomasses of similar species.

The panel concluded that in the context of the management regime in place in the SPF, any localised depletion of SPF target species that might arise from the DCFA was unlikely to affect the overall status of the target stocks in the SPF. However, the panel considered that this did not preclude the possibility of localised adverse environmental impacts on some protected species, particularly CPFs.

The panel considered that localised depletion caused by the DCFA has the potential to have adverse impacts on CPF species and that under the current monitoring regime it is unlikely that such impacts would be detected. It is possible to provide an indication of the CPF species most at risk from localised depletion but dietary data are lacking for many other CPF species. It is not possible, based on currently available data, to determine the degree of localised depletion that would result in adverse environmental impacts to protected CPFs.

Key advice

The panel has identified many possible management and operational responses and opportunities for research and monitoring to address the risks associated with the impacts of the DCFA on the Commonwealth marine environment, particularly for protected species of seals and dolphins. Of those, the panel considers that the following actions and associated research are central to addressing those risks.

- Spatial closures
  - Mitigate bycatch mortality of the threatened Australian sea lion in the SPF area by implementing spatial closures that encompass foraging areas around all colonies, including those in waters off Western Australia.
  - Mitigate bycatch mortality of fur seals by implementing spatial closures especially adjacent to breeding colonies.
  - Mitigate against the potential adverse impacts of localised depletion on protected CPF species by implementing closures that preclude the DCFA from critical habitats at important times.
- Excluder devices
  - Develop and optimise an excluder device or devices for seal and dolphin bycatch mitigation.
  - Once the excluder device is operationalised, use underwater video to monitor the behaviour of marine mammals within the trawl net and in the vicinity of the excluder device to assess its efficacy and quantify levels of cryptic mortality.
- Trigger limits
  - Reduce the daily and per-shot trigger limits for fur seals under which the DCFA was proposed to operate.
  - Introduce a bycatch rate trigger limit for the fishery or fishing area, or a total mortality trigger for a fishing season and/or fishing areas, for fur seal and dolphin species.

- — Ensure that move-on rules associated with trigger limits are evidence-based or implemented on a precautionary basis where necessary.
- — Ensure that move-on rules associated with trigger limits can be implemented effectively by requiring 100 per cent observer coverage of all fishing operations and ensuring that underwater interactions and mortalities are detected quickly enough to allow move-on rules to be effected in a timely manner.

- Research
  - — Identify critical habitats for protected species including key foraging areas for central placed foragers (seabirds and pinnipeds) and important habitats used by cetaceans that are at increased risk of interaction with the DCFA.
  - — Determine the cumulative fishery-related mortality of protected species in the SPF area that interact with the DCFA, to ensure that this does not compromise the sustainability of their populations.
  - — Confirm the integrity of the current management of SPF target stocks by clarifying the extent of sub-structuring of SPF target species in the Eastern and Western zones.

Concluding comments

The panel's assessment is based on a specific DCFA fishing scenario and some associated assumptions. These had a significant bearing on the outcome of its assessment and any changes to those would necessarily affect the validity of the panel's assessment and advice.

The panel has been able to identify the likely nature of the interactions of the DCFA with protected species in the SPF. The form of direct interactions, and the species most likely to be affected by both direct interactions and localised depletion, have been identified and the panel has provided specific advice on measures that could be taken to avoid, reduce and mitigate these impacts. However, even with these measures in place, the panel considers that direct interactions with protected species and localised depletion, as defined by the panel, will occur under the DCFA. The panel's assessment has confirmed that there are considerable uncertainties relating to the extent of those impacts and the level of impact that would create adverse environmental outcomes.

As in other fisheries facing similar uncertainties, a precautionary and adaptive, risk-based approach to management of the potential impacts of the DCFA is required. Further, it is important that the assessment of the DCFA be considered in the context of the role of SPF target species in the southern Australian marine ecosystem, the management regime and of the cumulative impacts of fishing in the area of the SPF on protected species affected by the DCFA.

1 Background

1.1 Introduction

In September 2012, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) was amended to include Part 15B[1]. The amendment enabled the Environment Minister, with the agreement of the Fisheries Minister, to prohibit certain commercial fishing activities while an expert panel undertook an assessment of those activities.

The amendment of the EPBC Act was prompted by a proposal to use the *FV Margiris*, a 142 metre (m) Lithuanian-registered, mid-water trawl vessel, in Australia's Small Pelagic Fishery (SPF). The vessel had an on-board processing facility and storage capacity for fish and/or fish products of approximately 4500 tonnes (t). Vessels of this size and nature had not previously operated in the SPF although proposals to use freezer vessels in the fishery date back to 2004.

After consideration of the environmental impacts of the proposal, the Environment and Fisheries Ministers concluded that there were uncertainties surrounding the use of large mid-water trawl freezer vessels in the SPF. These uncertainties related to the impacts of such vessels on species protected under the EPBC Act, particularly seals and dolphins, and whether such vessels could cause localised depletion which might have an effect on predatory species. On 20 September 2012, under Part 15B of the EPBC Act, the Environment Minister, after consultation with the Fisheries Minister, made the *Interim (Small Pelagic Fishery) Declaration 2012* which came into force on 21 September 2012. The Interim Declaration defined the Declared Commercial Fishing Activity (DCFA) as a commercial fishing activity which:

a. is in the area of the Small Pelagic Fishery;

b. uses the mid-water trawl method; and

c. uses a vessel which is greater than 130 m in length, has an on-board fish processing facility and has storage capacity for fish or fish products in excess of 2000 t.

The Interim Declaration prohibited the DCFA for a period of 60 days while the Environment Minister invited submissions from 'declaration affected persons', as defined in section 390SE of the EPBC Act. The Minister received 116 submissions, of which five were from 'declaration affected persons'.

On 19 November 2012, the Environment Minister made the *Final (Small Pelagic Fishery) Declaration 2012*, which came into force on 20 November 2012. The Final Declaration defined the DCFA in the same terms as the Interim Declaration and was founded on a number of uncertainties with respect to the operation of the DCFA. These uncertainties (see Box 1.1) were articulated in 2012 in a brief to the Environment Minister by his Department and summarised in Logan (2014).

Under the Final Declaration, the DCFA was prohibited for up to two years while an expert panel conducted an assessment and reported to the Environment Minister on the activity. Membership of the Expert Panel on a Declared Commercial Fishing Activity (the panel) and the panel's Terms of Reference were announced on 6 February 2013. The panel[2] comprised:

- Ms Mary Lack (chair), Director, Shellack Pty Ltd
- Dr Catherine Bulman, Research Scientist, CSIRO Oceans and Atmosphere Flagship
- Associate Professor Simon Goldsworthy, Principal Scientist, Threatened, Endangered and Protected Species Subprogram, South Australian Research and Development Institute
- Professor Peter Harrison, Director, Marine Ecology Research Centre, Southern Cross University.

The panel was supported by a secretariat provided by the Department of the Environment[3].

1 The ability to make new declarations under part 15B of the EPBC Act sunsetted 12 months after the day the *Environment Protection and Biodiversity Conservation Amendment (Declared Commercial Fishing Activities) Act 2012* commenced

2 Biographical details of the panel members can be found at http://www.environment.gov.au/node/16955

3 Known as the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) when the panel was established.

In April 2013, the Environment Minister made a second Final Declaration under Part 15B of the EPBC Act (*Final (Small Pelagic Fishery) Declaration (No. 2) 2013*). The second Final Declaration includes the use of a vessel of a certain size to receive or process quota fish species that have been taken in the SPF. In September 2014, the expert panel for the first Final Declaration was also appointed by the Environment Minister to conduct the assessment under the second Declaration. In accordance with the EPBC Act, the panel will report separately on the two Final Declarations. This report applies only to the first Declaration.

Box 1.1 Basis and nature of uncertainties underlying the first Final Declaration

"On the nature of fishing for small pelagic fish species with large mid-water trawl freezer vessels:

The length of time that large mid-water trawl freezer vessels are able to stay at sea pursuing and harvesting target pelagic fish gives rise to some uncertainty about the environmental impacts of such commercial fishing activities.

On the vessel's interactions with seals:

Given the evidence that mid-water trawl vessels do interact with seals in the SPF, and the target species of large mid-water trawl freezer vessels are key prey species of the Australian fur seal, the Department notes that there is some uncertainty re the level of environmental impact on seals from the operations of large mid-water trawl freezer vessels. The uncertainty stems from whether interaction rates are likely to increase due to habituation noting that Seal Excluder Devices are not yet at a stage of avoiding all seal mortality or injury.

On the vessel's interactions with dolphins:

The rareness and unpredictability of dolphin interactions experienced with smaller mid-water trawl vessels related to operations observed in near shore areas. In light of the findings of the AFMA [Australian Fisheries Management Authority] that dolphins may be attracted to the catch of large mid-trawl (sic) freezer vessels, the Department notes there is some uncertainty about the effects that large mid-water trawl freezer vessels might have on the nature and rate of interactions with dolphins.

On the vessel's interactions with seabirds:

The nature of interactions between seabirds and other types of trawl vessel is fairly well known. The department considers that based on the advice provided by Seafish [Seafish Tasmania Pty Ltd] about the depth at which the cod-end will be left in the water, together with the application of a seabird management plan, the impact on seabirds of large mid-water trawl freezer vessels entering the fishery may be less than for other trawl methods and therefore there is little or no uncertainty about the potential environmental impacts on seabirds.

On the vessel's interactions with Australian sea lions:

If large mid-water trawl freezer vessels were to operate outside the known foraging range of Australian sea lion and breeding and haul-out sites, there would be very low uncertainty about their impacts on the species.

On the likelihood of localised depletion:

The department notes there are areas of some uncertainty about the potential for and possible environmental effects of localised depletion of small pelagic fish species that may result from the introduction of a large mid-water trawl freezer vessel, namely:

a) Whether localised depletion is likely to occur;

b) If it did occur, what effect localised depletion would have on the species being fished; and

c) If it did occur, what effects localised depletion would have on predator species." (Logan 2014)

1.2 Terms of Reference

The panel's Terms of Reference (Appendix 1) require that the panel assess and advise on:

1. the likely nature and extent of direct interactions of the Declared Commercial Fishing Activity with species protected under the EPBC Act, particularly seals and dolphins
2. the potential for any localised depletion of target species (arising from the Declared Commercial Fishing Activity) to result in adverse impacts to the Commonwealth marine environment, including the target species' predators protected under the EPBC Act
3. actions that could be taken by operators of the Declared Commercial Fishing Activity or relevant regulatory authorities to avoid, reduce and mitigate adverse environmental impacts of the activity
4. monitoring or scientific research that would reduce any uncertainties about the potential for adverse environmental impacts resulting from the Declared Commercial Fishing Activity
5. any other matters about the environmental impacts of the Declared Commercial Fishing Activity that the expert panel considers relevant to its assessment
6. other related matters that may be referred to it by the Minister.

The panel assessed each of the matters identified in Terms of Reference one to four and has not assessed any other matters under the fifth Term of Reference. The Minister did not refer any other related matters to the panel.

1.3 Structure of the report

Details of the panel's approach to the assessment of the DCFA, including the panel's interpretation of the Terms of Reference, are described in Chapter 2. Contextual information on the SPF is provided in Chapter 3. The role of the SPF target species in the southern Australian ecosystem is discussed in Chapter 4. The panel's assessment of the potential direct impact of the DCFA on species protected under the EPBC Act and of the potential for any localised depletion arising from the DCFA to result in adverse impacts on the Commonwealth marine environment is provided in Chapters 5 and 6, respectively. A summary of the panel's assessment and advice on each of the Terms of Reference is provided in Chapter 7.

2 Approach and interpretation

2.1 Informing the assessment

The Terms of Reference identified seven broad areas of activities that the panel would undertake in carrying out its assessment. A summary of the range of activities undertaken by the panel against each of these requirements is provided in Table 2.1.

Table 2.1 Approach and activities

REQUIREMENT	ACTIONS
1. Examine existing scientific literature, other relevant information and any ongoing research and monitoring projects relevant to the impacts of the Declared Commercial Fishing Activity (DCFA)	An extensive range of relevant literature was provided to the panel by the secretariat. This was augmented substantially by literature reviews commissioned by the panel and by material identified by the panel members and by experts consulted by the panel. The Fisheries Research and Development Corporation, the Australian Fisheries Management Authority (AFMA) and the South Australian Research and Development Institute were approached to provide advice on past, current and proposed research projects in Australia. Enquiries were also made of those involved in overseas fisheries for small fish pelagic species in order to identify any relevant international research.
2. Consult with and seek submissions from experts in relevant scientific disciplines where the expert panel believes this is necessary to clarify areas of uncertainty about the environmental impacts of the DCFA	A list of people consulted by the panel, and the nature of the consultation, is provided in Appendix 2. The panel's assessment has been informed by input from experts in relevant scientific and operational disciplines and the broader community of stakeholders. The panel sourced information and advice through: • substantive submissions to the interim declaration[4] • nomination, by those who made submissions, of relevant experts with whom the panel should consult • face-to-face meetings with experts and the agreed written summaries of those meetings • invited submissions • responses to specific requests for information and assistance • literature collated and provided to the panel upon commencement of its assessment by the secretariat, identified by panel members, recommended by experts and identified by reviews commissioned by the panel • information and research arising from reviews and analyses commissioned by or undertaken on behalf of the panel • consultation meetings with stakeholders • attendance at the Technical Workshop and Stakeholder Forum on Small Pelagic Fisheries, 14–18 July 2014, Adelaide.
3. Consider the fisheries management arrangements under which the DCFA is proposed to operate and the extent to which those management arrangements address the relevant environmental impacts and uncertainties	The fisheries management arrangements for the Small Pelagic Fishery (SPF) and those that were proposed to be in place for large-scale mid-water trawl operations are summarised in Chapter 3. The extent to which these arrangements mitigate the impacts associated with the DCFA is discussed in Chapters 5 and 6.

4 The panel sought and received permission to access a selection of these submissions from those who had made them.

REQUIREMENT	ACTIONS
4. Take account of the requirements of the EPBC Act as they relate to the operation of and accreditation of Commonwealth fisheries	The tests applied by the Department of the Environment in assessing the SPF under Part 13 and Part 13A of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) have been taken into account in describing the regulatory conditions under which a DCFA may operate and in assessing the actions that could be taken by the DCFA and/or the regulatory authorities to avoid, reduce and mitigate adverse environmental impacts of the activity.
5. Commission new reviews, research projects, modelling or analyses which the expert panel believes are necessary to fill critical knowledge gaps and where the results of those projects and analyses will allow the expert panel to fulfil its Terms of Reference	The panel commissioned the following research. • A literature review on the impacts on EPBC Act protected species by large mid-water trawl vessels • A literature review of impacts of localised depletion of small pelagic fishes on predators and ecosystems • A technical review of the development and application of bycatch mitigation devices for marine mammals in mid-water trawl gear • A review of genetic connectivity and recent developments in genetic techniques likely to provide further insights into stock structure in six species in the SPF • A technical assessment of the role for spatial management strategies in mitigating the potential direct and indirect impacts of fishing by large mid-water trawl vessels in the SPF on protected species • Mapping of the distribution of EPBC Act protected species and fishing activity in the SPF. The nature of the research commissioned by the panel was influenced by the timeframe and budget available to it and by the panel's assessment of the factors that it considered directly relevant to its assessment.
6. Consult with relevant experts, including in the operations of the DCFA, on the nature and effectiveness of the measures available to reduce direct interactions with EPBC Act protected species and the potential ecological effects of any localised depletion resulting from the DCFA	The panel consulted with relevant experts including the Directors of Seafish Tasmania Pty Ltd (the proponents of large-scale mid-water trawl operations in the SPF) and with operators of other mid-water trawl vessels in Australian and overseas fisheries. Insights into the operations of similar vessels and their use of measures to reduce direct interactions with protected species were also gained from research reviews commissioned by the panel, from analysis of available literature and through targeted consultations.
7. Identify further necessary and practicable monitoring or research projects that would reduce critical uncertainties for decision making relevant to any future operations of the DCFA	The need for additional research and monitoring that would reduce critical uncertainties for decision making relevant to any future operations of the DCFA is identified in Chapters 5 and 6 and summarised in Chapter 7. These needs have been informed by research projects commissioned by the panel and by the panel's assessment of critical knowledge gaps.

During the course of its assessment the panel met in person on 10 occasions on a total of 30 days and by teleconference on six occasions. All records of panel meetings, teleconferences, records of meetings with experts, invited submissions and commissioned research reports were uploaded to the secure Govdex site to facilitate record keeping and for access by panel members.

2.2 Scope of the assessment

2.2.1 Introduction

The scope of the panel's assessment was dictated by its Terms of Reference. However during the course of the panel's work and in discussions with stakeholders and other experts, it became clear that some people's expectations of the panel's report significantly exceeded the scope specified in the Terms of Reference. The panel made its best efforts to ensure that there was a common understanding of what its report does and, importantly, does not address. The panel's Terms of Reference require the panel to "assess the Declared Commercial Fishing Activity, particularly the potential for the activity to result in adverse environmental impacts". Terms of Reference one to four each relate to various aspects of adverse environmental impacts. The panel considered that its Terms of Reference did not require an assessment of the adequacy of overall management of the SPF, including the process for setting total allowable catches (TACs), the sustainability of TACs, the quality or scientific rigor of the daily egg production method that underpins many of the TACs, AFMA's consultation and advisory processes, or resource allocation issues across sectors and jurisdictions. While these issues are clearly important components of the overall management of the SPF they are not central to the assessment of the potential environmental impacts of the DCFA.

However, the fifth Term of Reference provides for the panel to assess and advise on "any other matters about the environmental impacts of the Declared Commercial Fishing Activity that the Expert Panel considered relevant to its assessment". The panel considered a range of other matters that might be relevant to its assessment, including some of those identified above. The panel's consideration of these is provided below.

Overall depletion of target species

TACs for SPF target species are set in accordance with the SPF Harvest Strategy (AFMA 2008) and consistent with the Commonwealth Harvest Strategy Policy (Department of Agriculture, Fisheries and Forestry (DAFF) 2007). The Harvest Strategy aims to maintain sustainable biomass levels which take into account the requirements of the broader ecosystem. In the panel's view there were no specific attributes of the DCFA that would differentiate its impact on overall depletion of these species from that of other fishing operations, since under any fishing scenario overall catches would be constrained by the TACs.

Sustainability of TACs

The panel considered that it was outside the scope of its Terms of Reference to examine whether the TACs for SPF target species are set at sustainable levels. The panel acknowledged that some stakeholders remain concerned about the reliability or age of the data on the basis of which TACs are set. However, the panel noted that new egg production surveys for some target SPF species have been initiated since the panel's inception and that an international workshop has recently reviewed the current daily egg production methodology. The panel concluded that these concerns would be addressed independently of the panel's assessment.

Byproduct species

Catch levels have been low in the SPF (less than 600 t per year) since 2010–11 (Section 3.1.3). The panel accepts that the low economic value of the product as currently caught, together with the wide geographical area of the SPF, means that it is unlikely that the current TACs will be taken with the existing 'wet boat' fleet. The panel assumed that catches would increase above current levels under a DCFA and that it was, therefore, reasonable to also assume that there would be a concomitant increase in the level of byproduct, that is, catch that is not targeted but that has commercial value and may be retained. The main non-target species retained in the SPF that are not subject to quota arrangements in other fisheries are barracouta *Thyrsites atun* and yellowtail scad *Trachurus novaezelandiae*. The panel examined (Section 3.1.3) the nature and extent of byproduct of these species and the potential impact of the DCFA on these species. The panel concluded that they did not warrant specific assessment.

Socio-economic impacts

In the course of its consultations it was suggested to the panel that, under the fifth Term of Reference, the assessment should include socio-economic impacts of the DCFA. The panel considered this view but concluded that matters assessed under the fifth Term of Reference should relate to 'environmental' impacts. It is the panel's view that the uncertainties identified in making the Final Declaration (see Box 1.1) relate to the ecology of the marine environment rather than to a broader interpretation of 'environmental' that includes socio-economic factors. As a result, the panel has not conducted a socio-economic assessment of the impacts of the DCFA.

In particular, it was suggested to the panel that the potential impact of the DCFA on Indigenous fishing opportunities should be assessed. The panel considered that the assessment of the potential impacts of localised depletion under the second Term of Reference would be equally applicable to all fishing sectors including other commercial fisheries, Indigenous fisheries and recreational fisheries. The panel did not consider it was within the scope of its assessment to assess the socio-economic impacts on any of these sectors specifically.

Transshipment

It was also suggested to the panel that its assessment should interpret the DCFA to include a scenario in which the 'vessel' identified in the DCFA receives fish from other catching vessels. The panel acknowledged that the description of the DCFA in the first declaration did not preclude transshipment. However, it is a matter of public record that the *Final (Small Pelagic Fishery) Declaration (No. 2) 2013* deals with the potential impact of transshipment by a fishing activity of the type that is the matter of this assessment. As a result, the fishing scenario assessed in this report does not include transshipment activities and consideration of the potential impact of transshipment will be contained in the panel's assessment under the second Final Declaration.

Climate change

It was suggested to the panel that the impact of climate change should be considered in its assessment. The panel recognises that climate change is likely to have an impact on the availability and/or behaviour of small pelagic species, on the ecology of their predators and, more broadly, on the marine ecosystems within the SPF. Climate change represents an important source of long-term uncertainty. However, the panel took the view that such impacts would relate to the stocks as a whole and be more relevant to stock assessments and TAC setting processes than to consideration of the type of fishing activities that might be conducted for the species. As a result, the panel has not considered the impact of climate change specifically in assessing the impacts of the DCFA. However, potential effects of climate change on SPF target species are discussed in Chapters 4 and 6.

2.2.2 The Declared Commercial Fishing Activity

The DCFA is defined in the Terms of Reference as a commercial fishing activity which:

1. is in the area of the SPF;
2. uses the mid-water trawl method; and
3. uses a vessel which is greater than 130 metres (m) in length, has an on-board fish processing facility and has storage capacity for fish or fish products in excess of 2000 tonnes (t).

The vessel specified in the DCFA is defined in terms of length, the presence of a processing facility and a minimum storage capacity. The panel formed the view that the length of a vessel was, in itself, less likely to be of specific relevance to the assessment, since length is essentially a function of the presence and scale of the fish processing facility and the storage and freezer capacity on the vessel.

The impacts of the DCFA on the marine environment will be influenced not only by the specifications of the vessel and gear but also by the operational and fishing strategy employed. Information available to the panel on fishing operations similar to those specified in the DCFA, indicates that operating practices vary across fleets, among skippers and according to the owner's requirements. In addition, these practices are influenced by seasons, weather and ecosystem conditions that affect the availability of target fish species. Fishing plans will also be influenced by market conditions.

The panel's assessment of the DCFA required, therefore, development of an indicative scenario of how the DCFA might operate in the SPF (see Box 2.1). The DCFA fishing scenario was informed by the proponents of the use of a large-scale mid-water trawl operation in the SPF (Mr G. Geen and Mr J. Pirello, Seafish Tasmania pers. comm. 23 April 2013), the operations of large mid-water trawl freezer vessels in other Australian and international fisheries as described to the panel by the managers of and observers on similar vessels (Mr R. Wells, ResourceWise pers. comm. 28 April 2014, Mr J. Zeeberg pers. comm. 1 May 2014) and reports of the fishing practices in fisheries for small pelagic species internationally (e.g. Couperus *et al.* 2004), including those that have been certified by the Marine Stewardship Council (MSC) (Andrews *et al.* 2009, Andrews *et al.* 2010, Andrews *et al.* 2011).

Box 2.1 The indicative DCFA fishing scenario

Fishing operations

- The operators of the DCFA hold quota for each stock of all target species[5] and can operate throughout the area of the SPF. It is their intention to catch their full quota in any fishing year and to maximise efficiency within the management constraints imposed.
- The fishing season extends year round from 1 May to 30 April.
- The species targeted at any time reflects behavioural and seasonal patterns of the species and commercial considerations.
- The length of tows is likely to be variable but may last six hours or more.
- Fishing trips are between six and eight weeks.
- The DCFA does not involve receiving catch from other vessels operating in the SPF.

Gear

- The net has a headline length of approximately 80 m with a headline height of at least 35 m. The net is up to 370 m in length.
- Mesh size is up to 20 m knot to knot at the front end of the trawl, progressively declining to the codend but not less than 30 millimetres (mm) in the codend. Catch is pumped from the codend to storage tanks on the vessel and during the pumping operation the bag and codend of the trawl net are fully submerged to a depth of around 50 m. The fish pump operates at approximately 250 t/hour.
- Net electronics: sensors at the codend to detect level of catch; headline trawl sonar to assist in positioning the net with respect to the school; drop sensors to monitor the door spread; auto trawl to ensure the net stays in an open position even when the vessel is turning.
- Sonar is used to detect schools.

Vessel

- The vessel is greater than 130 m in length.
- Trawl speed is between 3 and 5 knots.
- Frozen storage capacity is greater than 2000 t and up to 4500 t.
- There is only one fishing activity of the type specified as a DCFA operating in the SPF.

Processing/freezing

- Fish are pumped into reception tanks and chilled quickly.
- Fish are pumped to the factory deck and onto the roller grader where they are graded for size and then transported by conveyers to the freezer plant where they are sorted.
- Whole fish are contact frozen into 20 kg blocks.
- Approximately 250 t per day can be contact frozen.
- Frozen blocks are bagged, boxed, strapped and weighed and stacked in the refrigerated hold.
- Catch is frozen whole onboard and the extent of processing onboard is confined to the grading of fish and packaging of frozen whole fish.
- No discarding[6] of catch or processing waste occurs in any form (i.e. no discards of biological material).

5 The best advice available to the panel suggests that, while it may be possible to target sardines with the minimum mesh size specified for mid-water trawl gear in the SPF, it is likely to be inefficient and therefore this species may not, in practice, be a target species of the DCFA.
6 This excludes captured protected species which must be reported and returned to the sea.

2.2.3 Direct interactions with EPBC Act protected species

Direct interactions

The panel was required to assess the "likely nature and extent of direct interactions of the Declared Commercial Fishing Activity with species protected under the EPBC Act, particularly seals and dolphins".

The panel considered the definition contained in a memorandum of understanding (MoU)[7], on the reporting of interactions with protected species by fishers, between the Department of the Environment and AFMA. The MoU defines an interaction as "Any physical contact an individual has with a protected species. This includes all catching (hooked, netted, entangled) and collisions with an individual of these species". However the panel considered that this definition excluded some important types of direct interactions including feeding from nets or on discards or wastes, the habituation of some marine mammals to fishing operations (Chilvers and Corkeron 2001, Allen and Loneragan 2010, Jaiteh *et al.* 2013) and acoustic disturbance from fishing operations on marine mammals (McCauley and Cato 2003, Nowacek *et al.* 2007). As a result, the panel agreed that 'direct interactions' include:

- any interactions with fishing operations or gear (including net feeding, feeding on discards or waste)
- any physical contact (including collisions on trawl warps)
- bycatch (hooked, netted or entangled) which can result in injury or mortality
- acoustic disturbance from fishing operations
- any behavioural changes in these species brought about by habituation to fishing operations.

The fishing scenario of the DCFA (Box 2.1) precludes the discarding of catch or processing waste at sea. As a result, the panel did not consider direct interactions from feeding on discards or waste in its assessment of the DCFA. For the purposes of the assessment direct interactions included net feeding, physical contact, bycatch, acoustic disturbance and/or behavioural change.

Protected species

Species protected under the EPBC Act[8] include:

1. listed nationally threatened species identified as critically endangered, endangered, vulnerable or conservation dependent
2. cetaceans (whales, dolphins, porpoises)
3. listed migratory species, including some species of:
   i. birds[9]
   ii. cetaceans
   iii. sharks and rays
   iv. marine turtles
   v. crocodiles
   vi. dugong.

7 Available at http://www.afma.gov.au/wp-content/uploads/2010/06/mou.pdf?afba77.

8 Species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are not protected species for the purposes of the EPBC Act. However, some species otherwise protected under the EPBC Act are also listed in CITES.

9 For the purposes of its assessment the panel has referred to all species of relevant birds as 'seabirds'.

4. listed marine species, including some species of:
    i. seasnakes
    ii. pinnipeds (fur seals, sea lions and phocid seals)
    iii. crocodiles
    iv. dugong
    v. marine turtles
    vi. seahorses, sea-dragons and pipefish
    vii. birds.

Species in group one (listed threatened species except for conservation dependent species) and group three (listed migratory species) above are matters of 'national environmental significance' under the EPBC Act. A species may fall into more than one of these groups, for example, a species may be a listed threatened species and a listed migratory species.

A full list of the EPBC Act protected species occurring in the SPF area and therefore considered relevant to this assessment is provided in Appendix 3. The list was developed by panel members and the Environmental Resources Information Network of the Department of the Environment.

The panel noted there is often some confusion in the terminology given to seals in many government environment and fisheries management related documents. The term 'seal' is often applied to all seals (pinnipeds), or sometimes only to fur seals. In this report, in relation to the SPF, references by the panel to:

- 'seals' refer to all pinnipeds, that is otariids and phocids (noting that odobenids (walrus) are also pinnipeds but do not occur in the Southern Hemisphere)
- 'fur seals' refer to otariids in the genera *Arctocephalus* and *Callorhinus*
- 'sea lions' refer to otariids in the genera *Neophoca*, *Eumetopias*, *Zalophus*, *Otaria* and *Phocarctos* (this follows the terminology detailed in Kirkwood and Goldsworthy (2013)).

Where government or industry management plans are cited in this report, ambiguity in the terminology may still exist.

2.2.4 Localised depletion of target species

Localised depletion

The panel noted that the term 'localised depletion' is widely used in fisheries science and management literature but there is no globally accepted definition. The Food and Agriculture Organization of the United Nations maintains an extensive glossary of fisheries management and scientific terms but does not include 'localised depletion'. The panel noted that the term is used but not defined in the Commonwealth Fisheries Harvest Strategy Policy (DAFF 2007). The SPF Harvest Strategy (AFMA 2008) makes explicit reference to localised depletion but does not define it, however, the Small Pelagic Fishery Resource Assessment Group (SPFRAG) has recently developed the following draft working definition of localised depletion for the SPF:

> "For the purpose of managing the Small Pelagic Fishery, localised depletion is defined as: a persistent reduction in fish abundance in a limited area, caused by fishing activity, over spatial and temporal scales that causes a negative impact on predatory species and/or other fisheries.
>
> Explanatory notes:
>
> - The risk of localised depletion is highest for target species with low mobility (e.g. abalone) and lowest for highly mobile species (e.g. pelagic fish). Predatory species with limited foraging areas, especially central place foragers, are most likely to be impacted by localised depletion. Localised depletion is less relevant to highly migratory species or species with large foraging areas.

- Geographical barriers (headlands, straits) can increase the likelihood of localised depletion by limiting movement rates.
- Localised depletion is not a reduction in the overall range of a target species due to fishing down or over-fishing the stock. Localised depletion is not a reduction in stock abundance due to the natural movement or population size of target species.
- User conflict issues that do not arise from localised depletion should be considered and resolved separately from any user conflict issues arising as a result of the identification of localised depletion occurring.
- The definition of localised depletion has been developed in the context of the management of the Small Pelagic Fishery and the potential impacts localised depletion has on predators and catches in other fisheries (NB: Broader ecological implications of the Small Pelagic Fishery can be managed by applying low exploitation rates)." (SPFRAG 2014a)

The panel commissioned a literature review of the impacts of localised depletion of small pelagic fishes on predators and ecosystems (Rogers *et al*. unpublished). That review noted that interpretation of 'localised depletion' varies in the international literature and identified a range of interpretations of the term in relation to small pelagic fishes, including:

> "Localised depletion in the Chesapeake Bay is defined as a reduction in menhaden [*Brevoortia tyrannus*] population size or density below the level of abundance that is sufficient to maintain its basic ecological (e.g. forage base, grazer of plankton), economic and social/cultural functions. It can occur as a result of fishing pressure, environmental conditions, and predation pressures on a limited spatial and temporal scale." (Maguire 2009)

> "The idea of localised depletion is extremely difficult to demonstrate in such a mobile species [Atlantic menhaden]; if it does occur then it could only occur at a relatively small scale for a relatively short time." (Haddon 2009)

> "Forage fish are vulnerable to localized depletion, which is a reduction, through fishing, in abundance or biomass in a specific area. Localized depletion occurring in key foraging areas and at critical feeding times may have a major effect on predators that have little ability to find more distant patches of abundant prey…." (Pikitch *et al*. 2012)

The panel also explored the interpretation of localised depletion with a number of fisheries science and management experts, who put forward various definitions of the term, reinforcing the findings of the Rogers *et al*. (unpublished) review.

Noting that the panel's Terms of Reference required it to assess and advise on the potential for any localised depletion of target species (arising from the DCFA) to result in adverse impacts to the Commonwealth marine environment, and considering outcomes of research and expert advice, the panel adopted the following working definition of localised depletion:

> 'a spatial and temporal reduction in the abundance of a targeted fish species that results from fishing'.

The panel considered that localised depletion is an inevitable consequence of fishing and that the issue of relevance to this assessment was the potential for adverse environmental impacts as a result of localised depletion caused by the DCFA.

Further discussion of localised depletion, including its differentiation from overall stock depletion, is provided in Chapter 6.

Target species

The Small Pelagic Fishery Management 2009 Plan (the SPF Management Plan) identifies five quota species:

- blue mackerel Sc*omber australasicus*
- jack mackerels (jack mackerel *Trachurus declivis* and Peruvian jack mackerel *T. murphyi*)
- redbait *Emmelichthys nitidus*
- Australian sardine *Sardinops sagax*.

In carrying out its assessment, the panel interpreted references to target species in the Terms of Reference to mean references to these five species. A profile of each of these species is provided in Appendix 4.

The current management arrangements in the SPF require that mesh in the net must not be less than 30 mm at any part of the net. Taking this into account the panel considered it unlikely that the DCFA would target any other small pelagic species.

2.2.5 Small pelagic species

AFMA's use of the name 'Small Pelagic Fishery', serves to differentiate the target species from larger pelagic species such as tunas and swordfish that are managed separately by AFMA (e.g. the Eastern Tuna and Billfish Fishery and the Southern Bluefin Tuna Fishery). Internationally, references to 'small pelagic fish' have included many species, most commonly anchovy, anchovetta and sardine (pilchard) but Freon *et al.* (2005) usefully defined them as "shoaling epipelagic fish characterized by high horizontal and vertical mobility in coastal areas and which, as adults, are usually 10-30 centimetres (cm) in length". They suggest that conventional 'small pelagic fish' include typical forage species such as sardine and anchovy that prey on phytoplankton and/or micro-meso-zooplankton while 'medium-sized pelagic fish' (20 cm to 60 cm) include mostly species from intermediate trophic levels such as horse mackerel, mackerels and coastal tunas.

Forage fish or low trophic level fish

These 'small pelagic' species are also known as forage fishes or lower trophic level (LTL) species, reflecting their trophic role in the marine food web. Recent studies on forage and LTL species by Pikitch *et al.* (2012) and Smith *et al.* (2011) examined the role and the effect of fishing on these species, using a large number of ecosystem models. The Lenfest Forage Fish Task Force conducted a seminal research program to provide "practical, science-based advice for the management of forage species because of these species' crucial role in marine ecosystems and because of the need for an ecosystem-based approach to fisheries management" (Pikitch *et al.* 2012). Their definition of forage fish was in terms of their function as a vital route for energy transfer from plankton to higher trophic levels and included non-fish species such as krill. They defined forage fish as those whose characteristics include "small body size, rapid growth, schooling behavior and strong responses to environmental variability". They did not include mackerels in their study. Smith *et al.* (2011), in a study for the MSC, explored the effects of fishing LTL species in five ecosystems and defined LTLs as "...species that are generally plankton feeders for the larger part of their life cycle. They are often present in high abundance and tend to form dense schools or aggregations. They include small pelagic 'forage' fish such as anchovy, sardine, herring, mackerel and capelin, but also invertebrate species such as krill." That study involved two south-eastern Australian ecosystem models that included jack mackerel, sardine and redbait as well as krill, squid and mesopelagic fishes (Johnson *et al.* 2010, Bulman *et al.* 2011). Results of that case study are discussed in Chapter 4.

In terms of size, Australian sardine is the only SPF species that could be classed as 'small'. The mackerels and redbait are 'medium'. In Lenfest terms, only the Australian sardine would fit into the category of forage fish specifically. In the MSC study (Smith *et al.* 2011), sardines, jack mackerels and redbait were all considered LTL species.

3 History and management of the Small Pelagic Fishery

3.1 Development and management

The history and development of the Small Pelagic Fishery (SPF) can be considered in two stages. Stage one comprises the period from the 1970s to 2000 during which the fishery was predominantly a purse seine fishery for jack mackerel (*Trachurus declivis* and *T. murphyi*) off Tasmania. Stage two, extending from 2001 to the present day, is characterised by a shift in both target species and gear, with much of this period focused on mid-water trawling for redbait, and the emergence of interest in using a freezer vessel in the fishery.

3.1.1 1970–2000

Surveys located large schools of mackerel along the western edge of the Great Australian Bight (GAB) and off eastern Tasmania in 1936. In the 1940s and 1950s purse seining (see Box 3.1) was trialled off New South Wales (NSW) and eastern Tasmania. In 1973, a fish meal plant was established at Triabunna in Tasmania to process jack mackerel and in 1979, the South East Fisheries Committee set a total allowable commercial catch (TACC) of 30,000 tonnes (t) for jack mackerel in Australian waters with 10,000 t reserved for waters off Tasmania (Daley *et al.* 2007a). In 1983, the Offshore Constitutional Settlement (OCS) came into effect. The OCS allows for the exchange of powers for controlling resources, such as small pelagic species, that cross state (within 3 nautical miles (nm)) and Commonwealth (3 nm to 200 nm) boundaries.

Box 3.1 Purse seine

A purse seine is made of a long wall of netting framed with floatline and leadline usually, of equal or longer length than the former, and having purse rings hanging from the lower edge of the gear, through which runs a purse line made from steel wire or rope which allow the pursing of the net. It is generally the most efficient gear for catching large and small pelagic species that are shoaling. Small purse seines can be operated entirely by hand in small scale fisheries. In artisanal or semi-industrial fisheries, the purse seine handling equipment may include: a purse seine winch or a capstan, a purse line reel, a brailer and a power block and in some fisheries, a net drum. In industrial purse seine fisheries, the basic equipment includes: a hydraulic power block, a powerful purse seine winch, a number of derricks, including a brailer or a fish pump, and small winches, an auxiliary boat 'skiff' and sometimes, a helicopter. The purse seine is set around a detected school of fish. After that, the net is closed underneath the school by hauling the purse line running through the rings (pursing). Hydroacoustic instruments, like sonars are important tools to locate fish aggregations.

Source: Food and Agriculture Organization of the United Nations (FAO) (2001–2014a)

Catches of small pelagic species (Figure 3.1) remained low until the mid-1980s (Bulman *et al*. 2008). In 1984 the first large catches of jack mackerel were taken off eastern Tasmania and by the mid-1980s the purse seine fishery off the east coast of Tasmania, based out of Triabunna and fishing surface schools of jack mackerel, was the largest fishery in Australia (by weight). Annual catches increased from 6000 t in the 1984–85 season to a peak of almost 42,000 t in the 1986–87 season. Annual catches in the following decade were between 8000 t and 32,000 t (Hobsbawn *et al*. 2009). Between 1991 and 2000 the jack mackerel purse seine fishery off Tasmania averaged around 12,000 t per annum characterised by strong inter-annual and within-season variability (Daley *et al*. 2007a).

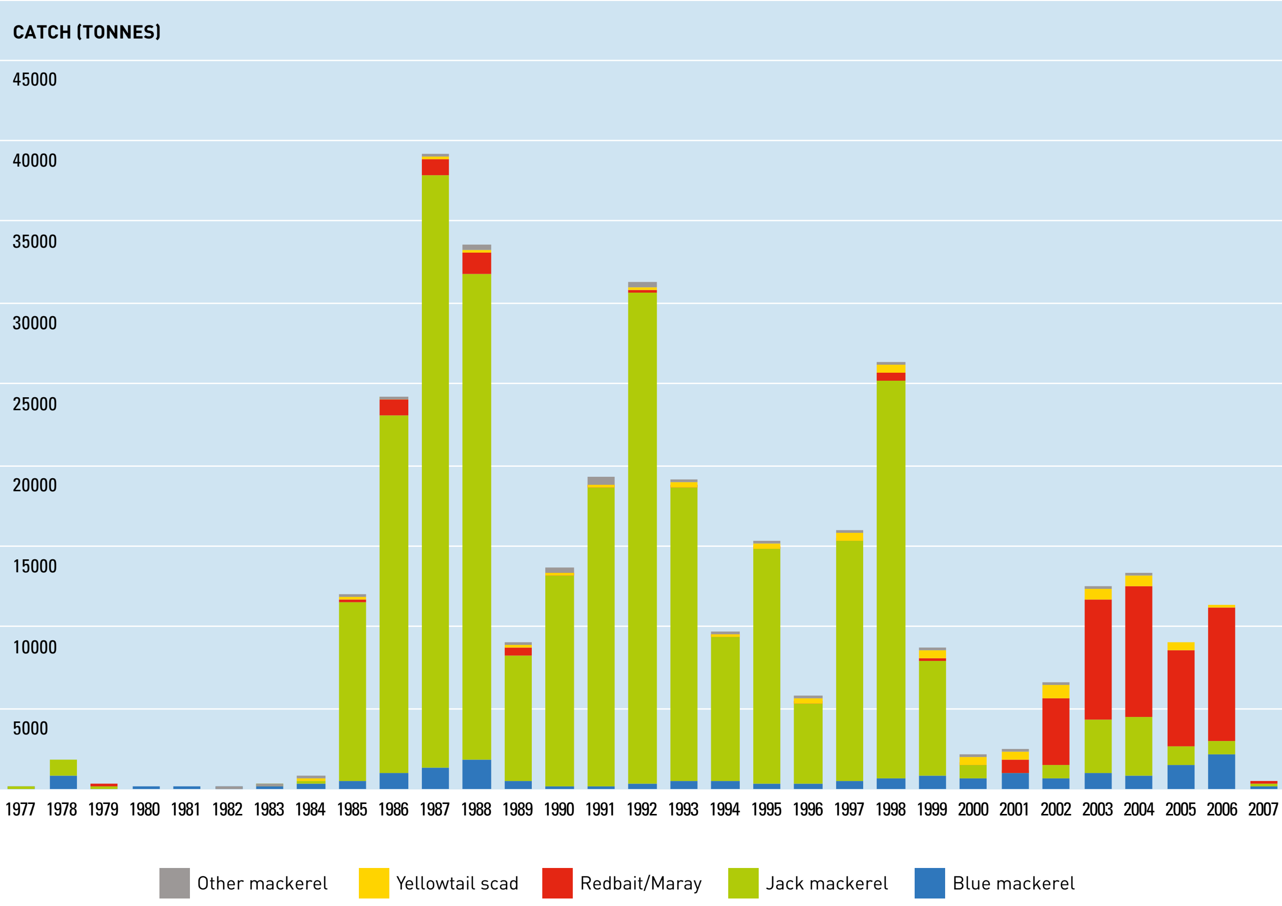


Figure 3.1 Total annual catches of all small pelagic fish species in the major state and Commonwealth fisheries compiled from a database held at CSIRO (not including Western Australia and Queensland). The data are summarised by calendar year and are incomplete for 2007. Species: yellowtail scad *Trachurus novaezelandiae,* redbait *Emmelichthys nitidus*, maray *Etrumeus teres,* jack mackerel *T. declivis* and *T. murphyi*, blue mackerel *Scomber australasicus*. **Source:** Bulman *et al.* (2008), reproduced with permission from the CSIRO and the Fisheries Research and Development Corporation.

By 1988, Tasmania had introduced a management plan for its state waters based on a total allowable catch (TAC) of 50,000 t. In 1991, the Jack Mackerel Fishery was divided into four zones: Zone A, the fishery off Tasmania; and Zones B, C and D (Figure 3.2). In 1995, the jurisdiction of the Tasmanian Jack Mackerel Fishery Management Plan was extended to include Commonwealth-licensed purse seine fishing vessels in Zone A, using a TACC for jack mackerel as the primary management tool. Under these arrangements, Zone A was managed jointly by the Australian Fisheries Management Authority (AFMA) and the Tasmanian Government and included waters both inside and outside 3 nm (Caton and McLoughlin 2004).

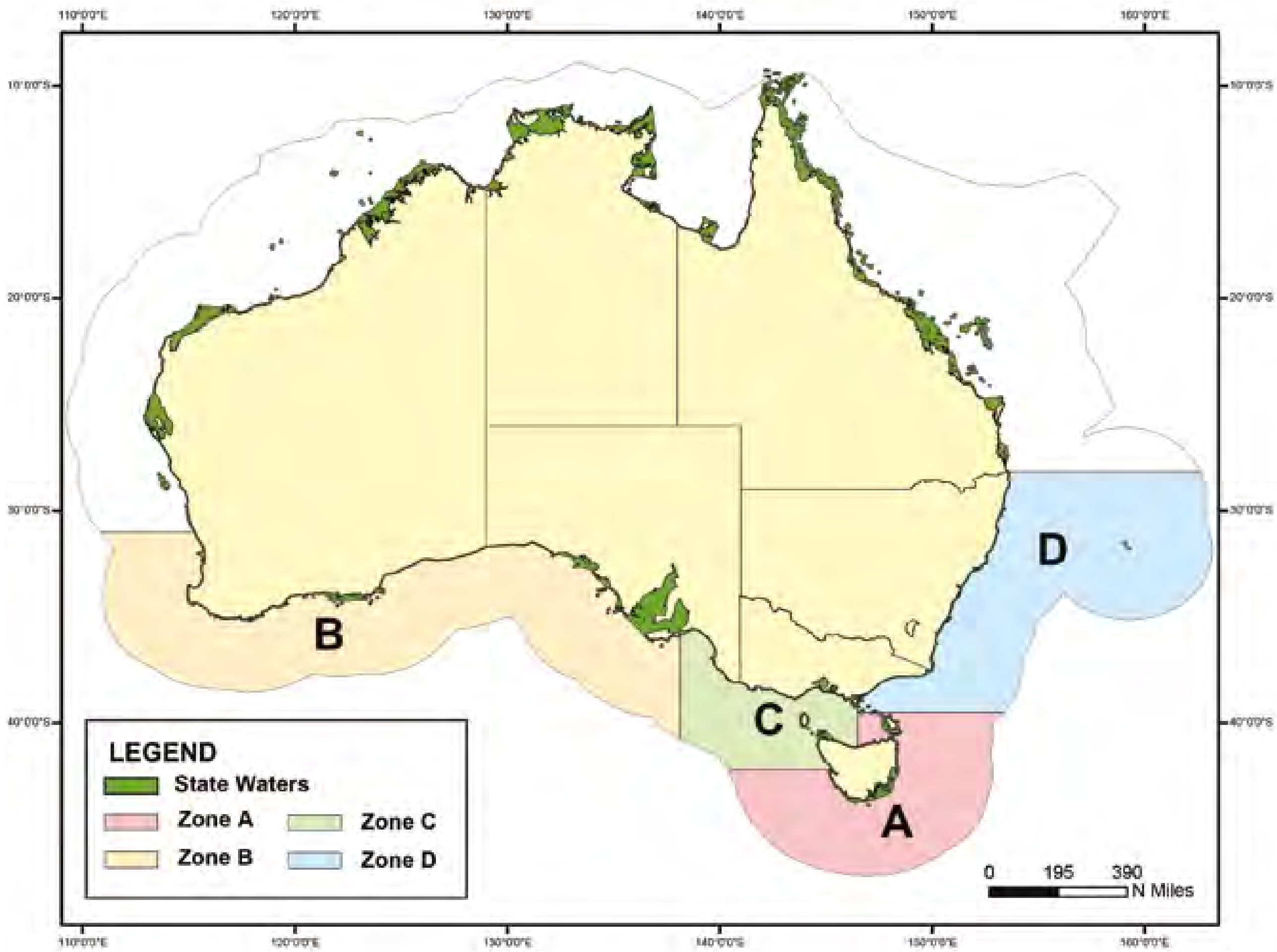


Figure 3.2 Historical management zones in the SPF **Source:** Anon. (2009)

Up until 2000, the Jack Mackerel Fishery was primarily a purse seine fishery, although some vessels were licensed to use mid-water trawl gear. Blue mackerel *Scomber australasicus*, redbait *Emmelichthys nitidus*, yellowtail scad *Trachurus novaezelandiae* and Australian sardines *Sardinops sagax* were taken opportunistically or as bycatch (Caton and McLoughlin 2000). However, in 2001–02 the first significant catches of redbait taken by mid-water trawl in Zone A were recorded (Bulman *et al.* 2008). This effectively marked the beginning of the second development stage in the fishery.

3.1.2 2001 onwards

From December 2001, the SPF was managed under AFMA's Management Policy for the Commonwealth Small Pelagic Fishery. Under that policy, trigger catch limits were set for blue mackerel, yellowtail scad, jack mackerel and redbait in Zones B, C and D. A TACC for small pelagic species in Zone A continued to be set under Tasmanian management arrangements (AFMA 2003, Caton and McLoughlin 2004, McLoughlin 2006).

In 2001–02 trials demonstrated that mid-water trawling (see Box 3.2) was a viable means of targeting small pelagic species and a multi-purpose mid-water trawler/purse seiner, the *FV Ellidi*, was brought to Tasmania in late 2002 for this purpose (AFMA 2003).

Box 3.2 Mid-water trawl

A mid-water trawl consists of a cone shaped body, normally made of four panels, ending in a codend with lateral wings extending forward from the opening. It is usually much larger than a bottom trawl and designed and rigged to fish in midwater, including in the surface water. The front parts are sometimes made with very large meshes or ropes, which herd the targetted fish inwards so that they can be overtaken by smaller meshes in the aft trawl sections. The horizontal opening is maintained either by otter boards or by towing the net by two boats (pair trawling). Floats on the headline and weights on the groundline often maintain the vertical opening. Modern large midwater trawls, however, are rigged in such a way that floats are not required; relying on downward forces from weights to keep the vertical opening during fishing. Sonar is a useful tool to detect fish concentration ahead the trawler and the trawl path and trawl depth can be adjusted accordingly. The fishing depth and the trawl are usually controlled by means of a netsounder (netsonde) or depth recorder. Trawl winches installed on deck control the trawling wires and store them when not in use. Gilson winches and lifting tackle are provided to assist with handling gear at the vessel. Net drums are common tools to handle midwater trawls onboard vessels.

Source: FAO (2001–2014b)

In 2004, foreign interests explored the possibility of bringing the *FV Veronica* into the fishery. The *FV Veronica* was 106 metres (m) in length and had significant fish processing capacity for human consumption (AFMA 2004). At that time there was very limited fishing activity in the SPF and no statutory management plan for the fishery. AFMA took the view that, in light of the apparent increased interest in fishing in the fishery, the management arrangements needed to be enhanced to preclude over-capitalisation (AFMA 2004). AFMA issued an investment warning in 2004 and later that year implemented a freeze on boat nominations in the fishery. This freeze effectively precluded the entry of the *FV Veronica* since the vessel could not be nominated against an SPF fishing permit.

In 2005, AFMA established the Small Pelagic Fishery Management Advisory Committee (SPFMAC) and identified the development of a statutory management plan as one of SPFMAC's first tasks. The AFMA Board lifted the freeze on boat nominations in December 2005 after having made a decision on the nature of the long-term management of the fishery and the nature of long-term access rights to the SPF (SPFMAC 2006).

Between 2005 and 2009, the Small Pelagic Fishery Management Plan 2009[100] (the SPF Management Plan) and the SPF Harvest Strategy (AFMA 2008) were developed (see Sections 3.2.1 and 3.2.2 respectively). At that time, mid-water trawl was the primary catch method in the SPF. However, since 2009, fishing effort by both purse seine and mid-water trawl vessels has declined (Moore *et al*. 2011, Moore and Skirtun 2012, Moore *et al*. 2013) and purse seine is now the dominant fishing method, albeit at low levels. AFMA attributes low levels of effort and catch in the fishery in 2010–11 and 2011–12 to factors including the loss of processing facilities in Eden, NSW, in late 2010, the difficulty in finding fish aggregations off Triabunna in Tasmania and operators waiting for statutory fishing rights (SFRs) to take effect (AFMA 2012a). Total catches declined from just over 5000 t in 2008–09 to 153 t in 2011–12.

10 The SPF Management Plan is available at: http://www.comlaw.gov.au/Details/F2010L00081

In February 2012, the SPF Resource Assessment Group (SPFRAG) considered a proposal by Seafish Tasmania Pty Ltd to bring a mid-water trawl freezer vessel into the SPF under a joint venture arrangement. The proposal included a research plan that would allow for the conduct of further daily egg production method (DEPM) surveys for target species.

In May 2012, the South East Management Advisory Committee (SEMAC)[11] was briefed on Seafish Tasmania's plan to enter into a joint venture with the Dutch fishing company Parlevliet & Van der Plas BV, under which Seafish Tasmania would provide the quota and Parlevliet & Van der Plas BV would provide a suitable freezer trawler (SEMAC 2012). On 30 August 2012, *FV Margiris*, a mid-water trawl vessel of 143 m length with on-board processing and freezing facilities, arrived in Australia. The hold capacity of the vessel was approximately 4500 t. On 5 September 2012, the vessel was renamed the *FV Abel Tasman* and registered as an Australian-flagged boat under the *Shipping Registration Act 1981* (Cwlth). On 20 September 2012, AFMA formally nominated the vessel to Seafish Tasmania's fishing concessions (SFRs). On 19 November 2012 the Environment Minister made the *Final (Small Pelagic Fishery) Declaration 2012*, which precluded large-scale mid-water trawl freezer vessels, such as the *FV Abel Tasman*, from fishing in the SPF for two years while an expert panel undertook an assessment.

Since that time fishing activity has remained low in the SPF (AFMA 2013a, SPFRAG 2014b) with total catch declining to around 40 t in 2012–13 and less than 20 t in 2013–14 (SEMAC 2013, 2014). In the last decade most fishing in the SPF has occurred off the east and west coasts of Tasmania and in the GAB, with little fishing activity off NSW or to the west of the GAB (Moore *et al*. 2011, Moore and Skirtun 2012, Moore *et al*. 2013).

3.2 Proposed management arrangements for the DCFA

The panel's Terms of Reference required it to "consider the fisheries management arrangements under which the Declared Commercial Fishing Activity [DCFA] is proposed to operate and the extent to which these management arrangements address the relevant environmental impacts and uncertainties". The panel took the management arrangements under which the DCFA is proposed to operate as comprising the existing management arrangements for the SPF and the management arrangements that were proposed for the operation of the *FV Abel Tasman*. Those arrangements are described below.

The existing regulatory environment in which the DCFA would operate is comprised of:

- the *Fisheries Administration Act 1991* (Cwlth), which establishes the administrative framework for Commonwealth fisheries, providing, for example, for the establishment of AFMA and the formation of management advisory committees
- the *Fisheries Management Act 1991* (Cwlth) (FM Act), which establishes the fisheries management framework, providing in particular for the preparation of fisheries management plans, the allocation of SFRs and establishing the broad fisheries compliance framework
- the SPF Management Plan and conditions imposed on SPF SFRs
- the SPF Harvest Strategy (AFMA 2008), reflecting the requirements of the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (Department of Agriculture, Fisheries and Forestry (DAFF) 2007)
- the SPF Bycatch and Discard Workplan (AFMA 2011) arising from AFMA's ecological risk management process
- any conditions imposed by the Environment Minister as a result of assessment of the SPF against the provisions of Parts 13 and 13A of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and any exclusions from areas of the SPF arising from the establishment of Commonwealth Marine Reserves.

The SPF Management Plan is made under the FM Act. The key provisions of the plan and the operation of the Harvest Strategy and Bycatch and Discard Workplan are discussed in Sections 3.2.1 to 3.2.3. All of the relevant provisions of these instruments and policies would apply to the DCFA. The application of the EPBC Act to the SPF is discussed in Section 3.2.4.

11 In July 2010 the role of the SPFMAC was assumed by SEMAC in line with a process of rationalisation of AFMA's Management Advisory Committees and Resource Assessment Groups.

3.2.1 SPF management plan

Area

Under the SPF Management Plan, stock-based management replaced the previous zonation of the fishery. Based on a study of stock structure (Bulman *et al.* 2008) the fishery for jack mackerels, blue mackerel and redbait was divided into two sub-areas east and west of longitude 146°30'E (Figure 3.3). The fishery was also extended north along the east coast to latitude 24°29'54"S and an Australian Sardine sub-area designated to accommodate activities authorised by Informally Managed Fishery permits. The area of the SPF, as defined in the SPF Management Plan, does not include state waters and extends to the outer limit of the Australian Fishing Zone (Anon. 2009). Small pelagic species managed under the SPF Management Plan have historically been taken in significant volumes within both Commonwealth and adjacent state jurisdictions. These species are also taken to a lesser extent in several other Commonwealth and state-managed fisheries, mainly the trawl sectors of the Southern and Eastern Scalefish and Shark Fishery (SESSF), the Eastern Tuna and Billfish Fishery (where they are caught for bait), the Western Tuna and Billfish Fishery and the NSW Ocean Hauling Fishery. While the eastern and western stocks are both multi-jurisdictional (state and Commonwealth), South Australia manages the western stock of Australian sardine and the Commonwealth manages the eastern stock (Moore *et al.* 2013).

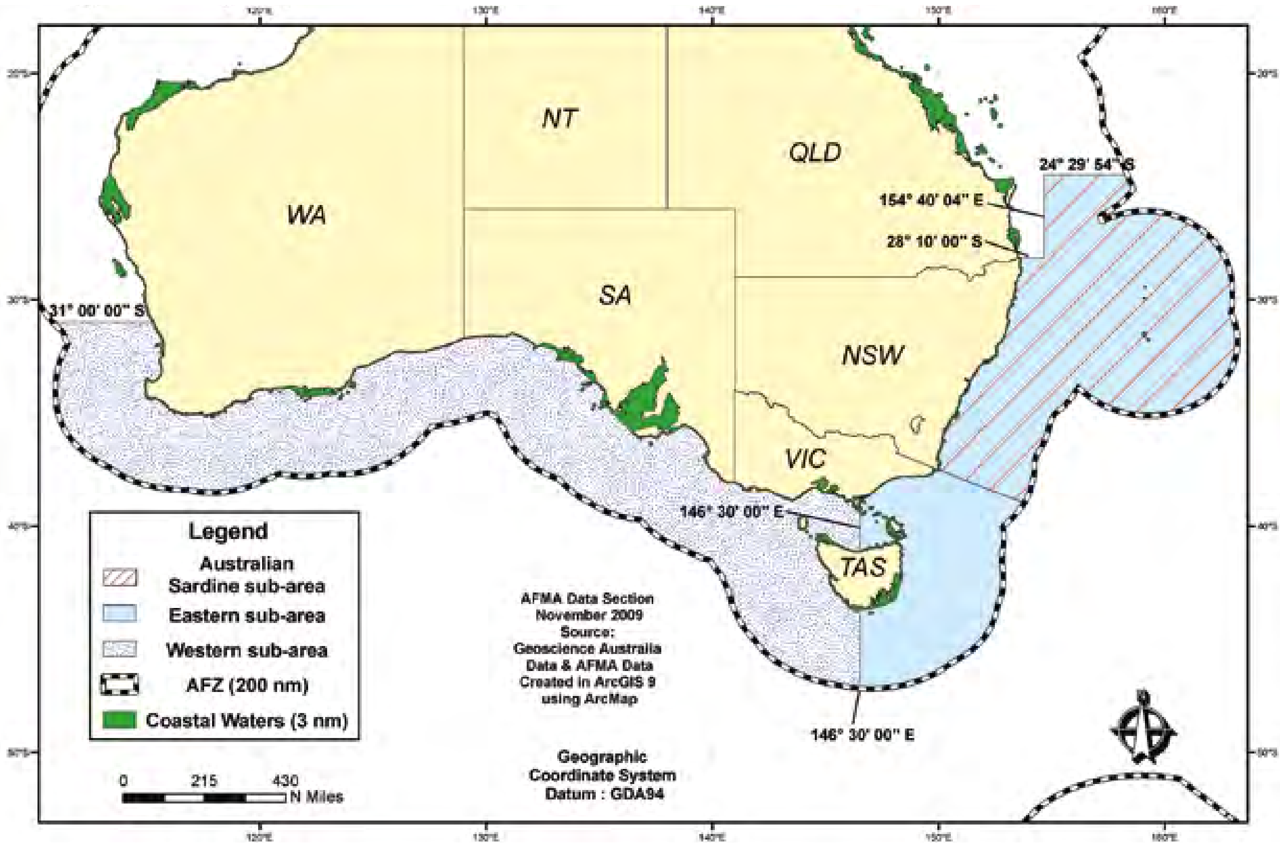


Figure 3.3 Area and sub-areas of the SPF. **Source:** AFMA (2014a), reproduced with permission from AFMA

Species

The SPF Management Plan identifies the quota species of the SPF as blue mackerel, jack mackerels, redbait and Australian sardine. Operators in the SPF may also take and keep non-quota species if quota for that species has been granted under another plan of management and the SPF SFR holder has or acquires the required amount of quota for that species (Anon. 2009), or if the species is not subject to quota arrangements under another plan of management or otherwise limited or restricted under Section 21 or Section 53 of the SPF Management Plan.

A profile of each of the five quota species, together with a summary of their stock assessment and stock status, is provided in Appendix 4. A summary of the TAC and catch by target stock since the eastern/western stock delineation was introduced is provided in Table 3.1.

The main byproduct species taken in the fishery include barracouta *Thyrsites atun*, silver warehou *Seriolella punctata*, silver trevally *Pseudocaranx georgianus* and yellowtail scad (Tuck *et al.* 2013). Silver warehou and silver trevally are subject to quota in the SESSF and retention of these species by SPF operators requires them to hold appropriate quota for those species. As a result, those species are not considered further in this report. There are, however, no restrictions on the catch of barracouta or yellowtail scad[12] in the SPF.

Between 2002 and 2011, 526 t of barracouta were reported as retained catch in SPF logbooks (Tuck *et al.* 2013). This represents an average of 53 t per year by all gear types in the SPF and 0.8 per cent of the retained catch of around 65,000 t over the period. Observer records for mid-water trawl operations in the SPF for the period 2007–11 report catch of barracouta in only one year with a total of 0.02 t discarded (Tuck *et al.* 2013). If all the current TACs, totalling nearly 35,000 t, were taken annually at the rate of catch between 2002 and 2011, it might be expected that less than 300 t per year of barracouta might be taken. Given this relatively low level of likely catch and noting that the productivity-susceptibility analysis (PSA) rating for this species is low (Daley *et al.* 2007b) the panel considered that this species did not warrant further explicit assessment.

Table 3.1 TAC and catch by target species 2008–09 to 2014–15 (t)

SPECIES	2008–09		2009–10		2010–11		2011–12		2012–13		2013–14		2014–15
	TAC	CATCH	TAC	CATCH	TAC	CATCH	TAC	CATCH	TAC	CATCH	TAC	CATCH	TAC
Australian sardine (east)	2800	1128	1600	636	400	115	400	23	200	39	270	16.9	560
Blue mackerel (east)	5400	175	4300	129	2500	0	2500	0	2600	1.5	2700	0.1	2660
Blue mackerel (west)	8400	1974	7000	966	4200	400	4200	130	6500	0	6500	0	6500
Jack mackerels (east)	5000	276	4900	146	4600	7	4600	0	10,100	0	9800	0	10,230
Jack mackerels (west)	5000	135	4900	111	5000	0	5000	0	5000	0	5000	0	5000
Redbait (east)	14,800	743	10,300	407	8600	13	8600	0	6900	0	5200	0	5000
Redbait (west)	5000	699	5000	120	5000	0	5000	0	5000	0	5000	0	5000
Total target species	46,400	5130	38,000	2525	30,300	535	30,300	153	36,300	40.5	34,170	17	34,950

Sources: AFMA (2012b), AFMA (2013b), Moore *et al.* (2011), Moore and Skirtun (2012), Moore *et al.* (2013), SEMAC (2013), SEMAC (2014), AFMA (2014b)

Yellowtail scad is taken predominantly in NSW state waters, with between 300 t and 500 t taken annually, predominantly by the NSW Ocean Haul Fishery (Ward *et al.* 2013). Bulman *et al.* (2008) note that the Commonwealth fishery reported catch of no more than 13 t per annum. Between 2002 and 2011, 23 t of yellowtail scad were reported in SPF logbooks as being retained (Tuck *et al.* 2013). This represents an average of 2.3 t per year by all gear types in the SPF and less than 0.1 per cent of the retained catch over the period. Observer records for mid-water trawl operations in the SPF for the period 2007–11 report no catch of yellowtail scad and only 0.06 t from purse seine operations, but do record 86 t of 'mackerel scad' *Trachurus* spp. from mid-water trawl catch (Tuck *et al.* 2013). It is not known what proportion of this might comprise yellowtail scad.

12 A 200 t TAC for yellowtail scad was removed upon the introduction of ITQs in the SPF on 1 May 2012 (AFMA 2012b).

The panel noted that yellowtail scad may form mixed schools with redbait (Daley *et al*. 2007b). If, under a DCFA, all the current TAC for redbait (10,000 t for both east and west stocks) was taken annually, at the rate of catch derived from logbook data, it might be expected that less than 10 t per year of yellowtail scad might be taken. Given this relatively low level of likely catch and noting that the bulk of the catch of this species is taken in NSW state fisheries, the panel did not consider that this species warranted further explicit consideration in this report. The panel notes, however, that some targeting of yellowtail scad has recently been initiated by an SPF operator supplying product to the domestic market (Mr A. Penney, Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) pers. comm. 21 May 2014). The level of this catch is not currently known.

Features of the management plan

The SPF Management Plan provides for a system of individual transferable quotas (ITQs), which take the form of SFRs for blue mackerel, jack mackerels and redbait in the eastern and western sub-areas of the fishery and for Australian sardine in the eastern sub-area. SFRs took effect in the SPF on 1 May 2012. SFRs are subject to a number of conditions (see

) and these can be amended by AFMA as required. Between 2008–09 and 2010–11 only three to five vessels operated in the fishery in any one year. During that time a maximum of two mid-water trawl vessels and four purse seine vessels operated (Moore *et al*. 2011, Moore and Skirtun 2012, Moore *et al*. 2013).

Other key features of the SPF Management Plan are:

- a requirement to set TACs for each quota species and sub-area of the fishery (Section 17)
- authorisation of the purse seine and mid-water trawl fishing methods and any other fishing method determined by AFMA (Section 25)
- obligations on SFR holders (Section 50) including:
  - taking all reasonable measures to ensure that bycatch and the impact of fishing operations on the marine environment are kept to a minimum
  - carrying an observer onboard when directed to do so by AFMA
  - having a compliant vessel monitoring system installed on their vessel
- obligations to take all reasonable steps to avoid interactions with cetaceans; listed threatened species, listed migratory species and listed marine species; and listed threatened ecological communities; and to record any such interactions (Section 52)
- provision for AFMA to direct that fishing is not to be conducted in the fishery, in a sub-area or part of a sub-area in a particular period or periods—this power can be exercised, on an emergency basis, if necessary, without the need for the otherwise prescribed consultation with SEMAC and without giving warning to SFR holders (Section 53).

3.2.2 Harvest strategy

The SPF Harvest Strategy (AFMA 2008) was adopted in 2008 and last updated in 2013. It reflects obligations under the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (DAFF 2007). The objective of the Harvest Strategy (AFMA 2008) is: "The sustainable and profitable utilisation of the Small Pelagic Fishery in perpetuity through the implementation of a harvest strategy that maintains key commercial stocks at ecologically sustainable levels and, within this context, maximises the net economic returns to the Australian community." The panel notes that this objective is consistent with AFMA's legislative objectives set out in sections 3(1)(b) and (c) of the FM Act.

The harvest strategy applies to the species that are subject to quota management under the SPF Management Plan, namely jack mackerels, blue mackerel, redbait and Australian sardine (East). The harvest strategy is used to develop advice on the recommended biological catches (RBCs) and TACs for these species.

The harvest strategy uses a three-tiered approach to determine the RBCs for each quota species, by eastern and western stocks, based on the stock assessment information available. The levels of assessment and monitoring that are required to inform the setting of RBCs at each tier are prescribed. Once the RBC has been derived, an allowance for state catches (based on an average of the previous five years) is deducted before the TACs for Commonwealth fishers are set.

The following description of the operation of the tiered approach is taken from the SPF Harvest Strategy (AFMA 2008).

SPF Harvest Strategy: Tier 1

Assessments must be based on a robust spawning biomass estimate from a DEPM survey and annual fishery assessments which include catch and effort data and size/age structure of the catch. The RBC for each stock in each Zone is based on the median spawning biomass estimated from the DEPM survey and all available information including biological, catch and spatial area of Zone.

Option 1

The RBC cannot exceed levels resulting from the relevant harvest rate which is set according to the age of the DEPM. The maximum harvest rate is 20 per cent of spawning stock biomass (SSB) when there are two DEPMs in three years or three in five years. The maximum harvest rates are then reduced in annual increments of 2.5 per cent to a minimum of 10 per cent to account for increasing uncertainty in stock status since the last survey (Table 3.2).

Table 3.2 Harvest rate for Tier 1, option 1 as defined in the SPF Harvest Strategy

AGE OF DEPM SURVEY (YEARS)	MAXIMUM HARVEST RATE AS % OF MEDIAN SSB ESTIMATES FROM DEPM SURVEY
5	10
4	12.5
3	15
≤2	17.5
2 in 3 or 3 in 5	20

Source: AFMA (2008)

Option 2

The RBC may be set at 15 per cent of the SSB for five fishing seasons following a DEPM survey of the stock. The DEPM cannot be used beyond five years.

Once the DEPM survey exceeds the formulae for either option, the stock must be assessed under Tier 2 or 3 depending on available information.

SPF Harvest Strategy: Tier 2

RBCs are determined by the SPFRAG on an annual assessment of catch and effort data including spatial and temporal patterns, and age structure of catch. The fishery assessment should aim to determine the likelihood of localised depletion or change in the size/age structure of the catch that cannot be adequately explained by reasons other than a decline in abundance.

Maximum RBCs for each Tier 2 species in each Zone are based on approximately 7.5 per cent of the median spawning biomass estimate based on information from the DEPM, outputs from ecosystem and population dynamics modelling and management strategy evaluations, but cannot exceed those listed in Table 3.3 (AFMA 2008).

Table 3.3 Tier 2 maximum RBC values for the western and eastern zones of the SPF (t)

SPECIES	WESTERN ZONE	EASTERN ZONE
Australian sardine	n.a.	3000
Blue mackerel	6500	3000
Jack mackerels	5000	10,600
Redbait	5000	5000

Source: AFMA (2008)

SPF Harvest Strategy: Tier 3

RBCs are determined by SPFRAG on the basis of catch and effort data. Maximum RBCs for Tier 3 species in each Zone may not exceed 500 t.

SPF Harvest Strategy: ecological impacts

The harvest strategy specifies the following approach (AFMA 2008) to accounting for ecological impacts when SPFRAG considers RBCs for target species:

"1. If evidence of significant interactions with threatened, endangered or protected species exists, SPFRAG must recommend one or more of the following:

- that a program be established to mitigate interactions; and/or
- an appropriate reduction in the RBC; and/or
- that the stock/s be reduced to a lower level Tier (i.e. with a smaller catch).

2. If, as a result of fishing, there is evidence of localised depletion or a concerning trend/change in age/size structure, SPFRAG must recommend one or more of the following:

- an appropriate reduction in the RBC; and/or
- appropriate spatial or other management measures.

3. If, as a result of fishing in the SPF, there is evidence of changes in ecosystem function (e.g. reduced breeding success of seabirds), SPFRAG must recommend one or more of the following:

- an appropriate reduction in the RBC; and/or
- appropriate spatial or other management measures; and/or
- that a program be established to:
    - i. assess the potential impacts of the fishery on the ecosystem;
    - ii. investigate potential ecological performance indicators for the fishery;
    - iii. report management performance against those indicators."

3.2.3 Ecological risk assessment

AFMA's Ecological Risk Assessment (ERA) process for each of the purse seine and mid-water trawl sectors of the SPF has comprised:

- a level 2 PSA using the Ecological Risk Assessment for the Effects of Fishing (ERAEF) risk assessment framework
- a residual risk assessment of the level 2 PSA
- a Sustainability Assessment for the Effects of Fishing;
- an Ecological Risk Management (ERM) report
- a Bycatch and Discard Workplan.[13]

13 Each of these documents can be found at http://www.afma.gov.au/managing-our-fisheries/environment-and-sustainability/ecological-risk-management/

The panel noted that the ERAEF approach is precautionary, in the sense that fishing activities are assumed to pose high risks in the absence of information, evidence or logical argument to the contrary (Hobday *et al*. 2007). However, the panel also noted that the ERA is based on the distribution of historical fishing effort rather than an assessment of the potential distribution of effort throughout the area of the fishery. This necessarily limits the use of the ERA for the purposes of guiding an assessment of the likely environmental impacts of increased fishing effort over potentially broader areas of the SPF, as might occur under a DCFA. Nevertheless, the ERA remained a useful source of information for the panel's assessment.

The ERM report for the mid-water trawl sector of the SPF identified eight threatened, endangered or protected species (TEPS), all marine mammals, as high-risk species for the mid-water trawl sector:

- Australian fur seal *Arctocephalus pusillus doriferus*
- Risso's dolphin *Grampus griseus*
- bottlenose dolphin *Tursiops truncatus*
- Indo-Pacific bottlenose dolphin *Tursiops aduncus*
- Fraser's dolphin *Lagenodelphis hosei*
- hourglass dolphin *Lagenorhynchus cruciger*
- southern right whale dolphin *Lissodelphis peroni*
- striped dolphin *Stenella coeruleoalba*.

The stated aims of the SPF Bycatch and Discard Workplan (AFMA 2011) are to:

- respond to high ecological risks assessed through AFMA's ERA process completed in 2010 and other assessment processes
- avoid interactions with species listed in the EPBC Act
- reduce discarding of target species to as close to zero as practically possible
- minimise overall bycatch in the fishery over the long term.

The SPF Bycatch and Discard Workplan defines bycatch as "catch other than of the four target species in the SPF and that part of the catch that does not reach the deck of the fishing vessel but is affected by interaction with fishing gear" and defines discarding as "catch (of either target species or bycatch) which is discarded because either it has low commercial value or because regulation precludes it from being retained".

As discussed in Section 3.2.1, it is an offence for SPF operators not to report interactions with species protected under the EPBC Act in their AFMA logbook. A memorandum of understanding between AFMA and the Department of the Environment allows AFMA to report interactions with protected species on behalf of Commonwealth fishers. AFMA provides quarterly interaction reports to the Department of the Environment and publishes the data on the AFMA website (AFMA 2014c).

Tuck *et al*. (2013) collated and analysed all available data on reported interactions with TEPS in the SPF for the period 2001 to 2011. As noted earlier, there has been very little fishing activity in the SPF since that time. The mid-water trawl sector (including pair mid-water trawling) of the SPF has recorded interactions with protected species of seabirds, dolphins and Australian fur seals in the period 2002 to 2007 (Tuck *et al*. 2013). No interactions have been reported with mid-water trawl gear in the fishery since that time (AFMA 2014c). It is a condition of SFRs that all mid-water trawl operators in the SPF are required to have in place vessel management plans (VMP) for seabirds and marine mammals. These mitigation measures are tailored to the operations of each vessel. VMPs are subject to review and monitoring by AFMA on an ongoing basis to ensure that they are effective in preventing interactions (Dr J. Findlay, AFMA *in litt.* 11 June 2013).

The Bycatch and Discarding Workplan states that it deals primarily with the reduction of the risk of bycatch of TEPS such as marine mammals and seabirds. This focus is supported by previous work that found that bycatch levels of finfish species are very low in the SPF. Tuck *et al*. (2013) reviewed logbook and observer data for the SPF for the period 2002–2011. They found that "discarding of fish target or bycatch species is not currently a concern in the SPF because (i) operators can selectively catch the four target species without catching significant amounts of other fish species; and (ii) catches of target species are generally well below the total allowable catch (TAC) limits". This is consistent with the ERA report for the fishery which states that the mid-water trawl fishery is: "Highly targetted and the volume of bycatch less than 1% of the total catch in a shot. Bycatch rates in mid-water trawl are much lower than in demersal trawl (up to 50%). Midwater trawling targets highly aggregated schools of the target species. The volume of bycatch is so small relative to the overall catch in a shot that it can be difficult to measure or even detect. A 30 t shot of redbait may contain 300 kg of barracouta and spotted warehou [*Seriolella punctata*] (Observer data)." (Daley *et al*. 2007b)

The Bycatch and Discarding Workplan identifies three areas of action:

- monitor the trial and use of top-opening seal excluder devices (SEDs) in the Commonwealth Trawl Sector of the SESSF and adapt as appropriate (having regard for health and safety issues) for SPF mid-water trawl boats
- develop and implement VMPs for mid-water trawl operators to minimise TEPS interactions and record procedures for reporting on catch and wildlife interactions
- develop triggers to identify shifts or expansion in effort within the fishery, including increased interactions with TEPS.

AFMA is currently undertaking a process to review and commission new ERAs for AFMA-managed fisheries. The need for review of ERAs will be determined based on a range of factors including a change in the incidence of interactions with species, increased effort or new areas of the fishery or use of new fishing gear. The ERAs will be peer reviewed by the ERA technical working group which has members from the CSIRO, ABARES and private scientists. Based on fishing operations in the SPF to date, these triggers have not been met in either the purse seine or mid-water trawl sectors of the fishery (Dr J. Findlay, AFMA *in litt*. 11 June 2013 and 2 October 2014).

3.2.4 Application of the EPBC Act to the DCFA

EPBC Act assessment

The EPBC Act requires the Australian Government to assess the environmental performance of Commonwealth-managed fisheries. These assessments are required under:

- Part 10, which provides for endorsement of a plan, policy or program following a Strategic Assessment of the impacts of actions under that plan, policy or program, on matters of National Environmental Significance (matters protected by a provision of Part 3 of the EPBC Act)
- Part 13, which provides for assessment of the impact of fishery operations in Commonwealth waters on species protected under Part 13 of the EPBC Act including cetaceans, listed threatened species and ecological communities, listed migratory species and listed marine species. If the assessment finds that the management arrangements require fishers to take all reasonable steps to avoid killing or injuring EPBC Act protected species and the fishery does not, or is not likely to, adversely affect the conservation status of these species, the fishery is accredited. Otherwise, the fishery is not accredited and fishers are liable for prosecution under the EPBC Act should they interact with protected species in Commonwealth waters without a permit
- Part 13A, which provides for assessment of a commercial fishery that wishes to export product against objectives relating to:
  - compliance with Australia's obligations under the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Convention on Biological Diversity
  - protection of wildlife that may be adversely affected by trade
  - promoting conservation of biodiversity in Australia and other countries

  - ensuring that commercial utilisation of Australian native wildlife for the purposes of export is managed in an ecologically sustainable way
  - promoting the humane treatment of wildlife
  - ensuring ethical conduct during research associated with utilisation of wildlife
  - ensuring the precautionary principle is taken into account in making decisions relating to the utilisation of wildlife.

- As a result of a Part 13A assessment, the Environment Minister may decide (a) to include product sourced from the fishery in the list of exempt native species thereby exempting the product from the export control prescribed by the EPBC Act; (b) declare the fishery an approved wildlife trade operation (WTO) for up to three years, subject to conditions; or (c) prohibit the fishery from exporting product.

The SPF is currently accredited, subject to certain conditions (see below), under Part 13 of the EPBC Act for the period that the first Final Declaration is in place.

Assessment of large freezer trawlers in the SPF

In the Schedule to the accreditation of the SPF made by the Environment Minister on 3 September 2012, the following conditions were specified for the operations of 'large-scale mid-water trawl operations' in the SPF. These were specified as 'Condition 1'.

Condition 1

Large-scale mid-water trawl operations must:

(a) "Prior to fishing, have in place demonstrably effective and scientifically proven mitigation approaches and devices to the satisfaction of AFMA to minimise interactions with dolphins, seals and seabirds, including gear handling and net setting rules. These mitigation devices must, as a minimum, include best practice seal excluder devices with top opening escape hatches or equivalent mechanisms

(b) In the event of one or more dolphin mortalities as a result of the mid-water trawl fishing activities:
  i. suspend fishing;
  ii. consult with any AFMA observer onboard and review the effectiveness of mitigation measures; and
  iii. not recommence fishing within 50 nm of the mortality event.

(c) Prior to fishing, have a seabird management plan in place that has been approved by AFMA in consultation with DSEWPaC. The seabird management plan must:
  i. contain appropriate physical mitigation measures and requirements to manage offal discharge; and
  ii. be complied with by the vessel operator and crew during all mid-water trawl fishing activities.

(d) Prior to fishing, have a seal[14] management plan in place that has been approved by AFMA in consultation with DSEWPaC. The seal management plan must:
  i. contain gear handling and net setting rules to minimise the level of seal mortalities;
  ii. be complied with by the vessel operator and crew during all mid-water trawl fishing activities;
  iii. in the event of three seal mortalities in any one fishing shot, require the operator to consult with any AFMA observer onboard and review the effectiveness of mitigation measures before recommencing fishing; and
  iv. in the event of:
    A. three or more seal mortalities in each of three consecutive shots; or
    B. more than 10 seal mortalities within a 24 hour period of fishing; or
    C. more than 10 seal mortalities in one shot

14 On advice from the Department of the Environment, the panel interprets this reference to seals to include only fur seals.

require the operator to

D. suspend fishing;

E. consult with any AFMA observer onboard and review the effectiveness of mitigation measures; and

F. not recommence fishing within 50 nm of the mortality event.

(e) Not fish in areas of the SPF on the continental shelf which are in the Australian sea lion closure area. The area of the Australian sea lion closure is the part of the exclusive economic zone adjacent to the coast of Australia bounded by a notional line beginning at the intersection of the meridian of longitude 129°00'E and the coast of southern Australia, and running progressively:

i. south along that meridian to the intersection with the 150 m depth contour of the continental shelf;

ii. generally easterly along the 150 m depth contour to the point of intersection with the meridian of longitude 140°05'E;

iii. north along that meridian to the intersection with the coastline of South Australia; and

iv. generally westerly along the coastline to the point where the line began.

(f) Ensure that there is an on-board observer at all times with 24 hour monitoring of mid-water trawl fishing activities and there is an underwater camera record of the operation of any bycatch excluder device at all times, and reviewed by an observer each day. The requirements under this Condition will apply to 1 November 2013 with monitoring arrangements to apply after this date to be determined following a review by AFMA and the Department.

(g) When fishing, report daily to AFMA on the level of protected species interactions, including mortalities."

Condition 1 was to be applied by AFMA through variations in SPF SFR conditions (Seafish Tasmania Pty Ltd *in litt.* 16 October 2012) and parts (c) and (d) were to be implemented through seabird and seal and dolphin VMPs.

In addition to the above condition, it was proposed that a further set of conditions would apply to AFMA in the event that a vessel such as the *FV Abel Tasman* operated in the fishery. That condition, specified as Condition 2 in a 'Draft – Two Year Instrument' sent to AFMA by the Environment Minister on 3 September 2012 read as follows.

Condition 2

"In order to manage potential impacts on protected species in the Small Pelagic Fishery, by mid-water trawl operators with a large scale, on-board processing facility on their vessel and the capacity to remain fishing at sea for an extended period, AFMA is to:

a. if protected species interactions occur, report the interaction(s) to the Department within 24 hours of AFMA receiving the report from the vessel.

b. make publicly available on a monthly basis summary reports of protected species' interactions, including mortalities, within the first three months of this instrument being made, and on a quarterly basis thereafter.

c. consider further management responses to mitigate protected species interactions as appropriate.

d. in consultation with relevant scientific experts, the Marine Mammal Working Group or other fora as appropriate and community and non-government organisations, review on a quarterly basis the observed interactions with protected species by Large Scale Mid-Water Trawl Operators in the Fishery, and the appropriateness of the management response.

e. drawing on the outcomes of existing or new research as appropriate and in consultation with the Department and relevant experts, assess and take into account any risk of more concentrated fishing activity disrupting the feeding behaviour of dependant predatory species, particularly protected species."

Ultimately, however, neither Condition 1 nor Condition 2 was imposed. Instead, on 19 November 2012 the first Final Declaration was made, precluding the operations of such vessels for a period of two years. On 28 November 2012 the Environment Minister accredited the SPF Management Plan for the period of the Final Declaration, subject to the following conditions which apply to all mid-water trawl vessels in the SPF.

- Prior to fishing, mid-water trawl vessels must have in place effective mitigation approaches and devices to the satisfaction of AFMA to minimise interactions with dolphins, seals and seabirds.
- AFMA requires that at least one observer be deployed on each new mid-water trawl vessel for the first 10 fishing trips with additional observer coverage or other monitoring implemented as appropriate, following scientific assessment of the SPF.

The panel assumed, for the purposes of its assessment, that the provisions of Conditions 1 and 2 above would have been implemented should an activity of the type specified as a DCFA have commenced operation in the SPF. These conditions are, therefore, included in the panel's interpretation of the fisheries management arrangements under which the DCFA was proposed to operate.

In addition to the above arrangements, the panel was aware that the operators of the *FV Abel Tasman* had expressed a willingness to implement a voluntary 'move-on' rule that limited the total catch during a six-week period to a maximum of 2000 tonnes within a 100 nm diameter area and required that when this limit was reached the vessel must not recommence fishing in the area for at least two weeks (Seafish Tasmania Pty Ltd *in litt*. 16 October 2012). AFMA had not implemented this rule as a formal condition but had offered to provide 'compliance' reporting in-line with any agreements reached between Seafish Tasmania Pty Ltd and other stakeholders (Dr James Findlay, AFMA *in litt*. 12 May 2014). As a result, this move-on rule has not been included in the management arrangements that apply to the DCFA.

The SPF and Commonwealth marine reserves

The South-east Commonwealth Marine Reserves Network (Figure 3.4) occurs within the area of the SPF. Under the *South-east Commonwealth Marine Reserves Management Plan 2013-23*, mid-water trawling is authorised in multiple use zones (depicted in Figure 3.4 in light blue), provided that the gear does not come into contact with the seabed at any stage. In all other zones, mid-water trawling is not allowed, though transiting in these areas is authorised.

The SPF also includes extensive areas of the more recently declared Temperate East and South-west Commonwealth Marine Reserves Networks (proclaimed in November 2012). These reserves are currently under 'no change on the water' transitional management arrangements. These arrangements are given effect through general approvals issued by the Director of National Parks under section 359B of the EPBC Act. They involve i) no zoning restrictions across new areas of reserve and ii) the continuation of any restriction that applied for those areas that used to be a marine park before November 2012 and that are now part of the new reserves. For example, some restrictions on use—including some relevant to the SPF— continue to apply to the area of the previous Great Australian Bight Marine Park (Commonwealth Waters), now part of the larger Great Australian Bight Commonwealth Marine Reserve (Figure 3.5). Specifically, mid-water trawling is authorised in both the Marine Mammal Protection Zone and Benthic Protection Zone provided it does not come in contact with the seafloor. Additionally, between 1 May and 31 August, all vessel access is prohibited (including all forms of fishing) in the Marine Mammal Protection Zone.

The 'no change on the water' arrangements will apply until new management plans for these networks come into effect following an independent review of the zoning and management arrangements of the reserves proclaimed in 2012. It is not possible to speculate on what implications, if any, that review may have for mid-water trawling activity in these areas of the SPF in the future.

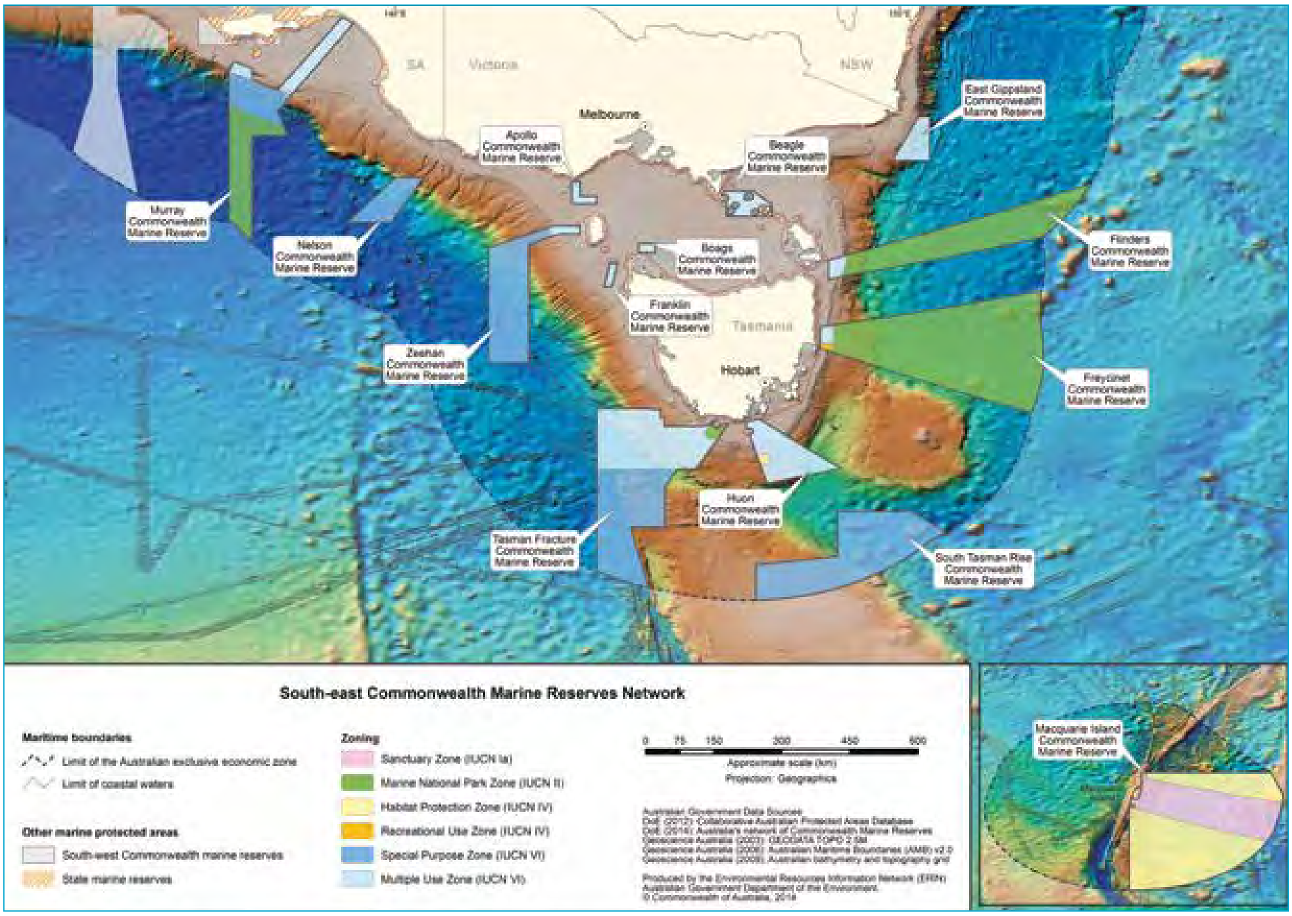


Figure 3.4 South-east Commonwealth Marine Reserves Network **Source:** Department of the Environment

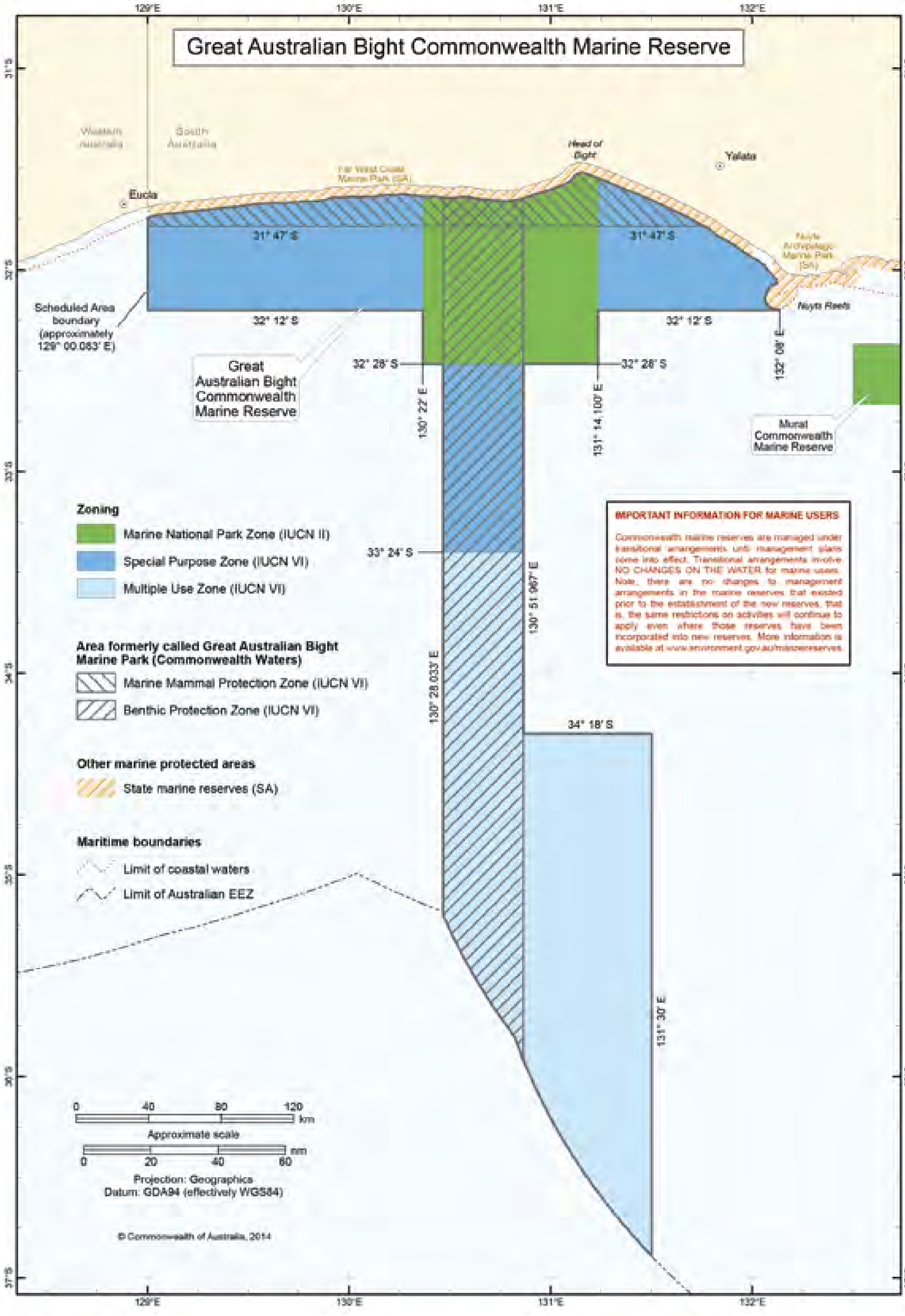


Figure 3.5 Great Australian Bight Commonwealth Marine Reserve map showing the area of the previous Great Australian Bight Marine Park **Source:** Department of the Environment

4 The Small Pelagic Fishery in the southern Australian ecosystem

4.1 Small pelagic fish

There is little doubt that coastal pelagic fishes, as defined by Freon *et al.* (2005) to include small– and medium–sized pelagic fish, play a crucial role in marine food webs. Typically, they are an important linkage of energy and biomass between primary production and higher trophic levels; hence it is essential to understand the dynamics of these species if they are to be exploited sustainably.

Small pelagic species occupy a central role in the major upwelling regions worldwide, the most productive being the eastern boundary currents of the Benguela in the Atlantic Ocean off southern Africa, the Canary in the Atlantic Ocean off northern Africa, the Californian Current in the Pacific Ocean off North America and the Humboldt in the South Pacific off South America (Bulman *et al.* 2011). The high productivity in these regions (Carr and Kearns 2003) supports large biomasses of plankton-feeding fishes of which sardine and anchovy represent a large proportion and upon which massive fisheries are based. According to the Food and Agriculture Organization of the United Nations (FAO), 23 species of the 1600 for which it collects statistics contribute 40 per cent of total marine production and, of those, almost two-thirds are small pelagic species (FAO 2014a). In 2012, 14.32 million tonnes (t) of herrings, sardines and anchovies and approximately 447,000 t of Peruvian jack mackerel *Trachurus murphyi* were landed (FAO 2014b).

However, the extremely productive Benguela, Canary, Humboldt and Californian upwelling regions are quite unlike those in Australia (see section 4.3.1). Australian catches of these small pelagic species are magnitudes smaller. Total annual catches of Australian sardine *Sardinops sagax* and jack mackerel *Trachurus declivis* in the Eastern Zone of the Small Pelagic Fishery (SPF) (in both state and Commonwealth waters) are currently in the order of 2000 to 3000 t and 0 to 56 t respectively (Moore *et al.* 2013, Ward *et al.* 2014). In the Western Zone, South Australian Sardine Fishery (SASF) catches have been around 28,000 t since the early 2000s and jack mackerel catches have declined from less than 500 t to negligible (Ward *et al.* 2014). In addition, catches of blue mackerel *Scomber australasicus* have been around 400 to 500 t and less than 500 t in the Eastern and Western Zones respectively over the past few years (Ward *et al.* 2014). Yellowtail scad *Trachurus novaezelandiae* catches declined from 400 t in the late 1990s to approximately 200 t before a jump to around 700 t in 2010–11 and a decline to 500 t most recently (Ward *et al.* 2014). As discussed in Chapter 3, yellowtail scad is not assessed in this report. Redbait *Emmelichthys nitidus* was intitially taken as bycatch in the jack mackerel purse seine fishery and actively avoided (Bulman *et al.* 2008), but since 2001 it has since been targeted by mid-water trawl. Catches of redbait from the Eastern Zone of the SPF peaked in 2003–04 at approximately 7000 t but have declined to only kilograms in recent years. Catches from the Western Zone peaked at approximately 3500 t in 2005–06 but have declined to zero in recent years (Ward *et al.* 2014) reflecting the effort trend in the SPF.

Changing oceanic conditions cause dramatic variability in small pelagic fish populations, particularly in the major upwelling current systems. The consequences of this on dependent predators and other species have been comprehensively reviewed by Cury *et al.* (2000). The small clupeid pelagic fishes such as anchovy, sardine, sardinella, herring and sprat are well-known for spectacular decadal fluctuations in biomass. Abundance regime shifts such as those between anchovies and sardines in the Humboldt Current can alter the entire ecosystem from phytoplankton to top predators (Alheit and Niquen 2004). These fluctuations have been associated with regime shifts of periods of warm or cold water driven by large-scale circulation shifts (Alheit *et al.* 2009). Warmer periods favour sardines while cooler water favours anchovy (Cury and Shannon 2004).

Locally, Australian sardines prefer to feed on small zooplankton favoured by warmer conditions while anchovy and jack mackerel prefer larger zooplankton including krill, favoured by cooler conditions. However, not all biomass fluctuations are related to environmental conditions. In the SPF, a mass mortality of Australian sardines occurred in 1995 and then again in 1998–99, caused by a herpesvirus (Whittington *et al.* 2008). Australian sardine biomass was reportedly reduced by

10–15 per cent and 70 per cent respectively (Ward *et al*. 2001a). Negative impacts of those reductions were documented for little penguins *Eudyptula minor* (Dann *et al*. 2000, Chiaradia *et al*. 2002, Chiaradia *et al*. 2003, Chiaradia *et al*. 2010), little terns *Sterna albifrons* in 1995–96 (Dann *et al*. 2000, Taylor and Roe 2004), crested terns *Sterna bergii* (McLeay *et al*. 2009) and Australasian gannets *Morus serrator* in 1998–99 (Bunce and Norman 2000, Bunce *et al*. 2002, Bunce 2004). This event, although dramatic, provides a good indication of how the ecosystem might respond to fishery- or climate-induced reductions of Australian sardines. See Section 6.7.4 for further discussion of this event.

4.2 Trophic role of small pelagic species

A technical review commissioned by the panel (Patterson *et al*. unpublished) collated dietary data, by numerical abundance, from 24 studies of six of the major central place forager (CPF) species in the Tasmanian region of the SPF, including eastern and western Bass Strait areas (Table 4.1). These data suggest that the SPF species are numerically important only for Australian fur seals *Arctocephalus pusillus doriferus* (redbait 31 per cent and jack mackerel 20 per cent) and for Australasian gannets (redbait 19 per cent and Australian sardine 20 per cent). However, the variances are very large and likely to mask and underestimate the importance of the SPF species. Furthermore, diet varies spatially and temporally again masking the importance that the SPF species may have at particular times for CPFs. These data were also based on a variety of methods including scat analysis (fur seals), regurgitates and DNA analyses, all of which have associated biases. Consequently, a single characterisation of the diet is very difficult to achieve resulting in the large variances seen (Patterson *et al*. unpublished) and is not particularly informative in the specific management of allocation of resources to dependent predators.

Table 4.1 Diet proportions and standard deviations (SD) of major central place foragers in the SPF by % numerical abundance

	LITTLE PENGUIN *EUDYPTULA MINOR*		AUSTRALIAN FUR SEAL *ARCTOCEPHALUS PUSILLUS DORIFERUS*		NEW ZEALAND FUR SEAL *ARCTOCEPHALUS FORSTERI*		AUSTRALASIAN GANNET *MORUS SERRATOR*		SHY ALBATROSS *THALASSARCHE CAUTA*		SHORT-TAILED SHEARWATER *ARDENNA TENUIROSTRIS*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Redbait	0.01	1.41	0.31	0.71	0.13	0.77	0.19	1.66	0.02	1.25	0.04	1.77
Jack mackerel	0.0	–	0.20	0.76	0.01	1.00	0.06	0.64	0.03	0.59	0.04	1.77
Blue mackerel	0.0045	1.41	0.02	2.79	0.001	2.00	0.04	0.72	0.02	1.73	0.04	1.77
Australian sardine	0.06	0.24	0.01	2.06	0.004	1.21	0.20	1.32	0.02	1.73	0.04	1.77
Other	0.93	0.04	0.49	0.51	0.86	0.13	0.54	0.51	0.91	0.12	0.85	0.29

Source: Patterson *et al.* (unpublished)

For consumption modelling, as used by Patterson *et al.* (unpublished), or for ecosystem modelling, dietary data need to be input in terms of biomass (usually wet weight). Therefore, dietary data as a percentage of total biomass (or wet weight) were collated (Table 4.2) for a broader variety of small pelagic fish predators from a range of studies and sources including Patterson *et al*. (unpublished). SPF species are an important proportion of many predators' diets by biomass including the Australian fur seal; short-beaked common dolphins *Delphinus delphis;* several seabirds, some of which are CPF species that breed within the SPF; larger teleosts such as southern bluefin tuna (SBT) *Thunnus maccoyii,* and sharks. Importance varies widely as indicated by ranges for some studies over longer time periods or different life stages (Table 4.2). Some of the data are now quite old, e.g., the eastern Tasmania and eastern Bass Strait (EBS) data are all 20 to 30 years old. This creates uncertainty in assessing importance; shifts in diet have occurred when there have been species regime shifts, e.g. the temporary shift of anchovy and sardine following the mass mortality events and the apparent changes in abundance between jack mackerel and redbait reflected in changes in fur seal diet (see Figure 5.7 in Chapter 5) (Kirkwood *et al.* 2008, McLeod *et al.* 2012, Kirkwood and Goldsworthy 2013).

Table 4.2 Proportions of SPF species and anchovy in diets of major predators in the SPF expressed as % of total prey biomass i.e. proportion of the total prey weight unless otherwise specified (%FO = frequency of occurrence, %NA = numerical abundance)

PREDATOR	AUSTRALIAN FUR SEALS *ARCTOCEPHALUS PUSSILLUS DORIFERUS*			NEW ZEALAND FUR SEALS *A. FORSTERI*		AUSTRALIAN SEA LIONS *NEOPHOCA CINEREA*	COMMON DOLPHIN *DELPHINUS DELPHIS*	BOTTLENOSED DOLPHIN *TURSIOPS TRUNCATUS*	LITTLE PENGUINS *EUDYPTULA MINOR*		SHORT-TAILED SHEARWATERS *ARDENNA TENUIROSTRIS*		LITTLE TERNS (ONLY BREEDING SEASON) *STERNA BERGII*	CRESTED TERNS *THALASSEUS BERGII*	AUSTRALASIAN GANNETS *MORUS SERRATOR*			SHY ALBATROSS *THALASSARCHE CAUTA*	
	Great Australian Bight (GAB)	W Bass Strait[1]	EBS[2]	GAB	S Tas.[3] %FO	GAB	GAB	GAB	Bass Strait	GAB	Bass Strait[1]	GAB	Bass Strait[5] %NA	GAB	Port Phillip Bay[1]	South Tas.[7]	GAB	Bass Strait[8]	GAB
Australian anchovy		0.1		0.1[1], 0.2–1.3			43.3		22[1] (19–61)[3]	61.6	8.5	13.7–19.4		30.7	4.9[1] (0–24)[6]	1.8	9		
Australian sardine				0.4[1], 0.9–2.1		0.1	20.8	2.1	7.3[1] (4–51)[4]	3.5	1.4	0.9–1.1	78	22.9	0.6[1] (4–50)[6]		16		
Jack mackerel	5.4	7.8	16	2.3[1], 4.3–7.7	21–43	0.8	11.4	1.5	0.41		21.5	10.4–27.1	~28	0.2	36.6[1] (6–20)[6]	13.1		43	46.8
Blue mackerel				0.2[1], 0.1–0.2			0.3	0.04		0.4		0.4–0.6					11		8.9
Redbait	44.8	22.1	13.3	11.3[1], 1.8–23.3	11–22				0.41	4.4	1	3.9–4.8			12.1[1]	55.6		2.9	2.9
Total SPF (exc. anchovy)	50.3	30	29.3	~16		0.9	32.5	3.6	8.1 (4–51)[4]	8.3	23.9	21.75	Not calculated	23.1	49.3[1] (24–50)[6]	68.7	27	45.9	58.6

It is also important to note that while some species may have a high preference for some prey, the size composition of the prey species may not overlap with the size composition of the fishery. For example, the Australasian gannets near Pedra Branca off the south coast of Tasmania (Tas.) were catching redbait and jack mackerel of less than 200 millimetres (mm) fork length (FL), smaller than the fishery-caught jack mackerel, between 250 and 370 mm FL, and redbait, between 190 and 290 mm FL (Brothers *et al.* 1993). Little penguins were found to take Australian sardine and anchovy of 8 centimetres (cm) standard length (SL) (Cullen *et al.* 1991) which for sardine is smaller than size-at-maturity (approximately 14.5 cm FL: Rogers and Ward 2007) and smaller than the average fishery catch in New South Wales (NSW) and the SASF (approximately 12 to 20 cm FL: Ward *et al.* 2014, Ward *et al.* 2010 respectively). While fishery and bird foraging zones may not overlap, it is still important that the mature stock is of sufficient size to maintain adequate recruitment of juveniles for the dependent predators and for the stock itself.

Trophic data, such as those presented in Tables 4.1 and 4.2, underpin the models constructed for the southern Australian ecosystems; however, each model preferentially uses region-specific data where these are available. Bulman *et al.* (2006) used such data and models to investigate the trophic role of small pelagic fishes in the SPF and the control exerted by the SPF fishes (see section 4.3). Their generic diagram of the food web (Figure 4.1) based on the data available at the time, illustrates some of the complexity that is inherent in the SPF ecosystem. Not all minor linkages are represented nor does this representation explicitly account for differences between slope and shelf fish sub-systems, and regional and temporal differences.

The food web for the Great Australian Bight (GAB) generated by the corresponding Ecosim with Ecopath (EwE) model shows all linkages including minor ones (Figure 4.2).

	AUSTRALIAN SALMON *ARRIPIS TRUTTA*	SOUTHERN BLUEFIN TUNA *THUNNUS MACCOYII*		THRESHER SHARK *ALOPIAS VULPINUS*	BRONZE WHALER *CARCHARHINUS BRACHYURUS*	COMMON SAWSHARK *PRISTIOPHORUS CIRRATUS*	SCHOOL SHARK *GALEORHINUS GALEUS*	BRIER SHARK *DEANIA CALCEA*	BLUE SHARK *PRIONACE GLAUCA*	BONITO *SARDA AUSTRALIS*	BARRACOUTA *THYRSITES ATUN*		RAY'S BREAM *BRAMA BRAMA*	LONG-FINNED PIKE *SPHYRAENA NOVAEHOLLANDIAE*	YELLOWTAIL KINGFISH *SERIOLA LALANDI*	STARGAZER *KATHETOSTOMA* SP	MIRROR DORY *ZENOPSIS NEBULOSUS*	JOHN DORY *ZEUS FABER*	GOULD'S SQUID *NOTOTODARUS GOULDI*	SOUTHERN CALAMARI *SEPIOTEUTHIS AUSTRALIS*
	GAB	GAB	Tas.[9]	GAB	GAB	EBS[10]	EBS[10]	EBS[11]	GAB	GAB	GAB	EBS[10]	EBS[11]	GAB	GAB	EBS[10]	EBS[10]	EBS[10]	GAB	GAB
	18.6	21.4	0–0.5	75.7	0.3						7.5			15.4					3.6	
	9.5	37.4	0.1–0	17.1	35.4					100	42.8			12.7	5.3			0.5	11.8	11.2
		3.2	45.8–24.5			35.9	49	24.3			7.2	4.1			7.1	35.5	50.4	43.9	10	39.5
	0.6	0.7			0.1				28.4		6.1				8.9				0.2	
	4.1	12.1	30.5–1.4								18.2		2.2		8.7			0.9	4.7	
	14.2	53.4	76.4–26.4	17.1	35.5	35.9	49	24.3	28.4	100	74.3	4.1	2.2	12.7	30	35.5	50.4	45.3	26.7	50.7

Sources:

GAB: Goldsworthy *et al.* (2011a),

1 Appendix 2 Patterson *et al.* (unpublished),

2 Littnan *et al.* (2007),

3 Lake (1997),

4 Chiaradia *et al.* (2002), Chiaradia *et al.* (2003), Chiaradia *et al.* (2010), Deagle *et al.* (2010),

5 Taylor and Roe (2004),

6 Bunce (2004),

7 Brothers *et al.* (1993),

8 Hedd and Gales (2001),

9 inshore-offshore samples: Young *et al.* (1997),

10 Bulman (unpublished data) and Bulman *et al.* (2001),

11 Blaber and Bulman (1987).

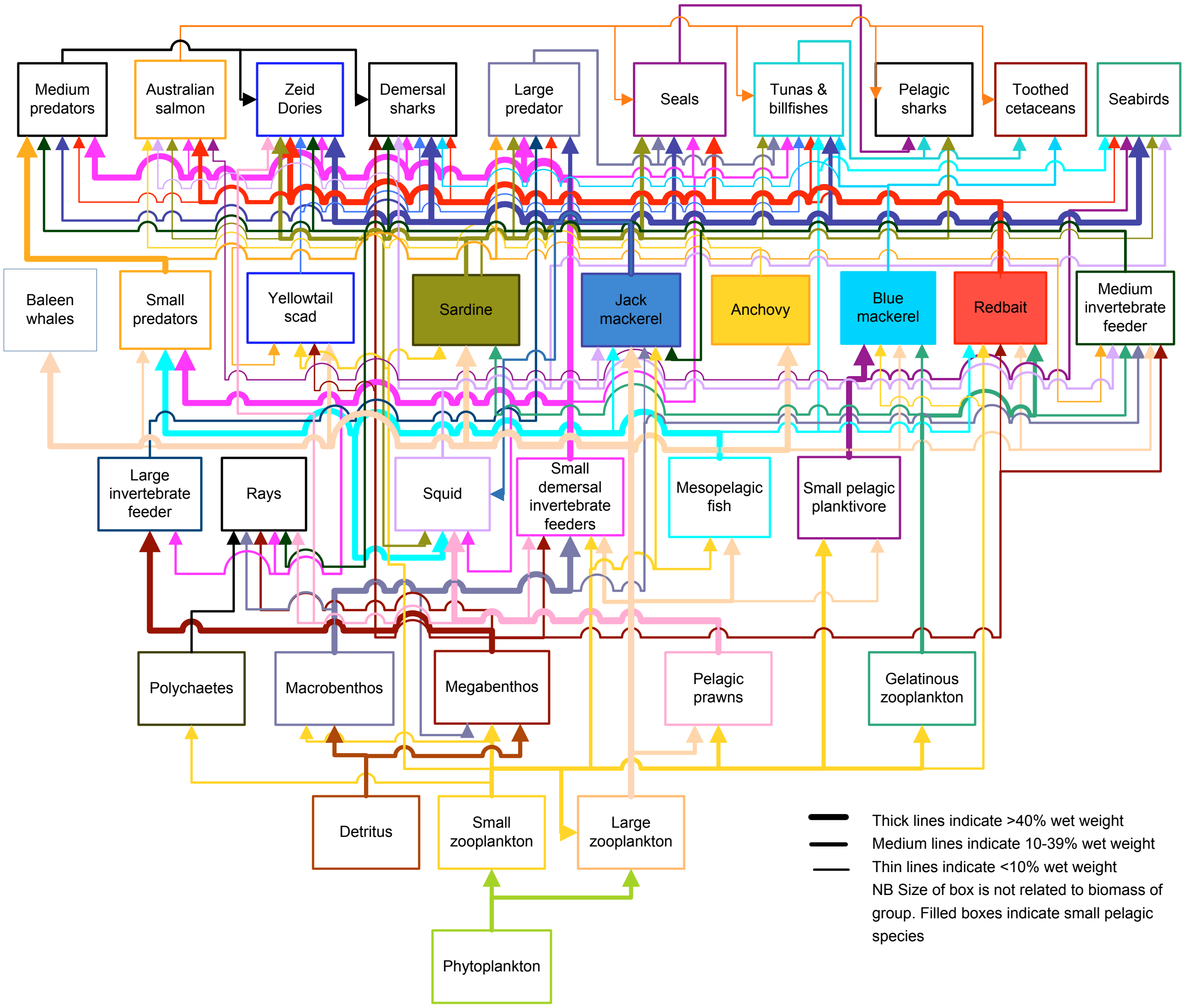


Figure 4.1 Generic small pelagic fish food web based primarily on dietary studies in southern Australia. Coloured boxes depict pelagic species of interest to this assessment. This representation does not explicitly differentiate between slope and shelf species. Source: C. Bulman (CSIRO)

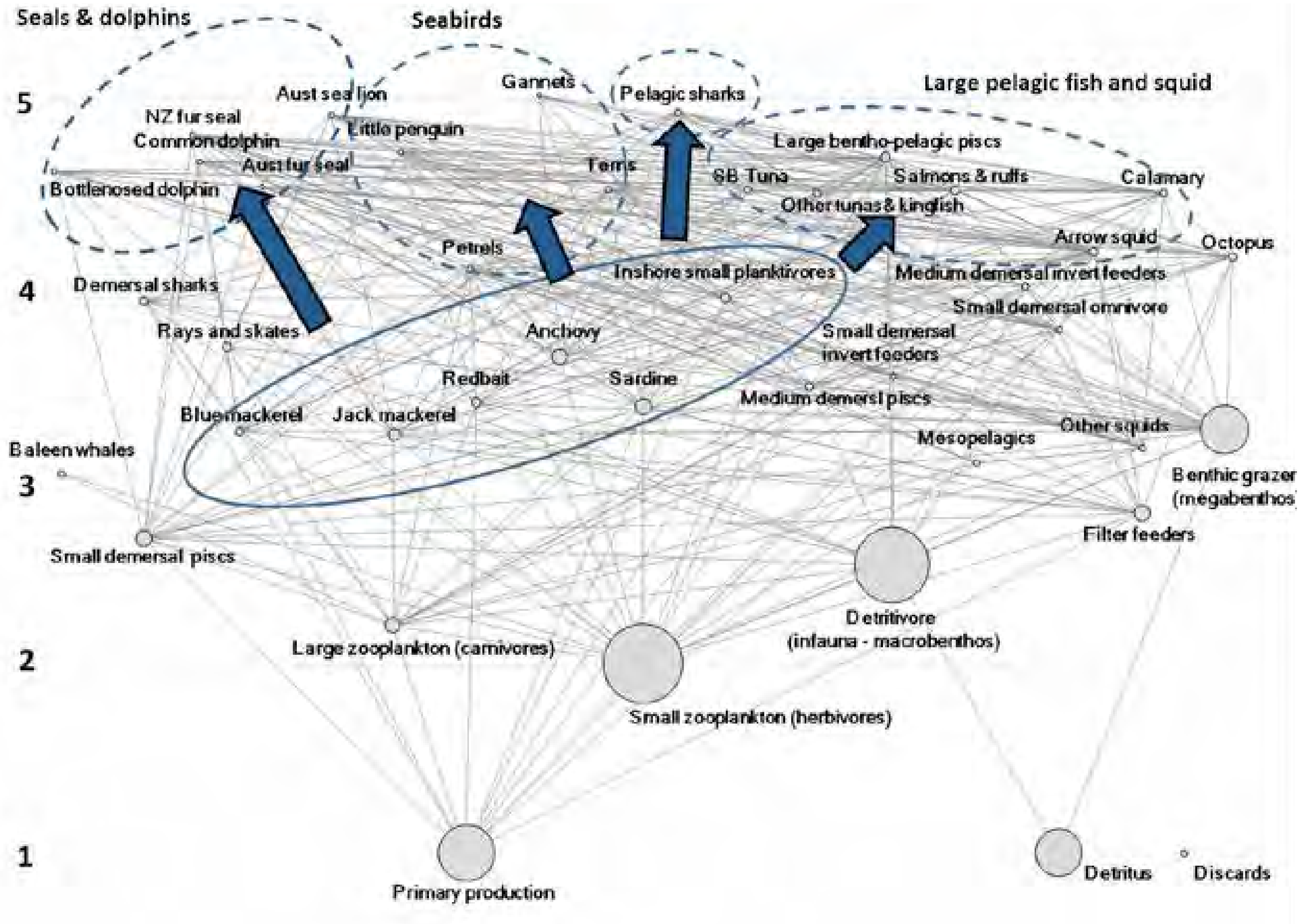


Figure 4.2 Food web for the Great Australian Bight EwE model. **Source:** S. Goldsworthy (South Australian Research and Development Institute)

4.3 Ecosystem modelling in the SPF

All models are simplifications of the systems they represent and it stands to reason that they have not been used for tactical purposes such as setting of catch quotas. They are, however, useful to investigate management or conservation strategies. Spatial issues can be addressed with spatially explicit models such as Atlantis, and Ecospace, the spatial module of the Ecopath modelling suite, but they do need to be developed at the appropriate scale. Testing harvest strategies at the ecosystem-scale will inform understanding of the consequences that could be expected at finer spatial scales, i.e. unsustainable harvest would imply similar or worse impacts at a finer scale, but they have not been used to inform understanding of localised depletion specifically. Modelling has an obvious advantage: even severe impacts can be explored without having to expose the system to the stress of severe fishing rates or climate regimes. Such explorations, particularly of exploitation levels, are frequently used in management strategy evaluations (MSE), e.g. Fulton *et al.* (2007). Various climate change implications have been investigated using a variety of the models available for Australia (Bulman *et al.* 2006, Brown *et al.* 2010, Fulton 2011).

Ecosystem models have been developed for the southern Australian region, encompassing either most or parts of the SPF (Bulman *et al.* 2006, Fulton *et al.* 2007, Savina *et al.* 2008, Goldsworthy *et al.* 2013a, Johnson *et al.* 2011a, Watson *et al.* 2013). Some of these have been used in the evaluation of the role of small pelagic species in the ecosystem and the broader ecosystem consequences of exploitation. While they all suffer from a lack of detailed information such as abundance and diet about many species, particularly the higher predators such as the seabirds and marine mammals, they do offer a way to investigate the potential effects of various impacts such as fishing and climate change.

The three EwE models that are most relevant to the SPF are the East Bass Strait Ecosystem (EBSE) model (Goldsworthy *et al.* 2003a), the EBS model (Bulman *et al.* 2006, Bulman *et al.* 2011) which is an updated and expanded version of the previous model, and the GAB model (Goldsworthy *et al.* 2013a) (Figure 4.3). While none of these models encompass the whole area of the SPF, they can be considered representative of their respective SPF Zones (Eastern or Western). The EBSE and EBS model domains extend from southern NSW to Wilsons Promontory, Victoria covering the shelf and slope to 700 metres (m), areas of approximately 40,000 and 30,500 square kilometres (km^2) respectively. The objectives of these models were to investigate the effects of fishing, climate change and the impact of fur seals in this area. The GAB model domain includes Investigator Strait and the lower portions of Gulf St Vincent and Spencer Gulf, South Australia, to 200 m, an area of approximately 154,000 km^2. The objectives for this model were to investigate the SASF impacts on the higher trophic level predators such as seals and seabirds. Details of the model construction, data and results can be found in the reports (Goldsworthy *et al.* 2011, Goldsworthy *et al.* 2013a). The dietary data collated in Table 4.2 and depicted in Figures 4.2 and 4.3 were just some that were used in the construction of the regional models. A major shift in diet might have occurred in the past decade or so, at least for higher predators, as discussed in section 4.2. However, a recent CSIRO dietary study re-sampled a subset of the fish species from the 1994–1996 South East Fishery shelf study (Bax and Williams 2000). The preliminary results of that study suggest minor differences for some species, but it is not yet certain whether they are significantly different from the natural variability of the diets (Dr C. Bulman, CSIRO unpublished data). It is necessary to monitor and update diets to maintain model relevance and performance.

The Atlantis South East model (Atlantis-SE) covers the majority of the SPF. Atlantis-SE was developed to provide insight into alternative integrated management solutions for the Commonwealth fisheries in south-east Australia (Fulton *et al.* 2007) (Figure 4.3). The model has also been used to identify robust indicators of the effects of fishing with simple indices such as relative biomass proving the most reliable (Fulton *et al.* 2004, Fulton *et al.* 2005). The original Atlantis-SE model covers 3.7 million km^2 of the waters within Australia's south-eastern Exclusive Economic Zone. Other versions of this model exist for eastern Victoria, Bass Strait and Tasmanian waters and the NSW coastal waters (Savina *et al.* 2008, Johnson *et al.* 2011b). A version of the Atlantis-SE model was used in a comparison with the EwE EBS model in a global investigation of exploitation on low trophic level (LTL) species by Smith *et al.* (2011). This model covers approximately 640,000 km^2 (Figure 4.3). A range of SPF issues has therefore been addressed by these models and are discussed below.

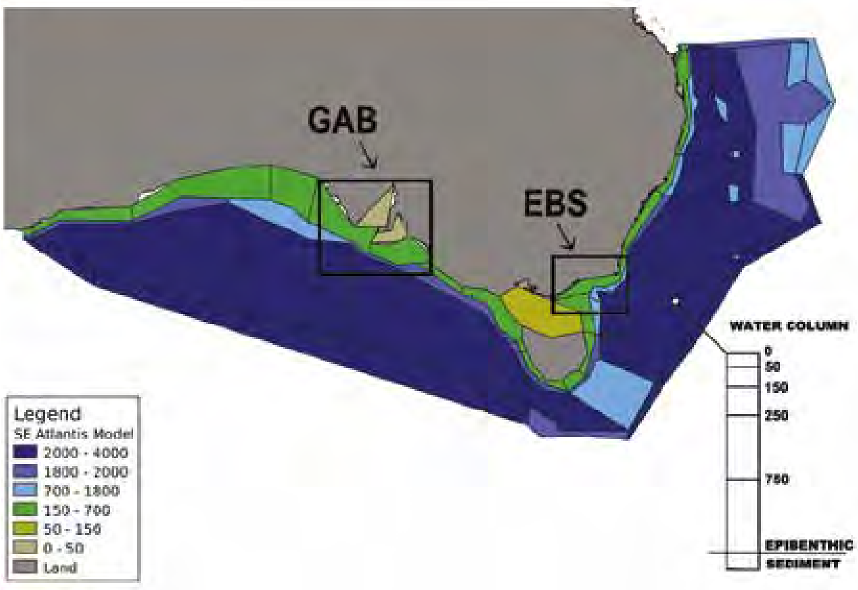


Figure 4.3 Atlantis-SE model domain also showing the indicative area of the EwE EBS and GAB models. Source: Dr E. Fulton (CSIRO)

4.3.1 Food web control

Bulman *et al*. (2011) note that "ecosystem dynamics differ among systems depending on the type of trophic control operating in the food web. Understanding the type of control in a system is fundamental not only to determining sustainable levels of harvest of pelagic fishes but could also help to determine the impacts on higher predators and their fisheries". Bottom-up controlled systems are those where large predators respond to changes in abundance of their prey, which is generally influenced by the environment. Top-down systems are those where higher predators control their prey. Wasp-waisted systems (Rice 1995) are those where small pelagic species exert top-down control on lower trophic levels such as zooplankton, but also a bottom-up control on their predators such as large pelagic fishes, birds, mammals and fishers. Freon *et al.* (2005) illustrated these types of control in their comprehensive review of small pelagic fishes (Figure 4.4).

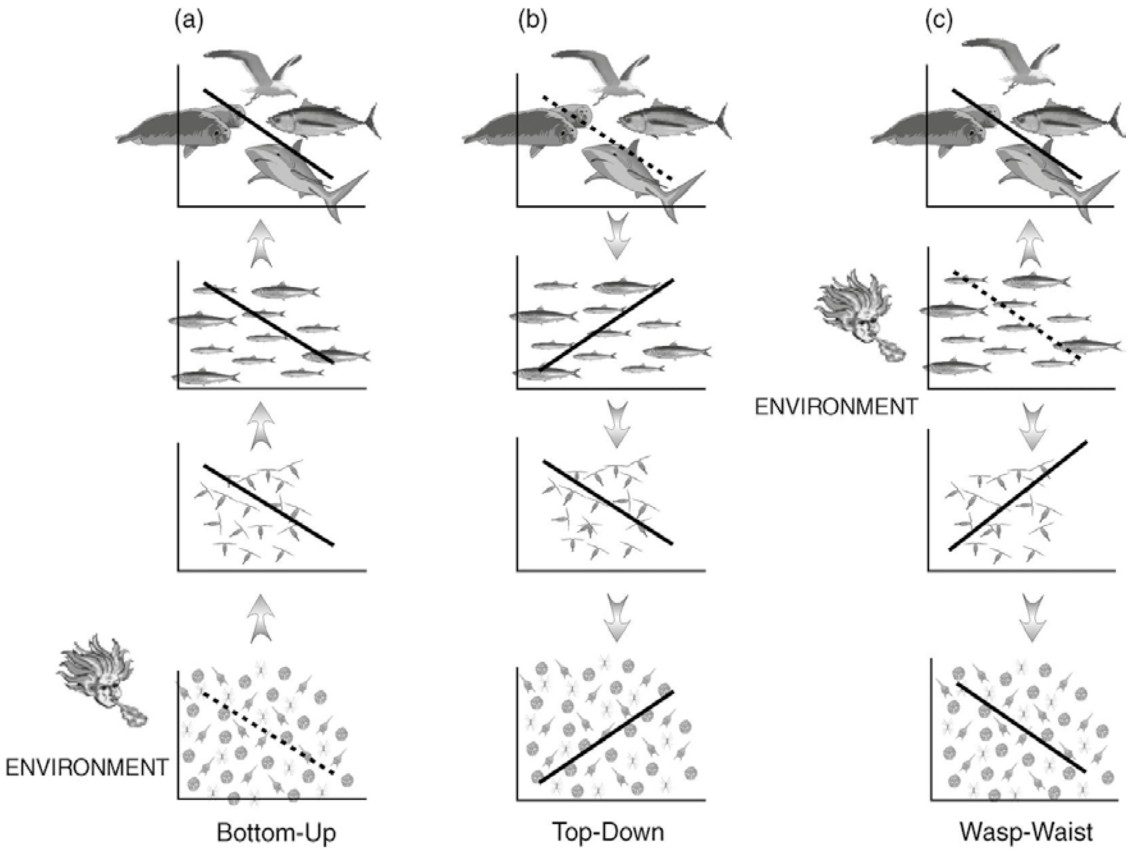


Figure 4.4 Types of potential trophic controls in linear pathways from phytoplankton through to large predators such as pelagic fishes, marine mammals and seabirds. The dotted line is the controlling factor and the solid lines represent the direction of responses of the impacted groups' biomass over time. Note that no fishing pressure responses are depicted. Source: Freon *et al.* (2005), reproduced with permission from the Bulletin of Marine Science. Image derived in part from Cury *et al.* (2003) in Sinclair and Valdimarsson (Eds). Copy right FAO.

Bulman *et al*. (2011) investigated the dynamics of food web control of the EBS and GAB EwE models and found that these systems are largely bottom-up forced, i.e. the abundance of the prey has a direct influence on the predator but that the more heavily fished EBS has more top-down controlling interactions. They also found that different pathways of the food web could show different control particularly in the EBS model, i.e. control isn't 'across-the-board' for all interactions in an ecosystem. Switching between bottom-up and top-down control may indicate pressures such as climate change and fishing.

The evidence for the classic wasp-waist control by any of the SPF target species was not particularly strong. Australian sardines (and anchovies) were involved in only two of the 25 most sensitive predator–prey interactions in the GAB and one in the EBS compared to one quarter to one half of those in the large upwelling system of the Benguela Current in a similar investigation (Shannon *et al.* 2008). Typically, 'wasp-waist' species are the small pelagic or 'forage fish' species and they dominate their trophic level with high biomass, channelling the energy flow through the mid-trophic level from plankton to large fish, seabirds and marine mammals. As discussed above, the pelagic fish biomass is much less dominant in the Australian ecosystem compared to those that support huge fisheries elsewhere. This is an important consideration in modelling the predator-prey interactions accurately and understanding the dynamics of these species in the food web.

A common factor in both the GAB and the EBS models was the dominance by both the New Zealand fur seal *Arctocephalus forsteri* and Australian fur seals respectively, despite their relatively low biomasses in the ecosystem (Bulman *et al.* 2011). In the GAB the interactions between fur seals and their prey were mostly bottom-up controlled for both species, i.e. if there was an increase in seal biomass the effect on their prey would not be particularly significant. However, in the EBS, fur seal interactions were largely top-down controlled, i.e. the fur seals would be more influential on their prey abundances. Specifically, important findings relevant to this assessment were that:

- the Australian fur seal–redbait interactions were bottom-up controlled in both models but the New Zealand fur seal–redbait interaction was not amongst the 'top 25' sensitive interactions
- the interactions of jack mackerel with both the Australian and New Zealand fur seals in the GAB were bottom-up controlled but in the EBS the jack mackerel–Australian fur seal interaction was top-down controlled.

The SPF species were also involved in other predator-prey interactions in the 'top 25' interactions. Relevant interactions were SBT–rebait and SBT–jack mackerel in the EBS; arrow squid–jack mackerel, pelagic sharks–Australian sardine and SBT–anchovy in the GAB, noting that anchovy is not an SPF species but is a small pelagic forage fish. These were all bottom-up controlled interactions apart from the squid–jack mackerel interaction. SBT predation on redbait and jack mackerel in the EBS ecosystem is probably 'under-played' in the Eastern Zone SPF since the data were averaged across inshore and offshore data for the purposes of the model; the 'inshore' dependence on jack mackerel and redbait combined was greater than 75 per cent (Table 4.2). Nevertheless, SBT in the Eastern Zone clearly have a preference for the medium-size pelagics (and squids) whereas they prefer the small-sized pelagics, sardines and anchovy, in the GAB.

One of the interesting findings in the EBS ecosystem and the Atlantis-SE modelling studies was that mesopelagic fishes and krill produced the most significant results, i.e. reducing their abundance affected more groups to a greater extent than reductions in small pelagic fishes (Bulman *et al.* 2011, Smith *et al.* 2011). The combination of a high initial biomass and heavy predation pressure on a group generally resulted in a higher likelihood of that group playing a central role in the functioning of the ecosystem, as occurred for krill in the Atlantis-SE model and for krill and mesopelagic fishes in the Ecosim-EBS model (Smith *et al.* 2011). A similar response was found in an oceanic model for the Eastern Tuna and Billfish Fishery where mesopelagic fish and squid had the significant wasp-waist role with effects cascading up and down the food web upon their removal (Griffiths *et al.* 2010).

The panel noted that these ecosystem models suggest that the GAB ecosystem, which is more dependent on the sardine and anchovy food base, is largely bottom-up controlled and so the predators have less effect on abundances of their prey than might other factors such as environmental conditions. By comparison, the EBS ecosystem does not have the same dependence on Australian sardine, with jack mackerel and redbait being more important and the Australian fur seals are particularly dominant and influential on their prey. Therefore, the roles that the SPF species play in each system are different as are the roles of the top predators, and may be important to consider for management and allocation of resources with respect to the ecosystem requirements (see Chapter 6).

4.3.2 Climate change

Ecosystem models found that climate change was very likely to have major impacts in any system, particularly in top-down systems already sensitive to fishing pressure (Bulman *et al.* 2011). A range of climate-change scenarios has been explored using a collection of EwE models for a dozen ecosystems around Australia including the EBS model, with generally linear responses to system productivity, although individual model specification and structure also influenced outcomes (Brown *et al.* 2010).

Fulton (2011) suggested that mid-trophic level species, particularly mesopelagic and small pelagic fishes, may be at the centre of a future oceanographic regime shift in waters off eastern Tasmania and Bass Strait. She used a collection of Atlantis models for north-east, north-west and south-east Australia to predict outcomes from climate-change scenarios. In the south-east model, plankton, other pelagic invertebrates, and pelagic fish all increased, while the demersal fish decreased. The modelled regime shift in the waters off eastern Bass Strait and Tasmania predicted a change from a demersal and mesopelagically dominated system to a more pelagically driven one. While primary production was predicted to increase, the plankton community shifted to a smaller sized plankton assemblage similar to the actual shift observed during 1988–89 (Harris *et al.* 1991, Harris *et al.* 1992). Such a shift was proposed by McLeod *et al.* (2012) to explain the apparent switch in dominance between jack mackerel and redbait since the early 2000s. They found that jack mackerel reliance on krill was about 60 per cent by weight compared to nearly total reliance in the 1980s (Young *et al.* 1993). Jack mackerel also ate myctophids, similar to the jack mackerel studied by Blaber and Bulman (1987) on the upper shelf off Maria Island, suggesting they fed deeper. Redbait had a higher dependence on krill than jack mackerel but also ate copepods so perhaps could take advantage of a more copepod-dominated assemblage. Macleod *et al.* (2012) suggested that a permanent shift to a smaller-sized plankton base mediated by warmer, less productive water would better support the small copepod–redbait pathway. Bulman *et al.* (2011) stated that a permanent regime shift "may lead to large-scale restructuring of the role of small pelagic fishes" which may "lead to a radically different context to the fishery than exists today".

4.3.3 Sustainable harvest and indicators

A challenge for management of the SPF is to not only maintain the target stocks at a sustainable level but at a level that avoids broader ecosystem impacts. Pikitch *et al.* (2012) point out that it is possible to manage a stock so that it is not overfished but still cause negative ecosystem effects, i.e. ecosystem overfishing, by not considering predator-prey relationships. Several modelling studies have explored sustainable harvest rates and indicators of relative importance of the SPF species.

Goldsworthy *et al.* (2003a) explored the consequences of fishing redbait and jack mackerel on the Australian fur seal populations in the East Bass Strait, a relatively small area of the SPF. They found that at a harvest of jack mackerel of 5000 t, equivalent to a fishing mortality (F) of 0.05 (of the whole biomass), the fur seal biomass would decline by about 10 per cent and a redbait harvest of 5000 t would cause a fur seal decline of around 2 per cent. It should be noted that this study did not model environmental variability, therefore biomass changes of this order due to fishing may either be added to that caused by environmental variability or absorbed by the population's ability to cope with a certain degree of change. In either case, low levels of change would be indiscernible from natural variability. At higher levels of exploitation, however, biomass changes are likely to be discernible.

Smith *et al.* (2011), in a study for the Marine Stewardship Council (MSC), explored the broader ecosystem effects of fishing LTL species in five ecosystems: three of the eastern boundary currents, i.e. northern Humboldt, southern Benguela, and Californian current; and two non-upwelling dominated systems, i.e. the North Sea and south-east Australian shelf. The LTL species in that study included small pelagic 'forage' fish such as anchovy, sardine, herring, mackerel and capelin, but also mesopelagic fishes and invertebrate species such as krill. Krill has been the focus of concerns in the Antarctic ecosystem in relation to increased harvesting and potential localised depletion effects (Constable *et al.* 2000, Plagányi and Butterworth 2012, Pikitch *et al.* 2014). The LTL investigation used three model structures to avoid model-specific structural assumptions. The two southeastern Australian ecosystem models included jack mackerel, Australian sardine and redbait as well as krill, squid and mesopelagic fishes (Atlantis-SE: Johnson *et al.* 2010, EwE EBS: Bulman *et al.* 2011).

The strategy of Smith *et al.* (2011) was to investigate the responses of all ecosystem model groups to a range of exploitation rates for each of the LTLs up to extirpation. They found impacts were widespread, and increasing exploitation rates tended to involve increasing numbers of groups (see Figure 2 in Smith *et al.* (2011)). The individual response of a species also varied: some species were more responsive even at low fishing rates. Marine mammals and seabirds were most often negatively impacted although not highly.

Indicators

The variability across the species and the potential implications for management prompted Smith *et al.* (2011) to look at generic properties that might explain and predict the variability observed. They calculated a connectance index (the number of connections a prey has in the model diet matrix relative to the total number of connections in the model), as an indicator of the importance of particular prey in the ecosystem. Prey with values greater than a threshold of 0.04 were considered highly connected. They found that abundant groups had consistently greater impacts as did the more highly connected groups.

This theme of connectedness was explored further by Plagányi and Essington (2014). They proposed a way to identify critical forage fish species in an ecosystem using the proportion of a predator's diet that the forage fish constitutes (by biomass) as well as the number of connections it has with other groups in the matrix. The supportive role to fishery ecosystems (SURF) index is similar to the connectance of Smith *et al.* (2011) but also considers the strength of those interactions. The primary motive for this development was to provide a quick but robust indicator to identify those key species whose removal might have the largest indirect impacts. The connectance of each of the EwE models was investigated in one or other of the studies mentioned, i.e. the MSC connectance index for EBS model (and Atlantis-SE model) (Smith *et al.* 2011) and the SURF (and connectance but values not given) for the GAB model (Plagányi and Essington 2014). In order to compare both indices for each of the models, the panel calculated the relevant 'missing' indices for the EwE models only (Table 4.3). As both of these indices were proposed to identify critical links in the food web it was useful to determine whether the Australian SPF species have a significant role using both methods.

Connectance for the EBS had been calculated by Smith *et al.* (2011) and none of the SPF species met the threshold, although jack mackerel was close, suggesting that none of these species is particularly critical in the system. However, the small pelagic group used in this study was an aggregated group of small pelagic species including Australian anchovy and sprats (as a minor component). Anchovy alone might produce a significant result since it comprises more than 20 per cent of some age classes of marine mammal diets in age-structured Atlantis models (Dr E Fulton, CSIRO pers. comm. 29 September 2014). In contrast, in the GAB model, all SPF species were above the threshold, with Australian sardine having the highest connectance, noting that Australian sardine in the GAB is managed in the SASF rather than in the SPF.

The SURF index identified no SPF species as being above the threshold in the EBS, whilst in the GAB, only Australian sardines were identified as above the threshold, as was anchovy. The SURF index uses the actual prey proportion and therefore gives a more quantitative indication of importance and this makes the model structure quite important in interpreting the results. Therefore, in the EBS model where the 'small pelagic' group was an aggregated group, as noted previously splitting out sardines was necessary in order to calculate the index. Anchovy, being dominant in little penguins' diets, might well have produced a significant result. While indices are useful they should be used only with careful interpretation and knowledge of the systems. It is worth noting that in the EBS model, krill and mesopelagic fishes produced above threshold values for both connectances (0.049 and 0.056 respectively: Smith *et al.* 2011) and SURF indices (0.002 and 0.004 respectively: this study). In the GAB model, krill had a high connectance index (0.063) but not SURF index (0.0003). The difference in results between the two models reflects the difference in the ecosystem characteristics they represent as shown in the earlier section on food web control.

Table 4.3 Ecosystem model connectance and SURF indices for SPF species and anchovy in EBS and GAB EwE models

INDEX	MODEL	AUSTRALIAN ANCHOVY	AUSTRALIAN SARDINE	REDBAIT	JACK MACKEREL	BLUE MACKEREL
Connectance	EBS	-	0.0315	0.0264	0.0368	0.021
	GAB	**0.0443***	**0.0601***	**0.0506***	**0.0570***	**0.0538***
SURF	EBS	~0.0004	~0.0006	0.0002	0.0005	<0.0001
	GAB	**0.0023#**	**0.0022#**	0.0008	0.0006	<0.0001

Bolded values > thresholds; * threshold > 0.04 (MSC), # threshold > 0.001 (SURF).

Sustainable harvest

Smith *et al*. (2011) concluded that considerable impact could be mitigated by a reduction in exploitation levels of LTL species from maximum sustainable yield (MSY), i.e. from about 60 per cent depletion to approximately 25 per cent depletion (see Figure S1 in supporting online material: Smith *et al*. 2011). They also concluded that this target could be achieved with a much lower fishing effort and may be close to long-term economic optimum return. Two further strategies were proposed that might be effective in managing these fisheries: using thresholds or 'set-asides', i.e. an allocation of the resource specifically to ensure against impacts such as those on central place foragers and broader ecosystem requirements, and spatial closures.

An important outcome of the Smith *et al*. (2011) study was a concern about the species-specific variability in response to the same exploitation rates and the implications that may have for using a 'blanket' target as in the SPF Harvest Strategy (Australian Fisheries Management Authority (AFMA) 2008). This concern is the focus of a current investigation (Fisheries Research and Development Corporation (FRDC) 2013/028) that is also assessing the ecosystem impacts of fishing simultaneously across all target species in the SPF (see Section 4.3.5). The earlier Smith *et al*. (2011) study assessed the impacts of only fishing one target species at a time (although all other fisheries and non-target species were modelled at status quo levels).

The outcomes of the Smith *et al*. (2011) study were supported by the Lenfest Forage Fish Task Force research (Pikitch *et al*. 2012). Its objective was to provide "practical, science-based advice for the management of forage species because of these species' crucial role in marine ecosystems and because of the need for an ecosystem-based approach to fisheries management". This comprehensive examination of forage fish ecosystems, their fisheries and management resulted in the development of specific management measures and general rules.

One of the findings from the Lenfest analysis of 72 ecosystem (EwE) models was that three-quarters of them had at least one predator that was highly dependent on forage species, i.e. ate 50 per cent or more forage species; 29 per cent had at least one predator that was extremely dependent (i.e. that ate 75 per cent or more), and 25 per cent had no predators that ate 50 per cent or more (Pikitch *et al*. 2012). Applying those criteria to observed diet data in Table 4.2, i.e. not modelled diet data, both ecosystems (GAB and EBS) had species that were extremely dependent on SPF species: bonito in the GAB, little terns in Bass Strait, and inshore SBT in eastern Tasmania. Of these, bonito and little terns were dependent on sardines and the SBT dependent on jack mackerel and redbait. Another five species in both areas were highly dependent when summing their diet across all forage species: Australian fur seal in the GAB and EBS; Australasian gannets in Port Phillip Bay; shy albatross in Bass Strait and GAB; SBT in the GAB; and school shark, barracouta and mirror dory in the EBS. However, if these criteria were applied to the model group data as Lenfest did, rather than observed data, the results were slightly less outstanding, i.e. only the Australian fur seal, SBT and the 'other tuna' group from the GAB model would rank as highly dependent and the last two results were as a result of inclusion of Australian sardine which is managed by South Australia in the GAB. This is because species aggregation within the model, a common necessity in modelling, hides specific species interactions as seen in the calculation of connectance indices. In addition, if a predator's diet is highly variable, it may have not been sampled adequately to have captured that variability. Even if it were adequately sampled, as discussed previously, the single characterisation of a highly variable diet for inclusion into a 'model diet' will smooth over those critical times when SPF species may be highly important

The indicators and guidelines derived from the MSC and Lenfest studies are in general agreement with original conclusions about the dynamics of the model systems, but the models point to other species and groups in each ecosystem that might also be important. It still remains necessary to 'drill down' to species-specific information to inform issues of ecological dependence and allocation, particularly for protected species of predators and other predator species of high commercial value.

4.3.4 South-east case study

Notwithstanding the problems of model specificity and architecture, ecosystem models do provide valuable insights into the dynamics of ecosystems under pressure. All of the models, particularly the Atlantis models, have been used to predict changes in ecosystem groups under various fishing scenarios. The two Australian models used in the MSC study were reported more fully in Johnson *et al*. (2010) and Bulman *et al*. (2011). As discussed in the previous section, for the broader

MSC study, Johnson *et al.* (2010) investigated the responses of the EwE-EBS and Atlantis-SE ecosystem model groups to a range of exploitation rates for each of the LTL species up to extirpation.

In the small pelagics simulations, they found that exploitation rates (F) of 0.1 in the EwE-EBS model and 0.05 in the Atlantis-SE model reduced the biomass to 75 per cent of unfished biomass (B_{75}). This biomass is close to the 80 per cent level recommended by the Lenfest task force for forage fisheries on a low information tier (Pikitch *et al.* 2012). In both EwE-EBS and Atlantis-SE, the level of biomass at which maximum sustainable yield can be achieved (B_{MSY}) was predicted to be similar to B_{40} (40 percent of biomass (usually spawning stock or available biomass)) and attained with F=0.33 and 0.15 respectively.

In the jack mackerel simulations, Fs of 0.01 and 0.02 were found to reduce the biomass to B_{75} in the EwE-EBS and Atlantis-SE models respectively. B_{MSY} (at slightly above B_{40}) was attained with Fs of 0.05 and 0.06 respectively.

The redbait simulations for Atlantis were not reported due to inappropriate calibration at the time and those for the EwE-EBS model were not representative of the eastern Tasmanian stock (Bulman *et al.* 2011) and so will not be discussed further here. It should be noted that the current Atlantis model being used in the FRDC Project 2013/028 has an appropriate redbait calibration (Dr E. Fulton, CSIRO pers. comm. 22 September 2014).

The responses of the model groups for a reduction of jack mackerel to B_{75} were small (Table 9; Figures 33 and 34 of Johnson *et al.* 2010). The largest adverse effects were decreases in abundance of approximately 5 per cent for tunas and seals, and less for sharks and dories in the EwE-EBS, and even smaller decreases in Atlantis-SE. The majority of the responses were small increases in biomass particularly in seabirds and baleen whales in Atlantis-SE. This is broadly consistent with Goldsworthy *et al.* (2003a) who found that an F equal to 0.01 of jack mackerel, i.e. catch of 1000 t, was predicted to result in an approximate 2 per cent decline of fur seals.

Both negative and positive responses to reductions of small pelagic species to B_{75} or less were far more wide-reaching in the EwE model compared to the Atlantis model (Table 12, Figures 12 and 13 of Johnson *et al.* 2010). Atlantis produced little response and some of the largest ones were actually positive increases in biomass. In the EwE-EBS model, little penguins declined by 20 per cent; however the small pelagic group was a combination of Australian anchovy and sardine and the little penguin's diet consists predominantly of anchovy (Tables 4.1 and 4.2), therefore it is the reduction in the anchovy, rather than the sardine, to which the little penguins might be responding. This might also apply to some of the other fish groups that showed strong responses.

The differences in the model responses were due to 'model architecture' and formulation and are discussed more fully in Johnson *et al.* (2011b). The issues to do with model structure, i.e. the aggregation of groups, have been addressed in the more recent Atlantis-SPF being used in the FRDC Project 2013/028. However, Johnson *et al.* (2011b) also specifically mention factors related to size structuring such as gape limitation, ontogeny and prey-switching that allow more flexible trophic connections in the Atlantis model than in the EwE configuration. The gape limitation and prey preference mechanisms used in Atlantis allow for prey switching if suitable alternative prey can be found, and therefore buffer predators from declines in their primary prey. This kind of switching has been seen in other ecosystems and is suggested by all the Atlantis model results as likely in this region for the SPF species but possibly not as simply for anchovy (Dr E. Fulton, CSIRO pers. comm. 26 September 2014).

4.3.5 Explorations of biomass and harvest strategy

Irrespective of model architecture, both the EwE and Atlantis models are calibrated to real observations including biomasses of the model groups. While these models are not used for setting total allowable catches (TACs), their value in evaluating scenarios such as those discussed above depends upon the models being either balanced, in the case of EwE, or numerically stable, in the case of Atlantis. The biomass used in the EwE-EBS model for jack mackerel was initially estimated from survey data (Bulman *et al.* 2006) from surveys of the South East Fishery (Bax and Williams 2000) which was consistent with the estimates of Neira (2011). Similarly, the biomass of redbait was estimated from estimates derived from daily egg production methods for redbait (Neira *et al.* 2008, Neira *et al.* 2009, Neira and Lyle 2011).

Fulton (2013) explored the hypothesis that the TAC for jack mackerel was too high by simulating a range of spawning biomass estimates between 20,000 and 170,000 t and evaluating the model's performance with each estimate. Biomasses of 20,000 to 30,000 t caused both models to 'fail'. The best performances for Atlantis were achieved for biomasses between 96,000 and 190,000 t with a mean of 143,000 t (Fulton 2013) similar to the mean of Neira (2011). For the EwE model, spawning biomasses of 130,000 and 170,000 t, equivalent to total biomasses of 145,000 t and 180,000 t (the current baseline value) that were input into the model, were the only values that would balance the model. It was concluded that very low biomass values, i.e. 20,000 to 30,000 t of jack mackerel, are not consistent with the current observations and knowledge of the ecology of the system.

Fulton (2013) also compared the current SPF Tier 1 Option 2 harvest control rule (HCR) of exploitation rate of 0.15 (the maximum harvest rate allowable in the three-tier system: see Section 3.2.2) with the more commonly used target of B_{48} across the range of most plausible jack mackerel biomasses. Some localised depletion was possible under the SPF Harvest Strategy (AFMA 2008) but most changes were less than 5 per cent, however, under the B_{48} strategy a number of complicated 'knock-on' effects were likely. The conclusion from this investigation was that "if smaller ecological footprints are desired, target reference points for jack mackerel should be increased to a high level, e.g. B_{75} as recommended by Smith *et al.* (2011)" (Fulton 2013). In other words, a target of B_{48}, i.e. a reduction to 48 per cent of the (usually spawning stock) biomass (SSB), is not an appropriate target reference point for jack mackerel and that the Tier 1 Option2 HCR of $F_{0.15}$ (i.e. a harvest rate of 15 per cent of SSB) broadly satisfies ecosystem requirements.

The current SPF Harvest Strategy is the focus of an investigation (FRDC 2013/028) lead by Dr Tony Smith (CSIRO). The two issues being examined are: Should exploitation rates be lowered to account for potential trophic impacts of fishing these species? And does the current strategy comply with the Commonwealth Harvest Strategy Policy (Department of Agriculture, Fisheries and Forestry, 2007) for each target species and stock? Preliminary results communicated to the panel (Dr A. Smith, CSIRO *in litt.* 6 June 2014) suggest that the impacts on predators and other groups of fishing the SPF stocks are low across the range of exploitation rates including the current rate. The changes in abundance of all other species and trophic groups were less than 20 per cent and mostly negligible and this was true even when all the SPF target species were simultaneously depleted. The model results predict that predators would switch diets to other species or groups when SPF species abundance is low which they found consistent with other model results for the region. The preliminary conclusion is that, "based on current evidence, the biomass targets and corresponding exploitation levels in the SPF harvest strategy need not be adjusted specifically to account for trophic impacts of fishing", i.e. the ecological allocation to maintain the predators and ecosystem as a whole is not impinged upon by the exploitation rate. Model simulations of the present TAC were shown to be even more conservative than the harvest strategy rule implying that fishing in recent years should not have been harmful (Dr E. Fulton, CSIRO pers. comm. 1 September 2014). Preliminary results from the MSE analysis confirmed that the current SPF harvest strategy settings are generally appropriate, and that the Tier 1 harvest strategy meets the Commonwealth Harvest Strategy Policy requirement that there be less than a 10 per cent chance of the stock falling below 20 per cent of unfished levels (Dr A. Smith, CSIRO *in litt.* 6 June 2014).

In the SASF, Goldsworthy *et al.* (2013a) found that the current level of harvest for Australian sardines of about 10 to 20 per cent of the estimated spawning biomass was conservative and that no broad ecosystem effects were evident. This exploitation rate is in accord with the recommendations of the Lenfest Fish Task Force (Pikitch *et al.* 2012) and the MSC study (Smith *et al.* 2011). However, Goldsworthy *et al.* (2013a) also note that the SASF is concentrated in a relatively small area, approximately 7 per cent of the model domain and broader area over which the fish are found and connectivity between the fish within the two areas is assumed to be high. If this assumption is incorrect, "localised depletion cannot be discounted as a meso-scale issue" (Goldsworthy *et al.* 2013a).

4.4 Conclusions

The predator-prey interactions are generally well-known for many of the main species in the SPF although some of the trophic data particularly in the Eastern Zone are at least 20 years old. While a major shift in diet might have occurred in the past decade or so, preliminary results from a recent study into diets of a small sub-set of the original South East Fishery shelf study (Bax and Williams 2000) fish species in the Eastern Zone, do not suggest large changes (Dr C. Bulman, CSIRO unpublished data). However, dietary information for Australian fur seals and little penguins from Victoria in the Eastern Zone are more current and do suggest diet changes indicative of an oceanographic regime shift (Kirkwood *et al.* 2008, Chiaradia *et al.* 2010 respectively). The data collected for GAB species is also recent and also includes diets for large predators and central place foragers. While the spatial coverage of the diet studies is relatively small when compared to the SPF, it is assumed to be representative of each Zone. There remains a lack of distributional and biological data for many higher predators, particularly seabirds, and particularly in the Eastern Zone. Therefore, some uncertainty remains about the nature and extent of ecosystem impacts that might arise if the main fishing effort in the SPF was to be again concentrated off eastern Tasmania, although the panel noted that the historical exploitation levels of jack mackerel in that area were higher than the present harvest strategy allows.

The ecosystem modelling studies in the SPF appear to have captured the dynamics of the systems reasonably well. The SPF species are apparently not as influential as small pelagic species in other upwelling systems. There is general agreement across model types and ranges of scenarios that exploitation under the current harvest strategy is unlikely to cause adverse environmental impacts to the broader ecosystem although some predator groups may decline slightly. The 'ecological allocation' to predators and the broader ecosystem is apparently adequate based on model simulations of the Tier 1 exploitation rate (greater than the present TACs). There is, however, the potential for localised depletion that might lead to adverse environmental impacts if fishing effort were spatially concentrated. Localised depletion is discussed further in Chapter 6.

5 Direct impacts on EPBC Act protected species

5.1 Introduction

There are 241 species (see Appendix 3) protected under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) that occur in the area of the Small Pelagic Fishery (SPF). These are comprised of:

- 10 pinniped species
- 44 cetacean species
- Dugong *Dugong dugon*
- 89 species of seabirds
- six marine turtle species
- nine seasnake species
- 13 shark and ray species
- 69 teleost species, of which 66 are syngnathids and three are other teleost fish.

The data compiled by Tuck *et al.* (2013) have been used as the primary source to inform the panel's understanding of the nature and extent of the direct interactions of mid-water trawling in the SPF with protected species to date. Tuck *et al.* (2013) report on 'interactions' with protected species but do not define 'interaction'. Since the data were compiled from Australian Fisheries Management Authority (AFMA) logbooks and observer records the panel has assumed that the interactions data reported in Tuck *et al.* (2013) reflect the definition in the memorandum of understanding (MoU) between AFMA and the Department of the Environment. As noted in Section 2.2.3, this definition excludes acoustic disturbance and behavioural changes brought about by habituation to fishing operations, which the panel includes in its definition of 'direct interactions' applied to the assessment of the Declared Commercial Fishing Activity (DCFA). As a result Tuck *et al.* (2013) understate the level of 'direct interactions'. However, in the absence of any more comprehensive assessment of historical interactions data, the panel has used the information collated by Tuck *et al.* (2013) as an indicator of the nature and extent of direct interactions with protected species by previous mid-water trawl activity in the SPF.

The panel's Terms of Reference specified the need to assess the likely nature and extent of direct interactions of the DCFA with seals and dolphins. The panel formed the view that pinnipeds and cetacean species generally warranted detailed consideration. Within each of those groups the panel identified species of particular interest (Sections 5.2 and 5.3).

The panel noted that the Department of the Environment did not ascribe a high level of uncertainty to the impacts of the DCFA on seabirds (Box 1.1). This appears to have been based largely on the fact that there would be no discharge of biological material by the DCFA, the net would remain submerged during the pumping operation and bird mitigation measures were relatively well developed and tested. The panel generally concurs with this assessment. As a result, its assessment of the impact of any direct interactions with seabirds (Section 5.4) is less extensive and less species-specific than that for pinnipeds and cetaceans. However, the panel formed the view that the potential for ecosystem effects, of any potential localised depletion arising from the DCFA, on seabirds, particularly on central place foragers (CPF), required more detailed assessment (Chapter 6).

The panel considered the need to assess direct interactions between the DCFA and protected species of dugong, turtles, seasnakes, sharks and teleosts and formed the view that this was not necessary. The rationale for this decision is provided in Appendix 3.

5.2 Pinnipeds

5.2.1 Pinniped species assessed

There are three resident pinniped species that breed in coastal areas and islands off southern Australia. These are the Australian sea lion *Neophoca cinerea*, the New Zealand fur seal *Arctocephalus forsteri*, and the Australian fur seal *A. pusillus doriferus*. All species are native to Australia, occur within the SPF and occur in sympatry (overlap in ranges) over parts of their range (Kirkwood and Goldsworthy 2013) (Figure 5.1).

In addition to these resident species, a number of vagrant species visit southern Australia irregularly (Figure 5.2). The most common is the subantarctic fur seal *A. tropicalis*. Its nearest breeding colonies are located at subantarctic Macquarie Island (Southern Ocean/South Pacific Ocean) and Amsterdam/St Paul Islands (Southern Ocean/Southern Indian Ocean). Southern elephant seals *Mirounga leonina* are also regularly sighted in southern Australia, most commonly between September and March with animals coming ashore to moult. There are a number of breeding records in southern Australia, most notably in Tasmania. Prior to European arrival in Australia this species used to breed on King Island, Bass Strait, but was eliminated by sealers by the early 1800s. The nearest breeding sites are now at subantarctic Macquarie and Heard Islands. Another regular visitor to southern Australia is the leopard seal *Hydrurga leptonyx*. Although there are records of sightings of crabeater seal *Lobodon carcinophagus*, Weddell seal *Leptonychotes weddelli*, Ross seal *Ommatophoca rossii* and Antarctic fur seal *A. gazella* in southern Australia, they are uncommon relative to the other vagrant species (Kirkwood and Goldsworthy 2013). The panel recognises that interactions between these vagrant pinniped species and SPF fishing vessels is possible but unlikely because of their irregular occurrence. Therefore, this report focuses largely on the three key resident species. The panel recognises that potential impacts from the DCFA could apply to the other seven pinniped species as well. A summary of distribution and abundance throughout the SPF, status and trends, conservation status and foraging ecology of these key species is provided below.

Australian sea lion *Neophoca cinerea* (Level 2 Productivity Susceptibility Analysis (PSA) Residual Risk – Medium)

Distribution and range

The Australian sea lion (ASL) is endemic to Australia, and restricted to South Australia (SA) and Western Australia (WA). Its extant breeding range extends from The Pages Islands (just east of Kangaroo Island) in SA to Houtman Abrolhos on the west coast of WA (Shaughnessy *et al.* 2011). Pupping has been recorded at 81 sites (islands and at several mainland sites); 47 in SA and 34 in WA (Shaughnessy *et al.* 2011, Goldsworthy *et al.* 2013b, Goldsworthy unpublished data) (Figure 5.3). Despite the large number of breeding sites, only seven sites produce more than 100 pups per breeding season, all of which are in SA. The average pup production per breeding site is just 40, with most sites (70 per cent), producing fewer than 30 pups per breeding season (Goldsworthy *et al.* 2009a, Goldsworthy unpublished data).

The population can be broadly separated into three main metapopulations, one in SA accounting for approximately 84 per cent of pup production; one on the south coast of WA accounting for approximately 10 per cent of pup production; and one on the west coast of WA accounting for approximately 6 per cent of pup production (Goldsworthy *et al.* 2009a, Goldsworthy unpublished data). All west coast WA colonies fall north of the SPF boundary (31°S) (although the southernmost colony at Buller Island is only 38 kilometres (km) to the north). Therefore, about 94 per cent of the species population occurs adjacent to the SPF area. Another 151 locations have been identified as haul-out sites (90 in SA and 61 in WA), but because records of haul-out sites are based on opportunistic observations, the actual number is likely to be higher than this (Goldsworthy *et al.* 2009a).

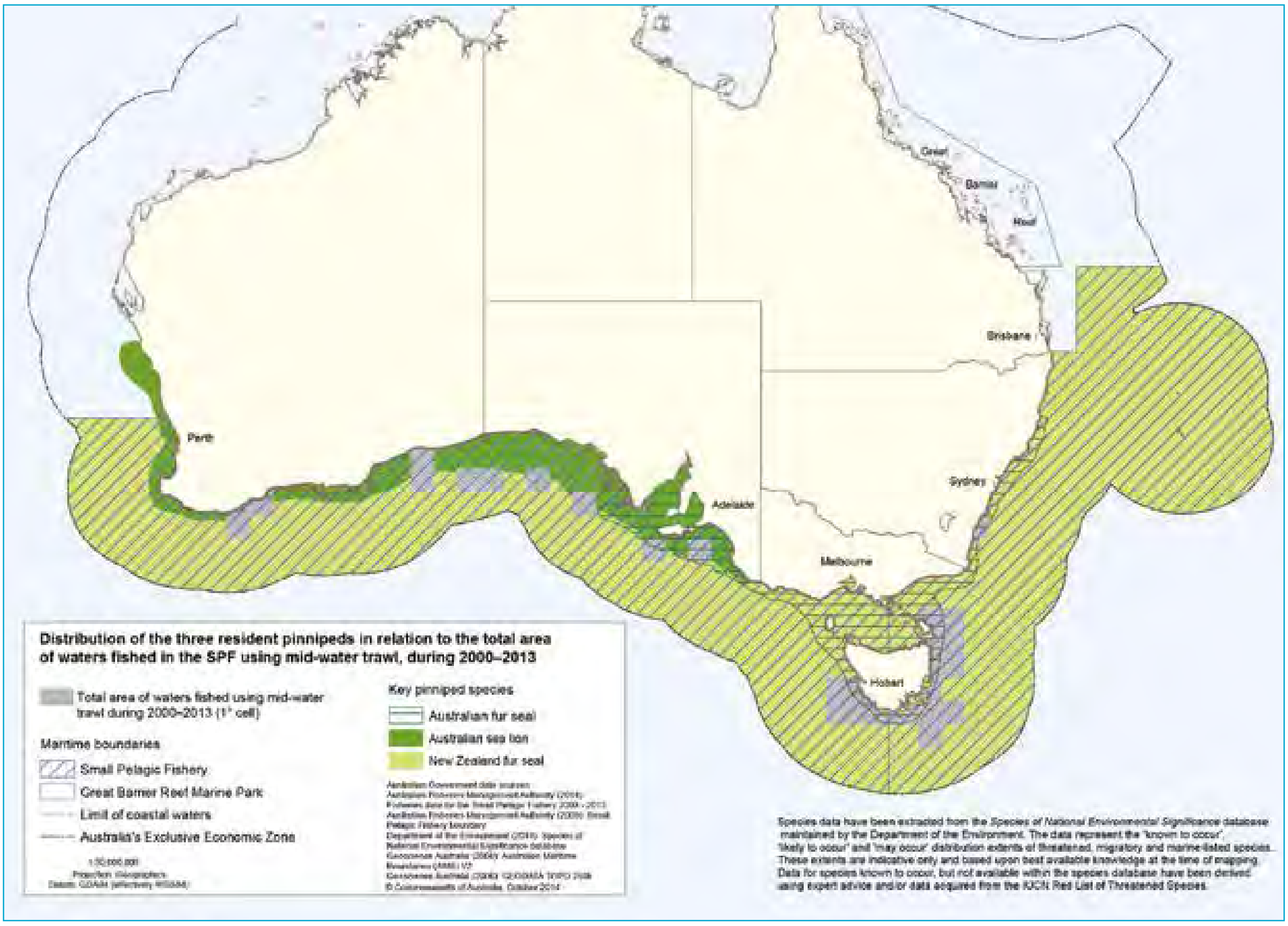


Figure 5.1 Distribution of the three resident pinnipeds in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by the Environmental Resources Information Network (ERIN), Department of the Environment using unpublished AFMA data.

Population size and trends

Total pup production is estimated to be 2691 in SA and 335 off the south coast of WA, and 182 off the west coast of WA (3208 in total) (Goldsworthy *et al.* 2009a, Shaughnessy *et al.* 2011, Goldsworthy *et al.* 2013b, Goldsworthy unpublished data, Goldsworthy in review). Pup production to total population multipliers developed for the species range from 3.83 to 4.08 (Goldsworthy and Page 2007, Goldsworthy *et al.* 2010) giving a total population estimate of approximately 12,690 (with a range of about 12,290–13,090), or approximately 12,000 (with a range of 11,590–12,350) adjacent to the SPF area.

ASL were subject to unregulated sealing in the late 18th and early 19th century (Ling 1999), resulting in a reduction in population size of unknown extent and extirpation of populations in Bass Strait and from many locations within their current range (Shaughnessy *et al.* 2011). The species has not recovered since harvesting ceased, unlike the two fur seal species in southern Australia that have undergone rapid recovery in recent years (Kirkwood *et al.* 2010, Shaughnessy *et al.* 2014).

The analysis of population trends requires consistent estimates or indices of pup production over a number of breeding seasons, and the non-annual and asynchronous breeding habits of the species have made collecting reliable time-series of pup abundance/production challenging (Goldsworthy *et al.* 2009a). Therefore, time series data from which trends in abundance can be estimated are limited (Goldsworthy *et al.* 2009a). The longest time-series data come from the three largest breeding colonies in SA, Seal Bay (Kangaroo Island), The Pages Islands (Backstairs Passage) and Dangerous Reef (Spencer Gulf). More recent time series have come from SA colonies along the Bunda Cliffs in the Great Australian Bight (GAB), at Olive Island (off Streaky Bay), Lilliput and Blefuscu Islands (Nuyts Archipelago) and two small colonies at Jones

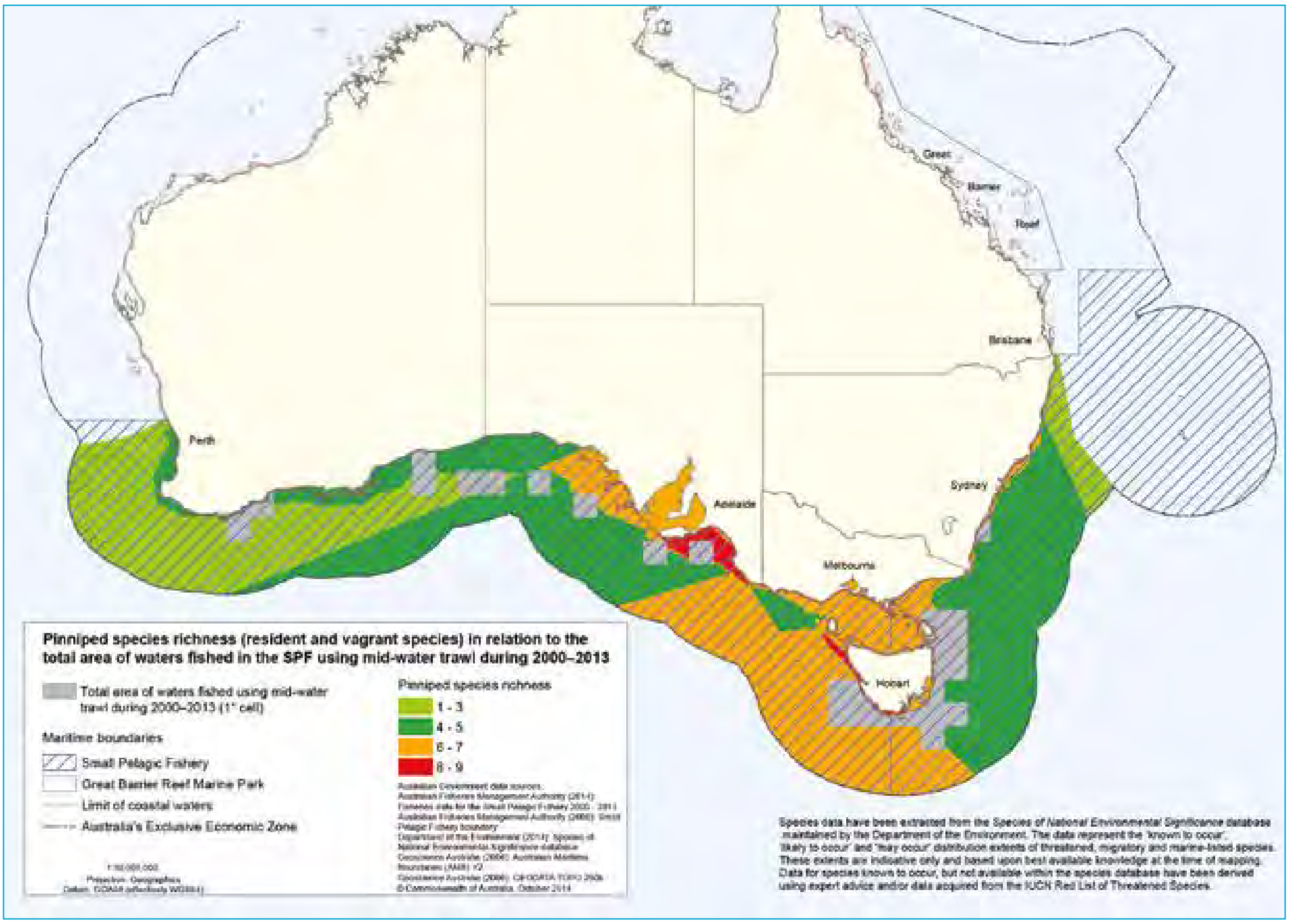


Figure 5.2 Pinniped species richness (resident and vagrant species) in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by ERIN using unpublished AFMA data.

Island (Baird Bay) and The Seal Slide (Kangaroo Island). In WA, ASL pup numbers have been surveyed in most breeding seasons since 1987 at three islands (Buller, North Fisherman and Beagle) on the central west coast of WA, but limited trend data are available for the breeding colonies off the south coast of WA (Goldsworthy in review).

Significant declines in pup numbers have been reported for Seal Bay (approximately 2 per cent decline per breeding season or about 32 per cent decline over 28 years; Goldsworthy *et al.* 2014a); colonies along the Bunda Cliffs (a 39 per cent decline in mean maximum number of pups counted per site over 19 years; Mackay *et al.* 2013); and at Olive Island (approximately 8 per cent decline per breeding season or 32 per cent decline over seven years; Goldsworthy unpublished data). Colonies that appear to be stable (no significant change in pup numbers) include The Pages Islands (surveys undertaken over 20 years; Shaughnessy *et al.* 2013); Lilliput and Blefuscu islands (data only available over five breeding seasons; Goldsworthy *et al.* 2013b); Jones Island and the Seal Slide (six and eight breeding seasons, respectively; Goldsworthy *et al.* 2013b, Goldsworthy *et al.* 2014a); and Buller, North Fisherman and Beagle islands off WA (Goldsworthy *et al.* 2009a). The only known breeding colony where pup numbers have increased is Dangerous Reef in Spencer Gulf. Here, pup numbers increased significantly between the mid-1990s and late-2000s, reaching a peak in 2006–07; since then pup numbers have declined (Goldsworthy *et al.* 2012, Goldsworthy *et al.* 2014c). It has been noted that the major period of increase in pup production at Dangerous Reef coincided with gillnet fishing effort in SA being reduced almost to zero following management changes in the fishery in 2001, which included closure of Spencer Gulf to the Commonwealth managed Gillnet Hook and Trap (GHAT) Fishery (Goldsworthy *et al.* 2007). During eight breeding seasons from 1994–95 to 2006–07 there was a significant negative relationship between gillnet fishing effort and pup abundance at Dangerous Reef (Goldsworthy and Page 2007, Goldsworthy *et al.* 2014c).

The most recent evaluation of the species' status and trends in abundance—using all available time series data on pup abundances from SA and WA subpopulations (23 subpopulations accounting for approximately 48 per cent of the species-wide pup production)—suggests the species' abundance has declined by almost 60 per cent in the past 40 years (Goldsworthy in review).

Biology and feeding ecology

ASL are unique among pinnipeds, being the only species that has a non-annual breeding cycle, with intervals between pupping seasons of approximately 17–18 months (Ling and Walker 1978, Higgins and Gass 1993, Shaughnessy *et al.* 2006, Goldsworthy *et al.* 2014a). All other pinnipeds have annual breeding seasons. Furthermore, breeding seasons are protracted in duration (six to nine months), and occur asynchronously across the species range (breeding can occur at any time of the year, Shaughnessy *et al.* 2006, Goldsworthy *et al.* 2014a). Asynchronous breeding is maintained through extremely low rates of interchange between colonies by adult females, as demonstrated by genetic studies that indicate extreme population sub-structuring of mitochondrial DNA lineages (maternally inherited), even for those separated by short distances (Campbell *et al.* 2008, Goldsworthy and Lowther 2010, Lowther *et al.* 2012). The evolutionary determinants of this unusual reproductive strategy remain enigmatic (Goldsworthy *et al.* 2009a). Pups are usually nursed for around 18 months, but this may be extended to three or more years if females do not pup in the subsequent breeding season or their new pup dies.

ASL restrict their foraging activities to continental shelf waters, with juveniles, adult females and adult males rarely exceeding depths of 90, 130 and 150 metres (m), respectively (Goldsworthy *et al.* 2010) (Figures 5.4 and 5.5). The maximum recorded dive depth for an adult male is approximately 250 m (Goldsworthy unpublished data). The maximum recorded foraging ranges of juvenile and adult female seals are 118 and 190 km, respectively (Goldsworthy *et al.* 2010). Adult males range much further and have been tracked up to 340 km from their colony. There is marked variability within and between-colonies in the foraging behaviour of juveniles, adult females and males (Goldsworthy *et al.* 2009b, Goldsworthy *et al.* 2010, Lowther and Goldsworthy 2011, Lowther *et al.* 2011). Foraging trips to sea are relatively short compared to other otariids (mean 1.1 days and maximum (max) 5.1 days in juveniles; mean 1.2 days and max. 6.2 days in adult females; mean of 2.5 days and max 6.7 days in adult males) (Kirkwood and Goldsworthy 2013). ASL are benthic foragers, they typically dive continuously while at sea and forage at all times of day. During dives they minimise the time spent during the descent and ascent phases in order to maximise foraging time on the seabed. Individual dives rarely exceed eight minutes in duration enabling animals to perform around 10 to 11 dives per hour (Kirkwood and Goldsworthy 2013).

Based on extensive satellite tracking studies, models of the spatial distribution of foraging effort are available for ASL populations in SA (Goldsworthy *et al.* 2003a, Goldsworthy and Page 2007, Goldsworthy *et al.* 2010) (Figure 5.5). Some have also been developed for WA populations based on limited data (Goldsworthy *et al.* 2003a, Campbell 2008, Hesp *et al.* 2012), although a recent study has provided significantly more satellite telemetry for the south coast WA populations (Goldsworthy *et al.* 2014b).

The diet of the ASL is poorly understood. Dietary information available is based on limited scat (faecal), digestive track (autopsied dead animals) and regurgitate analyses (Gales and Cheal 1992, Ling 1992, McIntosh *et al.* 2006), some crittercam footage (Fragnito 2013), and analyses of prey DNA recovered from faeces (Peters *et al.* 2014). Cephalopods appear to be a key component of the diet, and include octopus (Octopodidae), calamari (Loliginidae) and cuttlefish (Sepiidae) species. Key fish taxa include leatherjackets (Monacanthidae), wrasse (Labridae), flatheads (Platycephalidae), perch (Sebastidae, Serranidae), cods (Moridae), mullets (Mullidae), and nannygai/redfish (Berycidae), whiting (Siikginidae), rock-ling *Genypterus tigerinus*, stingaree/fiddler ray (Urolophidae, Rhinobatidae). Small pelagic fish including jack mackerel *Trachrus declivis*, yellowtail scad *T. novaezelandiae* and Australian sardine *Sardinops sagax* have been recorded in the diet, but are not common (McIntosh *et al.* 2006, Peters *et al.* 2014). Crustaceans have also been recorded in the diet and include crabs (stone crab), prawns, and rock lobster (*Jasus edwardsii*) (McIntosh *et al.* 2006, Fragnito 2013). Crittercam data indicate that diet and feeding behaviour can vary markedly between individual animals (Fragnito 2013).

Risks and threatening processes

A range of anthropogenic factors have been identified which may be impacting on the recovery of the ASL (Goldsworthy *et al*. 2009a, DSEWPaC 2013). The cumulative impact of many of these threats may vary across the range of the species. Fisheries bycatch (especially in gillnets) and entanglement in marine debris appear to pose the greatest threat to the Australia sea lion at present. Secondary threats include habitat degradation and interactions with aquaculture operations, human disturbance to colonies, deliberate killings, disease, pollution and oil spills, noise pollution, prey depletion and competition, and climate change (Goldsworthy *et al*. 2009a, DSEWPaC 2013).

Conservation and listing status

The ASL is listed as a threatened (Vulnerable) species under the EPBC Act; also listed as Marine (see Appendix 3). It is listed as a protected species (Rare) in SA under the *National Parks and Wildlife Act 1972*; in WA it is protected under section 14 of the *Wildlife Conservation Act 1950* and is listed as specially protected under the *Wildlife Conservation (Specially Protected) Fauna Notice 2005 (WA)*; and in Victoria the ASL is listed under the *Wildlife Act 1975* (protected wildlife; notable wildlife). Globally, the ASL is listed as Endangered under the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (Goldsworthy and Gales 2008) and is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Summary: Australian sea lion

- *The Australian sea lion is an endemic and threatened species.*
- *Around 95 per cent of its range is adjacent to the SPF area.*
- *The most recent evaluation of the species' status and trends suggests it has declined by almost 60 per cent in the past 40 years.*
- *Interactions with fisheries are identified as a key risk.*
- *Populations are vulnerable to these interactions due to their small size, high metapopulation structure and complex breeding dynamics (non-annual/asynchronous breeding).*
- *Small pelagic fish appear to be uncommon in its diet.*
- *There is a risk of direct interactions with mid-water trawl fishing operations under the DCFA.*

Australian fur seal *Arctocephalus pusillus doriferus* (Level 2 PSA Residual Risk – High)

Distribution and range

There are two subspecies of the Afro-Australian fur seal *Arctocephalus pusillus*, the Cape or South African fur seal *Arctocephalus pusillus pusillus* and the Australian (or brown fur seal) *Arctocephalus pusillus doriferus*. The Australian subspecies was possibly derived as a consequence of late Pleistocene/Holocene (approximately 12,000 years before present) migration events from southern Africa to southern Australia via west-wind drift across the Indian Ocean (Wynen *et al.* 2001, Deméré *et al.* 2003). They are endemic to southeastern Australian waters and are found from the coast of New South Wales (NSW), Tasmania to Victoria and across to SA with the centre of their distribution in Bass Strait (Kirkwood *et al.* 2010). They have not been recorded in WA. There are 21 known breeding sites that include nine established colonies in Bass Strait, Lady Julia Percy Island, Seal Rocks, The Skerries, and Kanowna Island in Victoria; Judgment Rocks, Moriarty Rocks, Reid Rocks, West Moncoeur Island, and Tenth Island in Tasmania; eight colonies that have established in the past 10 to 15 years, which are Rag Island and Cape Bridgewater (Victoria), Wright and Double Rocks (Tasmania), Bull and Sloop rocks (Tasmania), Montague Island (NSW) and North Casuarina Island (SA); and three haul-outs, with accessional pupping at Iles des Phoques (Tasmania), Williams Island and Baudin Rocks (SA) (Kirkwood *et al.* 2010, Shaughnessy *et al.* 2010, McIntosh *et al.* 2014, Shaughnessy *et al.* 2014) (Figure 5.3). The range of the species is expanding, with the new colonies in NSW and SA all establishing in the past 10 years. Historical ranges prior to colonial sealing (pre-1800s) are unknown.

Population size and trends

Three national surveys of pup production for the species have been done at approximately five-yearly intervals since 2002–03. One undertaken in 2002–03 estimated a pup production of 19,820, another undertaken in 2007–08 estimated a pup production of 21,881, and the most recent survey undertaken in 2013–14 estimated a pup production of 15,063 (Kirkwood *et al.* 2005, Kirkwood *et al.* 2010, McIntosh *et al.* 2014). The rate of increase in pup production between 1986 and 2002–03 was estimated to be 5 per cent per year, slowing to 0.3 per cent per year between 2002–03 and 2007–08 seasons (McIntosh *et al.* 2014). It is not clear if the apparent 6 per cent per year decline between the 2007–08 and 2013–14 estimate is due to a poor pupping season in 2013–14 or represents a real decline in population over that period, as there is no colony that is monitored on an annual basis (McIntosh *et al.* 2014). Based on the 2007–08 surveys, two colonies adjacent to the Victorian coast, Seal Rocks (5660 pups) and Lady Julia Percy Island (5574 pups), account for more than half (51 per cent) the total pup production (Kirkwood *et al.* 2010). Based on these surveys the total Australian fur seal population is estimated to be 120,000 individuals (Kirkwood *et al.* 2010).

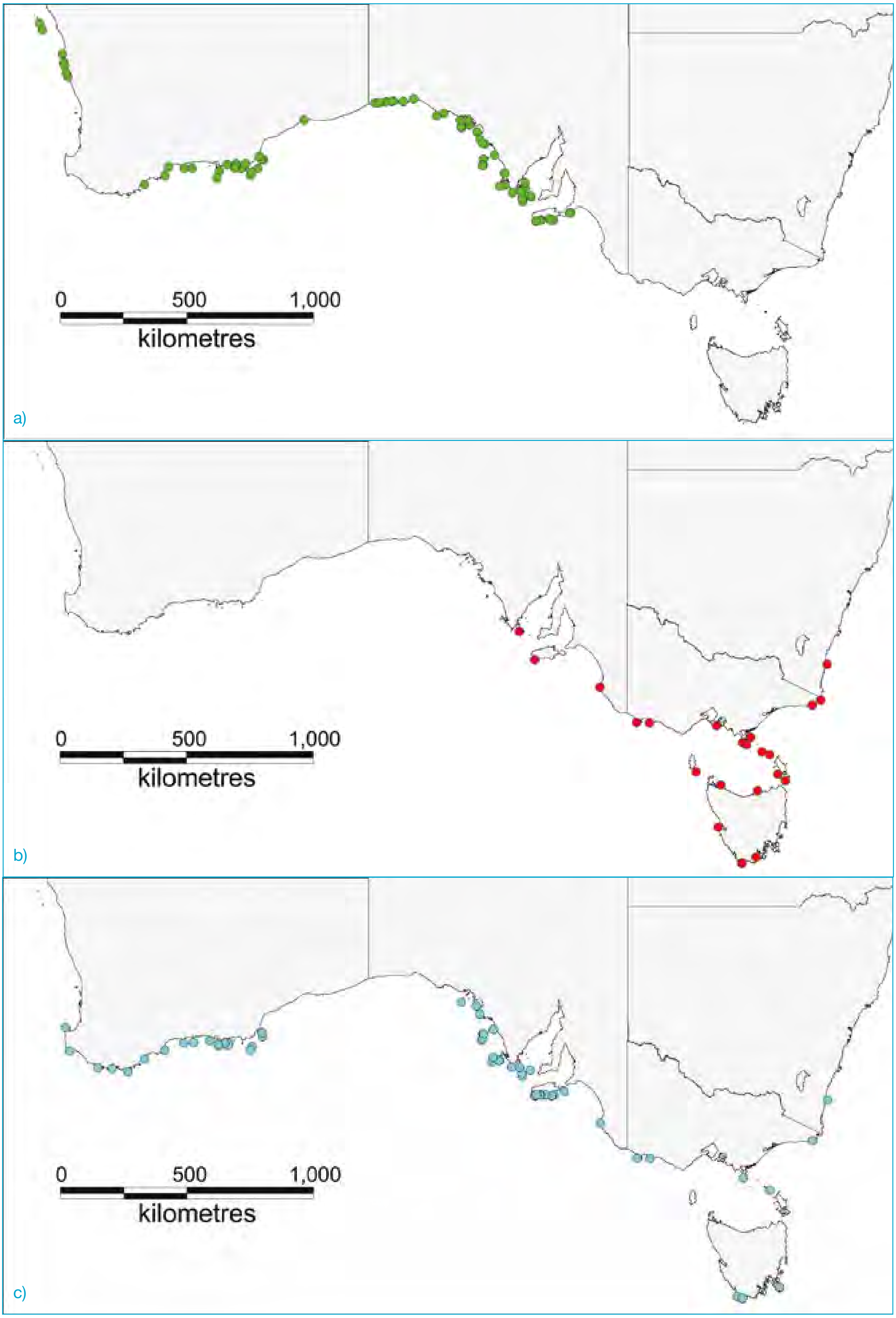


Figure 5.3 Location of known breeding sites for the Australian sea lion (a), Australian fur seal (b) and New Zealand fur seal (c) in Australian waters. **Source:** S. Goldsworthy South Australian Research and Development Institute (SARDI) unpublished data.

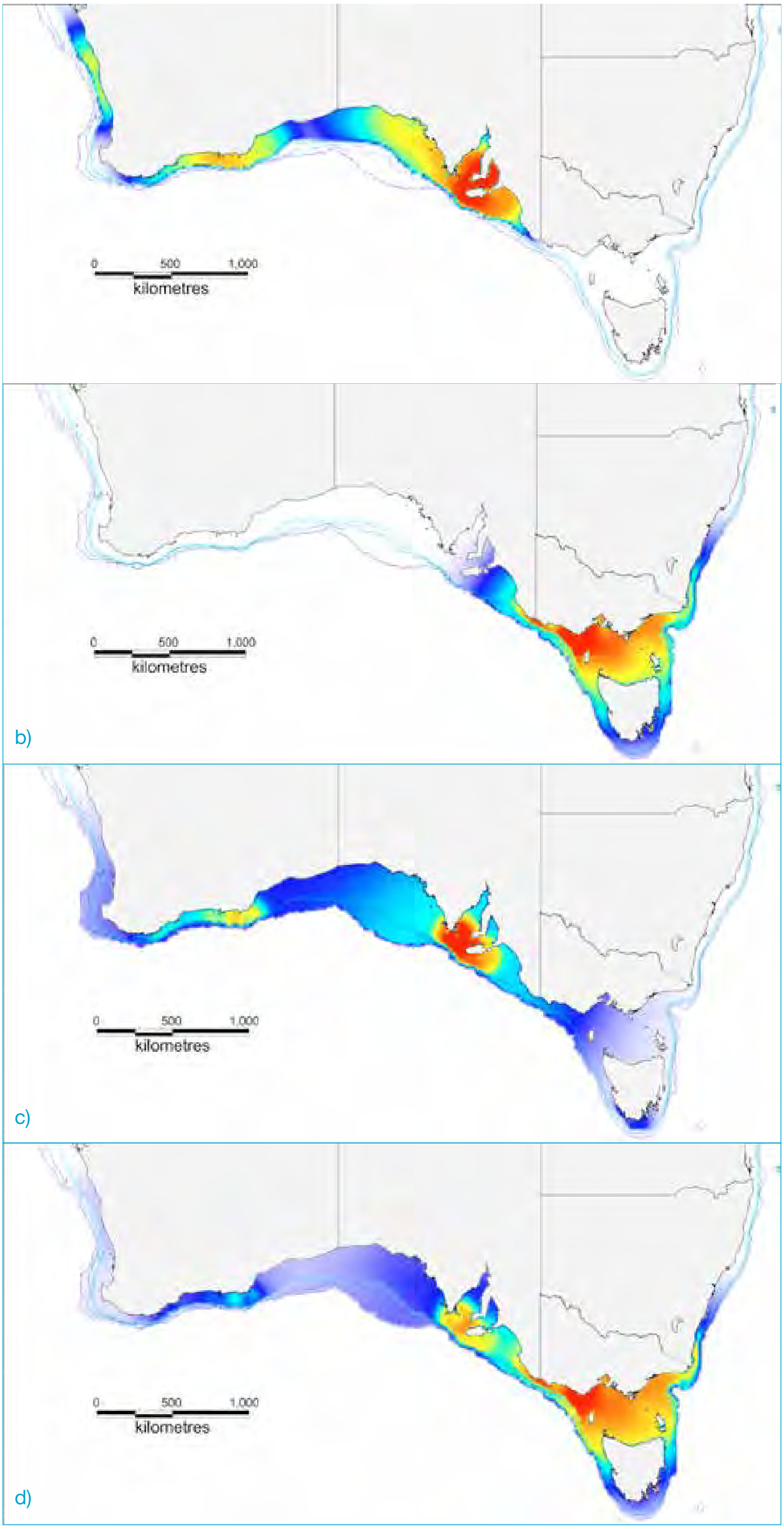


Figure 5.4 Heat plots representing the estimated spatial distribution of consumption effort by Australian sea lion (a), Australian fur seal (b) and New Zealand fur seal (c) populations, and all species combined (d). New Zealand fur seal estimates are only for consumption on shelf waters (oceanic consumption not modelled).

Source: S. Goldsworthy, SARDI, unpublished, redrawn from data presented in Goldsworthy *et al.* (2003a).

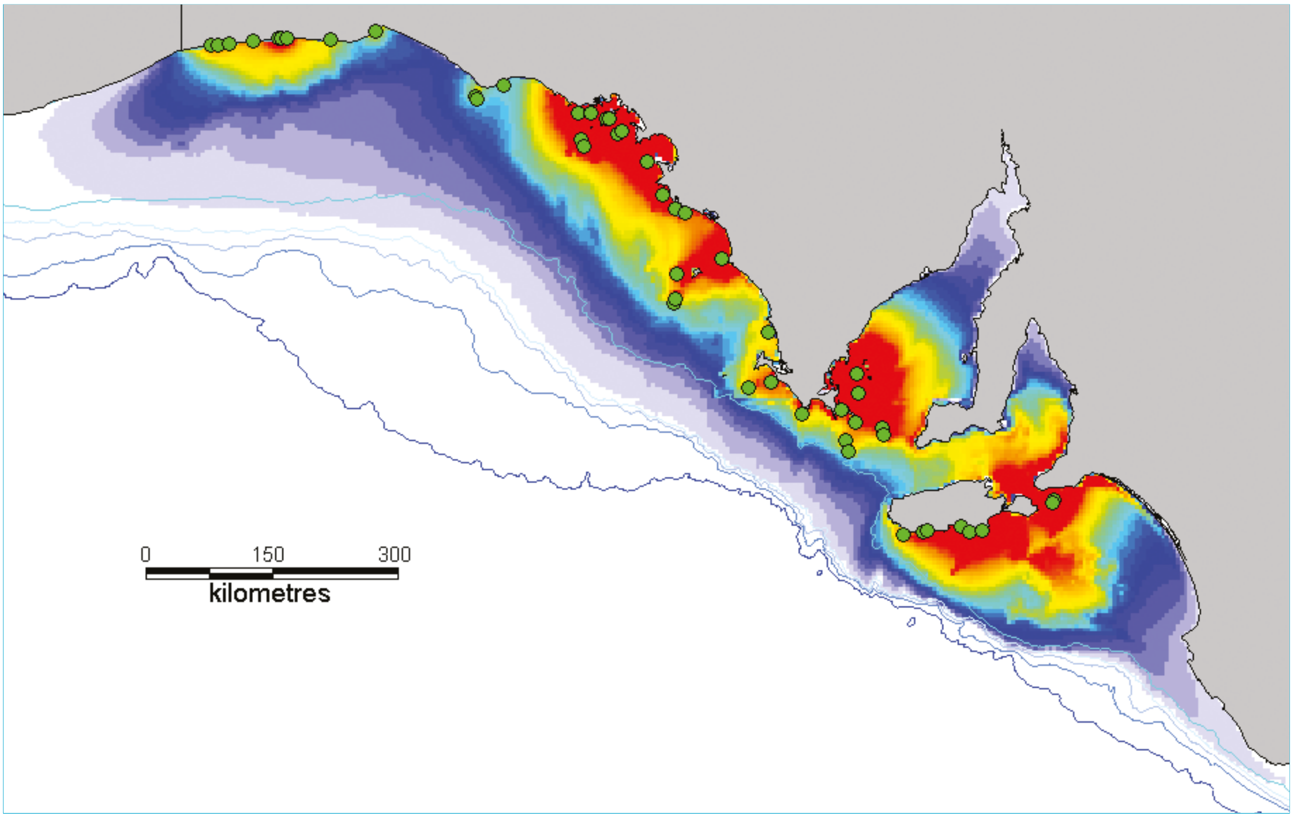


Figure 5.5 Model of the spatial distribution of foraging effort of the South Australian population of Australian sea lions including adult females, males and juveniles. The gradient from red to light blue colours indicates areas from highest to lowest foraging effort. Green dots indicate the location of breeding sites. Bathymetry lines are indicated from light to dark blue (100, 200, 500, 1000, 2000 m).
Source: Goldsworthy *et al.* (2010), reproduced with permission from SARDI – Aquatic Sciences, Simon Goldsworthy.

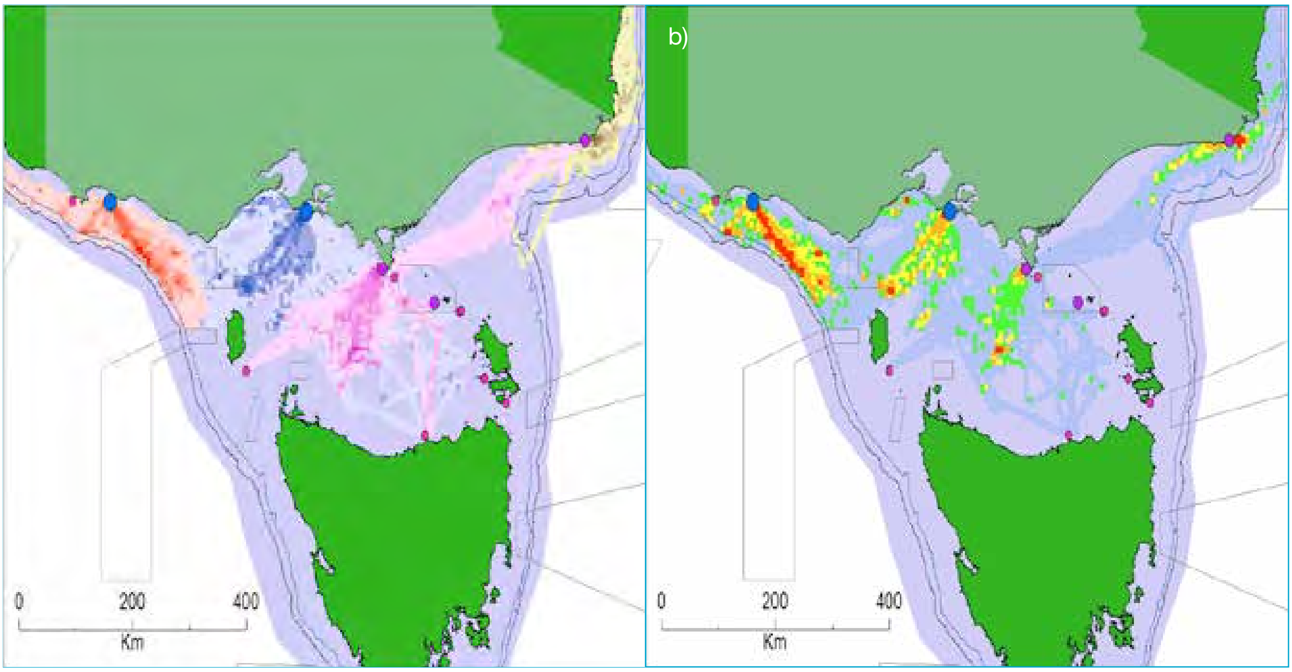


Figure 5.6 Habitat use, as time spent in 100 km^2 cells, by lactating Australian fur seals from the four main Bass Strait colonies: (a) by colony, plus 95 Kernel density polygons of locations at sea (red–Lady Julia Percy Island; blue–Seal Rocks; purple–Kanowna Island; brown–The Skerries), and (b) overall, proportional to numbers of live pups counted in 2002–03 (Kirkwood *et al.* 2005). Depth contours are 100, 200 and 1000 m, marine protected areas in the vicinity of where the females spent time at sea are included. Source: Kirkwood and Arnould (2011), reproduced with permission from CSIRO Publishing (http://www.publish.csiro.au/nid/90/paper/ZO11080.htm) and John Wiley and Sons Inc. Copyright 2005 by Society for Marine Mammalogy.

Biology and feeding ecology

Australian fur seals have an annual synchronous breeding season, with most pups born over a five-week period between early November and mid-December, with the peak in breeding usually in late November/early December (Kirkwood and Goldsworthy 2013). Most pups are weaned when they are 10–11 months old, just prior to the commencement of the next breeding season, although some may continue into a second year.

The Australian fur seal forages almost exclusively in association with the sea floor and rarely leaves the continental shelf, which reflects the benthic nature of their foraging (Arnould and Kirkwood 2008, Kirkwood and Arnould 2011, Kirkwood and Goldsworthy 2013) (Figure 5.6). Satellite tracking studies show that lactating adult females from the main breeding colony in eastern Bass Strait (The Skerries) travelled the shortest distance (20–60 km) while those in central Bass Strait (Seal Rocks, Kanowna Island) and western Bass Strait (Lady Julia Percy Island) typically forage out to 60 and 150 km from the colony (Arnould and Kirkwood 2008, Kirkwood and Arnould 2011). Foraging trip durations of lactating females last approximately six days, with most (greater than 90 per cent) time spent within 150 km of the colony (Kirkwood and Arnould 2011). Analysis of habitat use has indicated that individual seals selected areas with depths of 60–80 m, significantly more than other depths (Arnould and Kirkwood 2008). Females from colonies adjacent to productive shelf-edge waters (e.g. Lady Julia Percy Island and The Skerries) typically have shorter foraging trips, have smaller foraging ranges, forage closer to colonies and exhibit less diversity in foraging trip strategies than females from colonies more distant from the shelf-edge (e.g. Seal Rocks and Kanowna Island) (Kirkwood and Arnould 2011) (Figure 5.6). Females typically show strong fidelities to individual foraging hotspots (Arnould and Kirkwood 2008, Kirkwood and Arnould 2011).

Information on the movement of adult males comes mainly from animals satellite tracked from one colony (Seal Rock). Most foraged in western Bass Strait with many also travelling down the west coast of Tasmania to forage in southern Tasmanian waters, 500 km from Seal Rocks. One adult male travelled west of the Eyre Peninsula (SA), 1200 km from Seal Rocks (Kirkwood *et al.* 2007). A number of adult male Australian fur seals interacting with mid-water trawl gear on freezer vessels off the west coast of Tasmania in the winter blue grenadier *Macruronus novaezelandiae* fishery have also been satellite tracked (Tilzey *et al.* 2006). The tracked seals continually targeted the fishing operations, resting between foraging trips at haul-outs on Tasmania's west coast, until the fishing season ended. The seals then moved on to forage in southern Tasmania or Bass Strait (Tilzey *et al.* 2006). Juvenile Australian fur seals tracked from Lady Julia Percy Island and Seal Rocks display similar ranges to adult females (Kirkwood and Goldsworthy 2013).

The diet of Australian fur seals is reasonably well understood, with dietary studies having been undertaken across most of the species' range. In Bass Strait, southern Tasmania and SA they predominantly forage benthically but also eat a wide range of pelagic fish and cephalopod species (Goldsworthy *et al.* 2003b, Hume *et al.* 2004, Page *et al.* 2005a, Littnan *et al.* 2007, Kirkwood *et al.* 2008, Deagle *et al.* 2009). Key fish prey include redbait *Emmelichthys nitidus*, leatherjacket spp., jack mackerel, barracouta *Thyrsites atun*, red rock cod *Pseudophycis bachus* and flatheads. Cephalopods are also important prey with key species being Gould's squid (*Nototodarus gouldi*), *Octopus* spp. and cuttlefish *Sepia apama* (Hume *et al.* 2004, Page *et al.* 2005a, Kirkwood *et al.* 2008). Most of the dietary studies have used analyses of prey hard parts recovered from faecal (scat) samples, a method that can both under and over-represent prey species. One study analysed faecal DNA from samples collected at the three main Victorian colonies (Lady Julia Percy Island, Seal Rock, The Skerries). The study confirmed, based on the prevalence of sequences from redbait and jack mackerel, the importance of these species in the seals' diet. However, blue mackerel *Scomber australasicus* was also found to be important, suggesting hard-part analyses methods may have under-represented the importance of this species in the diet (Deagle *et al.* 2009).

Kirkwood *et al.* (2008) analysed annual variation in the diet of Australian fur seals at Seal Rocks over a nine-year period (1997–2006). The importance in the diet of redbait and jack mackerel varied considerably across the period, prevalent in some years, and near absent in others when it was replaced by increased proportions of barracouta, red cod and leatherjackets (Figure 5.7). Statistical analyses indicated that annual variation in redbait prevalence in the diet was significantly related to changes in mean sea surface temperatures in western Bass Strait where the seals foraged (Kirkwood *et al.* 2008). Redbait were most prevalent in the diet in cooler years and were less important in warmer years. They found no correlation between the prevalence of redbait in the diet with fishing effort (annual fisheries catch-per-unit-effort) nor the annual mean Southern Oscillation Index (Kirkwood *et al.* 2008).

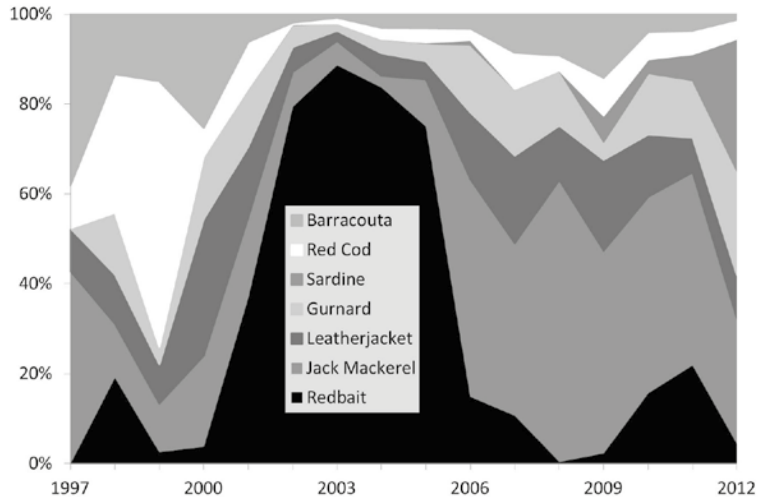


Figure 5.7 Annual variation in the diet of Australian fur seals at Seal Rocks (Victoria) based on prey hard-part analyses for scats collected at a nearly bimonthly frequency over nine years (1997–2012). Note the importance and variability of redbait and jack mackerel in the diet. **Source:** Kirkwood and Goldsworthy (2013), reproduced with permission from CSIRO Publishing (http://www.publish.csiro.au/pid/6491.htm).

Risks and threatening processes

Given that the foraging distributions of the Australian fur seal overlap extensively with commercial fishing activities, especially trawl fisheries operating in southeastern Australia (Goldsworthy *et al.* 2003b), fisheries interactions constitute the most significant risks and threatening processes to the species (Shaughnessy 1999, National Seal Strategy Group and Stewardson 2007). Australian fur seals are subject to significant and ongoing bycatch mortality associated with demersal and mid-water trawling operations, and they have constituted a significant bycatch in the mid-water trawl sector of the SPF (Knuckey *et al.* 2002, Hamer and Goldsworthy 2006, Tilzey *et al.* 2006, Lyle and Willcox 2008, Tuck *et al.* 2013). Indirect interactions, such as prey depletion from fishing, also pose a potential threat, especially in the SPF given its significant reliance on redbait, jack mackerel and blue mackerel (Goldsworthy *et al.* 2003a, Deagle *et al.* 2009) Details on fishery interactions are addressed in Section 5.2.2.

Australian fur seals interact regularly with finfish (salmon) aquaculture farms in Tasmania, where they enter net enclosures killing and damaging fish (Pemberton and Shaughnessy 1993, Hume *et al.* 2002, National Seal Strategy Group and Stewardson 2007, Robinson *et al.* 2008a). Seals are at risk of becoming entangled in nets and having their behaviour changed by becoming habituated to a predictable food source (National Seal Strategy Group and Stewardson 2007). A seal trapping and relocation program has operated since 1990, with more than 4500 individual relocations having taken place up to 2005. More than half (56 per cent) being repeat captures of previously trapped seals, with seals readily returning to the farms in southern Tasmania after release (Hume *et al.* 2002, Robinson *et al.* 2008a, b).

Other potential risks and threats to Australian fur seals include entanglement in marine debris, oil spills and disease (Shaughnessy 1999, Lynch *et al.* 2011a, Lynch *et al.* 2011b, Kirkwood and Goldsworthy 2013).

Conservation and listing status

The Australian fur seal is listed as Marine under the EPBC Act (see Appendix 3). It is protected under the Victorian *Wildlife Act, 1975* (protected wildlife; notable wildlife). And in Tasmania it is listed under Wildlife Regulations, 1999 (Schedule 1); the *Threatened Species Protection Act 1995*; and the *Nature Conservation Act 2002* (specially protected wildlife). In NSW it is protected under the *Threatened Species Protection Act 1995* (Vulnerable); and in SA under the *National Parks and Wildlife Act 1972* (Protected; Rare). Globally the species is listed as least concern under the IUCN Red List and is listed in Appendix II of CITES.

Summary: Australian fur seal

- *Australian fur seal distribution is restricted to the southeastern part of the SPF.*
- *Although the core part of its range (established colonies) may be relatively stable, the range of the species is still expanding and numbers are increasing in newly colonised areas.*
- *Its population has steadily increased over the past 30 years.*
- *Small pelagic fish (e.g. redbait and jack mackerel) are a key component of its diet.*
- *It readily interacts with a range of fisheries, particularly trawl fisheries.*
- *There is a risk of direct interactions with mid-water trawl fishing operations under the DCFA.*

New Zealand (Long-nosed) fur seal *Arctocephalus forsteri* (Level 2 PSA Residual Risk – Medium)

Distribution and range

The New Zealand (or long-nosed) fur seal is a native mammal of Australia that occurs in both New Zealand and Australian waters. Other common names include the black fur seal, Australasian fur seal, Antipodean fur seal and South Australian fur seal. The species was subject to heavy exploitation by colonial sealers between 1800 and 1830, resulting in major reductions in range and abundance (Kirkwood and Goldsworthy 2013). Numbers remained at very low levels for almost 140 years, after which they slowly began to build up and new colonies were established across their former range. In Australia, New Zealand fur seals occur in the coastal waters and on the offshore islands of South and Western Australia, from just east of Kangaroo Island, west to the south-west corner of the continent in WA, and also in southern Tasmania (Shaughnessy *et al.* 1994) (Figure 5.1). Small populations have recently been establishing in Bass Strait and Victorian and southern NSW coastal waters (Kirkwood and Goldsworthy 2013). In New Zealand, this species occurs around both the North and South Islands, with newly formed breeding colonies now established on the North Island and established and predominantly expanding breeding colonies around the entire South Island (Boren *et al.* 2006, Bouma *et al.* 2008). There are well established and expanding colonies also found on Stewart Island and all of New Zealand's subantarctic islands. Their range extends to Australia's Macquarie Island. Vagrants have been recorded in New Caledonia (Shaughnessy 1999).

The Australian population is centred off SA where more than 80 per cent of the national population occurs, with key breeding sites at Kangaroo Island, the Neptune Islands and Liguanea Island (Shaughnessy *et al.* 2014). Western Australian colonies are centred on the islands of the Recherche Archipelago with the westernmost population near Cape Leeuwin. In Tasmania, the New Zealand fur seal mainly occurs on the west and south coasts with a small number breeding on remote islands off the south coast.

Population size and trends

There are 65 known breeding sites for the species in Australia, most (86 per cent) are in South and Western Australia (SA 36; WA 20; Tasmania four; Victoria four; NSW one) (McIntosh *et al.* 2014, Shaughnessy *et al.* 2014, Campbell *et al.* in press, Department of Primary Industries, Parks, Water and Environment (DPIPWE) unpublished data). Pup production surveys were undertaken over the 2013–14 breeding season in SA, Victoria, Tasmania and NSW, and in the 2011–12 season in WA, which provide a comprehensive and current assessment of the status of the species' Australian population. In SA, total pup production was estimated to be 20,426, with most (10,133 pups) on Kangaroo Island (the largest colony in the Cape Gantheaume Wilderness Protection Area having 5333 pups); and the Neptune Islands and Liguanea Island off the southern Eyre Peninsula (9711 pups) (Goldsworthy *et al.* 2014a, Shaughnessy *et al.* 2014). Western Australian surveys estimated a total pup production of 3518 on breeding sites off the southern coast (Campbell *et al.* in press). Pup production in Victoria was estimated to be 276 pups; in Tasmania 399 pups and in NSW (Montague Island) 36 pups (McIntosh *et al.* 2014, DPIPWE unpublished data). The maximum pup production for the Australian population based on these surveys is 24,656 (about 25,000), with most pup production in SA (83 per cent) and WA (14 per cent). Based on a pup-to-total-population multiplier of 4.76 (developed by Goldsworthy and Page 2007) the Australian population is currently estimated to number approximately 117,400.

Populations of New Zealand fur seals in Australian waters appeared to begin their major recovery in the 1970s and 1980s. Between the 1989–90 and 2013–14 breeding seasons, the fur seal population in SA has increased 3.6 fold, with the average annual increase in pup production being 5.3 per cent (Shaughnessy *et al.* 2014). Recovery rates at some sites have been much greater. For example, in the Cape Gantheaume Wilderness Protection Area on Kangaroo Island, annual monitoring of pup production over a 26 year period from 1988–89 (457 pups) to 2013–14 (5333 pups), demonstrates a remarkable 11.7-fold increase at an average rate of 10 per cent per year (Goldsworthy *et al.* 2014c). In contrast, pup production at the Neptune and Liguanea islands appears to have peaked in the mid-2000s, with most of the available breeding habitat now full (Shaughnessy *et al.* 2014). The centre of population expansion is now on Kangaroo Island. The growth of New Zealand fur seal populations since the 1970s and 1980s in Australia is attributable to recovery from 19th century sealing (1800–1830) and subsequent take (Shaughnessy *et al.* 2014).

Biology and feeding ecology

New Zealand fur seals have an annual synchronous breeding season, with most pups (90 per cent) being born over a five-week period between late November and early January. On Kangaroo Island the breeding season peaks around 25–26 December (Goldsworthy and Shaughnessy 1994). New Zealand fur seal pups weigh 3-4 kilograms (kg) at birth, double their weight quickly in 60–100 days and wean at around 13–16 kg when about 10 months old (Goldsworthy 2006). Lactating females alternate between shore bouts lasting approximately 1.7 days in duration (when pups are nursed) and foraging trips to sea which increase in duration from about three to five days early in lactation, to eight to 11 days late in lactation (Goldsworthy 2006). However, foraging trips lasting more than 20 days are not uncommon (Goldsworthy 2006).

The core of Australia's New Zealand fur seal breeding distribution in SA is distributed across a relatively small geographic range characterised by narrow shelves in proximity to localised seasonal upwelling in summer and autumn (Figure 5.3). Satellite tracking studies show that early in lactation (December to March), females undertake short foraging trips to mid-outer shelf waters (70–90 km from the colony), in regions associated with localised upwelling (Page *et al.* 2006, Baylis *et al.* 2008a) (Figure 5.8). However, between April to May most females switch to foraging in distant oceanic waters associated with the Subtropical Front (STF), 700–1000 km to the south of breeding colonies, and continue foraging in these waters up until the weaning of their pups in September/October (Baylis *et al.* 2008a, Baylis *et al.* 2008b, Baylis *et al.* 2012) (Figure 5.9). These winter foraging trips last between 15 and 25 days. Once weaned, the pups head for oceanic waters south of Australia, and as juveniles, also forage in distant oceanic waters (mean maximum distance of 1095 km from the colony) (Baylis *et al.* 2005, Page *et al.* 2006)(Figure 5.5). In contrast to juveniles and adult females, adult males focus their forage efforts along the continental slope (Page *et al.* 2006).

New Zealand fur seals forage both on the shelf, where they target pelagic and bentho-pelagic prey, and off the shelf, where they target epipelagic prey that exhibit daily, vertical migrations (Kirkwood and Goldsworthy 2013). Adults can therefore forage both near or on the benthos in water depths ranging up to 200 m, and in the water column where the sea-floor might be less than 20 m or greater than 2000 m (Kirkwood and Goldsworthy 2013). The mean dive depth of adult female and male New Zealand fur seals are 41.5 m (maximum 312 m) and 52.1 m (to greater than 380 m), respectively (Page *et al.* 2005b). Mean dive durations are 2.7 minutes (maximum 9.3 minutes) for adult females and 3.6 minutes (maximum 14.8 minutes) for adult males (Page *et al.* 2005b).

Most information on the diet of New Zealand fur seals in Australia comes from studies undertaken in SA. As these seals forage both benthically and pelagically, on or off the shelf, their diet is broad. When foraging in shelf water, the main prey species include redbait, leatherjackets, western gemfish *Rexea solandri* and Gould's squid, while the main prey in the open ocean are lanternfish (Family Myctophidae) and Southern Ocean arrow squid *Todarodes filippovae* (Page *et al.* 2005b). Other important prey include jack mackerel, barracouta, Australian anchovy *Engraulis australis*, southern sea garfish *Hyporhamphus melanochir*, swallowtail *Centroberyx lineatus* and calamari squid *Sepioteuthis australis* (Page *et al.* 2005b). The diets of adult males, adult females and juveniles differ, mainly in relation to the extent to which they foraged on or off the shelf. Adult males tended to consume larger prey and were more likely than juveniles or females to consume birds (mostly little penguins *Eudyptula minor* and short-tailed shearwaters *Ardenna tenuirostris*) (Page *et al.* 2005b).

Risks and threatening processes

As the foraging distributions of the New Zealand fur seal overlap extensively with commercial fishing operations on Australian shelf waters, fisheries interactions constitute the most significant risks and threatening processes to the species (Shaughnessy 1999, National Seal Strategy Group and Stewardson 2007). Trawl and other fisheries are a source of entanglement and drowning for New Zealand fur seals (Page *et al.* 2004). It is likely that New Zealand fur seals make part of the bycatch of seals in the South East Trawl Fishery (part of the Commonwealth Trawl Sector (CTS) of the Southern and Eastern Scalefish and Shark Fishery (SESSF), but are not readily distinguished from Australian fur seals (Goldsworthy *et al.* 1997). Like all fur seals, New Zealand fur seals are vulnerable to oil spills because of their dependence on their thick pelage for thermoregulation (Gales 1991). They share most of their range with several other regularly occurring pinniped species and are at risk from transmission of infectious diseases such as morbilliviruses, brucellosis, leptospirosis and tuberculosis (MacKereth *et al.* 2005).

Conservation and listing status

The New Zealand fur seal is listed as Marine under the EPBC Act (see Appendix 3). In SA they are listed as Vulnerable under the *National Parks and Wildlife Act 1972*; in WA they are protected under the *Wildlife Conservation Act 1950* (protected, specially protected); in Victoria under the *Wildlife Act 1975* (protected wildlife, notable wildlife); in NSW under the *Threatened Species Protection Act 1995* (Vulnerable) and in Tasmania under the Wildlife Regulations 1999 (Schedule 1), *Threatened Species Protection Act, 1995, and Nature Conservation Act 2002* (specially protected wildlife, rare). Globally, they are listed as Least Concern under the IUCN Red List, and are listed in Appendix II of CITES.

Summary: New Zealand fur seal

- *The New Zealand fur seal is distributed throughout the entire SPF, but its core distribution in Australia is centred off South Australia.*
- *Although the core part of its range (established colonies) may be relatively stable, the range of the species is still expanding and numbers are increasing in recently colonised areas.*
- *Its population has steadily increased over the past 30 years.*
- *Small pelagic fish such as redbait and jack mackerel are important in its diet, as are squid.*
- *They readily interact with fisheries, including trawl fisheries.*
- *There is a risk of direct interactions with mid-water trawl fishing operations under the DCFA.*

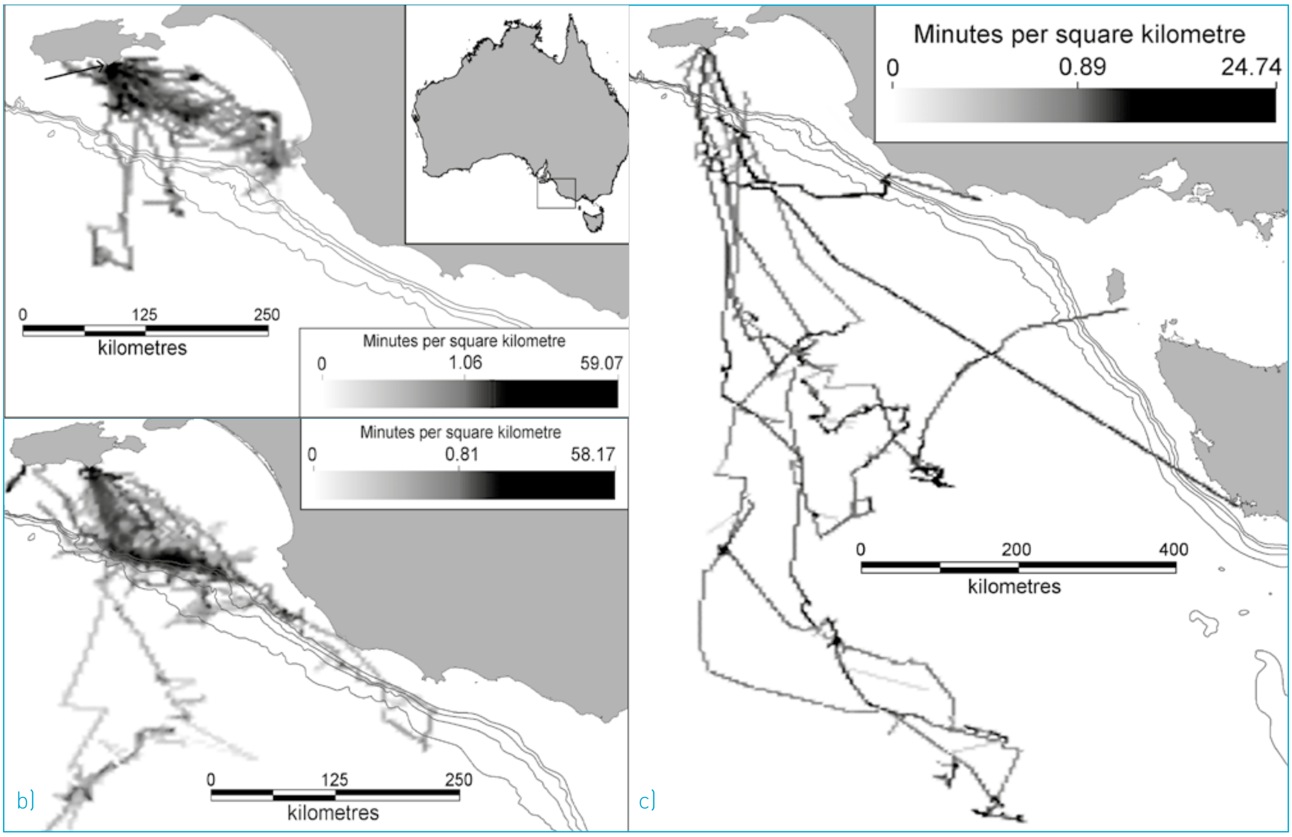


Figure 5.8 Time spent per 25 km² cells by (A) lactating female (n = 25), (B) adult male (n = 21) and (C) juvenile (n = 6) New Zealand fur seals, satellite-tracked from Cape Gantheaume on Kangaroo Island (SA). Location of Cape Gantheaume in relation to the continental shelf, shelf break (200, 500, 1000 and 2000 m depth contours) and pelagic waters (south of the shelf break) is shown. **Source:** Page *et al.* (2006), reproduced with permission from Marine Ecology Progress Series.

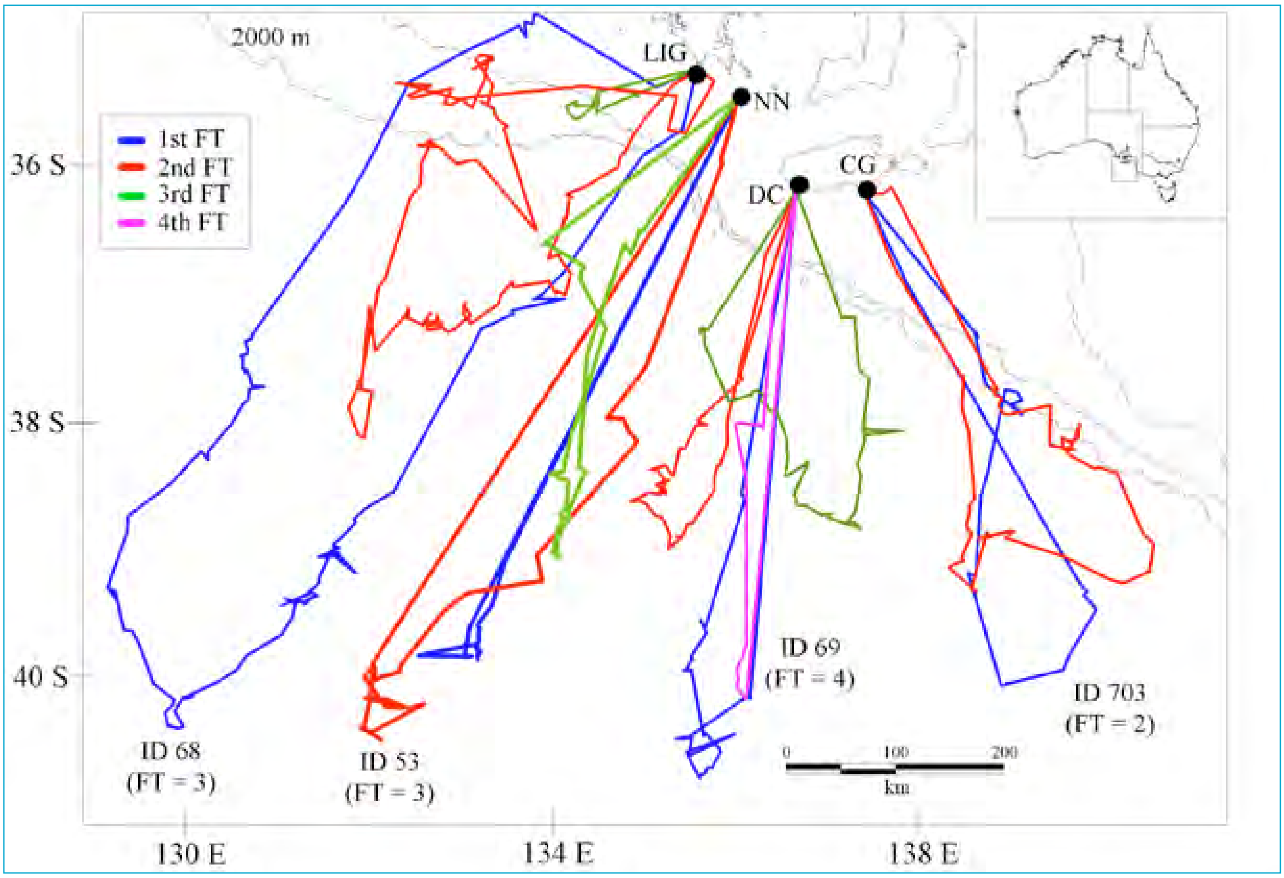


Figure 5.9 Examples of consecutive foraging trips undertaken by satellite-tracked lactating New Zealand fur seal females in oceanic waters typical of winter foraging from the four key breeding sites in SA: Cape Gantheaume, CG; Cape du Couedic, DC; North Neptune Island, NN; and Liguanea Island, LIG.

Source: Baylis *et al.* (2012), reproduced with permission from John Wiley & Sons Inc. © 2011 by the Society for Marine Mammalogy

5.2.2 Nature and extent of interactions

As detailed in Chapter 2, for the purpose of this assessment, direct interactions between the DCFA and protected species include net feeding, physical contact, acoustic disturbance, behavioural change and bycatch. For pinnipeds, acoustic disturbance is unlikely to be a significant issue (Carretta and Barlow 2011, Goetz and Janik 2013); however, net feeding, behavioural change and physical contact all contribute to bycatch interactions. Such interactions are generally not random or chance events, but occur as a direct consequence of animals deliberately interacting with fishing operations. Bycatch usually occurs as a consequence of 'net-feeding' where animals enter the net during fishing operations to feed on fish concentrated near the codend or enmeshed in the net ('stickers'). Animals that become trapped in the net while the net is being shot, or when actively fishing, will drown (the maximum dive duration of most otariid seals is less than 10 minutes); animals that become trapped in the net when it is hauled may survive until the net is retrieved, requiring release onboard the vessel (Hamer and Goldsworthy 2006, Tilzey *et al.* 2006). In general, the extent of bycatch interactions is largely a function of opportunity and the degree to which fishing operations reward seals for risky behaviour. If opportunities persist and fishing activity is predictable, then habituation of individuals or a population to fisheries interactions can result. As the number of fisheries interactions increases, so does the potential for bycatch.

Extent of trawl fishery interactions: global

Marine mammals and commercial fisheries often target the same food resource, leading to 'operational interactions' between animals and fisheries when they come into direct contact with fishing gear. Globally, the bycatch of marine mammals in fisheries is estimated to be in the hundreds of thousands of individuals per year (Read *et al.* 2006), and currently represents the dominant, recognised threat to global pinniped populations (Kovacs *et al.* 2012). Pinnipeds are readily attracted to, and interact, with trawl fisheries; they will take fish floating free from the net, stickers protruding through the net mesh, enter trawl nets to feed on fish inside the net and take discarded fish and offal (Wickens and Sims 1994, David and Wickens 2003).

Operational interactions with trawl fisheries that lead to significant levels of pinniped bycatch have been reported in most parts of the world where pinniped populations overlap with trawl fisheries. Documentation for these in many instances is limited to short-term studies where interaction rates have been reported and analysed based on independent fishery observer programs. Examples are given below by region.

South Africa

High interaction rates have been reported to occur between Cape fur seals and South African trawl fisheries (offshore demersal, inshore demersal and mid-water fisheries) where annual bycatch numbers ranged between 2524 and 3636 (Wickens and Sims 1994, David and Wickens 2003). Mortality levels were much higher in mid-water trawls (94 seals per 100 trawls), compared to inshore (4.6 seals per 100 trawls) and offshore demersal trawls (1.2 seals per 100 trawls) (Wickens and Sims 1994). This was thought to be due to a combination of factors including the wider opening of mid-water trawl nets, slower retrieval, lower buoyancy and tendency to trawl until the net reaches the vessel, which create opportunities for more seals to interact and be drowned (Wickens and Sims 1994).

South America

There is limited documentation on the level of pinniped interactions with trawl fisheries in South America. Significant bycatch of South American sea lion *Otaria flavescens* has been recorded in a small subset of observed trawls off south-central Chile conducted in September 2004, when 82 animals were caught in 69 observed trawls (1.2 seals per trawl, Reyes *et al.* 2013). In northern and central Patagonia, Argentina, based on observations from 1992 to 1994, between 175 and 602 sea lions were estimated to have been caught, mostly by factory/freezer mid-water and demersal trawl vessels (Crespo *et al.* 1997, Dans *et al.* 2003).

Antarctica

The commercial krill *Euphausia superba* trawl fishery in Antarctic waters began in the early 1970s and the prospect of a free-for-all fishery for Antarctic krill led to the signing of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) in 1981. Discussions on the level of Antarctic fur seal mortality associated with the krill trawl fishery first took place at the 2003 meeting of CCAMLR's Working Group on Incidental Mortality Associated with Fishing (Reid and Grilly 2014 cited in Elgin Associates unpublished (b)). Limited information is available on this interaction. In 2004, data provided to CCAMLR by the United Kingdom, as part of the CCAMLR Scheme of International Scientific Observation, indicated that 292 fur seals were caught during krill fishery trawl operations in CCAMLR Subarea 48.3 in the 2003–04 season (Reid and Grilly 2014 cited in Elgin Associates unpublished (b)).

USA

Foreign and joint venture trawl fisheries operating in the Gulf of Alaska and Bering Sea between 1966 and 1988 were estimated to have killed more than 21,000 Steller sea lions *Eumetopias jubatus* (Perez and Loughlin 1991). A particularly high level of bycatch mortality occurred in 1982 in the Gulf of Alaska (most from the Shelikof Strait walleye pollock joint venture fishery) when an estimated 1530 sea lions were killed (Perez and Loughlin 1991). Average bycatch mortality of Steller sea lions was estimated to be approximately 730 per year in the late 1960s, about 1300 per year in the 1970s, then declining to approximately 530 per year in the 1980s and declining further to between 10 and 15 per year between 1990 and 2011 (Perez and Loughlin 1991, Perez 2003, Breiwick 2013). During the 1970s and 1980s, catch rates of Steller sea lions were highest for large mid-water trawl freezer vessels targeting pollock, and lowest for small stern trawlers (Perez and Loughlin 1991). Declines in the number of Steller sea lions taken as bycatch in the 1980s were principally due to reduced fishing effort and declines in the sea lion populations (Perez and Loughlin 1991). Major declines from 1990 onwards have been attributed to spatial closures introduced around all Steller sea lion colonies in the Aleutian Island and Bering Sea in 1990 (Perez 2003). Although the Steller sea lion have been numerically the most significant pinniped subjected to bycatch mortality in the Alaskan fisheries, other pinnipeds including the northern fur seal *Callorhinus ursinus*, bearded seal *Erignathus barbatus nauticus*, harbor seal *Phoca vitulina richardsi*, ribbon seal *Histriophoca fasciata*, ringed seal *Phoca hispida hispida*, spotted seal *Phoca largha*, northern elephant seal *Mirounga angustirostris* and walrus *Odobenus rosmarus*, are also caught in Alaskan trawl fisheries (typically less than 10 each year per species, Perez 2003, Allen and Angliss 2013).

Elsewhere in the USA, pinnipeds have been identified as bycatch in the Pacific groundfish fishery (demersal trawl) operating in the North Pacific Ocean off the Washington, Oregon and Californian coasts (Carretta *et al.* 2013). Between 2004 and 2008, average annual bycatch of pinnipeds has been approximately 35 California sea lions *Zalophus californianus californianus*, around six harbor seals, approximately six Steller sea lions (Eastern Stock) (Allen and Angliss 2013, Carretta *et al.* 2013). There is also incidental bycatch of northern elephant seals (approximately one per year), Guadalupe fur seals *Arctocephalus townsendi*, and northern fur seals (Carretta *et al.* 2013). Off the Atlantic coast, grey seals *Halichoerus grypus grypus*, harp seals *Pagophilus groenlandicus* and harbor seals *Phoca vitulina concolor* are incidentally caught in the mid-Atlantic bottom and mid-water trawl fisheries; low numbers of harbor seals are taken as bycatch in the Northeast mid-water trawl fishery (approximately one per year); and low numbers of grey seals (about six each year), harp seal and harbor seal (approximately one per year) are taken as bycatch in the Northeast bottom trawl fishery (Waring *et al.* 2013).

As a global generalisation, phocid seals are most susceptible to bycatch in gillnet fisheries, whereas otariid seals are most susceptible to bycatch in trawl fisheries (Waring *et al.* 2013).

New Zealand

In New Zealand, bycatch in commercial trawl fisheries includes the New Zealand fur seal and the New Zealand sea lion *Phocarctos hookeri.* Southern elephant seals *Mirounga leonina* and leopard seals *Hydrurga leptonyx* are also caught occasionally (Thompson *et al.* 2013). A recent study by Thomson *et al.* (2013), has estimated the annual bycatch of New Zealand fur seals and New Zealand sea lions in New Zealand trawl fisheries between the 2002–03 and 2010–11, and 1995–96 and 2010–11 fishing seasons, respectively. Bycatch of New Zealand fur seals occurs in the hoki *Macruronus novaezelandiae*, southern blue whiting *Micromesistius australis*, middle depths, squid trawl, ling, hake, mackerel, scampi, deepwater and inshore trawl fisheries (Thompson *et al.* 2013). Fur seal bycatch across all trawl fisheries averages 775 per year (the maximum was 1471 in 2004–05), but has declined over the nine seasons by about 55 per cent, with an estimated bycatch of 376 seals in 2010–11 (Thompson *et al.* 2013). Bycatch rates average 0.72 seals per 100 tows, and has declined by approximately 32 per cent over the period to 0.44 seals per 100 tows in 2010–11 (Thompson *et al.* 2013). Declines in bycatch numbers correspond with an approximate 34 per cent reduction in fishing effort over the study period (Thompson *et al.* 2013). Fishing effort is greatest in July and August, with fur seal bycatch peaking in August, but also high in July and September (Thompson *et al.* 2013). The Bounty Islands and subantarctic areas had the highest bycatch rates, and distance from shore was negatively correlated with bycatch rate. Coastal areas (less than 25 km from shore) had 1.6 times the bycatch rate of areas fished between 25 and 90 km from shore, and areas fished greater than 180 km from shore had bycatch rates that were 20 per cent of those between 25 and 90 km from shore (Thompson *et al.* 2013).

New Zealand sea lions are taken as bycatch in a number of New Zealand subantarctic trawl fisheries, in the Auckland Islands (squid, scampi, non-squid/scampi) and Campbell Island southern blue whiting and Stewart-Snares shelf fisheries (Wilkinson *et al.* 2003, Thompson *et al.* 2013). The majority of bycatch mortalities recorded have been from the Auckland Island squid fishery (within management area SQU6T), where the distribution of New Zealand sea lion foraging overlaps significantly with the distribution of fishing effort (Chilvers 2008, Chilvers *et al.* 2011, Thompson *et al.* 2013). Between 1995 and 1999, approximately 100 sea lions per year were being caught as bycatch in all New Zealand trawl fisheries (Thompson *et al.* 2013). This has subsequently declined to approximately 55 per year between 2000 and 2004, about 39 per year between 2005 and 2009, and 29 in the 2010–11 fishing season (Thompson *et al.* 2013). Between 1995 and 2010, sea lion bycatch declined by approximately 80 per cent (Thompson *et al.* 2013). Part of the decline can be attributed to a 37 per cent reduction in fishing effort, but also a range of management actions have been introduced in an attempt to mitigate bycatch in these fisheries (detailed in Section 5.2.3).

Summary: global experience

- *Wherever pinniped populations and fisheries overlap, operational interactions generally follow.*
- *Direct interactions between fishing gear and pinnipeds is recognised as the dominant threat to global pinniped populations.*
- *Pinnipeds are readily attracted to and interact with trawl fisheries; they will take fish floating free from the net, 'stickers' (meshed fish) protruding through the net mesh, enter trawl nets to feed on fish inside the net and take discarded fish and offal.*
- *Globally, otariids (fur seals and sea lions) are highly susceptible to interactions with trawl fisheries. Key examples include:*
    - *Cape fur seals and South African trawl fisheries*
    - *South American sea lions and trawl fisheries off south-central Chile and factory/freezer mid-water and demersal trawl fisheries off northern and central Patagonia (Argentina)*
    - *Antarctic fur seals and Antarctic krill fisheries*
    - *Steller sea lions and mid-water freezer trawlers in US Alaskan fisheries*
    - *New Zealand sea lions and New Zealand fur seals and New Zealand mid-water and demersal trawl fisheries.*
- *Documentation and enumeration of the extent of interactions (including bycatch mortality) varies greatly. In many instances this is limited to short-term studies where interaction rates (usually only bycatch) have been reported and analysed based on independent fishery observer programs. Annual reporting and estimation of bycatch impacts is most consistent in US and New Zealand fisheries.*

Extent of trawl fishery interactions: Australia

In Australia the three main resident pinniped taxa frequently interact with a range of fisheries; Australian sea lions principally with gillnet fisheries and Australian and New Zealand fur seals mostly with trawl fisheries (Shaughnessy 1999, Knuckey *et al.* 2002, Goldsworthy *et al.* 2003b, Shaughnessy *et al.* 2003, Page *et al.* 2004, Hamer and Goldsworthy 2006, Tilzey *et al.* 2006, Goldsworthy and Page 2007, National Seal Strategy Group and Stewardson 2007, Campbell 2008, Lyle and Willcox 2008, Goldsworthy and Lowther 2010, Hesp *et al.* 2012, Kirkwood and Goldsworthy 2013, Tuck *et al.* 2013).

There are two main Commonwealth-managed fisheries that include trawl fisheries within the SPF area: the SESSF, which includes the CTS (comprising the South East Trawl (SET) and Victorian Inshore Trawl (VIT) sectors), the GAB Trawl sector (GABT) and the East Coast Deepwater Trawl sector (ECDWT); and the SPF. There are few observations (less than 10 over four years) of interactions between threatened, endangered and protected species (TEPS) in the ECDWT and none for VIT (Tuck *et al.* 2013), so these fisheries are not addressed further here.

Southern and Eastern Scalefish and Shark Fishery (SESSF)

The CTS extends from NSW state waters to the edge of Australia's exclusive economic zone (EEZ) from Barrenjoey Point southward around NSW, Victorian and Tasmanian waters to Cape Jervis in SA (Tuck *et al.* 2013). The main component of the CTS is the SET in which the main gears used are otter board trawl and Danish seine (the latter is not discussed further here). Most SET vessels are described as 'wet boats' that are small demersal trawlers (18–23 m in length) which store their catches using ice/brine with no freezing/processing capacity (South East Trawl Fishing Industry Association (SETFIA) 2009). In 1999, AFMA allowed 'factory/freezer trawlers' (using mid-water trawls) into the winter blue grenadier fishery off the west coast of Tasmania. As factory/freezer boats are processing at sea, they require on-board independent observers. In their first year of operation, 87 fur seals (assumed to be mostly Australian fur seals) (83 dead) were caught (13.1 seals per 100 tows) (Tilzey *et al.* 2006). The high levels of fur seal bycatch prompted AFMA to initiate analyses of Integrated Scientific Monitoring Program (ISMP) data (a scientific observer program that commenced in 1993 to gather information on catch composition and discarding levels), to estimate the number of seals caught in the broader 'wet boat' sector of the SET. This analysis found that annual seal bycatch rates by SET vessels varied greatly between 1993 and 2000, with the annual estimate being 720 seals per year across the fishery, and a total of approximately 5730 over the eight-year period monitored (Knuckey *et al*. 2002) (Table 5.1). This averaged about two seals per 100 tows, with the highest bycatch rates off the west coast of Tasmania (2.9 seals per 100 tows off west coast Tasmania; 1.9 seals per 100 tows off east coast Tasmania; 1.6 seals per 100 tows in central Bass Strait; two seals per 100 tows off NSW and eastern Bass Strait; and 1.3 seals per 100 tows off western Victoria, southeastern SA) (Knuckey *et al*. 2002). Most seals were caught in shots on continental shelf waters in less than 200 m (although they were also caught in deeper shots off western Tasmania and western Bass Strait), with the lowest bycatch rates occurring in summer and peaking during winter. About 68 per cent of seals caught were dead and the remainder were released alive (Knuckey *et al*. 2002).

Tuck *et al*. (2013) provided additional assessment of ISMP data across an additional four years (2005, 2006, 2009 and 2010) (Table 5.1). From these records, the interaction rates for 2005, 2006 and 2009 are an order of magnitude higher than those reported by Knuckey *et al*. (2002) (11.7–46.3 seals per 100 tows). It is possible these 'interactions' may include more than bycatch interactions, although Tuck *et al*. (2013) state clearly that these included "observations of wildlife directly interacting with fishing vessels (e.g. species entanglement in fishing gear)" (Table 5.1). This would imply higher levels of bycatch in the 2005–09 period. Seal mortalities averaged three per 100 tows across the four years, generally higher than those reported by Knuckey *et al*. (2002) throughout the 1990s (Table 5.1). In most years, details of species and sex are not reported in the ISMP data, although in the 2010 data, of the 30 recorded seal mortalities, 20 (66 per cent) were recorded as Australian fur seals and 10 (33 per cent) as New Zealand fur seals (Tuck *et al*. 2013). Tuck *et al*. (2013) indicated that ISMP sampling design has recently been re-designed to obtain effective and statistically robust coverage for recording of species identified as high risk through the ecological risk assessment (ERA) process, and to include TEPS. Tuck *et al*. (2013) highlighted difficulties associated with interpreting historical ISMP wildlife interactions data. These include inconsistent sampling effort between years; an apparent change in emphasis on a particular species group (e.g. birds or mammals) between years; and inconsistent species identification and coding. They stated that a "combination of improved reporting by industry, highly variable ISMP estimates and the introduction of various mitigation measures over the same time, means that the wildlife interaction data is impossible to interpret with any level of certainty at this stage". In the absence of any other data, based on the observed rates of bycatch mortality in the SET between 1993 and 2010, an average of approximately 597 fur seals may have died annually in the 'wet boat' sector of the SET as a consequence of fishery interactions over this period. This equates to approximately 12,000 fur seals over the past 20 years of the fishery.

Table 5.1 Estimates of annual fur seal bycatch in the SESSF-SET based on ISMP data, 1993–2010

YEAR	TOTAL SET SHOTS	OBS. SHOTS	OBS. SEAL INTERACTIONS	OBS. SEAL MORTALITIES	INTERACTIONS /100 TOWS	SEAL MORTALITY /100 TOWS	EST. SET SEAL INTERACTIONS	EST. SET SEAL MORTALITY
1993	35,779	564	10	7	1.8	1.2	374	254
1994	38,357	879	16	11	1.8	1.2	696	473
1995	37,850	603	10	7	1.7	1.1	735	500
1996	41,296	607	9	6	1.5	1.0	911	619
1997	42,652	727	12	8	1.7	1.1	804	547
1998	41,147	679	13	9	1.9	1.3	648	441
1999	42,774	947	9	6	1.0	0.6	344	234
2000	31,348	781	26	18	3.3	2.3	1222	831
2001	34,224	801	25	17	3.1	2.1	1068	726
2005	36,858	949	175	28	18.4	3.0	6797	1087
2006	30,311	855	100	5	11.7	0.6	3545	177
2009	21,488	633	293	27	46.3	4.3	9946	917
2010	22,564	706	35	30	5.0	4.2	1119	959
Sum	456,648	9731	733	178			28,209	7766
Average	35,127	749	56	14	7.6	1.9	2170	597

Source: 1993–2001 (Knuckey *et al*. 2002) 2005–2010 (Tuck *et al*. 2013). Total SET shots (AFMA 2009), 2009 and 2010 (AFMA 2012c).

AFMA have published quarterly reports of logbook interactions with TEPS on its website (AFMA 2014c). Over the past three calendar years (2011–13) a total of 688 fur seal interactions have been reported by fishermen in the SET, 521 (76 per cent) of which were bycatch mortalities. The level of reporting and the levels of species discrimination appear to be improving, but in the panel's view, the data are not a reliable indicator of the extent of bycatch interactions.

Minimising seal interactions has been a focus for the winter freezer trawler fishery for blue grenadier off western Tasmania. Seal excluder devices (SEDs) have been compulsory in this component of the SET since 2005, and modifications to fishing practices have been introduced to reduce the incidence of seal bycatch (see Section 5.2.3)(Table 5.2). Some research has been undertaken on the biology, ecology and nature of seal interactions in this fishery as a means to informing management and mitigation measures (Goldsworthy *et al.* 2003b, Hamer and Goldsworthy 2006, Tilzey *et al.* 2006). Intensive observations were undertaken on board fishing vessels to assess the relationship between seal numbers and a range of factors to do with trawling activity including on-board factors and the relationship to the proximity of other vessels, distances from seal colonies/haul-out locations and weather and sea conditions. In addition, underwater cameras were used to record seal activity in and around the codend of the net during trawling, primarily to record the timing and depths of net-entry. A complex suite of interacting parameters were found to be important in determining the number of seals present at any given time behind fishing vessels, including factors to do with the fishery (stage of fishing season, presence of other vessels), the vessel (speed), weather (barometric pressure) and the proximity to seal colonies/haul-outs. Numbers of seals increased in response to poor weather (decreasing barometric pressure/increasing swell height), increasing fishing activity (the number of nearby vessels and trawl frequency), and proximity to seal haul-outs/colonies. Numbers decreased with increasing vessel speed (Hamer and Goldsworthy 2006). Seal numbers at the surface generally increased throughout trawling operations, with brief declines during shooting and hauling phases (presumably when many seals were actively diving down to the net). This was substantiated with subsurface observations from a submersible video camera installed in the net, confirming the greatest period of seal activity within the net was during shooting and hauling (Hamer and Goldsworthy 2006). The numbers of seals observed in the net was similar during shooting and hauling; however, all seals observed to enter the net during shooting drowned; whereas most (86 per cent) that entered the net during hauling survived, with all seals entering during hauling observed to enter the net just prior to it breaching the surface and being hauled on board (Hamer and Goldsworthy 2006). The mean depth that seals were observed inside the net during shooting was 165 m (n=4) and 97 m (n=5) during hauling. The deepest recorded net entry during shooting and hauling was 190 m and 130 m, respectively (Hamer and Goldsworthy 2006).

Examination of the 87 dead seals collected over three consecutive fishing seasons indicated that all were Australian fur seals, most of them were males (94 per cent), most were between 2–13 years of age (although several exceeded 20 years) with a mean of 7.5 years (Goldsworthy *et al.* 2003b, Tilzey *et al.* 2006). This suggested that most fur seals interacting with the fishery were sub-adult males. A total of 50 stomachs recovered from dead seals were analysed. Fresh and undigested items within a stomach were categorised as 'net' feeding, indicating prey items consumed in the net immediately before drowning. Those that were somewhat digested were categorised as 'prior' feeding on prey that may have been consumed in prior trawls or independent of the fishery (Goldsworthy *et al.* 2003b). Results from dietary analysis indicate that seals feeding within the fishing ground were targeting trawling operations to feed on commercially-caught species (mostly blue grenadier and spotted/silver warehou *Seriolella punctata*). The similarities between 'net' and 'prior' samples gives strong evidence that seals attracted to the fishing grounds are there to feed principally on the contents of trawls. There was little evidence to suggest that any substantive foraging was undertaken away from trawling operations, as the predominant prey item in both 'net' and 'prior' samples was blue grenadier that could only be accessed by seals through net-feeding when brought into their diving range during trawling operations (Goldsworthy *et al.* 2003b, Tilzey *et al.* 2006). In contrast, dietary studies at Reid Rocks, the nearest breeding colony of Australian fur seals to the blue grenadier fishing grounds, found that fur seals consume mainly redbait, leatherjackets, jack mackerel and red cod (Hume *et al.* 2004).

A novel satellite telemetry study was undertaken to understand the movement patterns of seals directly interacting with freezer trawler vessels in the blue grenadier fishery. Seals were directly captured alongside fishing vessels at sea using a 'dip-net' lowered from each ship's crane, 1–2 m below the surface. Waste fish were used to lure seals into the net which was then raised onto the back of the trawl vessel where they were anaesthetised and fitted with a satellite transmitter (Goldsworthy *et al.* 2003b, Tilzey *et al.* 2006). Nine male Australian fur seals were tracked for up to seven months. All seals tracked foraged almost exclusively within the blue grenadier fishing grounds throughout the duration of the fishing season, and rested between foraging trips at either Hibbs Point or Reid Rocks (the nearest haul-out site/breeding colonies to the south and north, respectively). When leaving the fishing grounds, seals typically swam in a direct line towards haul-out sites, but on return, swam to the nearest edge of the continental shelf, possibly to enhance the likelihood of intercepting fishing vessels (Goldsworthy *et al.* 2003b, Tilzey *et al.* 2006). For seals that were tracked beyond the duration of the winter blue grenadier fishing season, there was a noticeable change in the focus of foraging effort. Most moved their foraging to areas south of the fishing ground, typically between Macquarie Harbour and Maatsuyker Island (south-west Tasmania). One seal foraged extensively over outer-shelf waters of southern Tasmania, as far north as Maria Island on the east coast of Tasmania, before returning to the west coast of Tasmania. The tracking studies clearly demonstrated the habitual nature of fur seals feeding in the fishing grounds in between resting at nearby haul-outs. The number of resights of satellite-tagged seals alongside fishing vessels (including one live capture and release in a trawl net), and the intensity of movements to and from the fishing grounds between haul-outs, suggested that the seal population interacting with the fishery may be relatively small and intransient during the period of the fishery (Goldsworthy *et al.* 2003b, Tilzey *et al.* 2006).

Table 5.2 Summary of the fishing effort and seal bycatch rates in the winter freezer trawler component of the blue grenadier fishery off the west coast of Tasmania, 1999–2004. Data for 1999 represent bycatch rates prior to introduction of seal-avoidance practices and Code of Fishing Practice (1999).

YEAR	VESSELS	NO. SHOTS	SEALS			INTERACTIONS /100 TOWS	SEAL MORTALITY /100 TOWS PER
			TOTAL	DEAD	% SURVIVAL		
1999	3	665	87	83	5	13.1	12.5
2000	2	453	53	22	58	11.7	4.9
2001	2	501	26	24	8	5.2	4.8
2002	2	557	58	37	36	10.4	6.6
2003	2	483	20	15	25	4.1	3.1
2004	1	239	12	8	33	5.0	3.3
2000–04*		2233	169	106	37	7.6	4.7

*per cent survival seals per shot and seal deaths per shot are presented as the mean of all shots, seals caught and killed between 2000 and 2004. **Source:** Tilzey *et al.* (2006).

Small Pelagic Fishery

From the commencement of mid-water trawling in the SPF in 2002, trawls were fitted with a 'soft' rope-mesh SED (Browne *et al.* 2005), and were subject to high levels of independent observer coverage (through AFMA), complemented by on-board monitoring by Tasmanian Aquaculture and Fisheries Institute (TAFI) scientists undertaking biological assessments of the target species (Lyle and Willcox 2008, Tuck *et al.* 2013). No marine mammal bycatch was observed in the fishery until 2004, when 14 dolphin mortalities occurred in two separate shots. In response to this, AFMA implemented 100 per cent observer coverage of fishing operations, and commissioned a pilot study (2005), followed by a larger project in 2006–2007 to investigate the nature and extent of marine mammal interactions, and trial and assess the performance of various exclusion devices (Browne *et al.* 2005, Lyle and Willcox 2008; discussed in detail in Section 5.2.3). Although these studies were initiated principally to assist in the development of cetacean bycatch mitigation, underwater video monitoring conducted during the pilot study identified that interactions with fur seals were far more numerous (Browne *et al.* 2005).

Between 2004 and 2010, a total of 184 seal interactions were recorded with mid-water trawl gear in the SPF, and of that, 175 interactions (95 per cent) were part of underwater video monitoring conducted during the scientific projects. The most detailed project was undertaken by Lyle and Willcox (2008) who used underwater video to monitor seal interactions in 98 trawls amounting to more than 700 hours of video footage. During the study, 151 seals (mostly Australian fur seals) were recorded inside the trawl net in the region of the SED in more than half of the monitored shots, peaking during autumn and winter months (70 per cent) and below 25 per cent at other times of the year. Most seals (87 per cent) entered the trawl net via the net mouth and exited via the SED opening (64 per cent), with a smaller percentage entering through the SED opening (13 per cent) and exiting via the net mouth (22 per cent, exit point of 14 per cent unknown) (Lyle and Willcox

2008). Seals entered the net at every stage of trawling, with the highest rates of interaction occurring during setting. However, numerically, most of the recorded net entries occurred during fishing (62 per cent), which accounted for most (73 per cent) of the trawl duration. As most fishing occurred in less than 150 m, the net was essentially available to seals at all stages of trawling (Lyle and Willcox 2008).

The overall interaction rates from the underwater video monitoring were 154.1 seals per 100 tows; with an estimated bycatch mortality rate of 19.4 seals per 100 tows, based on 19 observed mortalities (Lyle and Willcox 2008). However, Lyle and Willcox (2008) noted that for an additional eight seals the outcome of survival was uncertain; five of the seals were judged to be in very poor condition (low responsiveness) prior to being ejected from the net (four of which had been in the net more than 10 minutes); the remaining three seals were judged to be in the high risk range (submerged for more than 10 minutes) (Lyle and Willcox 2008). It is therefore possible that the mortality rate could have been as high as 27.6 seals per 100 tows.

A critical observation of the study was that without video monitoring, the extent of the bycatch issue would have gone unnoticed even with high levels of observer coverage, as all seal mortalities eventually dropped out of the net via the SED opening (Lyle and Willcox 2008). Consistent with this, no further records of seal bycatch were recorded by onboard observers in the SPF between 2007 and 2009 (Tuck *et al.* 2013).

Summary: Australian experience

- *Pinniped interactions with fishing gear appear ubiquitous in southern Australia where their populations overlap with trawl fisheries.*
- *Pinniped interactions occur predominantly with demersal trawl 'wet boats' and 'factory/freezer trawlers using mid-water trawl gear in the CTS of the SESSF and with mid-water trawlers of the SPF.*
- *The longest time series of data on bycatch interactions (1993–2010) exist for the 'wet boat' CTS where available ISMP data indicate persistent and significant ongoing bycatch mortality of fur seals. Extrapolation of these data suggests bycatch mortality in the order of 600 fur seals per year, or approximately 12,000 over the past 20 years (around 1.9 seals per 100 tows).*
- *Most research into the nature and extent of interactions (and their mitigation) has occurred in the winter factory/freezer mid-water trawl fishery for blue grenadier off western Tasmania. Results indicate a subpopulation of fur seals habitually interacting with and foraging in association with fishing operations for many months of the year.*
- *Information on the nature and extent of pinniped bycatch in the SPF mid-water trawl fishery is restricted to observations between 2006 and 2007, when underwater video monitoring of trawls and SEDs occurred. On-board observers significantly under-reported interactions because all seal mortalities were ejected from the SED opening and were undetectable by observers. Based on 151 observed interactions with a SED in place, bycatch mortality was an order of magnitude higher (19.4 seals per 100 tows) than that observed in non-SED CTS 'wet boat' vessels.*
- *Seals were observed to enter mid-water trawl SPF nets at every stage of trawling. Numerically, most net entries occurred during fishing (62 per cent), which accounted for most (73 per cent) of the trawl duration. As most fishing occurred in less than 150 m, the net was available to seals at all stages of trawling.*
- *In the US and New Zealand, annual reporting of marine mammal interactions includes routine analysis of the data on protected species interactions to provide an estimated take of these species. No such analysis is available for fisheries interacting with pinnipeds in southern Australia.*

5.2.3 Management

Existing management of operational interactions with pinnipeds globally and nationally

Management and mitigation of pinniped interactions with trawl vessels can include modifications to fishing gear (such as incorporating SEDs in the trawl net), modifications to fishing behaviour, bycatch trigger limits move-on rules, and spatial closures.

Seal excluder devices (SEDs)

Exclusion devices are widely used internationally throughout a range of trawl fisheries to mitigate bycatch of marine megafauna, including large sharks, stingrays, sea turtles, seals and cetaceans. Depending on their main function, they go by a range of names from more generic, including bycatch reduction devices (BRDs) and marine mammal excluder devices (MMED); to more specific including turtle excluder devices, cetacean exclude devices (CEDs), and sea lion excluder devices (SLEDs). In Australia, excluder/exclusion devices used to reduce the incidence of seal bycatch are usually referred to as SEDs.

Exclusion devices typically comprise an additional section of netting inserted between the entrance and the codend of the trawl net with an angled grid that directs marine megafauna to an escape hole in either the top or bottom of the net and prevents them from entering the trawl codend (Elgin Associates unpublished (b)) (Figure 5.10). Grids used to exclude the marine mammals are usually constructed of stainless steel (known as a 'hard' or 'rigid' grid) but can also be made from softer material such as fishing mesh or rope, or braided stainless wire and pipe (known as a 'soft' grid or 'semi-flexible' grid). Grids may be constructed as a single piece, or as a two or three piece unit. The spacing between the bars that form a grid, and the size, shape and location ('top' or 'bottom') of the 'escape hatch/hole' (or 'SED opening'), are dependent on the behaviour and size of the species that are intended to be excluded, and also the target species and fishing method used (e.g. demersal or mid-water trawl (Elgin Associates unpublished (b))(Figure 5.10).

Some SED openings are fitted with a 'hood' and 'kite', which consist of a forward-facing netted 'hood' with an opening held open by floats, and a panel ('kite') designed to direct water flow into the net and across the grid (Figure 5.10). These function to both minimise potential loss of commercial catch and to minimise the potential loss of dead or incapacitated megafauna so that mortalities or injuries can be detected (Elgin Associates unpublished (b)).

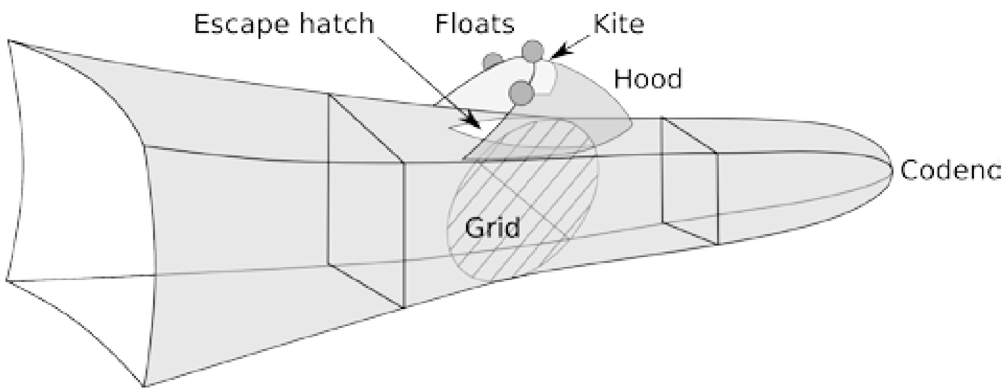


Figure 5.10 Schematic diagram of a SED consisting of a metal grid and an opening (escape hole) above it. The grid directs seals to the escape hole, enabling them to exit the net. The forward-facing hood is held open by floats, and a strip of material known as a kite. **Source:** Thompson *et al.* (2013), reproduced with permission from Ministry for Primary Industries, New Zealand.

Globally, most pinniped interactions with trawl fisheries involve otariids (fur seals and sea lions), which are predominantly a Southern Hemisphere group. Therefore, SED use in trawl fisheries is less common in the Northern Hemisphere where pinniped interactions with gillnet fisheries are generally a more significant issue (Read *et al*. 2006). Although Steller sea lions are known to interact regularly with trawl fisheries in the North Pacific Ocean and Bering Sea, SEDs do not appear to be used in commercial fisheries there, although recent trials of a MMED in a mid-water trawl net were undertaken off California (Dotson *et al*. 2010). SED use and development has been greatest in New Zealand (Auckland Islands squid trawl fishery) and Australian fisheries (CTS winter blue grenadier fishery and SPF), although some developmental work has also been undertaken in the Antarctic krill fishery. The application and effectiveness of SEDs in mitigating seal bycatch interactions in each of these fisheries is summarised below.

<u>Auckland Islands squid trawl fishery – SLED</u>

Due to high levels of bycatch of New Zealand sea lions (listed as critically threatened in New Zealand) in the Auckland Islands Squid Fishery, a SLED was developed to reduce bycatch mortality (Wilkinson *et al*. 2003). The SLED comprised an additional section of netting inserted between the lengthener and codend of a trawl net with an angled two or three panelled metal grid to guide sea lions to a top-opening escape (Hamilton and Baker 2014, see Figure 5.11).

A range of improvements to the basic design of the SLED have occurred over the past 10–15 years. These have included:

- adding a hood and kite to the top-mounted escape hole
- reducing the space between the grid bars from 26 centimetres (cm) to 23 cm (to reduce the probability of juvenile sea lions passing through the grid)
- modifying the SLED kite with additional floats on the top of the SLED hood to ensure the kites and hood operate properly in all conditions and the escape hole remains open during fishing (Ministry for Primary Industries 2012, in Elgin Associates unpublished (b)).

Since 2004–05, there has been widespread use of government-approved, standardised SLEDs in the Auckland Island Squid Fishery (Ministry for Primary Industries 2012, in Elgin Associates unpublished (b)) (Figure 5.11). Although not mandatory, the use of SLEDs is required by the current industry body, applied fleet-wide and monitored by fishery observers (Ministry for Primary Industries 2012, in Elgin Associates unpublished (b)). Following the introduction of SLEDs, the number of New Zealand sea lions captured in the Auckland Islands Squid Fishery declined from 14–142 per year (pre-SLED deployment, 1995–96 to 2001–02), to 4–31 per year (post-SLED deployment, for the period 2004–05 to 2010–11) (Thompson *et al*. 2013). SLEDs appear to be effective in enabling most sea lions to exit the trawl net, however some still drown and are retained, and there has been concern and uncertainty about the number that may drown and be ejected from the net, or escape but not survive the interaction (e.g. injuries sustained from collisions with grids). Although fisheries managers considered it unlikely that dead sea lions would fall out of a top-mounted SLED escape hole that has also been fitted with a hood (as detailed above), it has not been possible to verify this with video monitoring because of the poor visibility at fishing depth due to water turbidity, light limitations and fine debris and squid ink suspended in the water column (Hamilton and Baker 2015). Following the fleet-wide introduction of SLEDs, it has therefore been difficult to estimate the number of sea lions interacting with the fishery, and the operational effectiveness of SLEDs with respect to both the survival and mortality rates of sea lions interacting with them. This uncertainty has been exacerbated by a continued decline in the sea lion pup production at the Auckland Islands since 2004–05 (when SLEDs were in widespread use).

As a consequence, a range of research has been undertaken to assess whether SLEDs successfully eject sea lions, and if ejected sea lions survive. This research has included:

Placing cover nets over SLED openings to determine how many seal are ejected from the net: In 2001, vessels with SLEDs, and independent observers, fitted cover nets over SLED openings. In 276 tows, 33 seals were caught (12 seals per 100 tows), of which 30 were successfully ejected into the cover net by the SLED, giving an ejection rate of 91 per cent (Wilkinson *et al*. 2003). Underwater video monitoring inside the cover net of three animals (alive when they exited the SED opening), indicated that they would have likely survived if the cover net had not been in place.

Autopsies of bycatch sea lions: Examination of the retained and frozen carcasses by a veterinary pathologist concluded some of the animals exhibited severe internal trauma which, it was considered, would have led to their subsequent death (Gibbs *et al.* 2001 in Wilkinson *et al.* 2003). However, it was also acknowledged that freezing of carcasses often involved rough handling onboard fishing vessels (including dropping some animals six metres into fishing holds for storage), which may have induced changes that could be confused with true lesions. To look at effects of freezing and thawing on seal carcases, five chilled and five frozen New Zealand fur seals recovered from trawl nets without exclusion devices in the New Zealand hoki fishery were examined. Results from this study confirmed that some lesions originally thought to be caused by trauma were in fact an artefact of freezing (Roe and Meynier 2012).

Analysis of video footage of Australian fur seals interacting with SED in SPF: Because of the limited usable video footage available for New Zealand sea lion interactions/collisions with SLED grids, available footage of Australian fur seal interactions with SEDs in the SPF (Lyle and Willcox 2008) was used as a proxy to help assess the possible nature of New Zealand sea lion and SLED interactions and, in particular, the potential of head trauma injuries that may result from head-first collisions with a metal grid (Lyle 2011). Interactions with SEDs were described for 132 seals, and indicated that about one third of seals that entered via the net mouth experienced a head-first collision with the grid (usually the upper half of the SED grid) and usually the angle of the head was more or less perpendicular to the grid (Lyle 2011). Impact velocities were also estimated for these collisions.

A biomechanical study that simulated the impact of sea lions hitting the metal grid of a SLED: Ponte *et al.* (2010) used a validated method for measuring head impact injury in human pedestrians ('crash tests') with scaling and extrapolating to account for the relative head and brain mass of the New Zealand sea lion to assess the likelihood of mild traumatic brain injury (i.e. 'concussion') to a sea lion as a result of a head impact with a stainless steel SLED grid. For particular impact locations on the SLED grid, the likelihood of a brain injury, based on swim speed and effective sea lion head mass, was determined (Ponte *et al.* 2010). 'Crash test' results indicated that sea lions colliding with the grid may incur some sort of brain injury and the risk of life-threatening brain injury may be higher than 85 per cent for a female sea lion in a 10 metre per second (m/s) collision with the SLED grid at the stiffest location tested (based on trawl speed of 2 m/s and estimated burst speed of an adult sea lion of 8 m/s) (Ponte *et al.* 2010). However, this impact speed probably represents the worst case scenario, especially if Lyle's (2011) fur seal interaction speeds are considered indicative of New Zealand sea lion interactions (Hamilton and Baker 2014).

Modelling the risk of sea lions suffering mild traumatic brain injury after striking a SLED grid: Based on Ponte *et al.* (2010) and Lyle's (2011) analyses, Abraham (unpublished) developed a simulation-based probabilistic model to estimate the risk of a sea lion suffering a mild traumatic brain injury when striking a SLED grid. The estimated probability of mild traumatic brain injury from a single collision was estimated to be less than 5 per cent.

The New Zealand Ministry for Primary Industries considered that collectively, the research and assessments of SLED efficacy (summarised above), provides robust evidence that SLEDs greatly increase the survival probability of sea lions that enter a trawl net, and that the weight of evidence is that SLEDs are effective in reducing the incidental mortality of New Zealand sea lions in the Auckland Islands Squid Fishery (Ministry for Primary Industries 2012, in Elgin Associates unpublished (b)).

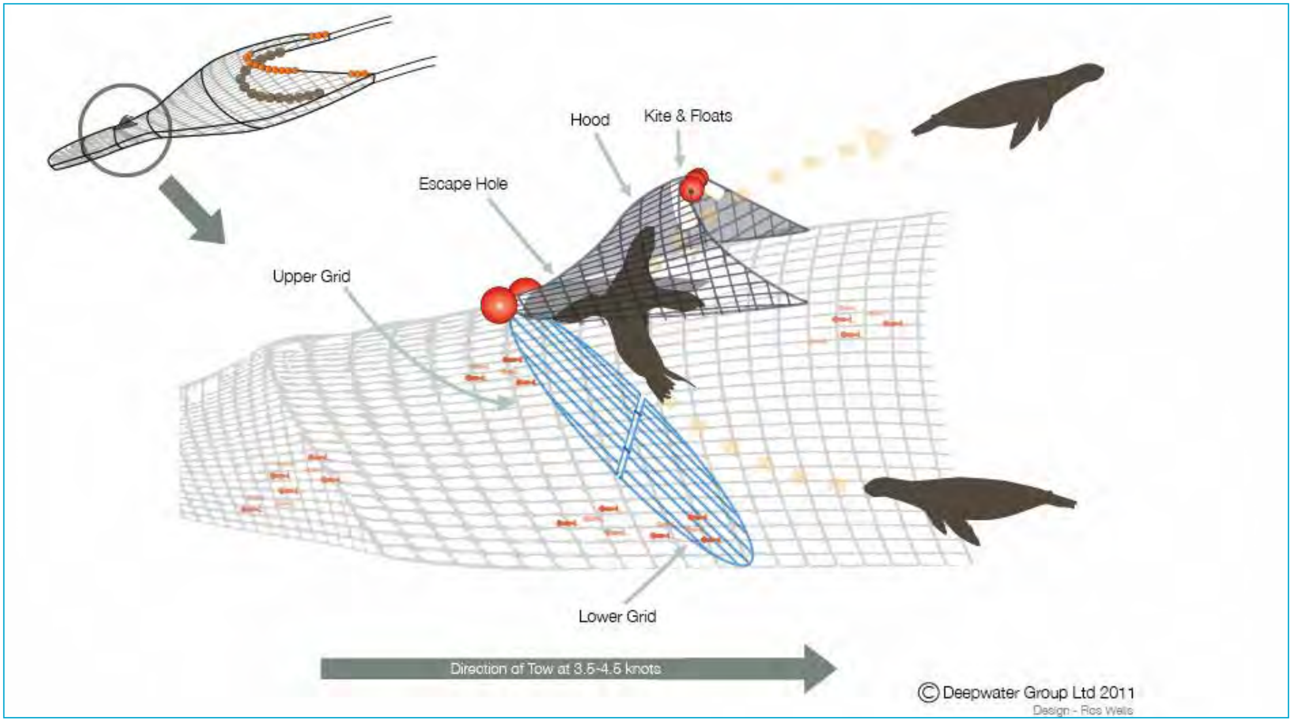


Figure 5.11 A standard SLED used in the Auckland Island Squid Fishery (SQU6T). **Source:** Reprinted from *Fisheries Research* 161 (2015) S. Hamilton and B. Baker, B. (2015). Review of research and assessments on the efficacy of sea lion exclusion devices in reducing the incidental mortality of New Zealand sea lions *Phocarctos hookeri* in the Auckland Islands squid trawl fishery. pp. 200–206. Copyright (2015), with permission from Elsevier B.V.

Antarctic krill fishery

The commercial trawl fishery for Antarctic krill is managed by CCAMLR. Large numbers (292) of Antarctic fur seal mortalities associated with the krill trawl fishery in Subarea 48.3 in the 2003–04 season (Reid and Grilly (2014) in Elgin Associates unpublished (b)), prompted the development and trialling of a range of SEDs to avoid fur seal deaths in the fishery (Hooper *et al.* 2005). Mitigation measures for fur seal bycatch were tested for krill vessels fishing around South Georgia in the 2004 fishing season (Hooper *et al.* 2005). Four approaches were trialled: physical barriers (panels of netting) excluding seals from entering the net; physical barriers (panels of netting) positioned within the net accompanied by escape channels or openings; manufactured SEDs in front of the codend that were composed of a separator grill that deflected seals to an escape opening; fishing gear configured with panels of a mesh size adequate to allow seals to escape (i.e. the forward part of the roof of the net had three large mesh panels inserted into it of mesh size 16 m and a further two panels of mesh size 4 m which appeared to allow the seals to escape alive and unharmed). It was considered that in all the above four cases, the incidence of seal entanglements during the 2004 season was either eliminated or greatly reduced (Hooper *et al.* 2005), however, the authors do not discuss the possibility that dead animals may have fallen out of the SED escape hole on hauling, and no underwater video monitoring was undertaken to confirm SED performance.

Low levels of bycatch mortality of Antarctic fur seals have since been reported in Subarea 48.3: one in the 2005–06 fishing season (from 15 per cent of the total fishing effort observed); zero in 2006–07 and six in 2007–08 (no details on observer effort) (Reid and Grilly (2014) in Elgin Associates unpublished (b)). CCAMLR has adopted a general mitigation measure (Conservation Measure (CM) 25–03) and introduced the mandatory use of marine mammal exclusion devices on trawls in the krill fisheries in Area 48 (CM 51–01), Division 58.4.1 (CM 51–02) and Division 58.4.2 (CM 51–03) (Elgin Associates unpublished (b)).

CCAMLR does not specify a standard exclusion device as there are a number of different vessels utilising different net designs, with each net design requiring a particular mitigation set up that suits the characteristics of the vessels. All exclusion device designs are included in the notification process for participation in CCAMLR fisheries and are reviewed prior to the vessels engaging in the fishery (Keith Reid, CCAMLR Science Manager, pers. comm. 7 October 2014).

SEDs in the Australian CTS, winter blue grenadier fishery

In 1999, in response to particularly high levels of incidental captures of seals on factory/freezer trawlers using mid-water trawl gear in the winter blue grenadier fishery off the west coast of Tasmania, the industry initiated a collaborative project with researchers to reduce seal bycatch (Tilzey *et al.* 2006)(Table 5.2). The project included trialling and developing a suitable SED and assessing its effectiveness in reducing seal mortalities. Tilzey *et al.* (2006) experimented with a range of different SED designs. Problems encountered included significant fish-loss via the SED escape hatch and blockage of the SED grid with larger sized target species (blue grenadier) and when catching high volumes of fish. A forward-facing 'top-hatch' SED had a significantly lower occurrence of seal bycatch than other SED designs and nets without a SED. The top opening SED was considered markedly superior to a bottom opening SED because it better facilitated both seal exit (seals more likely to swim upwards) and reduced the likelihood of seal entry via the escape hatch (Tilzey *et al.* 2006). Bycatch survival rate of seals in nets fitted with SEDs were 48 per cent compared to zero for nets without SEDs, largely because the SEDs prevented seals entering the codend where most deaths probably occur (Tilzey *et al.* 2006). However, SED performance remained largely unquantified because underwater video footage was limited and the numbers of seals interacting with the trawl net and successfully exiting the net via the SED escape hatch during this study were unknown. Obtaining significant results on SED performance by comparing replicate sets of trawl shots with and without a SED was difficult, because of the generally low level of seal bycatch and the complex suite of factors influencing seal interactions with the trawl net (Tilzey *et al.* 2006).

Hamer and Goldsworthy (2006) used underwater video monitoring to examine subsurface interactions with the SED to establish its effectiveness at reducing bycatch and mortalities. They provided details on the mortality of 13 fur seals; six entered the net during shooting, all of which died, while seven entered during hauling only one of which died. Six seals were caught while a SED was in place, three of which died, while seven seals were caught in trawls with no SED, four of which died. Based on this sample there was no significant difference in mortality rates between trawls with or without SEDs (Hamer and Goldsworthy 2006). Hamer and Goldsworthy (2006) suggested that, although a significant reduction in seal bycatch has been recorded since 1999 (see Table 5.2), attributing it to the introduction of SEDs was not supported by the evidence because all but one net-entry observed through underwater monitoring resulted in bycatch. The one animal that exited the net did so through the mouth and none were observed to exit through the SED opening. Instead, Hamer and Goldsworthy (2006) suggested that the apparent reduction in seal bycatch was due to a reduction in the incidence of seal-net interactions, as a consequence of other management measures. They also noted that seal bycatch was reduced when haul speeds were low which contradicted the recommendation in the 2007 Code of Fishing Practice, that nets should be hauled as quickly as possible to reduce the time that it remains within the diving range of fur seals (SETFIA 2007). Hamer and Goldsworthy (2006) suggested that net haul speed should be as fast as possible below the maximum dive range of seals (approximately 200 m) to reduce the length of time available to seals, but should then slow to speeds slower than the minimum average swim speed of fur seals (approximately 7.2 km per hour) to reduce the likelihood of seals becoming caught in the net in the upper water column. Further subsurface video monitoring of SED performance was recommended (Hamer and Goldsworthy 2006).

The current AFMA 'Gear Requirement' for the freezer processing vessels in the CTS of the SESSF includes a requirement that a SED is used in every trawl shot and that the SED complies with the following specifications.

- A grid is used to prevent seals from entering the codend of the trawl net, being a grid that is made of a rigid material strong enough to repel a seal (such as a 25 millimetre (mm) diameter stainless steel rod) with spacing between bars of no more than 250 mm. The grid must conform as closely as possible to the corresponding cross-section dimensions of the net.
- The escape hatch must be no smaller than 800 mm in length and 600 mm in width at its widest point and be free of obstruction and be located at the top of the net adjacent to the SED.

- The use of a 'hood' over the escape hatch is optional. If a hood is used it must be made of mesh no greater than 40 mm and have a kite attached to the leading edge of the escape hatch that ensures that the escape hatch egress is maintained.
- At least one single 20 cm diameter float is attached at the centre of the leading edge of the kite for initial flotation.

Ongoing SED performance issues in the winter blue grenadier fishery, mainly with SEDs clogging with large target species or higher fish volumes, has prompted some recent new developments with the design of the SED. AFMA has been working with the operators of the vessel *FV Rehua* to improve SED performance, for both seal exclusion and fish quality. The new design includes a hydrostatic net release, used to release a net binding after the gear has been shot away to an appropriate depth, as well as an acoustic transponder release of the SED gate (termed an 'Acoustic SED') which excludes seals from the codend during hauling (Mike Gerner, pers. comm. in Elgin Associates unpublished (b)).

Key features of the hydrostatic net release system include the net being bound with sisal, then hydrostatically released at a depth of 300 m (but could be adjusted to suit conditions/seal diving depth as required). The hydrostatic binding holds the net together very close to its mouth, preventing seals entering while the net is being shot, with the net only being opened at a depth considered below the typical diving depth of fur seals. This device was trialled in 2013 due to the observation of seals entering the mouth of the net during setting and resulting in mortalities during the 2012 season. As noted from previous underwater monitoring studies, most seal mortality occurs in this fishery during setting (Hamer and Goldsworthy 2006), so ensuring the net remains closed till reaching fishing depth (300–600 m) and below the typical dive range of fur seals, should significantly reduce the opportunity for seals to become entrapped in trawl gear.

The acoustic SED consists of a two-piece grid sewn into the net in front of the codend. The top half of the grid is hinged (the gate), while the bottom half is fixed. The top gate remains open during fishing at depths beyond the diving range of most fur seals, and provides an unimpeded path for fish flowing into the codend. While the top gate is in the open position, it covers the top opening SED escape hole, also preventing the loss of fish through the seal escape hole. Once sufficient fish have been caught, the gate can be triggered to close by an on-board acoustic transponder that sends a signal to the release device (sewn into the net), freeing the latch and allowing the gate to drop. Hauling then commences. Closing the gate opens the escape hole and closes the SED, prevents seals entering the codend and enables ejection through the SED opening.

A report on the efficacy of the acoustic SED is currently being prepared (Mike Gerner, pers. comm. in Elgin Associates unpublished (b)). At this stage the video footage has yet to be reviewed and reported on (pending funding availability).

SEDs in the SPF

Mid-water trawling commenced in the SPF in late 2002 (Lyle and Willcox 2008). From the commencement of this fishery, mid-water trawls were fitted with a 'soft' rope-mesh device (SED) (Browne *et al.* 2005). The mortality of 17 dolphins between 2004 and 2005, prompted AFMA to commission a pilot study (2005), followed by a larger project (2006–07) to investigate the nature and extent of marine mammal interactions and trial and assess the performance of various exclusion devices (Browne *et al.* 2005, Lyle and Willcox 2008). Lyle and Willcox (2008) trialled three SED configurations, including: (i) 'bottom opening, small escape hole', (ii) 'bottom opening, large escape hole', and (iii) 'top opening'. The bottom opening SED was composed of two panels, producing a 2.3 by 2.3 m steel grid, with 10 vertical steel bars with 21 cm spacing. The SED was angled forwards at about 15–25°, with the escape opening located at the base of the SED. The 'small escape hole' configuration, with an approximate 1 by 1 m escape opening, was trialled initially. The hole was subsequently enlarged to 1.9 m wide, producing the 'large escape hole' configuration. Escape holes were either left open, or had a flap of netting or short lengths of rope attached to the leading edge in an attempt to discourage the loss of target species while not hindering the exit of large bycatch species. The top opening SED was constructed from four panels, producing a 5 by 2.1 m grid with 23 cm spaced steel bars angled backwards at 45°. A 1.8 by 0.55 m deep escape opening was positioned on top of the net immediately in front of the SED. A cover flap of trawl netting was attached to the leading edge of the escape opening. The 'bottom opening, small escape hole' configuration was used continuously until early June 2006 when the escape opening was enlarged ('large escape hole' configuration) following several seal mortalities. The 'large escape hole' configuration was used to the end of January 2007. The 'top opening' configuration was then trialled for about a month but owing to operational problems (specifically difficulties in retrieving the SED onto the net drum), it was deemed operationally unsuitable for the vessel and replaced with the bottom opening configuration at the end of the study period (Lyle and Willcox 2008). Underwater video footage as detailed above (98 tows, 735 hours) was used to assess SED performance, however, only the two bottom opening SED configurations could be compared owing to the limited number of shots where the top opening SED was used. The 'large escape hole' SED (where the opening had been enlarged so that there was no floor in the net immediately in front of the grids) had a three-fold reduction in lethal interactions compared to the small escape hole SED (7.2 seals per 100 tows vs. 20.0 seals per 100 tows).

Summary: seal excluder devices

- *Although excluder devices are commonly used in trawl fisheries globally as a means to mitigate bycatch of marine megafauna, with the exception of one Antarctic fishery, SEDs are mostly used in New Zealand and Australian fisheries.*
- *SEDs are typically tailored to individual fisheries, fishing vessels and bycatch species because a single design is not suitable for all circumstances.*
- *A SED functioning under optimal operating conditions should reduce the incidence of bycatch mortality of pinnipeds, but will not eliminate it.*
- *SEDs leave on-board observers effectively blind to the extent of interactions and to the effectiveness of SEDs in ejecting seals in a healthy state from the net. Underwater video monitoring of SEDs is necessary to monitor interaction levels and cryptic mortality and to optimise SED design and efficacy.*
- *Innovations in SED design are emerging from the winter blue grenadier fishery. These include a hydrostatic net release, an acoustic transponder release grid gate and installation of smaller sized mesh on the hood. The acoustic SED shows promise for demersal trawling activities that take place below the normal diving range of seals. They are less likely to be effective in shallower, mid-water trawling where seals can access the net at any stage.*
- *SED trials in the mid-water trawl fishery of the SPF indicated lower seal mortality with a larger SED opening (in a bottom opening SED). Top opening SEDs were not able to be fully evaluated due to operational difficulties.*

Fishing behaviour

In many trawl fisheries, mandated or voluntary codes of practice have been developed and adopted by industry to reduce the level of interactions with seals. The most relevant to the DCFA come from those developed in New Zealand and Australian trawl fisheries. These are summarised below.

Marine Mammal Operational Procedures (MMOP) developed in New Zealand and agreed upon by quota holders are designed to reduce the risk of incidental capture of marine mammals during deepwater trawling operations (vessels greater than 28 m in length) in EEZ waters (Deepwater Group 2011). The MMOP assumes that marine mammals are most at risk when trawls are on or near the surface (less than 50 m). Fish in the nets is the key attractant to marine mammals, and any action taken to reduce the time the net is on the surface is effective in reducing this risk. All vessels must adopt the following practices (Deepwater Group 2011) to minimise incidental catches of marine mammals.

- Remove all 'stickers' (meshed fish) before shooting the trawl.
- Undertake shooting and trawling as quickly as possible.
- If large numbers (more than five) seals congregate around the vessel when the gear is hauled, the vessel should steam away from them before setting the gear again.
- Always endeavour to mend the trawl net with the whole net on deck; if this is not possible, avoid mending while hauling.
- Each vessel shall designate one or more crew member(s) to be on watch during every shoot or haul and determine if marine mammals have been captured and to organise timely humane assistance to release captured animals alive.

The procedure details that gear failures, especially when shooting or hauling (and if the trawl mouth is left open for extended periods), can create high-risk situations for marine mammals leading to multiple marine mammal capture events. In the event of a gear failure, which may delay the shooting or hauling of the gear, either of the following should occur:

- Keep the gear deep in the water, even if this means re-shooting the gear; if the gear is to remain in the water the gear headline height should be at least below 50 m and preferably below 100 m, or
- Bring the gear, or at least the ground rope and headline, on board to ensure the net mouth is closed.
- All vessels have offal management procedures and recommended fishing practices that are detailed in individual vessel management plans (Deepwater Group 2011). In support of these, the MMOP details the following actions relating to offal and rubbish disposal that will reduce the risks to marine mammals.
- Fur seals and sea lions eat fish and offal discarded from fishing vessels. These discards are likely to keep marine mammals near a vessel and this is to be avoided.
- Fish offal and waste fish must be fish-mealed where possible. If fish waste discharging is unavoidable, then do not discharge while shooting or hauling the net. Ensure a fish waste holding facility is available to allow this.
- Maritime regulations prohibit the dumping of any plastic waste and netting at sea. Marine mammals and seabirds are known to ingest such waste.

In the SET of the SESSF, the bycatch of fur seals by three freezer trawlers in 1999 prompted the development of a research program to mitigate seal bycatch in this fishery. The primary components of the program were the development of seal avoidance practices (SAPs) and SEDs both aimed at reducing the incidence of seal interactions in the fishery (Tilzey *et al.* 2006). Between 2000 and 2003 season, vessels generally adhered to the following SAPs (Tilzey *et al.* 2006).

- The vessel steamed at an average speed of 10–12 knots for at least 40 minutes prior to shooting the gear regardless of the number of seals observed.
- If seals were still present, gear deployment was delayed and the vessel continued steaming at 10–12 knots for a further 20 minutes.
- Fish meshed in the net (stickers) were removed prior to shooting the gear.
- All shooting and hauling was carried out as rapidly as possible.
- The vessel often made a sharp turn when shooting the bottom trawl to keep the net closed on descent.
- During fishing, the gear was not lifted into the top 150 m of the water column to make turns or a change in direction.
- After hauling, the vessel turned 90–180 degrees immediately after the net was on deck.
- The vessel steamed away from the hauling area at an average speed of 10–12 knots for at least 40 minutes after hauling, regardless of the estimated time of the next shot.
- When fixing the net or streaming it for cleaning, the codend was always open and the SED escape hatch closed. The mouth of the trawl was always on board at this time.
- The discarding of fish, processing offal or domestic waste on fishing grounds was rigorously avoided.

Adherence to these SAPs appeared to halve the incidence of seal bycatch in the winter fishery for blue grenadier from 1999 levels (Tilzey *et al.* 2006). Many of these measures were adopted into SETFIA's Code of Fishing Practice (SETFIA 2003, 2007), across the remainder of the 'wet boat' fleet, with some key exceptions. These exceptions included the requirement for vessels to actively steam away from seals before deploying the trawl net, and the removal of 'stickers' from the net prior to deployment (first three dot-points above) (SETFIA 2003, 2007, National Seal Strategy Group and Stewardson 2007).

The SPF's Bycatch and Discard Workplan included the development and implementation of vessel management plans (VMPs) to minimise TEPS interactions and record procedures for reporting on catch and wildlife interactions (AFMA 2011).

Spatial closures

Spatial closures, often termed 'time/area closures', are commonly used to manage interactions with both targeted and bycatch species in many fisheries (O'Keefe *et al.* 2014). Their use to mitigate bycatch typically occurs where there is a high degree of spatial and/or temporal overlap between target and bycatch species. Closures can produce simple and enforceable fisheries management outcomes. Some examples of their application in mitigating pinniped bycatch interactions are provided below.

New Zealand squid trawl fishery (Auckland Islands)

A 12 nautical mile (nm) (22 km) trawl exclusion zone was established around the Auckland Islands in 1982 in response to high levels of New Zealand sea lion bycatch mortality in the fishery (Wilkinson *et al.* 2003). This was converted to a Marine Mammal Sanctuary in 1995 (Chilvers 2008). However, the efficacy of this closure has been questioned, given that female New Zealand sea lions have been shown to forage over and utilise most of the Auckland Island Shelf, and that the Sanctuary does not include areas where the likelihood of interactions (and hence bycatch) are likely to be greatest (Chilvers 2008, Chilvers *et al.* 2011). Furthermore, since the closures were introduced, the pup production of the Auckland Island population has declined by 30 per cent (Chilvers 2008).

Alaskan fisheries

Since Steller sea lions were first listed as threatened under the US Endangered Species Act in 1990, a complex suite of time-area closures have been introduced around their breeding colonies and haul-out sites in Alaska, in order to mitigate adverse effects of fishing. Further measures were introduced after the western stock was listed as endangered in 1997 (Committee on the Alaska Groundfish Fishery and Steller Sea Lions 2003). A range of time-area closures were implemented in 1990s, the result being that most colonies are now protected by 20 nm trawl exclusion zones. Some of these are permanent closures; others are temporal to coincide with particular fishing seasons for specific target species (Committe on the Alaska Groundfish Fishery and Steller Sea Lions 2003). Although the major intent of these closures was to mitigate the potential adverse effects of localised depletion of key prey species in Steller sea lion critical habitat (Committe on the Alaska Groundfish Fishery and Steller Sea Lions 2003), it has been recognised that these closures also contributed significantly to the 90 per cent reduction in incidental bycatch mortality observed between the 1980s and 1990s (Perez 2003). This is discussed further in Chapter 6.

Australian fisheries

In 2010 and 2011, AFMA introduced spatial closures around all ASL colonies off SA, as part of a range of management measures introduced into the shark gillnet component of the GHAT Fishery (AFMA 2010a) (Figure 5.12). This followed research that integrated an on-board independent bycatch observer program on gillnet vessels, and an extensive ASL satellite tracking and spatial modelling program (Goldsworthy *et al.* 2010) (Figure 5.5). This study found a very strong positive relationship between observed sea lion bycatch rates and the underlying estimated sea lion density (i.e. lowest sea lion bycatch rates in lowest density areas; highest bycatch rates in highest density areas). As central place foragers, ASL density is typically highest in waters surrounding their colonies and haul-out areas; hence the spatial fishing closures introduced have resulted in a marked reduction in fishing effort in the high-density ASL area. Incidence of bycatch has reduced significantly since the introduction of the spatial closures and the other management actions (trigger limits; gear switching options).

Bycatch trigger limits/move-on rules

New Zealand trawl fisheries (Auckland and Campbell Islands)

Bycatch trigger limits are generally utilised to ensure that bycatch levels of protected species do not exceed a certain threshold that places the species or population at risk of further declines. The United States Marine Mammal Protection Act of 1972 (MMPA) specified that marine mammal stocks be maintained at an optimum sustainable population level (OSP). The act does not define OSP, but the National Marine Fisheries Service (NMFS) has interpreted OSP to be a population level that falls between maximum net productivity level (MNPL) and carrying capacity (K) (Moore 2013, Roman *et al.* 2013). In 1994, a new management approach was adopted under the MMPA, potential biological removal (PBR), which was specifically developed to assess marine mammal mortalities associated with commercial fisheries, and is defined as the maximum number of animals (excluding natural mortalities), that may be removed from a marine mammal stock while allowing that stock to recover to or be maintained within its OSP (Roman *et al*. 2013).

The PBR approach has been used in New Zealand to set an annual maximum allowable level of fishing-related mortality (MALFIRM). This sets the maximum limit of the number of New Zealand sea lions that can be killed incidentally in the Auckland Islands squid trawl fishery, before it is closed for the season. Since 1992, annual fishing operational plans have defined the management regime for each year including the required observer coverage to allow a statistically robust estimation of incidental captures, and steps to be taken if the estimated New Zealand sea lion mortality from squid fishing for that season approaches the bycatch trigger limit (Wilkinson *et al*. 2003). In 2003, this PBR/MALFIRM approach was superseded by the fishery-related mortality limit (FRML), developed from a more detailed Bayesian population model for the species (Breen *et al*. 2003). The fishery has been mandatorily closed by government fisheries managers in seven seasons since these bycatch trigger-limits were introduced, although the decision to close the fishery was overturned by court orders in the 2003 and 2004 fishing seasons (Robertson and Chilvers 2011).

With the introduction of SLEDs into the fishery, estimating the number of sea lion interactions has become increasingly difficult. The FRML now has to take into account the expected bycatch (strike) rate (if there were no SLEDs), and the number of animals that had they been caught would have escaped through the SLED opening (Thompson *et al*. 2013). Therefore, new models include both capture and SLED retention probabilities so that the total bycatch (observed and unobserved) can be estimated (Thompson *et al*. 2013). Adequate observer coverage has been critical in enabling a full and accurate assessment of New Zealand sea lion bycatch, and enabling assessment of risk and interaction levels in real time. Vessels are required to inform fisheries managers immediately on any sea lion capture event so the appropriate management response can be considered (Deepwater Group 2011).

<u>Australian fisheries</u>

Bycatch trigger limits have recently been utilised by AFMA to mitigate bycatch mortality in the GHAT Fishery, on Australian sea lion populations off SA (AFMA 2013d). In April 2011, AFMA put in place changes to the existing ASL Management Strategy (AFMA 2010a) to modify fishing arrangements in the GHAT fishery. AFMA determined that a bycatch rate of 1.5 per cent (of the female breeding population throughout one breeding cycle, an 18-month period, or 52 female sea lions) was likely to represent a sufficiently precautionary trigger level for ASL bycatch in the seven management zones identified in the ASL Management Strategy (AFMA 2010a). In 2012, AFMA amended the trigger-levels to take into account individual subpopulations (breeding colonies) within each of the seven management zones, several of which have been recognised as being at risk of becoming locally extinct. AFMA set an overall bycatch level of 15 animals per year, trigger limits within each zone ranging from one to five sea lions (Figure 5.12). Where zone trigger levels are met (or exceeded) the zone is closed to gillnet fishing for 18 months from the date of the last mortality. At any time, if the overall mortality number of 15 is exceeded, the entire ASL Management Zone will be closed for a period of 18 months from that time (AFMA 2013d). Given there is 100 per cent observer coverage in this fishery, mostly through electronic monitoring, there is high compliance and most sea lion bycatch is now reported in logbooks (AFMA 2013c).

The trigger limits had immediate effect, with bycatch incidents in February, March and April 2012 resulting in the closure of three fishing zones (A, B and D).

Summary: other management measures

- *Codes of practice have been used to reduce the level of interactions with seals. The most relevant elements of these include:*
  - *removing all 'stickers' before shooting the trawl*
  - *undertaking shooting and trawling as quickly as possible*
  - *suspension of trawling and moving away if seals are observed prior to trawling*
  - *no discarding of fish, offal or domestic waste on fishing grounds.*
- *Spatial closures can provide an effective means of reducing or removing fishing activity in locations or at times where direct interactions with seals are likely to be common, or present unacceptable risks to threatened or protected species' populations.*

- *Bycatch trigger limits are generally utilised to ensure that bycatch levels of protected species do not exceed a threshold that places the species or population at risk of further declines. They have been used to cap incidental mortality of the threatened New Zealand sea lion in the Auckland Island squid trawl fishery, and in Australia AFMA uses bycatch trigger limits to limit the bycatch of the threatened ASL in the GHAT Fishery.*

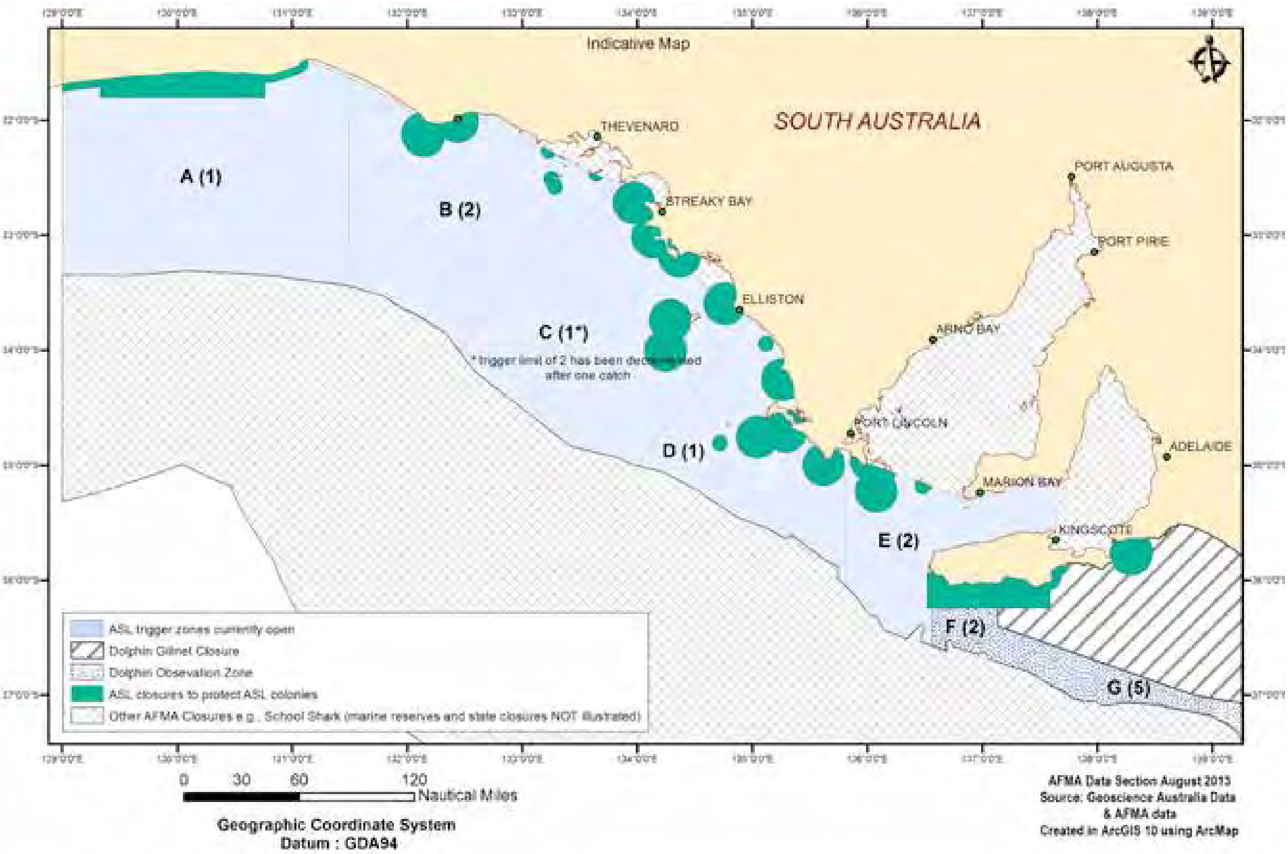


Figure 5.12 SESSF closures under the Australian sea lion management strategy, 23 August 2013. Source: AFMA (2013d).

Proposed management of direct interactions with pinnipeds in the DCFA

With respect to managing and mitigating pinniped interactions, the operations of large-scale mid-water trawl operations would have been subject to the conditions specified as 'Condition 1' in the Schedule to the accreditation of the fishery made by the Environment Minister on 3 September 2012 (see Section 3.2.4). Parts (a) and (d) of the condition relating to fur seals was to be implemented through a VMP. The VMP prepared by AFMA for managing and mitigating seal and dolphin interactions for the *FV Abel Tasman* is indicative of what was proposed (see Box 5.1).

Box 5.1 Proposed *FV Abel Tasman* Seal and Dolphin Management Plan: Boat Specific Mitigation Measures and Operational Requirements

Mandatory Gear Requirements: Exclusion Device

The concession holder must have an AFMA approved Seal and Dolphin Excluder Device installed within the net at all times while conducting fishing operations.

The concession holder must ensure the escape hole on the Excluder Device is upward opening and has a hood attached to reduce any potential fish loss and to not allow any large animals to fall out of the net if immobile and the net is inverted.

Mandatory Fishing Operation Requirements

Ensure an AFMA observer is onboard the boat at all times and assist the AFMA observer to monitor fishing operations at all times.

Ensure the boat has underwater cameras operational at all times while undertaking fishing and those cameras constantly record any take of bycatch and/or the excluder device.

Allow the onboard AFMA observer access to review any footage recorded by the underwater camera at least once every 24 hours for the duration of each fishing trip.

Not deploy any trawl nets if dolphins are sighted around the boat by any crew member or onboard observers, until the dolphins have dispersed of their own accord or the boat has steamed away and are no longer in sight of the boat.

Not deploy any trawl nets if seals are sighted within 300 m of the boat by any crew member or onboard observers, until the seals have dispersed of their own accord or the boat has steamed away and are no longer within 300 m of the boat.

Ensure observers are notified prior to the deployment and/or the recovery of trawl nets, day and night, in order to allow the observers to be present to detect any seals which become enfolded or caught at the surface, so the animals can be rapidly and humanely released.

Take all reasonable steps to ensure that, as far as practicable, if a seal or dolphin is captured in a trawl net as a result of fishing operations, the mammal is released alive and unharmed.

Record any interaction with any protected species in a logbook onboard the boat and notify AFMA in writing detailing any interactions with protected species, including any mortalities, every 24 hours for the duration of each fishing trip.

Mandatory Interaction Requirements

Dolphins

If fishing operations conducted by the method of mid-water trawling result in the death of one or more dolphins in any one shot the holder must:

- suspend fishing immediately;
- notify the AFMA observer onboard of the dolphin mortalities and with the assistance of the AFMA observer review the effectiveness of mitigation measures used in fishing operations; and
- not recommence fishing within 50 nm of the event.

Seals

If fishing operations conducted by the method of mid-water trawling result in the death of a seal in any one shot the holder must:

- suspend fishing immediately; and
- notify the AFMA observer onboard of the seal mortality/ies and with the assistance of the AFMA observer review the effectiveness of the mitigation measures used in fishing operations before recommencing fishing.

If fishing operations conducted by the method of mid-water trawling result in the death of:

- three or more seals in each of three consecutive shots; or
- more than 10 seals within a 24 hour period of fishing; or
- more than 10 seals in one shot,

the holder must:

- suspend fishing immediately;
- notify the AFMA observer onboard of the seal mortalities and with the assistance of the AFMA observer review the effectiveness of mitigation measures used in fishing operations; and
- not recommence fishing within 50 nm of the event.

Source: Dr J. Findlay, AFMA *in litt.* 19 April 2013.

In addition, the operations of large-scale mid-water trawl operations would have been subject to conditions (e) to (g) specified in 'Condition 1' of the Schedule to the accreditation of the fishery made by the Environment Minister on 3 September 2012 (see Section 3.2.4). In particular, a closure for Australian sea lions would have been imposed (Figure 5.13).

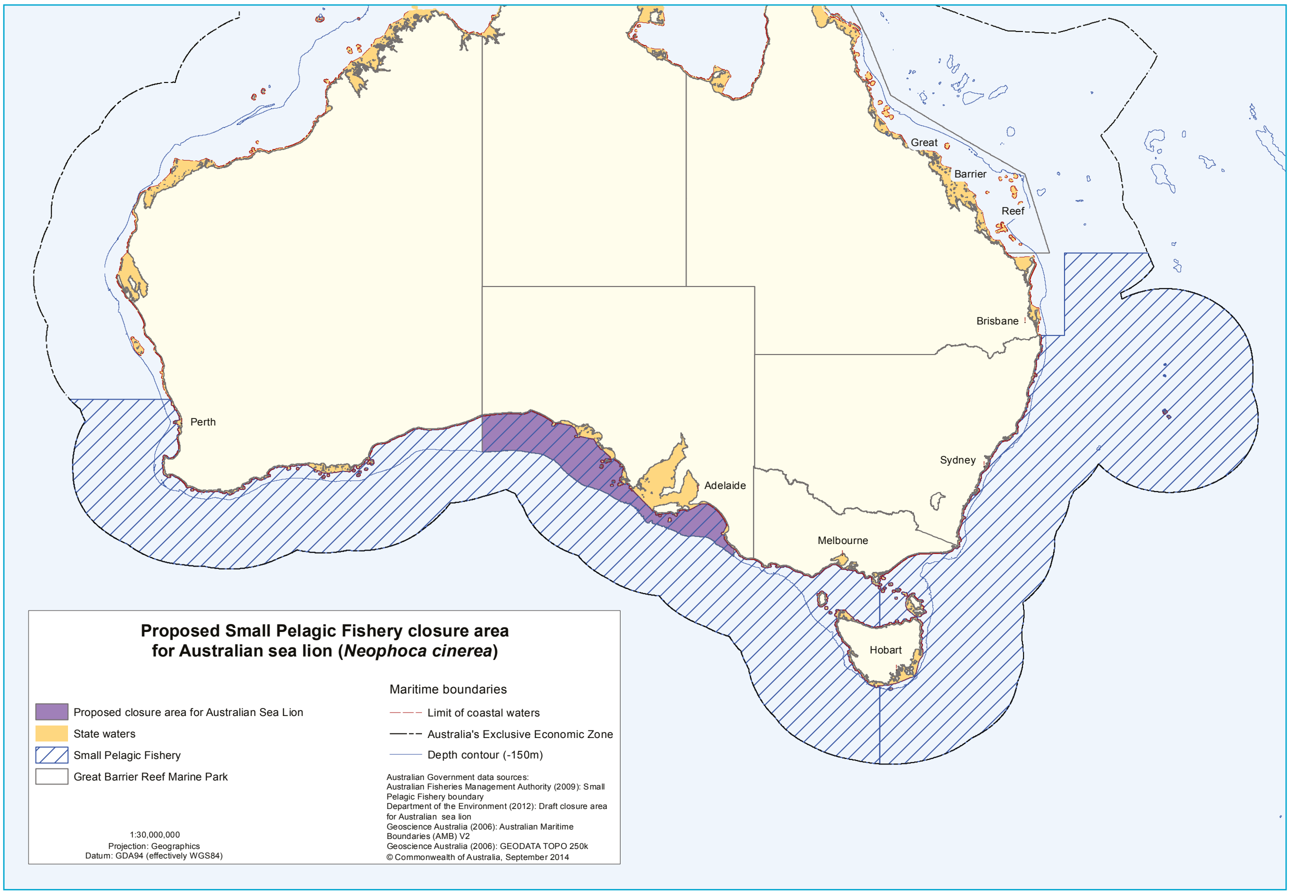


Figure 5.13 Proposed closure area for the Australian sea lion for large-scale mid-water trawl operations in the SPF. **Source:** ERIN.

5.2.4 Assessment of the likely nature and extent of direct interactions by the DCFA with pinnipeds

The panel's assessment of the likely nature of pinniped interactions with the DCFA are based on the above review and assessment of available information on the nature and extent of direct interactions between pinnipeds and trawl fisheries around the world and in Australia.

All of the breeding distribution of the Australian and New Zealand fur seals in Australia, and most of the breeding distribution of ASL, occurs within the area of or adjacent to the SPF. Seals are common marine predators in southern Australia; they are intelligent and curious animals and will be attracted to any fishing activity that occurs within their foraging range. The greater the level and frequency of fishing activity, or predictability in where and when fishing activity will occur within an area where seals forage, the greater the number of seals that are likely to be attracted to, and interact with fishing operations. This is especially the case if such interactions provide some reward. If fishing is persistent over time and fishing activities provide opportunities for seals to gain nutritional benefits, then sections of the population can become habituated to fishery interactions. This undoubtedly has happened in most trawl fisheries operating in the

SPF area, especially those in the SESSF, where persistent and ongoing bycatch interactions have been an issue for many decades (Knuckey *et al*. 2002, Hamer and Goldsworthy 2006, Tilzey *et al*. 2006, National Seal Strategy Group and Stewardson 2007, Lyle and Willcox 2008, Tuck *et al*. 2013).

The likely nature of direct pinniped interactions with the DCFA includes net feeding, entering the trawl net (during shooting, fishing and hauling), and as mentioned above, habituation to fishing activities. With these interactions, some level of bycatch mortality is inevitable and in areas of high seal abundance and/or high fishing activity, likely to be common, even with the proposed Seal and Dolphin Management Plan and a mandatory SED.

Most mid-water trawl operations that have occurred in the SPF area have been in the south-east of Australia (principally Tasmania and Bass Strait area) where the most common seals are Australian fur seals (see Figure 5.4). The major centre of the New Zealand fur seal population in Australia is off SA, with approximately 80,000 occurring in a relatively small geographic area between Kangaroo Island and the southwestern Eyre Peninsula (Figure 5.4). Any mid-water or demersal trawl fishery operating in shelf waters adjacent to these areas is likely to encounter high levels of interactions. The other main population centre of fur seals is in the Recherche Archipelago off the south coast of WA (Figure 5.4). Again, in the panel's view, seal interactions with fishing activities would be common if a trawl fishery was to operate in this region (Figure 5.4).

As summarised above, the information detailing the nature and extent of interactions between fur seals and trawl fisheries operating within the area of the SPF, indicate that where trawl fisheries and fur seals overlap, interactions will occur. However, given the limited historic and independently observed mid-water trawl activity in areas outside south-east Australia within the SPF, especially in regions off SA and WA, there is uncertainty in the likely nature and extent of interactions between Australian sea lions and the DCFA, if fishing operations were to occur there. Even though the limited dietary information suggests Australian sea lions tend not to forage on pelagic fish, like Australian fur seals, they are primarily benthic and opportunistic foragers. Furthermore, demersal foraging New Zealand sea lions readily interact with mid-water and demersal trawling operations in New Zealand. Therefore, if the DCFA were to operate in parts of the Australian sea lion range, the panel considered that some animals would interact with the fishery and that some level of bycatch is likely.

Panel assessment: likely nature and extent of direct interactions by the DCFA with pinnipeds

- *Seals occur throughout the entire area of the SPF. They are abundant and conspicuous marine predators and will be attracted to any fishing activity that occurs within their foraging range.*
- *They readily interact with all trawl fisheries in southern Australia, including the mid-water trawl fishery in the SPF.*
- *The greater the level and frequency of fishing activity, or predictability in where and when fishing activity will occur within an area where seals forage, the greater the number of seals that are likely to be attracted to, and interact with fishing operations.*
- *If fishing is persistent in an area over time, and fishing activities provide opportunities for seals to gain nutritional benefits, then sections of the population can become habituated to fishery operations and this may lead to an increase in interactions.*
- *The nature of these interactions with the DCFA would likely include net feeding, entering the trawl net (during shooting/hauling), habituation to fishing activities and bycatch.*
- *Some level of direct interactions with seals, including bycatch mortality, is inevitable and in areas of high seal abundance, likely to be common, even with current best practice mitigation devices and fishing behaviour.*
- *Historically, most mid-water and demersal trawl operations that have occurred in the SPF area have been in the south-east of Australia where most interactions are with Australian fur seals.*
- *If the DCFA were to operate in areas where threatened ASL occur, some level of direct interactions with this species, including bycatch mortality, is inevitable.*

- *There is uncertainty about the nature and extent of interactions with pinnipeds if the DCFA were to fish off SA and WA. In these regions, New Zealand fur seals and ASL are most common. Neither species has been exposed to the level of bycatch mortality from trawl fisheries experienced by Australian fur seals, so there is uncertainty about the differential impacts of bycatch on their populations. This is especially significant for the threatened ASL.*

5.2.5 Assessment of the effectiveness of proposed management measures to mitigate pinniped interactions in the DCFA

The degree to which any of the proposed management measures for a large mid-water trawl freezer vessel in the SPF would have been effective in mitigating interactions with pinnipeds is highly uncertain, largely because a vessel of the configuration of the *FV Abel Tasman* has never fished in Australian waters. As a result, the potential effectiveness of the proposed management arrangements has never been tested. The panel's assessment of the likely effectiveness, is therefore, based on a review and assessment of national and international experience documented in the literature and identified from discussions with experts on similar vessels and fishing operations around the world. The panel's assessment of each component of the proposed management arrangements is provided below.

Seal excluder device

The Seal and Dolphin VMP (Box 5.1) required the use of a top-opening SED with a hood. The SED proposed to be used on the *FV Abel Tasman* was designed by Maritiem, and was composed of a soft fibre grid made of a flexible and strong material called Dyneema twine (Maritiem 2012 in Elgin Associates unpublished (b)) (Figure 5.14). Dyneema has the same strength as steel for the same diameter and does not stretch (Maritiem 2012 in Elgin Associates unpublished (b)). A hard SED (e.g. constructed of steel bars) was not considered practical because it would not withstand the forces applied to the trawl (particularly during shooting and hauling), and because the *FV Abel Tasman* used a net drum and did not have ramp hauling and potential stowage of the SED trawl (i.e. the SED would bend out of shape if winched onto the net drum). The mesh size proposed for the soft grid was 200 by 200 mm, which previous research has indicated was adequate for preventing marine megafauna (including pinnipeds) passing through to the codend. The SED was proposed to be positioned between the intermediate (or conical) part of the trawl and the straight cylinder part of the trawl, approximately 50 m from the end of the codend (Maritiem 2012 in Elgin Associates unpublished (b)).

The proposed angle of the SED was between 15° and 25° (if parallel to the seams of the codend is 0° and perpendicular to the seams [vertical] is 90°). The small angle was chosen to increase the grid length, to improve the capacity of the grid to allow target species to pass through to the codend (Maritiem 2012 in Elgin Associates unpublished (b)). The SED was proposed to be top opening, with a cover (hood) held up by floats, which, when in operation would have an angle of approximately 45° (Maritiem 2012 in Elgin Associates unpublished (b)) (Figure 5.14). This configuration was considered optimal for preventing loss of target species as well as retaining megafauna (including seals) that do not make it out of the trawl, enabling the monitoring of mortalities (Maritiem 2012 in Elgin Associates unpublished (b)). Additional flotation was to be used around the hood so that a camera could be installed on the top of the panel to monitor SED performance. Due to the first Final Declaration, this SED was not trialled on the *FV Abel Tasman*.

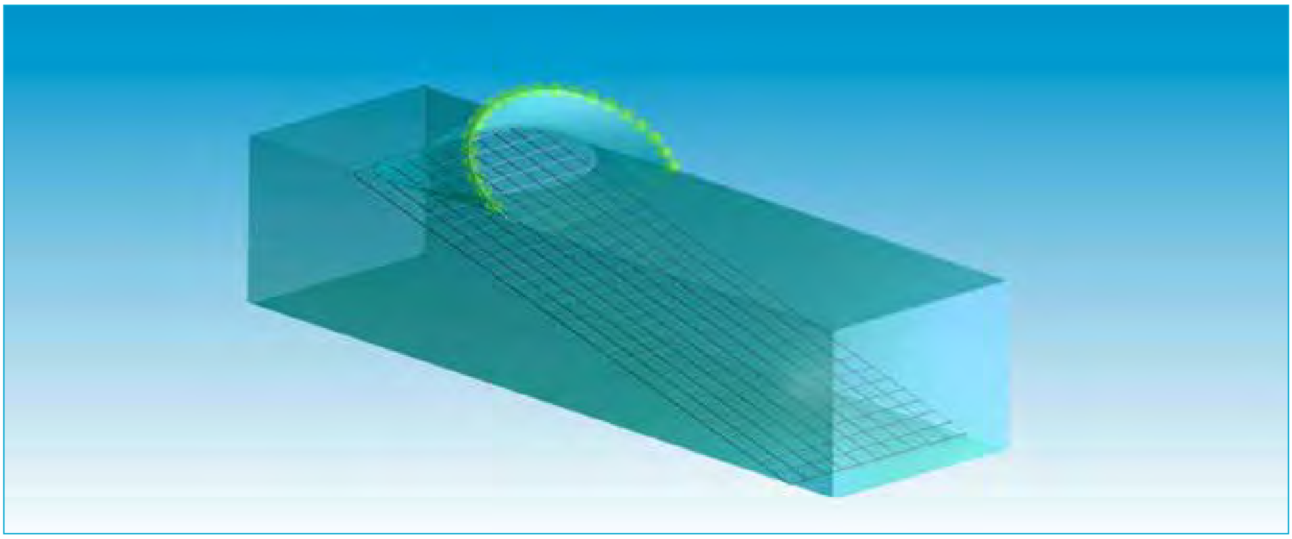


Figure 5.14 Schematic of the SED proposed to be used on the *FV Abel Tasman* in the SPF. Source: Maritiem 2012 in Elgin Associates unpublished (b), reproduced with permission from Seafish Tasmania Pty Ltd.

In addition to a SED, an auto-trawl system was planned to be utilised on the *FV Abel Tasman*. An auto-trawl system is controlled by telemetry and sensors maintain the shape of the trawl net when turning so that the net never closes up (Elgin Associates unpublished (b)). Ensuring the trawl mouth is always open is considered important in maintaining the effectiveness of the SED and in reducing marine mammal bycatch mortality. However, there is currently no evidence that demonstrates the efficacy of auto-trawl equipment in minimising bycatch mortality of marine mammals (Elgin Associates unpublished (b)).

The panel noted that SEDs are not commonly used internationally, and they are mainly utilised in New Zealand and Australian fisheries to mitigate interactions with otariid seals (fur seals and sea lions). SEDs need to be designed specifically for each fishery, taking into account the particular characteristics of the size of target species, gear type, fishing operation, the size and operation of gear, towing speed, the hydrodynamics of trawl set up in relation to scaling (trawl size/grid and escape hole ratios), how trawl nets are stored on the vessel, and bycatch species to be excluded (Elgin Associates unpublished (b)). For each new fishery or vessel to which a SED is being utilised, it is typical for there to be a developmental period during which SED design is modified and tailored to improve efficacy (Tilzey *et al.* 2006, Lyle and Willcox 2008).

The panel expects that had the DCFA commenced fishing operations, it is likely that there would have been operational and efficacy issues with the proposed SED design, and that, as experienced in other fisheries, a period of optimisation would have been required in order to identify a particular SED design that worked most effectively for the fishery, fishing vessel and bycatch species.

A SED functioning under optimal operating conditions will significantly reduce the incidence of bycatch mortality of pinnipeds, but will not eliminate it. The panel noted that the proposed top-opening SED with a hood enhances the escape of pinnipeds, but reduces the incidence of observed bycatch by on-board observers, because a proportion of seal mortalities may not be retained by the hood. Hoods likely enhance the retention of seal mortalities but are not 100 per cent effective, leading to potential for unobserved 'cryptic' mortality. The proposed utilisation of underwater video monitoring by the *FV Abel Tasman* would provide an essential tool to monitor SED efficacy and cryptic mortality.

The panel is aware that all trawl fisheries where SEDs have been utilised in recent years have universally used a rigid SED composed of a metal grid (New Zealand, Antarctica, Australia SET and SPF). In the one case where a soft grid was used (SPF mid-water trawl fishery), it was found to be less effective in directing seals towards the escape hole and replaced subsequently with a rigid SED design (Browne *et al.* 2005, Lyle and Willcox 2008). It is unclear if the soft-grid SED fabricated from Dyneema twine proposed to be used on the *FV Abel Tasman,* would have functioned as well as a hard metal grid in directing seals toward the escape hatch.

Fishing behaviour

The only activities detailed in the proposed seal and dolphin management plan (see Box 5.1 above) that constitutes a specific change in fishing behaviour to mitigate pinniped interactions is the requirement to "not deploy any trawl nets if seals are sighted within 300 m of the boat by any crew member or onboard observers, until the seals have dispersed of their own accord or the boat has steamed away and [sic] are no longer within 300 m of the boat".

The efficacy of this practice is uncertain. In the SPF most trawling activities commence in the evening when pelagic fish begin to school (Lyle and Willcox 2008). As most of the seal interactions in the SPF off Tasmania occurred between 1800 and 0700 hours, it is questionable whether the activity of seals within 300 m of the vessel could have been detected readily in twilight or darkness.

The panel noted that the proposed seabird vessel management plan for the large mid-water trawl freezer vessel (see Box 5.1) required that all biological material must be retained and that there should be no discard into the water while the gear is in the water. The panel noted that similar measures have been used elsewhere for this purpose (see Section 5.2.3) and considers that this requirement will also assist in reducing interactions with pinnipeds.

Bycatch trigger limits/move-on rules

A move-on rule was proposed as a key management arrangement for the large mid-water trawl freezer vessel. This required suspension of fishing and for the vessel to move at least 50 nm away if three or more seal mortalities occurred in each of three consecutive shots, or more than 10 fur seal mortalities in one shot or day. On advice from the Department of the Environment (Mr N Hanna, Department of the Environment *in litt.* 23 May 2014) the panel has concluded that this proposed restriction related only to fur seals and not to threatened Australian sea lions, noting that a closure for Australian sea lions had been proposed.

The rationale for this move-on rule and the number of fur seals permitted to be caught before it is triggered is unclear. This rule would require no change in fishing operations as long as no more than 10 fur seal mortalities occurred per day. The panel noted that three or more seals in each of three consecutive shots or 10 seals in one tow, is equivalent to a minimum bycatch rate of 300-plus seals per 100 tows. These rates would be one to two orders of magnitude higher than the mean rates observed previously in the SPF mid-water trawl fishery, in the winter blue grenadier fishery and in the wet boat sector of the SET (see Section 5.2.2). The panel considered that if such bycatch rates were occurring consistently under the DCFA, they would suggest that either the SED was ineffective, and/or that fishing activity was being conducted without due care, and/or in areas where seal density is too great to enable sustainable fishing activity to occur.

The panel considered that a permitted mortality of up to 10 fur seals per day of fishing was too high and questioned how consistent this provision is with Part 13 of the EPBC Act which requires fishing operators to take all reasonable steps to avoid killing or injuring listed marine species.

Therefore, the panel considered that any seal vessel management plan for the DCFA should include:

- *a reduction in the daily and per-shot trigger limit* to ensure that fishing operations are in compliance with the EPBC Act requirement to take all reasonable steps to avoid killing or injuring listed marine species
- *an acceptable maximum mean bycatch rate trigger limit for a fishing season and/or management zones* to ensure that average per-shot bycatch rates remain below acceptable levels and consistent with the EPBC Act requirement that fishing operators take all reasonable steps to avoid killing or injuring listed marine species by encouraging operators to move away from fishing areas of high seal density if their average bycatch rates were increasing, or close to, the maximum bycatch rate trigger limit (consideration of bycatch limits within regions/zones may be needed to prevent disproportional impacts on individual seal populations if fishing activities were concentrated in certain areas).

Further research needs to be undertaken to determine what levels of fishery-related mortality can be sustained by pinniped populations, and what the appropriate permissible level of bycatch mortality should be within the SPF (see Section 5.2.6).

The panel is also uncertain that if the trigger limits were exceeded, whether moving fishing operations at least 50 nm away is adequate or appropriate. This distance appears arbitrary and not evidence based. It is possible that in randomly moving a set distance, fishing operations could move to an area with higher seal densities where interactions are more likely than they were previously. The panel considered that a requirement to move to an area where interactions with seals are less likely, would provide a better response, but would need to be underpinned by available data on estimated at-sea density distributions (e.g. Figures 5.4, 5.5). Furthermore, if bycatch limits were applied to zones, then move-on rules would only need to be applied if zone triggers were exceeded.

As the proposed trigger limits and move-on rules only apply to fur seals, the panel noted that under the proposed management arrangements for the DCFA, there would be no restriction on fishing activity in the event of bycatch interactions with threatened ASL. Although an 'Australian sea lion closure area' in waters out to 150 m depth off SA was proposed by the Department of the Environment as a condition on the operations of the large mid-water trawl operations (see Section 5.2.3), no limit was proposed to be placed on the number of ASL that could be taken outside this closure.

In the GHAT Fishery off SA, Australian sea lion bycatch trigger limits (ranging from one to five sea lions per 18-month period), exist across seven fishing zones out to 183 m depth (AFMA 2013d). However, there would be no limit on the number of ASL permitted to be taken by the proposed large mid-water trawl freezer vessel in the 'gap' between the depth closure proposed for that vessel and the GHAT Fishery ASL closure area. Although available information indicates that most foraging occurs in waters less than 150 m depth (especially for adult females), some sea lions have been recorded foraging in depths up to 250 m.

The panel considered that the absence of trigger limits for ASL under the proposed arrangements for the large mid-water trawl freezer vessel in the SPF and inconsistencies between those arrangements and the trigger limits imposed on GHAT fishers where these fisheries overlap, are deficiencies in the proposed management measures.

Spatial closures

As noted above, Condition 1 part (e) of the Schedule to the accreditation of the fishery made by the Environment Minister on 3 September 2012, specified one spatial closure to mitigate pinniped interactions in the DCFA. The proposed 'Australian sea lion closure area' closed all shelf waters off SA, out to a depth of 150 m to fishing activity by the large mid-water trawl freezer vessel. Presumably this closure was put in place to mitigate the potential for bycatch mortalities of Australian sea lions, especially adult females, by the vessel if it fished in areas of overlap with ASL foraging effort on shelf waters off SA (see Figure 5.3). While the panel considered that this management measure would have provided significant protection for the South Australian populations of ASL it was unclear why such protection was not afforded to populations of ASL off the south coast of WA that also occur in the SPF area.

The panel noted that the proposed arrangements did not provide for any specific spatial closures to mitigate bycatch interactions with fur seals. The panel considered that central place foraging, lactating adult fur seal females may warrant similar protection.

Panel assessment and advice: assessment of proposed measures and actions to avoid, reduce and mitigate direct interactions of the DCFA with pinnipeds

<u>*Assessment: effectiveness of proposed measures*</u>

- *The proposed top-opening SED with a hood enhances the escape of pinnipeds, but reduces the incidence of bycatch observed by on-board observers. Hoods enhance the retention of seal mortalities but are not 100 per cent effective, leading to unobserved 'cryptic' mortality. The proposed utilisation of underwater video monitoring would be essential to monitor SED efficacy and cryptic mortality under the DCFA.*
- *The panel questions the effectiveness of the proposed requirement to halt deployment of the net if seals are sighted within 300 m of the vessel, given that most fishing activities in the SPF are likely to occur at night and it is questionable whether the activity of seals within 300 m of the vessel could be detected readily in twilight or darkness. In the panel's view, effectiveness is further compromised by the seals' ability to move quickly in and out of a 300 m range.*

- *The panel supports the inclusion of a prohibition on the discard of biological waste from the DCFA as a means of avoiding interactions with pinnipeds.*
- *The panel considered the requirement to suspend fishing immediately when a seal mortality is detected. However, it noted that it is likely that some mortalities will not be immediately known to the crew or the observer, but may subsequently be identified on review of video recordings which would reduce the efficacy of this requirement, i.e. by the time the mortality has been identified the vessel will no longer be in the area.*
- *The panel considered that the permitted mortality of up to 10 fur seals per day of fishing under the proposed arrangements was too high and that the 50 nm distance move-on rule was arbitrary and not evidence based.*

Advice: actions to avoid, reduce and mitigate adverse environmental impacts of the DCFA

- *Use a SED, with or without auto trawl, only after its operation has been optimised for the vessel, fishery and bycatch species under a scientific permit with the required level of performance developed in consultation with experts. For example, the panel noted that neither the soft mesh-grid, top-opening SED with hood, nor the auto trawl system proposed to be used by the FV Abel Tasman to mitigate pinniped bycatch, has undergone trials in the SPF.*
- *Use underwater video to monitor the SED efficacy and cryptic mortality.*
- *Reduce the daily and per-shot trigger limits on fur seals from the proposed limit of up to 10 per day and replace the associated 50 nm move-on rule with a requirement to move to an area where interactions with seals are less likely, based on available data on estimated at-sea density distributions*
- *Introduce a bycatch rate trigger limit for fur seals for the fishery or fishing areas, or a total mortality trigger for a fishing season and/or fishing areas.*
- *Ensure 100 per cent observer coverage of fishing operations and, if daily or per shot trigger limits are used in conjunction with move-on rules or with a requirement to review mitigation measures, provide sufficient observer capacity to ensure that underwater video footage is monitored at the end of each shot to maximise response times to mortalities.*
- *Require 'stickers' to be removed from the net before shooting, noting that this was a requirement of the proposed seabird VMP.*
- *Prohibit the discard of any biological waste (excluding the release of any protected fauna) noting that this was a requirement of the proposed seabird VMP.*
- *Implement spatial closures that mitigate bycatch interactions with fur seals, especially in regions adjacent to breeding colonies where there is high transit and foraging activity by central place foraging lactating adult females.*
- *Review the proposed Australian sea lion closure area off South Australia (out to 150 m depth) so as to provide consistency with the management arrangements for the GHAT Fishery (out to 183 m depth).*
- *Implement a similarly designed closure for the Australian sea lion colonies occurring within the SPF off Western Australia.*

5.2.6 Monitoring and research

For global pinniped populations, as for those in Australia, the most significant source of anthropogenic mortality is from fishery interactions (Shaughnessy 1999, National Seal Strategy Group and Stewardson 2007, Kovacs *et al.* 2012). In Australia, the most significant source of fishery-related pinniped bycatch is from trawl fisheries. A fishery targeting the key prey taxa of pinnipeds in their foraging grounds and within their foraging depth range will inevitably attract many animals, and potentially (as demonstrated in the mid-water trawl fishery of the SPF to date) result in significant levels of bycatch mortality. The panel has proposed a number of ways in which direct interactions of the DCFA with pinnipeds might be mitigated. The panel has also identified four key uncertainties (questions) relating to potential adverse impacts on pinnipeds resulting from the DCFA that could be addressed through further monitoring and research. They include the following.

1) What are the individual and cumulative fishery-related bycatch impacts on pinniped populations?

Seals interact with and potentially suffer incidental mortality from a range of different fisheries. A key uncertainty in assessing the potential adverse impacts resulting from any one fishery (such as the DCFA in SPF), is the extent to which that fishery contributes to the total impacts across all fisheries.

The panel considered that improved independent monitoring of pinniped bycatch and a requirement for annual reporting of estimated take of pinnipeds by all Australian fisheries is needed. This would enable the estimation of overall cumulative impacts on pinniped populations, and enable assessment of the relative contribution of individual fishery impacts.

2) What levels of fishery-related mortality can pinniped populations sustain?

Improved pinniped population models and ongoing monitoring of status and trends in abundance would provide a means to better evaluate what levels of bycatch mortality are sustainable, and reduce uncertainties about the potential for adverse environmental impacts. It would provide essential biological context to estimates of individual and cumulative fishery impacts (addressed in question one, above), and provide a direct quantitative measure to directly assess a fishery against Part 13 of the EPBC Act which requires that "the fishery does not, or is not likely to adversely impact the conservation status of protected species or affect the survival and recovery of listed threatened species".

Such information would not only inform what bycatch levels are sustainable, but also assist in apportioning and setting allowable take and maximum bycatch rate trigger limits for individual fisheries.

3) Where are the regions of critical foraging habitat for pinniped populations where the management of direct interactions with the DCFA may be most needed?

The panel considered that research to better understand the foraging distributions and critical habitat of pinnipeds could help identify regions where management of the potential adverse environmental effects of fishing may be most needed. There are two key components to such work.

a) Knowledge of the locations of key foraging areas where adult females may be particularly vulnerable to bycatch mortality in near colony waters. Adult female fur seals and sea lions spend most of their lives raising pups. The need to return regularly ashore to nurse a dependent pup requires that females make regular foraging trips to sea to forage. Bycatch of females has a disproportionate effect on populations (loss of mother, pup on teat and one in utero and future reproductive potential) compared to males. Reducing female bycatch can help reduce uncertainties about the potential for adverse impacts on pinniped populations. Such information may inform the location and timing of spatial closures to mitigate bycatch.

b) Knowledge of the locations of foraging hot-spots (areas of very high density of animals) used by one or more populations of seals could provide important information on which areas could be avoided to reduce the incidence and rate of bycatch.

4) Are there additional modifications to fishing gear and behaviour that can reduce the potential for direct interactions by the DCFA with pinnipeds?

The panel considered that additional research and fishing trials could be undertaken to optimise the proposed SED, or trial alternate SED designs appropriate to the fishing vessel and gear to be used in a DCFA. This would include testing of appropriateness of soft vs. hard grids, optimising the slope of the grid and configuration of the escape hole, hood and kites with the objective of improving the exit of healthy seals.

On-board observers should be required to monitor seal activity both on the surface and within the net, via underwater video monitoring, so that a data base can be developed to improve the understanding of the circumstances under which seal activity and interaction increase and decrease. This would help inform and promote codes of practice to further reduce interactions and maximise survival.

Panel advice: research and monitoring to reduce uncertainties

Research that addresses the following questions could reduce uncertainties about the potential for adverse environmental impacts of the DCFA on protected pinniped species.

- *What are the individual and cumulative fishery-related bycatch impacts on pinniped populations?*
- *What levels of fishery-related mortality can pinniped populations sustain?*
- *Where are the regions of critical foraging habitat for pinniped populations where the management of direct interactions with the DCFA may be most needed?*
- *Are there additional modifications to fishing gear and behaviour that can reduce the potential for direct interactions by the DCFA with pinnipeds?*

5.3 Cetaceans

5.3.1 Cetacean species assessed

A total of 47 cetacean species are recorded to occur in Australian waters (Bannister *et al.* 1996, Ross 2006, Woinarski *et al.* 2014), and of these, 44 species are known or are likely to occur in the SPF area (Appendix 3). Of these 44 species, 42 species were assessed in the Ecological Risk Assessment for the Effects of Fishing (ERAEF) process for the mid-water trawl sector of the SPF (Daley *et al.* 2007b). The two additional cetacean species recorded to occur in the SPF region (but not assessed in the ERAEF) are Omura's whale *Balaenoptera omurai* and spectacled porpoise *Phocoena dioptrica* (Woinarski *et al.* 2014). The ERAEF Level 2 PSA analysis identified a total of 20 threatened, endangered and protected cetacean species as High risk, a further 21 cetacean species as Medium risk, and one cetacean species as Low risk (Appendix 3). After Level 2 Residual Risk Guidelines were applied, seven cetacean species remained at High risk for the mid-water trawl sector of the SPF (AFMA 2010b). These are:

- Risso's dolphin *Grampus griseus*
- Fraser's dolphin *Lagenodelphis hosei*
- hourglass dolphin *Lagenorhynchus cruciger*
- southern right whale dolphin *Lissodelphis peronii*
- striped dolphin *Stenella coeruleoalba*
- Indo-Pacific bottlenose dolphin *Tursiops aduncus*
- common bottlenose dolphin *Tursiops truncatus*.

The 21 cetacean species detailed below include these seven species and 13 other cetacean species known to occur in the SPF area that are recorded to have interacted with trawl fisheries in Australia and/or internationally, and were therefore considered most relevant to assessing the risks and likelihood of interactions with large mid-water trawl vessels in the SPF (Elgin Associates unpublished (a)). In addition, the spinner dolphin *Stenella longirostris* is recorded taken as bycatch in purse seine, gillnet and trawl fisheries throughout its range, so is therefore also considered relevant to this assessment. For each of these 21 species a summary is provided of their known distribution range and overlap with the SPF area, population size and trends, relevant biology and ecology, key risks and threatening processes, and their conservation and listing status. These species' summaries are arranged in order of risk, with the seven dolphin species previously assessed as high risk described first, followed by other odontocete species then mysticete whales. The distribution of trawl effort in the SPF during 2000–2013 is shown in Figure 5.15 in relation to the pattern of species richness of the most relevant cetacean species, based on the available distribution data for these species held by the Department of the Environment.

The panel's Terms of Reference include specific mention of dolphins. Short-beaked common dolphins and *Tursiops* spp. bottlenose dolphins are the dolphin species considered most likely to interact with trawl fisheries (Elgin Associates unpublished (a)), and common bottlenose dolphins and possibly short-beaked common dolphins have previously been recorded as bycatch in mid-water trawls in the SPF (Lyle and Willcox 2008, Tuck *et al.* 2013). The panel recognised that interactions could occur between the DCFA and the other 23 cetacean species that have been recorded in the SPF area, but considered these other species to be at lower risk of interaction and therefore of less relevance to this assessment of direct interactions.

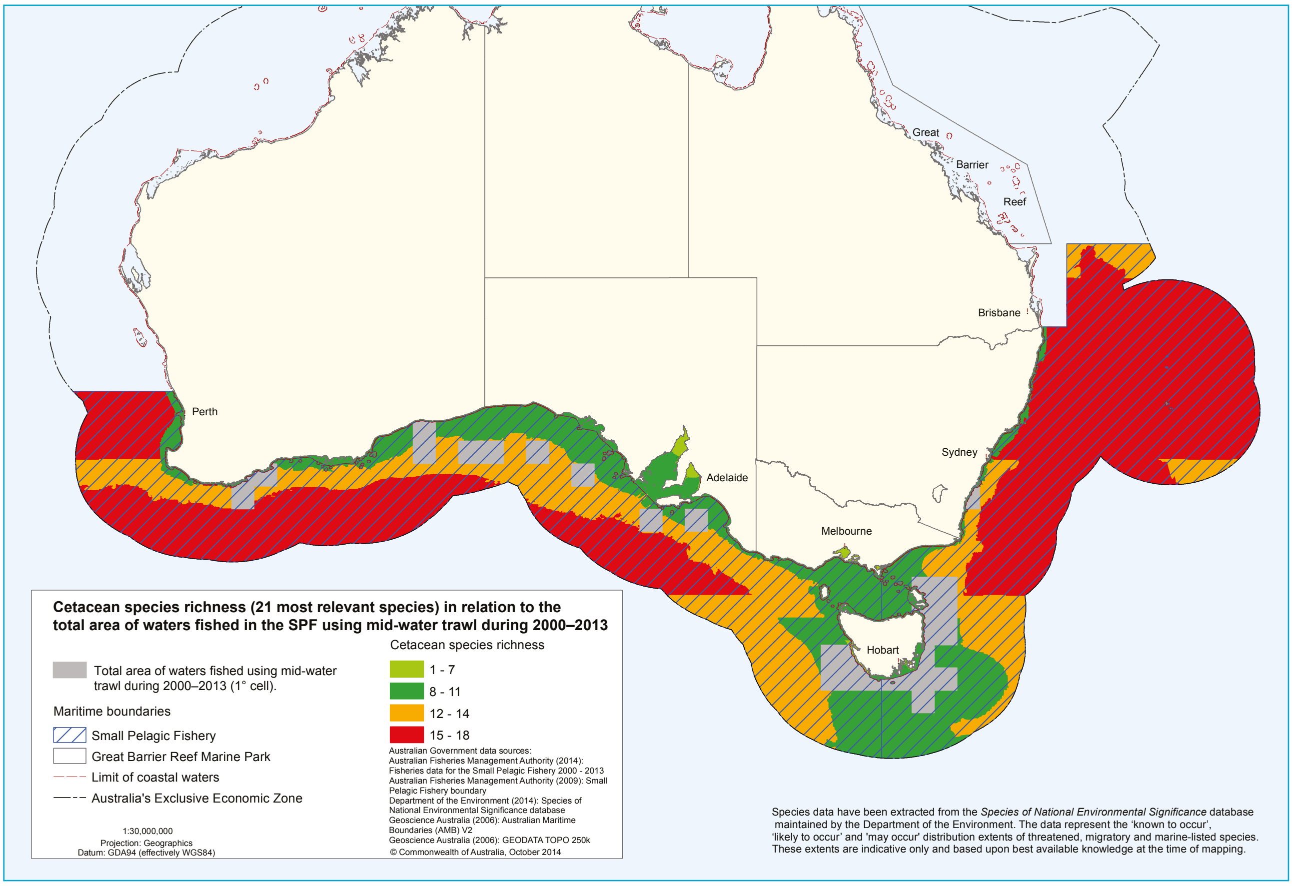


Figure 5.15 Cetacean species richness (21 most relevant species) in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by ERIN using unpublished AFMA data.

Risso's dolphin *Grampus griseus* (Level 2 PSA Residual Risk – High)

Distribution and range

Risso's dolphin is widely distributed from tropical to temperate and subantarctic regions in both hemispheres, ranging from about latitude 60°N to 60°S, but is mostly found in warmer waters within this range (Rice 1998, Baird 2009). This species has been recorded from all Australian states and Northern Territory waters, extending south to Tasmania at 43°S (Ross 2006, Warneke and Donnelly 2008). Its Australian range overlaps extensively with the SPF area.

Population size and trends

Risso's dolphins are considered to be relatively abundant throughout the main part of their Australian range (Ross 2006), but there are no estimates of the Australian or global population size or trends (Taylor *et al.* 2008a, Woinarski *et al.* 2014). Overseas, regional population estimates include about 175,000 in the eastern tropical Pacific region (Wade and Gerrodette 1993), 33,000 off the western United States coast, and 83,000 off Japan (Jefferson *et al.* 2008). There is some evidence of population structure within and between ocean basins (Baird 2009).

Biology and feeding ecology

Risso's dolphin grows to at least 3.8 m long and can weigh up to 400 kg and potentially nearer 500 kg (Jefferson *et al.* 2008). These large dolphins occur mainly in deeper water outer shelf and continental slope habitats particularly in areas of steeply sloping underwater topography and high productivity upwelling areas, and they have been sighted from inshore areas to well offshore in open pelagic habitats (Ross 2006, Jefferson *et al.* 2008, Warneke and Donnelly 2008). They occur in mostly small-to-medium-sized groups of about 4–100 dolphins, but groups of up to 4000 have been recorded (Jefferson *et al.* 2008, Warneke and Donnelly 2008). Longer-term changes in distribution patterns of Risso's dolphins off central California have been associated with oceanographic changes and movements of spawning squid (Jefferson *et al.* 2008).

These dolphins feed primarily on mid-water and bottom-dwelling squid, but also consume octopus and crustaceans, and possibly fish (Jefferson *et al.* 2008, Warneke and Donnelly 2008, Baird 2009). They appear to feed mainly at night possibly associated with diurnal vertical migrations of their prey (Jefferson *et al.* 2008, Warneke and Donnelly 2008). Diet may vary between sexes and among different age groups (Baird 2009). Females mature at about 8–10 years and males about 10–12 years, gestation is about 13–14 months, the interbirth interval is about 2.4 years, and longevity is about 34 years (Baird 2009). Generation length is estimated to be 19.6 years (Taylor *et al.* 2007).

Risks and threatening processes

Where Risso's dolphins occur in the SPF area there is a risk of incidental capture in fisheries gear (Elgin Associates unpublished (a)). Risso's dolphins have been incidentally captured in US north-east and mid-Atlantic mid-water trawl fisheries (Fertl and Leatherwood 1997, Zollett 2009, Elgin Associates unpublished (a)). Other overseas fisheries interactions include an annual drive fishery in Japan, incidental bycatch in driftnet and purse seine fisheries, and this species has been recorded taking bait from longlines, which has resulted in bycatch and instances of deliberate killing (Jefferson *et al.* 2008, Baird 2009). Other threats include ingestion of plastic, pollution resulting in high levels of contaminants in tissues, anthropogenic noise and acoustic disturbance (Bannister *et al.* 1996, Baird 2009, Woinarski *et al.* 2014). These dolphins occasionally ride bow waves of vessels which increases the risk of vessel strike, but they are considered to be mostly indifferent to vessels or avoid them (Baird 2009).

Conservation and listing status

Risso's dolphin is listed as a cetacean species under the EPBC Act, Rare in SA, Data Deficient in the Northern Territory, but is not listed in other states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, Risso's dolphin was assessed as Least Concern for the IUCN Red List in 2008 (Taylor *et al.* 2008a), and is listed in Appendix II of CITES.

Fraser's dolphin *Lagenodelphis hosei* (Level 2 PSA Residual Risk – High)

Distribution and range

Fraser's dolphin has a pantropical distribution between 30°N and 30°S (Rice 1998, Dolar 2009). Its distribution in Australian waters is poorly known, with records from NSW, Queensland and WA, and a stranding record from Corio Bay, Victoria at 38°S which is considered to be outside its normal range and possibly associated with anomalous movements of the warm East Australian Current (Bannister *et al.* 1996, Ross 2006, Dolar 2009). Its Australian range overlaps partly with the SPF area.

Population size and trends

There is no estimate of the Australian population size or trends for this species (Woinarski *et al.* 2014). Global abundance is estimated to be about 300,000, with about 289,000 individuals estimated in the eastern tropical Pacific region (Wade and Gerrodette 1993, Hammond *et al.* 2008a). The global population trend is also unknown (Hammond *et al.* 2008a).

Biology and feeding ecology

Fraser's dolphin grows to at least 2.6 m long and can weigh more than 210 kg (Jefferson *et al.* 2008). These dolphins occur mainly in deep offshore pelagic waters and along the outer continental shelf and slope, but they can occur nearer the shore where deep water occurs closer to the coast (Ross 2006, Dolar 2009). They occur in large groups containing hundreds or thousands of dolphins and are often mixed with other delphinid species (Jefferson *et al.* 2008).

Fraser's dolphins feed on mid-water myctophids and other mesopelagic fish, squid and crustaceans, and may selectively feed on larger prey (Ross 2006, Jefferson *et al.* 2008, Dolar 2009). Depth of feeding appears to vary in different regions, with records ranging from feeding near the sea surface to depths exceeding 600 m (Dolar 2009). Females mature at about five-to eight years with males maturing at 7–10 years, gestation is about 10–12 months, the interbirth interval is about two years and longevity is at least 18 years (Dixon 2008, Jefferson *et al.* 2008). Generation length is estimated to be 11 years (Taylor *et al.* 2007).

Risks and threatening processes

Where Fraser's dolphins occur in the SPF area there is a risk of incidental capture in fisheries gear (Elgin Associates unpublished (a)). Four dolphins with genetic affinities to Fraser's dolphin haplotypes were sampled in association with dolphins interacting with the Pilbara Fish Trawl Fishery off northwestern Australia (Allen and Loneragan 2010). This fishery operates between 50–100 m depth on the northwestern shelf off WA, hence these records are interesting because they indicate use of relatively shallow water shelf habitat that is unusual for this primarily deep-water species (Allen and Loneragan 2010, Jaiteh *et al.* 2013). Fraser's dolphins are hunted in Japan, Lesser Antilles and Indonesia, and have been incidentally captured in other overseas fisheries including as incidental bycatch in purse seines, gillnets, driftnets, trap nets and anti-shark nets (Jefferson *et al.* 2008, Dolar 2009). Other threats include pollution, anthropogenic noise and acoustic disturbance (Bannister *et al.* 1996, Woinarski *et al.* 2014).

Conservation and listing status

Fraser's dolphin is listed as a cetacean species under the EPBC Act, and the 'Southeast Asian population' is listed as migratory under the EPBC Act, but the species is not listed by states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, Risso's dolphin was assessed as Least Concern for the IUCN Red List in 2008 (Hammond *et al.* 2008a), and is listed in Appendix II of CITES.

Hourglass dolphin *Lagenorhynchus cruciger* (Level 2 PSA Residual Risk – High)

Distribution and range

Hourglass dolphins have a circumpolar distribution restricted to higher latitudes in the Southern Hemisphere from about 33°S down to the ice edge around 67°S, with most records from 45°S to 65°S (Rice 1998, Goodall 2009). Its distribution in Australian waters is not well known, with most sightings occurring south of Australian mainland waters around subantarctic Heard Island and Macquarie Island, and at 55°S to the south of Australia (Bannister *et al.* 1996, Thiele and Gill 1999, Ross 2006). Based on the rarity of sightings, Goodall (2008) considered that Australian waters could be considered to be the extreme distribution limits for the hourglass dolphin. Most of its Australian range is thought to lie within the Australian EEZ around subantarctic Heard Island and Macquarie Island (Woinarski *et al.* 2014); hence the distribution range of this species may only overlap marginally with the SPF area south of Tasmania.

Population size and trends

There are no estimates of the Australian or global population size or trends for this species (Hammond *et al.* 2008b, Woinarski *et al.* 2014). Abundance was estimated to be about 144,000 individuals to the south of the Antarctic convergence (Jefferson *et al.* 2008).

Biology and feeding ecology

Hourglass dolphins grow to 1.8–1.9 m long and weigh up to 88–100 kg (Jefferson *et al.* 2008, Goodall 2009). These small dolphins occur mainly in deep open ocean pelagic waters with some sightings and strandings from shallower waters near islands and banks (Jefferson *et al.* 2008, Goodall 2009). Remarkably little is known about these dolphins and they are considered to be one of the most poorly known small cetacean species (Jefferson *et al.* 2008). They have been recorded in small groups containing one to eight dolphins with some larger groups up to about 60 animals, and are often seen associated with fin whales and some other baleen whales, bottlenose whales and some other delphinid species (Jefferson *et al.* 2008, Goodall 2009).

There are few records of their diet, but stomach contents indicate that these dolphins feed on myctophids and other small fish, small squid and crustaceans (Goodall 2009). Stomach contents from one dolphin indicate that it had fed in surface waters (Goodall 2009). Very little is known about reproduction and life history of this species (Jefferson *et al.* 2008).

Risks and threatening processes

If hourglass dolphins occur in the SPF area there is a risk of incidental capture in fisheries gear (Elgin Associates unpublished (a)). Hourglass dolphins appear to be attracted to ships but there are few records of ship strike (Goodall 2009). Three female hourglass dolphins were incidentally taken in a gillnet operation from New Zealand, and one dolphin was taken in an experimental drift net in the southern Pacific Ocean (Jefferson *et al.* 2008, Goodall 2009). This species has not been recorded to interact with trawl fisheries. Potential threats include fisheries impacts on prey species, pollution, and climate and oceanographic change (Bannister *et al.* 1996, Woinarski *et al.* 2014).

Conservation and listing status

The hourglass dolphin is listed as a cetacean species under the EPBC Act. This species was previously assessed as No category assigned but possibly secure in Australian waters by Bannister *et al.* (1996) and Ross (2006), but was assessed as Least Concern by Woinarski *et al.* (2014) on the basis that it is unlikely to meet or approach any criteria for listing as threatened, and there is no evidence of decreasing population size or significant threats. Globally, the hourglass dolphin was assessed as Least Concern for the IUCN Red List in 2008 (Hammond *et al.* 2008b), and is listed in Appendix II of CITES.

Given that the Australian range of this dolphin species may only marginally overlap with the SPF area and these dolphins have not been recorded interacting with trawl fisheries, and the species is not obviously threatened and is assessed as Least Concern in Australian waters and globally, the panel did not consider it to be a high risk species for direct interactions associated with the SPF mid-water trawl sector.

Southern right whale dolphin *Lissodelphis peronii* (Level 2 PSA Residual Risk – High)

Distribution and range

The Southern right whale dolphin has a circumpolar distribution in cool temperate to subantarctic waters of the Southern Hemisphere, mostly between 25–30°S and 55–65°S (Rice 1998, Lipsky 2009). In Australian waters, most records are south of 37°S and offshore south of Tasmania, the GAB and southwestern WA, with five single stranding records from eastern Tasmania and southern NSW (Bannister *et al.* 1996, Ross 2006, Warneke 2008). Its Australian range overlaps extensively with the SPF area.

Population size and trends

There are no estimates of the Australian or global population size or trends for this species (Hammond *et al.* 2008c, Woinarski *et al.* 2014). Southern right whale dolphins are considered to be fairly common off the South Island of New Zealand, in the Tasman Sea and in waters south of Australia (Van Waerebeek *et al.* 2010).

Biology and feeding ecology

Southern right whale dolphins grow to at least 3.0 m long and can weigh up to 116 kg (Jefferson *et al.* 2008). These slender dolphins are poorly known but occur mainly in deep offshore pelagic waters and along the outer continental shelf and slope, or inshore in deep water (Ross 2006, Lipsky 2009). They are highly gregarious and can form large and active groups containing up to a thousand dolphins and are often associated with other delphinid species (Jefferson *et al.* 2008).

Southern right whale dolphins feed on a variety of myctophids and other mesopelagic fish, squid and some crustaceans, with euphausiids considered a potential food source (Ross 2006, Jefferson *et al.* 2008). They are considered to be capable of diving to depths exceeding 200 m for feeding (Jefferson *et al.* 2008). Almost nothing is known about the reproductive biology of these dolphins or their subpopulation structure or status (Hammond *et al.* 2008c, Jefferson *et al.* 2008). Age at first reproduction is possibly about 12 years, and generation length is estimated to be 18.3 years (Taylor *et al.* 2007).

Risks and threatening processes

Where southern right whale dolphins occur in the SPF area there is a risk of incidental capture in fisheries gear (Elgin Associates unpublished (a)). Southern right whale dolphins have been hunted off Peru and Chile, and incidentally captured in overseas fisheries including as bycatch in gillnet fisheries (Jefferson *et al.* 2008, Lipsky 2009). Potential threats include fisheries impacts on prey species, pollution, and climate and oceanographic change (Bannister *et al.* 1996, Woinarski *et al.* 2014).

Conservation and listing status

The southern right whale dolphin is listed as a cetacean species under the EPBC Act, but the species is not listed by states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, this species was assessed as Data Deficient for the IUCN Red List in 2008 (Hammond *et al.* 2008c), and is listed in Appendix II of CITES.

Striped dolphin *Stenella coeruleoalba* (Level 2 PSA Residual Risk – High)

Distribution and range

The striped dolphin is widely distributed from tropical to warm temperate regions ranging from about 50°N to 40°S (Rice 1998, Jefferson *et al.* 2008). This species has been recorded from WA south to Augusta, and from southern Queensland and NSW (Bannister *et al.* 1996, Ross 2006). Its Australian range overlaps partly with the SPF area.

Population size and trends

There are no estimates of the Australian population size or trends for this species (Woinarski *et al.* 2014). Globally, this species is abundant with estimates of more than a million individuals in the eastern tropical Pacific region, more than 570,000 in the northwest Pacific, and more than 200,000 in the Mediterranean Sea (Jefferson *et al.* 2008, Hammond *et al.* 2008d). The global population trend is unknown (Hammond *et al.* 2008d).

Biology and feeding ecology

Striped dolphins grow to about 2.6 m long and can weigh up to 156 kg (Jefferson *et al.* 2008, Archer 2009). These dolphins occur mainly in deeper water habitats from the continental slope out to oceanic areas particularly in high productivity upwelling areas, and occur nearer the shore where deep water occurs closer to the coast (Jefferson *et al.* 2008, Archer 2009). They occur in mostly medium-to-large-sized groups of about 30–500 dolphins, but some very large groups of a few thousand animals have been recorded (Jefferson *et al.* 2008).

These dolphins feed on a wide variety of small, mid-water, benthopelagic or pelagic fish species including myctophids, cod and anchovy but they also consume squid (Jefferson *et al.* 2008, Archer 2009). They are considered likely to dive to depths of 200 to 700 m for pelagic or benthopelagic feeding, and may forage on some diurnally migrating prey at night (Ross 2006, Archer 2009). Females are sexually mature between 5–13 years and males from 7–15 years, interbirth interval is two to four years, and gestation is 12–13 months (Ross 2008, Archer 2009). Striped dolphins are thought to have a polygynous mating system (a male mates with more than one female) (Jefferson *et al.* 2008). Maximum age is recorded as 58 years (Ross 2006) and generation length is estimated to be 22.5 years (Taylor *et al.* 2007).

Risks and threatening processes

Where striped dolphins occur in the SPF area there is a risk of incidental capture in fisheries gear. One striped dolphin was recorded as incidental bycatch in the Taiwanese drift gillnet fishery in northern Australian waters during 1974–1986 (Harwood and Hembree 1987), and these dolphins may be incidentally captured in nets off WA (Ross 2006). Striped dolphins have also been incidentally captured in a wide range of fisheries gear including trawl nets throughout their range overseas, particularly in purse seine and driftnet fisheries (Fertl and Leatherwood 1997, Jefferson *et al.* 2008, Zollett 2009, Archer 2009). These dolphins are also taken in harpoon and drive fisheries in Japanese waters resulting in serious depletion of these populations (Jefferson *et al.* 2008). Directed catches of striped dolphins for food or protection of fishing gear occur in some other regions overseas (Archer 2009). Other threats include pollution resulting in high levels of contaminants in tissues, anthropogenic noise and acoustic disturbance (Bannister *et al.* 1996, Archer 2009, Woinarski *et al.* 2014). These dolphins often ride bow waves of vessels which increases the risk of vessel strike (Ross 2006), except in the eastern tropical Pacific region where they tend to rapidly move away from vessels (Jefferson *et al.* 2008).

Conservation and listing status

The striped dolphin is listed as a cetacean species under the EPBC Act, but is not listed by states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the striped dolphin was assessed as Least Concern for the IUCN Red List in 2008 (Hammond *et al.* 2008d), and is listed in Appendix II of CITES.

Indo-Pacific bottlenose dolphin *Tursiops aduncus* (Level 2 PSA Residual Risk – High)

Distribution and range

Indo-Pacific bottlenose dolphins have a wide but discontinuous distribution from tropical to warm temperate coastal regions ranging from southern Africa to the Red Sea and eastwards to China and southern Japan, through south-east Asia and southward to New Guinea, Australia and New Caledonia (Ross 2006, Jefferson *et al.* 2008, Wang and Yang 2009). In Australian waters, this species has an extensive coastal distribution from eastern, northern and western Australian regions and some parts of southern Australia. Therefore, the southern Australian range of this species overlaps partly with the SPF area.

However, the full Australian range of this species is uncertain due to difficulties in identifying which species of bottlenose dolphin is present in some regions (Ross 2006, Woinarski *et al.* 2014). Smaller inshore coastal forms of bottlenose dolphins are usually regarded or identified as *T. aduncus*, whereas the larger and primarily offshore forms are referred to as *T. truncatus*, the common bottlenose dolphin (e.g. Hale *et al.* 2000, Kemper 2004, Ross 2006). Ross (2006) considered that *T. aduncus* occurs around the whole Australian mainland coast primarily in inshore waters and bays, and in parts of the northern coast of Tasmania. However, *T. truncatus* occurs sympatrically or possibly replaces *T. aduncus* in some southern Australian areas, and the taxonomic status of bottlenose dolphins in parts of Tasmania and the southern and western Australian coast remains uncertain (e.g. Hale *et al.* 2000, Kemper 2004, Ross 2006, Krützen and Allen 2008, Woinarski *et al.* 2014).

Population size and trends

Abundance estimates are available for some subpopulations of this species in Australian locations but there are no robust estimates of total population size or trends in Australian waters or globally (reviewed in Ross 2006, Hammond *et al.* 2008e, Wang and Yang 2009, Woinarski *et al.* 2014). In coastal regions within or adjacent to the SPF area, abundance estimates of subpopulations range from dozens to hundreds of dolphins (reviewed in Woinarski *et al.* 2014). For example, Indo-Pacific bottlenose dolphin abundance offshore from North Stradbroke Island in southern Queensland was estimated to be 861 (± standard error (SE) 137) in 1997 and 895 (± SE 74) in 1998 (Chilvers and Corkeron 2003).

In NSW waters, repeated surveys between 2003 and 2005 in the Byron Bay and Ballina region provided an abundance estimate of 865 (confidence interval (CI) 95 per cent 861–869) dolphins (Hawkins 2007), with average group sizes of 21 for female-calf groups and smaller adult-only groups (Hawkins and Gartside 2008). Repeated surveys from 2003 to 2006 provided abundance estimates of 34 (95 per cent CI 19–49) dolphins in the Richmond River estuary near Ballina, and 71 (95 per cent CI 62–81) dolphins in the larger Clarence River estuary further south (Fury and Harrison 2008). In Port Stephens in central NSW, minimum abundance of these dolphins was estimated to be 160 (95 per cent CI = 148–182) in 1998–99 and 143 (95 per cent CI = 132–165) in 1999–2000, with about 90 resident individuals that are genetically differentiated from adjacent coastal communities (Möller *et al.* 2002, 2007, Wiszniewski *et al.* 2010). Abundance estimates in Jervis Bay in southern NSW varied from 108 (95 per cent CI = 98–128) dolphins in 1997–98, to 61 (95 per cent CI = 58–72) dolphins in 1998–99 (Möller *et al.* 2002).

In the Port Adelaide River–Barker Inlet estuary near Adelaide in SA, 75 Indo-Pacific bottlenose dolphins were identified during surveys in 2006 and 2009–10, and about 30 dolphins are thought to be resident in this area, with some additional transient dolphins irregularly visiting the estuary (Cribb *et al.* 2013). In southern Western Australian waters, population estimates from the Bunbury region varied from 65 (95 per cent CI = 54–90) dolphins in winter 2007, to 139 (95 per cent CI: 134–148) dolphins in autumn 2009 (Smith 2012). A small resident community of about 17–18 Indo-Pacific bottlenose dolphins has been recorded from the Swan Canning Estuary adjacent to Perth (Chabanne *et al.* 2012).

Biology and feeding ecology

Indo-Pacific bottlenose dolphins grow to about 2.7 m long and can weigh up to 230 kg (Jefferson *et al.* 2008, Wang and Yang 2009). These dolphins occur mainly in shallow nearshore and inshore coastal waters less than 100 m deep, in some estuaries and bays, with some groups occurring further offshore across continental shelf habitats, while some deeper water offshore movements have also been recorded (Hale *et al.* 2000, Möller *et al.* 2002, Ross 2006, Krützen and Allen 2008, Fury and Harrison 2008, Wang and Yang 2009, Allen *et al.* 2012).

Indo-Pacific bottlenose dolphins are highly social and live in complex and dynamic fission-fusion societies where associations and group sizes vary over short-term, seasonal and longer-term timescales depending upon the numbers of resident dolphins and visitors or transient dolphins present (Connor *et al.* 2000, Möller *et al.* 2002). Smaller coastal bays and estuaries tend to have fewer resident dolphins (Möller *et al.* 2002, Fury and Harrison 2008, Cribb *et al.* 2013), whereas larger communities occur in large bays such as Moreton Bay in Queensland and Shark Bay in WA, and along some open coastal habitats (Preen *et al.* 1997, Hawkins and Gartside 2008, Ansmann *et al.* 2013). Association patterns vary among individuals and between sexes resulting in social and sexual segregation. Pairs or trios of males form long-term alliances for herding females and mating, while females form coalitions within larger social networks, and females with calves prefer shallow protected habitats (Mann *et al.* 2000, Connor *et al.* 2000, Möller *et al.* 2006, Fury *et al.* 2013).

Available global information indicates that Indo-Pacific bottlenose dolphins tend to form relatively small and localised subpopulations that are relatively isolated from each other (Wang and Yang 2009). Separate communities or genetically differentiated subpopulations with a pattern of isolation by distance are evident in some Australian coastal regions (e.g. Krützen *et al.* 2004, Möller *et al.* 2007, Bilgmann *et al.* 2007, Wiszniewski *et al.* 2010, Ansmann *et al.* 2013). Along the NSW coast, genetic analyses have demonstrated considerable genetic differentiation between most of the resident dolphin communities, with at least three genetically distinct subpopulations evident in northern NSW, Port Stephens and in southern NSW (Möller *et al.* 2007; Wiszniewski *et al.* 2010). Females in Port Stephens and Jervis Bay in NSW are relatively philopatric (remain at or return to their place of birth), whereas males exhibit greater levels of dispersal (Möller and Beheregaray 2004).

Indo-Pacific bottlenose dolphins are opportunistic feeders that prey on a wide variety of schooling, demersal, benthic and reef fish species, but there is considerable geographic variability in their diet and in some areas they also consume rays, small sharks, cephalopods and crustaceans (Ross 2006, Krützen and Allen 2008, Jefferson *et al.* 2008, Wang and Yang 2009). Prey are usually less than 30 cm long and include species from many families including Mugilidae, Belonidae, Sciaenidae, Engraulidae, Sepioteuthidae, Sepiidae, Sepiolidae, Loliginidae and Octopodidae (Wang and Yang 2009). Highly specialised foraging strategies are used by some dolphin groups to target specific prey types and these behaviours appear to be socially transmitted (Connor *et al.* 2000, Krützen *et al.* 2005, Wang and Yang 2009). Indo-Pacific bottlenose dolphins are considered to be behaviourally plastic and able to adapt to feeding in association with various fisheries. These dolphins have been observed feeding on discarded bycatch behind prawn trawlers in Moreton Bay, and large males appear to occupy optimal positions for feeding on discards behind these trawlers (Corkeron *et al.* 1990, Chilvers and Corkeron 2001).

Sexual maturity occurs from about nine to 9–15 years, gestation is about 12 months, and the average interbirth interval is about three to six years (Mann *et al.* 2000, Ross 2006, Wang and Yang 2009). Maximum age of males is about 35–40 years, whereas females live for more than 40 years and possibly more than 50 years (Ross 2006, Krützen and Allen 2008). Generation length is estimated to be 21.1 years (Taylor *et al.* 2007). These life history characteristics result in a relatively low reproductive rate and combined with high levels of philopatry and relatively small subpopulation sizes, Indo-Pacific bottlenose dolphins are likely to have a slow capacity for recovery from depletion (Woinarski *et al.* 2014).

Risks and threatening processes

Mortality from fisheries interactions and bycatch is considered to be the most serious anthropogenic threat to Indo-Pacific bottlenose dolphins (Wang and Yang 2009). An estimated 8400 Indo-Pacific bottlenose dolphins were killed from incidental bycatch in the Taiwanese drift gillnet fishery in northern Australian waters during 1974–1986 (Harwood and Hembree 1987, Ross 2006), and these dolphins are killed in shark nets and anti-predator nets around tuna feedlots in Australia and overseas (Kemper and Gibbs 2001, Kemper *et al.* 2005, Ross 2006, Jefferson *et al.* 2008). Indo-Pacific bottlenose dolphins are known to commonly interact with trawl fisheries (Elgin Associates unpublished (a)), and have been recorded feeding behind trawlers in Moreton Bay and taking food through the net mesh (Corkeron *et al.* 1990, Chilvers and Corkeron 2001). Bycatch occurs infrequently in these trawl nets, and the dolphins killed are mostly juveniles (Corkeron *et al.* 1990). One dolphin genetically identified as *T. aduncus* was sampled in association with dolphins interacting with the Pilbara Fish Trawl Fishery off northwestern Australia (Allen and Loneragan 2010).

Other threats to these dolphins (reviewed in Bannister *et al.* 1996, Ross 2006, Woinarski *et al.* 2014) include coastal development, port expansion, aquaculture and habitat loss (Watson-Capps and Mann 2005), bioaccumulation of elevated levels of persistent toxic pollutants (Evans 2003), chronic disturbance from dolphin-watching vessels and increased coastal vessel movements (Bejder *et al.* 2006, Steckenreuter *et al.* 2011), increasing anthropogenic noise and acoustic disturbance (McCauley and Cato 2003), vessel strike and intentional killing (Kemper *et al.* 2005). Potential threats include prey depletion from expanding commercial fisheries and increased recreational take of prey species (Bannister *et al.* 1996, Ross 2006), increased climate variability and altered environmental conditions including increased flood events (Fury and Harrison 2011, Woinarski *et al.* 2014).

Conservation and listing status

The Indo-Pacific bottlenose dolphin is listed as a cetacean species under the EPBC Act, and the 'Arafura/Timor Sea population' of the spotted bottlenose dolphin is listed as migratory under Appendix II of Convention on Migratory Species of Wild Animals. The species is listed as Least Concern in the Northern Territory, but is not listed in other states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the Indo-Pacific bottlenose dolphin was assessed as Data Deficient for the IUCN Red List in 2008 (Hammond *et al.* 2008e), and is listed in Appendix II of CITES.

Common bottlenose dolphin *Tursiops truncatus* (Level 2 PSA Residual Risk – High)

Distribution and range

Common bottlenose dolphins have a cosmopolitan distribution extending from tropical to temperate coastal, shelf and offshore waters between about 55°S and 65°N (Rice 1998, Hale *et al.* 2000, Ross 2006, Jefferson *et al.* 2008, Wells and Scott 2009). These dolphins are recorded from the Pacific, Indian and Atlantic Ocean regions and also occur in most enclosed or semi-enclosed seas, with an apparently higher population density in coastal or continental shelf habitats compared with oceanic regions further offshore (Ross 2006, Jefferson *et al.* 2008). Common bottlenose dolphins are broadly distributed around much of the Australian coastal shelf area in deeper waters out to the outer continental shelf, and in some offshore habitats mostly within 1000 km of the continental coast (Ross 2006, Hale 2008) including subtropical Lord Howe Island (Hutton and Harrison 2004). Therefore, their Australian range overlaps extensively with the SPF area.

The full extent of their distribution in Australian waters is not known, and part of this uncertainty arises from difficulties in identifying which species of bottlenose dolphin is present in some regions, particularly where they are sympatric with Indo-Pacific bottlenose dolphins in some inshore environments (Ross 2006, Woinarski *et al.* 2014). Common bottlenose dolphins generally occur in deeper waters further from the coast compared with Indo-Pacific Bottlenose dolphins, but these species co-occur in parts of their range, and the taxonomic status of coastal *Tursiops* bottlenose dolphins in some parts of the southern Australian coast and from Tasmanian waters is uncertain (Hale *et al.* 2000, Kemper 2004, Ross 2006, Möller *et al.* 2008, Charlton-Robb *et al.* 2011, Woinarski *et al.* 2014).

Species identification issues are further complicated by the recent description of a putative new southern Australian *Tursiops* species, the Burrunan dolphin *Tursiops australis*, that is recorded from some coastal waters of Victoria (including Port Phillip Bay and Gippsland Lakes), eastern Tasmania and SA west to St Francis Island (Charlton-Robb *et al.* 2011). The Society for Marine Mammalogy (Committee on Taxonomy 2014) has not included *T. australis* in the global list of recognised marine mammal species and subspecies, and considered the validity of this putative species to be uncertain. Some ongoing genetic and morphological research indicates that Burrunan dolphin specimens fall within the range of Common bottlenose dolphin *T. truncatus* specimens (M. Jedensjö *et al.*, pers. comm. in Woinarski *et al.* 2014). Therefore, the Burrunan dolphin was not evaluated in the recent assessment of the conservation status of marine mammals in Australia by Woinarski *et al.* (2014), and is not separately evaluated in this report. However, of relevance to the assessment of dolphins and matters of national environmental significance for the DCFA, if the Burrunan dolphin is considered a distinct species, Charlton-Robb *et al.* (2011) noted that it 'would qualify for listing as a threatened species' given its small range and area of occupancy, with only two known small resident populations that occur close to disturbed coastal urban and agricultural areas.

Population size and trends

There are no robust estimates of total population size or trends in Australian waters (Hale 2008, Woinarski *et al.* 2014). Hammond *et al.* (2008f) suggested a minimum global abundance estimate of 600,000 common bottlenose dolphins based on a summation of estimates from parts of their range. The global population trend is unknown but some populations are declining, and one subspecies and two subpopulations are assessed as threatened (Hammond *et al.* 2008f). Groups of up to 100 dolphins have been recorded in deeper waters off the coast of NSW and Queensland (Hale 2008), and 151 individuals were photographically identified foraging in association with a trawler off northwestern Australia in 2011 (S. Allen pers. comm. in Woinarski *et al.* 2014). Two small resident communities of bottlenose dolphins identified as Burrunan dolphins *T. australis* occur in Port Phillip Bay (about 80–100 dolphins) and in the Gippsland Lakes, Victoria (Charlton-Robb *et al.* 2011, Howes *et al.* 2012), which may also be relevant to assessment of *T. truncatus*.

Biology and feeding ecology

Common bottlenose dolphins grow to about 1.9–3.8 m long and can weigh up to 650 kg, but most are considerably smaller and there is considerable geographical variation in size (Jefferson *et al.* 2008, Wells and Scott 2009). Although these dolphins have been extensively studied in some other regions overseas and are considered to be one of the best known cetacean species (reviewed in Leatherwood and Reeves 1990, Wells and Scott 2009), relatively little information is available from the Australian region. Around Australia, common bottlenose dolphins mostly occur further offshore and in deeper water greater than 30–100 m habitats across the continental shelf and near the shelf edge compared with inshore Indo-Pacific bottlenose dolphins. Although, as noted above, the ranges of these species overlap in some coastal and inshore areas (Hale *et al.* 2000, Ross 2006, Hale 2008).

These dolphins are highly social and live in dynamic fission-fusion societies where group size and composition change over time (reviewed in Connor *et al.* 2000, Wells and Scott 2009, Möller 2012). Group size tends to be smaller in inshore bays and estuaries while larger groups occur in offshore waters, and group size ranges from about 2–15 dolphins up to aggregations of several hundred to more than 1000 dolphins (Hale 2008, Wells and Scott 2009). Community and subpopulation sizes vary over time corresponding to changes in the numbers of resident dolphins, occasional visitors and transient dolphins present. Strong social bonds exist between mothers and calves and between some related females, some dolphins form nursery groups or mixed sex groups of juveniles, some males remain solitary while others form long-term bonds with other males (Connor *et al.* 2000, Wells and Scott 2009, Möller 2012). Some coastal dolphin communities exhibit long-term residency within their home ranges over many decades, while dolphins in other regions undertake seasonal migrations or larger-scale movements over hundreds or thousands of kilometres (Connor *et al.* 2000, Jefferson *et al.* 2008, Wells and Scott 2009).

Common bottlenose dolphins are generalist feeders that forage in a range of habitats and prey on a wide variety of benthic and pelagic fish (often Sciaenidae, Scombridae and Mugilidae) and squid, and sometimes eat crustaceans (Hale 2008, Jefferson *et al.* 2008, Wells and Scott 2009). However, diets vary among individuals within and between populations and regionally (Wells and Scott 2009). Lactating females with calves tend to feed closer to shore, adolescents feed further away from the coast, and non-breeding females and males feed further offshore (Wells and Scott 2009). Coastal subpopulations forage in shallower areas including rocky reefs and seagrass habitats, whereas offshore subpopulations forage in deeper habitats ranging from about 50–200 m and up to 500 m depths (Hale 2008, Wells and Scott 2009, Gibbs *et al.* 2011, Dunshea *et al.* 2013). Analysis of the diets and feeding ecology of coastal common bottlenose dolphins and inshore *Tursiops* sp. bottlenose dolphins with overlapping ranges in South Australian waters revealed strong evidence of niche partitioning; common bottlenose dolphins feed at a higher trophic level than the inshore bottlenose dolphins (Gibbs *et al.* 2011). The diet of common bottlenose dolphins from the GAB region includes small percentages of Australian sardine, jack mackerel and blue mackerel (Table 4.2 in Section 4.2). Stomach contents of a common bottlenose dolphin that drowned in a fish net in Tasmania included cephalopod beaks and remains of fish including jack mackerel (Gales *et al.* 1992). Some groups of common bottlenose dolphins actively seek or become associated with fishing vessels and regularly forage on discarded catch or remove fish from the nets (Broadhurst 1998, Svane 2005, Allen and Loneragan 2010, Jaiteh *et al.* 2013, Allen *et al.* 2014).

Females become sexually mature at five to 13 years and males at nine to 14 years. Gestation is about 12 months, and the average interbirth interval is about three to six years (Connor *et al.* 2000, Wells and Scott 2009, Möller 2012). Maximum age of males is up to 48 years, while females remain reproductive until about 48 years and can live up to 57 years (Wells and Scott 2009). Generation length is estimated to be 21.1 years (Taylor *et al.* 2007). These life history characteristics result in a relatively low reproductive rate hence common bottlenose dolphin populations are likely to have a slow capacity for recovery from depletion (Woinarski *et al.* 2014).

Risks and threatening processes

Hale (2008) considered that successful conservation of common bottlenose dolphins in Australian waters and elsewhere will depend primarily on the success of minimising incidental bycatch in fishing gear. These dolphins are known to interact with various fisheries throughout their range and incidental bycatch has been recorded in gillnets, trawl nets, purse seine nets, shark nets and from hook and line gear (Paterson 1990, Fertl and Leatherwood 1997, Jefferson *et al.* 2008, Zollett 2009, Reeves *et al.* 2013). In Australian waters, mortality of common bottlenose dolphins has been recorded from bycatch in mid-water trawls from Zone A (pre-2009) of the SPF (Lyle and Willcox 2008, Tuck *et al.* 2013). Three *T. truncatus* dolphins and 14 other dolphins that may have been *T. truncatus* or common dolphins *Delphinus delphis* were recorded as bycatch mortality in 2004 (Lyle and Willcox 2008, Tuck *et al.* 2013). A further eight dolphins that were not identified to species level were recorded as bycatch mortality in Zone A, east Tasmania in 2005 (Lyle and Willcox 2008, Tuck *et al.* 2013).

An estimated 150–350 common bottlenose dolphins were caught in the Pilbara Fish Trawl Interim Managed Fishery (PFTIMF) between 2003–2009 (Allen and Loneragan 2010, Jaiteh *et al.* 2013). Observer-reported bycatch rates were about double the rates reported by trawler skippers (Allen *et al.* 2014). The rate of dolphin bycatch was reduced by about 45 per cent after BRDs were introduced; bycatch rates have not declined further since the introduction of BRDs in 2006 (Allen *et al.* 2014). Allen *et al.* (2014) concluded that modified BRDs to include a top-opening escape hatch might be more effective in reducing dolphin bycatch. Common bottlenose dolphins are known to forage on discarded catch or remove fish from the trawl net codend or sometimes from within trawl nets, which greatly increases the risk of incidental bycatch (Broadhurst 1998, Svane 2005, Allen and Loneragan 2010, Jaiteh *et al.* 2013). Subsurface behaviour of common bottlenose dolphins interacting with trawl nets in the PFTIMF showed very high rates of interaction during most trawls, with dolphins occurring inside nets in 29 of 36 tows recorded (Jaiteh *et al.* 2013). A total of 29 individual dolphins were identified within the nets, with seven of these repeatedly returning to feed within and between tows and during different fishing trips (Jaiteh *et al.* 2013). These results indicate that feeding within trawl nets occurs frequently and may be a specialised form of behaviour used by a subset of dolphins that associate with trawlers (Jaiteh *et al.* 2013).

Broadhurst (1998) noted that common bottlenose dolphins regularly associate with fish and prawn trawlers off the NSW coast and remove bycatch from codends during retrieval of trawl nets, and scavenge discarded catch during sorting. Furthermore, underwater video records showed common bottlenose dolphins manipulating prawn-trawl codends during trawling off northern NSW to remove and eat juvenile whiting *Sillago* spp. and other catch (Broadhurst 1998). The feeding patterns observed indicated that this was a well-established feeding behaviour by these dolphins (Broadhurst 1998).

A range of other threats are known to affect these dolphins (reviewed in Bannister *et al.* 1996, Ross 2006, Woinarski *et al.* 2014) including bioaccumulation of elevated levels of persistent toxic pollutants (Vetter *et al.* 2001, Evans 2003, Wells *et al.* 2005), cetacean morbillivirus infection (Stone *et al.* 2011), habitat degradation caused by coastal development, port expansion, aquaculture and associated increased vessel activity, increasing anthropogenic noise and acoustic disturbance (McCauley and Cato 2003), chronic disturbance from dolphin-watching vessels (Constantine *et al.* 2004, Lusseau *et al.* 2006, Howes *et al.* 2012), and vessel strike (Wells and Scott 2009). Potential threats include prey depletion from expanding commercial fisheries and increased recreational take of prey species (Bannister *et al.* 1996, Ross 2006), and increased climate variability and altered environmental conditions (Woinarski *et al.* 2014).

Conservation and listing status

The common bottlenose dolphin is listed as a cetacean species under the EPBC Act, and is listed as Least Concern in the Northern Territory, but is not listed in other states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in an earlier Australian status assessment by Bannister *et al.* (1996). Ross (2006) recommended that this species be classified as No category assigned but possibly secure. Globally, the Indo-Pacific bottlenose dolphin was assessed as Least Concern for the IUCN Red List in 2008 (Hammond *et al.* 2008f), and is listed in Appendix II of CITES.

Common dolphin *Delphinus delphis* (Level 2 PSA Residual Risk – Medium)

Distribution and range

The short-beaked common dolphin is widely distributed in continental shelf and pelagic waters from tropical to cool temperate regions in the Pacific and North Atlantic Oceans, and is possibly absent from most of the South Atlantic and Indian Oceans (Rice 1998, Jefferson *et al.* 2008, Perrin 2009a, Amaral *et al.* 2012). This species has been recorded from all Australian states and Northern Territory waters, including subtropical Lord Howe Island off NSW and southwestern Australia, with few records from northwestern Australia (Bannister *et al.* 1996, Chatto and Warneke 2000, Bell *et al.* 2002, Hutton and Harrison 2004, Kemper *et al.* 2005, Kemper 2008). There appear to be two main locations in Australian waters with one cluster occurring in the southern southeastern Indian Ocean and another in the Tasman Sea (Woinarski *et al.* 2014). Its Australian range overlaps extensively with the SPF area.

Population size and trends

Short-beaked common dolphins may be the most numerous dolphins in Australian waters and are often reported in coastal waters of southern Australia (Kemper 2008), but there are no robust estimates of the Australian population size or trends (Woinarski *et al.* 2014). The estimated size of the subpopulation of these dolphins in preferred habitat areas of the Gulf St Vincent in SA was about 2000 individuals (Filby *et al.* 2010). Substantial genetic differentiation has been recorded between short-beaked common dolphin subpopulations in SA and those in eastern Australia including Tasmania, with finer levels of subpopulation substructuring along the southeastern and southern Australian coasts possibly associated with spatial variation in oceanographic currents, upwellings or fish distributions (Bilgmann *et al.* 2008, 2014, Möller *et al.* 2011, Amaral *et al.* 2012). At least six different management units of these common dolphins have been identified and this population substructuring is of considerable significance for managing these populations, particularly in relation to managing mortality from fisheries bycatch in the purse seine fishery for sardines off SA and the gillnet fishery for gummy sharks off southern Australia (Bilgmann *et al.* 2008, 2014, Hamer *et al.* 2008).

Globally, this species is considered to be very abundant (Jefferson *et al.* 2008), but there is no robust estimate of global population size and population trends are unknown (Hammond *et al.* 2008g). Overseas, regional population estimates include about 3,000,000 in the eastern tropical Pacific region, and about 370,000 from the western United States coast (Jefferson *et al.* 2008).

Biology and feeding ecology

Short-beaked common dolphins can grow up to about 2.2–2.7 m long and can weigh up to 200 kg, but adult size and colouration varies geographically (Jefferson *et al.* 2008). These dolphins occur in open ocean habitats and over the continental shelf and in some regions they prefer areas of steeply sloping underwater topography and high productivity upwelling areas (Ross 2006, Jefferson *et al.* 2008, Perrin 2009a). They have been sighted from nearshore areas to thousands of kilometres offshore in open pelagic habitats (Jefferson *et al.* 2008). These dolphins are gregarious and form core groups of about 20–30 individuals but can form large aggregations of many thousands of dolphins, with aggregations of up to 100,000 dolphins observed from Australian waters (Bannister *et al.* 1996, Kemper 2008). Schools may be segregated by sex and age, and in the eastern tropical Pacific they can be associated with yellowfin tuna resulting in bycatch in the purse seine fishery (Jefferson *et al.* 2008). In some regions these dolphins appear to undergo seasonal movements and inter-annual migrations in response to changing oceanographic conditions and occurrence of prey (Perrin 2009a).

Short-beaked common dolphins feed primarily on small schooling fishes and squid, including small epipelagic schooling species from families Scombridae and Clupeidae (Perrin 2009a). In South Australian waters these dolphins feed mainly on southern calamari and fish from the Clupeidae and Carangidae families (Kemper 2008). The diet of short-beaked common dolphins from the GAB region includes a high proportion of Australian anchovy and Australian sardine, with smaller amounts of jack mackerel and blue mackerel (Table 4.2 in Section 4.2). In some regions these dolphins feed on mesopelagic species associated with the deep scattering layer that migrates into shallower waters at night (Jefferson *et al.* 2008, Perrin 2009a). These dolphins have been recorded on foraging dives to 200 m, and may dive to at least 280 m depth (Kemper 2008, Perrin 2009a).

Females mature at about six to eight years and males about 7–12 years, gestation is about 10–11.7 months, and the interbirth interval varies regionally from one to three years (Perrin 2009a). Maximum age estimates range from about 22–30 years (Kemper 2008, Perrin 2009a). Generation length is estimated to be 14.8 years (Taylor *et al.* 2007). These life history characteristics indicate that this species has a relatively low lifetime reproductive capacity, therefore populations are susceptible to adverse impacts from relatively low levels of fisheries bycatch mortality (Hamer *et al.* 2008).

Risks and threatening processes

Short-beaked common dolphins are known to commonly interact with trawl fisheries, and bycatch mortality in pelagic trawl, purse seine, gillnets and other fisheries gear has been reported throughout their global range (Fertl and Leatherwood 1997, Jefferson *et al.* 2008, Zollett 2009, Perrin 2009a). In Australian waters, bycatch mortality of short-beaked common dolphins is frequently recorded in fisheries nets, shark nets and in anti-predator nets around tuna feedlots (Paterson 1990, Kemper and Gibbs 2001, Shaughnessy *et al.* 2003, Hamer *et al.* 2008, Bilgmann *et al.* 2014). A total of 14 dolphins that may have been short-beaked common dolphins or *T. truncatus* common bottlenose dolphins were recorded as bycatch mortality in mid-water trawls from Zone A (pre-2009) of the SPF in 2004 (Lyle and Willcox 2008, Tuck *et al.* 2013). In 2005, a further eight dolphins that were not identified to species level were recorded as bycatch mortality in Zone A from east Tasmania (Lyle and Willcox 2008, Tuck *et al.* 2013). An estimated 337 short-beaked common dolphins were killed in the South Australian Sardine Fishery (SASF) between November 2004 and June 2005, with subsequent mitigation measures leading to a substantial reduction in bycatch mortality (Hamer *et al.* 2008). During 2011, a total of 33 short-beaked common dolphins were killed in fisheries netting interactions in Australian waters (Cusick *et al.* 2012). Some of these dolphins have been reported killed for bait or as perceived competition with fishers in Australian waters (Bannister *et al.* 1996, Kemper *et al.* 2005, Ross 2006).

Short-beaked common dolphins have also been recorded interacting with mid-water and other trawls in many regions of the world, with New Zealand trawl interactions include herding fish into nets, taking fish in the net mouth, and as bycatch in mid-water trawls (Thompson *et al.* 2013, Elgin Associates unpublished (a)). Other overseas fisheries interactions include large direct catches in the Black Sea until 1983 that resulted in significant declines, and large numbers killed in bycatch in the eastern tropical Pacific tuna fishery (Jefferson *et al.* 2008, Perrin 2009a). A precipitous decline in abundance of short-beaked common dolphins was recorded in coastal waters of the eastern Ionian Sea from 1996 to 2007 (Bearzi *et al.* 2008). A 12-month assessment of fishing effort and catch, together with circumstantial evidence, suggested that the decline in dolphin abundance was caused largely by prey depletion resulting from overfishing, which was mainly due to purse seining (Bearzi *et al.* 2008). Other threats include high levels of contaminants in tissues in some samples from Australian waters and in many regions overseas (Vetter *et al.* 2001, Lavery *et al.* 2008), detrimental impacts from seismic activities and other acoustic disturbance, and pathogens implicated in mortality events and strandings (Bannister *et al.* 1996, Kemper *et al.* 2005, Woinarski *et al.* 2014). Some vessel strike mortality has been reported for this species in Australian waters (Cusick *et al.* 2012).

Conservation and listing status

The short-beaked common dolphin is listed as a cetacean species under the EPBC Act, Data Deficient in the Northern Territory, but is not listed in other states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014), and was assessed as 'No category assigned but possibly secure' in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the short-beaked common dolphin was assessed as Least Concern for the IUCN Red List in 2008 (Hammond *et al.* 2008g), and is listed in Appendix II of CITES.

Pantropical spotted dolphin *Stenella attenuata* (Level 2 PSA Residual Risk – Medium)

Distribution and range

The pantropical spotted dolphin is widely distributed from tropical to temperate regions in all oceans and some seas, ranging from about latitude 40°N to 40°S, but is much more abundant in warmer tropical waters within this range (Rice 1998, Jefferson *et al.* 2008, Perrin 2009b). This species has been recorded from NSW, Queensland, Northern Territory, and WA waters extending south to Augusta (Ross 2006, Porter 2008). A record from Victorian waters is considered to be erroneous (Ross 2006). Its southern Australian range overlaps partly with the SPF area.

Population size and trends

Pantropical spotted dolphins may be the most abundant or second most abundant cetacean species globally, with about 2.5–3 million individuals (Porter 2008a, Perrin 2009b). They are considered to be potentially abundant within their Australian range, but there are no robust estimates of the Australian population size or trends (Woinarski *et al.* 2014). An estimated 640,000 northeastern offshore pantropical spotted dolphins were present in the eastern tropical Pacific (ETP) region in 1979–2000, representing a decline of about 80 per cent from their original abundance due to unsustainable bycatch in the purse seine tuna fishery in this region since the early 1960s (Gerrodette and Forcada 2005, Perrin 2009b). Despite significant fishery management to reduce bycatch to relatively low levels of a few 100 of these dolphins annually in more recent decades, this population has not exhibited signs of recovery (Gerrodette and Forcada 2005, Perrin 2009b). Other overseas regional population estimates include about 228,000 coastal pantropical spotted dolphins in the ETP, about 438,000 in Japanese waters in the 1990s, and about 15,000 in the eastern Sulu Sea (Jefferson *et al.* 2008, Perrin 2009b).

Biology and feeding ecology

Pantropical spotted dolphins adults grow to 1.6–2.6 m long and can weigh up to 119 kg but exhibit wide geographic variation, with different coastal and offshore forms recognised (Jefferson *et al.* 2008, Perrin 2009b). These dolphins occur mainly in deeper water outer shelf and continental slope habitats and open oceanic habitats, but are recorded closer to shore where deep water occurs nearer the coast, and in some shallower shelf habitats (Ross 2006, Jefferson *et al.* 2008, Porter 2008a). These gregarious dolphins occur in mostly small-to-medium-sized groups of less than 100 dolphins for the coastal form, but offshore groups are usually larger and may contain thousands of dolphins (Ross 2006, Jefferson *et al.* 2008). Larger groups are composed of three types of subgroups each with about 20 individuals: females and their young, juvenile dolphins, and mature males (Porter 2008a). Individual dolphins exhibit daily movements of 20–30 km and have home ranges up to 200–300 nm, with migration of some populations onshore during winter and offshore during summer (Ross 2006, Porter 2008a).

These dolphins feed primarily on small epipelagic and mesopelagic fishes, squids and crustaceans, but also consume nemertean marine worms (Ross 2006, Porter 2008a, Perrin 2009b). Their diet varies regionally and with reproductive state, and lactating females consume a higher proportion of fish, possibly due to their higher nutritional value (Bannister *et al.* 1996, Ross 2006). Diving behaviour off Hawai'i indicates that these dolphins feed mainly at night possibly associated with diurnal vertical migrations of their prey in the deep scattering layer (Perrin 2009b). The diet of pantropical spotted dolphins in the eastern Pacific overlaps strongly with the diet of yellowfin tuna *Thunnus albacares*, leading to strong dolphin and tuna associations, used by fishers to locate and catch tuna (Perrin 2009b).

These dolphins may have a promiscuous breeding system, females mature at about 9–11 years and males at 12–15 years, gestation is about 11.5 months, and the interbirth interval is about two to three years (Perrin 2009b). The maximum age reported is 50 years (Bannister *et al.* 1996), and generation length is estimated to be 23.1 years (Taylor *et al.* 2007).

Risks and threatening processes

Where pantropical spotted dolphins occur in the SPF area there is a risk of incidental capture in fisheries gear (Elgin Associates unpublished (a)). An estimated 560 pantropical spotted dolphins were caught as bycatch in the Taiwanese gillnet fishery off northern Australia between 1974 and 1986 (Harwood and Hembree 1987). Porter (2008a) noted that the Australian population is likely to be subject to significant bycatch in the shark gillnet fishery operating adjacent to, and sometimes illegally within, the northern EEZ. Some pantropical spotted dolphins have been captured in inshore shark nets in NSW and Queensland waters (Ross 2006).

An estimated 3 million offshore pantropical spotted dolphins were killed as incidental bycatch in the purse seine tuna fishery in the ETP from 1959 to 1972, leading to increased fishery management and regulations that significantly reduced bycatch rates (Gerrodette and Forcada 2005, Jefferson *et al.* 2008, Perrin 2009b). However, the population is not showing signs of recovery, possibly as a result of stress from ongoing chase and capture in nets affecting fecundity or survival, or changes to the carrying capacity of the ecosystem that may be preventing recovery (Jefferson *et al.* 2008, Perrin 2009b). Pantropical spotted dolphins have been recorded as bycatch mortality in trawl nets in Malaysia (Elgin Associates unpublished (a)). These dolphins are also recorded as bycatch in purse seine, trawl and gillnet fisheries throughout their range (Jefferson *et al.* 2008). Other overseas fisheries interactions include direct takes in drive and harpoon fisheries in Japan, Philippines, Indonesia and Solomon Islands, and pantropical spotted dolphins have been implicated in depredation and interference with line fisheries in some regions, resulting in deliberate culling of hundreds of dolphins (Reeves *et al.* 2003, Perrin 2009b). Pollution resulting in accumulation of heavy metals in tissues is a threat to these dolphins (Bannister *et al.* 1996, Woinarski *et al.* 2014). In regions where these dolphins are not harpooned or pursued by purse seine fishers, they readily ride bow waves of vessels (Perrin 2009b), which may increase the risk of vessel strike.

Conservation and listing status

The pantropical spotted dolphin is listed as a cetacean species and as a migratory species as '*Stenella attenuata* E Tropical Pacific, SE Asian populations' under the EPBC Act, Data Deficient in the Northern Territory, but is not listed in states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the pantropical spotted dolphin was assessed as Least Concern for the IUCN Red List in 2008 (Hammond *et al.* 2008h), and is listed in Appendix II of CITES.

Spinner dolphin *Stenella longirostris* (Level 2 PSA Residual Risk – Medium)

Distribution and range

The spinner dolphin has a pantropical distribution similar to that of the pantropical spotted dolphin encompassing tropical to most subtropical regions in all oceans and some seas, ranging from about latitude 30–40°N to 20–40°S (Rice 1998, Jefferson *et al.* 2008, Perrin 2009c). This species has been recorded from NSW, Queensland, the Northern Territory and Western Australian waters extending south to Bunbury, and from Christmas Island, the Cocos (Keeling) Islands and from Scott Reef off WA (Bannister *et al.* 1996, Ross 2006, Porter 2008b, Woinarski *et al.* 2014). Its southern Australian range overlaps partly with the SPF area.

The taxonomy of spinner dolphins is unsettled. Globally, four subspecies are recognised (Committee on Taxonomy 2014). Perrin *et al.* (1999) considered that two of these subspecies are present in Australian waters: Gray's spinner dolphin *S. l. longirostris* and the dwarf spinner dolphin *S. l. roseiventris*. They considered that the Australian distribution of the smaller inshore dwarf spinner dolphin encompassed northern tropical waters from about Broome in northwestern WA to the Gulf of Carpentaria across to Cape York Peninsula in Queensland and extending through the Timor and Arafura Seas, whereas the larger Gray's spinner dolphin subspecies occurred along the east and west coasts and further offshore in the Pacific and Indian Ocean regions (Perrin *et al*. 1999, Allen *et al*. 2012). In contrast, Porter (2008b) considered that only the dwarf spinner dolphin subspecies was present in Australian waters.

Population size and trends

The global abundance of spinner dolphins is estimated to be about 1.4–1.5 million individuals making this one of the most abundant dolphins in the world (Porter 2008b, Jefferson *et al*. 2008, Perrin 2009c). There is no robust estimate of the population size or trends in Australian waters (Woinarski *et al*. 2014), but surveys in the early 2000s indicated relatively low abundance off northern Australia (Porter 2008b). Estimates of abundance of eastern spinner dolphins *S. l. orientalis* in the ETP region were about 450,000 to 600,000 in 2000 and 2003 (Gerrodette and Forcada 2005, Bearzi *et al*. 2012). This subspecies was heavily impacted by bycatch in the yellowfin tuna purse seine fishery in the ETP that reduced their abundance to less than half of its original size, and although management actions have greatly reduced dolphin bycatch by two orders of magnitude in recent decades, the eastern spinner dolphin population has exhibited very slow rates of increase and limited signs of recovery (Gerrodette and Forcada 2005, Perrin 2009c). An estimated 801,000 whitebelly spinner dolphins were present in the ETP in 2000, with some subspecies population estimates available in other regions, but there are no abundance estimates for the dwarf spinner dolphin subspecies (Perrin 2009c, Bearzi *et al*. 2012).

Biology and feeding ecology

Spinner dolphins exhibit wide geographic variation among the recognised subspecies and coastal and offshore forms, and adults grow to about 1.3–2.3 m long and weigh 23–80 kg with males slightly larger than females in all subspecies (Jefferson *et al*. 2008, Perrin 2009c). These dolphins have an oceanic range but in many tropical regions they use shallow coastal waters including sandy-bottomed bays of oceanic islands and coral atolls by day and move offshore to deeper water at night to feed (Jefferson *et al*. 2008, Perrin 2009c). Spinner dolphins in the ETP are oceanic and prefer tropical surface water habitats where they are often closely associated with pantropical dolphins, yellowfin tuna and seabirds (Porter 2008b, Perrin 2009c). The dwarf spinner dolphin from northern Australia and Southeast Asia occurs almost exclusively in shallow water habitats and feeds over shallow reefs (Porter 2008b, Jefferson *et al*. 2008). The distribution of spinner dolphins along parts of the southern coast of WA may be associated with the warm Leeuwin Current (Bannister *et al*. 1996, Ross 2006).

Spinner dolphins from Hawai'i and some other tropical island groups have a fission-fusion society with dynamic and fluid association patterns of different family groups, whereas in other regions their social structure is characterised by more stable groups and some long-term association patterns (Porter 2008b, Jefferson *et al.* 2008, Perrin 2009c). Group sizes range from a few dolphins up to several thousand, and the maximum recorded movement of individuals was 275 nm over 16 days (Perrin 2009c).

In the western and eastern Pacific regions, oceanic spinner dolphins feed at night mainly on small mesopelagic fishes including myctophids, squids and crustaceans, and can dive 300–600 m or deeper, but most feeding is done at shallower depths (Jefferson *et al.* 2008, Perrin 2009c). In contrast, dwarf spinner dolphins feed over shallow reefs on benthic and reef fishes and some invertebrates (Perrin *et al*. 1999).

Females are sexually mature at about four to seven years and males at 7–10 years, gestation is about 10 months, nursing occurs for one to two years and the interbirth interval is about three years (Perrin 2009c). The maximum age reported is 26 years, and generation length is estimated to be 13.7 years (Taylor *et al*. 2007).

Risks and threatening processes

Spinner dolphins are recorded as bycatch in different fisheries throughout their range, including in purse seines, trawls, gillnets and driftnets (Jefferson *et al*. 2008, Bearzi *et al*. 2012). An estimated 4900 spinner dolphins were caught as bycatch in the Taiwanese gillnet fishery off northern Australia between 1981 and 1985 (Harwood and Hembree 1987). Porter (2008b) noted that the northern Australian population is likely to be subject to some level of bycatch in the shark gillnet fishery operating adjacent to, and sometimes illegally within, the northern Australian EEZ. Some spinner dolphins have been recorded as bycatch in inshore shark nets in Queensland waters (Ross 2006).

The close association of spinner dolphins with yellowfin tuna in the ETP resulted in very large bycatch mortality in the tuna purse seine fishery, and spinner dolphins are considered to be the second-most important dolphin species interacting with this fishery after the pantropical spotted dolphin (Jefferson *et al.* 2008, Bearzi *et al.* 2012). Increased fishery management including per-vessel mortality limits have significantly reduced bycatch rates for spinner dolphins, however, the eastern spinner dolphin population appears to be increasing much more slowly than the expected rate of increase and is not showing clear signs of recovery (Gerrodette and Forcada 2005, Bearzi *et al.* 2012). The slow population increase may be associated with underreporting of bycatch of these dolphins, stress associated with the chase and capture in purse seines affecting fecundity or survival, or changes to the carrying capacity of the ecosystem that may be limiting recovery (Gerrodette and Forcada 2005). Hundreds or thousands of spinner dolphins are estimated to be killed each year in fisheries in the Indian Ocean, and human use of spinner dolphin bycatch has led to increased catches in direct fisheries for these dolphins in the Philippines, Indonesia, Taiwan, Sri Lanka and the Caribbean (Bearzi *et al.* 2012). Chronic disturbance and harassment by dolphin-watching tourist operations is considered to be a threat to spinner dolphin populations in some regions including Brasil, Hawai'i and Indonesia (Perrin 2009c, Bearzi *et al.* 2012). Pollution resulting in accumulation of persistent toxic pollutants in tissues is considered a potential threat to these dolphins (Bannister *et al.* 1996, Woinarski *et al.* 2014).

Conservation and listing status

The spinner dolphin is listed as a cetacean species and as a migratory species as '*Stenella longirostris* E Tropical Pacific, SE Asian populations' under the EPBC Act. This species is listed as Data Deficient in the Northern Territory, in WA the full species is not listed but the subspecies *S. l. longirostris* is Priority 4, and in NSW and Queensland this species is not listed (Woinarski *et al.* 2014). This species and the two subspecies in Australian waters were recently all assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and the species was assessed similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the spinner dolphin was assessed as Data Deficient for the IUCN Red List in 2012 (Bearzi *et al.* 2012), and is listed in Appendix II of CITES.

Dusky dolphin *Lagenorhynchus obscurus* (Level 2 PSA Residual Risk – Low)

Distribution and range

Dusky dolphins have a wide but discontinuous distribution in cool temperate waters of the Southern Hemisphere (Rice 1998, Van Waerebeek and Wursig 2009). They occur in apparently disjunct populations off Tasmania and southern Australia, New Zealand, central and southern South America, southwestern Africa and around some oceanic islands (Gill *et al.* 2000, Jefferson *et al.* 2008). Their distribution in Australian waters is not well known, with only 12 records occurring intermittently over the 175–year period until 2000 (Gill *et al.* 2000). Australian records include offshore areas south-east of Tasmania, around eastern Tasmania and Bass Strait, from Victoria, SA and WA, and about 800 km south, south-east of southern WA (Gill *et al.* 2000). Based on the infrequent sightings in Australian waters, Gill *et al.* (2000) considered that these dolphins may not be resident, and that Australian records may be of dolphins temporarily visiting from the east coast of New Zealand where this species is more abundant. Similarly, Constantine (2008) noted that Australian waters might be considered as the extreme limits of the distribution of this species. The Australian distribution range of this species overlaps extensively with the SPF area.

Population size and trends

Dusky dolphins are rarely seen in Australian waters (Constantine 2008). There are no estimates of the Australian or global population size or trends for this species (Hammond *et al.* 2008i, Woinarski *et al.* 2014). Abundance was estimated to be about 7250 individuals off Argentina, and some populations have been depleted by directed catches and fisheries bycatch (Van Waerebeek and Wursig 2009).

Biology and feeding ecology

Dusky dolphins grow to a maximum size of 2.1 m and maximum weight of 100 kg, but most adults are less than 2 m long and weigh up to 70–85 kg (Jefferson *et al.* 2008, Van Waerebeek and Wursig 2009). These relatively small, mainly coastal, dolphins occur predominantly in neritic waters over continental shelf and upper slope habitats, but also occur in deep-water habitats where oceanic water approaches the coast such as along parts of the east coast of New Zealand (Van

Waerebeek and Wursig 2009). Dusky dolphins are highly social and gregarious, forming groups of up to 50–500 dolphins with some larger groups containing more than 1000 individuals (Jefferson *et al.* 2008). Groups of 3–70 individuals have been sighted in Australian waters (Gill *et al.* 2000). Dusky dolphins can move considerable distances, up to 780 km, and in some areas exhibit diurnal and seasonal inshore-offshore movements (Van Waerebeek and Wursig 2009). Most records of dusky dolphins from the Australian region occurred over warmer seasons from October through to April, and at least some may be associated with changes in oceanographic features such as the position of the Subtropical Convergence (Gill *et al.* 2000).

Dusky dolphins feed mainly on small schooling fishes including anchovies, lantern fishes and pilchards, but also feed on a wide variety of other fish species and squid (Van Waerebeek and Wursig 2009). During the day they can exhibit cooperative foraging on small schooling fish, but are adaptable and are also recorded feeding individually and nocturnally on lantern fish and squid off the east coast of New Zealand (Constantine 2008, Van Waerebeek and Wursig 2009). A group of dusky dolphins observed off eastern Tasmania was recorded associated with hundreds of short-tailed shearwaters *Puffinus tenuirostris* and large schools of fish that were probably jack mackerel (Gill *et al.* 2000).

Dusky dolphins may have a promiscuous mating system involving sperm competition, sexual maturity is reached at about four to six years, gestation lasts for 12.9 months, and the interbirth interval is about 2.4 years (Taylor *et al.* 2007, Van Waerebeek and Wursig 2009). Longevity is about 35 years, and generation length is estimated to be 16.4 years (Taylor *et al.* 2007).

Risks and threatening processes

Dusky dolphins have been recorded as bycatch in trawl nets internationally (Fertl and Leatherwood 1997). High rates of bycatch mortality of dusky dolphins occurred in mid-water trawls off the Patagonian coast from 1982–1994, with about 400–600 dolphins taken each year in the mid-1980s then declining by the mid-1990s, resulting in annual mortality of up to 8 per cent of the regional population (Hammond *et al.* 2008i). Fisheries-related mortality in Peruvian coastal waters in the early 1990s was considered unsustainable with up to 7000 dusky dolphins taken annually from harpooning and from directed and incidental catch in drift nets (Van Waerebeek and Wursig 2009). About 200 dusky dolphins were killed in gillnets off Kaikoura, New Zealand in 1984, with a lower but unknown level of bycatch in more recent decades (Van Waerebeek and Wursig 2009). Potential threats include incidental bycatch in discarded netting, fisheries impacts on prey species, pollution, impacts of dolphin-based ecotourism, and climate and oceanographic change which is predicted to have an unfavourable effect on the species' range (Bannister *et al.* 1996, MacLeod 2009, Van Waerebeek and Wursig 2009, Woinarski *et al.* 2014). Dusky dolphins often approach vessels and ride bow waves, which increases the risk of vessel strike (Jefferson *et al.* 2008).

Conservation and listing status

The Dusky dolphin is listed as a cetacean species and a migratory species under the EPBC Act, but is not listed in states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and similarly in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the dusky dolphin was assessed as Data Deficient for the IUCN Red List in 2008 (Hammond *et al.* 2008i), and is listed in Appendix II of CITES.

Short-finned pilot whale *Globicephala macrorhynchus* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Short-finned pilot whales have an extensive circumglobal distribution in tropical, subtropical and some warm temperate regions of all oceans and the Red Sea, with most records within the range from latitude 50°N to 40°S (Rice 1998, Jefferson *et al.* 2008, Olson 2009). Around Australia, this species has been recorded from strandings in all states and the Northern Territory and additional sightings from other Australian waters (Kemper *et al.* 2005, Ross 2006, Hindell and Gales 2008). Most records in Australian waters are located north of 30°S in oceanic and some coastal areas, and the southern distribution records may be related to southward flowing warm water currents (Bannister *et al.* 1996, Ross 2006). The southern range of this species overlaps with the northern range of the long-finned pilot whale *G. melas* (Hindell and Gales 2008). The southern Australian distribution range of short-finned pilot whales overlaps extensively with the SPF area.

Population size and trends

Short-finned pilot whales are considered to be relatively common within their Australian range and globally, but there are no robust estimates of the Australian or global population size or population trends (Taylor *et al.* 2008b, Woinarski *et al.* 2014). Abundance estimates are available for some populations in Northern Hemisphere regions including: around 589,000 in the eastern tropical Pacific, about 60,000 off Japan, and about 7700 in the Sulu Sea, Philippines (Jefferson *et al.* 2008, Taylor *et al.* 2008b).

Biology and feeding ecology

Short-finned pilot whales are highly sexually dimorphic with adult females growing up to 5.1 m whereas males grow up to 7.2 m in length and up to 3600 kg, with morphologically and genetically distinct geographic forms occurring in Japanese waters (Jefferson *et al.* 2008, Oremus *et al.* 2009). These pilot whales occur in both coastal and offshore oceanic habitats, with higher densities over outer shelf and continental slope habitats or associated with high relief underwater topography (Olson 2009). Short-finned pilot whales are largely nomadic, with some seasonal movements over the continental shelf in response to movements of their squid prey (Hindell and Gales 2008).

They are highly social odontocetes and typically form stable groups of 20–40 individuals that reflect close matrilineal associations, with larger groups containing hundreds of pilot whales reported in some regions (Jefferson *et al.* 2008, Hindell and Gales 2008, Olson 2009). Matrilineal groups contain individuals of both sexes and all age classes and these pilot whales typically remain within their natal group throughout their lifetime (Olson 2009). Although males stay with female kin, they are thought to breed with females from other family groups during temporary larger aggregations, which is an unusual social structure among mammals (Olson 2009). Their strong social bonds are thought to be a factor in the propensity for these pilot whales to mass strand (Olson 2009).

Short-finned pilot whales mostly eat squid, with cuttlefish, octopus and a range of fish species also consumed (Ross 2006, Jefferson *et al.* 2008, Hindell and Gales 2008). Dives to deeper than 600 m have been recorded, with dive patterns varying diurnally in response to movements of vertically migrating prey in the deep scattering layer (Olson 2009).

Short-finned pilot whales have a polygynous mating system, and genetic analyses show strong differentiation between ocean basins and within the Pacific Ocean, indicating that there is limited dispersal of female lineages between regional subpopulations (Oremus *et al.* 2009). Life history characteristics include long life span, delayed maturation, and long interbirth interval resulting in only four to five calves being produced by a female during her lifetime (Hindell and Gales 2008, Olson 2009). Females are sexually mature at eight to nine years and males at 13–17 years (Jefferson *et al.* 2008), there is an extended gestation period of 14.9 months, and females suckle young for an extended period leading to a remarkably long interbirth interval of 6.9 years (Ross 2006, Taylor *et al.* 2007, Hindell and Gales 2008). Females become post-reproductive at about 40 years, and female longevity is estimated to be at least 63 years (Jefferson *et al.* 2008). Generation length is estimated to be 23.5 years (Taylor *et al.* 2007). These life history characteristics and the slow rate of reproduction result in a slow capacity for recovery from depletion.

Risks and threatening processes

Short-finned pilot whales have been recorded as bycatch in a range of mid-water and bottom trawl fisheries operations in the mid-Atlantic, US east coast, off Mauritania and off north-east Africa in pelagic freezer/factory trawlers (Fertl and Leatherwood 1997, Zollett 2009, Elgin Associates unpublished (a)). Pilot whales are considered to be particularly susceptible to entanglement in driftnets and are taken as bycatch in driftnet fisheries in the North Pacific Ocean, and previously in the squid purse seine fishery off California (Jefferson *et al.* 2008, Taylor *et al.* 2008b). They are also killed in drive fisheries in Japan, and in harpoon fisheries in parts of the Philippines, Indonesia and in the Caribbean (Jefferson *et al.* 2008, Taylor *et al.* 2008b). A few short-finned pilot whales are taken in the longline fishery off Hawai'i, and some individuals have been killed by gunshot wounds and spear wounds in the Caribbean (Taylor *et al.* 2008b, Hamer *et al.* 2012). These pilot whales are considered likely to be susceptible to loud sounds such as those from navy sonar and seismic exploration, and some mass stranding events of short-finned pilot whales have been associated with high levels of anthropogenic sound and large-scale military exercises (Taylor *et al.* 2008b, Zirbel *et al.* 2011). Other potential threats include pollution resulting in bioaccumulation of toxic pollutants in tissues, and prey depletion from expanding commercial fisheries (Bannister *et al.* 1996, Woinarski *et al.* 2014).

Conservation and listing status

The short-finned pilot whale is listed as a cetacean species under the EPBC Act, Rare in SA, Data Deficient in the Northern Territory, but is not listed in other states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014) and as 'No category assigned but possibly secure' in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the short-finned pilot whale was assessed as Data Deficient for the IUCN Red List in 2008 (Taylor *et al.* 2008b), and is listed in Appendix II of CITES.

Long-finned pilot whale *Globicephala melas* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Long-finned pilot whales have a disjunct distribution in temperate to subpolar waters of the Northern and Southern Hemispheres (Rice 1998, Jefferson *et al.* 2008). The Southern Hemisphere subspecies *G. melas edwardii* is isolated from the Northern Hemisphere subspecies, and most records in the Southern Hemisphere occur within the range from 20°S to 65°S, but extend south to 68°S (Rice 1998, Jefferson *et al.* 2008, Olson 2009). Their distribution in Australian waters is poorly known. They have been recorded from sightings and strandings in many locations around and south of Australia, from all states and the Northern Territory, with additional records from subtropical Lord Howe Island and subantarctic Macquarie Island (Bannister *et al.* 1996, Hutton and Harrison 2004, Ross 2006, Gales and Hindell 2008). The northern range of this species overlaps with the southern range of the short-finned pilot whale (Gales and Hindell 2008). The Australian distribution range of long-finned pilot whales overlaps extensively with the SPF area.

Population size and trends

Long-finned pilot whales are considered to be relatively abundant within their Australian range and globally, but there are no robust estimates of the Australian or global population size or population trends (Taylor *et al.* 2008c, Woinarski *et al.* 2014). Abundance estimates are available for some populations, including about 200,000 in summer south of the Antarctic Convergence, and about 780,000 in the central and northeastern North Atlantic Ocean (Jefferson *et al.* 2008, Taylor *et al.* 2008c).

Biology and feeding ecology

Long-finned pilot whales are sexually dimorphic with adult females growing up to 5.7 m and weighing up to 1300 kg, while males grow up to 6.7 m and weigh up to 2300 kg (Jefferson *et al.* 2008). These pilot whales occur in deep oceanic waters and in areas of high productivity along the continental slope, and move into shallower continental shelf waters in pursuit of prey (Ross 2006). Long-finned pilot whales are considered to be migratory, with seasonal movements apparently occurring in response to movements of their main squid prey (Ross 2006).

Long-finned pilot whales are highly social and form stable groups containing 10–50 individuals, but can aggregate to form larger groups containing thousands of pilot whales (Jefferson *et al.* 2008, Gales and Hindell 2008). Matrilineal groups contain whales of both sexes and all age classes and individuals typically remain within their natal group throughout their lifetime (Olson 2009). Long-finned pilot whales are one of the most commonly recorded species involved in mass stranding events and their strong social bonds may influence this behaviour (Olson 2009). However, multiple maternal lineages were found among stranded long-finned pilot whales, which challenges the assumption that strong kinship cohesion leads to mass stranding of these whales (Oremus *et al.* 2013). Their strong social bonds also make these pilot whales susceptible to herding by whalers in drive fisheries (Jefferson *et al.* 2008, Olson 2009). More than 100 stranding events have been recorded around Australia, with about half from Tasmania (Bannister *et al.* 1996, Ross 2006). The majority of mass strandings from Australia have occurred in warmer months from December to March (Ross 2006), and recent satellite tracking of pilot whales that stranded in Tasmania and were successfully released has shown that these individuals survived, at least in the short term (Gales *et al.* 2012).

Long-finned pilot whales mostly eat squid, but will also take small to medium-sized fish such as mackerel, herring and cod when these are available (Ross 2006, Jefferson *et al.* 2008, Gales and Hindell 2008). Stomach contents of long-finned pilot whales that stranded in Tasmania included mainly cephalopod beaks and remains of fish (Gales *et al.* 1992). These pilot whales can dive deeper than 1000 m but tend to forage during shallower dives at night on their vertically migrating prey (Gales and Hindell 2008).

Long-finned pilot whales have a polygynous mating system (Jefferson *et al.* 2008). Life history characteristics include long life span, delayed maturation, and long interbirth intervals of three to six years (Gales and Hindell 2008, Olson 2009). Age at sexual maturity for females varies from 5–15 years and averages 17 years for males (Ross 2006), gestation lasts for about 12 months and lactation occurs over an extended period for up to three years (Gales and Hindell 2008). Longevity varies from 35–45 years for males and more than 60 years for females (Jefferson *et al.* 2008). Generation length is estimated to be 24 years (Taylor *et al.* 2007). These life history characteristics and slow rate of reproduction result in a slow capacity for recovery from depletion.

Risks and threatening processes

Long-finned pilot whales have been recorded as bycatch in offshore, mid-water and bottom trawls, and some individuals have been observed feeding in association with trawl nets (Fertl and Leatherwood 1997, Zollett 2009, Elgin Associates unpublished (a)). Pilot whales are susceptible to entanglement in driftnets and have been recorded as bycatch in driftnet, gillnet and purse seine fisheries (Jefferson *et al.* 2008, Taylor *et al.* 2008c). They have also been taken in large-scale drive fisheries in the North Atlantic Ocean, including in the Faroe Islands and Greenland (Jefferson *et al.* 2008, Taylor *et al.* 2008c). These pilot whales are considered likely to be susceptible to acoustic trauma from loud anthropogenic sounds, with possible links between naval activities and strandings (Taylor *et al.* 2008c, Zirbel *et al.* 2011). Other threats include pollution resulting in bioaccumulation of toxic pollutants in tissues, and potential for prey depletion from expanding commercial fisheries (Bannister *et al.* 1996, Woinarski *et al.* 2014).

Conservation and listing status

The long-finned pilot whale is listed as a cetacean species under the EPBC Act, but is not listed in any states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Least Concern in Australian waters (Woinarski *et al.* 2014) and as 'No category assigned but possibly secure' in previous Australian status assessments (Bannister *et al.* 1996, Ross 2006). Globally, the long-finned pilot whale was assessed as Data Deficient for the IUCN Red List in 2008 (Taylor *et al.* 2008c), and is listed in Appendix II of CITES.

Killer whale *Orcinus orca* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Killer whales are the most widely distributed marine mammal, with an extensive circumglobal distribution throughout all oceans and in most seas (Rice 1998, Ford 2009). Their latitudinal range encompasses equatorial to high latitude polar regions to the ice-edge and within pack ice (Baird 2000, Ford 2009). They are more commonly recorded in temperate regions of high productivity where prey are abundant, while less information is available from tropical and offshore oceanic regions where fewer sightings occur (Forney and Wade 2006, Ford 2009).

The taxonomy of killer whales is uncertain and needs revision. At present, one cosmopolitan species of killer whale with two unnamed subspecies are recognised (Committee on Taxonomy 2014), however it has long been known that morphologically different forms occur in some regions that may represent different species or subspecies (Rice 1998). In recent decades, a number of distinct ecotypes (A, B, C and D) have been identified that differ in their morphology and phenotypic characteristics, prey preferences and behaviour, and molecular phylogenetic analyses have indicated that at least some of these ecotypes should be considered to be separate species and others may be subspecies (e.g. Pitman and Ensor 2003, Pitman *et al.* 2007, Jefferson *et al.* 2008, Pitman *et al.* 2011, reviewed in Woinarski *et al.* 2014). These different ecotypes have different geographic ranges: Type A killer whales have the broadest distribution and occur in all oceans and seas from the equator to the edge of polar seas in the Northern and Southern Hemispheres; Type B whales are mainly recorded in the Antarctic and Southern Ocean with some groups exhibiting large-scale periodic movements to lower latitudes; Type C whales occur mainly in pack ice habitats in east Antarctica; Type D whales are primarily pelagic with a circumpolar subantarctic distribution range (Baird 2000, Pitman and Ensor 2003, Pitman *et al.* 2007, Ainley *et al.* 2009, Pitman *et al.* 2011, Durban and Pitman 2012, reviewed in Woinarski *et al.* 2014).

In the Australian region, killer whales have been recorded from all state and Northern Territory waters, around Christmas Island, subantarctic Macquarie and Heard Islands, and south of Australia in the Southern Ocean to high latitude polar waters close to the Antarctic coast (e.g. Bannister *et al.* 1996, Kemper *et al.* 2005, Ross 2006, Morrice and Gill 2008, Van Waerebeek *et al.* 2010, reviewed in Woinarski *et al.* 2014). They are commonly sighted in southeastern Australian coastal waters and along the edge of the continental shelf from southeastern Tasmania, Victoria and southern NSW, around Macquarie Island, and in some Australian Antarctic Territory waters (Bannister *et al.* 1996, Ross 2006, Morrice and Gill 2008, Van Waerebeek *et al.* 2010). Killer whale Types A, B and C occur in Australian Antarctic Territory waters, with some types occurring around Macquarie Island and in Australian coastal waters (Pitman and Ensor 2003, Morrice 2007, Morin *et al.* 2010, R. Pitman and D. Donnelly pers. comm. in Woinarski *et al.* 2014). The Australian distribution range of killer whales overlaps completely with the SPF area.

Population size and trends

Killer whales are commonly sighted in some coastal waters in southeastern Australia and around Macquarie Island but there is no reliable estimate of the Australian population size or trends (Bannister *et al.* 1996, Morrice 2007, Woinarski *et al.* 2014). Forney and Wade (2006) provided a minimum global abundance estimate of about 50,000 killer whales, but considered that this was likely to be an underestimate because abundance estimates are lacking for large areas of the South Pacific, Indian and South Atlantic Oceans, and some high latitude areas in the Northern Hemisphere. Killer whales are thought to be relatively abundant in the Southern Ocean where about 1600 were taken by Soviet whalers. The estimate of about 25,000 killer whales in the region south of 60°S is considered to be uncertain (Forney and Wade 2006, Taylor *et al.* 2008d). The global population trend for killer whales is unknown (Taylor *et al.* 2008d).

Biology and feeding ecology

Killer whales are the largest delphinids and are sexually dimorphic with adult females growing up to 7.7–8.5 m and weighing up to 7500 kg, while males grow up to 9.0–9.8 m and weigh nearly 10,000 kg (Jefferson *et al.* 2008, Ford 2009). Extensive geographic variation occurs among different ecotypes. Killer whales use a wide range of coastal to open ocean marine habitats and are occasionally reported in estuaries and rivers (Forney and Wade 2006, Ford 2009). Their density increases with latitude and in areas of high productivity, and large aggregations of tens to hundreds of Type B and C Killer whales are recorded close to ice-edge habitats in the Southern Ocean (Pitman and Ensor 2003, Forney and Wade 2006, Ainley *et al.* 2009). In Australian waters they occur in coastal areas, along the continental shelf, in deeper slope and oceanic regions, and in subantarctic and Antarctic areas (Bannister *et al.* 1996, Ross 2006, Morrice and Gill 2008, Van Waerebeek *et al.* 2010).

Movement patterns vary among ecotypes, with resident populations exhibiting seasonal movement and offshore forms showing larger-scale movement in response to prey (Baird 2000, Jefferson *et al.* 2008). Type A and some Type B ecotypes periodically migrate from Antarctic to lower latitude waters (Pitman and Ensor 2003, Ford 2009). Seasonal trends in sighting records suggest that some killer whales in Australian waters may undertake seasonal migrations in response to prey aggregations (Morrice 2007). Photo-identified individuals have been recorded moving from Jervis Bay in NSW to the Derwent River near Hobart, Tasmania, and one killer whale identified off Victoria was resighted off southern NSW (D. Donnelly pers. comm. in Woinarski *et al.* 2014).

Killer whales are highly social delphinids that form complex multi-level social groups. Some resident killer whale populations have matrilineal groups containing up to four generations of related whales that remain in their natal group throughout their life, and these groups can aggregate to form larger pods with up to three matrilines and 49 individuals (Baird 2000, Ford 2009). Pods form clans with similar vocal dialects to maintain social interactions and group cohesion, and some pods regularly associate with others to form higher-level communities (Baird 2000, Ford 2009). Some killer whale groups in Australian waters have high fidelity with long-term associations lasting at least 15 years (D. Donnelly pers. comm. in Woinarski *et al.* 2014). Killer whale groups containing up to 52 whales have been recorded south of Australia (Bannister *et al.* 1996), and aggregations containing more than 100 individuals have been observed off southern WA (D. Donnelly pers. comm. in Woinarski *et al.* 2014).

Killer whales are apex marine predators and are known to prey on more than 140 different species including at least 50 marine mammal species, many species of bony fish, penguins, turtles, sharks and other elasmobranchs, and cephalopod, with different ecotypes specialising in different types of prey such as marine mammals or fish (Baird 2000, Ford 2009). In Australian waters, these whales have been recorded attacking or preying on various fish species including fish caught on longlines, sharks, and a wide range of marine mammals including dolphins and whales, dugongs, fur seals and Australian sea lions (Bannister *et al.* 1996, Ross 2006, Morrice and Gill 2008, D. Donnelly pers. comm. in Woinarski *et al.* 2014). Foraging varies among different ecotypes but usually involves cooperative hunting and highly coordinated group behaviour such as herding of fish and attacks on marine mammals, with dive depths varying from shallow 20–30 m dives to more than 200 m (Baird 2000, Ford 2009).

Life history characteristics have been well studied in resident killer whales off British Columbia and Washington and include long life span, delayed maturation, and long interbirth interval resulting in a slow rate of reproduction (Ford 2009). Age at sexual maturity is 10–12 years for females and about 15 years for males, gestation extends over 15–18 months, weaning occurs at one to two years or older and the average interbirth interval is estimated to be about five years but ranges from 2–14 years (Baird 2000, Taylor *et al.* 2007, Ford 2009). Maximum longevity is about 50–60 years for males and 80–90 years for females, with females producing an average of five calves over their 25-year reproductive period that finishes at about 40 years of age (Jefferson *et al.* 2008, Ford 2009). Generation length is estimated to be 25.7 years (Taylor *et al.* 2007).

Risks and threatening processes

Killer whales commonly interact with trawl fisheries internationally and are frequently reported as scavenging around trawlers (Fertl and Leatherwood 1997, Elgin Associates unpublished (a)). Some bycatch has been recorded internationally in trawl net and driftnet fisheries but is considered to be rare, and no incidental bycatch mortality has been reported from Australian waters (Fertl and Leatherwood 1997, Taylor *et al.* 2008d, Elgin Associates unpublished (a)). Small numbers are taken in coastal fisheries in Japan, Indonesia, the Caribbean region and Iceland (Taylor *et al.* 2008d). Killer whales are considered to be one of the main species involved in depredation of fish catch from longline fisheries at higher latitudes including eastern and southern Australia, leading to reports of fishers illegally killing these whales off Tasmania and elsewhere (Bannister *et al.* 1996, Shaughnessy *et al.* 2003, Reeves *et al.* 2003, 2013, Taylor *et al.* 2008d, Hamer *et al.* 2012). Prey depletion is considered to be a threat to some populations of killer whales that specialise in feeding on fish species targeted by commercial fisheries such as Antarctic toothfish *Dissostichus mawsoni*, southern bluefin tuna *Thunnuss maccoyii* and salmon (Bannister *et al.* 1996, Taylor *et al.* 2008d, Ainley *et al.* 2009). As apex predators, killer whales are potentially at risk from bioaccumulation of toxic pollutants in tissues, and high levels of polychlorinated biphenyls (PCBs). Other pollutants have been recorded in killer whales from some regions (Ross *et al.* 2000, Rayn *et al.* 2004, Taylor *et al.* 2008d). Increased whale-watching activities and anthropogenic noise can result in disturbance and degradation of important habitats for killer whales (Williams *et al.* 2006), and scars and damage from vessel strikes are evident on some killer whales in Australian waters (D. Donnelly pers. comm. in Woinarski *et al.* 2014).

Conservation and listing status

The killer whale is listed as a cetacean species and as a migratory species under the EPBC Act, Data Deficient in the Northern Territory, but is not listed in other states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014). In previous Australian status assessments this species was assessed as 'No category assigned but probably secure' by Bannister *et al.* (1996), and 'No category assigned but possibly secure' by Ross (2006). Globally, the killer whale was assessed as Data Deficient for the IUCN Red List in 2008 (Taylor *et al.* 2008d), and is listed in Appendix II of CITES.

Sperm whale *Physeter macrocephalus* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Sperm whales are one of the most widely distributed marine mammal species, with a cosmopolitan distribution in most deeper-water marine habitats from equatorial to polar regions in both northern and southern hemispheres, and occurring in the Mediterranean Sea and some other seas (Rice 1998, Whitehead 2009). Females and young males mostly occur in lower latitudes extending to about 40–50°, whereas males range more widely and move to higher latitude habitats including polar waters as they mature, with periodic return movements to lower latitude warmer waters to breed (Whitehead 2003).

In the Australian region, sperm whales have an extensive distribution in Commonwealth waters and have been recorded from all state and Northern Territory waters, from Australian Antarctic Territory waters and other oceanic offshore areas around Australia (e.g. Townsend 1935, Bannister *et al.* 1996, Smith *et al.* 2012a, reviewed in Woinarski *et al.* 2014). Sperm whales are relatively concentrated in a narrow area near the steep continental shelf edge from Esperance to Cape Leeuwin off southern WA, and are more widely dispersed offshore from Perth to Carnarvon off the west coast of WA (Bannister 2008). Sperm whales occur off the north-west and west coasts of Tasmania, and seasonally off NSW including near Wollongong and Sydney, Lord Howe Island in the Tasman Sea, and off Stradbroke Island in Queensland (Bannister *et al.* 1996; Evans *et al.* 2002; Hutton and Harrison 2004). Historical sightings and catch records from American whalers in the 19th and early 20th centuries include many records of sperm whales off WA and parts of southern Australia, and along much of the east coast (Townsend 1935, Smith *et al.* 2012a). The Australian distribution range of sperm whales overlaps completely with the SPF area.

Population size and trends

There is no reliable estimate of the total sperm whale population size or overall trends in Australian waters (Bannister *et al.* 1996, Bannister 2008, Woinarski *et al.* 2014). 'Open boat' whaling records during the 1800s showed most catches occurred off WA and in the Tasman Sea (Townsend 1935, Bannister 2008). 'Modern' sperm whaling in the 1900s occurred primarily off Albany in southern WA mainly from 1955 to 1978 where annual catches exceeded 400 whales, with larger catches south of Australia prior to 1975 considered likely to have affected the demography of sperm whales in Australian waters (Bannister 1968, 2008). Whaling significantly reduced the abundance of large breeding males and caused a significant decline in pregnancy rate that contributed to the closure of the whaling station in 1978 (Kirkwood *et al.* 1980, Bannister 2008). Aerial surveys, catch records and modelled estimates indicated that abundance of sperm whales in this region substantially declined from 1947 to 1979, with females aged 13 years and older reduced to 91 per cent of their 1947 abundance, whereas males aged 20 years and older were heavily depleted to only 26 per cent of their 1947 abundance (Kirkwood *et al.* 1980). Aerial surveys off Albany in 2009 showed no evidence of recovery and an apparent further decline in the numbers of sperm whales in this region compared with the earlier aerial surveys during whaling from 1968 to 1978 (Carroll *et al.* 2013). It is not clear whether this change reflects a decline in the sperm whale population or movement of whales to other areas (G. Carroll pers. comm. in Woinarski *et al.* 2014), and the recent survey off Albany does not provide inference on population trends across other regions around Australia.

The estimated global pre-whaling population size was about 1,110,000 sperm whales (Whitehead 2002), but two overlapping phases of commercial whaling from 1712 through to 1988 caused substantial depletion of these whales and ongoing effects on population recovery (Whitehead 2009). The global population was estimated to have been reduced to about 71 per cent of its pre-whaling size by 1880 (Whitehead 2002), and an estimated 405,898 Sperm whales were killed in the Southern Hemisphere in the 1900s during the 'modern' whaling period (Clapham and Baker 2009). By 1999, the global population was estimated to be about 360,000, representing depletion to about 32 per cent of the pre-whaling abundance (Whitehead 2002). Although whaling caused a significant population reduction, sperm whales are among the most abundant large whale species (Jefferson *et al.* 2008), but there are insufficient data to accurately determine abundance or population structure in ocean basins (NMFS 2010a). There is no direct evidence of an increase in any part of the global population since whaling ceased, nor evidence in most regions that they have not increased, but there is ongoing concern that some regional populations of sperm whales are declining (Taylor *et al.* 2008e).

Biology and feeding ecology

Sperm whales are the largest odontocetes and the most sexually dimorphic cetaceans with adult females growing up to 11–12 m and weighing up to 13.5 tonnes (t), while mature males grow to about 16–18 m and weigh up to 57 t (Jefferson *et al.* 2008, Whitehead 2009). They occur primarily in deep water offshore pelagic or continental slope habitats and are generally more abundant in areas of higher primary productivity, including upwelling areas (Whitehead 2009). They may approach closer to coasts in deep water habitats near oceanic islands or where the continental shelf is narrow, such as off Albany (Bannister 2008). Sperm whales exhibit variable movement and migration patterns with mid-latitude groups tending to migrate pole-ward in summer then to lower latitudes in winter, whereas in some equatorial and temperate regions no clear seasonal migration patterns are evident (Whitehead 2003). They have been recorded off eastern Antarctica in Australian Antarctic Territory waters in summer in deep water habitats averaging about 4000 m depth (Gedamke and Robinson 2010). Sperm whales are known to travel westwards along the coast off Albany and have been reported to move across southern Australian waters between the western South Pacific and south-east Indian Ocean regions (Bannister 2008).

Female sperm whales form stable social 'nursery' groups of about 10–25 females and calves in oceanic habitats in water deeper than 1000 m where sea surface temperatures are warmer than about 15–18°C (Whitehead 2003, Bannister 2008). Female groups form multilevel societies in the Pacific Ocean, with temporary larger aggregations of female units from the same cultural clan, and these vocal clans contain thousands of females with distinct vocalisations that may be culturally transmitted (Whitehead 2003, Whitehead *et al.* 2012). Home ranges are usually smaller for females compared to males, although female groups sometimes undertake intra-ocean dispersal movements, while males tend to roam widely with more frequent inter-oceanic movements (Jefferson *et al.* 2008, Whitehead 2009). Young males remain with females in tropical and subtropical regions until they are between 4–21 years old then depart from their natal group to form loosely aggregated 'bachelor' herds (Whitehead 2003). Males subsequently move to higher latitude colder regions as they age and mature to become mostly solitary, then periodically return to warmer breeding grounds where they search for female nursery groups for mating (Whitehead 2003, Jefferson *et al.* 2008). Population structure is uncertain, with some evidence for genetic differentiation within and between some ocean basins but low or negligible nuclear DNA differentiation evident between populations in different ocean basins (Whitehead 2009). Recent molecular research in Australian waters indicates that sperm whales have a matrilineal population structure, with females more likely to exhibit natal philopatry whereas males are more likely to disperse (L. Moller pers. comm. in Woinarski *et al.* 2014).

Sperm whales strand frequently compared with many cetacean species, and strandings are relatively common in Tasmania (Bannister 2008). An 11–13 year periodicity in sperm whale and other cetacean stranding events in Tasmania and Victoria is correlated with climatic and oceanographic changes that may influence the northward movement of prey species and result in increased cetacean abundance and stranding events in these regions (Evans *et al.* 2005).

Sperm whales are key predators of oceanic cephalopods and also consume an extraordinary range of other species including some other invertebrates, large sharks, skates and demersal fishes in deeper ocean habitats (Jefferson *et al.* 2008, Whitehead 2009). They typically dive to about 400–600 m to forage, but are thought to be capable of reaching extraordinary depths of 3200 m or deeper and can dive for more than one hour (Bannister *et al.* 1996, Whitehead 2003, Jefferson *et al.* 2008). Sperm whales mainly prey on mesopelagic squid but also eat giant squid and demersal and mesopelagic fish and some crustaceans, with males tending to eat larger individuals than females (Evans and Hindell 2004, Jefferson *et al.* 2008; Whitehead 2009). Stomach contents from stranded sperm whales in Tasmania contained remains of more than 50 species from 17 cephalopod families and some myctophid fish and other species, with high variability among individuals indicating that these whales are opportunistic predators that target locally abundant prey species (Evans and Hindell 2004).

Sperm whales have a long life span, slow growth and delayed maturation, a very low birth rate, polygynous breeding and a complex social structure, which makes them highly susceptible to over-exploitation (Whitehead 2009). Females reach sexually maturity around 9–12 years and give birth about every five years with birth rates declining among older age classes; gestation is about 14–16 months and females suckle their young for several years (Taylor *et al.* 2007, Bannister 2008, Whitehead 2009). Males usually don't breed until they are about 25 years or older, and continue to grow and reach physical maturity at about 50 years (Bannister 2008, Whitehead 2009). Maximum longevity is thought to be at least 70 years and possibly older (Whitehead 2003, Jefferson *et al.* 2008). Generation length is estimated to be 27.3–27.5 years (Taylor *et al.* 2007). These life history characteristics result in low reproductive rates and slow rates of population increase that limit the capacity for sperm whale populations to recover after depletion, and populations are particularly sensitive to reduced survivorship of mature breeding whales (Whitehead 2002, Taylor *et al.* 2008e, Woinarski *et al.* 2014).

Risks and threatening processes

Sperm whales have been recorded as bycatch in trawl nets internationally (Fertl and Leatherwood 1997), but are thought not to commonly interact with trawl fisheries (Elgin Associates unpublished (a)). Entanglement and bycatch has been recorded in a variety of other fisheries gear including gillnets and driftnets in the Mediterranean Sea and in other nets and lines in many other regions (Reeves *et al.* 2003, 2013, Taylor *et al.* 2008e, Zollett 2009). Small numbers have been taken in coastal fisheries in Indonesia, and under International Whaling Commission (IWC) Special Permit by Japan (Taylor *et al.* 2008e). Sperm whales are one of the main species involved in depredation of fish catch from longline fisheries at higher latitudes, and this interaction has resulted in some entanglements and deaths, and reports of fishers shooting these whales (Taylor *et al.* 2008e, Hamer *et al.* 2012). As high trophic level predators, sperm whales are potentially at risk from bioaccumulation of toxic pollutants in tissues, and high levels of organochlorines and metals have been recorded in tissues of sperm whales from Australia and in some regions overseas (Evans 2003, Evans *et al.* 2004). Ingestion of marine debris including plastics has been recorded in some sperm whales from Australia and overseas, in some cases resulting in gut obstruction and death (Evans and Hindell 2004, Woinarski *et al.* 2014). Vessel strikes are known to cause injury and in some cases death of sperm whales (Laist *et al.* 2001), and climate and oceanographic changes may alter trophic interactions and prey distribution in southern Australian waters (Evans *et al.* 2005).

Conservation and listing status

The sperm whale is listed as a cetacean species and as a migratory species under the EPBC Act, Vulnerable in NSW, Rare in SA, Priority 4 in WA, Data Deficient in the Northern Territory, but is not listed in other states within its Australian range (Woinarski *et al.* 2014). This species was recently assessed as Vulnerable in Australian waters (Woinarski *et al.* 2014), and as insufficiently known in the previous Australian status assessment (Bannister *et al.* 1996). Globally, the sperm whale was assessed as Vulnerable for the IUCN Red List in 2008 (Taylor *et al.* 2008e), and is listed in Appendix I of CITES.

Summary: odontocete species at risk from direct interactions with mid-water trawls in the SPF

- *The 15 odontocete species described above have different distribution ranges that vary in their extent of overlap with the SPF area. The species at highest risk of interactions with mid-water trawls in the SPF are bottlenose dolphins and short-beaked common dolphins whose diet includes small pelagic fish and these dolphins are known to interact extensively with trawl fisheries in Australia and internationally; some common bottlenose dolphins and possibly short-beaked common dolphins were previously recorded as bycatch in mid-water trawls in the SPF.*
- *The other odontocete species exhibit a wide range of biological and ecological characteristics including abundance, diet and life history traits, and the nature and extent of their interactions with trawl fisheries and other fisheries varies; hence the risks of interactions with the DCFA need to be assessed separately for each species.*
- *Although the hourglass dolphin remained at high risk for the mid-water trawl sector of the SPF after the residual risk assessment, its oceanic distribution range may only overlap marginally with the SPF area, the species has not been recorded interacting with trawl fisheries, is not obviously threatened, and is assessed as Least Concern in Australian waters and globally. Therefore, the panel did not consider the hourglass dolphin to be a particularly high risk species for direct interactions associated with the SPF mid-water trawl sector.*

Southern right whale *Eubalaena australis* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Southern right whales have a circumpolar distribution in the Southern Hemisphere from about 20°S to about 55°S but are also recorded further south in Antarctic waters to about 65°S (Bannister *et al.* 1999, Jefferson *et al.* 2008, Bannister 2008). During the austral summer they occur on feeding grounds mainly between latitudes 40–55°S and part of the population migrates to warmer temperate waters for calving during winter, including coastal habitats along the southern Australian coast (Bannister 2008).

In the Australian region, southern right whales have an extensive distribution within Commonwealth and state waters, in some Australian Antarctic Territory waters, and in other oceanic areas south of Australia (Bannister *et al.* 1996, 1999, Pirzl 2008). Genetic analyses indicate that there are two subpopulations of these whales in Australian coastal waters, a larger south-west subpopulation and a smaller south-east subpopulation (Carroll *et al.* 2011). During winter, the southwestern subpopulation is distributed from about Ceduna in SA to Cape Leeuwin in WA with some whales recorded north to Exmouth (Pirzl 2008, Bannister 2011). The southeastern subpopulation is mainly distributed in waters south of Sydney in NSW, with a few individuals recorded as far north as Hervey Bay in Queensland (Franklin and Burns 2005, Pirzl 2008). The migration patterns and routes for these subpopulations are not well understood. Prior to whaling over-exploitation that caused severe declines, these whales had extensive calving grounds in southern Australia (Bannister 2008). The southwestern subpopulation is increasing, but the southeastern subpopulation remains relatively depleted with a restricted occupancy of coastal habitats following whaling (Pirzl 2008, Bannister 2011). The Australian distribution range of southern right whales overlaps extensively with the SPF area.

Population size and trends

The abundance of the total Australian population of southern right whales was estimated to about 3500 in 2009, with an estimated abundance of about 2900 whales including about 1220 adults in the larger southwestern subpopulation, and about 600 whales in the depleted southeastern subpopulation (Bannister 2011). Long-term monitoring of the southwestern subpopulation since 1976 has shown significant increases in abundance with an annual rate of increase of about 6.8 per cent during 1993–2010 (Bannister 2011). The southeastern subpopulation has not exhibited similar signs of recovery and appears to be relatively depleted (Pirzl 2008).

Whaling during the 1800s caused severe declines in abundance of these whales in Australian waters and throughout the Southern Hemisphere. The global population declined from an estimated size of about 55,000–70,000 prior to whaling down to about 300 whales by the 1920s, although more recent modelling indicates that the initial and minimum global population sizes may have been higher (Jackson *et al.* 2008). An estimated 26,000–40,000 southern right whales were killed in southeastern Australian and New Zealand waters from 1827 to 1930 and this unregulated whaling caused the commercial extinction of these whales (Bannister 1986). Protection from whaling in 1935 enabled some increase in abundance, but subsequent illegal Soviet whaling killed about 395 southern right whales in southern Australian and southern New Zealand waters between 1951 and 1971 that impaired this initial recovery phase (Tormosov *et al.* 1998, Clapham and Ivashchenko 2009). The global population in 2011 was estimated to have recovered to about 20–25 per cent of the original pre-whaling abundance (IWC 2011).

Biology and feeding ecology

Southern right whales are relatively large and rotund whales, growing up to 17 m long and weighing up to at least 80 t, with females growing larger than males (Jefferson *et al.* 2008). They aggregate along southern Australian coastal waters mainly between July and October, and usually occur within a few kilometres of the shore in shallow waters and sometimes within the surf zone (Bannister 2008). Females have high site fidelity to calving grounds, and their three-year calving cycle results in variable habitat occupancy along the southern Australian coast (Burnell 2001, Pirzl 2008). Individuals can travel westward over hundreds of kilometres along the southern Australian coast within a winter season (Burnell 2001, Bannister 2008), and larger scale movements of three right whales over 3700 km between southern Australian and subantarctic New Zealand regions have been recorded (Pirzl *et al.* 2009). Two of these whales were females with calves, which indicates that each female calved in both Australian and New Zealand winter calving grounds (Pirzl *et al.* 2009).

Major calving and coastal aggregation sites for the southwestern subpopulation include Head of Bight in SA, and Israelite Bay and Doubtful Island Bay regions in WA, with some smaller aggregation sites in these regions (Bannister *et al.* 1996, Burnell 2001, DSEWPaC 2012a). For the southeastern subpopulation, small and variable numbers of calving females aggregate off Warrnambool in Victoria, and small numbers of right whales are recorded from coastal Tasmania, Victoria, southern NSW and eastern SA (Pirzl 2008, DSEWPaC 2012a). These aggregation and breeding sites all overlap with the SPF area.

During spring and summer these whales migrate offshore to higher southern latitudes for pelagic feeding (Bannister 2008, Torres *et al.* 2013). They use surface skimming or shallow dives to trap plankton on their fine baleen, and this feeding behaviour makes them susceptible to vessel strike. They feed primarily on planktonic copepods and other crustaceans at latitudes below 40°S associated with the Polar Front, and south of 50–60°S their diet consists mainly of euphausiids (Bannister *et al.* 1996, Tormosov *et al.* 1998, Torres *et al.* 2013). Southern right whales from different breeding subpopulations apparently intermingle on southern pelagic feeding grounds and may potentially mate (Carroll *et al.* 2011, IWC 2011). Genetic analyses indicate that the southeastern and southwestern Australian subpopulations represent two distinct breeding stocks, and are consistent with maternal philopatry and male dispersal life history patterns with some recent historical or ongoing reproductive interchange (Carroll *et al.* 2011). Reduced breeding success in southern right whales has been correlated with increased sea surface temperatures associated with El Nino-Southern Oscillation events and climate change in the Australian population, and in the South Atlantic region (Leaper *et al.* 2006, Pirzl *et al.* 2008).

Southern right whales appear to have a promiscuous polygamous mating system whereby multiple males compete for breeding with females probably through sperm competition associated with sequential mating rather than by direct aggressive behaviour (Bannister *et al.* 1996, Jefferson *et al.* 2008). Sexual maturity occurs between five and nine years of age, and the mean calving interval is about 3.6 years but ranges from two to six years (Bannister *et al.* 1996, Burnell 2001). Maximum longevity is estimated to be more than 50 years (Bannister 2008) and may exceed 65 years (Burnell 2008). Generation length is estimated to be 28.8 years (Taylor *et al.* 2007). These life history characteristics result in relatively slow reproductive rates and slow capacity for populations to recover from depletion (Woinarski *et al.* 2014).

Risks and threatening processes

Southern right whales have been injured or killed from entanglements in fishing gear in Australian waters and internationally (Kemper *et al.* 2008, Reeves *et al.* 2013). Southern right whales are also known to be injured or killed from vessel collisions in Australian waters and internationally (Laist *et al.* 2001, Kemper *et al.* 2008). In the Australian region these whales face increased risk of vessel strike from heavy shipping traffic when they leave their southern Australian wintering grounds (Torres *et al.* 2013). Shipping movements are highest in the region used by the smaller and relatively depleted southeastern Australian subpopulation (DSEWPaC 2012a). Climate and oceanographic variability are known to affect foraging and subsequent reproductive success in southern right whales (Leaper *et al.* 2006, Pirzl *et al.* 2008), and habitat modelling indicates southward shifts and potential reduction in suitable foraging habitats in future, resulting from increased sea surface temperatures and altered oceanographic fronts (Torres *et al.* 2013). Other threats include increased port expansion and coastal development that may degrade coastal breeding and aggregation sites, which is particularly important for the smaller southeastern subpopulation, pollution, mortality from shooting, and increasing anthropogenic noise and acoustic disturbance from seismic surveys and other activities in southern Australian waters (Kemper *et al.* 2008, DSEWPaC 2012a, Woinarski *et al.* 2014).

Conservation and listing status

The southern right whale is listed as Endangered and as a cetacean species and as a migratory species under the EPBC Act, Threatened (Critically Endangered) in Victoria, Endangered in NSW and in Tasmania, Vulnerable in SA and in WA, and is not listed in Queensland (Woinarski *et al.* 2014). This species was recently assessed as Near Threatened in Australian waters (Woinarski *et al.* 2014), and was assessed as Vulnerable in the previous Australian status assessment (Bannister *et al.* 1996). Globally, the southern right whale was assessed as Least Concern for the IUCN Red List in 2008 (Reilly *et al.* 2008a).

Humpback whale *Megaptera novaeangliae* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Humpback whales have a cosmopolitan distribution encompassing all the major ocean basins of the world, but are absent from some equatorial regions, a few enclosed seas and some areas of the high Arctic region (Clapham and Mead 1999, Jefferson *et al.* 2008). They migrate from tropical winter breeding and calving grounds to colder productive high latitude summer feeding grounds, except for the Arabian Sea population that is resident year-round (Bannister 2008, Clapham 2009).

In the Australian region, humpback whales have an extensive distribution within Commonwealth, state and territory waters including some Australian Antarctic Territory waters and in the Southern Ocean south of Australia during summer (Bannister *et al.* 1996, Thiele *et al.* 2000, Kemper *et al.* 2005, Bannister 2008). Two migratory subpopulations occur in Australian waters; the eastern Australian subpopulation designated 'E1', and the western Australian subpopulation designated 'D' by the Scientific Committee of the IWC. E1 humpback whales breed and calves are subsequently born in tropical coastal shelf areas along the northern coast of eastern Australia with putative breeding grounds within the Great Barrier Reef lagoon and possibly in the Coral Sea (Bannister 2008, Gales *et al.* 2010, Smith *et al.* 2012b). The western Australian D subpopulation breeds along the north-west coast of WA in the Kimberley region (Jenner *et al.* 2001, Bannister 2008). Australian humpback whales migrate south along the east or west coasts to feed in summer in the productive waters of the Southern Ocean south of 55°S (Dawbin 1966, Thiele *et al.* 2000, Gales *et al.* 2010, Franklin *et al.* 2012). A low level of interchange occurs between the western and eastern Australian subpopulations (Noad *et al.* 2000, Anderson *et al.* 2010), and a few individuals have been recorded moving between eastern Australia E1 and the Oceania E2 subpopulation in the western South Pacific (Olavarría *et al.* 2007, Garrigue *et al.* 2011). The Australian distribution range of humpback whales overlaps completely with the SPF area.

Population size and trends

The abundance of humpback whales in Australian waters and globally has varied substantially over the past hundred years reflecting the severe depletion from whaling during the 1900s, and subsequent ongoing recovery of some populations (reviewed in Bannister 2008, Reilly *et al.* 2008b, Woinarski *et al.* 2014). Commercial pelagic and coastal whaling, exacerbated by illegal Soviet whaling during the 1900s, caused a 95 per cent reduction in humpback whale abundance, and resulted in extirpation of some subpopulations (Clapham *et al.* 2008). In the Southern Hemisphere, a total of 215,840 humpback whales were killed between 1904 to 1983 (Clapham and Baker 2009), including 48,721 whales taken by Soviet whalers, of which only 2710 were reported to the IWC (Ivashchenko *et al.* 2011).

Whaling over-exploitation caused the near extinction of the eastern Australian E1 subpopulation, which was possibly reduced to a few hundred whales from a pre-exploitation abundance estimated to be about 22,000–25,700 whales (Chittleborough 1965, Jackson *et al.* 2009). After whaling ceased, monitoring of E1 whales migrating along the coast of northern NSW and southern Queensland has shown increasing abundance since 1978 (e.g. Bryden *et al.* 1990, Paterson 1991, Paterson *et al.* 2001, Noad *et al.* 2008, Paton *et al.* 2011). Abundance in 2010 was estimated to be about 14,522 whales based on surveys at North Stradbroke Island, Queensland (Noad *et al.* 2011). The E1 subpopulation has continued to increase rapidly with annual rates of increase of 10.5–10.9 per cent from 1984 to 2010 (Paterson *et al.* 2004, Noad *et al.* 2011), which approach the maximum plausible rate of 11.8 per cent annual growth for humpback whale populations (Zerbini *et al.* 2010).

Similar patterns of whaling-induced decline and post-whaling increases in abundance are evident in the western Australian D subpopulation that has been monitored since 1963 from Shark Bay, WA. The pre-whaling abundance was estimated to be about 20,000 whales or higher, declining to fewer than 1000 whales by around 1963, then increasing since the mid-1970s (Bannister and Hedley 2001, Bannister 2008). Surveys off Shark Bay in 2008 provided a best-abundance estimate of 28,830 (Hedley *et al.* 2011). Surveys from North West Cape about 350 km north of Shark Bay provided estimates of this subpopulation D increasing from about 7276 whales in 2000 to about 26,100 whales in 2008 (Salgado Kent *et al.* 2012). This subpopulation is thought to be one of the largest subpopulations of humpback whales (Salgado Kent *et al.* 2012), and estimated rates of annual increase have ranged from 10.15 per cent for the period 1982–1994 (Bannister and Hedley 2001) to 9.7 per cent from 1999 to 2008 (Hedley *et al.* 2011).

Biology and feeding ecology

Humpback whales are distinguished from most other baleen whales by their relatively robust body shape and extremely long pectoral flippers that are about one-third of their body length. Adult females are usually 1–1.5 m longer than males, with reliable records of maximum adult lengths around 16–17 m, although sizes of 14–15 m are more typical (Clapham and Mead 1999, Clapham 2009). Maximum adult weight is about 40–45 t (Bannister 2008, Jefferson *et al.* 2008). Humpback whales are mostly solitary or occur in small groups, with larger groups temporarily forming in breeding and feeding areas (Clapham 2009).

Humpback whales are highly migratory and typically undertake long annual return migrations of up to 16,000 to 18,800 km (Rasmussen *et al.* 2007, Robbins *et al.* 2011) from summer feeding grounds in high-latitude cold productive waters to their winter breeding and calving grounds in warm subtropical and tropical waters (e.g. Chittleborough 1965, Clapham 2009, Burns *et al.* 2014, Constantine *et al.* 2014). Australian humpback whales migrate through the SPF area. Temporal segregation of different sex, maturational and reproductive classes of whales is evident during these annual migrations (Dawbin 1966, Clapham 2000, Franklin *et al.* 2011). The eastern Australian E1 subpopulation is thought to breed within the Great Barrier Reef lagoon region (Simmons and Marsh 1986, Gales *et al.* 2010, Smith *et al.* 2012b), but some whales may breed near Chesterfield Reef in the Coral Sea (Bannister 2008). Therefore, further research is needed to identify the key aggregation and breeding grounds for eastern Australian humpback whales. On their southern migration to Antarctic waters, large numbers of E1 whales aggregate in subtropical Hervey Bay, Queensland (Paterson 1991, Corkeron *et al.* 1994, Chaloupka *et al.* 1999, Franklin *et al.* 2011). Major aggregation and calving sites for western Australian D subpopulation whales include the southern Kimberley region between Broome and Camden Sound, with migratory aggregation and resting areas at Exmouth Gulf and Shark Bay and some locations further south (Bannister and Hedley 2001, Jenner *et al.* 2001, Bannister 2008).

Although some intermingling of whales from the western and eastern Australian subpopulations occurs on summer feeding grounds south of Australia, there is limited gene flow between these subpopulations and low levels of genetic differentiation (Anderson *et al.* 2010, Schmitt *et al.* 2014). Similarly, the low levels of interchange between E1 and Oceania E2 subpopulation in the western South Pacific results in limited gene flow (Olavarría *et al.* 2007, Garrigue *et al.* 2011).

After leaving Australian coastal waters these whales migrate to the highly productive Southern Ocean waters south of 55°S where they gorge feed on massive swarms of Antarctic krill that aggregate near the ice edge during summer (Chittleborough 1965, Bannister 2008, Gales *et al.* 2010, Constantine *et al.* 2014). Analyses of humpback whale catches off eastern and western Australia during the 1950s showed little evidence of local feeding by migrating whales, although a few whales had recently fed (Chittleborough 1965, Bannister 2008). Some opportunistic feeding on schools of small fish including sardines and coastal krill *Nyctiphanes australis* has been observed along the Australian coast, with feeding on small schooling fish regularly recorded off Eden in southern NSW (Bannister *et al.* 1996, Stockin and Burgess 2005, Stamation *et al.* 2007, Gales *et al.* 2009), which would supplement energy reserves during migration. Humpback whales in the Northern Hemisphere also feed on small schooling fish including herring, mackerel, sardines, anchovies and capelin (Clapham and Mead 1999). These whales are gulp feeders that engulf large volumes of seawater and prey via expanding ventral pleats to greatly increase their mouth capacity, and the prey are subsequently trapped on baleen plates as seawater is expelled from the mouth (Clapham 2009). Some individuals or groups of humpback whales use bubbles to form bubble nets or curtains to concentrate their fish prey (Clapham 2009).

Humpback whales have a broadly promiscuous and polygamous mating system (Clapham 2000). Sexual maturity occurs between 4–11 years of age, and breeding is highly seasonal with calves born between June and September, with peak births during August (Chittleborough 1965). Females usually give birth every two to three years, but can breed in successive years (Clapham 2000). Gestation is 11 to 12 months and lactation occurs for 10 to 12 months (Clapham and Mead 1999). Maximum longevity was initially estimated to be about 48 years but recent reanalysis of the data indicates longevity is about 96 years (Fleming and Jackson 2011). Generation length is estimated to be 21.5 years (Taylor *et al.* 2007).

Risks and threatening processes

Two humpback whales (one alive, one dead) were reported as incidental bycatch in trawl nets in the Atlantic region off the northeastern US (Fertl and Leatherwood 1997). Humpback whales are susceptible to entanglement in a range of fisheries gear including gillnets, shark nets, trap nets, ropes and lines, and these entanglements are known to occur in Australian waters and internationally and can lead to serious injury or mortality (reviewed in Paterson 1990, Shaughnessy *et al.* 2003, Johnson *et al.* 2005, Cassoff *et al.* 2011, Reeves *et al.* 2013). These whales are also known to be injured or killed from vessel collisions (Laist *et al.* 2001, Redfern *et al.* 2013), and their surface behaviour and relatively shallow dives while travelling increase the risk of vessel strike. The rapidly increasing abundance of humpback whales in Australian waters will result in increased numbers of these whales becoming entangled or injured from interaction with vessels in future. Other threats include increasing anthropogenic noise and acoustic disturbance from seismic surveys and other activities (McCauley and Cato 2003, Zirbel *et al.* 2011), increasing port expansion and coastal development and associated increased vessel traffic that may affect migration pathways, coastal aggregation and breeding sites (Bannister *et al.* 1996, Woinarski *et al.* 2014), pollution (Evans 2003), and increased disturbance from whale-watching activities (Department of the Environment and Heritage 2005). Climate and oceanographic variability and change could alter the distribution and abundance of krill and other prey resources and affect lower latitude migratory and breeding habitats, and resumption of large-scale whaling is a potential threat to the recovery of humpback whale populations (Woinarski *et al.* 2014).

Conservation and listing status

The humpback whale is listed as Vulnerable and as a cetacean species and as a migratory species under the EPBC Act, Endangered in Tasmania, Threatened (Vulnerable) in Victoria, Vulnerable in Queensland, NSW, SA and in WA, and Least Concern in the Northern Territory (Woinarski *et al.* 2014). This species was recently assessed as Least Concern in Australian waters (Woinarski *et al.* 2014), and was assessed as Vulnerable in the previous Australian status assessment (Bannister *et al.* 1996). Globally, the humpback whale was assessed as Least Concern for the IUCN Red List in 2008 (Reilly *et al.* 2008b).

Bryde's whale *Balaenoptera edeni* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Bryde's whales have a circumglobal distribution in tropical to temperate waters of the Pacific, Indian and Atlantic Oceans between latitudes 40°N and 40°S (Jefferson *et al.* 2008, Kato and Perrin 2009). They are unusual among balaenopterid whales in that they remain in tropical to warm-temperate waters where sea temperature is 16.3°C or warmer (Bannister 2008, Kato and Perrin 2009). In the Southern Hemisphere they may have a continuous distribution from eastern Australia to the central Pacific, and in the Indian Ocean their distribution extends west from WA (Kato and Perrin 2009). Distinct inshore and offshore forms of Bryde's whales are recorded in some regions, but the taxonomy and nomenclature of the 'Bryde's whale complex' is confused and the number of species or subspecies within this 'complex' is unclear (Best 2001, Reilly *et al.* 2008c, Kato and Perrin 2009).

In the Australian region, Bryde's whales have been recorded from all Australian state waters but there are no confirmed records from the Northern Territory (Bannister *et al.* 1996, Kemper *et al.* 2005, Arnold 2008). These whales are more likely to occur in warmer regions off the east and west coasts of Australia, particularly off Queensland and near the subtropical Abrolhos Islands and north of Shark Bay in WA, and are likely to be less abundant along the cooler southern Australian coast (Bannister *et al.* 1996, Bannister 2008). They have been observed in NSW near Byron Bay and in the Manning River, and from Scott Reef off northwestern Australia (Woinarski *et al.* 2014). There are 12 stranding records from southeastern Australia (Priddel and Wheeler 1997). In the Australian region, most individuals from the Indian Ocean conform to the larger 'ordinary' form of Bryde's whale, and three individuals from Victoria and one from WA are typical of *B. edeni* (Bannister *et al.* 1996, Bannister 2008). However, the identity of three individuals taken during whaling off WA and two off eastern Australia is uncertain, as they appear to be intermediate with other forms and may have been Omura's whales (Bannister 2008). The southern Australian distribution range of Bryde's whales overlaps partly with the SPF area.

Population size and trends

Bryde's whales are thought to be relatively uncommon off Australia but most records are from strandings, which may underestimate their abundance (Bannister 2008). There are no reliable estimates of population size or trends from Australian waters (Woinarski *et al.* 2014). Global abundance and the population trend of Bryde's whales are unknown, and estimates are complicated by the uncertain taxonomy, and whaling catch records that were combined with sei whales *Balaenoptera borealis* prior to 1972 (Reilly *et al.* 2008c). Whaling has reduced some populations, particularly in the western North Pacific (Reilly *et al.* 2008c). A total of 7881 Bryde's whales were taken in the Southern Hemisphere during the 1900s (Clapham and Baker 2009), including 1468 whales taken illegally by Soviet whalers, of which only 19 were reported to the IWC (Ivashchenko *et al.* 2011). Population estimates are available for some regions including about 10,000 in the Eastern Tropical Pacific and about 20,000 to 30,000 in the North Pacific but Southern Hemisphere populations have not been reassessed in recent decades (Reilly *et al.* 2008c, Jefferson *et al.* 2008).

Biology and feeding ecology

Female Bryde's whales are larger than males and may grow to about 16.5 m long while males grow to about 15.0 m, and maximum weight is about 40 t (Jefferson *et al.* 2008). Bryde's whales from the Southern Hemisphere are larger than those from the Northern Hemisphere, and the offshore pelagic form is larger than the smaller coastal form (Best 2001, Kato and Perrin 2009).

Migratory movements from higher latitudes in spring-summer toward equatorial regions in autumn-winter occur in some populations of the larger offshore pelagic form, but movement patterns of other Bryde's whales are poorly known (Best 2001, Reilly *et al.* 2008c, Kato and Perrin 2009). Genetic structure is evident within and between different ocean basins and hemispheres which indicates that these populations should be considered as separate management units (Kanda *et al.* 2007).

Bryde's whales feed mainly on pelagic schooling fishes, including anchovy, sardine, mackerel, pilchard and herring (Kato and Perrin 2009). They also feed opportunistically on some crustaceans including euphausiids, copepods, pelagic red crabs and on cephalopods (Best 2001, Kato and Perrin 2009). The inshore form appears to be more reliant on schooling fish whereas the offshore form may feed more on euphausiids, but they are also recorded to alter pelagic feeding from fish to euphausiids in different years (Best 2001, Bannister 2008, Kato and Perrin 2009). Bryde's whales lunge-feed on extensive schools of anchovies at Cape Cuvier in WA, and stomach contents of whales taken near the Western Australian coast contained large quantities of anchovies (Bannister 2008). These whales have also been observed feeding on large schools of small fish near Byron Bay, NSW and in other coastal locations (Arnold 2008, P. Beeman pers. comm. in Woinarski *et al.* 2014). Bryde's whales have also been observed using 'bubble net' feeding to concentrate prey (Kato and Perrin 2009). These whales are mostly solitary or occur in small groups, with larger groups of 10–20 whales observed on feeding grounds (Jefferson *et al.* 2008).

Breeding occurs over an extended season for the inshore form of Bryde's whales off South Africa, whereas offshore pelagic stocks have a winter peak in calving but their breeding grounds are largely unknown (Best 2001, Bannister 2008, Kato and Perrin 2009). Sexual maturity occurs at about seven years, and age at first reproduction is about eight to nine years (Kato and Perrin 2009). Gestation lasts for about 11–12 months, calves are weaned at about six months and the calving interval is about two years (Bannister 2008, Kato and Perrin 2009). Generation length is estimated to be about 18.4 years (Taylor *et al.* 2007).

Risks and threatening processes

Bryde's whales are occasionally recorded as bycatch in fisheries gear (Reilly *et al.* 2008c, Reeves *et al.* 2013), and one whale entangled in fishing gear around the mouth was considered to have probably died from impaired foraging and starvation over a long period (Cassoff *et al.* 2011). Anderson (2014) reviewed available information on baleen whales that are known to associate with oceanic tuna schools in the tropical Indian Ocean, and this association is used by purse seiners in the region to locate tuna schools. Although the whale species involved in these fishery interactions are uncertain in some areas, Anderson (2014) concluded that Bryde's whale are the main whale species involved with purse seine operations targeting tuna schools in the major fishing area east of the Seychelles. This species is also occasionally recorded to be injured or killed by vessel strike (Laist *et al.* 2001, Reilly *et al.* 2008c). Expansion of pelagic fisheries targeting schooling pelagic fishes such as anchovy, which is an important prey species for Bryde's whales, may increase direct and indirect interactions with these whales (Bannister *et al.* 1996, Elgin Associates unpublished (a)). Up to 50 Bryde's whales have been taken by Japanese whalers in the North Pacific Ocean under IWC Special Permit, and small numbers are taken by artisanal whalers in Indonesia (Jefferson *et al.* 2008). Other threats include increasing anthropogenic noise and acoustic disturbance, increasing port expansion and coastal development and associated increased vessel traffic (Bannister *et al.* 1996, Woinarski *et al.* 2014), and pollution (Evans 2003). Plastic and packaging film were found tightly packed in the stomach of a Bryde's whale that stranded and died near Cairns in Queensland (Arnold 2008).

Conservation and listing status

The Bryde's whale is listed as a cetacean species and as a migratory species under the EPBC Act, Data Deficient in Victoria and in the Northern Territory, Rare in SA, and is not listed in Queensland, NSW, Tasmania and WA (Woinarski *et al.* 2014). This species was recently assessed as Data Deficient in Australian waters (Woinarski *et al.* 2014), and was assessed as 'No category assigned but possibly secure' in the previous Australian status assessment (Bannister *et al.* 1996). Globally, the Bryde's whale was assessed as Data Deficient for the IUCN Red List in 2008 (Reilly *et al.* 2008c), and is listed in Appendix I of CITES.

Sei whale *Balaenoptera borealis* (Level 2 PSA Residual Risk – Medium)

Distribution and range

The sei whale has a cosmopolitan distribution and occurs in oceanic areas in all major ocean basins, but tends to be less common in shallower continental shelf seas (Jefferson *et al.* 2008, Horwood 2009). Two genetically different subspecies have been proposed, with *B. borealis schlegellii* occurring in the Southern Hemisphere including Australian waters (Rice 1998, Horwood 2009). Sei whales are thought to complete long annual seasonal migrations from subpolar summer feeding grounds to lower latitude winter breeding grounds but details of their migrations and locations of breeding grounds are largely unknown (Horwood 2009). In the Southern Hemisphere, sei whales mainly occur from 45–60°S during summer but some whales are recorded further south (Parker 1978, Thiele *et al.* 2004, Bannister 2008, Woinarski *et al.* 2014).

In the Australian region, sei whales are recorded from Australian Antarctic Territory waters and Commonwealth waters, with infrequent records off Tasmania, NSW, Queensland, the GAB and Western Australia (Parker 1978, Bannister *et al.* 1996, Thiele *et al.* 2000). A sei whale carcass was trawled from 113 m depth about 160 km offshore the Northern Territory (Chatto and Warneke 2000). Parker (1978) noted that sei whales were the most commonly observed whales during Australian National Antarctic Research Expedition voyages in the 1960s and 1970s. These whales are not commonly recorded near Australian mainland waters, but they are occasionally observed feeding in the Bonney Upwelling region in southern Australia during summer and autumn (Gill 2002, Miller *et al.* 2012). Sei whales including females with calves have been reported near the coast and 40 km south of Tasmania, and at 37°S, south of SA (Bannister 2008). Four sei whales were taken from mainland whaling stations between 1958–1963, and sei whales or Bryde's whales were commonly sighted by sperm whalers off Albany in WA during the 1900s (Bannister 2008). The Australian distribution range of sei whales overlaps completely with the SPF area.

Population size and trends

Sei whale population size and trends in Australian waters are unknown (Woinarski *et al.* 2014). Whaling significantly depleted sei whale populations in all regions and their global abundance is poorly known (Reilly *et al.* 2008d, Horwood 2009). A total of 203,843 sei whales were killed in the Southern Hemisphere last century (Clapham and Baker 2009), including 59,327 whales taken by Soviet whalers, of which only 33,001 were reported to the IWC (Ivashchenko *et al.* 2011). Global abundance was estimated to be about 130,000 in the 1930s and rapidly decreased during whaling in the 1960s to less than 20,000 in the 1970s (Reilly *et al.* 2008d). Whaling impacts were particularly severe in the Southern Hemisphere where sei whale abundance was estimated to have decreased by about 89 per cent from about 98,000 in 1930 down to about 11,000 in 2007 (Reilly *et al.* 2008d). This estimated severe decline corresponds to declining sightings and catches during the 1960s and 1970s (Parker 1978, Reilly *et al.* 2008d). The global population trend is unknown (Reilly *et al.* 2008d).

Biology and feeding ecology

Sei whales are sleek, streamlined whales that grow to almost 20 m but are more typically 15–17 m long, they weigh up to 20–45 t, and females are slightly larger than males (Jefferson *et al.* 2008, Horwood 2009). These whales mainly occur in offshore oceanic regions although some occur in coastal waters, and seasonal feeding and breeding cycles strongly influence their distribution and latitudinal movements (Horwood 2009).

Sei whales have greater flexibility in feeding techniques than other baleen whales and skim feed on copepods and amphipods in mid-latitudes using their relatively fine baleen fringes, whereas in higher latitude waters they lunge feed on Antarctic krill (Bannister 2008, Jefferson *et al.* 2008). These whales also lunge-feed on small schooling fish including sardines and anchovies, and feed on cephalopods when encountered (Jefferson *et al.* 2008, Horwood 2009). Sei whales are mostly solitary during migrations, but form small groups of two to five whales in warmer waters, with larger aggregations of 20–100 whales on feeding grounds (Horwood 2009).

Breeding occurs mainly in winter, and sei whales may occasionally hybridise with fin whales *Balaenoptera physalus* (Jefferson *et al.* 2008). Age at sexual maturity and age at first reproduction are estimated to be about 9–10 years (Taylor *et al.* 2007, Horwood 2009). Gestation lasts about 10–12 months, calves are weaned by six to nine months, and the mean calving interval is estimated to be about 2.5 years (Taylor *et al.* 2007, Jefferson *et al.* 2008). Longevity is estimated to be about 60 years (Bannister *et al.* 1996). Generation length is estimated to be 23.3 years (Taylor *et al.* 2007).

Risks and threatening processes

Two sei whales have been reported killed by vessel strike in the Northern Hemisphere (Laist *et al.* 2001, Reilly *et al.* 2008d). Sei whales have been reported entangled and drowned in fishing gear in coastal waters, and Japanese whalers in the North Pacific Ocean have an annual take of 100 whales under IWC Special Permit (Reilly *et al.* 2008d, Jefferson *et al.* 2008). Other threats include increasing anthropogenic noise and acoustic disturbance, habitat degradation, pollution, and climate and oceanographic variability and change (Bannister *et al.* 1996, Woinarski *et al.* 2014).

Conservation and listing status

The sei whale is listed as Vulnerable and as a cetacean species and as a migratory species under the EPBC Act, Vulnerable in SA and in WA, not Listed (Data Deficient) in Victoria, Data Deficient in the Northern Territory, and is not listed in Queensland, NSW and Tasmania (Woinarski *et al.* 2014). This species was recently assessed as Endangered in Australian waters (Woinarski *et al.* 2014), and was assessed as Vulnerable in the previous Australian status assessment (Bannister *et al.* 1996). Globally, the sei whale was assessed as Endangered for the IUCN Red List in 2008 (Reilly *et al.* 2008d), and is listed in Appendix I of CITES.

Fin whale *Balaenoptera physalus* (Level 2 PSA Residual Risk – Medium)

Distribution and range

The fin whale has a cosmopolitan distribution and occurs in all major ocean basins and some seas, but is uncommon or absent from equatorial and high latitude ice habitats (Jefferson *et al.* 2008, Aguilar 2009). Three subspecies are now recognised, with the subspecies *B. physalus quoyi* occurring in the Southern Hemisphere including Australian waters (Aguilar 2009, Committee on Taxonomy 2014). Fin whales in the Southern Hemisphere complete long annual seasonal migrations from higher latitude summer feeding grounds to lower latitude winter breeding grounds (Aguilar 2009), but more variable and complex movement patterns are evident in some regions of the Northern Hemisphere (Mizroch *et al.* 2009). In the Southern Hemisphere, fin whales mainly occur from 40–65°S during summer (Reilly *et al.* 2008e).

In the Australian region, fin whales occur within Commonwealth waters and most state waters, and from Australian Antarctic Territory waters (Bannister *et al.* 1996, Thiele *et al.* 2000, Bannister 2008). They are infrequently recorded in coastal areas around Australia (Bannister *et al.* 1996, Bannister 2008), but their calls have been recorded off WA during autumn and winter, and off southern Australia and sporadically off NSW (Gedamke *et al.* 2007, McCauley *et al.* 2000, R. McCauley pers. comm. in Woinarski *et al.* 2014). Fin whale calls have been recorded in Australian Antarctic Territory waters from January to February and April to June (Gedamke *et al.* 2007, Širović *et al.* 2009, Gedamke and Robinson 2010). Fin whales are occasionally sighted in the Bonney Upwelling region off Victoria in summer and autumn, including a female and calf in April 2000 (Gill 2002, Miller *et al.* 2012). The Australian distribution range of fin whales overlaps completely with the SPF area.

Population size and trends

Fin whale abundance and population trend in Australian waters are unknown (Woinarski *et al*. 2014). Globally, fin whales were very abundant prior to commercial whaling. Their estimated global abundance was about 400,000 whales in 1920, of which about 325,000 occurred in the Southern Hemisphere (Reilly *et al*. 2008e). A total of 725,331 fin whales were killed during commercial whaling last century in the Southern Hemisphere, which severely depleted the population by more than 70 per cent (Reilly *et al*. 2008e, Clapham and Baker 2009). More recently, 748 fin whales were recorded during the 2005–06 summer from the Antarctic region south of WA, with more than 100 whales sighted off the Ross Sea (Bannister 2008). Fin whales are relatively abundant in the North Pacific and North Atlantic, and global abundance may be about 140,000 (Jefferson *et al*. 2008). The global population trend is unknown, but some populations may be increasing following the cessation of whaling (Reilly *et al*. 2008e).

Biology and feeding ecology

Fin whales are the second-largest whale species and have a sleek and streamlined body (Jefferson *et al*. 2008). In the Southern Hemisphere females grow up to about 26–27 m and males to about 25 m, while fin whales in the Northern Hemisphere are less than 24 m (Jefferson *et al*. 2008, Aguilar 2009). The largest fin whales weigh up to 120 t, but most weigh less than 90 t (Jefferson *et al*. 2008).

Fin whales mostly occur in oceanic pelagic habitats and tend to aggregate in areas of high productivity, but commonly occur in coastal waters in some regions (Aguilar 2009). Around Australia, they are thought to occur mostly in deeper water habitats, with coastal records including a small number taken from mainland whaling stations and occasional stranding records (Bannister *et al*. 1996, Bannister 2008). Fin whales are mostly solitary or occur in small groups of up to seven whales, while larger groups of more than 100 whales may form during feeding (Bannister 2008). Fin whales sometimes form mixed feeding schools with blue whales *Balaenoptera musculus*, and the two species are known to occasionally interbreed (Aguilar 2009).

Fin whales lunge feed on dense swarms of crustaceans or small schooling fish by gulping large volumes of water and prey that become trapped on their baleen plates. Southern Hemisphere fin whales feed mainly on Antarctic krill *Euphausia superba and E. vallentini* and occasionally on other planktonic crustaceans (Bannister 2008, Aguilar 2009). In the Northern Hemisphere, they feed on euphausiids and other crustaceans, schooling fishes including herring, capelin *Mallotus villosus* and mackerel, and sometimes squid (Aguilar 2009). Dives range from 100–200 m depths with maximum depths of 500 m (Bannister 2008).

Breeding begins in late autumn and calving occurs mainly in winter (Mizroch *et al*. 2009). Females reach sexual maturity at about eight years with age at first reproduction estimated to be 9–10 years (Taylor *et al*. 2007, Reilly *et al*. 2008e). Gestation is about 10–11 months, weaning occurs after six to eight months, and the mean calving interval is about 2.2 years (Taylor *et al*. 2007, Bannister 2008). Longevity is estimated to be 90–100 years (Bannister *et al*. 1996). Generation length is estimated to be 25.9 years (Taylor *et al*. 2007).

Risks and threatening processes

Fin whales have been reported feeding behind a trawl codend (Fertl and Leatherwood 1997), and are occasionally recorded as bycatch in fishing gear (Reilly *et al*. 2008e, Zollett 2009, Reeves *et al*. 2013). Fin whales are one of the most commonly recorded large whale species involved with vessel collisions and vessel strike is known to cause injury and deaths, particularly in the Mediterranean fin whale population (Laist *et al*. 2001, Reilly *et al*. 2008e, Redfern *et al*. 2013). A small number of fin whales were taken by Japanese whalers under IWC Special Permit in the Antarctic region (Clapham and Baker 2009). Other threats include increasing anthropogenic noise and acoustic disturbance, habitat degradation, pollution, and climate and oceanographic variability and change (Bannister *et al*. 1996, Woinarski *et al*. 2014).

Conservation and listing status

The fin whale is listed as Vulnerable and as a cetacean species and as a migratory species under the EPBC Act, Vulnerable in Tasmania, SA and in WA, not listed (Data Deficient) in Victoria, and is not listed in NSW and Queensland (Woinarski *et al*. 2014). This species was recently assessed as Endangered in Australian waters (Woinarski *et al*. 2014), and was assessed as Vulnerable in the previous Australian status assessment (Bannister *et al*. 1996). Globally, the fin whale was assessed as Endangered for the IUCN Red List in 2008 (Reilly *et al*. 2008e), and is listed in Appendix I of CITES.

Blue whale *Balaenoptera musculus* (Level 2 PSA Residual Risk – Medium)

Distribution and range

Blue whales have a cosmopolitan distribution and are recorded from all oceans except the Arctic, with separate populations in the Southern Hemisphere, North Pacific and North Atlantic oceans (Reilly *et al.* 2008f, Bannister 2008, Jefferson *et al.* 2008). Four blue whale subspecies are recognised, with two subspecies occurring in Australian waters and elsewhere in the Southern Hemisphere: the Antarctic blue whale *B. musculus intermedia*, and the pygmy blue whale *B. musculus brevicauda* (Rice 1998, Bannister 2008, Committee on Taxonomy 2014). These two subspecies have different morphology, distribution, genetics, reproductive characteristics and vocal behaviours (e.g. Branch *et al.* 2007, 2009, Attard *et al.* 2010, McCauley and Jenner 2010).

Antarctic blue whales have a circumpolar distribution in the Southern Hemisphere and during summer they occur in Antarctic feeding grounds from the pack ice zone northward to the Antarctic Convergence around 52–56°S (Branch *et al.* 2007; Samaran *et al.* 2010). They are thought to migrate to lower latitude areas in winter but some remain in Antarctic waters over winter (Bannister *et al.* 1996, Stafford *et al.* 2004, Branch *et al.* 2007, Širović *et al.* 2009). Pygmy blue whales occur in the Indian Ocean and Southern Ocean from the Madagascar Plateau to WA and across southern Australia to Tasmania, with northward migrations to lower latitude regions including Indonesia (Branch *et al.* 2007, Gales *et al.* 2010, Double *et al.* 2014). Pygmy blue whales occur mainly at latitudes north of 54°S during the summer feeding season although some occur further south off Antarctica at latitudes 65–69°S (Branch *et al.* 2007, Attard *et al.* 2012).

In the Australian region, blue whales have been recorded from all state and Northern Territory waters, Australian Antarctic Territory waters and in the Southern Ocean south of Australia (e.g. Bannister *et al.* 1996, Thiele *et al.* 2000, Gill 2002, Bannister 2008, Širović *et al.* 2009). Antarctic blue whales occur in Australian Antarctic Territory waters during the summer feeding season and can undertake extensive movements (Thiele *et al.* 2000, Gedamke and Robinson 2010, Double *et al.* 2013). Some of these whales subsequently migrate to lower latitude winter breeding grounds in the Indian and Pacific oceans, but these breeding grounds are not yet well defined (Stafford *et al.* 2004, Branch *et al.* 2007). Antarctic blue whales have been recorded off Tasmania and at Cape Leeuwin, Geographe Bay and Perth Canyon off WA mainly from May to November, hence these areas may represent important migratory or breeding habitats (Stafford *et al.* 2004, Gedamke *et al.* 2007).

Feeding aggregations of pygmy blue whales occur mainly from November to May in the Bonney Upwelling off Victoria and SA, and in the Perth Canyon off WA (Gill 2002, Rennie *et al.* 2009, Gill *et al.* 2011, Miller *et al.* 2012, Double *et al.* 2014). Genetic analysis indicates that these whales are part of the same breeding subpopulation (Attard *et al.* 2010). Pygmy blue whales also migrate along the coast of Western Australia and some satellite tagged whales migrated north across the Timor Sea and into the Banda Sea and Molucca Sea regions in Indonesian waters (McCauley and Jenner 2010, Gales *et al.* 2010, Double *et al.* 2012, 2014). Pygmy blue whales also occur along the east coast of Australia but their migration routes are not known (McCauley and Jenner 2010). 'Tasman-Pacific' type pygmy blue whale calls have been regularly detected along the east coast and this subpopulation may use the Tasman Sea area over an extended period or year-round (McCauley *et al.* 2013). The Australian distribution range of blue whales overlaps completely with the SPF area.

Population size and trends

The total abundance of blue whales and the abundance of the subspecies in Australian waters are unknown (Woinarski *et al.* 2014). Prior to commercial whaling in 1904, blue whales were very abundant in the Southern Hemisphere. Total global whaling catches of blue whales last century are estimated to have been 382,595 (Branch *et al.* 2008), with 362,770 killed in the Southern Hemisphere from 1904–1973 (Clapham and Baker 2009). Soviet whalers killed 13,035 Antarctic and pygmy blue whales in the Antarctic from the 1950s to the early 1970s but only 3651 of these were reported to the IWC (Ivashchenko *et al.* 2011). The global abundance of blue whales is uncertain but is thought to be in the range 10,000–25,000, and the population trend is increasing (Reilly *et al.* 2008f).

The pre-whaling abundance of Antarctic blue whales in the Southern Hemisphere was estimated to be about 239,000, but these whales were severely overexploited, down to 0.15 per cent of this abundance resulting in only about 360 whales estimated to remain in 1973 (Branch *et al.* 2004). Antarctic blue whales were estimated to have increased to about 2280 by 1996, increasing at about 7.3 per cent per year (Branch *et al.* 2004, 2007). The abundance of pygmy blue whales is uncertain. Their pre-whaling abundance was likely to be an order of magnitude lower than for the Antarctic blue whale, and they may have been less depleted by whaling (Branch *et al.* 2007). The estimated abundance of pygmy blue whales from the Perth Canyon during surveys in 2000 to 2005 was 532–1754 whales (Jenner *et al.* 2008).

Biology and feeding ecology

Blue whales are the largest animals ever known to occur, and despite their huge size they have a relatively slender and streamlined body (Jefferson *et al.* 2008). Southern Hemisphere whales are a larger average size than those in the Northern Hemisphere, and females are larger than males (Sears and Perrin 2009). The largest blue whales recorded were 31.7–32.6 m, and the maximum recorded weight was about 190 t female, but adults mostly range from 50–150 t (Sears and Perrin 2009).

Blue whales are highly mobile and migratory, with one satellite-tagged Antarctic blue whale tracked moving over 5300 km in the Southern Ocean and Australian Antarctic Territory waters over 74 days (Andrews-Goff *et al.* 2013). They mostly occur in deeper water pelagic habitats with high productivity and zooplankton densities in the Antarctic and subantarctic regions during the austral summer, and along oceanographic fronts and in upwelling areas (Branch *et al.* 2007, Rennie *et al.* 2009). Many blue whales subsequently migrate to lower latitude putative feeding, breeding and calving grounds during the austral winter, but these are currently poorly defined and some blue whales may not migrate each year (Branch *et al.* 2007, Širović *et al.* 2009). At lower latitudes these whales aggregate in deeper waters along continental margins, and in some shallower habitats in the Bonney Upwelling off southern Australia and in Geographe Bay, WA (Branch *et al.* 2007, Gill *et al.* 2011). The pygmy blue whale subpopulation that occurs in southern Australian waters migrates north along WA to Indonesia, and the Banda and Molucca Seas region may be a calving and breeding area for this subpopulation (Branch *et al.* 2007, McCauley and Jenner 2010, Gales *et al.* 2010, Attard *et al.* 2010, Double *et al.* 2012, 2014). Recent genetic analyses of Antarctic blue whale biopsy samples have shown significant population structure among the six Antarctic management areas designated by the IWC that may result from some degree of female fidelity to Antarctic feeding grounds, and reflect the distribution and abundance of krill (Sremba *et al.* 2012).

Blue whales feed almost exclusively on krill, and use lunge feeding to engulf large swarms near the surface or by diving to 100 m or deeper (Sears and Perrin 2009). Antarctic blue whales in Antarctic waters feed primarily on Antarctic krill, and feed on other *Euphausia* species at lower latitudes (Branch *et al.* 2007, Bannister 2008a, Samaran *et al.* 2010). Pygmy blue whales feed on smaller *Nyctiphanes australis* euphausiids in southern Australian waters (Gill 2002), and deep water *Euphausia recurva* in the Perth Canyon at depths of 200–300 m (Rennie *et al.* 2009).

Female Antarctic blue and pygmy blue whales reach sexual maturity at about 10 years of age (Branch 2008), and age at first reproduction is about 11 years (Taylor *et al.* 2007). Antarctic blue whales breed in June to July, gestation extends for 10–11 months, and pregnant females calve in April to May the following year (Branch 2008). Mean calving interval is about 2.5–2.6 years (Taylor *et al.* 2007, Branch 2008). Lifetime ovulation rate for Pygmy Blue whales average 7.6, which is significantly lower than for Antarctic blue whales which average 13.6; these rates indicate that pygmy blue whales may recover more slowly from whaling impacts (Branch *et al.* 2009). Maximum longevity is estimated to be at least 80–90 years but is likely to be longer (Sears and Perrin 2009). Generation length has been estimated to be 30.8 years (Taylor *et al.* 2007). These life history characteristics result in a relatively low reproductive rate resulting in a slow capacity for recovery from the massive over-exploitation from whaling last century (Woinarski *et al.* 2014).

Risks and threatening processes

There are few reports of lethal entanglements of blue whales, but 12 per cent of blue whales in eastern Canadian waters have scars indicating that they had made contact with fishing gear (Sears and Perrin 2009). Their large size and power may enable most blue whales to tear through fishing gear if contact occurs (Sears and Perrin 2009). Vessel strike is known to cause injury and in some cases death of blue whales (Laist *et al.* 2001, Redfern *et al.* 2013), and shipping movements are increasing in Australian waters used by these whales. At least 25 per cent of identified blue whales in the St. Lawrence area have scars from vessel collisions including whale-watching vessels, and scars from vessel strikes are known from other regions particularly in areas of heavy shipping traffic (Sears and Perrin 2009). Blue whales are also recorded to react strongly to approaching vessels, hence increased noise and disturbance from vessel traffic is a threat to recovering populations (Sears and Perrin 2009, Double *et al.* 2014). Other forms of anthropogenic noise including military active sonar

(Goldbogen *et al*. 2013) and seismic surveys (Di Iorio and Clark 2010) that can cause disturbance and avoidance behavior in blue whales, and disturbance from seismic surveys may be important in pygmy blue whale habitats in southern Australia (Gill *et al*. 2011, Double *et al*. 2014). Persistent pollutants may affect the health status of blue whales, and PCBs are commonly found in whales from eastern Canadian waters (Sears and Perrin 2009). Climate and oceanographic variability and change are likely to alter sea-ice habitats (Nicol *et al*. 2008) and other environmental conditions in the Southern Ocean and other important habitats for blue whales, and may alter the distribution and availability of essential krill prey resources (Atkinson *et al*. 2004, Flores *et al*. 2012, Woinarski *et al*. 2014).

Conservation and listing status

The blue whale is listed as Endangered and as a cetacean species and as a migratory species under the EPBC Act, Threatened (Critically Endangered) in Victoria, Endangered in NSW, Tasmania, SA and in WA, Data Deficient in the Northern Territory, and is not listed in Queensland (Woinarski *et al*. 2014). This species was recently assessed as Endangered in Australian waters (Woinarski *et al*. 2014). In the previous Australian status assessment by Bannister *et al*. (1996) the conservation status of the full blue whale species was not assessed; the 'true' blue whale *B. m. musculus* (Antarctic blue whale) was assessed as Endangered and the 'pygmy' blue whale was assessed as 'No category assigned because of insufficient information'. Globally, the blue whale was assessed as Endangered for the IUCN Red List in 2008 (Reilly *et al*. 2008f), and is listed in Appendix I of CITES.

Summary: mysticete whale species at risk from direct interactions with mid-water trawls in the SPF

- *The six baleen whale species described above have different distribution ranges and these overlap extensively or completely with the SPF area. Five of these species are listed as threatened species and are therefore matters of national environmental significance requiring a high level of protection under the EPBC Act. Southern right whales and blue whales are listed as Endangered, while fin, sei and humpback whales are listed as Vulnerable.*
- *The six whale species exhibit different biological and ecological characteristics, and their abundance and the extent to which populations are recovering following significant depletion from whaling, varies. Their diet and life history traits, and the nature and extent of potential interactions with fisheries operations also differ between species. Bryde's whales feed mainly on small pelagic schooling fishes, while fin, sei and humpback whales feed mainly on crustaceans but also feed on small pelagic fish species to varying degrees.*
- *Humpback whale abundance is increasing rapidly and the southwest subpopulation of southern right whales is also increasing, hence there is increased risk of vessel strike and other interactions such as entanglement in fishing gear for these species within the SPF area. Vessel strike has also been recorded for the other whale species, particularly for fin whales. Entanglement or bycatch in various types of fishing gear has been reported for all six whale species. Occasional incidental bycatch in trawl nets and other fishing gear has been reported for humpback, fin and Bryde's whales, and fin whales have been reported feeding behind a trawl codend. Therefore these whale species have a wide range of known and potential interactions with mid-water trawl and other fisheries.*

5.3.2 Nature and extent of interactions

The nature of interactions and likelihood of cetaceans directly interacting with the mid-water trawl sector of the SPF vary significantly among the 21 species reviewed in Section 5.3.1. Many of the smaller odontocete cetaceans are known to interact with trawl nets and other fishing gear leading to entanglement and bycatch, and are at some risk from vessel collision and other anthropogenic threats including acoustic disturbance. The seven great whale species (southern right, humpback, Bryde's, sei, fin and blue whale mysticete species, and the odontocete sperm whale species) are at risk from trawlers and other vessels from collisions and from other anthropogenic threats including acoustic disturbance, and some of these whale species interact with trawl nets and are at risk from entanglement and bycatch in fishing gear. Some cetacean species in the SPF area feed on small pelagic fish species, which increases the potential for interactions. Short-beaked common dolphins and *Tursiops* spp. bottlenose dolphins are at higher risk as they have been recorded to interact extensively with trawl fisheries in Australian waters and internationally. Furthermore, common bottlenose dolphins and possibly short-beaked common dolphins have been recorded as bycatch in mid-water trawls in the SPF (Lyle and Willcox 2008). Three common dolphins were recorded as bycatch in the GHAT sector of the SESSF during 2009 and 2010 (Tuck *et* *al*. 2013). Eighty dolphins were reported as bycatch mortality interactions (with another four dolphins reported alive) in the GHAT sector of the SESSF during the three seasons from May 2011 to April 2013 (AFMA 2013f, 2014d). Analysis of 40 of the dolphin mortalities indicated that 38 were common dolphins and two were bottlenose dolphins (AFMA 2013f). Hundreds of short-beaked common dolphins are estimated to have died in purse seine fisheries targeting small pelagic fish species in the SASF (Hamer *et al*. 2008).

Tuck *et al*. (2013) reviewed the available information on fisheries bycatch in key Commonwealth fisheries including the mid-water trawl sector of the SPF for the period 2001–2010. Reported marine mammal interactions with mid-water trawls in the SPF during this period comprised of 184 reported pinniped interactions (refer to Section 5.2.2), and 25 reported dolphin mortalities in mid-water trawls during 2001–2009. At the commencement of the mid-water trawl operations in late 2002, a 'soft' rope-mesh SED was used and there was a high level of observer coverage (Lyle and Willcox 2008). In October 2004, 14 short-beaked common dolphins or common bottlenose dolphins (species not confirmed) died in two separate mid-water trawl tows to the east of Flinders Island, and in November 2004 three common bottlenose dolphins died in a tow about 150 nm further south (Lyle and Willcox 2008, Tuck *et al*. 2013). In April 2005, one unidentified dolphin was killed in a tow off eastern Tasmania, and in May 2005 seven unidentified dolphins were killed in tows in this region (Lyle and Willcox 2008, Tuck *et al*. 2013).

Tuck *et al*. (2013) noted that there had been no reported incidental interactions with dolphins and mid-water trawls in the SPF since June 2005, after the introduction of bycatch management measures. Furthermore, no interactions with cetaceans have been reported with mid-water trawl gear in the SPF since that time (AFMA 2014c). The absence of reported interactions with cetaceans and other TEPS coincided with a reduction in fishing effort in the SPF fishery, a decline in observer coverage to less than 13 per cent of observed shots since 2007, no observer coverage and little or no fishing in 2010 and 2011, and no mid-water trawl fishery catches in 2011 (Moore and Skirtun 2012, Tuck *et al*. 2013). Tuck *et al*. (2013) concluded "overall bycatch levels are difficult to estimate, given a decline in on-board observer coverage on mid-water trawls since 2007 which coincides with a reduction in effort in the fishery".

However, these limited bycatch mortality records from mid-water trawls in the SPF understate the nature and extent of interactions with cetaceans, as they do not include the full range of direct interactions that may have occurred (or could occur in future) between cetaceans and the mid-water trawl sector of the SPF. Tuck *et al*. (2013) reported on bycatch interactions for some cetacean species but other cetacean species are known to occur in this SPF area and may have been observed during fishing operations. As noted in section 2.2.2 the definition of 'direct interactions' with protected species used by the panel for this assessment, and which are directly relevant to assessing the nature and extent of interactions with cetaceans, includes any interactions with fishing operations or gear (including net feeding); any physical contact (including collisions); bycatch which can result in injury or mortality; acoustic disturbance from fishing operations; and any behavioural changes in these species brought about by habituation to fishing operations. Therefore, for the purposes of this assessment all of these direct interactions are discussed below.

Interactions with fishing operations or gear including net feeding

The frequency and risks of interactions between cetaceans and fishing operations in the SPF are uncertain, but cetaceans that prey on small pelagic fish such as common and bottlenose dolphins are more likely to interact with the mid-water trawl sector of the SPF. Interactions with fishing operations and gear are likely to mostly occur underwater and will be largely undetected unless some form of underwater monitoring and reviewable recordings are made. Feeding within and near trawl nets has been recorded for a range of cetacean species including short-beaked common dolphins and bottlenose dolphins in trawl fisheries in Australian waters and internationally (e.g. Corkeron *et al*. 1990, Broadhurst 1998, Jaiteh *et al*. 2013, Elgin Associates unpublished (a)), which increases the risk of bycatch. Common bottlenose dolphins are the cetaceans most often documented feeding in association with trawlers worldwide (Fertl and Leatherwood 1997, Broadhurst 1998). The mortality of dolphins recorded in mid-water trawls in the SPF probably resulted from these dolphins feeding in association with the trawl operations and may have occurred from feeding within the trawl nets, but the exact nature of the interactions leading up to the death of these dolphins is unknown. Underwater recording of numerous mid-water trawls in the SPF in 2005 did not coincide with any recorded dolphin interactions (Lyle and Willcox 2008) therefore dolphin behaviour and feeding positions during interactions with mid-water trawls in the SPF are unknown. Lyle and Willcox (2008) concluded that cetacean interactions with fishing activities in the SPF are relatively uncommon and unpredictable.

Four types of cetacean feeding patterns in association with trawlers have been reported. The majority of cetaceans that interact with trawlers are reported to forage behind trawl nets, cetaceans may enter trawl nets to feed, some cetaceans feed on discards or on fish that escape or fall from the net, and some cetaceans feed on prey that are attracted to fishing vessels (Corkeron *et al*. 1990, Fertl and Leatherwood 1997, Broadhurst 1998, Northridge *et al*. 2005, Jaiteh *et al*. 2013).

Physical contact including collisions

Direct interactions include physical contacts and collisions with cetaceans, but the risk of trawlers in the SPF colliding with and injuring cetaceans is uncertain. Another area of uncertainty arises from the extent of injuries resulting from collisions, as collisions can result in deep trauma to tissues and organs that may not be obvious externally (Laist *et al*. 2001, Moore *et al*. 2013). Many collisions of vessels with cetaceans go undetected, and this is more likely for larger vessels and ships such as the type proposed for use in the DCFA. Most severe or fatal injuries to whales are caused by ships that are 80 m or longer and involve vessels travelling 14–15 kilometres per hour or faster, where whales are usually not seen or are sometimes seen too late to be avoided (Laist *et al*. 2001, Vanderlaan and Taggart 2007). Smaller cetacean species are considered to be more at risk of vessel strike from small, fast vessels (Silber *et al*. 2009, Redfern *et al*. 2013).

Eleven whale species are known to be hit by ships, and of these, fin whales are struck most frequently, with right whales, humpback whales and sperm whales also commonly hit (Laist *et al*. 2001, Vanderlaan and Taggart 2007, Redfern *et al*. 2013). Ship strikes are a significant threat to small, depleted whale populations such as Northern Hemisphere right whales, and to fin and sperm whales in the Mediterranean Sea and Black Sea (Vanderlaan and Taggart 2007, Notarbartolo di Sciari and Birkun 2010). Populations of humpback whales, southern right whales and some other great whale species are increasing in Australian waters (reviewed in Bannister 2008, Woinarski *et al*. 2014) and many of these whales migrate into or through southern Australian waters in the SPF area, hence the incidence of vessel strike in this region is likely to increase in future. Vessel strikes are thought to be relatively common in Australian waters but are not well documented (Bannister *et al*. 1996, Ross 2006). Southern right whale mortalities from vessel collisions have been recorded in southern Australian waters (Kemper *et al*. 2008), and collisions with vessels and entanglement in fishing gear are regarded as the current main direct threats to humpback whales (Fleming and Jackson 2011). Blue whales are also reported to be injured and in some cases killed by collisions from ships in Australian waters, and surface feeding on krill swarms in upwelling areas such as the Bonney Upwelling increases the risk of vessel strike for these and other whale species that occur in this region (Gill 2002, Miller *et al*. 2012).

Bycatch injury or mortality

Entanglement, injury and fisheries bycatch mortality is the major threat to many smaller cetacean species in Australian waters and internationally, particularly from purse seine, gillnet and trawl fishing, and from discarded fisheries gear (reviewed in Shaughnessy *et al*. 2003, Zollett and Rosenberg 2005, Read *et al*. 2006, Zollett 2009, Reeves *et al*. 2013, Anderson 2014). Cetacean bycatch rates have been substantially reduced in some fisheries in recent decades, but there is potential for increased frequency and intensity of interactions and bycatch mortality as human populations and fisheries operations increase (e.g. Hall *et al*. 2000, Read *et al*. 2006, Stephenson *et al*. 2008, Allen *et al*. 2014). Globally, gillnets are a major threat to cetaceans with 75 per cent of odontocete species and 64 per cent of mysticete species plus many other groups of marine mammals recorded as bycatch in gillnets in the past two decades (reviewed in Reeves *et al*. 2013, Geijer and Read 2013). Longline fisheries are also a major threat to many odontocetes with 20 species recorded as bycatch from 1964 to 2010 (Hamer *et al*. 2012). Purse seine fishing has been the major cause of dolphin bycatch internationally (e.g. Gerrodette and Forcada 2005), and significant bycatch of short-beaked common dolphins has been recorded in the SASF (Hamer *et al*. 2008).

Globally, 25 cetacean species (23 odontocete and two mysticete) species have been recorded as bycatch mortality in working trawls or in discarded trawling gear (reviewed in Fertl and Leatherwood 1997, Zollett and Rosenberg 2005). Bycatch has been recorded in nearly all areas where trawling occurs including in waters around Australia and off New Zealand (Fertl and Leatherwood 1997). The risk of bycatch varies among cetacean species depending upon a range of factors including whether the cetaceans target prey species in feeding grounds that are also used by fisheries, the types of prey species and fisheries activities involved, and intersection of fishing zones with migratory pathways or habitats regularly used by cetaceans (Couperus 1997). Environmental and operational activities are important factors influencing bycatch including seasonal changes in prey availability, habitat and proximity to the continental shelf edge, vessel and net size, trawl tow speed and duration, trawl depth, diurnal trawling patterns, and whether single vessel or pair trawling is used (Couperus 1997, Zollett and Rosenberg 2005, Zeeberg *et al*. 2006, Fernández-Contreras *et al*. 2010, Elgin Associates unpublished (a)). The species of cetaceans present and their abundance and behaviour are also important, with different age classes and sexes likely to interact in different ways with trawls, with higher mortality of juveniles reported in some trawls indicating that inexperience may increase the risk of bycatch (e.g. Fertl and Leatherwood 1997, Chilvers and Corkeron 2001).

In New Zealand waters the primary threat to the endemic Hector's dolphin *Cephalorhynchus hectori* is from bycatch mortality in gillnet and trawl fisheries (Slooten *et al*. 2006, Slooten 2007, Slooten and Dawson 2010, Slooten 2013). Mid-water and bottom trawling for jack mackerel also results in bycatch of common dolphins in New Zealand waters and both trawl effort and dolphin captures have increased in recent decades (Thompson and Abraham 2009, Thompson *et al*. 2013). The jack mackerel trawl fishery off the west coast of the North Island was responsible for 91 per cent of observed dolphin mortalities in trawl fisheries from 1995 to 2007, and headline depth was the variable that explained most of the dolphin bycatch (Thompson and Abraham 2009). Other explanatory variables were trawl duration, light conditions, diurnal patterns and geographic location (Thompson and Abraham 2009).

In the SPF the 25 records of bycatch mortality of dolphins in mid-water trawls during 2004–05 are indicative of the bycatch problem (Lyle and Willcox 2008, Tuck *et al*. 2013), but do not provide sufficient information to determine the likely full extent of injury and bycatch mortality. This uncertainty arises from various related issues. Cetaceans that are injured from interactions with mid-water trawls but escape or are not caught in nets are largely undetected, and in some cases injuries may impair health status leading to subsequent unrecorded mortality. Where lethal interactions occur, some dead cetaceans may drop out of nets (particularly in bottom opening excluder devices e.g. Allen *et al*. 2014), which represents another form of undetected cryptic mortality. Where dead cetaceans are observed in nets, identity of the species may not be recorded or may be uncertain (as in most of the dolphin bycatch records from mid-water trawls in the SPF, see Lyle and Willcox 2008, Tuck *et al*. 2013). In some cases, cetacean mortality may be under-reported by fishers resulting in lower estimates of bycatch mortality from logbooks compared with independent observer records (e.g. Stephenson *et al*. 2008, Allen *et al*. 2014).

Of relevance to the DCFA, cetaceans are more often caught in mid-water trawls than in bottom trawls (Crespo *et al*. 1997, Fertl and Leatherwood 1997, Hall *et al*. 2000), and this may occur because:

- small pelagic fish species are important prey items for some groups of cetaceans and mid-water trawls are used to target these fish
- mid-water trawl gear is generally towed at relatively high speeds
- mid-water trawl nets are generally much larger than most demersal trawls
- mid-water trawl nets often operate for extended periods within the normal diving depth of cetaceans, hence where the trawl time exceeds the breath-holding capacity, individuals caught in the net drown (Zollett and Rosenberg 2005, Elgin Associates unpublished (b)).

Pair trawling is a relatively high-risk trawling technique and accounts for about half of the cetacean bycatch in waters off New Zealand (Fertl and Leatherwood 1997, Thompson *et al*. 2013). Pair trawlers tend to tow nets faster than single trawlers, and the nets have higher headlines and greater overall dimensions (Fertl and Leatherwood 1997). The introduction of large freezer/factory industrial fishing vessels and other improvements in fishing technology have enabled the expansion of trawl fisheries (Crespo *et al*. 1997, Zeeberg *et al*. 2006). These vessels fish with larger gear, for longer and often farther offshore, which increases the likelihood of interactions with cetaceans (Crespo *et al*. 1997, Reeves *et al*. 2003, Zollett and Rosenberg 2005). Nets with a larger circumference have a larger net opening and the greater extension of their bridles and doors may cause a significant herding effect for cetaceans and other large marine predators (Zeeberg *et al*. 2006).

Cetacean mortality in trawl nets can occur when nets are shot, during trawling, or when the vessel stops hauling and the trawl entrance collapses (haulback) trapping animals (Fertl and Leatherwood 1997). Long haul times also increase the risk of cetacean bycatch mortality in trawl nets (Du Fresne *et al*. 2007). Dolphins can get their rostrum caught in the net while attempting to extract fish, they can drown when their tail stock is caught in the hanging line of the trawl and have also been caught in turtle exclusion and cetacean excluder devices (Fertl and Leatherwood 1997, Stephenson *et al*. 2008). Where fish pumps are used to empty the catch from the net, cetacean bycatch is often not observed because the ability of the observer to record marine mammal catches is compromised (Morizur *et al*. 1999, Zollett and Rosenberg 2005), particularly where the final emptying of the codend occurs at night (Ross and Isaac 2004).

Discarded trawl nets contribute significantly to marine debris and cetaceans and other marine animals are caught in discarded nets resulting in 'ghost netting' (Fertl and Leatherwood 1997, Reeves *et al*. 2003). Trawl netting may also be ingested by some cetaceans (Fertl and Leatherwood 1997). Fishers often use a technique termed 'cutting out' of living entangled animals from fishing nets, resulting in these animals being released while still entangled. Mortalities occur from drowning after release or from a prolonged demise resulting from impaired foraging, increased drag, emaciation, infection, haemorrhage and severe tissue damage leading to death (Cassoff *et al*. 2011, Moore *et al*. 2013). Larger whales entangled in fixed trap and net gear can undergo a very slow demise, averaging six months in entangled North Atlantic right whales *Eubalaena glacialis*, but sometimes extending over several years (Moore and van der Hoop 2012). Similarly, entanglement in fishing gear is known to cause chronic injury, debilitation and death of southern right whales in Australian waters (Kemper *et al*. 2008). In the North Atlantic region between 1980 and 2004, aerial surveys detected that at least 73 per cent of 493 large whales sighted were currently entangled or had been entangled in fishing gear at least once previously (Moore and van der Hoop 2012). In humpback whale populations in the Northern Hemisphere, at least 50 per cent or more of the identified animals have scarring indicating previous entanglement in fisheries gear (Robbins and Mattila 2004, Johnson *et al*. 2005, Fleming and Jackson 2011). In Australian waters, cetacean species recorded entangled in marine debris include bottlenose dolphins, common dolphins, humpback whales and southern right whales (Shaughnessy *et al*. 2003, Kemper *et al*. 2008).

Acoustic disturbance

Acoustic disturbance from anthropogenic activities can be particularly important for cetaceans because their acoustic sense is very highly developed and therefore sounds are vitally important to their ecology and survival (McCauley and Cato 2003, Jefferson *et al*. 2008, Jensen *et al*. 2009). Sound-induced effects vary from no discernible effect; adverse effects on prey; masking of signals; various behavioural responses; temporary threshold shifts in hearing ability; permanent threshold shifts or, in extreme cases, direct damage to hearing or other organs (McCauley and Cato 2003, Nowacek *et al*. 2007, Zirbel *et al*. 2009). Heavy vessel traffic, seismic testing, drilling and pile driving, dredging and naval sonar can lead to increased underwater noise disturbance and can reduce habitat quality for cetaceans, particularly in areas important for feeding, breeding, calving or resting (Nowacek *et al*. 2007, Zirbel *et al*. 2009). The effect of most anthropogenic noise on cetaceans is uncertain or unknown (McCauley and Cato 2003), hence the effects of trawler and other fishing activities on cetaceans in the vicinity is difficult to determine (Reeves *et al*. 2003). Trawler operations are inherently noisy and the acoustic disturbance may affect cetacean behaviour. Acoustic 'pingers' are used as deterrents to reduce marine mammal bycatch in fishing nets in gillnet and some other fisheries (e.g. Carretta and Barlow 2011, Dawson *et al*. 2013). The use of pingers introduces another form of noise, and may induce altered behaviour and reduce bycatch of some cetacean species in some types of nets such as gillnets, but results are inconsistent for other cetacean species and when used in relatively noisy trawling operations (Carretta and Barlow 2011, Dawson *et al*. 2013, Allen *et al*. 2014).

Behavioural changes

Other forms of behavioural change from fisheries interactions can be important. For example, some individuals or groups of bottlenose dolphins frequently interact with trawlers in Australian waters and this alters their feeding ecology and increases the risk of bycatch and potential risk of predation by sharks or killer whales (e.g. Corkeron *et al*. 1990, Broadhurst 1998, Jaiteh *et al*. 2013, Allen *et al*. 2014). Trawl fisheries may provide a more reliable source of food from bycatch disposal and catch depredation in an otherwise patchy environment for food resources, and this altered food availability and predictability can affect social interactions and population demographics leading to habitual interactions with trawlers by some groups of dolphins (Corkeron *et al*. 1990, Chilvers and Corkeron 2001). Interactions with trawlers may increase at night (Fertl and Leatherwood 1997, Crespo *et al*. 1997), and bottlenose dolphins have been seen to exploit fish attracted to illumination of surface waters from deck lights on trawler vessels (Zollett and Rosenberg 2005). Up to 30–40 killer whales have been reported interacting with Dutch mid-water trawl freezer vessels off the Shetland Islands, and scavenged off discards or fed on fish that slipped through the net or slipped overboard during hauling or shooting of the net (Couperus 1994). Subtle changes in behaviour and potential for habituation can be difficult to detect and require detailed long-term monitoring of behaviour and ecology, which is beyond the capability of most fisheries observer programs.

Summary: nature and extent of interactions of mid-water trawl gear with cetaceans

- *The SPF area encompasses the known distribution range of most cetacean species occurring in Australian waters; this area is known to be important to many cetacean species and interactions with mid-water trawl and other fisheries have occurred for many species.*
- *A total of 25 dolphin mortalities were reported in mid-water trawls in the SPF during 2004 and 2005, comprising of some common bottlenose dolphins and possibly short-beaked common dolphins. The absence of reported interactions with cetaceans in this fishery in more recent years coincides with low levels of fishing and observer effort. Therefore, it is difficult to estimate the overall extent of direct interactions with cetaceans by mid-water trawl gear in the SPF.*
- *The nature and likelihood of interactions between cetaceans and mid-water trawl fisheries varies substantially among species. Bottlenose dolphins and short-beaked common dolphins are likely to be at higher risk based on reported interactions with trawls and bycatch in Australia and internationally.*
- *Direct interactions with fishing operations include net feeding, foraging behind trawlers, and feeding on discards and fish escaping from nets. Vessel collisions resulting in injury or death of whales and some other cetaceans are thought to be relatively common in Australian waters but are not well documented. Most severe or fatal injuries to whales are caused by collisions from vessels greater than 80 m.*
- *Fisheries bycatch mortality is the major threat to many smaller cetacean species in Australian waters and internationally. Cetacean bycatch occurs in most areas where trawling occurs and they are more often caught in mid-water trawls than in bottom trawls. The risk of bycatch increases where prey species are also targeted by fisheries and where fishing grounds overlap with important habitats used by cetaceans for aggregating, feeding, breeding and as migratory routes.*
- *Analyses of common dolphin bycatch in New Zealand mid-water trawl fisheries showed that bycatch occurred in vessels longer than 90 m, and bycatch was highest in trawls where the headline depth was between 10–40 m, and during longer tows of two to six hours in duration. Light conditions and fishing location also significantly influenced common dolphin bycatch rates. Sharp vessel turns and changes in speed may increase the risk of bycatch.*
- *Cetaceans that frequently interact with trawlers and other fisheries can become habituated, leading to altered social interactions and increased risk of bycatch.*
- *Acoustic disturbance can be important for cetaceans because they have a very highly developed acoustic sense and sounds are vitally important for their ecology and survival.*

5.3.3 Management

Management of interactions between cetaceans and fishing operations

Management actions and mitigation measures to reduce cetacean bycatch can include modification to fishing gear including the use of excluder devices, modification to fishing practices including offal management, temporal and spatial closures, and fisheries bycatch triggers and move-on rules. These management measures are reviewed below, and then discussed in relation to the DCFA.

Cetacean excluder devices (CEDs)

Various types of excluder devices have been developed and used in trawl fisheries to reduce bycatch of cetaceans and other marine megafauna (e.g. Northridge *et al.* 2005, Stephenson *et al.* 2008, Elgin Associates (unpublished (b)). The design and function of excluder devices to facilitate the escape of large marine animals that enter trawl nets are reviewed in Elgin Associates (unpublished (b)), and are outlined in Section 5.2.3.

Excluder devices need to be carefully designed for each fishery, to take into account a range of variables including the size and behaviour of the species to be excluded from the fishing gear, characteristics of each gear type including size and operation, fishing operations, towing speed, the hydrodynamics of trawl set up in relation to trawl size/grid and escape hole ratios, storage of trawl nets on the vessels, and the size of target and non-target species (Zollett and Rosenberg 2005, Elgin Associates (unpublished (b)). Hence, an excluder device that proves to be effective in reducing bycatch mortality in one fishery while maintaining catch per unit effort of target species may not be effective in another fishery that encounters different marine mammals and is targeting different fish species.

Appropriately designed excluder devices have been shown to be effective in reducing bycatch of some pinnipeds (refer to Section 5.2.3), but there are no studies that indicate excluder designs tested to date are consistently effective in reducing cetacean bycatch in trawls (reviewed in Elgin Associates unpublished (b)). This may be because dolphins, for example, are less manoeuvrable within the trawl net than are fur seals and sea lions. Underwater cameras monitoring the effectiveness of excluder devices have shown that some dolphins appear distressed when they are near excluder grids and seem reluctant or unable to enter a narrow and confined release route and instead tend to swim upstream out of the mouth of the net (e.g. Zeeberg *et al*. 2006). Elgin Associates (unpublished (b)) concluded that further information is required on the escape behaviour of dolphin species known to interact with trawl nets, and at present there is no solution to filter or deter cetaceans from the net opening. Some studies indicate that modified CEDs with top-opening escape hatches may be the most effective way of further reducing cetacean bycatch because some dolphins have been observed to seek an exit in the upper part of the trawl (e.g. Northridge *et al*. 2005, Allen *et al*. 2014). However, Zollett and Rosenberg (2005) reported that three female bottlenose dolphins preferred to exit at the bottom of a trawl net tested during experiments in a captive facility.

As noted in Section 5.2.3, from the commencement of mid-water trawls in the SPF, the nets were fitted with a 'soft' rope-mesh SED (Browne *et al*. 2005). Following dolphin bycatch in mid-water trawls, Lyle and Willcox (2008) examined three SED designs and were able to evaluate interactions with seals. However, no cetacean interactions were recorded in the 98 tows used to assess SED performance from underwater video footage; hence their effectiveness for mitigating dolphin bycatch is unknown. That study identified that an upward-opening SED should be trialled for the mid-water trawl fishery in the SPF to examine the effect in mitigating dolphin and seal mortalities, but this has not been done due to lack of funding and the recent minimal trawl effort in the fishery (AFMA 2011, Tuck *et al*. 2013). Seafish Tasmania Pty Ltd commissioned the design of a soft-grid SED (see Section 5.2.5) for use on its proposed large mid-water trawl freezer vessel in the SPF, but this has not been tested during trials at sea. Until the behaviour of the cetacean species most likely to interact with mid-water trawls in the SPF is better understood, it will be difficult to design an excluder device that effectively mitigates both pinniped and cetacean bycatch in this fishery. It is also possible that common dolphins and bottlenose dolphins and other cetacean species in the SPF area may react differently to the stress of being constrained within trawl nets and may require different excluder designs, which would further complicate bycatch mitigation planning.

Three fisheries case studies where excluder devices were assessed in relation to cetacean behaviour and bycatch in trawl fisheries were reviewed by Elgin Associates (unpublished (b)), and are summarised below.

<u>European (Dutch and Irish) pelagic fleet fishing off Mauritania, northwest Africa</u>

Zeeberg *et al*. (2006) noted that between 40 and 70 foreign trawlers (Russian, Lithuanian, and Icelandic) including 5–10 European (Dutch and Irish) pelagic freezer/factory trawlers (with net openings of around 90 by 50 m) operated in this fishery and are among the largest fishing vessels in the world. Significant bycatch of marine megafauna occurs in this fishery, and cetaceans comprised 8 per cent of the megafauna bycatch recorded by observers with 70–720 dolphins captured between 2001 and 2005, with the main bycatch species being common dolphins (Zeeberg *et al*. 2006). Heessen *et al*. (2007) noted that observations by trawler crew are likely to underestimate the extent of megafauna bycatch. Cetacean bycatch occurred almost exclusively at night, and there was a strong seasonal relationship with cetacean bycatch associated with the return of migrating sardines (Zeeberg *et al*. 2006). Pods of 10–20 short-finned pilot whales or groups of 5–30 dolphins were captured by trawl operations in spring.

The large animal excluder device used in this fishery was not designed specifically to reduce dolphin bycatch, but to mitigate bycatch of all megafauna including sharks, manta rays, sea turtles, and dolphins (Zeeberg *et al*. 2006, Heessen *et al*. 2007). Captured megafauna are retained by a part of the net consisting of a large mesh filter 'shark-grid' that allows smaller fish to pass, but prevents larger animals from entering the codend. The grid is designed to guide pelagic megafauna to an escape route along the bottom of the trawl (Figure 5.16). As some dolphins had been observed to seek an exit in the upper part of the net, a cetacean exit was built in ahead of the grid (Figure 5.16) to enable cetaceans to accelerate upwards to reach the water surface (Zeeberg *et al.* 2006). Usually the captured megafauna are discarded into the sea while the codend is still in the water but before the fish pumping starts to prevent megafauna blocking the fish pump (Heessen *et al.* 2007). Zeeberg *et al.* (2006) noted that several types of cetacean 'barriers' consisting of vertical ropes in the front part of the trawl and acoustic deterrents were under development to prevent dolphins from entering the net opening or guide them out during hauling, but no details are available on their efficacy in reducing dolphin bycatch (Elgin Associates unpublished (b)).

Zeeberg *et al.* (2006) tested the tunnel exclusion on Dutch mid-water trawl freezer vessels. The vessels alternately fished with and without the excluder, and use of the excluder did not significantly influence the catches of the target species (Heessen *et al.* 2007). A 40–100 per cent reduction in bycatch of the megafauna species most vulnerable to bycatch was recorded. However, although cetaceans made up only 8 per cent of the retained bycatch, none were released alive. These bycatch results show that further research is needed to reduce cetacean bycatch mortality using excluder devices in that fishery (Elgin Associates unpublished (b)).

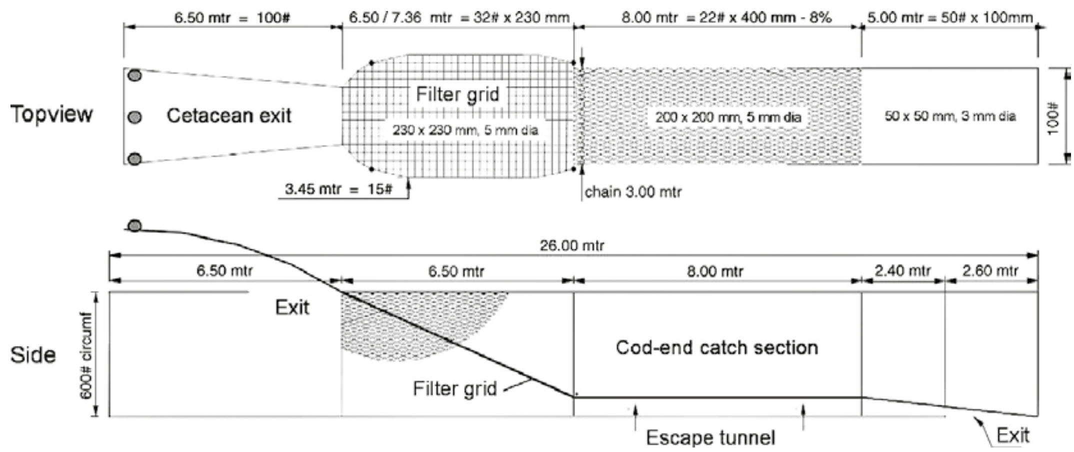


Figure 5.16 Diagram of the aft section of a mid-water trawl (about 50–70 m in front of the codend), showing the position of the cetacean exit ahead of the filter grid and connection to the escape tunnel. The filter grid slopes top-downwards with about a 20° inclination that forces larger non-target species downward to the tunnel entrance. Source: Reprinted from *Fisheries Research* 78, 2-3, J. Zeeberg, A.Corten and E. de Graaf. Bycatch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. pp. 186–195, Copyright (2006) with permission from Elsevier B.V.

Western Australian Pilbara Fish Trawl Interim Managed Fishery

The PFTIMF is an otter trawl fishery targeting demersal scalefish species. In 2002, bycatch data were obtained from 427 trawl shots representing 1581 hours of trawling and an observer coverage rate of 7.7 per cent. Common bottlenose dolphins were observed around and in almost every trawl shot, with four incidental dolphin deaths reported (Stephenson and Chidlow 2003). Allen *et al.* (2014) subsequently compared data from skippers' logbooks and independent observers to assess trends in common bottlenose dolphin bycatch patterns between 2003 and 2009. Dolphins were caught in all fishery areas, across all depths and throughout the year. Bycatch rates reported by independent observers (n = 52 dolphins in 4124 trawls, or 12.6 dolphins per 1000 trawls) were approximately double those reported by skippers (n = 180 dolphins in 27,904 trawls, or 6.5 dolphins per 1000 trawls).

The effectiveness of exclusion grids and escape hatches fitted to trawl nets in the PFTIMF to reduce dolphin interactions was assessed by Stephenson *et al.* (2008) in conjunction with an assessment of acoustic pingers (Stephenson and Wells 2006). During this research, dolphins were recorded entering trawl nets to forage in more than 98 per cent of trawls and purposely made contact with the fishing gear including clinging to the headrope and bouncing along the net (Stephenson *et al.* 2008). Similar high rates of interactions and behaviour were observed during subsequent research on modified net designs (Allen and Loneragan 2010, Jaiteh *et al.* 2013). In more recent observer programs, common bottlenose dolphins were the only species observed to deliberately enter trawl nets and were recorded feeding on captured fish in more than 75 per cent of trawls (Wakefield *et al.* 2014). Seven dolphins were observed within close proximity to exclusion gear inside trawl nets (Wakefield *et al.* 2014).

BRDs have been mandatory in the PFTIMF since 2006 and initially consisted of a semi-flexible metal grid and a bottom-opening escape hatch with a loose skirt of netting covering the hatch to prevent the loss of target species (Stephenson *et al.* 2008, Allen *et al.* 2014). In 2008, the BRDs were moved forward in the net from a position just before the codend to the beginning of the net extension to prevent dolphins from backing down into the extension, thereby providing a shorter escape route between the BRDs and the opening of the net (Allen *et al.* 2014). More recently, different excluder devices have been trialled with top or bottom opening net configurations. These devices were not designed specifically to mitigate dolphin bycatch, but to reduce the bycatch of all marine megafauna including turtles, seasnakes, sawfish, rays and sharks.

Use of a semi-flexible exclusion grid constructed from braided stainless wire and pipe (Figures 5.17, 5.18) appeared to reduce the bycatch of dolphins by almost half (Stephenson *et al.* 2008). Allen *et al.* (2014) categorised dolphin bycatch data on three broad net configurations as follows.

1. Prior to the introduction of the BRDs (August 2003 until February 2006; excluding BRD trials) bycatch was 8.9 dolphins per 1000 trawls (skipper's logbook) and 18.8 dolphins per 1000 trawls (independent observer data).
2. In BRD trials from the previous period, after the compulsory introduction of the BRDs and before BRDs were moved forward (primarily March 2006 to May 2008), bycatch was 5.2 dolphins per 1000 trawls (skipper's logbook) and 10.3 dolphins per 1000 trawls (independent observer data).
3. After the BRDs were moved forward in the net (June 2008 until September 2009) bycatch was 3.9 dolphins per 1000 trawls (skipper's logbook) and 11.3 dolphins per 1000 trawls (independent observer data).

Stephenson *et al.* (2008) tested the semi-flexible cetacean exclusion device, and underwater video footage was obtained for 446 shots. Most dolphins backed down into the net to about 3 m from the grid and then swam upstream out of the net. Seven dolphins were recorded interacting with the grid or escape opening. Three dolphins were assumed to have escaped alive and four were distressed and were assumed to have died (Stephenson *et al.* 2008). Two dolphins had their tail fluke caught in the grid, so it was suggested that the bar spacing should be reduced to less than 155 mm, to reduce the likelihood of this occurring (Stephenson *et al.* 2008). Dolphins were generally caught during daylight. Net depth (50–80 m) did not affect the capture rate of dolphins (Stephenson *et al.* 2008).

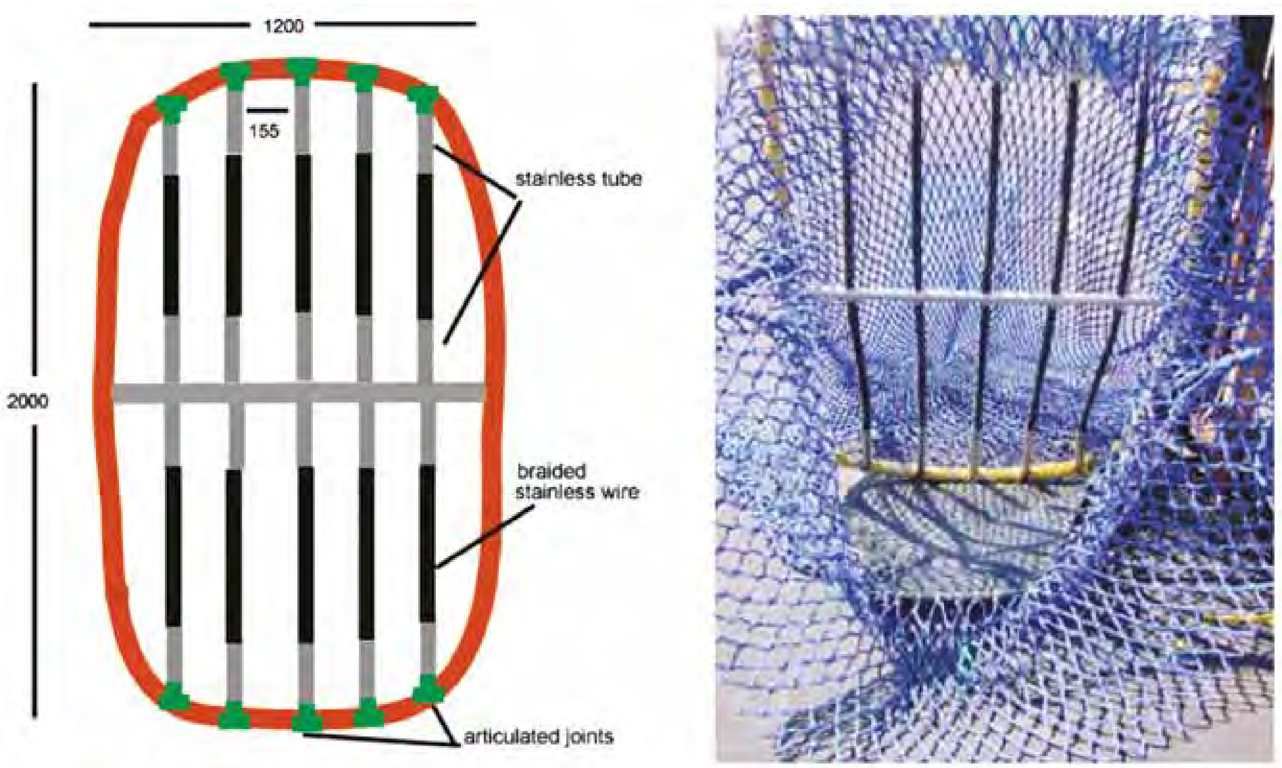


Figure 5.17 Semi-flexible grid constructed from stainless tube and braided stainless wire.

Source: Stephenson *et al.* (2008), reproduced with permission from the Department of Fisheries, Government of Western Australia.

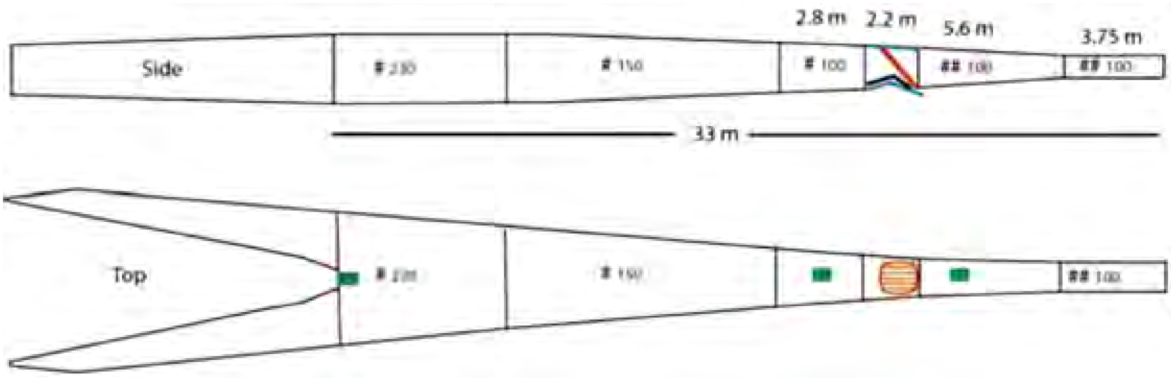


Figure 5.18 Net design used during the selection grid trials showing the grid (red), cover net at the bottom opening escape (blue), the Kevlar flap (black), and the location of the cameras (green).

Source: Stephenson *et al.* (2008), reproduced with permission from the Department of Fisheries, Government of Western Australia.

In 2012, three exclusion gear configurations in trawl nets were evaluated in trials conducted on the three vessels fishing in the PFTIMF (Wakefield *et al.* 2014). The 'downward excluding net' configuration included a semi-rigid downward-angled exclusion grid (six stainless steel tubes spaced at 150 mm apart with a side tube length of 795 mm) with an escape hatch cut into the bottom of the trawl net forward of the grid and a mesh cover opening backward to facilitate the expulsion of megafauna and benthos during trawling (Figure 5.19a).

The 'upward excluding net' had an upwardly inclined grid and the escape hatch and mesh cover were moved to the top of the net immediately forward of the grid (Figure 5.19b). The grid was rigid and the spacing of the stainless steel tubes was increased to 200 mm with the length of the side bars increased to 1030 mm (Wakefield *et al.* 2014).

The second modified 'experimental net' used the same rigid grid as the upward excluding net, but it was orientated downward (Figure 5.19c). The escape hatch was cut into the bottom of the net forward of the grid with a similar mesh cover opening backwards, but the grid and escape hatch were stitched into 50 mm square mesh to keep this section of the net cylindrical, to improve water flow through the net (Figure 5.19c). An additional 3 m longitudinal escape slit was cut into the top of the square mesh net forward of the exclusion grid, to facilitate the escape of predominantly air-breathing animals, based on the assumption that they would tend to push upwards to escape (Allen and Loneragan 2010). The escape slit was held together with magnets along its edges to keep it closed during trawling and after an animal had passed through it (Wakefield *et al.* 2014).

The effectiveness and efficiency of these three different exclusion gear configurations in mitigating dolphin and other megafauna species interactions were assessed. All trawl vessels in the PFTIMF were fitted with above-water and subsurface within-net camera systems, and observer coverage during the trials was high (Wakefield *et al.* 2014). Despite more than 75 per cent of trawls having high levels of interaction around and within trawl nets by common bottlenose dolphins, captures of megafauna were rare (Wakefield *et al.* 2014).

Ten dolphin mortalities were recorded during the trials and another seven common bottlenose dolphins were observed underwater in close proximity to exclusion gear inside the trawl nets during five trawls (Wakefield *et al.* 2014). All seven of these dolphins appeared to be distressed and exhibited short and infrequent bursts of swimming towards the mouth of the net, but did not always move upwards toward the top of the net. Four of the seven dolphins asphyxiated and died and were retained within the net ahead of the exclusion grid. Two of the other three dolphins exited from the upward excluding net through the top opening escape hatch within 0.3–5.0 minutes, and were considered to have a high chance of survival. Interestingly, the dolphin that exited the net in the shortest time approached the exclusion grid head first and exited through the escape hatch head first, whereas the other six interactions involved dolphins approaching the grid tail first and this usually led to the tail passing through the grid and becoming lodged. The other dolphin appeared to asphyxiate and was retained within the net forward of the grid until the trawl was near the surface during hauling and under excessive turbulence, causing the tail to become dislodged from the exclusion grid, and the dolphin fell out of the net through the top opening escape hatch that was now orientated downward. This was the only observation of an asphyxiated dolphin passing through an escape hatch. No megafauna or scalefish were observed to exit the trawl nets through the top opening escape slit in the 'experimental net', but one dolphin was observed attempting to enter the trawl net through this escape slit (Wakefield *et al.* 2014).

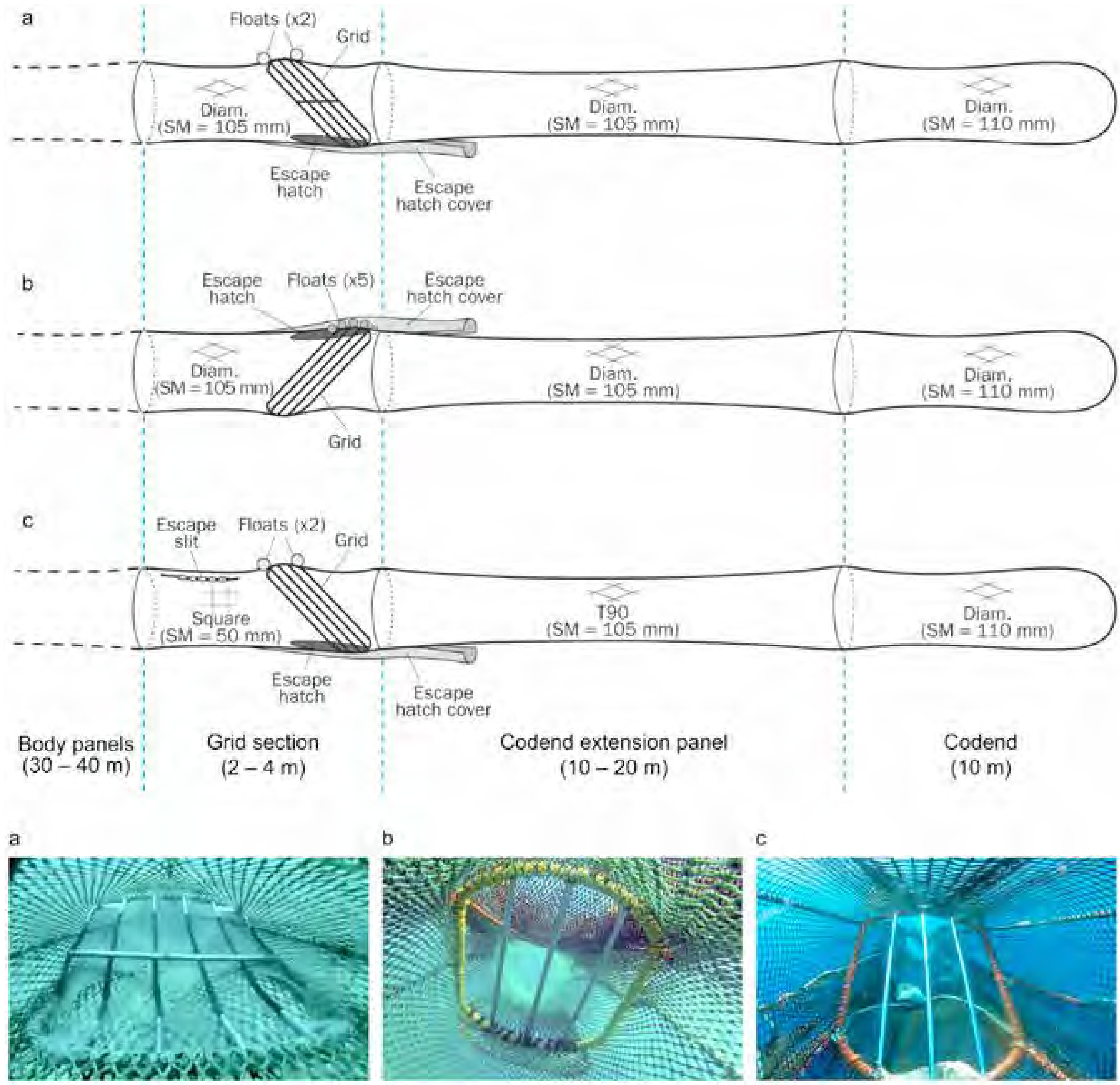


Figure 5.19 Diagrams and *in situ* images taken from the net camera systems with the camera positioned behind the grid facing forward for the three different net configurations (a) downward excluding net, (b) upward excluding net and (c) experimental stretched mesh net. **Source:** Wakefield *et al.* (2014), reproduced with permission of the Department of Fisheries, Government of Western Australia.

UK Bass Pair Trawl Fishery and adjacent European fishery

The European sea bass *Dicentrarchus labrax* commercial fishery is located in the western English Channel and Bay of Biscay, where mid-water pair trawlers target these shoaling fish offshore prior to spawning (Northridge *et al.* 2011). The UK pelagic pair trawl fishery is usually operated by two pairs of Scottish 30–40 m trawlers with trawl nets towed near the surface, with up to 50 pairs of French boats operating the same gear mostly in the Bay of Biscay area (Northridge 2007). Cetacean bycatch rates are very high, with mean bycatch rates of about one short-beaked common dolphin per tow (Table 5.3, Northridge *et al.* 2011).

Table 5.3 Common dolphin bycatch in the UK bass pair trawl fishery

WINTER SEASON	POINT ESTIMATE OR CENSUS	LOWER CONFIDENCE LEVEL	UPPER CONFIDENCE LEVEL
2000–01	190	172	265
2001–02	38	23	84
2002–03	115	88	202
2003–04	439	379	512
2004–05	139	139	146
2005–06	84	84	85
2006–07	70	55	117
2007–08	0	0	0
2008–09	2	2	2
2009–10	28	28	28

Source: Northridge *et al.* (2011).

Necropsies of stranded animals showed that bycatch, most probably from pelagic fishing operations, was the cause of death in 65 per cent of stranded common dolphins that were assessed and where cause of death was established (Department for Environment, Food and Rural Affairs 2003). Data from 2004–09 showed that the overlap between pelagic fisheries and a short-beaked common dolphin 'hotspot' led to direct mortality through bycatch and, together with recent range-shifts, may have contributed to a localised decline of these dolphins in this winter hotspot since 2007 (de Boer *et al.* 2012).

After extensive consultation, an exclusion grid to reduce common dolphin bycatch in the bass pair trawl fleet was developed and tested at sea with the Scottish Pelagic Fishermen's Association, but no cetaceans were encountered during the initial trial. Among 37 tows observed during March 2002, only two tows had dolphin bycatch (eight animals in total), compared with dolphin bycatch in 11 out of 52 tows in March 2001 (Northridge *et al.* 2011), demonstrating the unpredictable nature of dolphin bycatch.

During the 2004–05 season, some common dolphins were observed to use a 2 by 3 m escape opening fitted into the net midway along its length (Northridge 2006). A barrier immediately behind the escape opening allowed fish to pass but was not passable by dolphins. Nine dolphins were observed escaping with 32 dolphins recovered from the nets having drowned, representing a minimum 22 per cent escape rate (Northridge 2006). Most of the animals that drowned had done so some distance in front of the escape hatch and barrier, indicating that they may have detected the barrier and stopped further forward in the net where they tried to escape. A few other dolphins reached the barrier but did not use the escape hatch, indicating that escape routes need to be more numerous and more obvious (Northridge 2006). Although these trials with exclusion devices showed some promise, the trials ceased in 2006 after intervention from an animal welfare organisation, resulting in subsequent research focusing on the use of acoustic deterrents to reduce bycatch (Northridge *et al.* 2011).

A preliminary model of a barrier to prevent dolphins from entering a trawl net in tuna and sea bass fisheries was tested in a flume tank as part of the 'Necessity' project (Meillat *et al.* 2006), and various bycatch excluder devices were being considered for adaptation to this model (reviewed in Elgin Associates unpublished (b)).

Pingers

Active sound emitting 'pingers' are small self-contained battery-operated devices that are designed to emit regular or randomised acoustic signals at a range of frequencies that are loud enough to alert or deter marine animals from the immediate vicinity of fishing gear, and were originally developed for use in gillnet fishing operations and to deter pinnipeds from mariculture operations (reviewed in Dawson *et al.* 2013, Elgin Associates unpublished (b)). Pingers differ in the level of sound emitted, ranging from relatively low-intensity sounds (less than 150 decibels (dB) re 1 μPa at 1 m) known as acoustic deterrent pingers, through to high output emitters (more than 185 dB) referred to as acoustic harassment devices that were designed to cause discomfort or pain when an animal approached closely (Dawson *et al.* 2013). Other mid-range acoustic emitting devices have been designed to deter depredation by common bottlenose dolphins from static fishing gear or designed to deter bycatch of pelagic dolphin species in mid-water trawls; these are marketed under various trade names such as Dolphin Dissuasive Devices (DDD), Aquamark, Aquatec and Cetasaver, and some of these pingers have higher 165–190 dB source levels (Table 1 in Dawson *et al.* 2013). The term DDD is also more broadly used to refer to loud pingers (Elgin Associates unpublished (b)).

Pingers have been shown to be effective in several gillnet fisheries to reduce the bycatch of small cetaceans and in some cases reduce depredation rates (reviewed in Caretta and Barlow 2011, Geijer and Read 2013, Dawson *et al.* 2013). Significant reductions in bycatch of short-beaked common dolphins, striped dolphins, harbour porpoise *Phocoena phocoena*, franciscana *Pontoporia blainvillei* and some beaked whales, have been demonstrated in replicated experiments and long-term monitoring in some gillnet fisheries (Caretta and Barlow 2011, Dawson *et al.* 2013). For example, in the California-Oregon drift gillnet fishery for swordfish and shark, and the New England groundfish fishery, the mandatory use of pingers has been monitored for more than a decade and bycatch rates of dolphins and porpoises have been reduced by 50–60 per cent (Palka *et al.* 2008, Caretta and Barlow 2011, Dawson *et al.* 2013). However, compliance rates have been highly variable resulting in lower reductions in bycatch than were found in the initial controlled experiments that tested pingers for these fisheries (Geijer and Read 2013, Dawson *et al.* 2013). Continued poor compliance rates with requirements to use pingers in the New England gillnet fishery has resulted in harbour porpoise bycatch exceeding the calculated sustainable PBR levels in recent years (Geijer and Read 2013, Dawson *et al.* 2013). Harbour porpoises appear to avoid areas with pingers, with 14 replicated controlled experiments in North America and Europe showing significant reductions in bycatch associated with the use of pingers (Dawson *et al.* 2013). However, some studies have indicated that some degree of habituation can occur and can result in increased harbour porpoise bycatch over time, particularly in inshore areas where harbour porpoises are at least seasonally resident (reviewed in Dawson *et al.* 2013). Beaked whales have not been recorded as bycatch in the California-Oregon drift gillnet fishery since pingers were used after 1995 (Caretta and Barlow 2011, Geijer and Read 2013).

Cetacean bycatch rates were significantly higher in nets in which one or more pingers had failed or were sparsely distributed (Caretta and Barlow 2011, Dawson *et al.* 2013). Interestingly, harbour porpoise bycatch rates in gillnet fisheries along the northeastern US were more than 2.5 times higher in nets equipped with some pingers but not a full complement, compared with nets without any pingers, which indicates that partial use of pingers may be worse than not using any pingers (Palka *et al.* 2008). For common bottlenose dolphins, studies of pinger use to reduce depredation in gillnet fisheries generally show small and inconsistent improvements in fish catches and some reduced damage to nets, but pingers do not appear to effectively reduce bycatch of bottlenose dolphins (Dawson *et al.* 2013).

The use of pingers has been extended to trials and use in some pelagic trawl fisheries, but in these relatively noise-saturated pelagic trawler operations the effectiveness of pingers in reducing bycatch of cetaceans is unclear (Werner *et al.* 2006, Zeeberg *et al.* 2006), with mixed results reported from different studies (reviewed in Elgin Associates unpublished (b)). Pingers were trialled in the PFTIMF but were found to be ineffective in keeping common bottlenose dolphins out of the trawl net, and pingers were therefore rejected as a dolphin bycatch mitigation method (Stephenson and Wells 2006). Further trials with larger, louder pingers in the PFTIMF have commenced but the results of these trials are not yet known (Allen *et al.* 2014). Allen *et al.* (2014) concluded that pingers are unlikely to deter common bottlenose dolphins from interacting with trawl nets or to mitigate bycatch for this species.

Extensive testing of a range of pingers has been done in the UK bass pair trawl fishery and the adjacent European fishery (Morizur *et al.* 2008, Northridge *et al.* 2011). Trials have evaluated the sound source levels, pulse durations, immersion depths, placement within trawl gear, and distance from dolphin groups in relation to their behavioural responses. Trials have produced mixed results, with significant reductions in bycatch rates observed when loud pingers have been used in some pelagic trawls, however insufficient numbers of control tows during these trials prevent confidence in the results of some experiments (reviewed in Elgin Associates unpublished (b)).

In the UK pair trawl fishery, preliminary trials using standard pingers designed for gillnets showed no reduction in bycatch of common dolphins, however, after the introduction of more powerful DDD pingers (peak source levels approximately 165 dB re 1 µPa at 1 m) as a mitigation device in 2006–07, a substantial 77 per cent reduction in observed bycatch of common dolphins was reported (Table 5.4, Northridge *et al.* 2011, de Boer *et al.* 2012). The overall observed bycatch rate in tows with DDDs during 2007–2009 was 0.178 common dolphins per tow, compared with an overall observed bycatch rate of 0.772 common dolphins per tow for the seasons 2001–06 prior to the use of DDDs (Northridge *et al.* 2011). The lower bycatch rate may be attributed to the use of pingers, but interpretation of these results is complicated by the absence of a significant number of control tows without DDDs with associated dolphin bycatch, hence it is possible that, after 2006, the bycatch rate declined independently of the use of pingers (Elgin Associates unpublished (b)).

Table 5.4 Observed bycatch of common dolphins by season in the UK bass pair trawl fishery before and after the introduction of DDD pingers in the winter of 2006–07

WINTER SEASON ENDING	DAYS	TRIPS	HAULS	DOLPHINS	RATE PER TOW
2001	57	10	92	52	0.565
2002	50	14	91	9	0.099
2003	76	16	113	27	0.239
2004	98	26	136	169	1.243
2005	133	39	176	176	1.000
2006	61	21	53	77	1.453
2007	15	5	34	8	0.235
2008	0	0	0	0	0.000
2009	23	10	28	2	0.071
2010	133	41	188	28	0.149
Totals	646	182	911	548	0.602

Source: Northridge *et al.* (2011).

The vessels involved in the bass pair trawl fishery voluntarily requested pingers and observers each season in recent years to ensure that detailed records were maintained of dolphin bycatch and the deployment patterns and functioning of the pingers (Northridge *et al.* 2011). Some pinger malfunctioning occurred in the 2009–10 season and 28 common dolphins were recorded as bycatch, but Northridge *et al.* (2011) estimated that about 39 fewer dolphins died in bass pair trawls than would have occurred if pingers had not been used. Monitoring of pinger deployment and bycatch in this fishery over three years showed encouraging results, but three potential problems with the use of pingers were identified: pingers were not always fully charged or working when deployed, pingers were sometimes placed in a suboptimal position and needed to be deployed in more than 10 m of water, and pingers can degrade after three years and may not be able to hold adequate charge (Northridge *et al.* 2011). Accordingly, it was recommended that a code of best practice in the fishery should address these issues and ensure that DDDs are fully charged, functioning and deployed on the lower wing ends or bridles of the trawl gear (Northridge *et al.* 2011). In summary, Northridge *et al.* (2011) concluded that DDDs appear to be effective in reducing bycatch of common dolphins, but they noted that there are still important challenges to address including determining the most effective configuration of pingers for mid-water trawls.

Trials with various types of pingers have been completed to test their effectiveness in reducing bycatch of common dolphins by French trawlers in the European bass trawl fishery in the Bay of Biscay (Van Canneyt *et al.* 2007, Morizur *et al.* 2007, 2008). Initial tests with seven models of commercial pingers in August 2005 and August 2006 showed that four models were ineffective at deterring common dolphins, whereas three DDD models caused an obvious change in behaviour but with a variable response level (Van Canneyt *et al.* 2007). Trials were also done using Cetasaver pingers that were developed to mitigate common dolphin bycatch in this fishery as part of the European 'Necessity' project; the Cetasaver uses a conical direction beam that is directed towards the opening of the trawl with an averaged sound level of 178 dB, which results in 139 dB sound level at the entrance to the trawl (Morizur *et al.* 2008). Directivity tests using Cetasaver 3 on six groups of common dolphins showed that when the dolphin swimming direction and the emitted sound direction were 180 ° apart, the dolphins reacted at distances of up to a 200 m (Van Canneyt *et al.* 2007). The Cetasaver 3 system created an acoustic barrier that was effective on all the dolphin groups tested and they did not approach within 200 m in frontal experiments (Van Canneyt *et al.* 2007). French trawler operators prefer to have the Cetasaver set on the rear part of the trawl rather than use the DDD set on the wings of the trawls, because there is less interference with the netsonder because of the geometry of the beams (Morizur *et al.* 2007).

A modified Cetasaver 7 pinger was trialled during winter 2006–07 in the fishery and observers noted that the bycatch of common dolphins decreased by 80 per cent, but the number of test trawls was too low to be conclusive (Morizur *et al.* 2007). More extensive and rigorous trials with Cetasaver pingers were completed in 2007 and 2008, using commercial pelagic trawls in the bass fishery and usually in the presence of scientific observers (Morizur *et al.* 2008). The tests involved a total of 121 tows using the Cetasaver pinger in which six common dolphins were caught in five tows, and a total of 129 tows without the pinger in which 20 dolphins were caught in 10 tows (Morizur *et al.* 2008). The results indicated a reduction in recorded common dolphin bycatch of about 70 per cent during the two years of trials, but analyses showed that twice the number of observations would be needed for the trials to provide statistically significant differences to fully evaluate the effectiveness of Cetasaver pingers (Morizur *et al.* 2008).

At-sea trials off Ireland indicated that Cetasaver pingers may not provide a consistently effective deterrent signal for all groups of common dolphins (Berrow *et al.* 2009), which may explain why bycatch was not suppressed in all trawls in the Bay of Biscay (Morizur *et al.* 2007, 2008). Pingers have been deployed in the New Zealand jack mackerel trawl fishery but it is not known whether the use of pingers has significantly reduced the mortality of common dolphins in this fishery (Mr R. Wells, Deepwater Group Ltd New Zealand pers. comm. in Elgin Associates unpublished (b)).

Another area of uncertainty associated with the use of pingers in trawl fisheries is whether or not dolphins or other cetaceans could become habituated to pingers over time, which could cause a decline in effectiveness. A decline in the effectiveness of pingers in reducing bycatch could be difficult to detect and distinguish from other factors operating in trawl fisheries, and would require detailed studies and long-term assessments of bycatch rates involving observer programmes such as those developed for managing gillnet fisheries (reviewed in Caretta and Barlow 2011, Dawson *et al.* 2013). The widespread use of more powerful pingers such as DDDs to overcome noise from trawl vessels and gear could potentially exclude some cetaceans from important feeding, resting and breeding or nursery areas and may reduce their foraging success and ultimately affect their survival (Zollett and Rosenberg 2005, Northridge *et al.* 2011). Experiments using DDDs to test their potential to exclude cetaceans have produced mixed results, although there was some evidence of decreased cetacean activity up to at least 1.2 km from the DDD and possibly up to a distance of 3 km or more (Northridge *et al.* 2011). Preliminary tests using a less powerful Aquamark 100 pinger appeared to have an effect up to about 400 m (Northridge *et al.* 2011).

Fishing behaviour and codes of practice

A range of voluntary or mandated management measures can be used in trawl fisheries to modify or adapt fishing practices to reduce interactions with cetaceans and other non-target species. These include the use of observer programs and fishers' logbooks to assess the levels and patterns of interactions to enable altered fishing practices, altered timing and depths of trawls, haulback procedures and managing vessel turns.

Independent observer programs are very important for assessing fisheries management options because they can provide more reliable data on interactions and bycatch mortality with non-target species including protected species. Independent observer data can result in higher bycatch mortality estimates than those based on fishers' logbooks that may under-report rates of interactions and bycatch mortality (e.g. Stephenson *et al*. 2008, Hamer *et al*. 2008, Moore *et al*. 2010, Allen *et al*. 2014). Therefore, observer programs can provide more effective data to estimate bycatch within a fishery over time, and for estimating total cetacean bycatch mortality across all fishing effort within a region (e.g. Tuck *et al*. 2013). Reliable data on interactions and bycatch mortality also enable fishing practices to be altered to reduce these risks through adaptive management. Thompson *et al*. (2013) noted that trawl fisheries are often characterised by high fishing effort with low rates of observer coverage, which prevents reliable estimates of bycatch. In New Zealand waters this is particularly important for estimating and trying to reduce the key threat of bycatch in gillnet and trawl fisheries of the endangered endemic Hector's dolphin and the critically endangered Maui's dolphin subspecies *Cephalorhynchus hectori* ssp. *maui*, which are characterised by relatively small and decreasing populations (e.g. Dawson and Slooten 2005, Slooten *et al*. 2006, Slooten and Dawson 2010).

Thompson *et al*. (2013) analysed patterns of bycatch of 135 common dolphins observed captured in trawl fisheries in New Zealand from 1995–96 to 2010–11, including 119 common dolphins captured in the mackerel trawl fishery on the west coast of the North Island. All captures occurred with vessels longer than 90 m, with the majority of common dolphin bycatch occurring with vessels longer than 100 m (Thompson *et al*. 2013). The highest number of captures (70 per cent) occurred during tows where the headline depth (depth of the headline below the surface) was between 10–40 m, with reduced dolphin captures recorded when the headline depth was lower in the water column down to 110 m (Thompson *et al*. 2013). Nine common dolphins were captured at fishing depths between 115 m to 184 m, during the period 2001–05 (Du Fresne *et al*. 2007). About 73 per cent of dolphin bycatch occurred during tows that were between two and six hours duration. Headline depth and trawl duration were the most important variables that best explained patterns of bycatch of these dolphins. Statistical modelling indicated that increasing the headline depth by about 21 m would halve the probability of capture of common dolphins, and decreasing trawl duration would also reduce the probability of capture (Thompson *et al*. 2013). Du Fresne *et al*. (2007) noted that common dolphin bycatch mortality occurred when total winch time of trawls exceeded 24 minutes.

Geographic location, light conditions and lunar phase also influenced patterns of common dolphin bycatch in trawls, with 80 per cent of captures associated with trawls at night particularly during lunar phases with no moonlight (Du Fresne *et al*. 2007, Thompson *et al*. 2013). Diurnal patterns in trawling effort and the extent of moonlight or light spill from trawlers have also been observed to influence cetacean behaviour in other regions and increase the extent of interactions with trawl gear and bycatch at night for some species (e.g. Fertl and Leatherwood 1997, Zollett and Rosenberg 2005, Zeeberg *et al*. 2006). In contrast, most common bottlenose dolphins are caught during daylight hours in the PFTIMF (Stephenson *et al*. 2008, Allen *et al*. 2014). Other factors influencing cetacean bycatch include location of trawling on or near the continental shelf edge, and the season of fishing (Couperus 1997, Zeeberg *et al*. 2006, Fernández-Contreras *et al*. 2010).

Cetaceans are susceptible to capture during different operational phases of trawling. They may become trapped during shooting or haulback if they fail to abandon the net or if the net mouth collapses, and can die if the nets remain submerged in the water for long periods before they are checked (Fertl and Leatherwood 1997, Fernández-Contreras *et al*. 2010). Sharp vessel turns and changes in speed may increase the risk of bycatch (Couperus 1997, Zollett and Rosenberg 2005), although dolphin bycatch can also occur when trawlers are travelling in a straight line at an even towing speed (Northridge *et al*. 2005). Some trawlers use auto-trawl systems that use self-tensioning winches to maintain the shape of the trawl gear when turning, to ensure that the entrance to the net remains open at all times. Net monitoring systems are also designed to maintain net geometry through monitoring and controlling the trawl doors via telemetry and sensors (Elgin Associates unpublished (b)). It has been suggested that the use of auto-trawl systems might reduce the likelihood of marine mammal entrapment from net collapse and therefore may provide some mitigation of the risk of bycatch for pinnipeds and cetaceans (Wakefield *et al*. 2014, Mr G. Geen Seafish Tasmania Pty Ltd pers. comm. in Elgin Associates unpublished (b)). However, auto-trawl systems have not been specifically evaluated as an approach to mitigating marine mammal bycatch, hence their effectiveness in mitigating cetacean bycatch is uncertain (Elgin Associates unpublished (b)).

Wakefield *et al*. (2014) reported on discussions with fishers in the PFTIMF in relation to the potential for entrapment of dolphins following collapse of the net mouth resulting from reduced trawl speed or sharp turning of the vessel during hauling. It was suggested that a small number of the 14 dolphin mortalities recorded in statutory logbooks during a six-month observer program may have resulted from a few instances of net collapse that occurred when a relief skipper, unfamiliar with the operation of the auto-trawl system, was on board. Wakefield *et al*. (2014) noted that development of a vessel operating code of practice may help prevent net collapse, and documenting other standard operational procedures would help maintain a consistent standard of mitigating dolphin interactions. Underwater video records within the trawl net indicated that common bottlenose dolphins may initially become stressed toward the mouth of the net, therefore *in situ* records of dolphin behaviour in this part of the net would enable better understanding of this issue and could lead to development of further mitigation strategies to reduce bycatch (Wakefield *et al*. 2014).

A code of practice was adopted for mid-water trawling in the SPF in 2005, following an incident involving 13 common dolphin mortalities (Mr G. Geen Seafish Tasmania Pty Ltd, pers. comm. 23 April 2013). Following meetings of the Cetacean Mitigation Working Group to develop plans to mitigate bycatch of TEPS, voluntary rules for mid-water trawl operations were implemented by SPF industry members in 2004 and 2005 (Tuck *et al*. 2013). The first rule stated that fishing must stop and the vessel must relocate if dolphins were seen following incidental dolphin captures, and the second rule involved conducting long wide turns to maintain net configuration rather than winching gear to blocks prior to turning (Tuck *et al*. 2013). As discussed in Section 3.2.4 all mid-water trawl vessels in the SPF are now required to have "effective mitigation approaches and devices to the satisfaction of AFMA to minimize interactions with dolphins … ". AFMA implements this requirement through vessel-specific VMPs, consistent with the provisions of the SPF Bycatch and Discard Workplan (AFMA 2011).

Hamer *et al*. (2012) noted that a 'move on' tactic has been used by some longline fishers to try to reduce depredation of fish catches but they concluded that "the success of this strategy seems to be ambiguous at best and is likely to be costly, thus affecting profit margins". Similarly, Tilzey *et al*. (2006) analysed the use of the 'move on' tactic for avoiding pinniped bycatch in the winter blue grenadier fishery off west Tasmania and they concluded it was only occasionally successful because depredating individuals were able to travel long distances to remain with the vessel.

Similar measures to reduce marine mammal bycatch in trawl fisheries in the north-east and mid-Atlantic region have been identified by the Atlantic Trawl Gear Take Reduction Team, which include reducing the number of turns made by the fishing vessel, decreasing tow times at night, and increasing communication between fishers about sightings or incidental takes of marine mammals (Zollett 2009).

Temporal and spatial closures

The only long-term conservation management measure that has been proven to reduce bycatch of small cetaceans in fisheries is the separation of nets and cetaceans in space and time (Reynolds 2008). Time and area closures can be effective in areas where the risks of bycatch are relatively high and consistent, but the utility of such closures are fishery-specific and require detailed knowledge of spatial and temporal use of habitats by cetaceans within the fishery area (Zollett and Rosenberg 2005). Time and area closures may have unintended consequences and cause a shift in the type of fisheries gear used or displace the fishing effort to other areas, which can impact on other populations or different species (Zollett and Rosenberg 2005, O'Keefe *et al*. 2014).

Hamer *et al*. (2012) concluded that the implementation of spatial closures using marine-protected areas to mitigate fisheries impacts on marine mammals has generally proven to be more effective for pinnipeds than for cetaceans because pinnipeds are central placed foragers, which enables their at-sea movements and population trends to be more effectively quantified. They noted that marine protected areas that effectively protect odontocete cetaceans are difficult to implement because: (1) determining where closures should be located is difficult in the absence of reliable data on odontocete movement or migration patterns; (2) protected areas are often smaller than required, due to stakeholder pressure to minimise their impact on fisheries using these areas; (3) monitoring compliance by fishers can be difficult due to the lack of capacity and resources; and (4) quantitative assessment of the performance of these closures is hampered by the statistical uncertainties associated with the limited and potentially unrepresentative data (Hamer *et al*. 2012).

Time and area closures have been used to protect threatened cetacean species from fisheries bycatch in some regions but with mixed success (reviewed in O'Keefe *et al*. 2014). For example, sanctuaries and fisheries closures have been implemented in parts of the range of the endangered Hector's dolphin and critically endangered Maui's dolphin subspecies in New Zealand (Dawson and Slooten 2005, Slooten *et al*. 2006, Slooten 2007, 2013) and for the critically endangered vaquita porpoise *Phocoena sinus* in the northern Gulf of California (Jaramillo-Legorreta *et al*. 2007, Gerrodette and Rojas-Bracho 2011, Senko *et al*. 2014). These closures have reduced the rate of bycatch and enabled the previously rapid rate of decline to be slowed in some areas, which proves that area-based management can work if applied at sufficiently large scales (Slooten 2013). However, because these closures have not encompassed the full range of areas used by these threatened species, their effectiveness in reducing overall population decline and risk of extinction has been compromised (Gerrodette and Rojas-Bracho 2011, Slooten 2013).

In the Australian region, bycatch records in the PFTIMF indicated that common bottlenose dolphins were caught in all fishing areas, across all depths and throughout the year, hence seasonal or spatial adjustments to fishing effort would be unlikely to significantly reduce dolphin bycatch in this fishery (Stephenson *et al*. 2008, Allen *et al*. 2014).

In the SPF area, the proposed Australian sea lion closure area for the DCFA would prevent fishing activity from the DCFA in shelf waters off SA out to a depth of 150 m (Section 5.2.3), and some restriction on the use of mid-water trawls are in place under the South-east Commonwealth Marine Reserves Network occurring within the area of the SPF (see Section 3.2.4). The South-east Commonwealth Marine Reserves Management Plan 2013–23 authorises mid-water trawling in multiple use zones provided that the gear does not come into contact with the seabed, whereas mid-water trawling is not allowed in all other zones (see Figure 3.4 in Section 3.2.4). In the Great Australian Bight Commonwealth Marine Reserve (see Figure 3.5 in Section 3.2.4), mid water trawling is authorised in the Marine Mammal Protection Zone and Benthic Protection Zone provided it does not come in contact with the seafloor; however, all vessel access is prohibited (including all forms of fishing) in the Marine Mammal Protection Zone between 1 May and 31 August.

In the SPF area off SA, a gillnet fishing closure was in force from September 2011 to August 2014 in the Coorong Dolphin Zone (see Figure 5.12), to minimise dolphin bycatch within the GHAT sector of the SESSF (AFMA 2014d). This closure resulted from a significant increase in dolphin bycatch reported by fishers using bottom-set gillnets, mainly in the Coorong Zone east of Kangaroo Island (AFMA 2014d). During late 2010 to September 2011 a total of 52 dolphins were reported to have been caught in gillnets resulting in 50 mortalities, with 18 dolphin mortalities and one live dolphin interaction reported in logbooks for the 2012-13 season (AFMA 2013f, 2014d). Of the 40 dolphins identified 38 were common dolphins and two were bottlenose dolphins (AFMA 2013f). AFMA temporarily closed the area to gillnet fishing while it consulted on a dolphin strategy for minimising gillnet bycatch (AFMA 2014d). AFMA also established a dolphin observation zone adjacent to the closed area (see Figure 5.12 in Section 5.2.3), in which all gillnet fishing was required to be monitored by observers or by e-monitoring systems. Gillnet fishers are now allowed to fish within the Coorong Dolphin Zone provided that they are compliant with the AFMA Dolphin Strategy (AFMA 2014d).

Bycatch trigger limits

As outlined in Section 5.2.3, maximum allowable bycatch limits or PBR limits may be set for a fishery to ensure that bycatch levels allow marine mammal populations to be maintained at a sustainable level or recover from depletion (Hall *et al*. 2000, Roman *et al*. 2013). The IWC has adopted a precautionary approach to cetacean bycatch, recommending that bycatch should not exceed one half of the maximum growth rate of a population. Most odontocete species are considered to be at risk from bycatch mortality in more than one fishery due to their extensive ranges that overlap with multiple fisheries such as gillnet and longline fisheries and in some cases purse seine and trawl fisheries (Shaughnessy *et al*. 2003, Bilgmann *et al*. 2008, 2014, Hamer *et al*. 2008, 2012). Hence, PBR models need to take into account all forms of anthropogenic mortality including impacts from bycatch in all relevant fisheries. However, most cetacean species that occur in the SPF area and more broadly in Australian waters are assessed as Data Deficient because there is insufficient information to determine their population size and trends and current conservation status (reviewed in Ross 2006, Woinarski *et al*. 2014). Therefore, until further detailed research is done on genetic structure (e.g. Bilgmann *et al*. 2008) and the abundance and trends of relevant subpopulations of cetaceans, it is not feasible to determine PBR bycatch limits for cetacean species within the SPF.

Reducing vessel strike of cetaceans

Vessel strike is a threat to some cetacean species and particularly for threatened large whale species with depleted populations (e.g. Laist *et al*. 2001, Kemper *et al*. 2008, Silber *et al*. 2009). As noted in Section 5.3.2, vessel strikes are thought to be relatively common in Australian waters including the SPF area but these are not well documented, and the incidence of vessel strikes is likely to increase in future as some whale populations continue to increase following severe depletion from whaling. The risk of vessel strike from large fishing vessels in the SPF area is uncertain, but international data indicate that most severe or lethal vessel strikes are caused by vessels that are 80 m or longer and which travel at speeds greater than 14–15 kilometres per hour (Laist *et al*. 2001, Vanderlaan and Taggart 2007). Silber *et al*. (2009) noted that reducing the co-occurrence of whales and vessels is the only certain means of reducing vessel strikes, but that this is not possible in many situations, particularly where major shipping routes overlap with whale aggregation areas (Redfern *et al*. 2013). Identification of key feeding grounds or aggregation areas such as the Bonney Upwelling and Perth Canyon, major migration routes, and important calving and nursery grounds for whales and other cetaceans in the SPF area would allow the risk of vessel strike to be assessed in marine spatial planning. A diverse range of cetaceans have been recorded from the Bonney Upwelling region including blue, fin, sei, sperm, killer, pilot and beaked whales, and various dolphin species (Gill 2002, Gill *et al*. 2011, Miller *et al*. 2012); hence this upwelling region has high cetacean activity that increases the risk of vessel strike and other interactions with large trawlers and other vessels. Identification of important habitats for cetaceans can inform marine spatial planning to assess the need for altered shipping routes to reduce the risks of vessel strike (Redfern *et al*. 2013). Alternatively, reduced vessel speed zones could be used to reduce the likelihood of fatal vessel strikes in identified high-risk areas (Redfern *et al*. 2013).

Marine mammal observers can be used to alert vessel crew to the presence of cetaceans and other large marine mammals in the vicinity or path of vessels, but visual detection of marine mammals is often difficult especially in poor weather and low light conditions and at night. Observer programs can be expensive and detection may occur too late to avoid a collision. Potential technological solutions to reduce the risk of vessel strike such as remote sensing using acoustic detections from passive acoustic or sonar devices, radar, and thermal imaging, may improve detection of whales and other cetaceans, but these technologies are not yet proven to be capable of significantly reducing vessel strikes and require further development and testing (Silber *et al*. 2009).

Summary: management of interactions

- *Management and mitigation measures that have some potential for reducing direct interactions with and associated bycatch of some species of cetaceans include excluder devices and other gear modifications, acoustic deterrent pingers, modified fishing practices, temporal and spatial closures, bycatch triggers and move-on rules.*
- *Excluder designs tested to date have not been consistently effective in reducing cetacean bycatch in trawls, and at present there is no solution to filter or deter cetaceans from entering the net opening.*
- *Excluder devices have reduced bycatch mortality of some marine megafauna in some trawl fisheries in Australian waters and internationally, but these need to be carefully designed and optimised for each fishery and for different species of cetaceans.*
    - *Underwater cameras have shown very high rates of interaction between dolphins and trawl operations in some fisheries, and further research and monitoring is needed to understand the behaviour of cetaceans in trawl nets. Common dolphins and bottlenose dolphins may behave differently when constrained within nets and may require different excluder designs and location of escape holes, which complicates the development and optimisation of excluder devices in the SPF area where both species occur.*
- *Acoustic pingers have been effective in reducing bycatch of some cetaceans in some gillnet fisheries, but their effectiveness in reducing cetacean bycatch in relatively noise-saturated pelagic trawl fisheries is unclear, with mixed results reported in different studies in Australia and overseas.*
    - *Some studies have reported significant reductions in bycatch mortality of common dolphins. But pingers appear unlikely to deter common bottlenose dolphins from interacting with trawl nets or effectively mitigate bycatch for this species.*
- *Codes of practice to reduce the risk of interactions include suspension of fishing and relocation to another area following bycatch events, but the success of the 'move on' tactic for cetaceans is uncertain.*
- *Spatial and temporal fishing closures can reduce interactions and bycatch mortality of cetaceans where the risks of interactions and bycatch are relatively high and consistent and where closures encompass sufficient parts of the range. However, effective planning of closures requires detailed knowledge of spatial and temporal use of habitats, which is lacking for most cetacean species in the SPF area.*

- *Data on population size and trends, genetic structure, and mortality from fisheries bycatch and other anthropogenic threats are lacking for most cetacean species in the SPF area. This precludes the development of population demographic models needed to determine sustainable biological removal limits for these species and bycatch trigger limits for cetaceans in the SPF mid-water trawl fishery.*
- *Independent observer programs are very important for assessing fisheries management options because they provide more reliable data on cetacean interactions and bycatch mortality, enabling adaptive management to reduce the risks of interactions.*

Proposed management of direct interactions of the DCFA and cetaceans

To manage and mitigate direct interactions with dolphins, the DCFA would have been subject to the provisions of the SPF Management Plan, SPF Harvest Strategy and SPF Bycatch and Discard Workplan and to provisions (a), (b), (f) and (g) of Condition 1 in the Schedule to the accreditation of the SPF made by the Environment Minister, as follows:

(a) Prior to fishing, have in place demonstrably effective and scientifically proven mitigation approaches and devices to the satisfaction of AFMA to minimise interactions with dolphins, seals and seabirds, including gear handling and net setting rules. These mitigation devices must, as a minimum, include best practice seal excluder devices with top opening escape hatches or equivalent mechanisms

(b) In the event of one or more dolphin mortalities as a result of the mid-water trawl fishing activities:

  i. suspend fishing;

  ii. consult with any AFMA observer onboard and review the effectiveness of mitigation measures; and

  iii. not recommence fishing within 50 nm of the mortality event.

(f) Ensure that there is an on-board observer at all times with 24 hour monitoring of mid-water trawl fishing activities and there is an underwater camera record of the operation of any bycatch excluder device at all times, and reviewed by an observer each day. The requirements under this Condition will apply to 1 November 2013 with monitoring arrangements to apply after this date to be determined following a review by AFMA and the Department.

(g) When fishing, report daily to AFMA on the level of protected species interactions, including mortalities.

As noted in Section 3.2.4, all mid-water trawl vessels in the SPF are now subject to the following conditions.

- Prior to fishing, mid-water trawl vessels must have in place effective mitigation approaches and devices to the satisfaction of AFMA to minimise interactions with dolphins, seals and seabirds.
- AFMA requires that at least one observer be deployed on each new mid-water trawl vessel for the first 10 fishing trips with additional observer coverage or other monitoring implemented as appropriate, following scientific assessment of the SPF.

Furthermore, the DCFA would also have been subject to conditions proposed in the *FV Abel Tasman* Seal and Dolphin Management Plan (Box 5.1), and those requirements relevant to dolphins (and potentially to other cetaceans) are evaluated in Section 5.3.5 together with assessment of their likely effectiveness.

5.3.4 Assessment of the likely nature and extent of direct interactions by the DCFA with cetaceans

The panel's assessment of the likely nature and extent of direct interactions of dolphins and other cetaceans with the DCFA is based on the review of the available information on the 21 cetacean species in the SPF area that are considered to be most relevant to this assessment (Section 5.3.1), and the review of available information on interactions between cetaceans and trawl fisheries in Australia and internationally (Section 5.3.2).

As noted above, there is considerable uncertainty with respect to the nature, extent and risks to cetaceans from interactions with mid-water trawl operations in the SPF and therefore considerable uncertainty with respect to interactions with the DCFA. This uncertainty arises from a number of issues including the lack of information or insufficient knowledge about the distribution, abundance and current conservation status of most cetacean species within the SPF area; the location and seasonal use of important feeding, breeding and nursery grounds and migration pathways for most cetacean species within the SPF fishing area; the extent to which dolphins and other cetacean species feed on or rely on small pelagic fish in their diets; the range of dolphin and other cetacean species that would be likely to directly interact with the DCFA, and the extent to which some may become habituated to fishing activities; and the risks and effects of bycatch mortality or vessel strikes on populations of these cetaceans (e.g. Ross 2006, Bannister 2008, Bilgmann *et al*. 2008, Woinarski *et al*. 2014). In addition, the spatial and temporal distribution of fishing effort of the DCFA cannot be predicted with any confidence.

Cetaceans are a diverse group of intelligent marine mammals, and some species are readily attracted to fishing operations which increases their risk of injury or mortality (e.g. Fertl and Leatherwood 1997, Broadhurst 1998, Zollett and Rosenberg 2005, Allen *et al*. 2014). Therefore, the nature and extent of direct interactions with the DCFA is likely to vary significantly among cetacean species, and these interactions include feeding within nets, behavioural changes leading to increased interactions with fisheries, injury or mortality from incidental bycatch, injury or mortality from vessel collision, and acoustic disturbance (see Section 5.3.2). The risks associated with these interactions will also vary among species, ranging from higher risk species such as short-beaked common dolphins and bottlenose dolphins that are known to feed on small pelagic fish and interact extensively with trawl fisheries leading to intermittent bycatch, through to larger whale species that do not usually feed on small pelagic fish but may be at higher risk from vessel strike or acoustic disturbance (Bannister *et al*. 1996, Ross 2006, Bannister 2008, Woinarski *et al*. 2014).

Based on the previous records of dolphin and other cetacean bycatch mortality with mid-water trawls in the SPF and elsewhere, the panel considers that some degree of cetacean bycatch would be likely to occur with the DCFA. Direct interactions, injuries and mortality are likely to be higher in areas of increased cetacean abundance that overlap with zones of increased fishing intensity, and particularly for cetaceans that are opportunistic feeders able to take advantage of herding and aggregation of fish resulting from trawling activities.

The panel noted that very little information is available on direct interactions between cetaceans and mid-water trawls in the SPF area. Based on the limited recorded bycatch mortality of 25 dolphins including common bottlenose dolphins and possibly short-beaked common dolphins in mid-water trawls off Tasmania in the SPF during 2001–10 (Lyle and Willcox 2008, Tuck *et al*. 2013), cetacean interactions resulting in bycatch have been considered to be relatively rare and unpredictable events. However, a large mid-water trawl freezer vessel such as that used in the DCFA would enable fishing to potentially occur throughout the SPF area wherever target fish are available; hence a greater range of habitats and increased numbers of cetacean species may be encountered compared with previous trawling operations in the SPF off Tasmania. This could result in a greater range of cetacean species interacting with the DCFA, increasing the uncertainty about the likely nature and extent of direct interactions with cetaceans. Spatial and temporal patterns of distribution and abundance of cetacean species are highly variable throughout the SPF area (see Section 5.3.1). Some species exhibit marked changes in distribution and abundance resulting from seasonal aggregations and use of feeding grounds, annual or multi-year breeding cycles and migratory movements (Ross 2006, Bannister 2008, Woinarski *et al*. 2014), which further increases the uncertainty about the likelihood of interactions with cetaceans in the DCFA.

The extent to which mortality from bycatch or vessel strike arising from interactions with the DCFA may affect cetacean populations is unknown, because most cetacean species in the SPF area are categorised as Data Deficient based on insufficient knowledge of their population size and trends and other relevant parameters required to assess their conservation status (Woinarski *et al*. 2014).

Summary: likely nature and extent of direct interactions by the DCFA with cetaceans

- *There is considerable uncertainty about the nature, extent and risks to dolphins and other cetaceans in the SPF area from interactions with mid-water trawl operations under the DCFA.*
- *Interactions would vary among species, with higher risk species such as bottlenose dolphins and short-beaked common dolphins known to prey on small pelagic fish and interact extensively with trawl fisheries, whereas some larger whale species may be at higher risk from vessel strike or acoustic disturbance.*

- *The risks of mortality from bycatch or vessel strike for the cetacean species likely to interact with the DCFA are uncertain, but some bycatch mortality could be predicted to occur based on previous reported bycatch of dolphins in mid-water trawls in the SPF area and interactions with trawl fisheries reported in other regions.*
- *The DCFA would enable fishing to occur throughout the SPF area, which would increase the range of cetacean species likely to be encountered.*

5.3.5 Assessment of the effectiveness of proposed management measures to mitigate interactions by the DCFA with cetaceans

The proposed mitigation measures for the DCFA as specified in the Seal and Dolphin VMP (Box 5.1) are assessed below. The panel noted that the VMP refers specifically to dolphins, whereas a range of other cetacean species that occur in the SPF area are at risk of interacting with the DCFA (refer to Sections 5.3.1 and 5.3.4) and therefore mitigation measures specified in the VMP are potentially relevant to other cetaceans.

Mandatory gear requirements: exclusion device

The Seal and Dolphin VMP specifies that the DCFA must have an AFMA approved seal and dolphin excluder device installed within the net at all times while conducting fishing operations.

The panel supports the requirement to have an excluder device installed within the net at all times while fishing. However, the panel noted that excluder devices are often designed to mitigate bycatch of seals or dolphins rather than being optimised for both groups of marine mammals. Hence, a single type of excluder device may mitigate bycatch for pinnipeds but may be less successful for cetaceans, and vice versa. For example, dolphins may need a different spacing of bars in the excluder grid to reduce the risk of their tail flukes becoming trapped, compared with an optimal grid design for excluding seals. There is some evidence indicating that different dolphin species may react differently to excluder devices and their location in relation to the mouth of the net (see Section 5.3.3). Furthermore, the panel noted that a range of designs for dolphin excluder devices have been developed and tested in various fisheries with varying degrees of success, hence at present the optimum design for effectively mitigating bycatch of dolphins and other cetaceans is uncertain. The efficacy of using a SED for mitigating bycatch of dolphins is highly uncertain, as dolphins and seals may behave differently within trawl nets and in response to excluder devices and the location of the escape hole (see Section 5.3.3). Furthermore, previous research has shown that excluder devices and their position within trawl nets may need to be varied for different species of dolphins (e.g. Northridge *et al.* 2005, Stephenson *et al.* 2008, Wakefield *et al.* 2014), which complicates the design process and optimisation of an excluder device for different types of marine mammals.

Under Condition 1(a) (see Section 5.3.3), a best practice seal excluder device with top opening escape hatch or equivalent mechanism would be required to be used; however the panel considers that the efficacy of such a device in mitigating dolphin bycatch is uncertain and may provide only opportunistic or suboptimal mitigation of interactions with dolphins and other species of cetaceans likely to be encountered in the DCFA. What constitutes best practice remains open to question.

The VMP requires that the escape hole on the excluder device is upward opening and has a hood attached to reduce any potential fish loss and to not allow any large animals to fall out of the net if immobile and the net is inverted. The panel noted that there is evidence of some dolphins escaping through upward opening escape holes; however some captive female bottlenose dolphins have been reported to prefer downward opening escape holes and the behaviour of most cetacean species in trawl nets is unknown. Therefore, the efficacy of this approach for mitigating interactions with different dolphin species or other cetaceans likely to interact with the DCFA is uncertain, and requires further research. The panel supports the requirement to attach a hood to the excluder device to increase the chance of retaining any bycatch of dolphins and other species.

As noted in Section 5.2.5, the SED proposed for use in the *FV Abel Tasman* was designed by Maritiem and was intended to have a soft-fibre grid rather than a hard grid, with a top opening escape hole and a hood cover to retain bycatch. However, the efficacy of this excluder device in mitigating seal and dolphin interactions is uncertain, as a soft grid has previously proved less effective than a hard metal grid for directing seals towards the escape hole (see Section 5.2.5), and this new SED design would require extensive testing at sea and monitoring to optimise its efficiency over an extended developmental period (e.g. Northridge *et al.* 2005, Zeeberg *et al.* 2006, Lyle and Willcox 2008, Stephenson *et al.* 2008).

Mandatory fishing operation requirements

The panel supports the requirement to have an AFMA observer onboard the DCFA at all times, noting that it interprets this as requiring that there must be AFMA observer coverage (observer onboard and/or electronic) of all fishing activities to ensure full observer coverage and electronic monitoring of all shots and hauls.

The panel supports the requirement to ensure the boat has underwater cameras operational at all times while undertaking fishing and that those cameras constantly record any take of bycatch and/or behaviours near the excluder device. The panel noted the importance of recording all interactions with dolphins or other cetaceans including their behaviour around the excluder grid and escape hole, and recording the number, condition and timing of dolphins and potentially other cetaceans that use the escape hole or are taken as bycatch. Multiple underwater cameras would need to be used to ensure coverage of interactions near the excluder device and the escape hole. Recording of dolphin behaviour within the net nearer the net mouth would also be beneficial based on observations in the PFTIMF that common bottlenose dolphins appear to become distressed initially near the net mouth (e.g. Wakefield *et al.* 2014).

The panel supports the requirement to allow the on-board AFMA observer access to review any footage recorded by the underwater camera at least once every 24 hours for the duration of each fishing trip. However, the panel noted the importance of monitoring and assessing the extent of interactions with dolphins and potentially other cetaceans on as near a real-time basis as possible, so that Condition 1(b) to suspend fishing (see Section 5.3.3) can be complied with in the event of one or more dolphin mortalities occurring. The panel interprets this requirement to indicate that all recorded footage would be archived for future reference so all fishing operations can be reviewed, noting that it may be possible only to monitor and review a subset of trawls and hauls onboard. Therefore, if one or more dolphin mortalities occurred but were not quickly detected through real-time monitoring, a subsequent review of the footage would occur too late to suspend fishing in the immediate area in which the mortality event occurred and consequently the risk of further bycatch would not be mitigated.

The panel supports the requirement to not deploy any trawl nets if dolphins are sighted around the boat by any crew member or on-board observers, until the dolphins have dispersed of their own accord or the boat has steamed away and are no longer in sight of the boat. This requirement refers only to dolphins but it is likely that other cetaceans may be intermittently present in the vicinity of the vessel. The panel also noted that visual observations of dolphins and other cetaceans near the vessel by crew members and on-board observers will be dependent upon sighting efficiency and detectability that will vary during vessel operations and are highly dependent on time of day (significantly lower during low light and at night), sea state and weather conditions, which introduces further uncertainty in assessing this requirement. Most trawls in the SPF commence at night when visual detection of cetaceans would be very limited. Remote sensing technology could be considered for detecting cetaceans in the vicinity of the vessel using passive acoustic or sonar devices, radar, or thermal imaging. However, Silber *et al.* (2009) noted that these technologies need further development and testing and are likely to be costly. Dolphins and other cetaceans may remain submerged below the surface for some time so detectability will vary depending upon their behaviour states and dive duration. It is unlikely that an on-board observer would be able to continually view all areas around the vessel to ensure dolphins are not present prior to and during deployment and hauling of nets. The time required for dolphins and other cetaceans to disperse sufficient distance away from the vessel to reduce the risk of interactions is unknown, and the distance the vessel should steam away from the area of dolphin sightings to reduce the risk of interactions is uncertain. The panel noted the requirement that trawl nets should not be deployed if seals are sighted within 300 m of the vessel, but the distance between the vessel and dolphins is not similarly specified.

The panel supports the requirement that observers are notified prior to the deployment and/or the recovery of trawl nets, day and night, in order to allow the observers to be present to detect any seals which become enfolded or caught at the surface, so the animals can be rapidly and humanely released. The panel noted that this requirement is also relevant for detection and rapid and humane release of any dolphins and potentially other cetaceans that may become enfolded or caught in the net.

The panel supports the requirement to take all reasonable steps to ensure that, as far as practicable, if a seal or dolphin is captured in a trawl net as a result of fishing operations, the mammal is released alive and unharmed, and noted that this measure is also relevant to other cetaceans.

The panel supports the requirement to record any interaction with any protected species in a logbook onboard the boat and notify AFMA in writing, detailing any interactions with protected species, including any mortalities, every 24 hours for the duration of each fishing trip. The panel noted that the degree to which all interactions with protected species are recorded in a logbook and reported to AFMA every 24 hours will be dependent upon the coverage of the underwater cameras and the extent to which all shots and hauls are reviewed within each 24-hour period. The ability to identify and report on the species of dolphin or other cetacean interacting with the DCFA would be determined by the extent of training in species identification for observers and crew. Identification of cetacean species at sea is often difficult. If dead dolphins or other cetaceans are retained in the net or hood and brought onboard, there is increased scope for detailed examination and identification by trained observers. Further, the collection of small biopsy samples for genetic analysis would enable the species identification to be confirmed. Accurate identification and reporting of interactions with dolphin and other cetacean species would enable management measures to be more effectively adapted to account for different species.

Mandatory interaction requirements

The VMP requires that, if fishing operations conducted by the method of mid-water trawling result in the death of one or more dolphins in any one shot the holder must:

- suspend fishing immediately
- notify the AFMA observer onboard of the dolphin mortalities and with the assistance of the AFMA observer review the effectiveness of mitigation measures used in fishing operations
- not recommence fishing within 50 nm of the event.

The panel supports the requirement to suspend fishing immediately when a mortality is detected. However, it noted that it is likely that some mortalities will not be immediately known to the crew or the observer, but may subsequently be identified on review of video recordings which would reduce the efficacy of this requirement, i.e. by the time the mortality has been identified from recordings the vessel will no longer be in the area.

The panel supports the requirement to notify the AFMA observer of any mortality event. However, the panel noted that in practice there will be considerable uncertainty with respect to how the effectiveness of mitigation measures used in fishing operations could be reviewed at sea to decrease the risk of further interactions and mortalities.

The panel supports the move-on rule in principle, but noted that the rationale for requiring the vessel to move away a distance of 50 nm is unclear. This distance may reduce the likelihood of further interactions by some smaller cetaceans, however, some cetaceans are known to follow fishing vessels for extended periods once depredation events have occurred so whether 50 nm is too large or too short a distance to move is uncertain. As with pinnipeds, it is possible that in randomly moving a set distance, fishing operations could move to an area with higher cetacean densities where interactions are more, rather than less likely. Further, as noted above, mortalities detected by the underwater camera are unlikely to be identified on a real-time basis and some mortality may remain undetected until the gear is hauled, so the likely effectiveness of the move-on rule is uncertain.

Panel assessment and advice: effectiveness of proposed measures and actions to avoid, reduce and mitigate impacts of direct interactions by the DCFA with cetaceans

Assessment: effectiveness of proposed measures

- *The efficacy of the proposed mitigation measures for dolphin interactions with the DCFA is highly uncertain, primarily because these measures have not proven to be consistently effective at mitigating bycatch of dolphins and other cetaceans in other fisheries, nor specifically in the SPF. In particular:*
  - *there is no currently accepted optimum excluder device for mitigating interactions with dolphins and there is evidence to suggest that a single excluder device may not effectively mitigate bycatch of both seals and dolphins, or different species of dolphins*
  - *effective enforcement of measures related to dolphin mortality and suspension of fishing and move-on rules is limited by the capacity for rapid detection of all mortalities using delayed review of underwater recordings that would reduce the efficacy of these measures*
  - *the effectiveness of measures that require a response to sightings of dolphins is questionable given that most fishing in the SPF takes place at night and visual detection of dolphins is highly variable at other times.*

Advice: actions to avoid, reduce and mitigate adverse environmental impacts of the DCFA

- *Use an excluder device only after its operation has been optimised for the vessel, fishery and different dolphin species , including both bottlenose and short-beaked common dolphins, under a scientific permit with the required level of performance developed in consultation with experts, noting that excluder designs tested to date have not been consistently effective in reducing cetacean bycatch in trawls, and at present there is no solution to filter or deter cetaceans from entering the net opening.*
- *Use underwater video to monitor dolphin behaviour within the net and around the excluder device to determine the efficacy of the excluder device and levels of cryptic mortality.*
- *Introduce a bycatch rate trigger limit for dolphin species for the fishery or fishing areas, or a total mortality trigger for a fishing season and/or fishing areas on a precautionary rather than evidentiary basis.*
- *Replace the 50 nm move-on rule in response to a single dolphin mortality, with a requirement to move to an area where interactions with cetaceans are less likely, based on available data on estimated at sea density distributions.*
- *Assess the efficacy of acoustic deterrent pingers (during rigorous controlled trials under scientific permit with the required level of performance developed in consultation with experts), and temporal and spatial closures, that have been shown elsewhere to have potential to reduce the risk of interactions for some cetacean species, including dolphins.*
- *Prohibit the discard of any biological waste (excluding the release of any protected fauna) noting that this was a requirement of the proposed seabird VMP.*
- *Ensure 100 per cent observer coverage of fishing operations and, if trigger limits are used in conjunction with move-on rules or requirements to review mitigation measures, provide sufficient observer capacity to ensure that underwater video footage is monitored at the end of each shot to maximise response times to mortalities.*
- *In addition to the above actions to mitigate impacts on dolphins, ensure that monitoring and agreed management responses are in place to allow a timely management response if other cetacean species interact with the DCFA.*

5.3.6 Monitoring and research

The previous Sections have highlighted the considerable uncertainties associated with assessing the likely nature and extent of direct interactions of cetaceans with the DCFA (Section 5.3.4), and the efficacy of the proposed management measures to mitigate interactions with cetaceans and the DCFA (Section 5.3.4). These uncertainties require further monitoring and research to improve knowledge so that these issues can be more effectively addressed. The key questions that arise from assessment of the DCFA in relation to likely interactions with cetaceans, and the rationale for these, are outlined below.

1. What regions in the SPF area are important habitats used by cetaceans that have increased risk of interactions with the DCFA?

As noted in Section 5.3.1, remarkably little information is available on the distribution and abundance and important habitat areas used by most cetaceans in the SPF area for aggregating, feeding, breeding and nursery areas (Ross 2006, Bannister 2008, Woinarski *et al*. 2014). Important seasonal aggregation and feeding habitat areas are known for some larger whales such as the Bonney Upwelling and Perth Canyon where endangered blue whales and a diverse range of other cetaceans have been recorded. Major migratory pathways for humpback whales and some other cetaceans, and breeding or aggregation grounds for southern right whales and the depleted population of sperm whales, occur in various locations along southern Australia within the SPF area. There is insufficient knowledge of important habitat areas for the depleted south-east subpopulation of southern right whales, and the location of important habitats and areas of increased abundance for most other cetaceans in the SPF area are unknown. This is particularly problematic for smaller cetaceans including bottlenose dolphins and short-beaked common dolphins that are known to be at particularly high risk of interactions and bycatch from trawl fisheries. Improved knowledge and identification of important habitats for cetaceans occurring in the SPF area is essential to enable hotspots of increased cetacean abundance and activity to be identified, so that the degree of overlap with potential areas of increased fishing activity likely to occur from the DCFA could be determined. This would allow areas of increased risk of interactions between cetaceans and the DCFA to be identified, which in turn would enable more effective spatial planning for management of the DCFA. Risk-based management would enable assessment of the need for, and likely efficacy, of seasonal spatial closures for the DCFA to reduce the likelihood of interactions with cetaceans and adverse outcomes arising from net feeding, entanglement and bycatch, noise disturbance and vessel strike. Further research using satellite tracking of cetaceans would provide essential information for identifying important habitats and seasonal and migratory movements within the SPF area, and the potential for overlap with fishing activities in the DCFA.

2. What levels of mortality arising from interactions with the DCFA could be sustained by cetacean populations in the SPF area?

The most recent comprehensive assessment of the conservation status of Australian mammals (Woinarski *et al*. 2014) concluded that blue whales are Endangered with Antarctic blue whales Critically Endangered, fin whales and sei whales are Endangered, and sperm whales are Vulnerable, hence these species are at more obvious risk of anthropogenic impacts. As the abundance and population trends of most cetacean species occurring in the SPF area are unknown and most of these species are assessed as Data Deficient, assessment of the likely impacts of fishing and other anthropogenic threats is seriously impaired (Ross 2006, Woinarski *et al*. 2014). Therefore, further monitoring and research on population size and trends, and research on genetic structure to identify management units within these populations are essential to provide the information needed to develop population models that can be used to assess the likely impacts of mortality arising from interactions with the DCFA. At present it is not possible to effectively determine PBRs for fishing-related mortality for cetacean species at risk of interactions with the DCFA, which hinders assessment of the potential for adverse environmental impacts arising from the altered fishing practices associated with the DCFA. This information is necessary to assess the DCFA against Part 13 of the EPBC Act in relation to interactions with EPBC Act listed species in Commonwealth waters, which requires that "the fishery does not, or is not likely to, adversely affect the conservation status of protected species or affect the survival and recovery of listed threatened species".

Adequate monitoring and reporting of interactions and bycatch mortality are necessary for calculating sustainable PBRs in relation to the DCFA and other fisheries in this region that are known to cause mortality of cetaceans. The panel also considers that a total mortality trigger leading to suspension of fishing operation to enable a detailed review of the fishing operations and mitigation measures is needed (refer to Section 5.3.5). Therefore, the panel reaffirms the importance of ensuring full independent observer coverage and monitoring of fishing activities at all times, as part of the proposed mandatory fishing operation requirements (see Section 5.3.5). As noted in Section 5.3.3 independent observer programs are important because they provide more reliable data on interactions with TEPS and bycatch mortality (e.g. Stephenson *et al*. 2008, Hamer *et al*. 2008, Tuck *et al*. 2013, Allen *et al*. 2014). Where there is sufficient observer coverage, data on interactions and bycatch mortality can be used to effectively assess the performance of fisheries operations and management measures to reduce interactions and bycatch. Tuck *et al*. (2013) concluded that a number of measures that have been introduced to reduce interactions with TEPS and bycatch in Australia's Commonwealth-managed fisheries have been successful to varying degrees, but that data availability or precision are insufficient for some fisheries to judge the effectiveness of these measures. Adequate monitoring and reporting of interactions is also required for estimating total cetacean bycatch mortality across all fishing effort within a region (Tuck *et al*. 2013), and therefore for identifying the extent to which the DCFA might contribute to this total fishing mortality. An important issue related to adequate monitoring and reporting of interactions and bycatch mortality, is to ensure that observer training and fisher education programmes include training in identification of cetacean species and other protected species to improve records of interactions and bycatch, and to more effectively identify species of concern.

3. What modifications to the proposed fishing gear and operations of the DCFA are needed to improve management and reduce the potential for interactions including bycatch of cetaceans?

The panel concludes that substantial research and monitoring are needed to assess the effectiveness of the proposed management measures to mitigate cetacean interactions with the DCFA (see Section 5.3.5). In relation to the SED proposed for use in the DCFA, detailed research and monitoring using a quantitative experimental design and trials conducted at sea would be needed to evaluate SED performance and provide the data needed to optimise its effectiveness in mitigating bycatch. Different designs of excluder devices have been developed for reducing bycatch of common dolphins and bottlenose dolphins (see Section 5.3.3). An upward opening escape hole seems to be preferred by some small cetaceans, but some captive female common bottlenose dolphins have been reported to prefer a downward opening escape hole. These issues complicate the design process; hence it may not be possible to optimise an excluder device to effectively mitigate bycatch of all cetacean species and pinnipeds that could potentially interact with the DCFA. The performance of the proposed auto-trawl system to maintain net integrity and SED performance also needs to be tested during trials at sea.

Specific aspects of the excluder device that require research and monitoring include the performance of the proposed soft grid versus the use of a hard grid, the optimal placement of the excluder within the net, the spacing of the grid bars and angle of the grid, and the position and size of the escape hole to facilitate safe exit of cetaceans and other TEPS. The performance of the hood in retaining bycatch would also need to be evaluated during trials at sea. Underwater video cameras and archived recordings of cetacean behaviour within the net and near the excluder device are needed to monitor and evaluate the efficacy of the excluder device, and to facilitate adaptations of the design. Monitoring the health status of cetaceans and other TEPS that exit from the escape hole and post-release survival of any identified individuals would help to reduce uncertainties about cryptic mortality rates. As excluder devices are not consistently effective at reducing bycatch, underwater monitoring of the behaviour of dolphins and other cetaceans during night versus day trawls and in the forward part of the net would be beneficial in assessing the extent to which cetaceans become distressed within different areas of the net, leading to reduced probability of survival.

Other mitigation measures that could be assessed in relation to reducing interactions with cetaceans include the use of acoustic deterrent pingers such as DDDs, and physical deterrents to prevent cetaceans entering the net (see Section 5.3.3). Further research is required to develop monitoring systems that will enable remote detection of cetaceans in the vicinity or path of the fishing vessel to reduce the risk of vessel strike and other interactions, particularly when visual observation is impaired.

Research on aspects of fishing operations that would be beneficial in assessing rates of cetacean interactions and risks of bycatch mortality include comparisons of night versus day trawls, variation in net headline depth, tow duration and speed, and the distance required for the vessel to move away from an area in which bycatch mortality occurred to reduce the risks of interacting cetaceans remaining with the vessel during relocation to a new fishing area.

Panel advice: research and monitoring to reduce uncertainties

Research that addresses the following questions could help to reduce uncertainties about the potential for adverse environmental impacts of the DCFA on protected cetacean species:

- *What regions in the SPF area are important habitats used by cetaceans that have increased risk of interactions with the DCFA?*
- *What levels of mortality arising from interactions with the DCFA could be sustained by cetacean populations in the SPF area?*
- *What modifications to the proposed fishing gear and operations of the DCFA are needed to improve management and reduce the potential for interactions including bycatch of cetaceans?*

In addition, observer data on all cetacean interactions should be collected, analysed and published.

5.4 Seabirds

Little information or data specific to seabird bycatch in large mid-water trawl freezer vessels was located. The panel's assessment is, therefore, based largely on information available on the impacts on seabirds of trawling more generally, and mid-water trawling, in particular, including in the SPF.

5.4.1 Species

There are 89 protected species of seabirds that occur within the SPF area (see Appendix 3). Seabird species richness overlaid with mid-water trawl effort in the SPF is shown in Figure 5.20. Of those, the groups most impacted by direct interactions with fisheries are albatrosses and petrels (Baker *et al.* 2002, Croxall 1998 cited in Elgin unpublished (a)). The ERA for the SPF mid-water trawl sector (Daley *et al.* 2007b) assessed 76 bird species of which 53 were albatrosses and petrels. The remainder comprised penguins, cormorants, gannets, boobies, tropicbirds, skuas, gulls and terns, which are considered likely to be of lower risk from mortality in trawl fishing operations (Elgin Associates unpublished (a)).

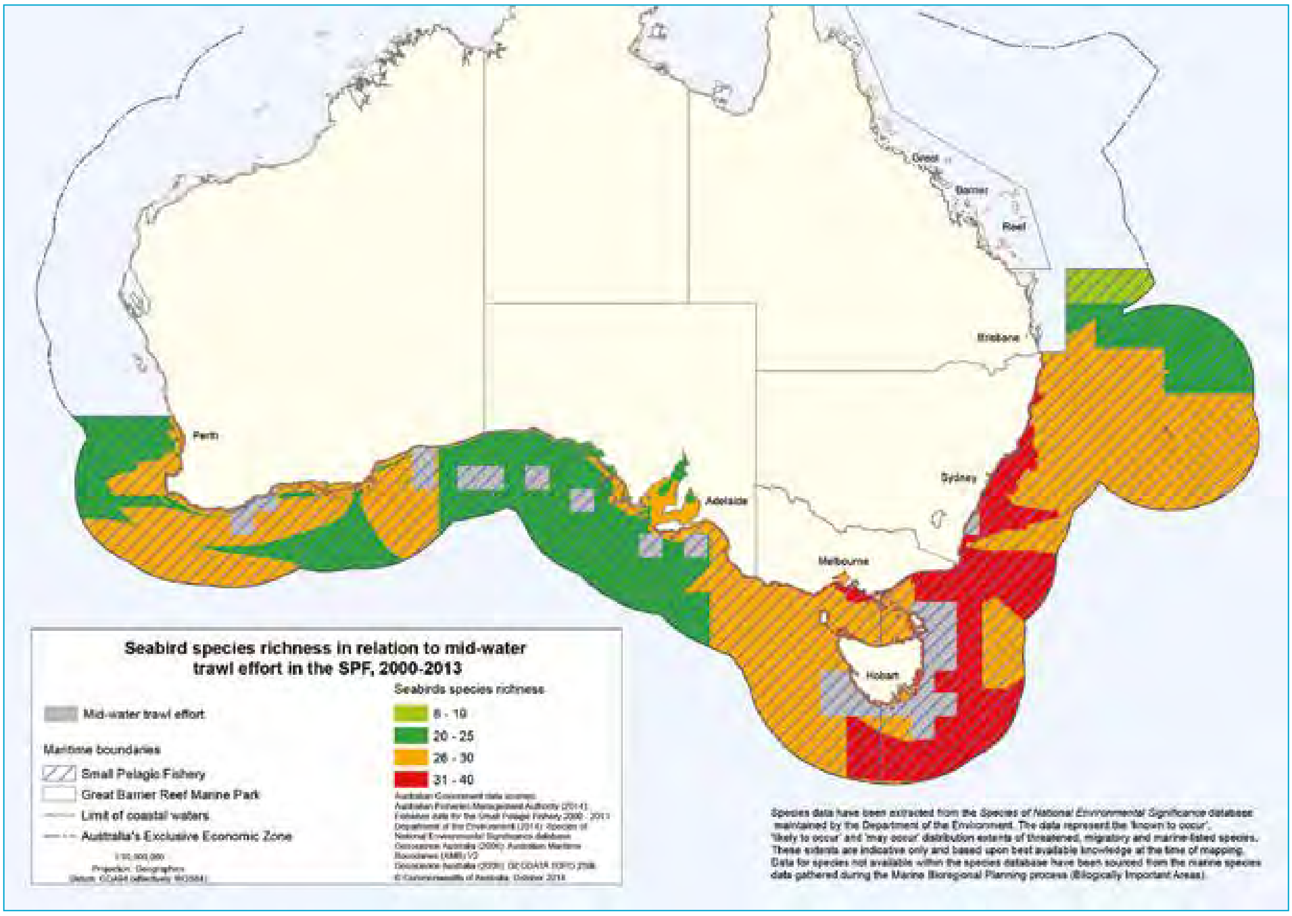


Figure 5.20 Seabird species in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by ERIN using unpublished AFMA data.

Of the 76 bird species assessed in the ERA, only three (shy albatross *Thalassarche cauta*, Chatham albatross *T. eremita* and black-browed albatross *T. melanophris*) were assessed at 'high' risk (Daley *et al.* 2007b). These assessments were reduced to 'medium' risk as a result of the residual risk assessment (AFMA 2010b). Thus, as a result of the ecological risk assessment and management processes, all bird species assessed were found to be at medium (43) or low (33) risk from mid-water trawl operations in the SPF.

5.4.2 Nature, extent and management of seabird interactions in the SPF

Extent of interactions in the SPF to date

The National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011–2016, identifies the most critical foraging habitat for these species to be those waters south of 25°S where most species spend the majority of their foraging time (DSEWPaC 2011). The entire area of the SPF is south of 24°S.

The most comprehensive compilation of data on interactions with protected species in the mid-water trawl sector of the SPF has been compiled by Tuck *et al.* (2013). They report that, between 2001 and 2011, there were 37 recorded seabird interactions with mid-water trawl gear in the SPF (Tuck *et al.* 2013). Of those, 36 occurred in the first half of 2006 and involved shearwaters; 24 flesh-footed shearwaters *Puffinus carneipes*, eight short-tailed shearwaters and four unidentified shearwater species. Of those, 22 mortalities were recorded. Both flesh-footed and short-tailed shearwaters have an ecological risk management rating of 'medium' risk.

As noted in Section 5.1, the data reported in Tuck *et al.* (2013) exclude any impacts on seabirds resulting from acoustic disturbance and behavioural changes brought about by habituation to fishing operations. The panel found no evidence to suggest that acoustic disturbance from fishing vessels was likely have an adverse impact on seabirds. However, there is evidence to suggest that discarding of fish and waste from processed fish (offal) does result in habituation to fishing operations. This issue is discussed below. While the panel acknowledges that neither fishers nor observers are able to detect or report on the extent of habituation in the same way that they report on collisions with the vessel or gear or captures of seabirds in nets, the omission of the impact of habituation from data on 'interactions' with seabirds necessarily understates the extent and impact of 'interactions' as defined for the purposes of this assessment.

In its *Small Pelagic Fishery Management Arrangements Booklet 2014-15* (AFMA 2013e), AFMA defines interactions with protected species as "any physical contact an individual (person, boat or gear) has with a protected species that causes, or may cause death, injury or stress to the species". In relation to seabirds, AFMA (2013e) provides the following example of what is and what is not an interaction:

"An interaction includes:

- where a seabird has to be assisted back into the water
- when heavy contact occurs with the boat/gear, causing the bird to be dragged underwater or to deviate from its course
- any collisions with the fishing boat, fishing gear (i.e. warps, wheel house)
- a bird gets snagged on loose or protruding wire ends (e.g. splice ends)
- a high speed collision with boat/gear
- a bird gets caught in the net or snagged on the net while attempting to feed (on 'stickers') and has to be assisted back into the water or air.

An interaction does not include:

- seabirds landing on a boat or diving into/onto a net of fish and swimming or flying off uninjured and without assistance
- where a bird is flying and has light contact with boat/gear, and the bird does not deviate from its course
- a bird floating on the water, and has light contact with boat/gear
- where a bird 'hitches a ride' on the trawl arms for a period of time and then flies away unassisted."

The panel considered that this advice is inconsistent with the definition of interactions agreed in the MoU between the Department of the Environment and AFMA (see Section 2.2.3). The MoU, correctly in the panel's view, includes "any physical contact" as an interaction, while the examples cited by AFMA exclude seabirds landing on the boat or diving into the net of fish and other forms of 'light' contact with the vessel or gear.

The definition of interactions agreed with AFMA by the Department of the Environment is narrower than that considered appropriate by the panel. In addition, in applying that definition, AFMA further constrains its interpretation by excluding certain types of interactions. As a result, the panel considered that seabird 'interactions' as interpreted by the panel, are likely to be underreported by both observers and in fishers' logbooks. The report by Tuck *et al.* (2013), which relies on these sources of information, is therefore also likely to underestimate interactions.

Nature of interactions in the SPF to date

The causes of mortality of seabirds in trawl fisheries have been summarised by the Agreement on the Conservation of Albatrosses and Petrels (ACAP) (2013a) as: "Varied and dependent on the nature of the fishery (pelagic or demersal), the species targeted and fishing area. Mortalities may be categorised into two broad types: (1) cable-related mortality, including collisions with net-monitoring cables, warp cables and paravanes; and (2) net-related mortality, which includes deaths caused by net entanglements." Tuck *et al.* (2013) provide no indication of the cause/nature of the interactions with seabirds reported in the first half of 2006 in the mid-water trawl sector of the SPF.

The panel found that there was widespread agreement that there is a strong link between the discharge of biological material from trawl vessels and seabird interactions. This is evidenced by the following:

- ACAP's assessment that: "Seabird interactions have been demonstrated to be significantly reduced by the use of mitigation measures that include protecting the warp cable, managing offal discharge and discards, and reducing the time the net is exposed on the surface of the water … In all cases the presence of offal and discards is the most important factor attracting seabirds to the stern of trawl vessels, where they are at risk of cable and net interactions. Managing offal discharge and discards while fishing gear is deployed has been shown to reduce seabird attendance" (ACAP 2013a).
- Elgin Associates (unpublished (a)), in a review of the impacts on EPBC Act protected species by large mid-water trawl vessels conducted for the panel, concluded that, in the mid-water trawl sector of the SPF, "there is a risk of incidental mortality for seabirds that follow fishing vessels and attempt to feed on discards and offal through warp strike and entanglement in trawl gear" and "the concentration of prey items during or following fishing activities is known to attract feeding seabirds. It is possible that reliance on offal or discards from fishing operations may affect breeding success".
- The South Pacific Regional Fisheries Management Organisation's (SPRFMO) Conservation and Management Measure for minimising bycatch of seabirds exempts trawl vessels that discharge no biological material from the seabird mitigation specification for trawl fishing (SPRFMO 2014a).
- The New Zealand National Plan of Action for Seabirds noted that: "Warp strikes are uncommon when fish waste and discards are not being discharged. Vessels fishing without discharging fish waste and discards therefore present less danger to seabirds of warp strike" (Ministry for Primary Industries, 2013).
- "With seabirds, the biggest risk factor is offal and fish waste" (Mr R. Wells, ResourceWise Ltd, pers. comm. 28 April 2014).
- In New Zealand, there are a variety of regulatory and non-regulatory measures to mitigate impacts on seabirds including the mandatory use of bird scaring devices (tori lines and bird bafflers) for trawl vessels greater than 28 m length overall to keep seabirds away from trawl warps through to non-regulatory VMPs, specific to each vessel, to control factors such as offal management (Mr D. Turner, Ministry for Primary Industries New Zealand *in litt.* 25 June 2014). Mr Turner noted that: "The effectiveness of these measures depends on the type of interaction. Tori lines are effective at reducing warp strikes with long-winged seabirds such as albatrosses, however there is little mitigation that can be employed to stop short-winged birds diving on or into the net to take fish during hauling. Offal management, when done well, can be very effective."
- Seabirds are attracted to trawlers due to offal, smell and history (Mr F. Drenkhahn and Mr S. Boag *in litt.* 28 October 2013).

Summary: nature and extent of interactions with seabirds in the mid-water trawl sector of the SPF

- *The SPF area is known to be important to many seabird species, and interactions with the mid-water trawl sector have occurred.*

- *Despite issues with regard to interpretation of 'interactions', the panel formed the view that the rate of interactions of SPF mid-water trawl operations with seabirds is likely to have been low.*
- *It is likely that the relatively low level of seabird interactions in the SPF can be at least partly explained by the low level of discharge of biological material that would attract seabirds.*

Management of seabird interactions in the SPF

There are no specific seabird mitigation measures in place for mid-water trawl vessels in the SPF. However, Part 13 accreditation of the SPF under the EPBC Act requires that mid-water trawl boats must have in place effective mitigation approaches and devices to minimise interactions with seabirds. AFMA enforces this by requiring the development and implementation of an approved seabird VMP. These plans are developed by AFMA in consultation with the Department of the Environment and industry. All SPF mid-water trawl operators are required to comply with and enforce them onboard. The VMP sets out individually tailored mitigation measures for the boat that minimise seabird interactions. These include requirements for physical devices to minimise interactions. The VMP may also include measures to manage the discharge of biological waste from boats to reduce seabird attraction and move-on provisions for any interactions (AFMA 2013e). The application of this policy was apparent in relation to the proposal to introduce the *FV Abel Tasman* to the SPF in 2012. The VMP that was proposed to apply to that vessel is described in Box 5.2.

Box 5.2 Proposed *FV Abel Tasman* Seabird Management Plan

Seabird Hazard Summary:

Hazard	Threat to Seabirds
Net	Entanglement on hauling and setting
Warp Wire/Net Sonde Cable	Contact through mid-air collisions Injury or drowning by warps/cables from surface Snagging on warp sprags

Boat Specific Mitigation:
The agreed mitigation actions employed by the skipper and crew of the [FV mid-water trawler]

Mitigation measures	Details
Discharge management	The holder must retain all biological material and not discharge into the water while gear is in the water
Cleaning net before deployment of fishing gear	The holder must clean the nets prior to deployment of gear removing all accessible entangled fish ("stickers")
Bird bafflers	The holder must deploy bird bafflers[15] while gear is in the water
Warp maintenance	The holder must maintain warps and remove all sprags
Warp Deflectors[16]	The holder must deploy warp deflectors from both warps while gear is in the water.

Handling Practices:
If seabirds are incidentally caught and are still alive:

- Make every reasonable effort to ensure that seabirds are released alive:
- When possible, attempt to remove seabirds from netting or meshes without jeopardizing the life of the bird; and
- Always wear gloves, long sleeves and protective eyewear when handling seabirds because they have sharp beaks and are capable of serious bites.

15 A 'bird baffler' comprises two booms attached to both stern quarters of a vessel. Two of these extend out from the sides of the vessels and two from the stern. Dropper lines are attached to the booms to create a curtain to deter seabirds from the warp-sea interface zone (ACAP, 2013a).

16 Warp deflectors (scarers) comprise weighted devices attached to each warp with clips or hooks allowing the device to slide up and down the warp freely and stay aligned with each warp, creating a protective area around the warp.

Crew Awareness:

- Crew and boat safety remains paramount. In this context and in line with this VMP, all reasonable care should be taken to minimise seabird interactions
- Ensure crew are briefed on the seabird mitigation procedures and fully understand the actions required
- Crew need to be aware of the seabird activity around the boat and report any additional observed risks to seabirds to the skipper, who will inform AFMA
- Ensure skippers are informed of any mitigation gear failures immediately so they can be addressed rapidly or of potential improvement that may increase seabird mitigation effectiveness
- Any Occupational Health and Safety issues arising from the use of seabird mitigation measures or procedures must be reported immediately to the skipper to be forwarded to AFMA.

Reporting Requirements:

- Provided an operator is fishing in accordance with your SPF Management Plan accredited under Part 13 of the EPBC Act it is not an offence to have an interaction with a protected species. However, failure to report an interaction in your daily fishing log is an offence.
- All seabirds are protected under Australian law and as such seabird interactions must be recorded in the Listed Marine and Threatened Species Form at the back of your daily fishing log and submitted to AFMA with the relevant fishing log sheets.
- Notes on the effectiveness of the mitigation devices should be recorded in the comments section of your log page.
- Try to identify seabirds that are captured. All boats should have a copy of the protected species identification guide onboard.
- If a tagged/banded seabird is captured, operators should record the band number with as many details as possible in the Listed Marine and Threatened Species Form, noting the condition in which it was released.

Source: Dr J. Findlay, AFMA, *in litt.* 19 April 2013.

5.4.3 Nature and extent of direct interactions by the DCFA with seabirds

The likely nature and extent of interactions of the DCFA with seabirds will depend on the fishing practices adopted, fishing effort, the spatial and temporal pattern of fishing and the seabird mitigation measures used. It is the panel's view that all these factors may differ under a DCFA compared to previous mid-water trawl operations in the SPF. This limits the extent to which the nature and extent of seabird interactions in these previous operations can inform an assessment of the DCFA.

Fishing practices

The information available to the panel suggested that the configuration of the gear on the vessel used in the DCFA is likely to differ markedly from that used previously on mid-water trawl vessels in the fishery. However, the fishing scenario of the DCFA (Box 2.1) excludes the disposal of biological material. This is a point of difference between the DCFA and previous mid-water trawl operations in which discarding of biological material was permitted, although only low levels of discarding are recorded (Tuck *et al.* 2013). Based on the discussion in Section 5.4.2, the panel considered that the practice of no discards of biological material is likely to have a mitigating effect on the potential for impacts on seabirds through habituation and through physical interactions by way of cable strike or net entanglement.

The potential impact of the practice of pumping fish from the net to the vessel on seabird interactions had been identified, initially, by the Department of Sustainability, Environment, Water, Population and Communities, as an uncertainty related to large mid-water trawl freezer vessels (DSEWPaC 2012b) due to the possibility that fish in the net may be available at the surface during the pumping operation and therefore attractive to seabirds. Ultimately, however, the Department reached the conclusion that: "The nature of interactions between seabirds and other types of trawl vessels is fairly well known. The department considers that based on the advice provided by Seafish about the depth at which the cod-end will be left in the water, together with the application of a seabird management plan, the impact on seabirds of large mid-water trawl freezer vessels entering the fishery may be less than for other trawl methods and therefore there is little or no uncertainty about the potential environmental impacts on seabirds." (Logan 2014). While the panel's Terms of Reference do not identify uncertainties in relation to impacts of the DCFA on seabirds in particular, the panel decided that it was appropriate to reach its own conclusions on this matter.

The panel noted that pumping has been used in previous mid-water trawl and purse seine operations in the SPF (Seafish Tasmania Pty Ltd *in litt.* 16 October 2012). The panel was advised that, during pumping, the bag and codend of the trawl net hang vertically beneath the vessel and the net is fully submerged to a depth of 50–70 m (Seafish Tasmania Pty Ltd *in litt.* 16 October 2012 and pers. comm. 23 April 2013) and that the higher pumping capacity likely to be on a vessel involved in the DCFA compared to vessels previously operated in the SPF, would reduce the time taken for the codend to be emptied.

Fishing effort

The highest annual catch taken by mid-water trawling since 2000 was nearly 9000 t in 2003 (AFMA unpublished data).

Catches in the SPF in recent years have been significantly lower than the available TACs (Table 3.1). It is claimed (for example, Mr A. Ciconte *in litt.* 15 October 2012; Ms M. Valente *in litt.* 16 October 2012; Mr F. Drenkhahn, on behalf of eight SPF SFR holders, *in litt.* 16 October 2012) that the limited range of the wet boat fleet of vessels that has fished in the SPF to date has restricted the fishery's ability to catch the available TACs in an economically efficient way. The proposal for a large-scale mid-water trawl operation was a response to this situation. The panel considered that to be economically viable, substantial proportions of the available TACs would need to be taken by the DCFA and that it is, therefore, reasonable to assume the DCFA would result in increased trawl shots and increased catches compared to those of recent years.

A significant increase in fishing effort might be expected to result in an increase in the number of interactions with seabirds. However, whether the rate of interactions with seabirds under a DCFA, would necessarily increase from the relatively low rate of the past, will depend on other factors that are discussed below.

Spatial and temporal pattern of fishing

The panel considered that the spatial and temporal pattern of fishing under a DCFA is likely to differ markedly from that of previous mid-water trawl activities in the SPF since the rationale for the introduction of a large mid-water trawl freezer vessel into the SPF relies on the ability to fish areas of the fishery that have not been previously accessible due to their distance from ports, the ability to stay at sea for longer periods and the greater capacity to fish to the available TACs.

Figure 5.20 shows that the fishery has been operating in the area of the SPF where the highest species richness of seabirds occurs, however, the abundance and distribution of birds overall is unknown. Central place foragers are more likely to be vulnerable to interactions if fishing occurs in close proximity to their rookeries. The most abundant seabird is the short-tailed shearwater, which numbers approximately 23 million, although there has been substantial decline over the past few decades (BirdLife International 2014). There are more than 280 rookeries situated on numerous, relatively inaccessible offshore islands with the largest of more than 2.8 million individuals, on Babel Island in eastern Bass Strait (Patterson *et al.* unpublished). Little penguins are also abundant with about 35,000 birds distributed throughout southern Australia and the largest colony on Gabo Island. There have been no recorded interactions with little penguins in the SPF. The population of Australasian gannets was estimated to be about 20,000 pairs in 1999–2000, with the largest colony approximately 12,000 on Black Pyramid Rocks in Tasmania (Bunce *et al.* 2002 in Patterson *et al.* unpublished). There are no recorded interactions of gannets with the SPF mid-water trawl fishery. Short-tailed shearwaters and Australasian gannets forage on the shelf for SPF species but can range approximately 200 km from their rookeries during breeding season while little penguins are restricted to around 30 km during breeding season and are less dependent on the SPF species.

These species are amongst the most numerous CPFs in the SPF but did not appear to be particularly vulnerable to direct interactions in the SPF previously. Tuck *et al.* (2013) reported 36 shearwater interactions from observed trips in 2002 and 2006, (eight of which were confirmed short-tailed shearwaters) resulting in 22 fatalities. However, while this suggests a very low mortality rate, the level of observer coverage is low therefore the real rate of interaction and mortality in the SPF may be higher. Daley *et al.* (2007b) in assessing marine birds in the ERA found: "two [of three] of the high risk bird species are large species observed in high numbers on the fishing grounds: black-browed albatross and shy albatross. No captures of these birds have been recorded in the SPF but albatross have been killed in other Commonwealth mid-water trawl fisheries through warp strikes which are a concern overseas, particularly in New Zealand and other southern hemisphere countries." They also note that the third bird species was rated high because of lack of data and that there are no sustainable mortality rates estimated for these species. Observer records for seabird interactions are very patchy throughout the SESSF and not robust enough for detailed analysis (Tuck *et al.* 2013), but in the South East Trawl component of the SESSF, the rate of seabird interactions for 2005 and 2006 was approximately 0.67 to two birds per tow (i.e. approximately between 700 and 1600 interactions per year respectively). Fifteen mortalities were recorded in 2005 and none in 2006. The panel considered that there is some uncertainty about the potential rate of direct interactions by the DCFA with seabirds but that the level of mortality would likely to be low.

Panel assessment: likely nature and extent of direct interactions by the DCFA with seabirds

- *It is likely that the rate of interactions with seabirds with mid-water trawl vessels in the SPF has been low, despite most operations having been in areas of high seabird species richness.*
- *In the context of the DCFA, the practice of pumping from the codend does not pose a specific risk to seabirds and may mitigate the risk, on a shot-by-shot basis, compared to the same practice applied by smaller vessels with reduced pumping capacity.*
- *Since it is not possible to predict with any certainty where or when the DCFA might fish or the intensity of that fishing, it is not possible to provide any firm conclusions on the likely differential impacts on seabirds that might arise from the DCFA. However, if the DCFA operated in areas or at times of the year that have not been fished previously by mid-water trawl vessels it is reasonable to expect that:*
  - *the rate of interaction might vary in comparison to previous mid-water trawl operations*
  - *the species involved in such interactions may differ from those of the past*
  - *the risk profile of those species could vary compared with those encountered in previous mid-water trawl operations.*
- *These matters constitute ongoing uncertainties associated with the operation of the DCFA.*

Seabird mitigation measures

The panel has used the VMP for seabirds that was proposed to be applied to the *FV Abel Tasman* (see Box 5.2) as a basis for consideration of the actions that could be taken by regulatory authorities to avoid, reduce and mitigate adverse environmental impacts of the DCFA on seabirds.

The panel considered the most recent advice from ACAP for reducing the impact of pelagic trawl gear on seabirds (ACAP 2013a, b, c) represents current best practice in the area of seabird mitigation. To inform its assessment of the likely effectiveness of the mitigation measures required by the VMP, the panel has compared the measures contained in the VMP to the ACAP advice (Table 5.5).

Table 5.5 Comparison of proposed Seabird VMP and ACAP best practice advice

MITIGATION MEASURES	DETAILS IN VMP	ACAP ADVICE (ACAP 2013A, B, C)	COMPARISON OF VMP AND ACAP ADVICE
Discharge management	The holder must retain all biological material and not discharge into the water while gear is in the water.	Avoid any discharge during shooting and hauling. Where possible and appropriate, convert offal into fish meal and retain all waste material with any discharge restricted to liquid discharge/sump water to reduce the number of birds attracted to a minimum. Where meal production from offal and full retention are not feasible, batching waste (preferably for two hours or longer) has been shown to reduce seabird attendance at the stern of the vessel. Mincing of waste has also been shown to reduce the attendance of large albatross species.	Proposed measures consistent with ACAP advice.
Cleaning net before deployment of fishing gear	The holder must clean the nets prior to deployment of gear removing all accessible entangled fish ('stickers').	Clean nets after every shot to remove entangled fish ('stickers') and benthic material to discourage attendance during gear shooting.	Proposed measure consistent with ACAP advice
Time net on surface		Minimise the time the net is on the water surface during hauling through proper maintenance of winches and good deck practices.	ACAP advice not relevant to the DCFA since fish to be pumped from the net to the vessel rather than the net be hauled.
Net binding		For pelagic trawl gear, apply net binding to large meshes in the wings (120–800 mm), together with a minimum 400 kg weight incorporated into the net belly prior to setting.	Measure not included in the proposed VMP and therefore inconsistent with ACAP advice.
Bird bafflers	The holder must deploy bird bafflers while gear is in the water.	Generally, bird bafflers are not regarded as providing as much protection to the warp cables as bird scaring lines or warp scares. ACAP has insufficient evidence to recommend bird bafflers, noting that there were a variety of bird baffler designs and trials would be needed to demonstrate the efficacy of a particular design.	Based on ACAP advice it is not clear that the measure proposed by the VMP would be effective unless the VMP specifies a proven bird baffler design.
Warp maintenance	The holder must maintain warps and remove all sprags.	Not specified.	Not inconsistent with ACAP advice.
Warp deflectors	The holder must deploy warp deflectors from both warps while gear is in the water.	Insufficient evidence to recommend this measure. Warp scarers have been shown to reduce contact rates but not to significant levels and were not as effective bird scaring lines.	Based on ACAP advice it is not clear that the measure proposed by the VMP would be effective.
Bird scaring line		Deploy bird scaring lines while fishing to deter birds away from warp cables and net monitoring cable. Recommended even when appropriate offal discharge and fish discard management practices in place.	Measure not included in the proposed VMP and therefore inconsistent with ACAP advice.
Snatch block		Install a snatch block at the stern of a vessel to draw the net monitoring cable close to the water to reduce its aerial extent.	Measure not included in the proposed VMP and therefore inconsistent with ACAP advice.

Panel advice: effectiveness of proposed measures and actions to avoid, reduce and mitigate adverse environmental impacts on seabirds

- *The requirements in the proposed VMP regarding discharge of biological material, the removal of stickers and warp maintenance should be consistent with or equivalent to the ACAP advice.*
- *Adopt the ACAP advice regarding net binding, bird scaring lines and the use of a snatch block noting that the use of bird scaring lines and net binding are part of the seabird VMP for Australia's winter blue grenadier fishery.*
- *If bird bafflers and warp deflectors are to be used, develop and optimise the design under scientific permit, noting that seabird captures in the SESSF have been reduced by 75 per cent using 'pinkies' (Pierre et al. 2014).*
- *Direct deck lighting inboard and keep to the minimum level necessary for the safety of the crew.*
- *Develop advice on the correct interpretation of 'interactions' with seabirds in consultation with the Department of the Environment to ensure it is consistent with the intent of the MoU between the Department and AFMA and ensure that DCFA operators and crew are familiar with this advice.*
- *Ensure that the seabird VMP for the DCFA meets the requirements of the National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011–2016 (DSEWPaC 2011).*
- *If unacceptable levels of interactions with protected seabird species occur, suspend fishing immediately and adopt one of the following options:*
  - *time and area closures, noting that these will rely on knowledge of spatial and temporal uses of habitats that overlap with the fishery*
  - *trigger limits and move-on rules*
- *Consistent with the measures suggested above for pinnipeds and cetaceans, ensure 100 per cent observer coverage of all fishing activity.*

5.4.4 Monitoring and research

Given the uncertainties identified above in relation to the potential for changes in the spatial and temporal pattern of fishing under a DCFA to alter the nature and extent of past interactions with seabirds in the mid-water trawl sector of the SPF, it is imperative that full observer coverage apply to a DCFA.

The panel heard of the potential risk posed by uninitiated crews (Mr R. Wells, ResourceWise Ltd pers. comm. 28 April 2014) and the importance of education of the crew in ensuring that mitigation measures were properly implemented (e.g. Mr F. Drenkhahn and Mr S. Boag *in litt.* 28 October 2013 in Elgin Associates unpublished (a)).

Panel advice: research and monitoring to reduce uncertainties

The following proposals for monitoring and research could help to reduce uncertainties about the potential for adverse environmental impacts of the DCFA on protected seabird species:

- *Identify key ecologically sensitive seabird species, areas and times where spatial management strategies may be appropriate to mitigate direct interactions if required.*
- *Collect, analyse and publish observer data on all seabird interactions, including on the levels and causes of seabird bycatch, focusing especially on recording of warp interactions and trawl entanglement.*
- *Use electronic monitoring via video camera/s to assist in quantifying warp strikes.*
- *Ensure crews are properly trained in the use of the required seabird mitigation and on reporting requirements.*

6 Localised depletion

6.1 Introduction

The panel's Terms of Reference require it to assess and advise on "the potential for any localised depletion of target species (arising from the Declared Commercial Fishing Activity) to result in adverse impacts to the Commonwealth marine environment, including the target species' predators protected under the EPBC Act".

As discussed in Chapter 2, and expanded on below, the panel's definition of localised depletion is a relatively simple one. Examination of the nature and extent of environmental impacts that might arise from it, and whether or not those impacts constitute 'adverse impacts', is much more complex. This complexity is exacerbated by the fact that the panel's assessment is essentially of a hypothetical Declared Commercial Fishing Activity (DCFA): a scenario subject to a range of possible spatial and temporal patterns of fishing for species that are themselves mobile and difficult to locate, despite there being some predictable patterns of schooling behaviour.

The panel's assessment of the localised depletion arising from the DCFA is structured as follows.

- Localised depletion, its meaning, potential impacts and the factors that influence whether those impacts occur, and their extent, is discussed in Sections 6.2 to 6.4.
- The potential for localised depletion to adversely affect the target species themselves is considered in Section 6.5.
- The potential impacts of localised depletion on central place forager (CPF) species, particularly those species protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), are discussed in Section 6.6.
- The panel's assessment of adverse environmental impacts that might arise from localised depletion by the DCFA is provided in Section 6.7, followed by advice on management measures, and on monitoring and research, in Sections 6.8 and 6.9 respectively.

6.2 Definition

From the panel's commissioned literature review (Rogers *et al.* unpublished), and discussions with experts and stakeholders, it is clear that there are many interpretations of localised depletion.

A number of key points arose from the panel's discussions and the literature review.

- Localised depletion is defined differently by different people and for different species.
- Localised depletion has both spatial and temporal components.
- Localised depletion could be thought of as a disproportionate and persistent reduction in abundance of a stock in a particular area.
- There is a relationship between the mobility of a species and its potential for localised depletion.
- There is a relationship between the extent of habitat preference of a species and the potential for localised depletion.
- Localised depletion can be caused by factors other than fishing.
- Fishing, even at the smallest spatial and temporal scale, causes localised depletion, but, at greater scales, may cause changes to characteristics of the target stock such as the size and age composition, distribution and genetic diversity.
- It is the level of depletion by fishing, and its persistence at a level that compromises the stock and the role of that species in the ecosystem, e.g. its trophic role, that will determine whether localised depletion constitutes an unacceptable risk to the broader ecosystem.

- Localised depletion is difficult to detect and measure.
- Localised depletion is different from overall depletion of a stock (by fishing) and it is often difficult to distinguish between these two impacts.

The panel noted, in particular, the following description of localised depletion:

"Localised depletion occurs when local removals are greater than local production + net immigration/emigration, resulting in a local reduction in abundance compared to elsewhere and in the absence of local removals. It is a deformation of the density field of the species that may persist for a long or short time depending on the dynamics of local production + net immigration/emigration. Localised depletion happens for some period every time a fish is removed from the water." (Dr K. Sainsbury, Institute of Marine and Antarctic Studies (IMAS) *in litt*. June 2013)

In their search for relevant research and literature, Rogers *et al*. (unpublished) adopted the following definition:

"Localised depletion is a persistent and significant reduction in the abundance/density of a targeted pelagic species over a defined area within the range of a population that is caused by a spatial and temporal concentration of fishing."

They took into consideration localised depletion brought about by fishing alone, the space and time scales over which it took place, and whether it was of a magnitude that caused an adverse impact on the ecosystem. They did not consider depletion caused by environmental fluctuations or depletion of the stock as a whole.

The panel noted that the following factors increased the vulnerability of a species to localised depletion from fishing:

- low mobility and/or dispersal (as adults and/or juveniles) therefore slow rate of re-aggregation of survivors after removal or disruption
- schooling behaviour especially in the same or predictable locations (site fidelity) therefore high probability of detection by a fishery
- weak management controls such as high allowable catches/fishing mortality and/or high spatial concentration of fishing effort and catch.

Of central importance to the panel's assessment is whether localised depletion arising from the DCFA is likely to have adverse environmental impacts. Dr É. Plagányi, CSIRO (*in litt*. 4 November 2013) identified the following factors that may determine whether the extent of the localised depletion is likely to cause adverse environmental impacts.

- The proportion of the available biomass of each targeted species that is being caught and the current status of the stocks of those species.
- Whether fishing effort is concentrated in specific areas (or at specific times) rather than being spread more widely.
- Whether there is a substantial overlap in fishing effort/catches and important foraging grounds of dependent predators.
- Whether there are land-based predators that rely on the local availability of dense concentration of prey, because they have limited ability to travel large distances during the breeding season.
- How mobile the prey species are and whether there are transport/advective/movement mechanisms that serve to replenish prey that might otherwise become depleted in an area.
- Which and how many alternative prey types are available in the area.
- Whether there are any technical interactions and whether fishing vessels themselves might disrupt prey in the foraging grounds of a predator, with a resultant positive or negative impact on a predator in addition to any impact from reducing the abundance of prey through fishing.

What is clear is that in defining exactly what is meant by localised depletion in the context of this assessment, the species of concern, the cause of the depletion, the scale of the depletion, and the nature and extent of any adverse impacts from that depletion must be clearly articulated.

It became apparent to the panel that the term 'localised depletion' has been used in the context of the debate about the introduction of a large mid-water trawl freezer vessel into the Small Pelagic Fishery (SPF) in ways that may confuse localised depletion, as defined by the panel, with overall stock depletion or with overfishing. It is important to this assessment that localised depletion is not confused with overall depletion or with overfishing.

Dr K. Sainsbury, IMAS (*in litt.* June 2013) noted that overall depletion combined with the density-dependent habitat selection that is common among pelagic fishes will result in a range contraction that may look the same as localised depletion. To explain fluctuations observed in anchovy *Engraulis mordax* populations in the northern Californian Current, MacCall (1990) developed a density-dependent habitat selection model known as the 'basin model'. The principle underlying this model is that, as a population increases, it spreads into more marginal or less desirable habitats, like a fluid filling a basin, but as it falls, the population contracts to core or more preferred habitat. Species have degrees of mobility analogous to degrees of viscosity (or 'stickiness'); the more mobile the species, i.e. the less viscous or more free-flowing, the quicker the response and movement. Bertrand *et al.* (2004) derived a different habitat-based model in which anchovy concentration or density increases in the preferred habitat as the habitat quality increases. This has been demonstrated in sardine and anchovy populations off California, Peru, South Africa and Japan (Barange *et al.* 2009) where area of occupation and packing density increased with population size.

A well-known Australian example of a species range contraction is that of southern bluefin tuna *Thunnus maccoyii* (SBT). As the population declined to about 5 per cent of the virgin spawning biomass from global over-fishing (Commission for the Conservation of Southern Bluefin Tuna (CCSBT) 2011, Polacheck 2012), the population contracted away from the coasts of Australia and New Zealand, illustrated by the absence of juvenile SBT from coastal New South Wales (NSW) where it had been present prior to the mid-1990s. Aerial surveys over the past decade in the Great Australian Bight (GAB) also provided evidence of the contraction of juvenile SBT to the eastern GAB (Basson *et al.* 2012). However, there is anecdotal evidence that juveniles of a smaller size than typical have been observed migrating into southern Tasmanian waters over autumn in recent years (Dr S. Tracey, IMAS pers. comm. 14 August 2014), indicating strong recruitment following introduction of tighter international management and aided by favourable oceanographic conditions sweeping across southern Tasmania waters. The mass mortality of Australian sardines *Sardinops sagax* in southern Australia, particularly in 1998–99, could be classed as an example of range contraction not caused by fishing. Sardines also disappeared from NSW waters, contracting back to Victorian waters where catch rates around Lakes Entrance remained high (Stewart *et al.* 2010). In following years, sardines were gradually observed extending northwards again as populations improved.

Therefore, it is important to note that while localised depletion and range contraction caused by fishing or other factors may look the same, especially to land-based predators and even fishers, the mechanisms that cause them are fundamentally different. In a range contraction, local habitat would be abandoned by the species even if there were no localised fishing, whereas localised depletion is caused and maintained by localised fishing (Dr K. Sainsbury *in litt.* June 2013). This distinction is important to the panel's assessment of impacts from any localised depletion.

The panel found only limited examples of studies of the impacts of localised depletion of small pelagic species. Rogers *et al.* (unpublished) were unable to find cases of localised depletion studies within the SPF and only limited examples globally. Some examples are provided in Box 6.1. The panel noted that all of these examples relate to purse seine fisheries for small pelagic species.

Box 6.1 Examples of localised depletion effects in fisheries for small pelagic species

Scads and mackerel in the Java Sea

A study by Cardinale *et al.* (2011) demonstrates serial depletion, a series of consecutive localised depletions, over a period of 20 years, in a purse seine fishery targeting scads and mackerels (*Decapterus russelli, D. macrosoma*, *Rastrelliger kanagurta* and *Selar crumenopthalmus*) in the Java Sea. This fishery is driven by market forces and lacks any management that would limit exploitation. There were upward of 500 boats operating in the early part of the study period declining to below 200 in the previous four years, but their time at sea was increasing as they expanded into more distant grounds when catch rates dropped on previously exploited grounds. The fishing grounds for the main target species were sequentially depleted with distance from fishers' home port. Cardinale *et al.* (2011) concluded that the genetic studies of *D. macrosoma* and *D. russelli* suggested population sub-structuring resulting from 'philopatric' behaviours, i.e. those which cause a species to return to its home area such as for breeding, and lack of management, contribute to the risk of depletion. The rate of exploitation in this fishery was unknown as were ecological impacts.

Anchovy in Humboldt Current off Peru

A similar pattern of progressive depletion of resources was found in the purse seine fishery on anchovy *Engraulis ringens* in the Humboldt Current off Peru, but the impact was detected on the foraging distances of Peruvian boobies *Sula variegata.* For this land-based bird the critical issue is not necessarily just of global depletion but also of localised depletions at a critical life-history stage such as breeding and rearing of chicks. In a tracking study of boobies and their foraging patterns in the anchovy fishery, Bertrand *et al.* (2012) concluded that the birds needed to forage progressively further afield as prey were depleted by intense fishing in their immediate region. More recently, Bertrand *et al.* (2012) note that the fishery management has changed from open access to quota-managed; catches are now spread, allowing the fish to redistribute and avoid localised depletion; and a National Reserve has been declared to protect the colonies, including a 3.7 kilometre (km) marine zone which, however, was not thought adequate to protect the foraging zone of seabirds.

Atlantic menhaden in Chesapeake Bay

Localised depletion of Atlantic menhaden *Brevoortia tyrannus* in Chesapeake Bay, USA, was also suspected but not proven. This purse seine fishery operates on the north east-coast of the USA. More than 100,000 tonnes (t) per year were taken annually up to 2006 when a total allowable catch (TAC) was set at approximately 100,000 t. The species is not considered overfished. Atlantic menhaden spawns off the coast but larvae recruit into nearby bays and site fidelity is suspected (Haddon 2009). Rogers *et al.* (unpublished) found that there was no clear evidence for localised depletion nor empirical evidence to attribute negative impacts on striped bass *Morone saxatilis*, bluefish *Pomotomas saltatrix* and osprey *Pandion haliateus* to localised depletion of menhaden.

Summary: interpretation of localised depletion

- *For the purposes of its assessment, the panel interpreted localised depletion as a spatial and temporal reduction in the abundance of a targeted fish species that results from fishing.*
- *Localised depletion is an inevitable consequence of fishing so that whenever fishing occurs there will be a local depletion of target (and non-target) species.*
- *Localised depletion should not be confused with range contraction or overall stock depletion.*
- *The central issue for the panel's assessment was whether the fishing activity of the DCFA could be concentrated enough, both spatially and temporally, to cause a localised depletion of the target species sufficient to cause adverse environmental impacts to the Commonwealth marine environment.*
- *Whether or not such adverse impacts occur will depend on a wide range of factors.*
- *There are limited examples of studies of localised depletion of small pelagic species.*

6.3 Potential impacts

The panel's assessment of localised depletion requires it to identify what adverse environmental impacts there might be, but beyond that, there is a need to consider what impacts are of most concern, when that impact becomes unacceptable, and how to detect, quantify and assess those effects.

The extent to which an impact is adverse (harmful) depends on the target species' resilience to impact and the type and scale of the impact. Fishing tends to change a population's age and size structure, reproduction and genetic diversity (Jennings *et al.* 2001, Walters and Martell 2004), so it is the degree of fishing pressure combined with the species' resilience that will determine the severity of impact. The most severe impacts of direct removal from fishing on the target species could result in local extinctions e.g. several species of sharks and large fishes from south-eastern Tasmania during the 1900s (Last *et al.* 2011) or in extreme cases, whole population collapses e.g. Icelandic spring-spawning herring *Clupea harengus* (Beverton 1990). Recovery, if possible, depends on the species' reproductive capacity or even genetic diversity (Beverton 1990) but environmental variability and continuing fishing pressure will affect rates of recovery.

Impacts of fishing 'target' species on other species may be direct, i.e. arising from being coincidentally caught in the fishery, or indirect, i.e. through changes in the food web or habitat modification. Species that are already threatened may be further impacted by fishing if taken as bycatch, particularly if they are available to several fisheries, e.g. sharks and elephant fish caught in both trawl and gillnet fisheries and fur seals caught in mid-water and demersal trawl fisheries. Cumulative impacts from multiple fisheries and other sources are recognised but often difficult to assess in data-poor fisheries (Moore *et al.* 2013).

Indirect impacts are commonly non-intuitive, arising from the complex web of predator-prey interactions, often once-removed from the direct target species, and the strength of those interactions. For example, increases in abundance might result from release from predation or competition for the same prey resource; species may expand to fill a niche or habitat which had been unavailable previously, e.g. alternation between sardines and anchovies in the Benguela Current upwelling system (Cury and Shannon 2004); or the population may decline if predation mortality increases from predators unable to find their preferred prey. Dependent predators may even starve, e.g. seal populations in northern Benguela were reduced by 30 per cent during the mid-1990s in response to environmental anomalies and consequent extensive declines in fish biomass (Cury and Shannon 2004). Predators may switch to other prey that may not be as well-suited to their nutritional needs—coined the 'junk food hypothesis' by Alverson (1992), describing the hypothesis for the decline in the western stock of Steller sea lions *Eumetopias jubatus* in Alaska—resulting in reduced breeding success and subsequent population decline. Examples of such events include sandeels and kittiwakes in the North Sea (Rindorf *et al.* 2000, Frederiksen *et al.* 2008); sprats and common terns in Firth of Forth, Scotland (Jennings *et al.* 2012); and juvenile rockfish and murres, guillemots and auklets in the Californian Current (Field *et al.* 2010).

Adverse effects from direct fishing impacts, at a broader ecosystem level, could be as severe as degradation of biodiversity such as that occurring at a global scale (Worm *et al.* 2005), resulting in instability, cascading trophic effects (Scheffer *et al.* 2005, Coll *et al.* 2008, Baum and Worm 2009, Coll *et al.* 2009a, Coll *et al.* 2009b) and proliferation of invasive or 'break-out' species (Bakun and Weeks 2006) such as jellyfish (Jackson *et al.* 2001) . Whether these types of effects could be seen at a 'local' scale is the question. Interwoven with the effects of fishing are those of natural environmental fluctuations and climate change, which are not inconsequential but difficult to disentangle. Variable environmental conditions have contributed significantly to dramatic, small pelagic fishery collapses worldwide over the past several decades and are discussed in many scholarly reviews (see, for example, Beverton 1990, Schwartzlose *et al.* 1999, Cury *et al.* 2000, Jackson *et al.* 2001, Freon *et al.* 2005, Mullon *et al.* 2005, Pikitch *et al.* 2014). While regime shifts are largely thought to be responses to oceanic and climate shifts, fishing has contributed to a regime shift in the Namibian ecosystem (Cury and Shannon 2004). Management of small pelagic fish therefore needs to take into account natural environmental variability as well as the impacts of fishing.

Compounding the difficulty of managing for environmental variability is the prospect of climate change which increasingly presents a significant threat to fisheries (Hobday 2010, Hobday 2011). Cheung *et al.* (2009) explored the potential effect climate change could have on more than 1000 species of fish and invertebrates. They found local extinctions and species invasions in many regions were possible and a 60 per cent turnover in present diversity was possible. Hobday (2011) similarly demonstrated the possibility of physical changes in east Australian waters by simulating climate-change scenarios from the Intergovernmental Panel on Climate Change in a finely-resolved Bluelink model nested within the broader CSIRO Mk 3.5 global climate model. Fulton (2011) predicted that, as a result of climate change, there will be "winners and losers" and some surprises. There have already been changes in the distribution of Tasmanian fishes as a result of recent warming in the local marine environment (Last *et al.* 2011).

At a more fundamental level of the food web, Kelly (2014) found that the zooplankton off Maria Island, Tasmania has been influenced by intrusions of the warm subtropical waters of the East Australian Current (EAC) in recent years, resulting in not only a higher abundance of copepods, but also changes in composition of the zooplankton. Calanoid copepods are a dominant prey for redbait *Emmelichthys nitidus* (McLeod *et al.* 2012) and are predicted to continue to thrive under warmer conditions hence favouring redbait. The flow-on effects of increased copepod abundance could also result in hotspots for copepod predators such as whales or tuna but also shift the spring bloom, potentially causing mismatches in phytoplankton and zooplankton availability for larval fishes. The transport of primary productivity between inshore and offshore areas is critical to the survival of marine species and the EAC presents a partial barrier to onshore transport but entrains waters offshore particularly where the currents diverge from the coast (Condie *et al.* 2011). Blue mackerel *Scomber australasicus* spawn in these areas of divergence aiding dispersion of larvae. In the GAB the Leeuwin Current tends to have the opposite affect i.e. eggs and larvae of sardine and anchovy are retained inshore.

Kelly (2014) suggests that there is a continuing warming trend and intensification of the EAC which may alter these transport systems and the dispersion of eggs and larvae of marine species, but also ultimately the composition of the ecosystem from phytoplankton through to fish. The panel also heard that the present oceanographic regime in the Tasman Sea has been vacillating for decades but that present indications are it will shift permanently to a new state (Dr V. Lyne, CSIRO pers. comm. 4 July 2013).

6.4 Factors influencing the extent and impacts of localised depletion

6.4.1 Scales of depletion and persistence

The temporal and spatial scale over which the fishing activity occurs is pivotal to whether adverse environmental impacts will arise from localised depletion. A single event is unlikely to cause an impact unless the effect is persistent, i.e. the effect of the removal remains long after the removal, as might occur if the target species was so immobile that the 'hole' cannot be readily filled, e.g. abalone (Prince 2005), chitons (Salomon *et al.* 2007) and crab and shrimp (Orensanz *et al.* 1998). Dr Eva Plagányi, CSIRO (*in litt.* 4 November 2013) noted that "... we have considered the distribution of fishing effort as being important when considering relatively sessile resources such as abalone and sea cucumbers, but not when considering more mobile fish stocks". For small pelagic fishes, it is more likely that fishing would need to be constant, or at least at a rate of removal that would lower the species' ability to re-aggregate or repopulate the area in some way, for adverse environmental impacts to occur.

Whether the localised depletion occurs as a result of one or many boats is irrelevant according to international and Australian fisheries managers and scientific experts interviewed by the panel. Vessels of a smaller capacity tend to concentrate effort around their home ports because their ranges are restricted by their limited fish handling and storage facilities, and fuel and provisioning capacity. A fleet of many smaller vessels has the potential to create localised depletion if the fishing intensity is spatially and temporally dense.

It has been suggested that localised depletion of jack mackerel *Trachurus declivis* occurred off east Tasmania in the 1980s. For example, Environment Tasmania (2014) states: "It is believed that localised depletions have already occurred around Tasmania. Large surface schools of jack mackerel were once common off Tasmania until they were targeted by trawlers more than 20 years ago. These surface schools soon disappeared and have not been seen since" and it has been stated that "earlier annual capture records from the Tuna Club of Tasmania have shown that localised depletion has occurred in the past when purse seine trawling occurred off the East Coast of Tasmania earlier this century" (Mr K. Antonysen *in litt.* October 2012). This view is also supported by a recent survey of offshore recreational fishers in Tasmania for whom the biggest issue is "the perceived or historically realised overfishing" (Tracey *et al.* 2013).

In the 1980s, a fleet of six to seven small purse seiners (24–47 metres (m) length overall; 100–500 t hold capacity) operated in the jack mackerel fishery (Williams *et al.* 1986, Williams *et al.* 1987). These vessels were small but with the aid of an aerial spotter, landed nearly 118,000 t in four years (Williams *et al.* 1987, Williams and Pullen 1993). The majority of the effort was concentrated between Maria Island (off the home port of Triabunna) and Tasman Peninsula and within state waters (Williams *et al.* 1987). The fishery then declined and fluctuated over the next two decades. The surface schools of fish had largely disappeared and the sub-surface schools were harder to find and target. The 'disappearance' of fish has been often attributed to localised depletion resulting from fishing, as discussed in preceding paragraphs, but the most significant underlying cause was linked directly to a change in factors that underpin the surface-schooling behaviour of the fish, i.e. changing oceanographic conditions affecting the availability of their major prey, krill *Nyctiphanes australis* (Harris *et al.* 1991, Harris *et al.* 1992).

Jack mackerel caught from the surface schools by the fishery were found to be feeding on swarms of krill (Williams and Pullen 1993). Krill will form dense schools of 100–200 m diameter when abundant in waters of about 15°C (Harris *et al.* 1992). The reason that 15°C water is important is because this is the temperature at which nitrate appears in the water column over summer, supplying nutrients to phytoplankton production (Harris *et al.* 1992). Krill feed on large diatoms, detritus and copepod faecal pellets (Harris *et al.* 1991, Harris *et al.* 1992). Diatoms and large phytoplankton dominate the plankton community in cooler, more productive water conditions, whereas smaller copepods dominate in warmer less productive conditions. The zonal westerly winds normally entrain cold productive water up the Tasmanian east coast shelf waters, favouring krill, but after 1987 these winds were weak. This period of weak westerlies and the intrusion of warm sub-tropical waters of the East Australian Current led to the shelf waters warming to 20°C and productivity dropped. The waters became oligotrophic leading to domination of small copepods and elimination of large zooplankton, including the krill. Consequently, the fish had moved to the southern-most tip of Tasmania beyond the reach of the purse seine fishery at the time. Furthermore, similar warming events have occurred in the past: once in the 1950s (Harris *et al.* 1992) and again in the 1970s. When the latter event occurred, the jack mackerel fishery on the east coast collapsed but extensive shoals of fish were sighted by aerial surveys off the south-west coast of Tasmania in 1976 (Williams 1981).

6.4.2 Vulnerability of SPF target species to localised depletion

Small pelagic fishes are those that are relatively small; abundant; form schools; are short lived; mature early and are highly fecund; are subject to high inter-annual recruitment variability; and are usually planktivorous, or largely so (Alheit *et al.* 2009, Pikitch *et al.* 2014). These biological characteristics make them highly sensitive to changes in ocean climate reflected in often dramatic changes in abundance (Alheit *et al.* 2009) but also provide a level of resilience. Small pelagic species are important in the diets of predators.

Productivity

The small pelagic fish assemblage within Australia is dominated by the smaller-sized clupeids (e.g. Australian sardines and Australian anchovy *Engraulis australis* but also includes the larger carangids (e.g. jack mackerel and Peruvian jack mackerel *Trachurus murphyi,* emmelichthyids (e.g. redbait) and scombrids (e.g. blue mackerel). The suite of target species in the SPF fishery therefore ranges from the small Australian sardine, at about 20 centimetres (cm) and six years (common age), to the medium-sized mackerels around 40 cm and 16 years. A full profile of each SPF target species is provided in Appendix 4, however a summary of relevant biological attributes is presented in Table 6.1. Australian anchovy is not an SPF managed species but is included here for comparison.

Small pelagic fishes, particularly clupeids and small gadoids (cods), are generally considered to have low resilience to fishing based on the ability of the stock to replace itself, whereas larger species generally have higher resilience (Mace and Sissenwine 1993, Musick 1999). Musick (1999) developed categories of resilience/productivity based on intrinsic rates of increase, r_m, von Bertalanffy coefficients, *K*, fecundity, and age parameters (Table 6.1) in an attempt to assess vulnerability to 'extraordinary' mortality, such as that arising from fishing. Cheung *et al.* (2005) derived intrinsic vulnerability to fishing values, which integrated life history and ecological characteristics via a fuzzy logic system, and showed that they are more closely correlated with observed population declines. Animals with von Bertalanffy growth coefficients *K* of less than 0.10 and/or intrinsic rates of increase of less than 10 per cent per year, are particularly vulnerable to fishing (Musick 1999), i.e. they have a high vulnerability with 100 being the most vulnerable.

Table 6.1 Summary of biological attributes of SPF target species and Australian anchovy. 'Common' (average) size and age based on Yearsley *et al.* (1999) and observations from fishery data. Von Bertalanffy *K,* resilience/productivity and vulnerability recalculated based on Australian data for populations where available. FL = fork length; TL = total length; SL = standard length.

SPECIES	COMMON SIZE (TL CM)	COMMON AGE	TROPHIC LEVEL	NATURAL MORTALITY	AGE AT MATURITY T_M	FECUNDITY	K	R_M	RESILIENCE/ PRODUCTIVTY[2]	VULNERABILITY
Australian Sardine *Sardinops sagax*	20	6	2.4	0.66 @22°C	2	10–45,000 per batch/500 eggs per g	0.47	2.34	Medium, min. pop. doubling time 1.4–4.4y	34 (low–moderate)
Redbait *Emmelichthys nitidus*	36	21	3.6	0.34 @8°C	2–4	186 eggs per g	0.22	1.06	Medium, min. pop. doubling time 1.4–4.4y	42 (moderate)
Jack mackerel *Trachurus declivis*	25–40	16	3.9	0.36 @12°C	3–4	63,000 per batch/205 eggs per g	0.29	1.12	Medium, min. pop. doubling time 1.4–4.4y	50 (moderate–high)
Peruvian jack mackerel *T. murphyi*	45	16	3.5	0.12 @15°C	2–3	n.a. in Australia	0.1	0.42	Low, min. pop. doubling time 4.5–14y	67 (high–very high)
Blue mackerel *Scomber australasicus*	35 FL	7	4.2	0.41 @15°C	2–3	70,000 per batch/135 eggs per g	0.24	1.34	Medium, min. pop. doubling time 1.4–4.4y	43 (moderate)
Australian anchovy *Engraulis australis*	10 SL[3]	>2	3.0	0.82 @15°C	1[4]	~15,600 per batch[5]	0.39 (1.3[6])	3.04	High, min. pop. doubling time <15 months	29 (low–moderate)

Source: Rogers *et al.* (unpublished), Appendix 4 and references therein, FishBase (Froese and Pauly 2014).1 Vulnerability from FishBase based on Cheung *et al.* (2005); 2 resilience from FishBase (Musick 1999): minimum population doubling time; 3 Yearsley *et al.* (1999);4 Blackburn (1950); 5 Dimmlich *et al.* (2009); 6 Dimmlich and Ward (2006).

As the smallest species in this suite, Australian anchovies and sardines have the highest natural mortality, growth coefficients and relative fecundity of all small pelagic species. The other species fall into a slightly larger group (medium-size: about 30-40 cm) with similar attributes, apart from Peruvian jack mackerel which, curiously, has lower mortality, growth coefficients, resilience/productivity values and, consequently, higher vulnerability value. Whether the parameters used in the calculations of resilience/productivity and vulnerability for this species are representative of the Australian population is unknown. Peruvian jack mackerel doesn't appear to spawn in Australian waters but is abundant across the Pacific Ocean basin. Bulman *et al.* (2008) note that the species is taken only occasionally in Australian fisheries. It occurs in mixed schools with jack mackerel, and is not identified specifically in catch records. The panel considered that it was unlikely that incidental catches of this species in the SPF are significant.

SPF target species are all batch spawners, producing batches of eggs over a period of time. Relative fecundity, i.e. the numbers of eggs per gram (g) of body weight increases with body size, therefore the presence of older, larger fish increases potential reproductive capacity (Jennings *et al.* 2001, Garcia *et al.* 2013). These species all mature relatively quickly at within 2–4 years of age (Tm).

Resilience/productivity and vulnerability indices for SPF fishes and Australian anchovy were calculated in FishBase using Australian population parameters where possible (Table 6.1). The SPF species have medium resilience/productivity and vulnerability scores of 50 or less, except for Peruvian jack mackerel, for which the values for both attributes are similar to those of blue grenadier *Macruronus novaezelandiae* and gemfish *Rexea solandri* (low resilience for both and vulnerabilities of 66 and 65 respectively). Jack mackerel and jackass morwong *Nemadactylus macropterus* have the same vulnerability of 50 but morwong has a low resilience. Therefore, the SPF species are similarly or less vulnerable to fishing than other commercial species based on life history and ecological characteristics.

Behaviour

One of the areas of uncertainty that underpinned the first Final Declaration is related to the ability of the DCFA to stay on a school of small pelagic fish, implying an ability to detect, follow and capture the whole school. An examination of the schooling behaviour of small pelagic species is therefore warranted.

Schooling is common among fishes; about 80 per cent of all fishes school at some stage in their life (Freon and Misund 1999). One of the primary functions of schooling is to decrease an individual's chance of predation i.e. 'safety in numbers'. Ironically, it is this behaviour that increases the vulnerability of the species to detection and capture by fishing.

However, fish display surprising flexibility in their schooling behaviour and consequently their ability to avoid capture. For example, Norwegian herring schools demonstrated different and rapid responses to the approach of other schools, and small and large predators (including a vessel) (Pitcher *et al.* 1996). The herring responded to vessel approach in the same way as to an attack by a large predator; they dived to 150 m but this incurred an energetic cost.

The panel spoke with Mr J. Zeeberg, a researcher in the sardinella *Sardinella aurita* and *S. maderensis* fishery off Mauritania during the 2000s, who described the fishing strategy of the large Dutch mid-water trawl freezer vessels in that fishery. Sardinella form large shoals during the day and disperse at night. The trawlers use a 'spaghetti' search pattern to hunt schools of fish, often concentrating on temperature fronts where the fish are known to aggregate (Zeeberg *et al.* 2006). Occasionally, whole schools of up to 200 t were caught, but usually catches were 50–60 t and the whole school was not taken (Zeeberg *et al.* 2006, Mr J. Zeeberg pers. comm. 1 May 2014). In Australia, schooling behaviour of Australian sardines is variable, both spatially and temporally (Associate Professor T. Ward, unpublished data cited in Ward *et al.* (2010)).

The early jack mackerel purse seine fishery off the east coast of Tasmania in the 1980s relied on surface schooling behaviour of the fish during the daytime to enable detection and capture (see Section 3.1.1). Schools occurred in spring and autumn off NSW and in summer and autumn off Tasmania probably as feeding aggregations in response to locally abundant krill swarms at the time (Williams and Pullen 1993). Entire schools were usually caught, ranging in size from 2 to 1850 t and most sets were during the day (Williams and Pullen 1993). During winter and spring, sub-surface schools increased. The composition of the schools was mostly jack mackerel in early summer, but became mixed with redbait, particularly in spring, and blue mackerel migrating from deeper water on shore, in late autumn. As discussed above, the surface schools disappeared in response to changed oceanographic conditions.

In southeastern Australia, fishing is targeted at summer feeding aggregations of blue mackerel, which begin to form in December when sea surface temperature (SST) is around 18°C to 22°C (Ward *et al.* 2001b). Blue mackerel migrates southwards as the EAC extends as far as southern Tasmania and retreat as the warm water retreats (Ward *et al.* 2001b), accounting for the increased occurrence in Tasmanian catches into autumn. At this time, blue mackerel is largely caught by the recreational and game fishers as bait for striped marlin *Tetrapturus audax* in NSW waters (Ward *et al.* 2001b).

Between 2003 and 2009, the SPF mid-water trawl fishery targeted redbait. The panel spoke with fishers and scientists about the schooling characteristics of redbait and the implications for fishing. Redbait typically aggregate into layers or form small (about 1 km) shoals during the night, which are patchily distributed and probably loosely connected. The time over which these schools or shoals hold together is also quite variable and they can vanish as quickly as they form. Dr J. Lyle noted that "over a period of 24 hours fish schools appear highly dynamic, scattering and reforming, they do not maintain formation" (Dr J. Lyle, IMAS pers. comm. 18 March 2013). Similarly (Seafish Tasmania Pty Ltd *in litt.* 16 October 2012) noted that "schools form, fragment and disperse within short timeframes, sometimes before there is even time to set the trawl".

Habitat association

The Rogers *et al.* (unpublished) review found that if an adverse effect of localised depletion on the stock was to occur, "a component of the fish population or meta-population must exhibit a degree of site fidelity to the fished area, and that some components (e.g. aggregations, size/age classes or sub-stocks) of the small pelagic fish populations exhibit separation from the broader stock over a particular time scale". Generally, species that would exhibit such site attachments are those that are strongly dependent on physical habitats for protection or food, such as reef-associated species, but could include species that have particular habitat requirements depending on life stages. Geographical features such as bays, headlands and straits may also contribute to the structuring of populations. This is particularly true in regard to Australian anchovy, which tend to be confined to embayments (Schwartzlose *et al.* 1999), and to some extent to Australian sardines, as in the Port Phillip Bay nursery grounds (Neira *et al.* 1999). Atlantic menhaden in Chesapeake Bay were suggested as potentially vulnerable to localised depletion due to populations being restricted to embayments. However, while site fidelity was exhibited by this species, there is no clear evidence that localised depletion occurs at a detectable and adverse level (Haddon 2009, Pikitch *et al.* 2012).

Pelagic species are highly mobile and more likely to be associated with prevailing oceanography in three-dimensional space, making the task of defining preferred habitat more difficult as the boundaries or range distributions will be highly fluid (Bulman *et al.* 2008). The oceanic or pelagic 'habitat' is complex and characterised by abiotic factors such as temperature, salinity, oxygen, light, current speed; and biotic factors such as prey, predators and fishes of similar functional role including conspecifics (Freon and Misund 1999). Barange *et al.* (2009) found that it was important to know the spatial extent and habitat characteristics of the species to fully understand the population dynamics. Rogers *et al.* (unpublished) found that small pelagic fishes are "responsive to oceanographic features, such as eddies, sea surface temperature and chlorophyll fronts that border upwelling systems, enhance food availability and determine the suitability of environmental conditions for growth, reproduction and recruitment". The scale at which oceanographic features occur can be from tens to hundreds of kilometres and may even define sub-structuring in populations. However, these features can serve to aggregate the fish, making them vulnerable to fishing, e.g. sardinella in North Africa (Zeeberg *et al.* 2006, Zeeberg *et al.* 2008). It is also the variability of oceanographic conditions and features that determine to a large degree the rise and fall of small pelagic species, with or without fishing (Lluch-Belda *et al.* 1989, Schwartzlose *et al.* 1999, Chavez *et al.* 2003, Cury and Shannon 2004, Lehodey *et al.* 2006, Tourre *et al.* 2007, Zeeberg *et al.* 2008) and, indeed, these were implicated in the collapses of the jack mackerel fishery off Tasmania in the 1970s and late 1980s (Harris *et al.* 1991, Harris *et al.* 1992).

Habitat can be defined at the population-scale in the sense of a global environment suitable for the whole stock or at a micro-habitat scale relevant to life-history stages of the species such as spawning or feeding (Freon and Misund 1999). It is the latter scale that is relevant to the potential for localised depletion to occur within a species. For example, juvenile SBT show a strong summer site fidelity to the GAB where the combination of SST and chlorophyll *a* is characteristic of their preferred habitat (Basson *et al.* 2012) and increases their susceptibility to capture. In the 1990s, 'fish favourable habitats' for all tuna species and jack mackerel were characterised by using combined logbook data on catch and satellite imagery (ocean temperature). This knowledge was used to assist fishers to locate schooling fish (Dr V. Lyne, CSIRO pers. comm. 4 July 2013).

Ovenden (unpublished), reviewed genetic studies on the SPF target species and supported Richardson's (1982) suggestion that overlapping, but genetically distinct, populations of jack mackerel probably occur as a result of spawning site fidelity. Maxwell (1979) proposed that jack mackerel migrated southward with the 17°C thermocline as the EAC extended, based on observations that jack mackerel schools surfaced when the SST was 17°C. Jordan *et al.* (1995), however, asserted that a resident population occurs in eastern Tasmania which might be supplemented by a small southerly migration. They thought resident schools surfaced as the thermocline advanced rather than a migrating school 'following' the thermocline. This hypothesis tends to support the original conclusion of distinct populations on the east coast of Tasmania but also highlights an association of jack mackerel with SST.

Whichever hypothesis is correct, jack mackerel off eastern Tasmania were found to move from shelf to deeper water to spawn during the summer probably to avoid the more variable surface conditions of the EAC (Jordan *et al.* 1995). This migration to deeper water, leaving the smaller non-spawning fish on the shelf, rendered them less susceptible to capture. A peak in landings indicated that adults returned to the shelf in autumn (Jordan *et al.* 1995). Coincidentally, 'deeper' jack mackerel took advantage of the 'bloom' of mesopelagic fish that occurs on the upper slope at this time which follow the primary productivity blooms in the early summer (Blaber and Bulman 1987, May and Blaber 1989). These observations again suggest an 'association' of jack mackerel with oceanographic conditions that are favourable to them when they are spawning or feeding and which would dictate their behaviour and movement, and consequently, their susceptibility to capture.

Mobility

Mobility was commonly mentioned in discussions with stakeholders and other experts as an important factor in determining how vulnerable SPF target species would be to localised depletion, or in other words, how long a localised depletion event (i.e. a removal by fishing) would persist and whether that length of time would impact their predators. Local and international fishers and scientists described the ephemeral nature of the fish schools and their ability to disappear from the sounder display. The ability of small pelagic fish to swim fast is an obvious advantage in avoiding capture; herring were measured to swim at 10 knots (Pitcher *et al.* 1996), and sardinella at 7 knots, easily outrunning the vessels towing at 5–6 knots (Mr J. Zeeberg pers. comm. 1 May 2014). However, their ability to evade capture also depends on their endurance, which is proportional to body length (Jennings *et al.* 2001). Peraltilla and Bertrand (2014) measured Peruvian anchovy schools swimming at an average *in situ* speed of 0.6 metres per second (m/s) (approximately 2.2 km per hour) but slower than the larger clupeids that they reviewed. They calculated that anchovy could travel a maximum distance of about 26 km (14 nautical miles (nm)) per day which corresponded to observations by fishermen of 22–33 km per day (12–18 nm). As discussed in the preceding section on habitat association, association of pelagic species with their favourable oceanographic habitats can only be achieved by a superior ability to swim.

Swimming speed and endurance is also important in evaluating how quickly a stock can redistribute to fill a void created by a fishing event and thus its ability to withstand depletion from fishing. Faster-swimming pelagic species would be expected to do this more quickly than slower-swimming demersal or site-associated species. Schools are highly mobile and constantly forming and reforming, therefore 'holes' are unlikely to remain in the same place in which they were formed for very long. The length of time of the depletion depends upon the species removed, but there are no specific studies on the SPF species.

6.5 Impacts of localised depletion on target species

Localised depletion of a target species has the potential to affect overall stock status, reproductive capacity and genetic diversity. Each of these is discussed below.

6.5.1 Stock status

The impact of localised deletion of a target species on its stock status will depend in part on whether the stock as a whole is being managed sustainably. A stock that is in an overfished state, or for which catch/effort limits are not set sustainably, is clearly more susceptible to the impact of localised depletion events than well-managed stocks.

In the SPF, no target species is considered overfished or subject to overfishing. Only the western stock of redbait is considered uncertain, since there is no biomass estimate (Moore *et al*. 2013). Catch levels in the SPF are set in accordance with the SPF Harvest Strategy (Australian Fisheries Management Authority (AFMA) 2008) which was developed in line with the Commonwealth Harvest Strategy Policy (see Section 3.1.4) which requires that all Commonwealth-managed fisheries are managed to maximum economic yield (MEY) or 1.2 times the biomass at maximum sustainable yield (B_{MSY}). B_{MEY} is not considered an appropriate reference point for species in the SPF because of the high inter-annual variability in the abundance of small pelagic fish species and their ecological importance as forage fish. The SPF Harvest Strategy is based on direct estimates of spawning stock biomass from daily egg production method (DEPM) surveys. Exploitation rates are limited to 20 per cent of spawning stock biomass (Ward *et al.* 2013a).

The panel considered that this approach is sufficiently precautionary to ensure the sustainability of the target species themselves. However, the panel acknowledges that many stakeholders remain concerned about the age and accuracy of the DEPM data used to estimate spawning biomass and set recommended biological catches (RBCs) under the SPF Harvest Strategy. The panel interviewed several experts on the DEPM (Dr F Neira, Marine Sciences Consulting; Assoc. Prof. T. Ward, South Australian Research and Development Institute; and Dr J Lyle, IMAS) in April 2013 and reviewed the re-analyses by IMAS (Hartmann 2012, Lyle *et al.* 2012) and the review of IMAS estimates by Dr N. Lo (retired from the United States National Marine Fisheries Service (NMFS), *in litt.* 11 February 2013). Two panel members attended a recent Technical Workshop and Stakeholder Forum on Small Pelagic Fisheries (Adelaide, 14–18 July 2014). The outcomes from that workshop will include a review of DEPM methods used in Australia and suggestions for improvement of those methods.

The panel was informed of egg surveys undertaken in the most recent spawning season that will allow updated assessments of stock biomass for jack mackerel and Australian sardine (East). The panel remains confident that, should these assessments show the need to revise RBCs for these species downwards, action will be taken in accordance with the SPF Harvest Strategy. As a result, the panel considered that concerns about the DEPM and RBC estimates are being dealt with effectively in parallel to its assessment and the panel saw no value in duplicating effort in that area.

6.5.2 Change in size and age structure and reproductive capacity

Removal by fishing changes the size structure of the population, particularly if schools are of similar-sized fish, as is often the case in small pelagic species. Selectively taking the larger fish in the population, often based on economic considerations by the fishers, can reduce reproductive potential of the population as the older fish are bigger and fecundity is relative to size. To some extent, this reduction may be compensated by increases in fecundity such as that demonstrated by orange roughy *Hoplostethus atlanticus* when fecundity and the proportion of females spawning increased when the stock had been reduced to very low levels of spawning biomass (Pitman *et al.* 2013). The opposite trend, i.e. declining fecundity with increasing population density, was found in Gulf of Riga herring although recruitment was thought to be more variable (Raid *et al.* 2010).

Other density-dependent effects include earlier sexual maturation at smaller size. Jørgensen *et al.* (2007) detected widespread changes in maturity across decades of fisheries data that were thought "unlikely to be explained by environmental influences alone". Fishing that is selective with respect to size, maturity status, behaviour or morphology causes further evolutionary pressures (Jørgensen *et al.* 2007). Walters and Martell (2004) discussed size-selection as an inevitable result of fishing but noted that there is considerable variation in the way growth and maturity are linked. 'Age-linked' fish show declines in body size for age under selective fishing as in the case of Pacific salmon, whereas 'size-linked' fish tend to have increased growth rates and earlier maturation, affording them a selective advantage over the older, larger fish being fished. The difficulty in separating the genetic selection process from density-dependent and climate-change effects results in ambiguous conclusions about size-selective fishing (Walters and Martell 2004).

In the South Australian Sardine Fishery (SASF) in 2005, management was faced with the possibility that localised depletion may be occurring in Spencer Gulf with a total allowable commercial catch (TACC) of more than 50,000 t taken largely within around 3000 square kilometres (km^2) and particularly from the grounds closest to Port Lincoln (Shanks 2006). While the evidence that suggested that localised depletion had occurred was based on low egg counts from surveys in 2005, there were mitigating factors that precluded a definitive conclusion. It was assumed that stocks of Australian sardines were mixing due to their 'highly motile nature' and therefore replenishing those caught in the fishery in Spencer Gulf (Shanks 2006). This challenged the conventional notion of localised depletion of geographically separated or limited mixing stocks. However, the fishery effort was also moving further from fishing grounds (as in the cases of serialised depletion of mackerels in the Java Sea and anchovy in the Humboldt Current off Peru in Box 6.1). Therefore, while there was no definite conclusion regarding whether localised depletion was occurring, management decided to adopt a precautionary approach and the TACCs were lowered and are now set at around 30,000 t. However, in the Spencer Gulf fishery, modal size has declined from approximately 15.0 cm fork length (FL) to 13.0 cm FL in 2012 (Ward *et al*. 2012a). This decline was thought to be partially due to lower growth rates, but fish older than three were declining while the proportion of immature fish was increasing, and a decreased egg density in 2011 DEPM surveys suggested that a concentration of fishing effort in Spencer Gulf was also contributing.

The most recent assessment of the SPF examined all length frequency data for jack mackerel collected from the beginning of the purse seine operations in the 1980s until 2010–11 when there was no fishery operating (Ward *et al.* 2014). The early purse seine catches (1984–91) were dominated by four to five year olds, but in 1991–92 and 2004–05 catches were dominated by three to four year olds, and in 2009–10 the two and three year olds dominated purse seine and mid-water trawl catches. This might be evidence for overfishing but other factors such as recruitment variability and targeting were suspected as more likely, since catch and effort was low in the latter years (Ward *et al.* 2014). Data collected during the early fishery (Williams *et al*. 1986, Williams *et al.* 1987) indicated that the older fish were often absent from catches but it was thought that they moved to deeper water to spawn and were therefore unavailable to the fishery (Jordan *et al.* 1995). This hypothesis was supported by trawl surveys over the upper slope at around 400 m off Maria Island in the mid-1980s in which jack mackerel were the third most abundant species caught in mid-water trawls (May and Blaber 1989). As mentioned previously, these fish were feeding primarily on myctophids which were particularly dense around autumn (Blaber and Bulman 1987) and when the adult fish had probably finished spawning.

There have been no detectable changes in the age or size composition of redbait in recent years (Ward *et al*. 2014), suggesting that there were no impacts from fishing. There are too few data available for the Australian sardine in the Eastern Zone and blue mackerel to determine significant changes with confidence, but the low levels of effort and catch suggest little likelihood of recent fishing impacts on reproductive capacity (Ward *et al*. 2014).

6.5.3 Loss of genetic diversity

Localised depletion could potentially reduce genetic diversity if there was strong sub-structuring of the populations with the possible effects of reduced recruitment, reduced population size and an overall reduction in the genetic diversity of the resource (Ovenden unpublished). Two types of genetic changes resulting from fishing were considered by Walters and Martell (2004) as "particularly worrisome: erosion of spatial structure, and selection for changes in body size and maturity". Lindholm and Maxwell (1988) identified the potential risk to genetic diversity posed by the purse seine fishery for jack mackerel because of its ability to catch entire schools.

Ovenden (unpublished) reviewed the literature on genetic studies of SPF species in Australia, finding evidence for the existence of Wahlund effects in jack mackerel and Australian sardine. Wahlund effects indicate genetic sub-population structuring and thus are relevant to stock structure and management at a localised level. They occur when two or more genetically different populations are inadvertently sampled from the same sampling location. Normally, genetically different populations do not co-occur, or they are distinguishable and are not co-sampled. The Wahlund effect occurs when there is a deficit of heterozygotes at the majority of loci and is extremely rare in pelagic fish populations. Pope *et al*. (in prep.) (cited in Ovenden (unpublished)) found that of published studies on 41 finfish species in Australia, only two (jack mackerel and damselfish *Acanthochromis polycanthus*) exhibit the Wahlund effect. Dixon *et al*. (1993) and Yardin *et al*. (1998) observed a deficit of heterozygotes for Australian sardine suggesting a Wahlund effect (Ovenden unpublished). The effect did not appear evident in species such as blue grenadier, orange roughy, jackass morwong, atherinid fish *Craterocephalus capreoli*, spikey oreo *Neocyttus rhomboidalis*, SBT and black marlin *Makaira indica*, all of which occur within the region of the SPF (Ovenden unpublished).

The presence of the Wahlund effect in jack mackerel and Australian sardine may, therefore, be associated with the presence of genetically distinct spawner groups (GDSG) plus the mixing of genetically distinct offspring, possibly during the feeding (i.e. non-breeding) phase. The Wahlund effect may have been observed because of the life-history stage of samples that were taken for genetic analyses. How genetically distinct populations are produced and maintained is unknown, but could include natal homing associated with spawning, schooling behaviour and post-mating reproductive barriers. Whatever the mechanism, it is highly likely that it operates between and within GDSGs, at and during spawning times and at spawning locations.

Summary: Potential impact of localised depletion arising from the DCFA on target SPF species

- *SPF target species:*
  - *— have a schooling behaviour that is dynamic and difficult to predict, although there are some diurnal patterns in schooling behaviour*
  - *— are vulnerable to capture by way of their schooling behaviour and associations with oceanographic features such as eddies, and temperature and chlorophyll fronts*
  - *— are proficient swimmers that can avoid capture to some extent and also redistribute relatively rapidly*
  - *— are productive and fecund but subject to fluctuating environmental conditions to which they may respond dramatically*
  - *— have some inherent characteristics that make them vulnerable to localised depletion, but have others that are likely to reduce the temporal and spatial extent of any such depletion and the level of adverse environmental impacts on predator species that might arise.*
- *Given the conservative exploitation rates in the SPF and that concerns about the basis for spawning stock biomass estimates are being addressed, the panel considered that any localised depletion of SPF target species that might arise from the DCFA was unlikely to affect the overall status of stocks of those species in the SPF.*
- *The ability of a vessel to stay on a school of fish and therefore take a greater proportion of that school, so as to increase the extent of localised depletion:*
  - *— is dictated more by the behaviour of the school than by the particular characteristics of the mid-water trawl vessel*
  - *— is not significantly affected by the freezing and processing capacity of the vessel specified in the DCFA.*
- *According to the panel's definition, localised depletion of jack mackerel inevitably occurred during the 1980s, at least temporarily, but there is also clear evidence for a non-fishing, i.e. environmental, cause for the changed behaviour of jack mackerel and its perceived absence. Despite active research in the fishery, there were no apparent indications of adverse environmental impacts directly resulting from the fishery on jack mackerel in the 1980s.*
- *The available genetic evidence for jack mackerel did not suggest that past, apparently high, levels of fishing had significantly affected reproductive capacity.*
- *There have been no significant changes in the age or size composition of redbait in recent years that might indicate a potential impact on reproductive capacity. There are too few data available for the Australian sardine in the Eastern Zone, or blue mackerel, to determine with confidence if there have been significant changes to date, but the low levels of effort and catch suggest little likelihood of fishing impacts on age, size structure or reproductive capacity.*

- *There is no evidence to suggest that localised depletion has caused any impacts on genetic diversity in the SPF stocks. Further research into stock structure would be required in order to inform management of the potential risks of localised depletion at the sub-population level and the appropriate spatial scale at which to manage effort and catch.*

6.6 Ecological allocation to central place foragers

Hannesson *et al.* (2013) found that, for four small pelagic fish crashes, effects were felt on marine mammals and seabirds, but very little impact was seen on other commercial fish stocks, due to 'replacement' species taking on the support food role, or at least partially, for those predators. However, for birds, the effects are far more evident. In addition to the examples cited in Section 6.3, the carrying capacity of South African penguins *Spheniscus demersus* has declined by 80 to 90 per cent due to competition from the sardine fishery and fur seals (Crawford *et al.* 2007) and declining populations of Guanay cormorants *Phalacrocorax bougainvillii* and Peruvian boobies in the Humboldt Current have also been linked to fisheries (Bertrand *et al.* 2012). The general rule 'a third for the birds' was coined by Cury *et al.* (2011) who examined the effect of low trophic level species depletion on seabird populations. They modelled the empirical relationships between breeding success of 14 seabird species from nine sites in seven ecosystems, to their prey abundances. They concluded that, to maintain healthy top predator populations and ecosystem function, forage fish populations should be maintained at above one-third of the maximum long-term observed biomass (Cury *et al.* 2011).

Hannesson *et al.* (2013) suggested that trade-offs are necessary in order to support the world's growing food supply with supplements of fish meal and oil for agricultural use. Essington and Munch (2014) developed a method to assess these trade-offs in 27 ecosystems. Their findings were highly variable and they concluded that the limited ability to predict food web implications necessitated that a "precautionary risk-based approach be applied to decisions about acceptable biological removals of forage fish and biological targets used for their management" (Essington and Munch 2014).

The critical issue is to determine the level of removal of the prey species that, when added to the requirements of the overall ecosystem and taking into account natural variability, will not cause unacceptable adverse impacts to the ecosystem or components. As discussed in Chapter 4, ecological modelling of the southern Australia region, particularly by the spatially explicit Atlantis-SE model or Atlantis-SPF model (being applied in the current review of the SPF harvest strategy, Fisheries Research and Development Corporation (FRDC) project 2013/028), indicate that current exploitation rates under the SPF Harvest Strategy appear to provide an adequate 'ecological allocation' to the CPFs and other dependent predators, and that no adverse impacts are likely at that current level of allowable harvest. However, the models give results at a spatial scale that is less finely resolved than is required to identify adverse impacts on particular species of CPF such as fur seals, sea lions and birds. To avoid those impacts the ecological allocation needs to be within reach of the CPFs, both spatially and temporally.

The ability of predators to switch prey in times of reduced prey availability can mitigate the effects of depletion. This ability is inherent in predators of small pelagic species so as to be able to cope with the fluctuations of abundance of their prey that are caused by environmental variability, and which may be indistinguishable from the fluctuations caused by fishing. However, some predators, while being able to switch prey when necessary may be switching to sub-optimal diets that in the long term reduce breeding success or longevity.

It is also important to recall that, while there is a difference between localised depletion and overall stock depletion and range contraction, to some site-dependent species, such as land-based marine mammals and seabirds, the distinction is irrelevant. They may suffer the consequences of reduced availability of prey within their foraging ranges in either case.

The case of the decline of the western Alaskan stock of Steller sea lion *Eumetopias jubatus* (see box 6.2) demonstrates the complex interplay of ecological processes, environmental variability and anthropogenic pressures at work in an ecosystem, and the need to consider temporal and spatial scales as we have discussed previously. It provides an insight to the challenge of managing fisheries for the potential adverse effects on ecosystems. A vast amount of research conducted over the past decade has not reached a conclusion about the cause of the decline of the Steller sea lion stock. This serves to highlight not only the need to understand the role that prey fish or 'forage' fish play in ecosystems but, more importantly, that there can be several interacting factors that make effective management difficult to implement. Management measures for the Steller sea lion are further discussed in section 6.7.2.

Box 6.2 Steller sea lions in Alaska

The endangered western population of Steller sea lions in the Aleutian Islands and Bering Sea had declined by 90 per cent by 2000. Prior to 1990, the cause for the decline was blamed on commercial harvest of the sea lion and fatal interactions with the state commercial fisheries including juvenile entanglement in fishing gear and illegal shooting. However, following the cessation of direct harvesting, the western population failed to recover, unlike the eastern population.

> "Many have speculated on reasons for the decline in the 1980s and 1990s, including a climate regime change in the late 1970s that may have altered habitat conditions and prey abundance and diversity, increased predation, intentional and non-intentional human-caused mortalities, and fishery effects. It is generally agreed that the primary factor or factors responsible for the steep decline in the 1980s will never be identified with any assurance. Likely it is a combination of multiple factors (National Research Council (NRC) 2003). In this last decade, the available information on birth and death rates indicates that adult and juvenile survival rates are similar to those pre-decline, but that natality with some exceptions has declined on the order of 30 per cent relative to the pre-decline era. Our understanding about changes in these vital rates is limited as the number of sub-regions properly studied in the western DPS [distinct population segment] is limited to three at best." (NMFS 2010)

The difficulty in explaining the decline of the western population of sea lions is partly due to a high degree of spatial and temporal variability in the population and environmental variables thought to be responsible (Wolf *et al*. 2006). The fact that the sea lions show a degree of site fidelity was a clue to looking more closely at finer-scale analyses. By using data resolved to a finer-scale and a multiple (10) hypothesis approach, Wolf *et al*. (2006) demonstrated that there were possibly several mechanisms at play. Two strong effects were that food availability affected the fecundity of the animals and that, as pollock in the diet increased, pup recruitment declined. Whether this was from too much pollock or not enough other fish was unknown. To a lesser degree, harbour seal density was correlated with sea lion 'non-pup' survival, i.e. when harbour seals were less abundant, orcas ate more sea lion pups.

In 2010, the NMFS issued an Endangered Species Act (USA) (section 7) biological opinion on the authorisation of the groundfish fisheries of the Bering Sea and Aleutian Islands, Gulf of Alaska and the State of Alaska. The biological opinion found that NMFS could not ensure that the groundfish fisheries were not likely to jeopardise the western stock of Steller sea lions or adversely modify or destroy critical habitat. Localised depletion of Atka mackerel *Pleurogrammus monopterygius*, pollock and Pacific cod *Gadus macrocephalus* were suggested as impacting sea lions' growth and productivity and reproduction. Highly controversial new restrictions were implemented to protect the species and critical habitat, particularly in the Aleutian Islands, which were not popular and resulted in legal challenges. NMFS was required to produce a cooperative Environmental Impact Statement and a range of alternative spatial closures. Several scientific reviews were also conducted on the biological opinion, all of which were critical. As a result, NMFS identified areas that warranted further analysis or modification. The most recent 2014 biological opinion has been developed by NMFS after reviewing the Environmental Impact Statement, previous biological opinions and relevant management plans, the Steller Sea Lion Recovery Plan and the best available data.

The management actions currently proposed are a suite of measures to control the location, gear type, timing, and harvest amount for Atka mackerel, pollock, and Pacific cod fishing in the Aleutian Islands to avoid jeopardising the western population of Steller sea lions or adversely modifying their critical habitat; and to minimise, as far as possible, economic impacts to the fisheries. Further research on fish abundance and distribution, and movement of Atka mackerel was also recommended to understand potential impacts of commercial fisheries on Steller sea lion prey species, particularly the potential for fisheries to cause localised depletion of sea lion prey and the efficacy of trawl-exclusion zones.

Source: NMFS 2010 and 2014

6.7 Impacts on central place foragers

6.7.1 Potential nature and extent of adverse impacts

Because central-place foraging predators (seabirds and pinnipeds) raise offspring on land, the availability of key prey resources near their breeding colonies at key times (e.g. incubation and chick rearing in seabirds, lactation in pinnipeds) is critical to their reproductive success and the longer-term sustainability and maintenance of breeding populations. This dependency on near-colony prey resources at certain locations and times increases the vulnerability of these species to localised depletion of prey in their key foraging areas.

Central-place foraging marine predators are highly responsive to changes in prey availability, which have been shown to impact their foraging behaviour, reproductive performance and survival (Croxall *et al.* 1988, Furness and Tasker 2000, Rindorf *et al.* 2000, Boyd and Murray 2001, Boyd *et al.* 2006, Croxall 2006, Daunt *et al.* 2006, Hamer *et al.* 2006, Furness 2007, Einoder 2009). Some impacts can be short-term (within a breeding season impacting chick/pup growth rates, survival, fledging/weaning success), or longer-term (broader demographic impacts on survival, recruitment, fecundity, age-structure, population growth rates and size). Many studies, particularly on seabirds, have shown that foraging and breeding success parameters can reliably predict and/or track changes in stock abundance, distribution and recruitment of commercially targeted species (Anderson and Gress 1984, Berruti and Colclough 1987, Montevecchi *et al.* 1987, Monaghan *et al.* 1989, Cairns 1992, Hatch and Sanger 1992, Bertram and Kaiser 1993, Montevecchi 1993, Croxall *et al.* 1999, Furness and Tasker 2000, Velarde *et al.* 2004, Cury and Christenson 2005, Furness 2007). In most of these studies, the actual causes of variability in the availability of commercially targeted fish stocks that impact predator foraging and reproductive performance are uncertain, however, some have been directly attributed to overfishing (Furness and Tasker 2000, Lewis *et al.* 2001, Bertrand *et al.* 2012). With the exception of the study by Bertrand *et al.* (2012), studies typically focus on attributing changes in predator performance to changes in prey availability, not whether the reduced prey availability has occurred as a consequence of overall stock depletion or localised depletion. For CPFs, such distinctions are largely semantic, as any reduction in prey availability within their restricted foraging ranges could lead to adverse impacts. For these reasons the panel considered that any case study where reduction in prey availability has been shown to contribute to impact on CPF species provided a valid example of the possible nature and extent of adverse impacts that could result from localised depletion.

The nature and extent of impact on CPFs of prey depletions within their foraging ranges will depend on the spatial and temporal scale of depletion (Reid *et al.* 2005, Croxall 2006). Short-term prey depletions on the scale of days may reduce foraging efficiency and increase the energetic costs of foraging due to reduced prey densities and longer search periods. This could lead to longer foraging trips and/or reduced meals size/milk transfer and rates of provisioning to offspring (chicks/pups). If depletions persist they will result in reduced chick/pup growth rates at the scale of weeks, and result in lower fledging/weaning mass and reduced chick/pup survival and adult-breeding success at the scale of months (depending on age at fledging /weaning). Longer-term depletions over the scale of years and decades can impact major demographic factors such as survival, recruitment and reproductive rates that drive population age structure, growth rates and ultimate size.

Summary: potential impact of localised depletion on CPF species

- *The dependency on near-colony prey resources at certain locations and times increases the vulnerability of CPF species to localised depletion of prey in their key foraging areas.*
- *Although CPF species have been shown to be highly responsive to changes in prey availability within their key foraging areas, very few studies have linked reduced foraging and reproductive performance to the impacts of fishing, and even fewer to localised depletion.*
- *There may be no biological distinction between the nature and extent of adverse impacts on CPF species from any source of fishing induced prey depletion (at the stock or local level) within their restricted foraging range, although, by their nature, adverse environmental impacts caused by localised depletion may be shorter in duration (days to months) and less persistent than those caused by stock depletions.*

- *The nature and extent of impact will depend on the spatial and temporal scale of the depletion. Short-term impacts may reduce foraging efficiency resulting in longer foraging trips and/or reduced rates of provisioning to offspring. If these persist they can result in reduced offspring growth rates, fledging/weaning mass and reduced survival, and reduced adult breeding success. Longer-term impacts can affect major demographic factors such as survival, recruitment and reproductive rates that drive population age structure, growth rates and, ultimately, population size.*

6.7.2 Managing impacts of localised depletion on CPF species

The panel is aware of five main case studies where the potential impacts of localised depletion caused by fishing on CPF species are managed at some level. These are summarised below.

<u>Peruvian anchovy and Peruvian boobies</u>

The Humboldt Current System (HCS) off the coast of Peru hosts one of the largest guano-producing seabird populations in the world that includes the Peruvian booby, Guanay cormorant and Peruvian pelican *Pelecanus thagus*, which is underpinned by the largest, small pelagic fishery for Peruvian anchovy (Bertrand *et al.* 2012). The HCS is subject to high environmental variability, including El Nino (Chavez *et al.* 2008). Abundance of these seabirds varied between 3 and 8 million individuals between the early 1900s and 1940s to up to 16–28 million in the 1950s following protection of nesting areas in the 1940s (Bertrand *et al.* 2012). Industrial fishing for anchovy began in the late 1950s and grew rapidly, and by the early 1970s the stock had collapsed in response to overfishing, environmental conditions less favourable to anchovy and a major El Nino event (Bertrand *et al.* 2004). These events also lead to major collapses in seabird populations. Since then, both anchovy and seabird populations have recovered, although seabird numbers generally oscillate at historically lower levels (0.4 to 4 million, Bertrand *et al.* 2012).

Since the early 1990s, the anchovy fishery has been relatively stable with annual catch levels around 6 million tonnes per year. As the fishing season overlaps with the seabird-breeding season, concentration of fishing effort may impact on prey availability to seabirds during this critical period. Bertrand *et al.* (2012) simultaneously tracked fishing activity (all vessels fitted with a vessel monitoring system) and seabird foraging behaviour (birds fitted with GPS and dive logger tags) from the opening of the fishing season in 2007, to investigate if the foraging behaviour of Peruvian boobies was impacted by the distribution and intensity of fishing within their core foraging areas.

The study found that as the fishing season progressed, both the range of the daily trips and distances of the dives by birds from the colony increased, and were significantly related to concomitant fishing activity. The increase in foraging effort was significantly related to increasing removal of anchovy by the fishery, which was at more than 100 times greater than the daily anchovy requirements of the seabird colonies. Bertrand *et al.* (2012) concluded that the boobies foraged further as a consequence of localised depletion created by the intensive fishing within their core foraging areas, and that foraging efficiency of central placed foraging seabirds may be impacted by not only the global quantity, but also the temporal and spatial distribution of fishery removals. Bertrand *et al.* (2012) estimated that the fishery took around 1.1 million tonnes of anchovy in the study area, around half of which was taken during the tracking experiment. This equated to removal of around 30 per cent of the available anchovy biomass during the tracking study and 63 per cent during the entire fishing season.

Two key management changes in the Peruvian anchovy fishery have been introduced since the study by Bertrand *et al.* (2012), that may reduce some of the potential impacts of localised depletion on dependent seabird populations. Firstly, the fishery changed from open access to individual quota management in 2009, ending the competitive race for fish and, as a consequence, the fishing season is much more extended (e.g. from 48 days in 2007 to 189 days in 2009). Although the total quantity of anchovy catch remains similar between years, extending the fishing season has reduced the mean daily removals of fish from around 110,000 t per day in 2007 to around 29,000 t per day in 2009 (Bertrand *et al.* 2012). Because of the high mobility of anchovy, the probability of locally intense depletions is considered lower since the introduction of individual quotas (Bertrand *et al.* 2012). Secondly, marine reserves excluding the anchovy fishery out to 3.7 km from key seabird-breeding sites (22 islands and 11 headlands) were introduced in 2010, although Bertrand *et al.* (2012) suggest, based on their data, that these areas are not sufficient to sustain the foraging of seabirds during the fishing season.

North Sea sandeels and seabirds

Sandeels *Ammodytes marinus* are small energetically valuable bony fish that burrow into the seabed and form aggregations in the water column where they are accessible to, and form an important prey source for, many marine predators, including seabirds, seals and cetaceans (Camphuysen *et al.* 2006, Rogers *et al.* unpublished). The sandeel fishery began in the early 1970s and peaked at around 800,000 t per year in the late 1970s. In the past decade, catches have averaged around 425,000 t per year (Pikitch *et al.* 2012, Rogers *et al.* unpublished). The effects of the severe collapse in sandeel stocks on some predator species have been reported and recognised (Bailey *et al.* 1991), but the relationship between sandeel densities and predator response are not well understood, and the degree to which seabird data are a proxy for fish abundance varies among species and needs to be interpreted with caution (Furness and Camphuysen 1997, Camphuysen *et al.* 2006). For example, where some seabird species fail to reproduce when sandeel stocks are low (Monaghan 1992), others appear to be able to adjust their foraging and switch to alternative prey (Martin 1989). A number of studies have examined the potential impacts of the sandeel fishery on seabirds; these generally assume that the availability of sandeels is critical to the breeding success of seabirds and that fishing intensity can reduce their availability. The key seabird species include black-legged kittiwake *Rissa tridactyla*, common guillemot *Uria aalga*, northern gannets *Morus bassanus*, Arctic terns *Sterna paradisaea*, Atlantic puffin *Fratercula artica*, razorbill *Alca torda* and European shag *Phalacrocorax aristotelis*. Rindorf *et al.* (2000) showed that breeding success in seabirds was significantly reduced when sandeel availability to the fishery in June was low, and that the timing of the peak in sandeel availability affected reproductive success (lower when the peak occurred early). Seabird mortalities have also been related to low prey availability and competition with the fishery, and reduced reproductive success has been shown to correlate positively with sandeel abundance in Arctic terns and black-legged kittiwake (Monaghan *et al.* 1989, Furness and Tasker 2000, Rindorf *et al.* 2000, Furness 2002).

A key factor of sandeel ecology is their dependence on patchily distributed sandy substrates that can create the potential for low dispersal in juvenile fish and increase their potential risk to localised depletion (Pikitch *et al.* 2012). Furthermore, because the fishing season coincides with the main seabird-breeding season, there was considerable concern over the potential impacts of the fishery on seabird populations at this critical time. In response to scientific advice provided by the International Council for the Exploration of the Sea (ICES) Study Group on Effects of Sandeel Fishing on the dependency of seabirds on sandeel abundance, public pressure following a seabird mortality event, and in response to a precautionary ecological indicator (breeding success of kittiwakes falling below 0.5 chicks per pair over three consecutive breeding seasons), a near-shore area from eastern Scotland to north-east England was closed to the sandeel fishery (a spatial closure named the 'sandeel box') in 2000 (Frid *et al.* 2005). The fishery cannot reopen until breeding success exceeds 0.7 for three consecutive years (Frid *et al.* 2005). Hence, management of the potential impacts of localised depletion caused by this fishery is based on an ecosystem objective (seabird population health), is precautionary (the link is not yet proven), and uses kittiwake breeding success as an ecological performance indicator (EPI) of the ecosystem effects of fishing (Frid *et al.* 2005) (essentially an EPI trigger and fishery closure system). Daunt *et al.* (2008) concluded that the spatial closure can have benefits to those top predators sensitive to changes in the availability of target species, but noted that it was difficult to attribute the entire response to the spatial closure, as environmental variability that led to strong sandeel recruitment may have also been significant.

The latest advice from ICES suggests that although uncertainties still exist regarding the precise drivers of seabird-breeding performance in the North Sea and the possible role of climatic and environmental change, concerns regarding the risks to seabird breeding success from sandeel fisheries remain, and without further management control, sandeel aggregations targeted by breeding seabirds could be subject to significant depletion. There is also much debate regarding the criteria by which the spatial closure might be re-opened (ICES 2014).

Benguela anchovy/sardine and African penguins

A major pelagic fishery targeting sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus* has operated in the Benguela and Agulhas current systems off South Africa since the 1940s (Coetzee *et al.* 2008). They are also a key prey species of African penguin populations off South Africa and Namibia making up most (approximately 82 per cent) of their diet (Pikitch *et al.* 2012). The species appears highly vulnerable to changes in the spatial distribution and abundance of their prey, increasing during a period of relatively high fish abundance in 2000–2004, and declining since then as fish stocks have declined and shifted eastward (Crawford *et al.* 2006a, de Moor *et al.* 2011). Reduction in food availability is thought to be the main cause of higher adult mortality and reduced breeding success. The recent decline in African penguin populations resulted in the upgrading of their conservation status to 'endangered' by the International Union for Conservation of Nature and Natural Resources (BirdLife International 2013).

As a consequence there has been increasing pressure to manage the South African purse seine fishery to ensure adequate escapement of anchovy and sardine to avoid excessive negative impacts on the breeding success of vulnerable predators such as the African penguins, by setting some threshold on stock abundance below which no catch can be taken (Crawford *et al.* 2006b, Cunningham and Butterworth 2006). To this end, the Pelagic Scientific Working Group (PSWG) of the Department of Agriculture, Forestry and Fisheries (South Africa) was tasked to evaluate if the available evidence suggested that fishing in the vicinity of penguin-breeding colonies negatively impacted their reproductive success. The working group examined data from two major breeding colonies on the west coast, Robben and Dassen islands, for which time series of indices of reproductive success were available, but results were not clear (Butterworth *et al.* 2011). The PSWG considered commencing a programme of experimental closures around penguin-breeding colonies to better estimate these indirect impacts, however, power analyses suggested that such an experiment might take up to two decades to provide reliable results because of the large variances in the relationship between the impact on reproductive success and the extent of fish catches (Brandao and Butterworth 2007 cited in Butterworth *et al.* 2011). This prompted a feasibility study for two pairs of island colonies (Robben/Dassen and St Croix/Bird with pelagic fishing suspended around one of each pair—20 km radius) for indices related to reproductive success.

Pichegru *et al.* (2010) compared the foraging effort of breeding African penguins at St Croix Island and Bird Island and found that the foraging effort of the St Croix Island (20 km fishing closure) penguins decreased by 30 per cent within three months of the introduction of the fishing closure while those at Bird Island (50 km away, opened to fishing), increased their foraging effort during the same period. In addition, following the closure at St Croix Island, Pichegru *et al.* (2010) noted that most of the penguins shifted their feeding effort inside the closed area. Pichegru *et al.* (2010) claimed their study reflected the immediate benefits of the introduction of the fishery closure, but this has been disputed by Coetzee (2010) and Butterworth *et al.* (2011) who pointed out that fishing effort was very low around St Croix Island in 2008 (before the closure) and that the results may simply reflect natural variability in prey abundances rather than impacts from the fishery. In contrast, penguin abundance has remained stable at Robben Island (open to fishing), but declined at Dassen Island (closed to fishing) during 2008 and 2009 (Coetzee 2010). Recent research by Robinson (2013) who examined relationships between penguin demographic parameters at these colonies and extractions of forage fish, taking account of fish abundance through biomass estimates from, have also proved inconclusive.

Fishery closures were introduced as a precautionary measure which, in conjunction with ongoing monitoring of penguin demographic parameters, provide a means to assess, over time, whether or not such closures benefit penguins (Coetzee 2010). However, results to date highlight the challenges in studying the indirect effects of fishing on dependent predator populations (Pikitch *et al.* 2012), and reinforce earlier assessments that such relationships may take decades to provide reliable results (Brandao and Butterworth 2007 cited in Butterworth *et al.* 2011). Attempts are being made to incorporate functional relationships between predators (namely penguins) and prey into the operating models for sardine and anchovy, augmented by population dynamics model(s) for the predator(s) of concern (Patterson *et al.* unpublished).

<u>Alaskan fisheries and Steller sea lions</u>

Steller sea lions (SSL) in the northern Pacific are the largest otariid pinniped. Key prey species in their diet include walleye pollock *Gadus chalcogrammus*, Pacific cod, and Atka mackerel which are also targeted by some of the world's largest fisheries. Following large declines, western stocks of SSL were listed as 'endangered' under the *US Endangered Species Act* in 1997, with the eastern stock listed as 'threatened' but recently de-listed.

Multiple hypotheses have been developed to explain the rapid decline in the western SSL stocks, many of which are still being robustly debated (NRC 2003, Wolf *et al.* 2006, Wolf and Mangel 2008, Boyd 2010). In fact, 10 hypotheses have been detailed, which can generally be categorised into four groups, including: food limitation; 'junk-food'; fishery-related mortality and predation-mortality hypotheses (Wolf *et al.* 2006, Wolf and Mangel 2008). The recent analyses suggest that food, both the quantity and quality of it, are likely to have been key factors in SSL decline (Wolf *et al.* 2006, Wolf and Mangel 2008). This is consistent with the major expansion of fishing roughly coinciding with the period of the SSL decline, and the considerable overlap in prey species and size classes of fish that are utilised by SSL and fisheries (Hennen 2006).

Fisheries' activities could plausibly affect SSL populations by changing fish species composition, distribution and/or abundance in a way that decreases SSL foraging efficiency (Hennen 2006). Both broad-scale stock depletions reducing the overall biomass of fish, and the uneven removal of fish that can lead to localised depletions, have been considered as contributing to the decline in SSL populations (NRC 2003). There is evidence that localised depletions of Atka mackerel has occurred as a result of fishing intensity in certain areas along the Aleutian Islands and in the Gulf of Alaska. This includes evidence for seasonal, localised depletion by trawl fisheries in eight areas between 1992 and 1995; a persistent depletion in the Gulf of Alaska between 1993 and 1994; and depletions at some sites in 1996 and 1997 (Lowe and Fritz 1997, Fritz 1999, NRC 2003). There is also evidence of localised depletion of walleye pollock in the eastern Bering Sea. Battaile and Quinn II (2006) used data from 1995–1999, stratified by small areas, short seasons and years. They identified a number of areas where localised depletion had occurred and noted that cumulative depletion over a season was inversely related to estimated initial biomass, total catch, and total effort, indicating that depletion is detected more easily in areas of low abundance and consequently lower catch and effort (Battaile and Quinn II 2006). Based on their findings, pollock may repopulate exploited areas in a relatively short time period (weeks).

A range of SSL protection measures were introduced between the 1990s and 2000s to mitigate against the potential indirect effects of fishing. These focused less on the overall rates of harvest and more on the temporal and spatial apportionment of catches so as to mitigate against the potential for localised depletion effects from the Alaskan groundfish fisheries (NRC 2003). These included fishing closures at specific times and locations to protect near-shore areas considered to be critical foraging areas. These 'critical habitat zones' consist of a 20 nm (37 km) buffer around all major haul-outs and breeding colonies as well as three large offshore foraging zones (Figure 6.1). Additional 3 nm (5.5 km) no-entry zones have been enacted within which no ground fishing or transit of vessels is allowed. The intent of the closures is to disperse fishing effort temporally and spatially in this region.

Have spatial closures been successful in mitigating the effects of localised depletion on SSL? As closures were introduced around all major breeding colonies in the western SSL stock range, a comparison between 'treatment' vs 'control' is not possible, and precludes a conclusive cause-and-effect relationship between fishing and the SSL population trend to be determined (Hennen 2006). Hennen (2006) showed a positive correlation between several metrics of historical fishing activity and SSL population decline. However, the relationship was less consistent following the introduction of management measures in 1991, supporting the hypothesis that management measures around some of the rookeries have been effective in moderating the localised effects of fishing activity on SSL. These results do not preclude additional factors having contributed to the stabilisation and in some cases increases in the populations; but population modelling analyses suggest that management actions taken since 1990 have probably been effective (Boyd 2010).

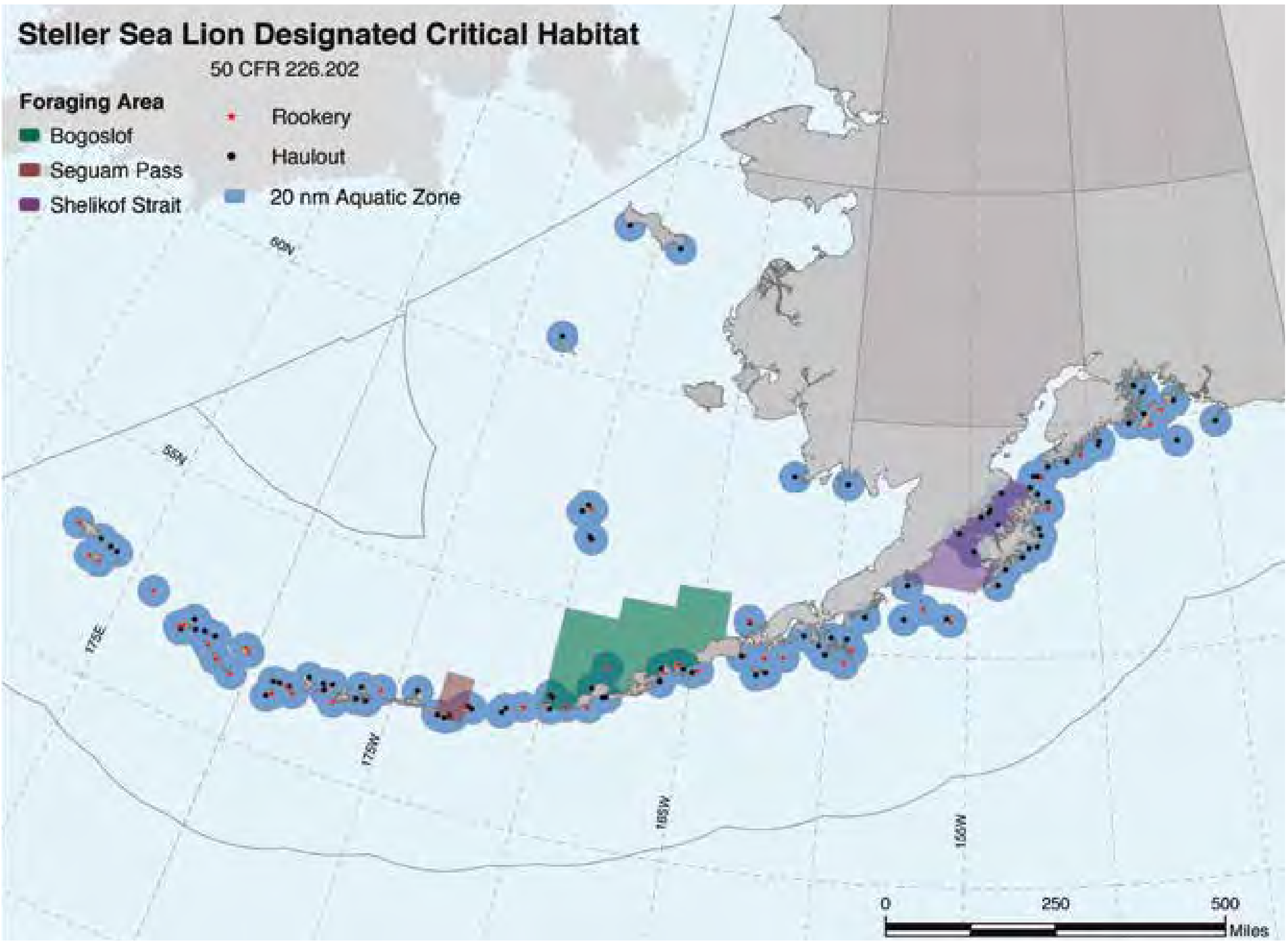


Figure 6.1 Designated critical habitat zones and fishery exclusion zones around Steller sea lion breeding (rookeries) and haul-out sites in Alaska. Source: National Oceanic and Atmospheric Administration, NMFS Alaska Regional Office (2014), (http://alaskafisheries.noaa.gov/protectedresources/stellers/maps/criticalhabitat_map.pdf)

Antarctic krill and key CPF species

Antarctic krill *Euphausia superba* are a critical component of Antarctic and Southern Ocean food webs, supporting populations of baleen whales, seals, fishes, birds and cephalopods, which are all significant predators of krill. The krill fishery is managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

A fishery for Antarctic krill has been operating for more than three decades, and has been characterised as one of the world's largest underexploited fisheries (Nicol *et al.* 2012). Catches peaked in the 1980s at more than 500,000 t annually. Since the early 1990s the catches have been between 100,000 t and 200,000 t with further fishery development being constrained by the expense of fishing in the Southern Ocean and also a limited market for krill products. Both of these issues may be set to change, with increases in catches being perceived as likely (Nicol *et al.* 2012). In the Scotia Sea, where the bulk of the fishing occurs, catches are limited by a trigger level of 620,000 t until a procedure for dividing the precautionary total limit for the region of 5.61 million t amongst 15 selected small-scale management units (SSMUs) can be devised (Constable and Nicol 2002, CCAMLR 2012) (Figure 6.2). The trigger level was based on concerns that a regional limit is not sufficient to prevent spatially localised, indirect impacts on krill predators (Constable 2011). The intent of these SSMUs is to minimise indirect impacts of the krill fishery on dependent predators (Hewitt *et al.* 2004), and especially address concerns about localised depletion (Pikitch *et al.* 2012). CCAMLR is yet to formalise how these areas are to be managed and is developing a set of candidate decision rules and testing around these (CCAMLR 2011). SSMUs are designed to facilitate spatial management options that would operate at finer spatial scales (Plagányi and Butterworth 2012).

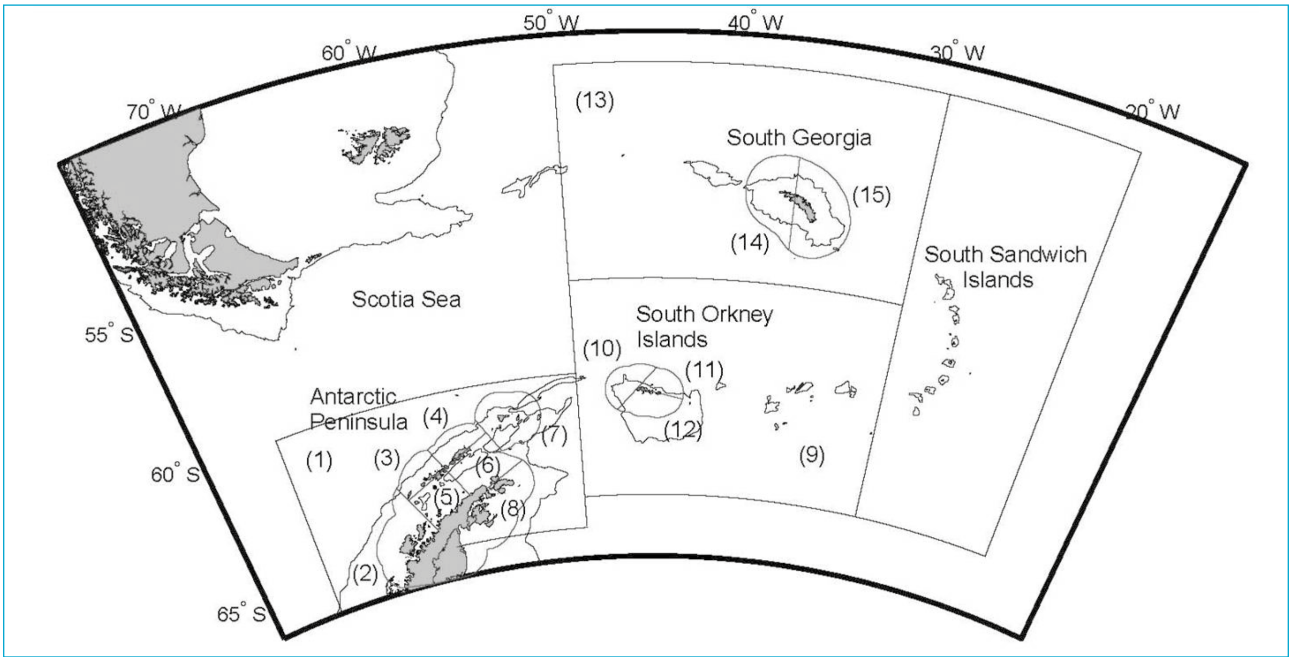


Figure 6.2 CCAMLR small-scale management units in the Antarctic Peninsula and South Georgia region.

Source: Hewitt *et al.* (2004), with permission from *CCAMLR Science*

Summary: localised depletion on CPF species

- *Based on the findings of many studies, and in the opinion of the panel, there is a potential for localised depletion of target species by the DCFA to adversely impact their predators. The most susceptible to impact would include CPF species, especially those with restricted foraging ranges while raising offspring and where species targeted by the SPF constitute a significant portion of their diet. Concentrated fishing activity at locations and times when CPFs are most susceptible to the impacts of prey depletion could reduce foraging success and lead to lower reproductive outputs and survival. If persistent, such impacts could lead to declines in populations.*
- *The panel is aware of five case studies where the potential impacts of localised depletion caused by fishing on CPF species are actively managed at some level. These are:*
  - *Peruvian anchovy and Peruvian boobies*
  - *North Sea sandeels and seabirds*
  - *Benguela anchovy /sardine and African penguins*
  - *Atka mackerel and Steller sea lions – Alaska*
  - *Antarctic krill (CCAMLR fisheries).*
- *In only one case study (Peruvian boobies) is there compelling evidence for localised depletion. In three case studies (North Sea, Benguela, Alaska) where impacts on CPF predators have been identified (declines in population size and reproductive success), spatial closures have been introduced as a precautionary measure to mitigate potential adverse impacts of localised depletion, even though the causes of those impacts are uncertain. In one case study (the Antarctic krill fishery), spatial closures to protect CPF predators from indirect fishing impacts are only in development.*

6.7.3 Key CPF species and areas in the SPF

The SPF region contains some of the largest populations of CPF predators in coastal Australian waters, including all of its fur seal populations (about 200,000 animals) and almost all of its Australian sea lion population (about 13,000 animals) (see Section 5.2), and numerous populations of seabirds including Australia's most abundant and biomass seabird, the short-tailed shearwater *Ardenna tenuirostris* (around 23 million) (Patterson *et al.* unpublished).

Dietary information on a range of marine predators, including CPFs, highlighting the importance of SPF species is summarised in Table 4.2. Based on available data summarised in this table, the subset of protected species of CPF seals and seabirds that occur within the SPF area and for which SPF target species occur in significant proportions in the diet (more than 10 per cent at some stage) include:

- Australian fur seal *Arctocephalus pusillus doriferus*
- New Zealand fur seal *Arctocephalus forsteri*
- Australasian gannet *Morus serrator*
- short-tailed shearwater *Ardenna tenuirostris*
- little penguin *Eudyptula minor*
- crested tern *Thalasseus bergii*
- shy albatross *Thalassarche cauta*.

Little terns are considered highly coastal and unlikely to forage extensively within the SPF area. Other potential species for which there is limited information on diet within the SPF area and which may rely on SPF targeted species during their breeding seasons include the flesh-footed shearwater *Puffinus carneipes* and wedge-tailed shearwater *Puffinus pacificus* (Gould *et al.* 1997, Bond and Lavers 2014).

With respect to areas within the SPF that constitute critical foraging habitat for key CPF species, there is a spectrum of data available across species. For pinnipeds, there have been broad global analyses of foraging distribution that use very simple foraging metrics to identify key regions at large spatial scales (e.g. Figure 5.4), and one instance where a very detailed regional model of foraging distribution has been developed for the Australian sea lion (Figure 5.5). As detailed in Chapter 5, most of the Australian and New Zealand fur seal populations reside in southeastern Australia, with the former most abundant in Bass Strait and the latter in South Australia (SA) (Figure 6.3). The panel is aware that extensive tracking data exists for both Australian and New Zealand fur seals (mostly from Bass Strait and SA, respectively) that could be used to identify key foraging areas. Most critical are those areas used by lactating females while raising dependent pups located onshore. For both species, pups are raised over a 10 to 11 month period between November and October. Although Australian fur seal females forage in shelf waters year round, New Zealand fur seals (at least in SA), partition their foraging by feeding in shelf waters between December and May, then transitioning to oceanic waters until the commencement of the next breeding season. The distance from breeding colonies that female Australian and New Zealand fur seals forage varies from colony to colony, often relative to the distance to key oceanographic features, but can also vary throughout lactation and in response to the distribution and availability of prey.

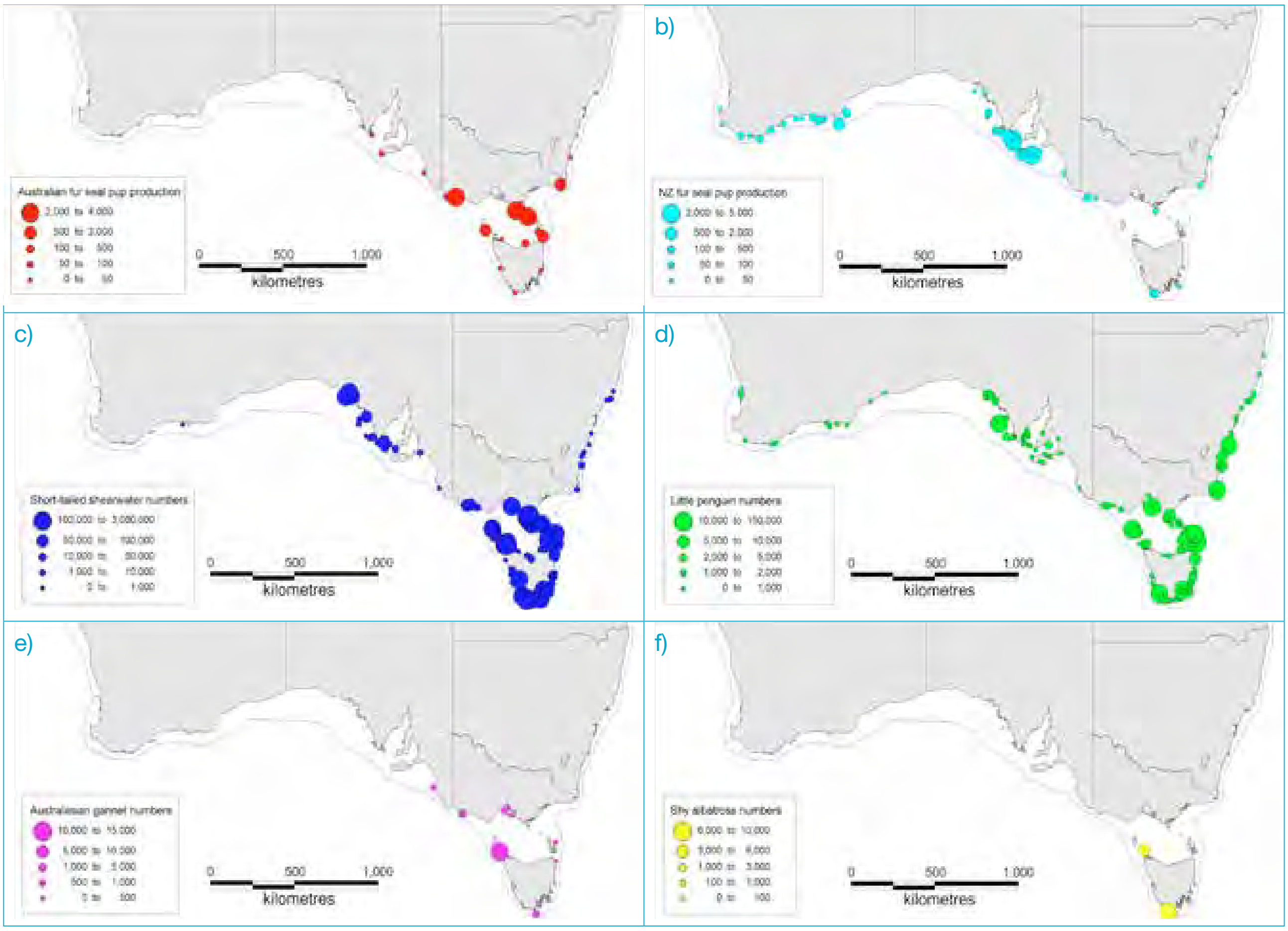


Figure 6.3 Distribution of breeding colonies of six key CPF predators that occur in the SPF: a) Australian fur seal, b) New Zealand fur seal, c) short-tailed shearwater, d) little penguin, e) Australasian gannet, and f) shy albatross. Symbols are scaled to the size of the populations. The 200 m bathymetry isobath is indicated. Data for crested terns were not available for presentation. **Source:** S. Goldsworthy, South Australian Research and Development Institute (SARDI) unpublished.

Thirty-two CPF seabird species were identified as occurring within the SPF area (i.e. those CPF seabirds that breed somewhere within the SPF area). A CPF seabird density plot provides some measure of the distribution of CPF seabird species throughout the SPF, and highlights Lord Howe Island, Bass Strait and Tasmania, and coastal regions of NSW, SA and Western Australia (WA) (centred around islands with seabird populations) as key areas (Figure 6.4). However, Figure 6.4 does not accurately represent the at-sea distribution of CPF seabirds, nor does it identify the breeding sites for all species. For those key SPF seabirds identified above, both the number of breeding sites and the size of populations are concentrated in southeastern Australia (Figure 6.4). This is exemplified by the most abundant Australian seabird, the short-tailed shearwater (around 23 million, Patterson *et al*. unpublished)(Figure 6.4). Also, most Australasian gannet colonies and all shy albatross colonies are located in Bass Strait and Tasmania (Figure 6.4). Little penguins breed across southern Australia, with the bulk of the population centred in Bass Strait (Figure 6.4). At least some satellite telemetry data exist for each species in parts of their range, but none of the datasets are comprehensive and cover all stages of the breeding period.

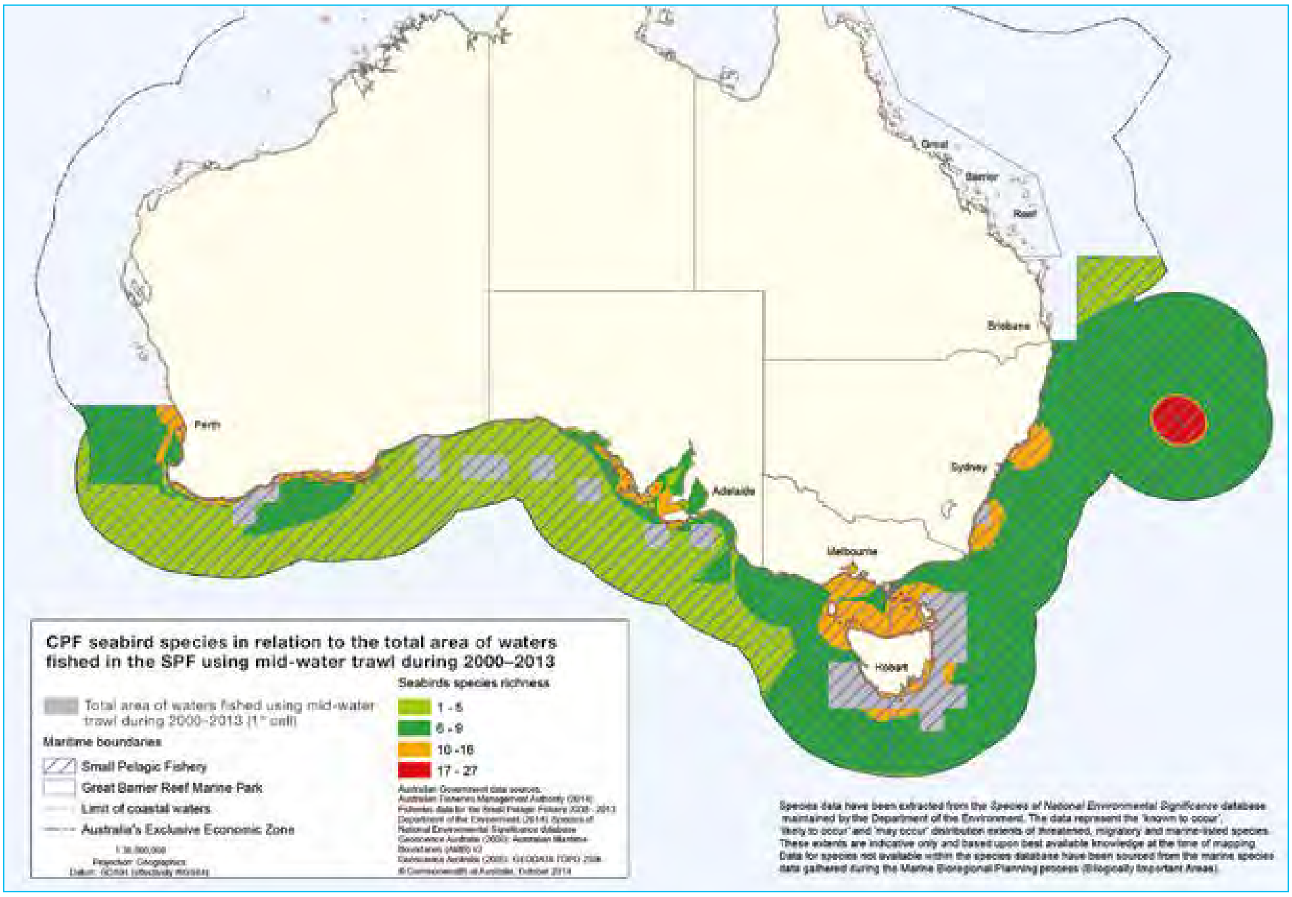


Figure 6.4 CPF seabird species in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by the Environmental Resources Information Network (ERIN), Department of the Environment using unpublished AFMA data.

The most comprehensive regional assessment and estimate of CPF species consumption and foraging distribution comes from research undertaken in SA by Goldsworthy *et al.* (2011), as part of a study into ecosystem-based management of the SASF. They undertook extensive satellite telemetry studies on five key CPF species, including the New Zealand fur seal, Australian sea lion, little penguin, short-tailed shearwater and crested tern. For each species, based on a subset of animals from representative sites, generic foraging models (statistical models of data distributions based on distance and depth) were developed and then applied to all known breeding sites, and using population data and consumption models, estimated the spatial distribution of foraging and consumption effort off SA (Goldsworthy *et al.* 2011) (Figure 6.5). Species foraging models were also combined to provide an overall estimate of the distribution of consumption effort of prey species by these CPF predators across shelf waters (Figure 6.6). Although such spatial models highlight regions of critical importance to CPF, they were not developed to assist in spatial management of the SASF or to manage the potential impacts of localised depletion. These models were global models in the sense that they pooled all the foraging effort of animals throughout the year, and did not just focus on critical periods (e.g. lactating females raising pups/adult seabirds raising chicks).

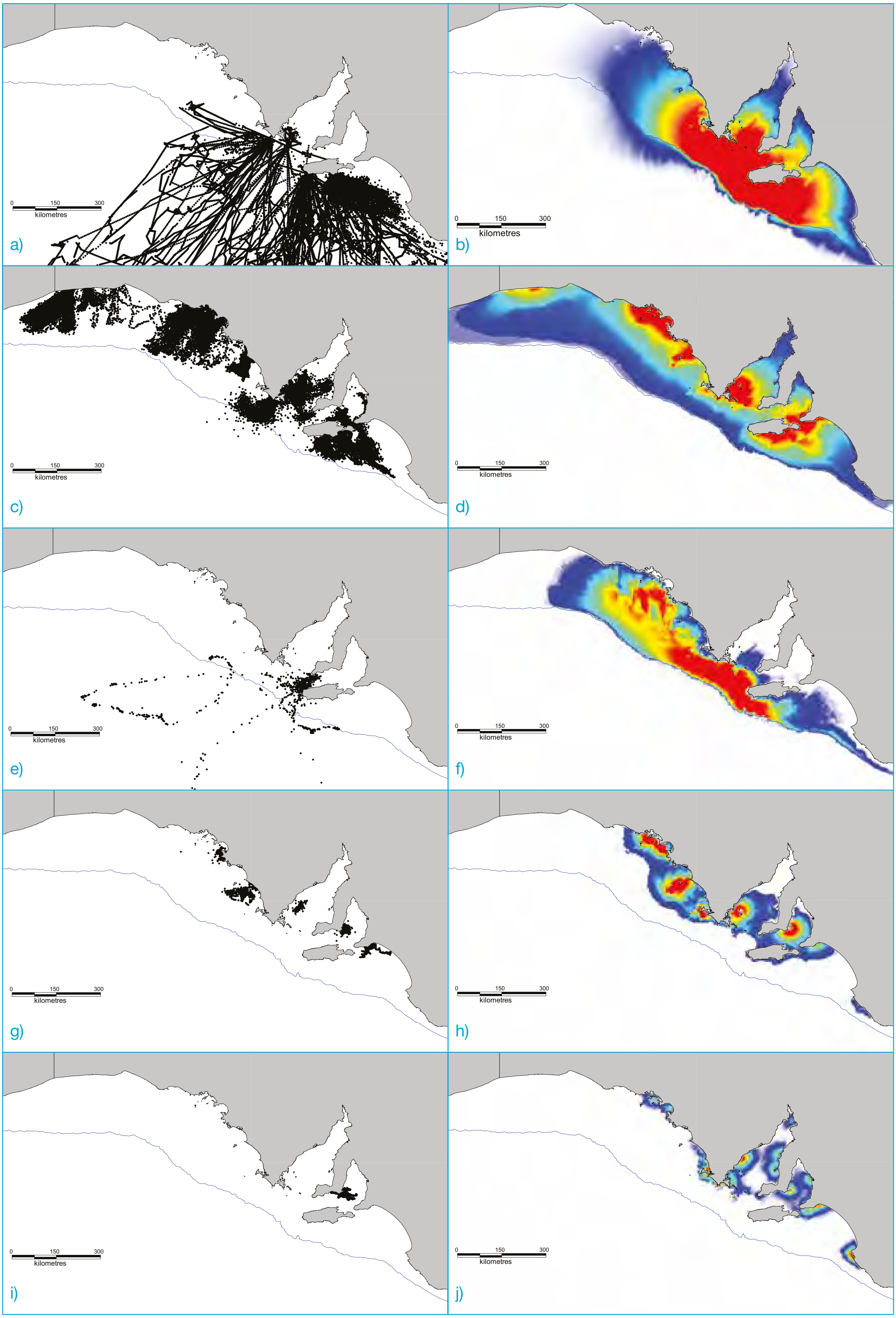


Figure 6.5 Raw satellite telemetry data (left column) that was used to model the spatial distribution of foraging effort across all breeding sites over shelf waters of SA, drawn as heat plots (right column). Species are New Zealand fur seal (a, b), Australian sea lion (c, d), short-tailed shearwater (e, f), little penguin (g, h) and crested tern (i, j). **Source:** S. Goldsworthy, SARDI unpublished; redrawn from data from Goldsworthy *et al.* (2011)

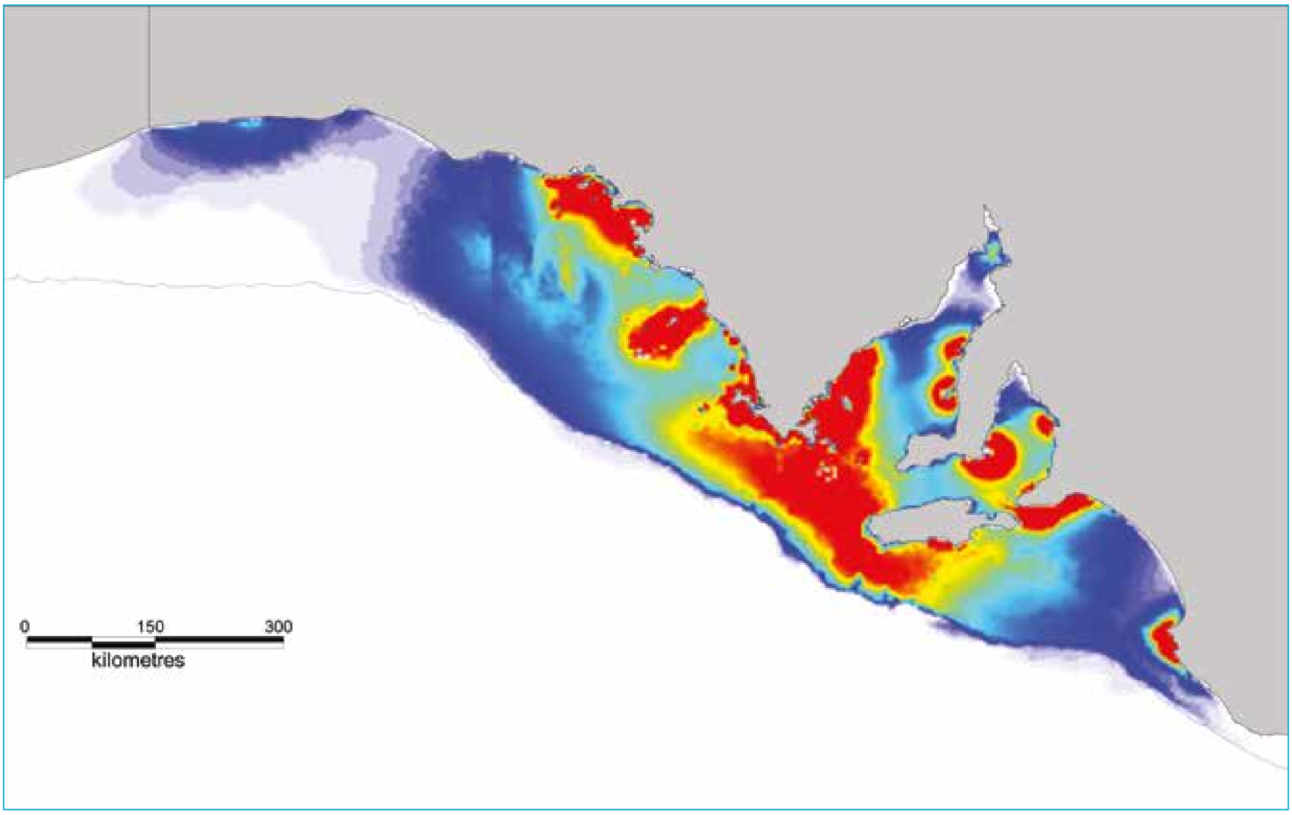


Figure 6.6 Combined model of the spatial distribution of foraging effort for five CPF predators over shelf waters off SA, drawn as heat plots (New Zealand fur seal, Australian sea lion, short-tailed shearwater, little penguin and crested tern). **Source:** S. Goldsworthy, SARDI unpublished; redrawn from data from Goldsworthy *et al.* (2011)

Summary: key central place foragers in the SPF

- *CPF predators that forage within the SPF and for which SPF target species make a significant (more than 10 per cent) contribution to the diet, include Australian fur seal, New Zealand fur seal, Australasian gannet, short-tailed shearwater, little penguin, crested tern and shy albatross.*
- *Key areas of importance to these species include south-eastern Australia, especially Bass Strait, Tasmania and SA.*
- *There remains some uncertainty about other CPF species that might be susceptible to localised depletion since diet information is poor or unavailable.*

6.7.4 The potential for adverse impacts of localised depletion on CPF species in SPF

There is very limited information currently available that enables the panel to assess the potential for adverse impacts on CPF species in the SPF from localised depletion. As with the global assessment, studies that have identified links between prey abundance and CPF predator performance provide the only types of studies that provide some insight about the likely nature of adverse impacts from localised depletion. There are very few of these available for the key CPF species identified above within the area of the SPF.

Seabird response to sardine mortality events

In March 1995 and October 1998, a disease-related mortality event is estimated to have killed approximately 70 per cent of the sardine stock biomass in southern Australia over three to four months (Gaughan *et a*l. 2000, Ward *et al*. 2001a) The cause of the diseases was considered to be an exotic herpesvirus originating in SA which spread 2500 km east and west (Jones *et al*. 1997, Murray *et al*. 2003). This catastrophic event provided a unique opportunity to assess the potential adverse effects on some dependent CPF species when a major prey species suddenly becomes unavailable. Three case studies are summarised below on little penguins, Australasian gannets and crested terns.

Little penguins and sardine mortality event

Dann *et al*. (2000) monitored the effects of the major and widespread mortality of sardine that occurred around southern Australia from March to May 1995. They noted that in May 1995, the numbers of little penguins coming ashore declined at Phillip Island and St Kilda concurrently with the recording of many penguin deaths in western Victoria. Around 2.3 per cent of those banded birds at risk of recovery were recovered dead, a much greater number compared to the annual mean of 0.7 per cent (for 1970–1993). The sudden and major absence of sardines following the mortality event is also considered to have had a major impact on breeding success, with birds laying two-weeks later than usual, and only producing 0.3 chicks per pair compared to the long-term average of 1.0 (Dann *et al*. 2000). Dann *et al*. (2000) concluded that both the increase in penguin mortality and the significant reduction in breeding success were associated with the widespread Australian sardine mortality. Breeding success and the number of birds coming ashore had returned to normal levels two years following the sardine mortality event (Chiaradia *et al*. 2010).

Australasian gannets and sardine mortality event

Bunce *et al*. (2005) noted a significant decline in the breeding success and chick growth of Australasian gannets in Port Phillip Bay during the 1998–99 breeding period immediately following the major sardine mortality event. The apparent unavailability of sardines following the mortality event was reflected in major declines in the representation of sardines in the diet of gannets, from approximately 60 per cent prior to the mortality event, to 5 per cent following it, which was also coincident with low commercial catches and catch rates of sardine by commercial fisheries (Bunce and Norman 2000). The reduced fledging mass of chicks during the 1998–99 breeding season is thought to have been caused by reduced provisioning, as evident by significantly smaller food samples recorded in the 1998–99 breeding period, indicating that food was indeed limited (Bunce *et al*. 2005). The recovery to normal breeding success in the subsequent Australasian gannet breeding season (1999–2000), despite the continued absence of sardine in their diet is thought to have been facilitated by the expansion in the distribution and abundance of other small, inshore pelagic schooling fish, such as anchovy, following the sardine mortality (Ward *et al*. 2001a, Bunce *et al*. 2005). Sardine abundance in the diet of Australasian gannets has shown a strong correlation with local commercial catches and catch rates, suggesting that the relative proportion of sardine in the diet may be a useful index of sardine abundance (Bunce 2004).

Crested terns and sardine mortality event

McLeay *et al*. (2009) studied a population of crested terns at Troubridge Island in Gulf St Vincent, SA, taking advantage of a banding program where around 1350 chicks have been banded in most years since 1975. They investigated the diet, age structure, and morphology of the crested tern population to determine if survival and growth of adults was reduced for cohorts reared in years immediately following the sardine mortality events. Both anchovy and sardine are important prey species for crested terns, representing 36 per cent and 15 per cent of the prey fed to chicks, respectively. Based on the recaptures of adult birds during breeding seasons, McLeay *et al*. (2009) determined that crested terns were physically smaller and had lower survival rates in years following the two sardine mass mortality events in 1995 and 1998.

Potential CPF ecological performance indicators in the South Australian sardine fishery

As part of a study examining the potential use of EPIs and reference points to assess the need for ecological allocations in the SASF, Goldsworthy *et al.* (2011) developed a suite of reproductive and foraging success parameters of key CPF seals and seabirds to compare against annual changes in sardine catch and estimated spawning biomass. A total of 181 potential EPIs were used to describe trends in abundance and breeding success and feeding ecology of crested terns (44 EPIs), New Zealand fur seals (66 EPIs), little penguins (54 EPIs), short-tailed shearwaters (17 EPIs), that were compared to five sardine indicators (three biomass and two catch), resulting in a total of 905 relationships (Goldsworthy *et al.* 2011). Negative correlations were observed between sardine annual catch and the morphology and growth of New Zealand fur seal pups, the breeding success of little penguins, the morphology of crested terns and the growth of shearwaters. However, for most species, the EPI times series were too short (three to four years collected over the period of the study) to enable robust analyses and, as a consequence, the number of significant correlations detected for species' EPIs did not differ from that expected by chance alone (Goldsworthy *et al.* 2011). It was also noted that sardines were only a minor part of the diet of New Zealand fur seals, little penguins and short-tailed shearwaters, and that their foraging areas did not significantly overlap with the area of the SASF. Because of the very short time series and unclear trophic and spatial overlap between the fishery and some of the predators, the authors expressed the need for caution when interpreting the results and noted that longer time series were needed to enable more robust analyses.

Summary: potential for localised depletion on key CPF species in the SPF

- *As with the global assessments, studies that have identified links between prey abundance and CPF predator performance are the only types of studies that provide some insight about the likely nature of adverse impacts from localised depletion. There are very few of these available for the key CPF species identified within the area of the SPF.*
- *Studies on little penguins, Australasian gannet and crested terns—following the sardine mortality events of 1995 and 1998, that were estimated to have killed around 70 per cent of the sardine stock biomass in southern Australia over a short period—provide some insight on the potential impacts on CPF predators when a major prey species suddenly becomes unavailable. Impacts included dietary shifts, reduced provisioning rates and chick, juvenile and adult survival.*
- *A study undertaken in SA attempted to identify a suite of reproductive and foraging performance indicators in four CPF predations to potentially act as EPIs for the SASF. However, the short time series (three to four years) for most species precluded a meaningful conclusion.*
- *There is a potential for localised depletion to impact CPF predators in the SPF since there is very limited monitoring of CPF predator populations and the chance of detecting any indirect fishery-related impacts within the SPF area is extremely low.*

6.8 Assessment of adverse impacts arising from any localised depletion by the DCFA

6.8.1 Focus of assessment

Under the definition of localised depletion adopted by the panel, it is inevitable that the DCFA will result in localised depletion. The nature of the potential adverse environmental impacts that might arise from localised depletion in the SPF under the DCFA has been discussed above. The panel considered that the greatest potential for adverse impacts relates to CPF species, and its assessment was focused on these species. However, the panel noted that SBT while not a CPF, is a protected species (conservation-dependent) predator of SPF target species and this species was included in the panel's assessment.

6.8.2 Adverse environmental impacts

Whether or not there are adverse environmental impacts on protected species of central place foragers and SBT arising from localised depletion caused by the DCFA, and the extent of any such impacts, will depend on:

- the species that is locally depleted
- the area over which the depletion occurs and quantitative extent of that depletion
- the time taken for the depletion to be corrected
- the spatial and temporal overlap of the localised depletion with key foraging and/or breeding grounds and key times of the year for CPFs
- the nature and extent of reliance of SBT on the species that is locally depleted.

Our understanding of each of these factors in the context of the DCFA fishing scenario is discussed below.

The species depleted

As discussed above, the spatial, quantitative and temporal extent of localised depletion is likely to vary across the main SPF target species. As noted in Section 6.4.2, these species have some inherent characteristics that make them vulnerable to localised depletion, but have other characteristics that are likely to reduce the temporal and spatial extent of any such depletion and adverse environmental impacts on predator species that might arise. The target species vary in size, age and specific habitat preferences and their resilience to fishing impacts varies.

However, we know little about their finer-scale movement patterns or site fidelity. This has implications for the nature and extent of potential adverse environmental impacts on predator species, since their reliance on the target species varies. The data provided in Tables 4.1 and 4.2 (Chapter 4) suggest that the CPF species that rely heavily on one or more SPF target species are the Australian fur seal, New Zealand fur seal, Australasian gannet, common dolphin *Tursiops truncatus*, short-tailed shearwater, shy albatross and crested tern and, to a lesser extent, little penguin. SBT also relies heavily on these species.

Location and spatial extent of the depletion

Where localised depletion occurs depends upon the distribution of the target species, their availability in a particular season and the economics of fishing (costs and market price).The panel considered that the main target species of the DCFA are jack mackerel, blue mackerel and redbait.

The historical pattern of fishing for these species in the SPF has been dictated largely by the availability of fish and their proximity to ports. A key rationale for the DCFA is that it can fish further away from ports so the historical pattern of fishing is not necessarily a good guide to the spatial distribution of fishing effort under the DCFA. However, the SPF target species are distributed predominantly on the shelf and slope (see Figures A4.1 to A4.4 in Appendix 4) and the panel has assumed that most fishing by the DCFA will occur in these areas of the SPF.

The spatial extent of any localised depletion will depend on the distribution and movement patterns of the species targeted. The quantitative extent of localised depletion of any of the target species will depend on catch rates of the target species and how long those catch rates remain sufficiently high to support the fishing operation. Catch rates will depend on the availability and catchability of fish. Availability depends on environmental conditions that influence the schools' behaviour and which fluctuate seasonally and inter-annually, and the number of, and biomass of, schools in the area. Catchability depends on behavioural characteristics of the fish such as schooling, which affects the density of aggregation within a school and the ability to avoid the fishing operations, and the characteristics of the fishing gear, method and fishing strategy.

Given the range of factors in play, the panel cannot predict with any certainty the location or the extent of localised depletion under the DCFA.

The temporal extent of depletion

The persistence of localised depletion caused by the DCFA will depend on how much is removed from a particular area, target species mobility, and the frequency and intensity of the fishing pressure. The SPF target species vary in size, age and habitat preference, however they are mobile and fast swimmers and are not confined to embayments, estuaries etc. that would impede movement or mobility.

The panel cannot predict with any certainty the temporal extent of localised depletion under the DCFA. However, all the information available to the panel confirms that the high mobility of SPF target species is likely to reduce the temporal extent of localised depletion relative to more sedentary species.

Spatial and temporal overlap with central place foragers and SBT

CPF species

Because CPF species (seabirds and pinnipeds) raise offspring on land, they have a high dependency on near-colony prey resources at certain locations and times (Figure 6.7 and Table 6.2). This increases their vulnerability to localised depletion of prey in their key foraging areas. The CPF species most susceptible to localised depletion of SPF target species have been identified by taking into account both their dietary reliance on SPF target species and their reliance on near-colony prey resources while raising offspring. They are Australian fur seal, New Zealand fur seal, Australasian gannet, short-tailed shearwater, little penguin, crested tern and shy albatross. However, the dietary data available for CPFs in the area of the SPF are by no means comprehensive and therefore this list of most susceptible species is unlikely to be comprehensive.

The information available on key areas of critical foraging habitat for these CPF species in the SPF is variable and there are few studies (Section 6.7.4) that have examined the potential impact of localised depletion on these species.

As discussed above, it is not possible to accurately predict whether and where localised depletion might occur or how long that depletion might persist under a DCFA. The DCFA has a greater ability to range away from ports and there is, therefore, the potential for increased exposure of more CPF colonies to fishing by the DCFA. Conversely, the DCFA has an increased ability to avoid those areas or move out of them if a problem occurs, since it has more options available to it than smaller vessels.

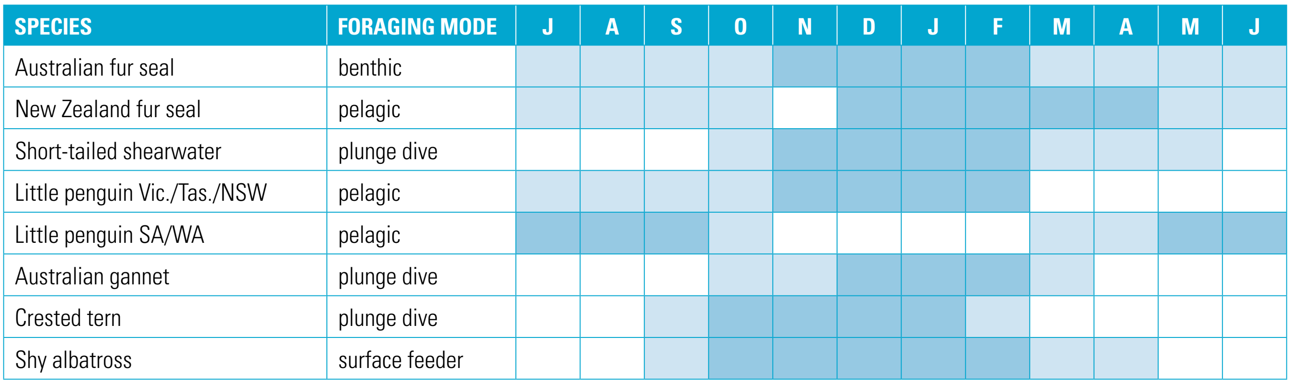


Figure 6.7 Approximate timing, by month, of breeding and offspring growth for key CPF predators in the SPF area (light blue). The periods of greatest vulnerability to CPF predators' (incubation, chick feeding, early lactation) when offspring are young are indicated in dark blue. General foraging mode is also indicated. **Source:** adapted from Patterson *et al.* (unpublished) and S. Goldsworthy, SARDI, unpublished data.

Table 6.2 Examples of satellite telemetry studies undertaken on key CPF predators in the SPF area, detailing the average foraging distances and bathymetry. Type of tag indicates GPS or Platform Transmitter Terminal (PTT) (Argos transmitter). AF = adult female.

SPECIES	LOCATION	SAMPLE SIZE	DISTANCE (KM)		BATHYMETRY (M)		TAG TYPE	SOURCE
			AVERAGE	SD	AVERAGE	SD		
Australian fur seal	Kanowna Is., Victoria	71	18.2	45.0	34.5	19.6	GPS	Patterson *et al.* unpublished
Australian fur seal	Four sites, Victoria[1]	48	120.5	142.5	48.2	70.5	PTT	Patterson *et al.* unpublished
New Zealand fur seal	Kanowna Is., Victoria	6	23.0	95.9	34.0	192.8	PTT	Patterson *et al.* unpublished
New Zealand fur seal (AF)	Four sites, SA[2]	44	53.0	51.4	81.0	33.1	PTT	Goldsworthy *et al.* 2011
Short-tailed shearwater	Griffith Is.	40	6.9	20.1	12.0	95.4	GPS	Patterson *et al.* unpublished
Short-tailed shearwater	Gabo Is.	47	7.7	11.9	27.6	26.9	GPS	Patterson *et al.* unpublished
Short-tailed shearwater	Althorpe Is., SA	22	39.2	27.0	79.9	27.0	PTT	Goldsworthy *et al.* 2011
Little penguin	Gabo Is.	117	16.6	15.7	131.0	283.5	GPS	Patterson *et al.* unpublished
Little penguin	London Bridge	98	10.1	9.3	49.1	21.7	GPS	Patterson *et al.* unpublished
Little penguin	Seven sites, SA[3]	85	14.2	13.9	35.6	15.2	PTT	Goldsworthy *et al.* 2011
Australian gannet	Point Danger, Victoria	69	30.2	71.5	58.1	392.1	GPS	Patterson *et al.* unpublished
Australian gannet	Pope's Eye, Victoria	141	19.5	37.7	9.7	22.1	GPS	Patterson *et al.* unpublished
Crested tern	Troubridge Is., SA	22	35.0	11.4	22.0	11.6	GPS	Goldsworthy *et al.* 2011

1 Seal Rock, Lady Julia Percy Is., Kanowna Is., The Skerries; 2 Cape Gantheaume, Cape du Couedic (Kangaroo Island), North Neptune Is., Liguanea Is.; 3 Granite Is., West Is., Olive Is., Pearson Is., Reevesby Is., Troubridge Is., Kingscote (Kangaroo Is.)

SBT

The few dietary studies of SBT indicate a high reliance on SPF species in Australian waters depending on region, i.e. sardine in the GAB and redbait and jack mackerel off southern and eastern Tasmania respectively (Table 4.2). However, SBT is a single stock, highly migratory species whose pelagic habitat includes both the high seas and the exclusive economic zones of various countries. SBT has even greater mobility than the target species and is able to forage widely often in association with oceanic features such as frontal systems. It is highly unlikely that localised depletion of SPF target species would cause adverse environmental impacts on a pelagic predator such as SBT. Under these circumstances, any spatial and temporal concentration of fishing effort by the DCFA in the SPF, under sustainable catch limits, is unlikely to have significant adverse impacts on SBT.

6.8.3 Relevance of vessel and gear to localised depletion

A common concern expressed by some stakeholders was the greater capacity of the DCFA to catch fish compared to the fishing fleet in the SPF, which currently consists predominantly of purse seine fishing vessels but has in the past included one or two mid-water trawl vessels. Purse seines have been used traditionally in Australian fisheries for jack mackerel, Australian sardines and tuna. The carrying capacity of a purse-seiner is proportional to the vessel size. The carrying capacities of the purse seiners operating off Tasmania in the 1980s were between 120 t to 400 t. That fleet landed a maximum annual catch of 41,000 t of jack mackerel—four times greater than the entire current Eastern Zone TAC for that species—for nearly four years, of which the smaller vessels accounted for 60 per cent (Williams and Pullen 1993). Purse-seiners operating in the GAB capturing juvenile SBT for wild-fish farming are similarly-sized with 200–600 t fish holding capacity (International Seafood Sustainability Foundation 2013). Some of these vessels could also operate in the SPF.

The proposed DCFA fishing scenario uses a mid-water trawl, also referred to as pelagic trawl (see Box 3.2). Unlike purse seining which encircles schools of fish with a net (see Box 3.1), the mid-water trawl net is towed through a school of fish. In Australia, mid-water trawling is used in fisheries such as the winter blue grenadier fishery in the Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF), and in the Heard Island and McDonald Islands (HIMI) mackerel icefish fishery. Many small pelagic species are targeted by mid-water trawling in international fisheries, e.g. capelin *Mallotus villosus*, sardines, herrings, mackerels, blue whiting *Micromesistius poutassou* and pollock. The vessels usually tow at 3.5 knots or more depending on the swimming ability of the target species.

Mid-water net configuration can vary hugely with total mouth opening areas varying from 200 to 20,000 m2 (Freon and Misund 1999). The pelagic nets that have been commonly used in mid-water research in southern Australia are the Engels 308, Engels 152, Isaac-Kidd Midwater Trawl and International Young Gadoid Pelagic Trawls, more recently with specialised opening and closing devices attached (Webb and Grant 1979, Maxwell 1982, Young and Blaber 1986, May and Blaber 1989, Young *et al*. 1996, Kloser *et al*. 2011). These nets have relatively small mouth openings in the order of less than 500 m^2 (CSIRO unpublished data). May and Blaber (1989) used an Engel 152 pelagic net off east Tasmania to catch mesopelagic and pelagic fishes (i.e. jack mackerel) for abundance estimates with dimensions of headline length 49.3 m, headline height 13–13.75 m, wingspread 16–24 m giving mouth area of 200–300 m^2.

Commercial nets used in the mid-water trawl fishery for blue grenadier are generally larger than the research nets. In 2004 FV Aoraki used a net with headline length of 242 m and a mouth area of 7500 m^2 (Kloser *et al*. 2011). The panel heard that smaller nets are currently used in that fishery (e.g. nets with a headline length of 171.5 m and a mouth area of around 3000 m^2) (Mr. L. Scott, Australian Longline Pty Ltd *in litt*. 9 October 2014). The ecological risk assessment of the SPF mid-water trawl sector (Daley *et al*. 2007b) was based on a net with a mouth area of approximately 1500 m^2.

The net used in the DCFA fishing scenario has a headline length of around 80 m and height of around 35 m. The panel heard that "Larger nets than that used in the DCFA fishing scenario are common in the commercial pelagic trawl fishing industry sectors" (Mr M. Exel, Austral Fisheries *in litt*. 3 July 2013). The panel noted that the nets used in the Dutch mid-water trawl freezer vessel fishery, have net openings of 30 to 60 m and horizontal spread of the wings from 80 to 120 m (Couperus *et al*. 2004) and that in the pelagic freezer trawler fishery off Mauritania net openings are around 90 m by 50 m (Zeeberg *et al*. 2006).

Factors such as the power of the vessel, and sounding and sonar equipment, enable modern vessels to be more effective at finding and catching fish. Greater power enables the vessels to tow and manoeuvre larger nets faster. For best performance, mid-water nets are designed to be towed at certain speeds: small pelagics can usually be caught by towing at 3–5 knots while larger pelagics require higher speeds. Auto-trawl systems are now regularly employed to maintain nets in optimal position to allow greater catching ability.

On-board factory/freezing facilities allow vessels to stay at sea for much longer but also allow a better quality product. There are several vessels of this type operating in Australian fisheries acting as carrier vessels supplying freezer capacity to smaller fishing vessels, as in the Northern Prawn Fishery, and freezer vessels using mid-water trawl gear also operate in the HIMI fisheries and in the winter fishery for blue grenadier in the SESSF.

The DCFA could carry sufficient fuel to enable it to stay at sea for extended periods of up to three to four months, but port visits to unload fish are likely to occur every six to eight weeks. Based on similar vessels, the panel has assumed that the factory processing plant could process 250 t of fish per day, thus limiting the optimal daily fish catch. The panel heard from experts that, historically, the average catch (shot) in the mid-water trawl fishery for redbait in the SPF was 60–100 t, and that with net monitors, fishers are able to end a tow when the net reaches optimum capacity (approximately 60–100 t) to enable and ensure efficient handling and processing. The panel heard that the proposed target optimum catch size for the *FV Abel Tasman* would have been similar to that used on the most recent mid-water trawl vessel to operate in the SPF (Mr G. Geen, Seafish Tasmania Pty Ltd, pers. comm. 23 April 2013).

When exploring the claim that a large mid-water trawl freezer vessel is more likely to cause localised depletion than a fleet of smaller vessels, the panel heard that: "Where the resources permit (abundance, aggregation and schooling density) larger trawl vessels can clearly catch more fish, more quickly than smaller trawlers. Linking this ability to make large catches to cause of local depletion is a big jump and it is not clear that a 'super trawler' is more likely to cause local depletion than a fleet of smaller vessels working the same school structure of fish. Such concerns may arise, and be more supportable, in areas where management is weak" (Mr D. Turner, Ministry for Primary Industries New Zealand *in litt* 25 June 2014). Also, the panel was informed that "larger vessels will have a higher catch rate threshold to remain profitable and thus they will have a greater incentive to move from an area beginning to suffer from depletion than smaller vessels that will remain profitable at lower catch rates" (Mr D. Turner, Ministry for Primary Industries New Zealand, *in litt.* 25 June 2014).

Panel assessment: potential for the DCFA to cause localised depletion that has adverse environmental impacts on CPF species

- *The overall catch of the DCFA is likely to be higher than that of the current vessels in the SPF fleet. It is possible therefore that the quantitative extent of localised depletion may be higher than for a single wet boat, but not necessarily for a fleet of wet boats.*
- *The DCFA is likely to be more efficient in its operations, and has greater ability to catch the quota available.*
- *Compared to smaller wet boats, the DCFA:*
    - *can range faster and farther afield in search of fish and for extended times*
    - *is more likely and is better able to leave an area when catch rates decline, thus reducing the potential for localised depletion arising from its operations to have adverse impacts on CPF species.*
- *The size of the net in the DCFA fishing scenario is similar in size to the net currently used in the Australian winter blue grenadier mid-water trawl fishery and smaller than some nets used in other Australian mid-water trawl fisheries and in international pelagic fishing fleets.*
- *The vessel used in the DCFA is larger in length and storage capacity than vessels already operating in Australian fisheries but its ability to locate and catch fish is not dependent on its size per se.*
- *The ability to 'stay on a school of fish' is largely dependent on the schooling behaviour of the fish and the DCFA has no advantage over smaller vessels in this regard. While the DCFA has greater capacity to resume targeting schools in an area, since it can stay in the area for longer than 'wet boats', it cannot be assumed that the DCFA would be fishing the same, reformed, school of fish on multiple occasions.*

- *Whether the localised depletion arising from the DCFA causes adverse environmental impacts on CPF species will depend on all of the factors discussed in Sections 6.8.2 and 6.8.3. The key distinguishing feature between the DCFA and current and historical fishing operations in the SPF is that it can stay at sea longer and fish more extensively.*
- *The DCFA has greater ability to range further than smaller vessels, and the potential to operate in close proximity to more colonies of CPFs and their foraging zones exists, but the spatial and temporal distribution of fishing effort cannot be predicted with any confidence.*
- *The DCFA, like any fishing operation in the SPF, has the potential to have adverse impacts on CPF species through localised depletion. While it is possible to identify the species most at risk (see Section 6.8.2), it is not possible to quantify the extent of any such impacts.*

6.8.4 Management of adverse environmental impacts of localised depletion

The management arrangements for the SPF include three main mechanisms that can contribute, directly or indirectly, to managing the risk of localised depletion in the fishery or responding to it if detected. In broad terms these relate to:

1. management settings, including the use of precautionary reference points in the harvest strategy
2. zoning of the stocks and quota statutory fishing rights (SFR)
3. prescribed responses to localised depletion.

The management measures proposed to apply to the DCFA, do not, in the panel's opinion, attempt to manage the risk of adverse environmental impacts of localised depletion arising from the DCFA. The DCFA would be subject only to those broad measures that apply to the fishery as a whole. These are discussed below.

Management settings

It is increasingly recognised that small pelagic species, including at least some of those fished in the SPF, need to be managed to more conservative biomass levels than that associated with maximum sustainable yield (B_{MSY}) (Pikitch *et al.* 2012, Smith *et al.* 2011). Pikitch *et al.* (2012) recommended that "in most ecosystems, fishing should be half the conventional rate (50 per cent of unfished biomass (B_0)) or less and leave at least twice as many forage fish in the ocean". For fisheries where little is known about the forage fish and their interactions with predators and the environment, Pikitch *et al.* (2012) recommended that at least 80 per cent of the estimated unfished forage biomass be maintained for those in the 'low information tier', 50 per cent in the 'intermediate' tier and 30 per cent in the 'high information tier'. The panel considered that the SPF fell in between the 'intermediate' and 'high' information tiers as defined by Pikitch *et al.* (2012). The current highest exploitation rate for the SPF ensures that 80 per cent of spawning biomass is maintained. This meets and exceeds the recommendation for the intermediate to high tiers.

The Commonwealth Harvest Strategy Policy (DAFF 2007) requires that all Commonwealth managed fisheries are managed to MEY, which is more conservative than MSY. The default Harvest Strategy Policy target is B_{48}; however, the SPF Harvest Strategy takes into account the ecological importance of these species and has a higher target reference point. Therefore, harvest rates are set at considerably lower levels than they would be if they targeted MEY (Smith 2011 cited in AFMA 2008).

The extent to which the current harvest strategy settings and exploitation rates account for potential trophic impacts of fishing these species is currently being investigated (FRDC project 2013/028). Preliminary results from that analysis suggest that the trophic impacts of fishing SPF stocks on predators and other parts of the food web are low and this suggests that "based on current evidence, biomass targets and corresponding exploitation levels in the SPF harvest strategy need not be adjusted specifically to account for trophic impacts of fishing" (Dr A. Smith, CSIRO *in litt.* 6 June 2014).

The SPF Harvest Strategy claims to be deliberately precautionary and to take account of the ecological importance of SPF species as key prey species. However, this relates to the broad 'ecological' importance of SPF target species in the ecosystem. It does not suggest that the Harvest Strategy is concerned with ensuring that a temporary depletion of a target SPF stock at a local level does not have an adverse effect on one or more CPF species at a particular point in time. For example, Pikitch *et al.* (2012) recommended that, regardless of the information level, managers should consider when and where to allow fishing, noting that "it may be appropriate to close forage fisheries during spawning season or around colonies of seabirds that rely heavily on forage fish". Smith *et al.* (2011) also noted that targeted spatial closures that reduce impacts on predators should "help inform harvest strategies that achieve ecological objectives". They also recommended that forage fish be managed "with predators in mind" and that a "dependent predator performance criterion" be adopted that specifies a management objective of "ensuring that there is a greater than 95% chance that predators do not become vulnerable to extinction, as determined by international criteria".

Zoning

In 2007, the Small Pelagic Fishery Management Advisory Committee (SPFMAC) recommended that the fishery be managed as having stocks east and west of 146°30'E based on Bulman *et al.* (2008). In doing so, the committee noted that:

- the evidence for a stock delineation for redbait at that point is not as strong as that for the other key species, but that industry experience supports a separation
- while there is some evidence that separate stocks occur in the far west of the fishery, there is no strong basis upon which to recommend a meaningful boundary to further split the Western Zone (SPFMAC 2007)
- the potential for separate stocks in the Western Zone related largely to blue mackerel (Bulman *et al.* 2008).

The target species have since been zoned into broad Eastern and Western stocks and quota SFRs allocated accordingly (see Chapter 3). This ensures that fishing effort is spread across the acknowledged stocks of these species.

More recently, Ovenden (unpublished) suggested that overlapping but genetically distinct populations of jack mackerel and sardines probably occur. Knowledge about genetically distinct spawner groups is essential for the sustainable management of the SPF fishery. However, the panel noted that there is some inertia to using genetics as a tool to identify stocks (Dichmont *et al.* 2012).

There is currently no additional information that might better inform a review of stock structure and potential sub-structuring of stocks, therefore, it is uncertain how to detect, manage or mitigate for adverse impacts of localised depletion within genetically distinct populations.

In relation to the potential contribution of the Eastern/Western Zones to the management of potential localised depletion impacts on CPF species, the panel noted that the zones are extensive geographically. For example, the Western Zone is a huge geographical area but under the current arrangements the whole of the Western Zone TAC for a target species could be taken in a relatively small area of that Zone and in an unrestricted time frame. While the South-east Commonwealth Marine Reserve Network and Great Australian Bight Marine Park (see Section 3.2.4) exclude mid-water trawling from some areas of the SPF, these exclusion areas do not address the needs of CPF species specifically.

Responses to localised depletion

Localised depletion remains undefined in the SPF Harvest Strategy. The need for a definition and for the management objectives around localised depletion to be clarified in the Harvest Strategy were identified by Knuckey *et al.* (2008). Small Pelagic Fishery Resource Assessment Group (SPFRAG) has developed a draft working definition (see Section 2.2.4). Nevertheless, the SPF Harvest Strategy provides that if, as a result of fishing, there is evidence of localised depletion or a concerning trend/change in age/size structure, SPFRAG must recommend one or more of the following:

- an appropriate reduction in the RBC and/or
- appropriate spatial or other management measures.

In addition, while the following provision of the SPF Harvest Strategy (AFMA 2008) is not linked directly to localised depletion, it could be invoked in response to a localised depletion event that resulted in a detectable change in ecosystem function:

"If, as a result of fishing in the SPF, there is evidence of changes in ecosystem function (e.g. reduced breeding success of seabirds), SPFRAG must recommend one or more of the following:

- an appropriate reduction in the RBC and/or
- appropriate spatial or other management measures and/or

- that a program be established to:

  i) assess the potential impacts of the fishery on the ecosystem

  ii) investigate potential ecological performance indicators for the fishery

  iii) report management performance against those indicators."

In addition to the responses included in the SPF Harvest Strategy, AFMA has powers under the *Fisheries Management Act 1991* to issue a 'direction' in response to the need for immediate action in any fishery. The panel noted that any adverse environmental impacts on CPF species are unlikely to be detected until well after the fishing event, thus mechanisms that provide for immediate action are less relevant in this instance.

Panel assessment: proposed measures to manage the risks to CPF species arising from localised depletion caused by the DCFA

- *The overall level of exploitation permitted in the SPF appears to be consistent with the best available advice on management of small pelagic species.*
- *At a fishery wide and zone level, the exploitation rates applied in the SPF Harvest Strategy may adequately account for tropic impacts.*
- *The precaution that is inherent in the SPF Harvest Strategy settings is unlikely to make a significant contribution to avoiding adverse environmental impacts of localised depletion on CPF species since the TACs set under the Harvest Strategy can be taken in any area of the East or West Zones.*
- *The provisions of the Harvest Strategy do not provide a mechanism to detect or manage the risk of localised depletion having adverse environmental impacts on CPF species. Rather, these provisions outline responses to localised depletion once it has been detected.*
- *There are no measures in place in the SPF or proposed for large-scale mid-water trawl operations, that would detect the spatial and temporal extent of localised depletion or adverse environmental effects that arise from it.*
- *There are no spatial and temporal closures in place, or proposed, for large-scale mid-water trawl operations that address potential trophic impacts to CPF species in the SPF.*
- *The measures proposed to apply to the DCFA did not include any that would be effective in minimising the risk of adverse environmental impacts on CPF species that might arise from localised depletion caused by the DCFA.*

6.8.5 Actions that could be taken to manage localised depletion in the SPF

It is not possible to accurately predict the extent of any adverse environmental impacts on CPF species arising from localised depletion under a DCFA. However, it is possible to identify species, times and areas that, subject to the spatial and temporal extent of such depletion, may be most susceptible to it. This allows for management of the risks of such impacts occurring.

As detailed in Section 6.7, there are very few examples where impacts of fishing on CPF predators have been shown to be directly caused by localised depletion. Due to the large uncertainty in the impacts of fishing on the marine ecosystem and CPF predators, and the challenges in attributing cause and effect, in most instances where there are concerns over the potential adverse impacts of fishing on CPF species, some form of precautionary management has been considered.

There are three main precautionary management approaches that could be implemented in order to mitigate the potential adverse impacts of localised depletion caused by the DCFA on CPF predators. These are discussed below.

Spatial allocation of TAC

The use of spatially allocated TACs would require the SPF fishery to be managed in smaller spatial management units within which the consumption needs of predators of SPF species (including CPF) would be assessed and taken into account. Area-specific TACs would be set for each management unit. However, unless the management units are relatively small in scale, spatial allocation may not prevent most of the allocated catch within a management unit being taken in a small geographic space over a short time period, and as a result this may be a less effective management tool to mitigate the potential impacts of localised depletion on CPF predators.

Move-on rules

Move-on rules could be applied to critical foraging zones of CPF predators and/or at critical times, for example during breeding season, chick or pup rearing periods, to manage the potential adverse impacts from localised depletion by the DCFA on CPFs. These rules are a form of spatial closure that is enforced after a certain level of catch has been taken within a sensitive CPF area and at sensitive times.

The panel understands that, after consideration of various options to address the risk of 'localised depletion' SPFRAG is focusing its effort on the use of move-on rules (SPFRAG 2014a). The panel noted that SPFRAG has previously discussed how the fishing activity of the proposed large mid-water trawl freezer vessel might be monitored in space and time, particularly in the context of the data confidentiality rules that apply to commercial fishing data, including 'the five boat rule' (AFMA 2014e). The panel agrees that, should a move-on rule be adopted for the purposes of spreading catch (as distinct from avoiding interactions with protected species), then there would need to be greater transparency about the spatial distribution of catch and effort.

In the panel's view there is less information available to inform the setting of a meaningful level of catch over space and time required by a move-on rule than is the case for broader, spatial/temporal closures.

Spatial closures

Spatial closures are used to prevent any fishery catch taking place in critical foraging areas, typically adjacent to CPF species' breeding colonies. Closures may be temporary, to protect CPF predators at critical time periods, such as during the breeding season; or permanent, where animals may reside at colonies or haulouts year round, and where offspring may be provisioned over longer time periods (e.g. seals with long lactation periods). Typically, the extent of the spatial closure(s) would be determined by an understanding of where the key foraging areas are, or on limitations in the foraging ranges or spatial at-sea distribution, and would potentially vary among species and populations in their scale, timing and duration. The panel noted that the use of spatial/temporal closures has been discussed by SPFRAG (2014a) and that there was some support in the group for such an approach if sufficient information is available to establish meaningful closures.

Globally, spatial closures are the most common form of precautionary management of the potential adverse impacts of localised depletion on CPF predators. Examples of these are detailed in section 6.7.2. Critically, for none of these examples has the effectiveness of spatial closures in preventing adverse environmental impacts to CPF predators been clearly demonstrated.

A key challenge for the introduction of spatial management into the SPF for the purposes of managing the potential adverse impacts of localised depletion on CPF predators, would be to determine the scale of spatial closures that would be appropriately precautionary for particular species at particular locations and at particular times. For some areas of the SPF, such as the waters off SA and to a lesser extent Bass Strait, there are reasonable datasets on species distributions, some data on relative abundances, diet and foraging behaviour (Goldsworthy *et al.* 2011, Patterson *et al.* unpublished). In these regions, use of the available movement, foraging and diet data for some CPF species may be sufficient to design and evaluate suitable spatial management strategies to manage the potential adverse risks to CPF populations from localised depletion. However, elsewhere throughout the SPF, CPF populations are generally poorly monitored and there is limited information on species' diet, abundance and at-sea distributions. There may be challenges in extrapolating the at-sea distribution models developed for those regions where there are sufficient data, to those where there are not (Patterson *et al.* unpublished). However, precautionary spatial closures could be implemented based on the best available data until more relevant data can be obtained.

The panel concluded that should a significant increase in the level of fishing effort in the SPF be envisaged, through the operation of a DCFA, consideration should be given to finer scale management of catch in order to minimise risks associated with adverse environmental impacts of localised depletion on CPF species. As discussed in Section 6.6.5, the identification of smaller-scale management units for which TACs take into account the consumption needs of CPF species may be an option, however, unless these are quite small in scale they may not prevent concentration of the catch in space and time in areas of key ecological importance. The panel considered that spatial/temporal closures to fishing that specifically address the needs of the identified CPF species were the most appropriate way to manage the risks to these species associated with localised depletion arising from the DCFA. The panel acknowledged that the effectiveness of such closures, for this purpose, has not been clearly demonstrated.

In the longer term, the adoption of finer scale management of stock, i.e. subdivision of the current Eastern and/or Western Zones by species, may also have a role to play in minimising the risk of localised depletion occurring. The panel noted that there is currently no basis on which to make an informed decision on such subdivision. Finer scale management that potentially better reflects population structure will provide additional protection for target stocks and of the role of those stocks in the overall ecosystem. In the panel's view, it will not necessarily preclude adverse environmental impacts on protected species of CPF species. This is because such an approach may not provide the level of protection required by these species, either spatially or temporally.

Panel advice: actions that could be taken to manage the risks to CPF species arising from localised depletion caused by the DCFA

- *There are three main precautionary management approaches that could be implemented to mitigate the potential adverse impacts of localised depletion caused by fishing on CPF predators: spatial allocation of catch, move-on rules, and spatial closures.*
- *Spatial closures are the most common form of precautionary management used to mitigate the potential adverse impacts of localised depletion on CPF predators; however, the effectiveness of spatial closures for this purpose has not been clearly demonstrated. Their effectiveness depends heavily on the ability to determine the scale of spatial closures that would be appropriately precautionary for particular species at particular locations and at particular times.*
- *The panel considered that the risks to protected species of CPFs from localised depletion caused by the DCFA should be managed through the adoption of a proactive approach that separates the fishing activity from the key foraging areas and times used by CPF species rather than through move-on rules. This does not discount the potential value of move-on rules in the context of direct interactions with protected species.*
- *While determining the appropriate scale of the required closures in particular times and areas will remain a challenge, there are reasonable datasets available in at least some areas of the SPF that could inform these decisions. It may be necessary to extrapolate from this information in order to define appropriate spatial closures elsewhere in the SPF.*
- *It is likely that these spatial closures will need to be modified adaptively to reflect additional information as it becomes available, either through fishing or targeted research.*
- *Global studies on CPF predators demonstrate that they are responsive to changes in the availability of prey within their foraging range, but they do not distinguish between changes caused by localised and overall stock depletion. Careful consideration of how management of the entire stock, and especially the reduction in available biomass through fishing, impacts on CPF predators at a local scale and at critical times, is required.*

6.9 Monitoring and research

The panel found no conclusive evidence of historical localised depletion that caused adverse environmental impacts in the SPF. The high level of dependence by some predators, particularly CPF species, highlights the need to manage for the risk of such impacts. It also points to the potential to use populations of these species to monitor the health of the SPF resources.

Many of the uncertainties that have been identified in relation to the panel's ability to assess the extent of local depletion likely under a DCFA cannot be addressed through monitoring and research. Some uncertainties reflect the dynamic nature of the marine environment and consequently, responses of small pelagic species. Some reflect the dynamics of fishing operations and economics. Thus many of the uncertainties will remain and management must, therefore, be precautionary and adaptive.

6.9.1 Target species

The panel considered that it is reasonable to expect that a significant increase in catch of SPF target species is only likely to occur under a fleet configuration that involves a capacity to stay at sea longer and to fish the area of the SPF more broadly. That configuration may or may not approximate the specific type of activity specified in the DCFA, but, in any case, this would allow more catch to be taken, within the constraints of the TACs. In order to minimise the risk that fishing is concentrated on sub-populations of redbait, blue mackerel and jack mackerel, further investigation into the population structure of these species may be warranted. In particular, given that more fishing is likely to occur in the Western Zone of the SPF under a DCFA than under the current fleet configuration, further investigation of the possibility of separate stocks of blue mackerel in the Western Zone may be warranted.

Ovenden (unpublished) identified several projects that could improve the understanding of stock structure in the SPF species and hence allow better and more appropriate spatial management for all stocks. More robust spatial management of the stocks should reduce the likelihood and risks associated with localised depletion of those species. The projects identified ranged between a very cost-effective re-analysis of existing jack mackerel and sardine data, if available, using the latest statistical methods, to more targeted studies, at increasing costs, on all SPF species, including blue mackerel, yellowtail scad *Trachurus novaezelandiae* and redbait for which there is very poor information. Some of the latter studies could easily be added into the fishery-independent surveys currently being conducted or planned in the SPF. Ovenden (unpublished) also advocated that a combination of genetics and single-generation markers such as otolith chemistry, parasite, abundance, tagging and tracking, is needed to define stocks and better understand 'crinkles in connectivity between populations' but the panel noted that the SPF has limited resources to support such a range of research programs. The panel supports further well-designed and targeted research in this area to clarify the extent of sub-structuring within the Eastern and Western Zones specifically, and the SPF more broadly.

The panel considered that ongoing monitoring of the length frequency of catch taken by the DCFA will be important for monitoring both overall stock health and detecting any localised effects on target stocks. Given that catch will be frozen onboard the vessel, management measures will need to ensure that arrangements are made for observers to collect this information.

6.9.2 CPF species

The panel has determined that there are widespread and large uncertainties in the population status and abundance of CPF predators, the spatial distribution of foraging effort, and the diet of most species. To address these uncertainties and inform about potential impacts of reduction in prey due to SPF depletion within CPF key foraging areas, the panel highlights the following four key research and monitoring needs.

1. Dietary studies to determine which key CPF predators or other commercially or ecologically important predators are most reliant on SPF species

In general, information on the importance of SPF species and other commercially targeted species in the diets of CPF predators is patchy, leading to large uncertainties due to the lack of representativeness in locations and years. For some species the basic information is absent. As a consequence, there may be other species for which there are limited data that may well be susceptible to impacts associated with the SPF.

2. Studies to better understand the critical foraging areas, habitats and times for key CPF species

There are major gaps in information on the distribution of key foraging areas for CPF species throughout the SPF area. Critical gaps include comprehensive and representative data on the foraging distributions and ranges at critical life-history stages for seabirds, during incubation and chick rearing to fledging; and for seals, the key foraging areas of adult females throughout lactation. In managing for the potential adverse impacts of localised or stock depletion on dependent CPF predators, such information is necessary to determine the scale of spatial closures that would be appropriately precautionary for particular species at particular locations and at particular times. This does not preclude the introduction of interim precautionary closures based on available information.

3. Biological response of key CPF predators to changes in prey availability

There are a number of global studies that provide an important foundation to our understanding of how CPF species respond to variation in prey availability over short and long time scales (see Boyd *et al*. 2006 and chapters therein). Unfortunately, there are few such studies in Australia that can be drawn upon to provide any insight into the likely nature and consequence of indirect fishing impacts on protected CPF species. Long-term monitoring of key CPF species' populations in the SPF area could provide important information on assessing the indirect effect of fishing. Such studies could monitor foraging efficiency, provisioning rates and offspring growth rates and fledging/weaning mass, survival and adult breeding success. Monitoring of annual production and/or population size would also provide very relevant time series and key performance indicators of CPF predator health, and also an indirect measure of the degree to which potential indirect effects of fishing are being managed/mitigated.

4. Establishment of ecological performance indicators

The panel noted the provision in the SPF Harvest Strategy for the establishment of a program to assess the potential impacts of the fishery on the ecosystem, investigate potential EPIs for the fishery and report management performance against those indicators if there is evidence of changes in ecosystem function (e.g. reduced breeding success of seabirds). The panel considered that there would be merit in establishing such a program in a proactive way, i.e. to detect such events, rather than as a response mechanism.

Panel advice: research and monitoring to reduce uncertainty associated with the risk of localised depletion

- *Well-designed and targeted research to clarify the extent of sub-structuring of SPF target species within the Eastern and Western Zones specifically, and the SPF more broadly.*
- *Dietary studies to determine which key CPF predators or other commercially or ecologically important predators are most reliant on SPF species.*
- *Studies to better understand the critical foraging areas, habitats and times for key CPF species.*
- *Examination of the biological response of CPF predators to changes in prey availability.*
- *Ongoing monitoring of the length frequency of catch taken by any DCFA at a statistically appropriate sampling intensity.*
- *Development and implementation of potential ecological performance indicators for the fishery.*

7 Assessment of the Declared Commercial Fishing Activity

7.1 Introduction

The panel's Terms of Reference required it to assess and advise on the Declared Commercial Fishing Activity (DCFA), particularly the potential for the activity to result in adverse environmental impacts. The assessment related to:

- the likely nature and extent of direct interactions of the DCFA with species protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), particularly seals and dolphins
- the potential for any localised depletion of Small Pelagic Fishery (SPF) target species, arising from the DCFA to result in adverse impacts to the Commonwealth marine environment, including the target species' predators protected under the EPBC Act.

Based on its assessment of those issues, and consideration of the proposed management of the DCFA, the panel has provided advice on actions that could be taken to avoid, reduce and mitigate adverse environmental impacts of the DCFA and on scientific research and monitoring that could reduce uncertainties about those impacts.

A synthesis of the panel's assessment, guidance on interpretation of the outcomes of the assessment and the panel's advice, and concluding comments are provided below.

7.2 Assessment and advice on direct interactions with protected species

The DCFA is defined in terms of the fishery in which it operates, the type of fishing gear used, the length of the vessel and its storage capacity. The fishing scenario developed by the panel assumed that the freezer capacity of the DCFA would enable it to stay at sea for longer periods (up to six to eight weeks before needing to unload product) and to fish more extensively in the SPF area than has been the case in the past.

To date, mid-water trawling in the fishery has been concentrated around Tasmania. The DCFA would most likely focus its fishing effort on the shelf and slope areas of the SPF, where the target species are predominantly distributed, but would likely fish these areas more extensively and might fish in slightly deeper water off the shelf, than previous fishing operations in the SPF. Historical fishing patterns and interaction data do not, therefore, necessarily provide a good guide to the likely fishing patterns or protected species interactions of a DCFA. Further, it is not possible to predict with certainty the species composition, the spatial/temporal pattern of fishing or the intensity of fishing by the DCFA, because the fishing plan will be dictated by the prevailing environmental and economic conditions.

The panel concluded that if the DCFA operated in areas or at times of the year that have not been fished previously by mid-water trawl vessels, it is reasonable to expect that rates of interaction, the species involved and the risk profile of those species may differ from those of the past; this results in considerable uncertainty about the likely extent of direct interactions by the DCFA with protected species.

Nevertheless, the panel concluded that it is inevitable that the DCFA will interact with species protected under the EPBC Act. These species potentially include pinnipeds (referred to here as seals), cetaceans, dugong (possible but unlikely), seabirds, turtles, seasnakes, sharks and rays, syngnathids and other teleost fishes. The panel assessed each of these groups and focussed its assessment on pinnipeds, cetaceans and seabirds. The rationale for this decision is provided in Chapter 5 and Appendix 3.

There is considerable uncertainty about the level of direct interactions resulting in injury or mortality of protected species that could occur without causing an adverse environmental impact. This level would vary within and among the pinniped, cetacean and seabird groups assessed in accordance with their abundance, population trend and the resilience of the species. Some of the protected species at risk of interacting with the DCFA are listed as threatened and/or migratory species under the EPBC Act and are therefore matters of national environmental significance that are afforded a higher level of protection and require assessment of significant impacts against criteria. For example, of the pinniped species assessed, the threatened Australian sea lion, currently listed as Vulnerable under the EPBC Act, can sustain less mortality without risk of adverse environmental impacts than the more plentiful Australian and New Zealand fur seals where populations have undergone recent recovery. Similarly, while many protected seabird species occur within the area of the SPF, some of these are known to have depleted populations and are listed as threatened and/or migratory species.

For many protected species, such as most cetaceans in the SPF area, there is a lack of information about population size and trends, location of important habitats and other biological and ecological characteristics. In the absence of such information it is not possible to establish evidence-based benchmarks for direct interactions by the DCFA with protected species that would avoid adverse environmental impacts.

The panel noted the SPF and generally all fisheries are managed in similarly uncertain environments. In relation to the DCFA, the panel considered that there are actions that could be taken to avoid, reduce and mitigate the risks of adverse environmental impacts occurring and that research and monitoring could be undertaken to reduce the uncertainties.

The panel assessed the likely nature and extent of direct interactions of the DCFA with three species of pinnipeds and 21 species of cetaceans. A broader assessment of interactions with seabirds was conducted. A summary of the panel's assessment and advice on these three taxa is provided below.

7.2.1 Pinnipeds

Nature and extent of interactions

Australian fur seals *Arctocephalus pusillus doriferus,* New Zealand fur seals *A. forsteri* and Australian sea lions *Neophoca cinerea* are highly susceptible to interactions with trawl fisheries and occur throughout the entire area of the SPF. In southern Australia, pinniped interactions with fishing operations have occurred predominantly with demersal trawl 'wet boats' and freezer trawlers using mid-water trawl gear in the Southern and Eastern Scalefish and Shark Fishery (SESSF), and with mid-water trawlers in the SPF. Most mid-water and demersal trawl operations that have occurred in the SPF area have been in the south-east of Australia and most interactions in that area have been with Australian fur seals.

Seals will be attracted to any fishing activity that occurs within their foraging range and the nature of interactions with these activities are likely to include net feeding, entering the trawl net (during shooting/fishing/hauling), habituation to fishing activities and bycatch. The greater the level and frequency of fishing activity and the more predictable the presence and timing of fishing activity in areas where seals forage, the greater the number of seals likely to be attracted to, and interact with, fishing activity. If a pattern of fishing persists and provides nutritional benefits to seals, parts of the population can become habituated to fishing operations and interactions may increase over time.

While it is not possible to quantify the extent of direct interactions between seals and the DCFA, the panel considered that such interactions would occur and that some would result in mortalities. Given the broad distribution of fur seals within the SPF, the DCFA would inevitably have direct interactions with fur seals, some of which would be fatal. In areas of high fur seal abundance, interactions and mortalities are likely to be common even with current best practice mitigation devices and fishing behaviour. The Australian sea lion occurs in the area of the SPF in waters off South Australia and Western Australia. If the DCFA operated within those waters, direct interactions with and bycatch mortality of this species would be likely.

New Zealand fur seal and Australian sea lion populations off South and Western Australia have not been exposed to the same level of bycatch mortality from trawl fisheries experienced by Australian fur seals elsewhere in the SPF, so there is uncertainty about the impacts of bycatch on those populations. This is especially important for the threatened Australian sea lion.

Actions to avoid, reduce and mitigate adverse environmental impacts

The panel considered that the following actions could be used to manage the risk of adverse environmental impacts arising from direct interactions between the DCFA and pinniped species:

- use a seal excluder device (SED), only after its operation has been optimised for the vessel, fishery and bycatch species under a scientific permit, with the required level of performance of the SED developed in consultation with experts
  - for example, the panel noted that neither the soft mesh-grid, top-opening SED with hood, nor the auto trawl system proposed to be used by the *FV Abel Tasman* to mitigate pinniped bycatch has undergone trials in the SPF
- use underwater video to monitor SED efficacy and cryptic mortality
- reduce the daily and per shot trigger limits on fur seals from the proposed limit of up to 10 per day and replace the associated 50 nautical mile (nm) move-on rule with a requirement to move to an area where interactions with seals are less likely, based on available data on estimated at sea density distributions
- introduce a bycatch rate trigger limit for fur seals for the fishery or fishing areas, or a total mortality trigger for a fishing season and/or fishing areas
- ensure 100 per cent observer coverage of fishing operations and if daily or per shot trigger limits are used in conjunction with move-on rules or with a requirement to review mitigation measures, provide sufficient observer capacity to ensure that underwater video footage is monitored at the end of each shot to maximise response times to mortalities
- require 'stickers' to be removed from the net before shooting, noting that this was a requirement of the proposed seabird vessel management plan (VMP)
- prohibit the discard of any biological waste (excluding the release of any protected fauna) noting that this was a requirement of the proposed seabird VMP
- implement spatial closures that mitigate bycatch interactions with fur seals, especially in regions adjacent to breeding colonies where there is high transit and foraging activity by central-place foraging lactating adult females
- review the proposed Australian sea lion closure area off South Australia (out to 150 m depth) so as to provide consistency with management arrangements for the Gillnet Hook and Trap Fishery (out to 183 m depth)
- implement a similarly designed closure for the Australian sea lion colonies occurring within the SPF off Western Australia.

Research and monitoring to reduce uncertainties

The following research and monitoring could reduce uncertainties about the potential for adverse environmental impacts arising from direct interactions between the DCFA and protected pinniped species:

- determine the individual and cumulative fishery-related impacts on pinniped species
- establish what levels of fishery-related mortality the pinniped species can sustain
- identify regions of critical foraging habitat for the pinniped species where the management of direct interactions with the DCFA may be most needed
- investigate modifications to fishing gear and fishing behaviour that can reduce the potential for direct interactions by the DCFA with pinnipeds.

7.2.2 Cetaceans

Nature and extent of interactions

Nearly all cetaceans recorded to occur in Australian waters have ranges that overlap to some extent with the SPF area. The nature and likelihood of interactions between cetaceans and mid-water trawl fisheries varies substantially among these species. Bottlenose dolphins *Tursiops* spp. and short-beaked common dolphins *Delphinus delphis* are likely to be at higher risk of interaction based on reported interactions with trawls and bycatch mortality in Australia and internationally.

Direct interactions with fishing operations include net feeding, foraging behind trawlers, and feeding on discards and fish escaping from nets. Vessel collisions resulting in injury or death of whales and some other cetaceans are thought to be relatively common in Australian waters but are not well documented. Most severe or fatal injuries to whales from vessel strike are caused by collisions from vessels greater than 80 metres, and higher speed increases the risk of serious injury or death.

Fisheries bycatch mortality of the device is the major threat to many smaller cetacean species in Australian waters and internationally. Differences in the type of fishing operations also influence the risk of bycatch, with cetaceans more often caught in mid-water trawls than in bottom trawls, and in trawls of longer duration. The risk of bycatch increases where prey species are also targeted by fisheries and where fishing grounds overlap with important habitats used by cetaceans for aggregating, feeding, breeding and migratory routes. Acoustic disturbance can be important for cetaceans because they have a very highly developed acoustic sense and sounds are vitally important for their ecology and survival. Cetaceans that frequently interact with trawlers and other fisheries can become habituated, leading to increased risk of bycatch.

As noted above, the lack of information on the distribution and abundance, population trend, genetic structure, and location and timing of use of important habitats for most cetacean species, greatly increases the uncertainties about the likelihood of direct interactions occurring and whether such interactions would result in significant environmental impacts for these protected species.

It is highly likely that there will be some direct interactions between the DCFA and cetaceans. The DCFA would enable fishing to occur more extensively in the SPF area, which would increase the range of cetacean species likely to be encountered. The nature and extent of direct interactions by the DCFA with cetaceans is uncertain but some cetacean mortality is likely. The Panel concluded that species such as bottlenose dolphins and short-beaked common dolphins, that are known to prey on small pelagic fish, and interact extensively with trawl fisheries, are at increased risk of being taken as bycatch by the DCFA, whereas some larger whale species may be at higher risk from vessel strike or acoustic disturbance.

Actions to avoid, reduce and mitigate adverse environmental impacts

The panel considered that the following actions could be taken to manage the risk of adverse environmental impacts arising from direct interactions of the DCFA with cetaceans:

- use an excluder device only after its operation has been optimised for the vessel, fishery and for different dolphin species including both bottlenose and short-beaked common dolphins under a scientific permit with the required level of performance developed in consultation with experts, noting that excluder designs tested to date have not been consistently effective in reducing cetacean bycatch in trawls, and at present there is no solution to filter or deter cetaceans from entering the net opening
- use underwater video to monitor dolphin behaviour within the net and around the excluder device to determine the efficacy of the excluder device and levels of cryptic mortality
- introduce a bycatch rate trigger limit for dolphin species for the fishery or fishing areas, or a total mortality trigger for a fishing season and/or fishing areas on a precautionary rather than evidentiary basis
- replace the 50 nm move-on rule, in response to a single dolphin mortality, with a requirement to move to an area where interactions with cetaceans are less likely, based on available data on estimated at sea density distributions

- assess the efficacy of acoustic deterrent pingers (with using rigorous controlled trials under a scientific permit with the required level of performance developed in consultation with experts), and temporal and spatial closures, that have been shown elsewhere to have potential to reduce the risk of interactions for some cetacean species, including some dolphins
- prohibit the discard of any biological waste (excluding the release of any protected fauna) noting that this was a requirement of the proposed seabird VMP
- ensure 100 per cent observer coverage of fishing operations and, if trigger limits are used in conjunction with move-on rules or with a requirement to review mitigation measures, provide sufficient observer capacity to ensure that underwater video footage is monitored at the end of each shot to maximise response times to mortalities
- in addition to the above actions to mitigate impacts on dolphins, ensure that monitoring and agreed management responses are in place to allow a timely management response if other cetacean species interact with the DCFA.

Research and monitoring to reduce uncertainties

The following research and monitoring could reduce uncertainties about the potential for adverse environmental impacts arising from direct interactions between the DCFA and protected cetacean species:

- identify regions in the SPF area that are important habitats for cetaceans where the management of direct interactions with the DCFA may be most needed
- determine the level of mortality arising from interactions with the DCFA that could be sustained by cetacean populations in the SPF area
- investigate modifications to the proposed fishing gear and operations of the DCFA that could reduce the potential for, or the impacts of, interactions with cetaceans
- collect, analyse and publish observer data on all cetacean interactions.

7.2.3 Seabirds

Nature and extent of interactions

The panel concluded that the past rate of interactions of SPF mid-water trawl operations with seabirds was likely to have been low and this could be at least partly explained by the low level of discharge of biological material in the fishery. Nevertheless, interactions have occurred and the SPF is an area that is known to be important to many seabird species.

Direct interactions between trawl vessels and seabirds include collisions with net-monitoring cables, warp cables and paravanes, net entanglements and habituation to fishing operations. Each of these interactions could be expected to occur with the DCFA. However, given that the DCFA fishing scenario precludes the discard of any biological material, the panel expected that the likelihood of habituation and, as a result, other forms of direct interactions was likely to be lower than in many other trawl operations.

Since it was not possible to predict with any certainty the location, timing or intensity of fishing by the DCFA the panel could not quantify the likely extent of direct interactions with seabirds.

Actions to avoid, reduce and mitigate adverse environmental impacts

The panel considered that the following actions could be taken to manage the risk of adverse environmental impacts arising from direct interactions of the DCFA with seabirds:

- the requirements in the proposed seabird VMP regarding discharge of biological material, the removal of stickers and warp maintenance be consistent with or equivalent to the advice of the Agreement on the Conservation of Albatrosses and Petrels (ACAP)

- adopt the ACAP advice regarding net binding, bird scaring lines and the use of a snatch block noting that the use of bird scaring lines and net binding are part of the seabird VMP for Australia's winter blue grenadier fishery
- if bird bafflers and warp deflectors are to be used, develop and optimise the design under scientific permit and in consultation with experts, noting that seabird captures in the SESSF have been reduced by 75 per cent using 'pinkies'
- direct deck lighting inboard and keep to the minimum level necessary for the safety of the crew
- develop advice on the correct interpretation of 'interactions' with seabirds in consultation with the Department of the Environment to ensure that it is consistent with the intent of the memorandum of understanding between the Department and AFMA and ensure that DCFA operators and crew are familiar with this advice
- ensure that the seabird VMP for the DCFA meets the requirements of the National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011-2016
- if unacceptable levels of interactions with protected seabird species occur, suspend fishing immediately and adopt one of the following options:
  - time and area closures, noting that these will rely on knowledge of spatial and temporal uses of bird habitats that overlap with the fishery
  - trigger limits and move-on rules
- consistent with the measures suggested above for pinnipeds and cetaceans, ensure 100 per cent observer coverage of all fishing activity.

Research and monitoring to reduce uncertainties

The following research and monitoring could reduce uncertainties about the potential for adverse environmental impacts arising from direct interactions between the DCFA and protected seabird species:

- identify ecologically sensitive seabird species, areas and times where spatial management strategies may be appropriate to mitigate direct interactions if required
- collect, analyse and publish observer data on all seabird interactions, including on the levels and causes of seabird bycatch, focusing especially on recording of warp interactions and trawl entanglements
- use electronic monitoring via video camera/s to assist in quantifying warp strikes
- ensure crews are properly trained in the use of the required seabird mitigation and on reporting requirements.

7.3 Assessment and advice on localised depletion

The panel interpreted localised depletion as a spatial and temporal reduction in the abundance of a targeted fish species that results from fishing. As a result, localised depletion is an inevitable consequence of fishing by the DCFA and of any fishing activity. The central issue for the panel's assessment was, therefore, whether the fishing activity of the DCFA could be concentrated enough, both spatially and temporally, to cause a localised depletion of target species sufficient to cause adverse environmental impacts to the Commonwealth marine environment.

The panel found no conclusive evidence of historical localised depletion that caused adverse environmental impacts in the SPF. However, the high level of dependence by some predators, particularly central place foragers (CPFs), highlights the need to manage for the risk of such impacts.

The panel assessed the potential impact of localised depletion on the target species and on protected CPFs. A summary of those assessments is presented below.

7.3.1 SPF target species

The panel found that SPF target species have some inherent characteristics that make them potentially susceptible to localised depletion; they are susceptible to capture as a result of their aggregating or schooling behaviour and associations with oceanographic features such as eddies and temperature and chlorophyll fronts. However, the panel also noted that other characteristics, such as being proficient swimmers, having a schooling behaviour that is dynamic and difficult to predict, and being productive and fecund, are likely to reduce the temporal and spatial extent of any such depletion.

Impacts of localised depletion on target species could result in changes in reproductive capacity and genetic diversity. However the available genetic evidence for jack mackerel *Trachurus declivis* did not suggest that past apparently high levels of fishing had significantly affected their reproductive capacity. Similarly, there have been no significant changes in age or size composition of redbait *Emmelichthys nitidus* in recent years that might indicate a potential impact on reproductive capacity. There are too few data available for the Australian sardine *Sardinops sagax* in the Eastern Zone or blue mackerel *Scomber australasicus* to determine if there have been significant changes to age or size structure or reproductive capacity but the low levels of effort and catch suggest little likelihoodthat changes have occurred. Further, there is no evidence to suggest that localised depletion has caused any impacts on genetic diversity in the SPF stocks. Additional research into stock structure would be required in order to inform management of the potential risks of localised depletion at the subpopulation level and the appropriate spatial scale at which to manage effort and catch.

Given that the exploitation rates in the SPF are considered to be conservative against international benchmarks for small pelagic fisheries and that concerns about the basis for spawning stock biomass estimates and the SPF Harvest Strategy Policy are being addressed, the panel considered that any localised depletion of SPF target species that might arise from the DCFA was unlikely to affect the overall status of stocks of those species in the SPF.

Panel advice: research and monitoring

Research and monitoring in the following areas could reduce uncertainties associated with stock structure and hence with the adverse impacts of localised depletion arising from the DCFA on target species:

- well-designed and targeted research to clarify the extent of sub-structuring of SPF target species within the East and West Zones specifically, and the SPF more broadly
- ongoing monitoring of the length frequency of catch taken by the DCFA at a statistically appropriate sampling intensity

7.3.2 Central place foragers

The dependency on near-colony prey resources at certain locations and times increases the vulnerability of CPFs to localised depletion of prey. Although CPF species have been shown to be highly responsive to changes in prey availability within their key foraging areas, very few studies have linked reduced foraging and reproductive performance to the impacts of fishing, and even fewer to localised depletion.

The nature and extent of impact of localised depletion will depend on the spatial and temporal scale of the depletion. Short-term impacts may reduce foraging efficiency resulting in longer foraging trips and/or reduced rates of provisioning to offspring (chicks/pups). If these persist they can result in reduced offspring growth rates and fledging/weaning mass and reduced offspring survival and adult breeding success. Longer-term impacts, over years and decades, can affect major demographic factors such as survival, recruitment and reproductive rates that drive population age structure, growth rates and ultimately population size.

There are few examples where the potential impacts on CPF species of localised depletion caused by fishing are actively managed. Only the case study on Peruvian boobies found compelling evidence for localised depletion. In three other case studies in the North Sea, Benguela and Alaska where declines in population size and reproductive success in CPF predators have been identified, spatial closures have been introduced as a precautionary measure to mitigate potential adverse impacts of localised depletion even though the causes of the declines are uncertain.

CPF predators that forage in the SPF, and for which SPF target species comprise or have made a significant (greater than 10 per cent) contribution to the diet, are Australian fur seal, New Zealand fur seal, Australasian gannet *Morus serrator*, short-tailed shearwater *Ardenna tenuirostris*, little penguin *Eudyptula minor*, crested tern *Thalasseus bergii* and shy albatross *Thalassarche cauta*. Key foraging areas for these species within the SPF are Bass Strait, Tasmania and South Australia. However, there remains some uncertainty about the importance of SPF species to other CPF predators, because diet information is poor or unavailable.

Since the overall catch of the DCFA is likely to be higher than that of the current SPF fleet, it is possible that the extent of localised depletion might be greater than for a single wet boat but not necessarily greater than for a fleet of wet boats. The key distinguishing feature between the DCFA and current and historical fishing operations in the SPF is that it can stay at sea longer and so fish more broadly in the area of the SPF. While this may mean that the DCFA could stay in an area for a protracted time, the need to maintain an economically viable catch rate suggests that it is more likely to move on thereby reducing the potential for localised depletion arising from its operations to have adverse impacts on CPF species.

The panel concluded that the DCFA has the potential to have adverse impacts on CPF species through localised depletion. Whether that potential is realised depends on where, when and how intensively the DCFA fishes. In addition, the panel noted that there is very limited monitoring of CPF predator populations and the chance of detecting any indirect fishery-related impact on CPFs within the SPF area is extremely low.

Actions to avoid, reduce and mitigate adverse environmental impacts

Spatial closures are the most common form of precautionary management used to mitigate the potential adverse impacts of localised depletion on CPF predators; however, the effectiveness of spatial closures for this purpose has not been clearly demonstrated. Their value depends heavily on the ability to determine the scale of spatial closures that would be appropriate for particular species at particular locations and at particular times.

The panel concluded that the risks to the key CPF species identified above from localised depletion caused by the DCFA could be addressed proactively by separating the fishing activity from their critical foraging areas. Determining the appropriate temporal or spatial scale of the closures will be challenging but reasonable datasets exist for at least some CPF species in some areas of the SPF. It may be necessary to extrapolate from this information in order to define appropriate spatial closures elsewhere in the SPF. Closures would need to be modified adaptively to reflect new information from fishing or targeted research.

Panel advice: research and monitoring

Many of the uncertainties that were identified in relation to the panel's ability to assess the extent of localised depletion likely under a DCFA reflect the dynamics of fishing operations and the economics of fishing. These types of uncertainties cannot be reduced through monitoring and research. However, research and monitoring in the following areas could reduce the uncertainties associated with the adverse impacts of localised depletion arising from the DCFA on CPF species:

- dietary studies to determine which key CPF predators or other commercially or ecologically important predators are most reliant on SPF species
- studies to better understand the critical foraging areas, habitats and times for key CPF species
- examination of the biological response of CPF predators to changes in prey availability
- investigation of potential ecological performance indicators.

7.4 Interpretation and context

7.4.1 The ecosystem

The panel noted that the ecosystem modelling studies available indicate that the SPF target species are not as influential in the southern Australian ecosystem compared to small pelagic species in other more productive global upwelling systems that support much larger biomasses of similar species. In the panel's view it is important that its assessment of the DCFA is considered in this context.

The predator-prey interactions are generally well-known for many of the commercial or 'ecologically important' species in the SPF. The panel's assessment relied on the available information but it noted that some information is now quite dated.

7.4.2 Catch levels

The panel noted that exploitation levels in the SPF are determined under the SPF Harvest Strategy in accordance with the Commonwealth Harvest Strategy Policy and Guidelines. The Department of the Environment has assessed the SPF against the Guidelines for the Ecologically Sustainable Management of Fisheries and has not imposed any conditions relating to the total allowable catches (TACs). The Panel was aware, however, that some stakeholders have concerns about the application of the Harvest Strategy by AFMA, the accuracy and age of biomass assessments and consequently, the sustainability of the TACs for SPF target species. The panel considered that these concerns are being addressed through new daily egg production surveys for the target species that will provide new data on which to assess the status of the stocks, and through a review of the SPF Harvest Strategy.

The panel noted that the preliminary findings of the recent review of the SPF Harvest Strategy suggested that current exploitation rates in the SPF are unlikely to cause adverse environmental impacts to the broader ecosystem and that the 'ecological allocation' to predators and the broader ecosystem is adequate. The panel's assessment took this finding into account while acknowledging that this does not preclude the possibility of localised adverse environmental impacts on some protected species, particularly CPFs.

The panel assumed that, under the DCFA, total catch in the SPF would be higher than over the last decade, but noted that catches would be capped by the TAC for each species and the quota holding of the DCFA operator. After consideration of all the available information and with regard to international advice on appropriate management settings for small pelagic species, the Panel assumed, for the purposes of its assessment, that the TACs for SPF target species are sustainable and enforceable. In that context the panel considered that the impact on the status of target stocks by the DCFA would be no greater than if the same quantity of catch were taken by any other fishing operation. In the Panel's view the only source of uncertainty in regard to the impact of total catches by the DCFA, related to the potential for sub-structuring of target species within the Eastern and Western Zones of the fishery. If subpopulations of the target stocks exist, and catches from these subpopulations increased as a result of the DCFA, there remains the possibility that the TAC for a Zone could be taken from one of these subpopulations; this would potentially increase the risk of overfishing of that subpopulation.

7.4.3 The DCFA fishing scenario

The panel's assessment is based on a specific DCFA fishing scenario and some associated assumptions. Some of these had a significant bearing on the outcome of its assessment and any changes to the following would necessarily affect the validity of the panel's assessment and advice:

- the DCFA does not discard any biological material
- the activity does not receive product from other fishing vessels (i.e. there is no transshipment)
- catch is pumped from the codend to the vessel rather than the net being hauled onboard

- TACs for target species are set according to the requirements of the Commonwealth Harvest Strategy Policy, the SPF Harvest Strategy and the latest available information
- there is 100 per cent independent observer coverage of all shots and pumping operations
- there is only one DCFA active in the SPF.

7.4.4 Advice on operational and regulatory actions

The panel has provided advice on actions that could be taken by the operators of the DCFA or by regulatory authorities to avoid, reduce and mitigate adverse environmental impacts of the DCFA. In the panel's view the individual actions identified have the potential to contribute to management of the risks of adverse environmental impacts arising from the DCFA. The optimal combination of these actions would, in practice, need to be determined in relation to the specific characteristics of the proposed vessel, gear and fishing plan.

7.4.5 Research and monitoring

The panel identified research and monitoring that could be undertaken to reduce uncertainties about the impact of the DCFA. Some of the identified uncertainties relate equally to previous operations in the SPF and indeed to other fisheries. It is not the panel's intention to suggest that all the research and monitoring identified in this report is a pre-requisite to the operation of the DCFA. Fisheries management in Australia and globally is conducted in the context of uncertainty and it is how this uncertainty is managed that will determine whether unacceptable levels of adverse impacts arise from fishing. The level of precaution adopted should be positively correlated to the level of uncertainty. That precaution can be reduced as new information from research, monitoring and/or fishing operations becomes available and uncertainty is reduced. Fisheries management involves trade-offs between precaution and the time and cost involved in acquiring new information to reduce uncertainty. Consideration of research and monitoring associated with the DCFA is no different in this respect.

7.4.6 Cumulative impacts

In the panel's view it is important that its assessment of the DCFA be considered in relation to other fishing activity in the SPF area. Many of the potential impacts assessed in relation to the DCFA in this report might equally result from an expansion of fishing effort by any fishing method and in any fishery that operates in the same area as the SPF. For example, while the DCFA has the potential to have direct impacts on protected species, the risks of adverse environmental impacts arising from the DCFA need to be considered in the context of the cumulative effect on these species by all fisheries in the SPF area. Such consideration is not possible until information across the relevant fisheries is collated and a holistic estimate is made of the level of interactions with protected species in the area of the SPF.

7.5 Concluding comments

The panel has identified the likely nature of the interactions of the DCFA with protected species in the SPF. The form of direct interactions, and the species most likely to be affected by both direct interactions and localised depletion, have been identified and the panel has provided specific advice on measures that could be taken to avoid, reduce and mitigate these impacts. However, even if these measures were adopted the panel considers that direct interactions with protected species and localised depletion, as defined by the panel, will occur under the DCFA. The panel's assessment has confirmed that there are considerable uncertainties relating to the extent of the impacts that would arise from the DCFA and the level of impact that would cause adverse environmental outcomes.

The panel noted that similar uncertainties are confronted in many other fisheries in Australia and elsewhere. As is the case in those fisheries, a precautionary and adaptive, risk-based approach to management of the potential impacts of the DCFA would be required. Further, as noted above, it is important that the panel's assessment of the DCFA be considered in the context of the role that SPF target species play in the southern Australian ecosystem, the fisheries management regime for those species, and of the cumulative impacts of fishing in the area of the SPF on protected species.

Appendix 1 Terms of Reference for the Expert Panel on a Declared Commercial Fishing Activity

Background

On 19 November 2012, the Minister for Sustainability, Environment, Water, Population and Communities made the Final (Small Pelagic Fishery) Declaration 2012 (the Final Declaration), which came into force on 20 November 2012.

The Final Declaration provides that a commercial fishing activity which:

a. is in the area of the Small Pelagic Fishery;

b. uses the mid-water trawl method; and

c. uses a vessel which is greater than 130 metres in length, has an on-board fish processing facility and has storage capacity for fish or fish products in excess of 2000 tonnes

is a Declared Commercial Fishing Activity for the purposes of Part 15B of the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (the EPBC Act).

The Declared Commercial Fishing Activity is prohibited for up to two years while an expert panel conducts an assessment and reports to the Minister on the activity.

The Expert Panel is established under section 390SH of the EPBC Act, as are the terms of reference for its assessment.

Terms of Reference

The Expert Panel will assess the Declared Commercial Fishing Activity, particularly the potential for the activity to result in adverse environmental impacts.

The Expert Panel will assess and advise on:

1. the likely nature and extent of direct interactions of the Declared Commercial Fishing Activity with species protected under the EPBC Act, particularly seals and dolphins;
2. the potential for any localised depletion of target species (arising from the Declared Commercial Fishing Activity) to result in adverse impacts to the Commonwealth marine environment, including the target species' predators protected under the EPBC Act;
3. actions that could be taken by operators of the Declared Commercial Fishing Activity or relevant regulatory authorities to avoid, reduce and mitigate adverse environmental impacts of the activity;
4. monitoring or scientific research that would reduce any uncertainties about the potential for adverse environmental impacts resulting from the Declared Commercial Fishing Activity;
5. any other matters about the environmental impacts of the Declared Commercial Fishing Activity that the Expert Panel considers relevant to its assessment; and
6. other related matters that may be referred to it by the Minister.

Date for report

The Expert Panel must report to the Minister by 22 October 2014.

Manner of carrying out assessment

In carrying out its assessment, the Expert Panel will:

a. examine existing scientific literature, other relevant information and any ongoing research or monitoring projects relevant to the impacts of the Declared Commercial Fishing Activity;

b. consult with and seek submissions from experts in relevant scientific disciplines where the Expert Panel believes this is necessary to clarify areas of uncertainty about the environmental impacts of the Declared Commercial Fishing Activity;

c. consider the fisheries management arrangements under which the Declared Commercial Fishing Activity is proposed to operate and the extent to which those management arrangements address the relevant environmental impacts and uncertainties;

d. take account of the requirements of the EPBC Act as they relate to the operation and accreditation of Commonwealth fisheries;

e. commission, through the Department of Sustainability, Environment, Water, Population and Communities, new reviews, research projects, modelling or analyses which the Expert Panel believes are necessary to fill critical knowledge gaps and where the results of those projects and analyses will allow the Expert Panel to fulfil its terms of reference;

f. consult with relevant experts, including in the operations of the Declared Commercial Fishing Activity, on the nature and effectiveness of measures available to reduce direct interactions with EPBC Act protected species and the potential ecological effects of any localised depletion resulting from the Declared Commercial Fishing Activity; and

g. identify further necessary and practicable monitoring or research projects that would reduce critical uncertainties for decision making relevant to any future operations of the Declared Commercial Fishing Activity.

Appendix 2 Advice provided to the panel

The panel is very grateful to the many people that provided insights and inputs to inform the panel's assessment. Those people and the nature of their input to the panel's work are identified below. The panel also contacted a number of other national and international experts who, for various reasons, were unable to contribute to the panel's assessment.

Table A2.1 People who provided advice to the panel

NAME AND POSITION	EXPERTISE	NATURE OF CONSULTATION
Mr K. Antonysen, Recreational fisher	Recreational fishing	Submission to Interim Declaration Nomination of experts
Professor Gavin Begg, Research Chief, South Australian Research and Development Institute (SARDI) Aquatic Sciences	Fisheries science: relevant fisheries research	Written response to request for information
Mr Simon Boag and Mr Fritz Drenkhahn, South East Trawl Fishing Industry Association	Commercial fishing operations: trawl	Submission to Interim Declaration Nomination of experts Invited submission
Mr Jon Bryan, Conservation Member, Small Pelagic Fishery Resource Assessment Group (SPFRAG)	Conservation	Phone meeting
Mr Anthony Ciconte, Commercial fisher	Commercial fishing	Submission to Interim Declaration
Professor Doug Butterworth, Department of Maths and Applied Maths, University of Cape Town, South Africa	Fisheries science	Written response to request for information
Dr Ad Corten, Chief Scientist, Corten Marine Research, Netherlands	Fishing operations and bycatch	Written response to request for information
Dr Bram Couperus, Researcher, Institute of Marine Resources and Ecosystem Studies, University of Wageningen , Netherlands	Fishing operations and bycatch	Written response to request for information
Mr Martin Exel, General Manager, Environment and Policy, Austral Fisheries	Commercial fishing operations: mid-water trawl	Meeting
Dr James Findlay, Chief Executive Officer, Australian Fisheries Management Authority	Fisheries management	Meeting and written responses to requests for information and questions
Mr George Day, Senior Manager, Demersal and Midwater Fisheries, AFMA	Fisheries management	Meeting and written responses to requests for information and questions
Mr Peter Douglas. Douglas Fishing Super Fund	Commercial fishing operations	Submission to Interim Declaration

NAME AND POSITION	EXPERTISE	NATURE OF CONSULTATION
Dr Elizabeth Fulton, Principal Research Scientist and CEO's Science Leader Fellow, CSIRO Oceans and Atmosphere Flagship	Fisheries science: ecosystem modelling	Meeting
Mr Gerry Geen, Director, Seafish Tasmania Pty Ltd	Commercial fishing operations: mid-water trawl	Submission to Interim Declaration Meeting
Mr John Holdsworth, Blue Water Marine Research, New Zealand	Recreational fishing	Written response to request for information.
Dr Patrick Hone, Executive Director, Fisheries Research and Development corporation (FRDC)	Fisheries science: relevant fisheries research	Written and verbal response to request for information
Ms Rebecca Hubbard, on behalf of Stop the Super Trawler Alliance	Conservation	Submission to Interim Declaration Nomination of experts
Mr Darren Kindleysides, Director, Australian Marine Conservation Society (AMCS)	Conservation	Submission to Interim Declaration
Dr Jeremy Lyle, Senior Research Scientist, Institute of Marine and Antarctic Studies (IMAS), University of Tasmania	Fisheries science: marine mammal bycatch mitigation and SPF daily egg production method (DEPM) biomass assessment	Meeting
Dr Vincent Lyne, Research Scientist, CSIRO Marine and Atmospheric Research	Science: fisheries oceanography	Meeting
Professor Jessica Meeuwig, Director/ Research Professor, Centre for Marine Futures, University of Western Australia	Science: marine ecology	Submission to Interim Declaration Meeting
Ministry of Primary Industries, New Zealand	Fisheries management	Written response to request for information
Mr Andy Moore, Fisheries and Quantitative Sciences, Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)	Fisheries science	Meeting
Dr Francisco Neira, Marine Sciences Consulting	Fisheries science: DEPM biomass assessment	Meeting
Dr Jonathon Nevill	Environmental science: aquatic conservation policy	Submission to Interim Declaration Invited submission
Mr Mark Nikolai, Chief Executive Officer, Tasmanian Association for Recreational Fishing Inc. (TARFish)	Recreational fishing	Invited submission
Mr Andrew Penney, Domestic Fisheries and Marine Environment, ABARES	Fisheries science	Meeting

NAME AND POSITION	EXPERTISE	NATURE OF CONSULTATION
Mr Graham Pike, Recreational and Charter Fishing Member, SPFRAG	Recreational fishing	Submission to Interim Declaration Nomination of experts
Mr Joe Pirello, Managing Director, Seafish Tasmania Pty Ltd	Commercial fishing operations: mid-water trawl	Submission to Interim Declaration Meeting
Dr Éva Plagányi, Senior Research Scientist, CSIRO Marine and Atmospheric Research	Fisheries science: ecosystem modelling	Invited submission
Dr Cristian Canales Ramirez, Department of Resource Evaluation, Fisheries Development Institute, Chile	Fisheries science	Written response to request for information
Professor Keith Sainsbury, Professor, Marine System Management, IMAS, University of Tasmania	Fisheries science and management	Meeting
Mr Les Scott, Managing Director, Australian Longline Pty Ltd	Commercial fishing operations: mid-water trawl	Meeting
Mr Sean Sloane, Director, Fisheries and Aquaculture Policy, Primary Industries and Regions, South Australia (PIRSA)	Fisheries management	Meeting
Dr Tony Smith, Ecosystem Based Management Stream Leader, CSIRO Oceans and Atmosphere Flagship	Fisheries science and marine resource assessment and modelling	Meeting
Dr Ilona Stobutzki, Assistant Secretary, Fisheries and Quantitative Sciences, ABARES	Fisheries science	Meeting
Assoc. Professor Tim Ward, Principal Scientist, Finfish, SARDI Aquatic Sciences	Fisheries science: resource assessment	Meeting
Ms Marcia Valente, Director, Valente Holdings Pty Ltd	Commercial fishing	Submission to Interim Declaration
Mr Richard Wells, ResourceWise Ltd, New Zealand	Fisheries specialist	Phone meeting
Mr JaapJan Zeeberg, former researcher, Netherlands Institute for Fisheries Research	Fishing operations and bycatch	Phone meeting
Dr Ian Knuckey, Director Fishwell Consulting	Fishing operations	Response to request for advice

Table A2.2 Participants in consultation meetings

ORGANISATION	ATTENDANCE
Australian government agencies: phone conference 11 April 2014	
ABARES	Dr Ilona Stobutzki Mr Andrew Penney Mr Andy Moore
AFMA	Dr James Findlay Mr George Day
Department of Agriculture	Mr Gordon Neil Ms Terri McGrath
Department of the Prime Minister and Cabinet	Ms Hannah Keal
FRDC	Mr Crispian Ashby
Indigenous community: meeting 1, 2 May 2014, Hobart (teleconference)	
NSW Indigenous Fishing Consultative Committee	Assoc. Prof. Stephan Schnierer
Conservation groups meeting 1, 2 May 2014, Hobart	
Environment Tasmania	Ms Rebecca Hubbard
Tasmanian Conservation Trust	Mr Jon Bryan
Humane Society International	Mr Alistair Graham
Scientific community: meeting 1, 2 May 2014, Hobart	
CSIRO	Dr Neil Klaer (apology)
FRDC, Small Pelagics Research Co-ordination Program	Prof. Colin Buxton
Agreement on the Conservation of Albatrosses and Petrels	Mr Warren Papworth (apology)
Australian Marine Sciences Association	Dr Tim Lynch
University of Western Australia Oceans Institute	Dr Tim Langlois (by phone)
IMAS (meeting 3, 2 May 2014, Hobart)	Dr Caleb Gardner
Recreational fishing groups: meeting 2, 2 May 2014, Hobart	
Tuna Club of Tasmania	Mr John Edwards
Game Fish Tasmania Sports Fishing Club Inc.	Mr Neil Clark Mr Martin Haley
TARFish	Mr Mark Nikolai
Australian Recreational Fishing Foundation	Mr Allan Hansard (apology)
Recfishwest	Mr Leyland Campbell (apology)
Recreational Fishing Alliance of NSW	Mr Malcolm Poole (by phone)
Game Fishing Association Australia	Mr Brett Cleary
Australian National Sportfishing Association	Mr John Burgess
State government agencies: meeting 3, 2 May 2014, Hobart	
Department of Fisheries, Western Australia	Ms Heather Brayford (by phone)
Sea Fishing and Aquaculture, Tasmanian Department of Primary Industries, Water and Environment	Mr Rob Gott Ms Frances Seaborn
Resource and management advisory bodies: meeting 3, 2 May 2014, Hobart	

ORGANISATION	ATTENDANCE
South East Management Advisory Committee	Ms Debbie Wisby
Commercial fishing industry: meeting 3, 2 May 2014, Hobart	
Seafish Tasmania	Mr Gerry Geen
Commonwealth Fisheries Association	Mr Martin Exel Ms Renee Vajtauer (by phone)
Tasmanian Seafood Industry Council	Mr Neil Stump

Appendix 3 EPBC Act protected species in the SPF area

Protected species

Table A3.1 Protected species list

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
MARINE MAMMALS				
Pinnipeds				
Arctocephalus forsteri	New Zealand fur seal	Marine	Medium	Medium
Arctocephalus gazella	Antarctic fur seal	Marine	Not assessed	Not assessed
Arctocephalus pusillus	Australian fur seal, Cape fur seal	Marine	High	High
Arctocephalus tropicalis	Subantarctic fur seal	Vulnerable Marine	Medium	Medium
Hydrurga leptonyx	Leopard seal	Marine	High	Medium
Leptonychotes weddelli	Weddell seal	Marine	Not assessed	Not assessed
Lobodon carcinophagus	Crabeater seal	Marine	Not assessed	Not assessed
Mirounga leonina	Southern elephant seal	Vulnerable Marine	High	Medium
Neophoca cinerea	Australian sea lion	Vulnerable Marine	Medium	Medium
Ommatophoca rossii	Ross seal	Marine	Not assessed	Not assessed
Cetaceans: Baleen whales				
Balaenoptera acutorostrata	Common minke whale	Cetacean Migratory	Medium	Medium
Balaenoptera bonaerensis	Antarctic minke whale	Cetacean Migratory	Medium	Medium
Balaenoptera borealis	Sei whale	Vulnerable Cetacean Migratory	Medium	Medium
Balaenoptera edeni	Bryde's whale	Cetacean Migratory	Medium	Medium
Balaenoptera musculus	Blue whale	Endangered Cetacean Migratory	Medium	Medium

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Balaenoptera omurai	Omura's whale	Not listed (all cetaceans protected in the Australian Whale Sanctuary)	Not assessed	Not assessed
Balaenoptera physalus	Fin whale	Vulnerable Cetacean Migratory	Medium	Medium
Caperea marginata	Pygmy right whale	Cetacean Migratory	Medium	Medium
Eubalaena australis	Southern right whale	Endangered Cetacean Migratory	Medium	Medium
Megaptera novaeangliae	Humpback whale	Vulnerable Cetacean Migratory	Medium	Medium
Cetaceans: Toothed cetaceans				
Berardius arnuxii	Arnoux's beaked whale	Cetacean	Medium	Medium
Delphinus delphis	Common dolphin, short-beaked common dolphin	Cetacean	Medium	Medium
Feresa attenuata	Pygmy killer whale	Cetacean	High	Medium
Globicephala macrorhynchus	Short-finned pilot whale	Cetacean	High	Medium
Globicephala melas	Long-finned pilot whale	Cetacean	High	Medium
Grampus griseus	Risso's dolphin, grampus	Cetacean	High	High
Hyperoodon planifrons	Southern bottlenose whale	Cetacean	High	Medium
Kogia breviceps	Pygmy sperm whale	Cetacean	Medium	Medium
Kogia sima	Dwarf sperm whale	Cetacean	Medium	Medium
Lagenodelphis hosei	Fraser's dolphin, Sarawak dolphin	Cetacean Migratory	High	High
Lagenorhynchus cruciger	Hourglass dolphin	Cetacean	High	High
Lagenorhynchus obscurus	Dusky dolphin	Cetacean Migratory	Low	Low
Lissodelphis peronii	Southern right whale dolphin	Cetacean	High	High
Mesoplodon bowdoini	Andrew's beaked whale	Cetacean	High	Medium
Mesoplodon densirostris	Blainville's beaked whale, dense-beaked whale	Cetacean	High	Medium
Mesoplodon ginkgodens	Gingko-toothed beaked whale	Cetacean	High	Medium
Mesoplodon grayi	Gray's beaked whale	Cetacean	High	Medium
Mesoplodon hectori	Hector's beaked whale	Cetacean	High	Medium
Mesoplodon layardii	Strap-toothed beaked whale	Cetacean	High	Medium
Mesoplodon mirus	True's beaked whale	Cetacean	High	Medium

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Orcinus orca	Killer whale, orca	Cetacean Migratory	Medium	Medium
Peponocephala electra	Melon-headed whale	Cetacean	Medium	Medium
Phocoena dioptrica	Spectacled porpoise	Cetacean	Not assessed	Not assessed
Physeter macrocephalus	Sperm whale	Cetacean Migratory	Medium	Medium
Pseudorca crassidens	False killer whale	Cetacean	High	Medium
Sousa chinensis	Indo-Pacific humpback dolphin	Cetacean Migratory	Medium	Medium
Stenella attenuata	Spotted dolphin, pantropical spotted dolphin	Cetacean Migratory	Medium	Medium
Stenella coeruleoalba	Striped dolphin	Cetacean	High	High
Stenella longirostris	Long-snouted spinner dolphin	Cetacean Migratory	Medium	Medium
Steno bredanensis	Rough-toothed dolphin	Cetacean	Medium	Medium
Tasmacetus shepherdi	Shepherd's beaked whale	Cetacean	Medium	Medium
Tursiops aduncus	Indo-Pacific bottlenose dolphin	Cetacean Migratory	High	High
Tursiops truncatus	Common bottlenose dolphin	Cetacean	High	High
Ziphius cavirostris	Cuvier's beaked whale	Cetacean	High	Medium
Dugong				
Dugong dugon	Dugong	Marine Migratory	Medium	Medium
Seabirds (central place forager species bolded)				
Anous minutus	Black noddy	Marine	Low	Low
Anous stolidus	Common noddy	Marine	Low	Low
Anous tenuirostris melanops	Australian lesser noddy	Vulnerable Marine	Low	Low
Apus pacificus	Fork-tailed swift	Marine Migratory	Not assessed	Not assessed
Ardea alba/Ardea modesta/ Egretta alba	Great egret, white egret	Marine Migratory	Not assessed	Not assessed
Ardenna tenuirostris (listed Marine as *Puffinus tenuirostris*)	Short-tailed shearwater	Marine Migratory	Medium	Medium
Botaurus poiciloptilus	Australasian bittern	Endangered	Not assessed	Not assessed
Calonectris leucomelas (listed Migratory as *Puffinus leucomelas*)	Streaked shearwater	Marine Migratory	Medium	Medium
Catharacta skua	Great skua	Marine	Medium	Medium
Daption capense	Cape petrel	Marine	Medium	Medium

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Diomedea epomophora epomophora (listed Marine and Migratory as *D. epomophora* (sensu stricto))	Southern royal albatross	Vulnerable Marine Migratory	Medium	Medium
Diomedea exulans amsterdamensis	Amsterdam albatross	Endangered Marine Migratory	Medium	Medium
Diomedea exulans antipodensis	Antipodean albatross	Vulnerable Marine Migratory	Medium	Medium
Diomedea exulans exulans (listed Marine and Migratory as *D. dabbenena*)	Tristan albatross	Endangered Marine Migratory	Medium	Medium
Diomedea exulans (sensu lato)	Wandering albatross	Vulnerable Marine Migratory	Medium	Medium
Diomedea exulans gibsoni/D. gibsoni	Gibson's albatross	Vulnerable Marine Migratory	Medium	Medium
Diomedea sanfordi	Northern royal albatross	Endangered Marine Migratory	Medium	Medium
Eudyptula minor	Little penguin	Marine	Low	Low
Fregetta grallaria grallaria	White-bellied storm petrel (Tasman Sea, Australasian)	Marine	Medium	Medium
Fregetta tropica	Black-bellied storm petrel	Marine	Medium	Medium
Fulmarus glacialoides	Southern fulmar	Marine	Medium	Medium
Garrodia nereis	Grey-backed storm petrel	Marine	Medium	Medium
Haliaeetus leucogaster	White-bellied sea eagle	Marine Migratory	Not assessed	Not assessed
Halobaena caerulea	Blue petrel	Vulnerable Marine	Medium	Medium
Larus dominicanus	Kelp gull	Marine	Low	Low
Larus novaehollandiae	Silver gull	Marine	Low	Low
Larus pacificus	Pacific gull	Marine	Low	Low
Lugensa brevirostris	Kerguelen petrel	Marine	Medium	Medium
Macronectes giganteus	Southern giant petrel	Endangered Marine Migratory	Low	Low
Macronectes halli	Northern giant petrel	Vulnerable Marine Migratory	Low	Low
Morus capensis	Cape gannet	Marine	Low	Low
Morus serrator	Australasian gannet	Marine	Low	Low

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Neophema chrysogaster	Orange-bellied parrot	Critically endangered Marine	Not assessed	Not assessed
Oceanites oceanicus	Wilson's storm petrel	Marine	Low	Low
Pachyptila desolata	Antarctic prion	Marine	Not assessed	Not assessed
Pachyptila belcheri	Slender-billed prion	Marine	Not assessed	Not assessed
Pachyptila salvini	Salvin's prion	Marine	Not assessed	Not assessed
Pachyptila turtur	Fairy prion	Marine	Medium	Medium
Pachyptila vittata	Broad-billed prion	Marine	Not assessed	Not assessed
Pandion haliaetus	Osprey	Marine Migratory	Not assessed	Not assessed
Pelagodroma marina	White-faced storm petrel	Marine	Low	Low
Pelecanoides urinatrix	Common diving petrel	Marine	Low	Low
Phaethon rubricauda	Red-tailed tropicbird	Marine	Low	Low
Phalacrocorax fuscescens	Black-faced cormorant	Marine	Medium	Medium
Phoebetria fusca	Sooty albatross	Vulnerable Marine Migratory	Medium	Medium
Phoebetria palpebrata	Light-mantled sooty albatross	Marine Migratory	Medium	Medium
Procellaria aequinoctialis	White-chinned petrel	Marine Migratory	Medium	Medium
Procellaria cinerea	Grey petrel	Marine Migratory	Low	Low
Procellaria parkinsoni	Black petrel	Marine Migratory	Medium	Medium
Procellaria westlandica	Westland petrel	Marine Migratory	Medium	Medium
Procelsterna cerulea	Grey ternlet	Marine	Low	Low
Pseudobulweria rostrata	Tahiti petrel	Marine	Low	Low
Pterodroma cervicalis	White-necked petrel	Marine	Medium	Medium
Pterodroma lessoni	White-headed petrel	Marine	Low	Low
Pterodroma leucoptera leucoptera	Gould's petrel	Endangered Marine	Medium	Medium
Pterodroma macroptera	Great-winged petrel	Marine	Medium	Medium
Pterodroma mollis	Soft-plumaged petrel	Vulnerable Marine	Medium	Medium
Pterodroma neglecta neglecta	Kermadec petrel (western)	Vulnerable Marine	Low	Low
Pterodroma nigripennis	Black-winged petrel	Marine	Medium	Medium
Pterodroma solandri	Providence petrel	Marine	Medium	Medium

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Puffinus assimilis	Little shearwater	Marine	Medium	Medium
Puffinus bulleri	Buller's shearwater	Marine	Medium	Medium
Puffinus carneipes	Flesh-footed shearwater, fleshy-footed shearwater	Marine	Medium	Medium
Puffinus gavia	Fluttering shearwater	Marine	Low	Low
Puffinus griseus	Sooty shearwater	Marine	Low	Low
Puffinus huttoni	Hutton's shearwater	Marine	Low	Low
Puffinus pacificus	Wedge-tailed shearwater	Marine	Medium	Medium
Stercorarius antarcticus	Brown skua	Marine	Not assessed	Not assessed
Sterna albifrons	Little tern	Marine	Low	Low
Sterna anaethetus	Bridled tern	Marine	Low	Low
Sterna caspia	Caspian tern	Marine	Low	Low
Sterna dougallii	Roseate tern	Marine Migratory	Not assessed	Not assessed
Sterna fuscata	Sooty tern	Marine	Low	Low
Sterna hirundo	Common tern	Marine	Low	Low
Sterna paradisaea	Arctic tern	Marine	Low	Low
Sterna striata	White-fronted tern	Marine	Low	Low
Sterna sumatrana	Black-naped tern	Marine	Low	Low
Sternula nereis nereis	Australian fairy tern	Vulnerable	Not assessed	Not assessed
Sula dactylatra	Masked booby	Marine	Low	Low
Thalassarche bulleri platei	Buller's albatross, Pacific albatross	Vulnerable Marine Migratory	Medium	Medium
Thalassarche cauta cauta (listed Marine and Migratory as *T. cauta* (sensu stricto))	Shy albatross, Tasmanian shy albatross	Vulnerable Marine Migratory	High	Medium
Thalassarche chlororhynchos bassi/T. carteri	Indian yellow-nosed albatross, Atlantic yellow-nosed albatross	Vulnerable Marine Migratory	Medium	Medium
Thalassarche chrysostoma	Grey-headed albatross	Endangered Marine Migratory	Medium	Medium
Thalassarche eremita	Chatham albatross	Endangered Marine Migratory	High	Medium
Thalassarche melanophris	Black-browed albatross	Vulnerable Marine Migratory	High	Medium
Thalassarche melanophris impavida (listed Marine and Migratory as *T. impavida*)	Campbell albatross	Vulnerable Marine Migratory	Medium	Medium

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Thalassarche salvini	Salvin's albatross	Vulnerable Marine Migratory	Medium	Medium
Thalassarche steadi	White-capped albatross	Vulnerable Marine Migratory	Medium	Medium
Thalasseus bergii (listed Marine as *Sterna bergii*)	Crested tern	Marine	Low	Low
MARINE REPTILES				
Turtles				
Caretta caretta	Loggerhead turtle	Endangered Marine Migratory	Medium	Medium
Chelonia mydas	Green turtle	Vulnerable Marine Migratory	Medium	Medium
Dermochelys coriacea	Leatherback turtle	Endangered Marine Migratory	Medium	Medium
Eretmochelys imbricata	Hawksbill turtle	Vulnerable Marine Migratory	Medium	Medium
Lepidochelys olivacea	Olive ridley turtle, Pacific ridley turtle	Endangered Marine Migratory	Not assessed	Not assessed
Natator depressus	Flatback turtle	Vulnerable Marine Migratory	Not assessed	Not assessed
Seasnakes				
Acalytophis peroni	Horned seasnake	Marine	Medium	Medium
Aipysurus laevis	Olive seasnake	Marine	Not assessed	Not assessed
Aipysurus pooleorum	Shark Bay seasnake	Marine	Not assessed	Not assessed
Astrotia stokesii	Stokes' seasnake	Marine	Medium	Medium
Disteira kingii	Spectacled seasnake	Marine	Medium	Medium
Disteira major	Olive-headed seasnake	Marine	Not assessed	Not assessed
Hydrophis elegans	Elegant seasnake	Marine	Low	Low
Hydrophis ornatus/Chitulia ornata	Spotted seasnake, ornate reef seasnake	Marine	Medium	Medium
Pelamis platurus	Yellow-bellied seasnake	Marine	Medium	Medium

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
SHARKS AND RAYS				
Carcharias taurus (east coast population)	Grey nurse shark	Critically endangered	Medium	Medium
Carcharias taurus (west coast population)	Grey nurse shark	Vulnerable	Medium	Medium
Carcharodon carcharias	Great white shark	Vulnerable Migratory	Medium	Medium
Centrophorus harrissoni	Harrisson's dogfish, endeavour dogfish, dumb gulper shark, Harrisson's deepsea dogfish	Conservation dependent	Not assessed; not listed at the time of ERA	Not assessed
Centrophorus zeehaani	Southern dogfish, endeavour dogfish, little gulper shark	Conservation dependent	Not assessed, not listed at the time of ERA	Not assessed
Cetorhinus maximus	Basking shark	Migratory	Not assessed	Not assessed
Galeorhinus galeus	School shark, eastern school shark, snapper shark, tope, soupfin shark	Conservation dependent	Not assessed, not listed at the time of ERA	Not assessed
Isurus oxyrinchus	Shortfin mako, mako shark	Migratory	Not assessed, not listed at the time of ERA	Not assessed
Isurus paucus	Longfin mako	Migratory	Not assessed, not listed at the time of ERA	Not assessed
Lamna nasus	Porbeagle, mackerel shark	Vulnerable Migratory	Not assessed, not listed at the time of ERA	Not assessed
Manta birostris	Giant manta ray	Migratory	Not assessed: not listed the time of ERA	Not assessed
Pristis zijsron	Green sawfish, dindagubba, narrowsnout sawfish	Vulnerable	Not assessed, not listed at the time of ERA	Not assessed
Rhincodon typus	Whale shark	Vulnerable Migratory	Medium	Medium
TELEOST FISH				
Syngnathids				
Acentronura australe	Southern pygmy pipehorse	Marine	Low	Low
Acentronura tentaculata	Shortpouch pygmy pipehorse	Marine	Low	Low
Campichthys galei	Gale's pipefish	Marine	Low	Low
Campichthys tryoni	Tryon's pipefish	Marine	Low	Low
Choeroichthys suillus	Pig-snouted pipefish	Marine	Low	Low
Corythoichthys amplexus	Fijian banded pipefish, brown-banded pipefish	Marine	Low	Low
Corythoichthys ocellatus	Orange-spotted pipefish, ocellated pipefish	Marine	Low	Low
Cosmocampus howensis	Lord Howe pipefish	Marine	Low	Low

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Festucalex cinctus	Girdled pipefish	Marine	Low	Low
Filicampus tigris	Tiger pipefish		Low	Low
Halicampus boothae	Booth's pipefish	Marine	Low	Low
Halicampus brocki	Brock's pipefish	Marine	Low	Low
Halicampus grayi	Mud pipefish, Gray's pipefish	Marine	Low	Low
Heraldia nocturna	Upside-down pipefish, eastern upside-down pipefish	Marine	Low	Low
Hippichthys cyanospilos	Blue-speckled pipefish, blue-spotted pipefish	Marine	Low	Low
Hippichthys heptagonus	Madura pipefish, reticulated freshwater pipefish	Marine	Low	Low
Hippichthys penicillus	Beady pipefish, steep-nosed pipefish	Marine	low	Low
Hippocampus abdominalis	Big-belly seahorse, eastern potbelly seahorse, New Zealand potbelly seahorse	Marine	Low	Low
Hippocampus angustus	Western spiny seahorse, narrow-bellied seahorse	Marine	Low	Low
Hippocampus breviceps	Short-head seahorse, short-snouted seahorse	Marine	Low	Low
Hippocampus kelloggi	Kellogg's seahorse, great seahorse	Marine	Low	Low
Hippocampus kuda	Spotted seahorse, yellow seahorse	Marine	Low	Low
Hippocampus minotaur	Bullneck seahorse	Marine	Low	Low
Hippocampus planifrons	Flat-face seahorse	Marine	Low	Low
Hippocampus subelongatus	West Australian seahorse	Marine	Low	Low
Hippocampus whitei	White's seahorse, crowned seahorse, Sydney seahorse	Marine	Low	Low
Histiogamphelus briggsii	Crested pipefish, Briggs' crested pipefish, Briggs' pipefish	Marine	Low	Low
Histiogamphelus cristatus	Rhino pipefish, Macleay's crested pipefish, ring-back pipefish	Marine	Low	Low
Hypselognathus horridus	Shaggy pipefish, prickly pipefish	Marine	Low	Low
Hypselognathus rostratus	Knifesnout pipefish, knife-snouted pipefish	Marine	Low	Low
Kaupus costatus	Deepbody pipefish, deep-bodied pipefish	Marine	Low	Low
Kimblaeus bassensis	Trawl pipefish, Bass Strait pipefish	Marine	Low	Low
Leptoichthys fistularius	Brushtail pipefish	Marine	Low	Low
Lissocampus caudalis	Australian smooth pipefish, smooth pipefish	Marine	Low	Low
Lissocampus fatiloquus	Prophet's pipefish	Marine	Low	Low
Lissocampus runa	Javelin pipefish	Marine	Low	Low
Maroubra perserrata	Sawtooth pipefish	Marine	Low	Low
Micrognathus andersonii	Anderson's pipefish, shortnose pipefish	Marine	Low	Low

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Micrognathus brevirostris [A]	Thorntail pipefish, thorn-tailed pipefish	Marine	Not assessed	Not assessed
Microphis manadensis	Manado pipefish, Manado River pipefish	Marine	Low	Low
Mitotichthys meraculus	Western crested pipefish	Marine	Low	Low
Mitotichthys mollisoni	Mollison's pipefish	Marine	Low	Low
Mitotichthys semistriatus	Halfbanded pipefish	Marine	Low	Low
Mitotichthys tuckeri	Tucker's pipefish	Marine	Low	Low
Nannocampus subosseus	Bonyhead pipefish, bony-headed pipefish	Marine	Low	Low
Notiocampus ruber	Red pipefish	Marine	Low	Low
Phycodurus eques	Leafy seadragon	Marine	Low	Low
Phyllopteryx taeniolatus	Common seadragon, weedy seadragon	Marine	Low	Low
Pugnaso curtirostris	Pugnose pipefish, Pug-nosed pipefish	Marine	Low	Low
Solegnathus dunckeri	Duncker's pipehorse	Marine	Low	Low
Solegnathus hardwickii [B]	Pallid pipehorse, Hardwick's pipehorse	Marine	Not assessed	Not assessed
Solegnathus lettiensis	Gunther's pipehorse, Indonesian pipefish	Marine	Low	Low
Solegnathus robustus	Robust pipehorse, robust spiny pipehorse	Marine	Low	Low
Solegnathus spinosissimus	Spiny pipehorse, Australian spiny pipehorse	Marine	Low	Low
Solenostomus cyanopterus/ paegnius	Robust ghost pipefish, blue-finned ghost pipefish	Marine	Low	Low
Solenostomus paradoxus	Ornate ghost pipefish, harlequin ghost pipefish, ornate ghost pipefish	Marine	Low	Low
Stigmatopora argus	Spotted pipefish, gulf pipefish	Marine	Low	Low
Stigmatopora nigra	Widebody pipefish, wide-bodied pipefish, black pipefish	Marine	Low	Low
Stipecampus cristatus	Ringback pipefish, ring-backed pipefish	Marine	Low	Low
Syngnathoides biaculeatus	Double-end pipehorse, double-ended pipehorse, alligator pipefish	Marine	Low	Low
Trachyrhamphus bicoarctatus	Bentstick pipefish, bend stick pipefish, short-tailed pipefish	Marine	Low	Low
Urocampus carinirostris	Hairy pipefish	Marine	Low	Low
Vanacampus margaritifer	Mother-of-pearl pipefish	Marine	Low	Low
Vanacampus phillipi	Port Phillip pipefish	Marine	Low	Low

[A] The panel noted that this species is not valid in Australia. Now *M. pygmaeus*. (Codes for Australian Aquatic Biota (CAAB) Taxon code 37 282087).

[B] The panel noted that this species is not valid in Australia. Current valid species likely to be Solegnathus sp. 1. (CAAB Taxon code 37 282099).

GROUP/SCIENTIFIC NAME	COMMON NAME/S	EPBC ACT LISTING STATUS	LEVEL 2 PSA RISK (DALEY *ET AL.* 2007B)	LEVEL 2 PSA RESIDUAL RISK (AFMA 2010B)
Vanacampus poecilolaemus	Longsnout pipefish, Australian long-snout pipefish, long-snouted pipefish	Marine	Low	Low
Vanacampus vercoi	Verco's pipefish	Marine	Low	Low
Other teleost fish				
Hoplostethus atlanticus	Orange roughy	Conservation dependent	Not assessed, not listed at the time of ERA	Not assessed
Rexea solandri	Gemfish	Conservation dependent	Not assessed, not listed at the time of ERA	Not assessed
Thunnus maccoyii	Southern bluefin tuna	Conservation dependent	Not assessed, not listed at the time of ERA	Not assessed

Rationale for not assessing direct interactions of the DCFA with species groups

Dugong *Dugong dugon*

The panel did not assess the possible impact of direct interactions on dugong specifically, due to the very marginal overlap of the species' distribution with the area of the Small Pelagic Fishery (SPF) and noting that no interactions with dugong in the mid-water trawl sector of the SPF had been recorded in the period 2002–2011 (Tuck *et al.* 2013). The distribution of dugong overlaid with trawl effort in the SPF (2000–2013) is mapped in Figure A3.1.

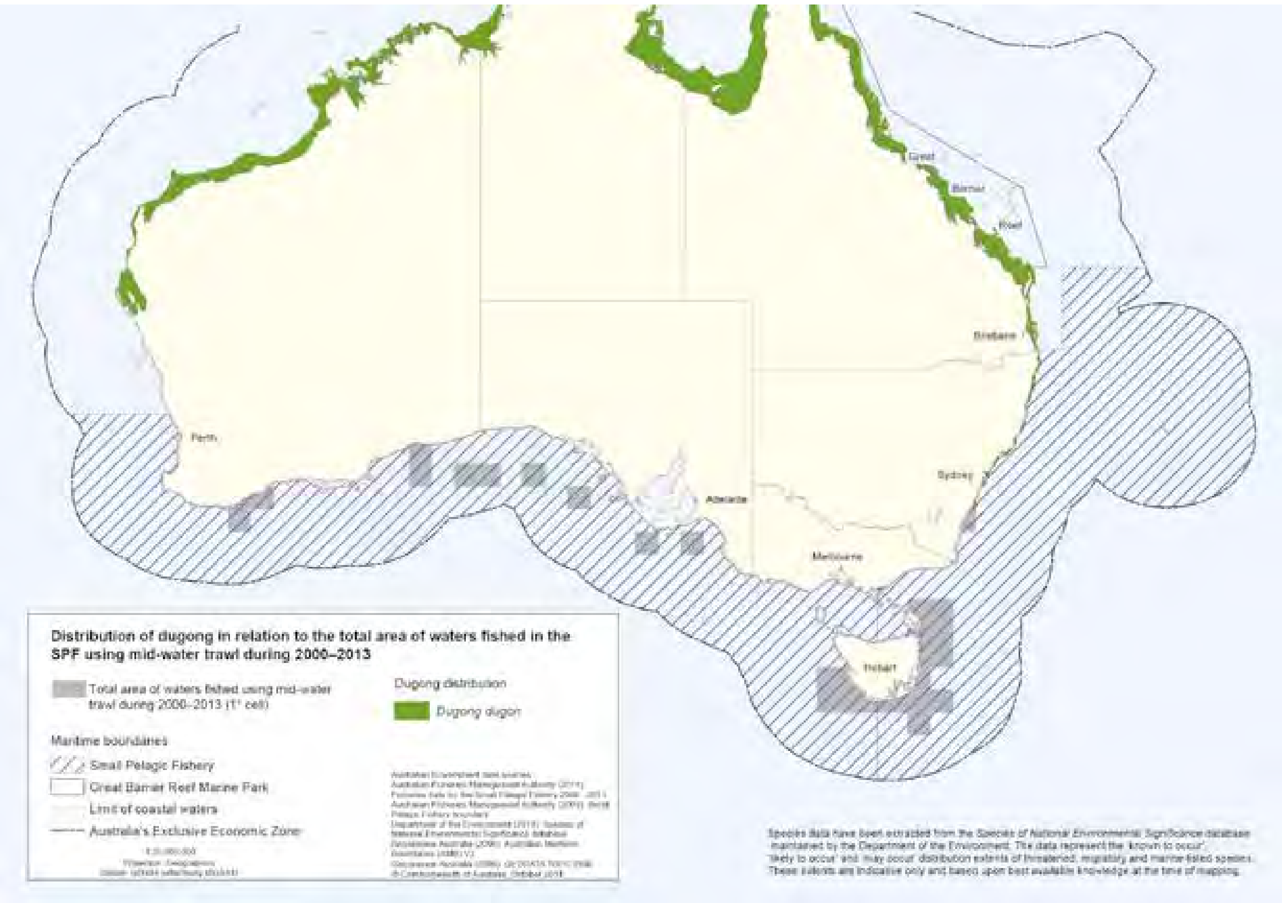


Figure A3.1 Distribution of dugong in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by the Environmental Resources Information Network (ERIN), Department of the Environment using unpublished AFMA data.

Turtles

Elgin Associates (unpublished (a)) found that the likelihood of interaction of mid-water trawl gear with turtles in the SPF was low to moderate. The panel noted that that no interactions with turtles in the mid-water trawl sector of the SPF had been recorded in the period 2002–2011 (Tuck *et al*. 2013). As a result, the panel did not assess the possible impact of direct interactions on turtles specifically. The distribution of protected species of turtles overlaid with trawl effort in the SPF (2000–2013) is mapped in Figure A3.2.

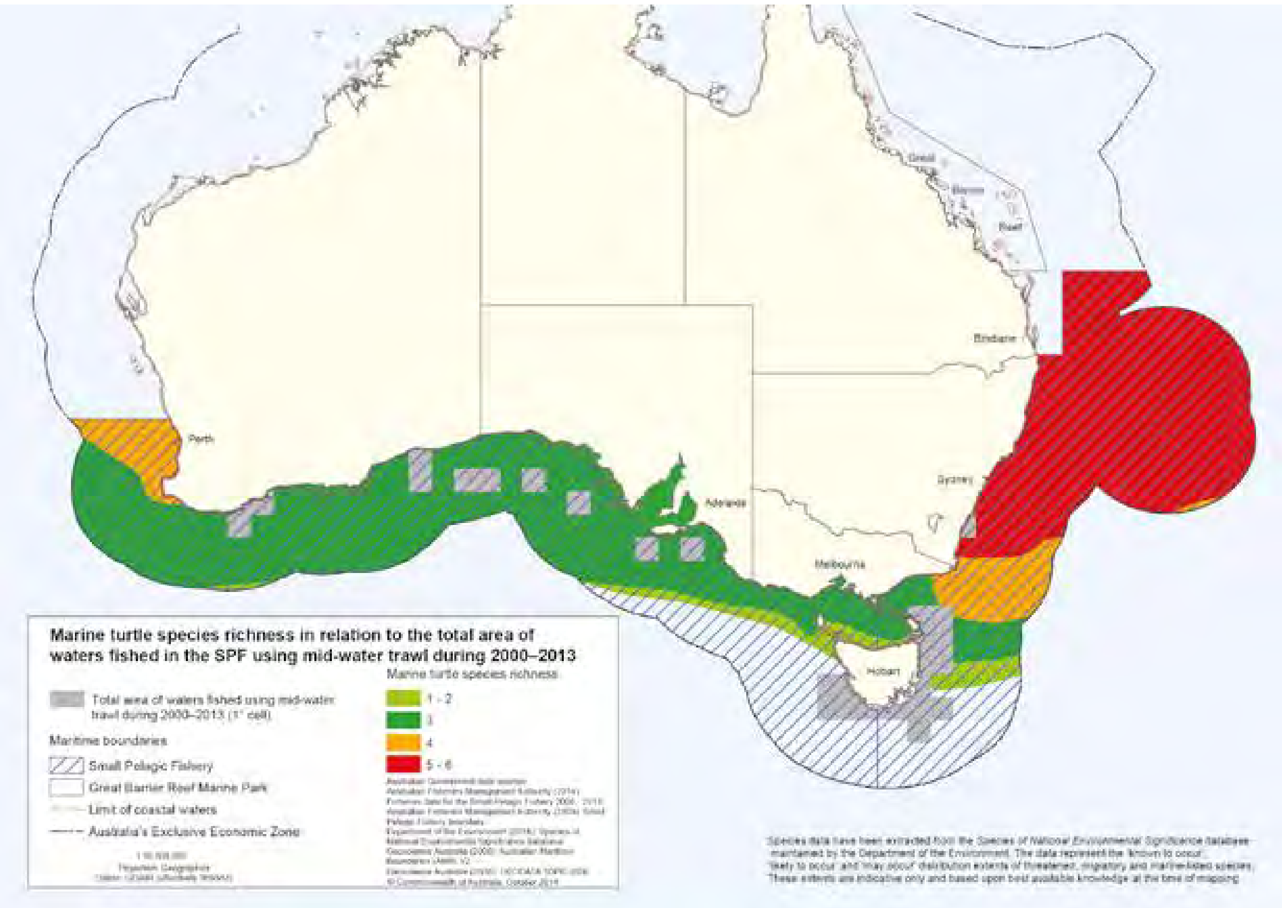


Figure A3.2 Marine turtle species richness in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. Source: Map produced by ERIN using unpublished AFMA data.

Seasnakes

The panel did not assess the possible impact of direct interactions on protected species of seasnakes specifically, due to the generally low overlap of the species' distribution with the area of the SPF and noting that no interactions with seasnakes in the mid-water trawl sector of the SPF were recorded in the period 2002–2011 (Tuck *et al.* 2013). The distribution of protected species of seasnakes overlaid with trawl effort in the SPF (2000–2013) is mapped in Figure A3.3.

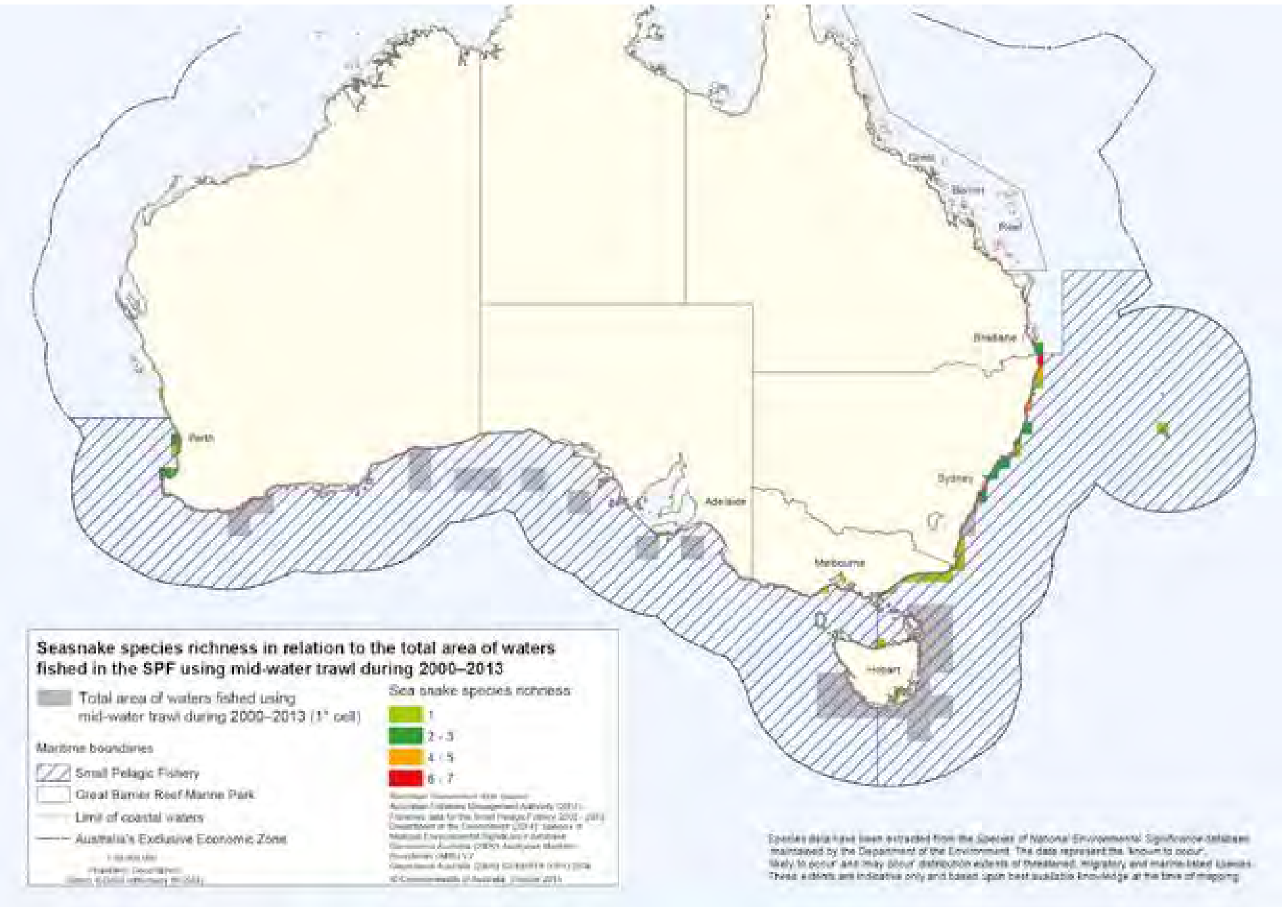


Figure A3.3 Seasnake species richness in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by ERIN using unpublished AFMA data.

Sharks and rays

Of the 13 protected species (including separate east and west stocks of grey nurse shark *Carcharias taurus*) of sharks and rays occurring in the area of the SPF, only four (grey nurse shark east and west stocks, great white shark *Carcharias carcharodon* and whale shark *Rhincodon typus,* were assessed in the SPF mid-water trawl ecological risk assessment (ERA) (Daley *et al.* 2007b). Each of these was assessed at medium risk by both the ERA and subsequent residual risk assessment. The ERA did not assess basking shark *Cetorhinus maximus* and the remaining species were not protected species at the time the ERA was conducted.

The panel noted that there are only two records of protected shark species being captured in the SPF mid-water trawl sector in the period 2000 to 2011 (Tuck *et al.* 2013). In each case a single individual of great white shark and of shortfin mako shark *Isurus oxyrinchus* was captured. Further, of the other protected shark species occurring in the SPF, the panel considered that Harrisson's dogfish *Centrophorous harrissoni*, southern dogfish *C. zeehaani* and school shark *Galeorhinus galeus*, are generally likely to be out of the depth range of mid-water trawl gear. Elgin Associates (unpublished (a)) found that it was unlikely that the mid-water trawl sector of the SPF would interact with grey nurse shark or longfin mako *Isurus paucus*. While Elgin Associates (unpublished (a)) found that it was possible that interactions could occur with porbeagle *Lamna nasus* and basking shark, no interactions with these species were recorded in the mid-water trawl sector of the SPF in the period 2002–2011 (Tuck *et al.* 2013). Similarly, there are no records of interactions with the giant manta ray *Manta birostris* and extremely low records of catch of any skates or rays in the mid-water trawl sector of the SPF (Tuck *et al.* 2013).

As a result, the panel has not assessed the possible impact of direct interactions with protected species of sharks and rays specifically. The distribution of these species overlaid with trawl effort in the SPF (2000–2013) is mapped in Figure A3.4.

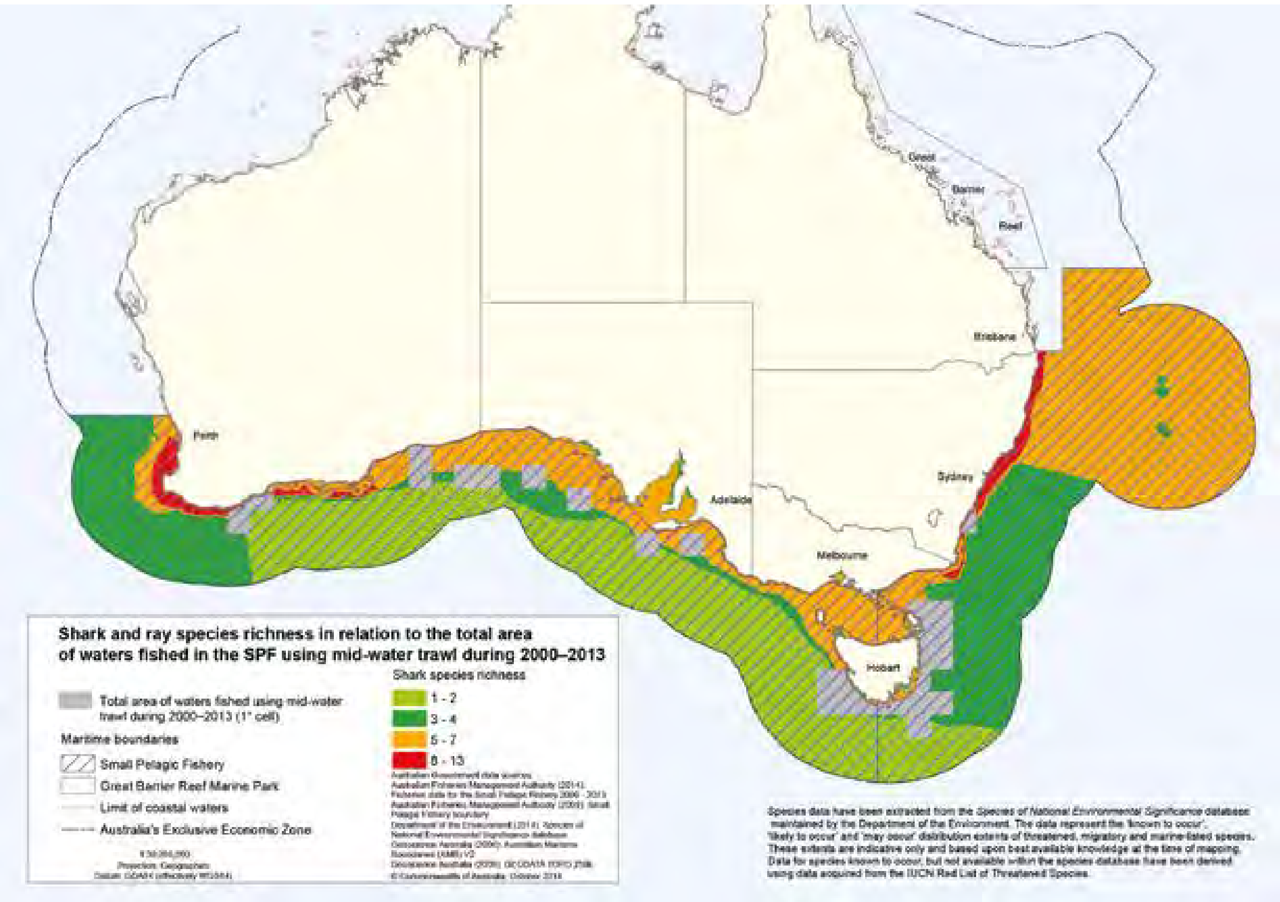


Figure A3.4 Shark and ray species richness in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by ERIN using unpublished AFMA data.

Teleosts

Sixty-six species of syngnathids occur within the area of the SPF. Sixty-four of these were rated as low-risk in the mid-water trawl sector ERA (Daley *et al.* 2007b). This rating largely reflects a low susceptibility of these species to the fishing gear/method. The remaining two species were not assessed in the ERA but the panel considered that these two species had limited overlap with the area of the SPF and that it was reasonable to assume these species were unlikely to be more susceptible to the fishing gear/method than the other 64 syngnathid species assessed in the ERA. The panel noted that there were no reported interactions between syngnathids and mid-water trawl gear in the period 2001–11 (Tuck *et al.* 2013). The distribution of protected species of syngnathid overlaid with trawl effort in the SPF (2000–2013) is mapped in Figure A3.5.

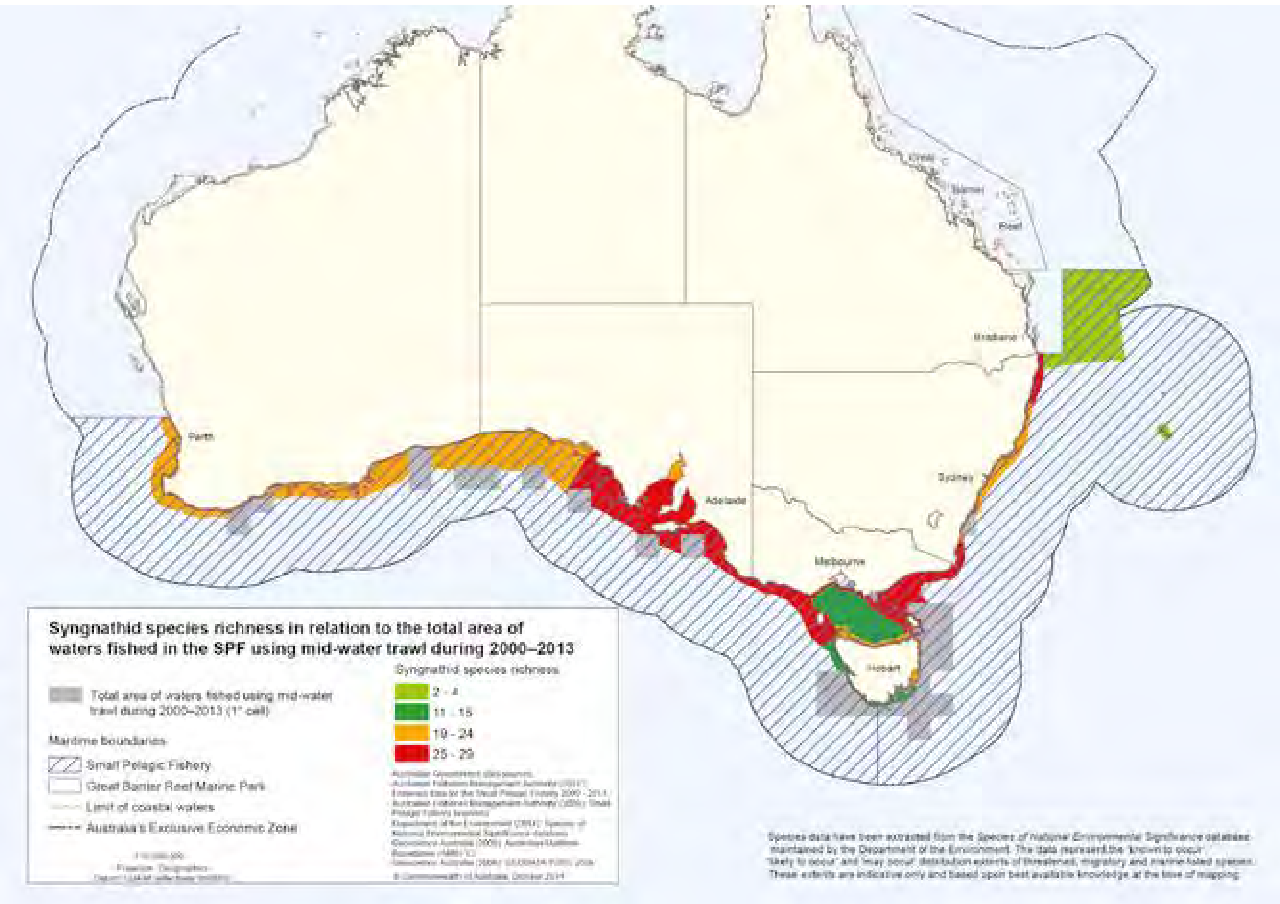


Figure A3.5 Syngnathid species richness in relation to the total area of waters fished in the SPF using mid-water trawl during 2000–2013. **Source:** Map produced by ERIN using unpublished AFMA data.

In addition, there are a three protected species of teleost fishes occurring in the area of the SPF (gemfish *Rexea solandri*, orange roughy *Hoplostethus atlanticus* and southern bluefin tuna *Thunnus maccoyii*). The panel considered that orange roughy is likely to be out of the normal depth range of mid-water trawl gear. Very small quantities of gemfish and no southern bluefin tuna or orange roughy were recorded in the SPF mid-water trawl sector in the period 2002–2011 (Tuck *et al.* 2013). As a result, the panel has not assessed the possible impact of direct interactions with protected species of teleosts specifically.

Appendix 4 Target species' profiles and stock status

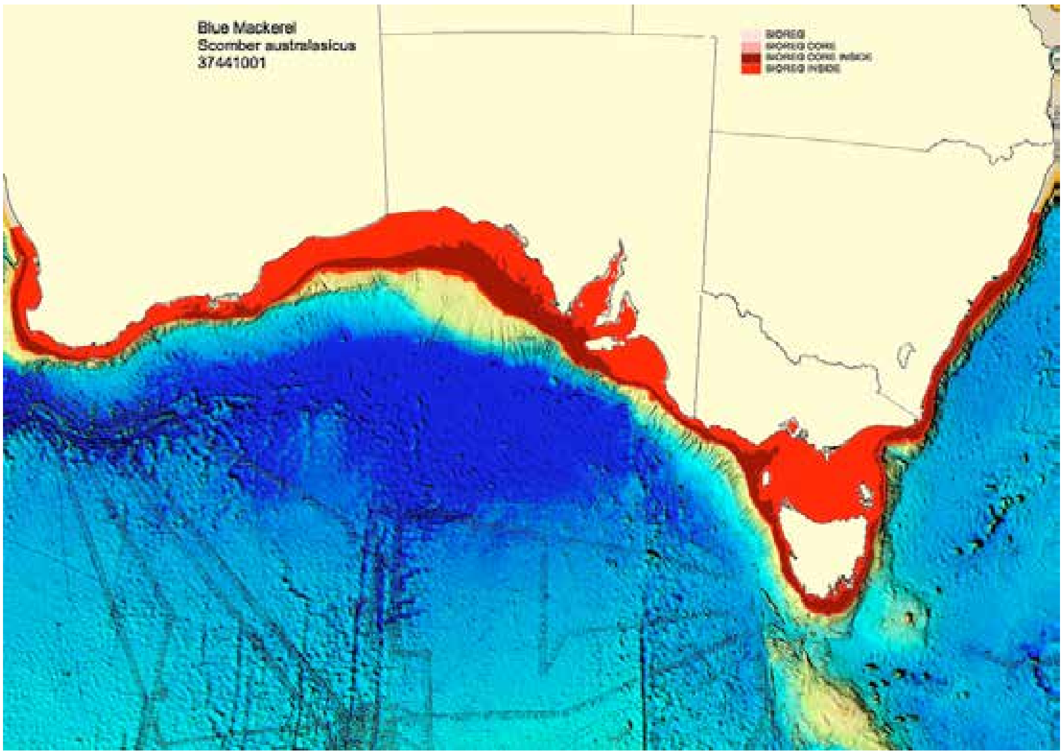
Target species' profiles

Information on each of the Small Pelagic Fishery (SPF) target species is presented in Tables A4.1 to A4.5. Data for lengths and weights from Yearsley *et al.* (1999) are considered as most appropriate for species in Australia. They evaluated all information recorded in literature, anecdotes and museum species and provided maximum and average sizes. Lengths are recorded as total lengths unless otherwise stated. Other data are provided where considered relevant.

Table A4.1 Australian sardine *Sardinops sagax* (Jenyns, 1842)

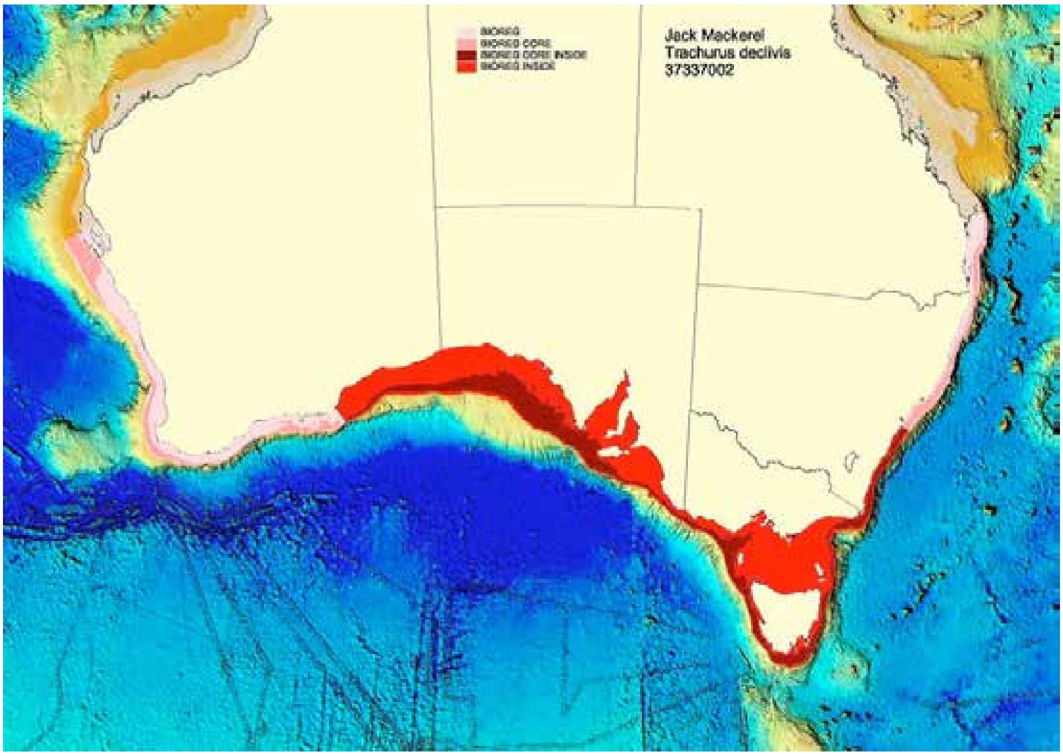
Family	**Clupeidae**	
Distribution	The species is found in waters off Australia, New Zealand, Japan, North and South America, and Africa. In Australia, it is found throughout southern temperate waters from the mid-coast of Queensland ~23°S to Shark Bay (WA ~25° S) including northern Tasmania (Kailola *et al.* 1993, Gomon *et al.* 1994, Ward *et al.* 2013).	
Stock structure	There are no detailed studies of stock structure in Australia (Ward *et al.* 2013). The consensus is for four separate biological stocks: a single biological stock off SA and western Victoria, two separate biological stocks off the south and west coasts of WA and an eastern stock separated from the southern Australian stocks by Bass Strait (Ward *et al.* 2012b).	
Movement	Movement patterns of sardines in Australian waters are poorly understood (Ward *et al.* 2013) but were found to migrate northwards up the east coast of Australia into southern Queensland to spawn similar to reported migrations in North America, southern Africa and Japan (Ward and Staunton-Smith 2002).	
Habitat	Coastal pelagic; often in bays, inlets and inshore waters from surface to 200 m (Kailola *et al.* 1993); mainly schooling offshore on continental shelf to edge (Yearsley *et al.* 1999); near surface in summer but submerged in winter (Gomon *et al.* 1994).	
Age	Longevity:	to 6 years (Kailola *et al.* 1993), rarely beyond 6–8 years (Ward *et al.* 2013); up to 9 years (Rogers and Ward 2007, Rogers *et al.* unpublished)
	Recruitment to the fishery:	1.5 years (Moore *et al.* 2011)
	Maximum reported age:	25 years (Whitehead 1985)
Size	Maximum length:	to 21 cm TL (Yearsley *et al.* 1999), to 25 cm (Rogers *et al.* unpublished), 39.5 cm SL (Whitehead and Rodriguez-Sánchez 1995 in Froese and Pauly 2011)
	Common length:	18 cm TL (Yearsley *et al.* 1999), in South Australia 12–20 cm FL (Rogers and Ward 2007), 20 cm SL (Whitehead 1985)
	Maximum weight:	<0.1 kg (Yearsley *et al.* 1999)
	Growth rates and maximum size vary according to food availability and environmental conditions, they are higher in South Australia than elsewhere in Australia (Ward *et al.* 2013).	
Reproduction	Age at maturity (50%):	1–3 years (Kailola *et al.* 1993)
	Size at maturity:	7–13 cm TL (Kailola *et al.* 1993); 14.6 and 15.0 cm for males and females respectively (Ward *et al.* 2013)
	Peak spawning season is variable: western WA in winter, SA and southern WA in summer-autumn, in Victoria spring-early summer, in southern Queensland in winter-early Spring, and in southern NSW between winter-early summer (Ward *et al.* 2013).	

Table A4.2 Blue mackerel *Scomber australasicus* (Cuvier, 1832)

Family	**Scombridae**
Distribution	Blue mackerel is found in the south-east Indian Ocean through to the north Indian Ocean and Red Sea, in the western Pacific Ocean including New Zealand and Australia, in the north-west Pacific Ocean and East China Sea and in the north-east Pacific off Hawaii and Mexico (Collette and Nauen 1983, Scoles *et al.* 1988, Smith *et al.* 2005). Distributed around most of Australia except in the Gulf of Carpentaria, Northern Territory (Gomon *et al.* 1994, Yearsley *et al.* 1999); core distribution is considered to be southern Australia; unclear whether the distribution is continuous around Tasmania and through Bass Strait (Bulman *et al.* 2008).  Figure A4.1 Distribution of blue mackerel (based on CSIRO CAAB data). Bioreg = range determined by the Bioregionalisation project based on Codes for Aquatic Australian Biota (CAAB) database, CSIRO. Core = preferred depth range, Inside = unverified core distribution range (P. Last, CSIRO, pers. comm. 2007). **Source:** Bulman *et al.* (2008), reproduced with permission from the CSIRO and FRDC
Stock structure	Stock structure is uncertain (Ward *et al.* 2013). Bulman *et al.* (2008) note that stock structure studies strongly suggest separate east and west stocks but finer resolution of stocks is unlikely based on lack of definition between Queensland and New Zealand fish, and broad, seasonal distribution. In the SPF the species is managed as separate stocks east and west of 146°30′ E.
Movement	Little is known about the movement patterns of blue mackerel in Australian waters (Ward *et al.* 2013).
Habitat	Coastal pelagic near surface around continental margins and islands in temperate waters but wanders into tropical waters (Yearsley *et al.* 1999); migratory and schooling in coastal waters and open seas (Gomon *et al.* 1994). Depth: Juveniles and small adults usually occur in inshore waters and large adults form schools in depths of 40–200 m across the continental shelf (Kailola *et al.* 1993)

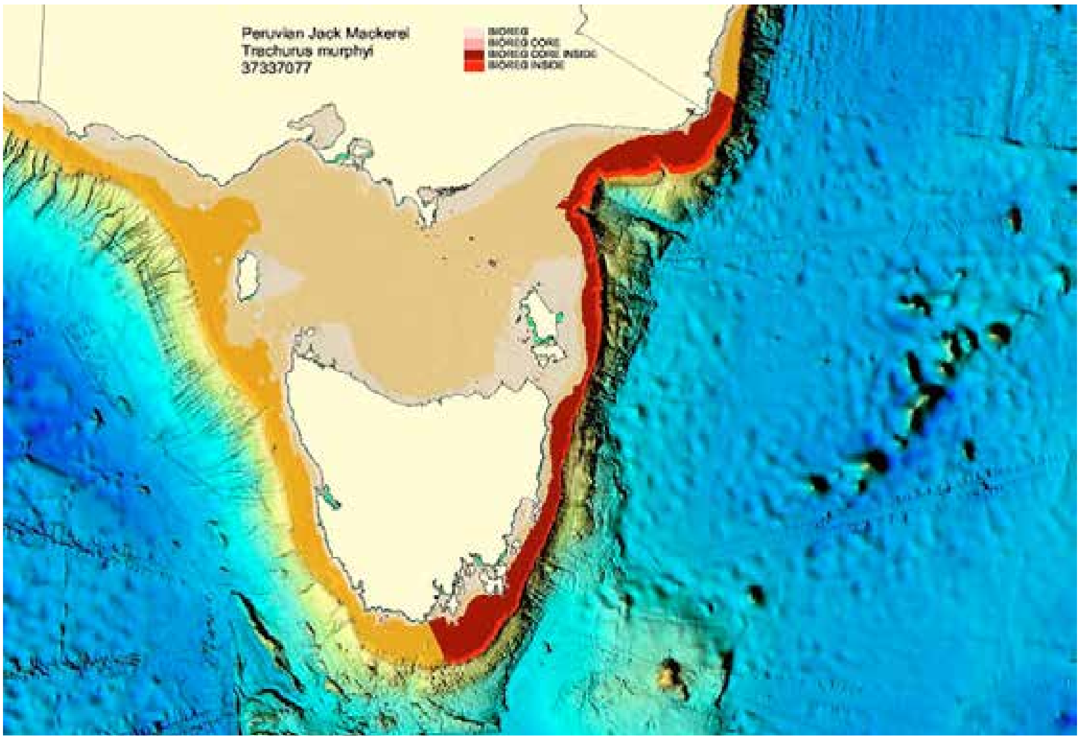
Family	Scombridae	
Age	Longevity:	7 years NSW (Stewart and Ferrell 2001); GAB at least 8 years old (commonly 2–5) (Stevens *et al.* 1984); in New Zealand maximum age 21 (males) and 23 (females) (Morrison *et al.* 2001)
	Recruitment to the fishery:	2 years (Moore *et al.* 2011)
Size	Maximum length:	50 cm FL (commonly 20–35 cm) (Yearsley *et al.* 1999); >45 cm in GAB (Rogers *et al.* 2007)
	Maximum weight:	at least 1.5 kg (commonly 0.2–0.7 kg) (Yearsley *et al.* 1999)
Reproduction	Age at maturity (50%):	2 years (Moore *et al.* 2011); in New Zealand, age 2 (Bulman *et al.* 2008)
	Size at maturity:	28 cm FL (Stevens *et al.* 1984); L50 (length at which 50% of the population is mature) 23.6 cm FL (females), 21.6 cm FL (males) (Rogers *et al.* 2009); 28 cm (FL) in New Zealand (Bulman *et al.* 2008)
	Blue mackerel are serial spawners, spawning multiple times over a prolonged spawning season of indeterminate fecundity (Ward and Rogers 2007; Rogers *et al.* 2009). Mean batch fecundity ~70,000 and ~135 eggs per g (ovary-free weight) (Rogers *et al.* 2009). Spawning in southern Australia occurs from spring to early autumn and late winter to spring off eastern Australia (Rogers *et al.* 2009).	

Table A4.3 Jack mackerel *Trachurus declivis* (Jenyns, 1841)

Family	**Carangidae**
Distribution	Jack mackerel is widely distributed throughout southern Australia from Wide Bay, Queensland to Shark Bay, WA including Tasmanian waters (Williams and Pullen 1993, Gomon *et al.* 1994).  Figure A4.2 Distribution of jack mackerel in Australia (based on CSIRO CAAB data). Bioreg = range determined by the Bioregionalisation project, Core = preferred depth range, Inside = unverified core distribution range (P. Last, CSIRO, pers. comm. 2007). **Source:** Bulman *et al.* (2008)
Stock structure	There is some evidence to suggest that at least two populations of jack mackerel occur within Australian waters, with a third population occurring in New Zealand (Ward *et al.* 2013). Genetic studies found distinct differences between GAB and New Zealand fish (Richardson 1982). In Australia, stock structure studies suggest there are east and west subpopulations of jack mackerel (Bulman *et al.* 2008) and there was an early suggestion of a split in the eastern population but no real evidence either way. Recent re-examination of the original studies (Ovenden, unpublished) has suggested that overlapping but genetically distinct populations could account for the possible Wahlund effect proposed by Richardson (1982). Jordan *et al.* (1995) suggested the existence of a resident winter population off eastern Tasmania boosted in spring by migration from the north.

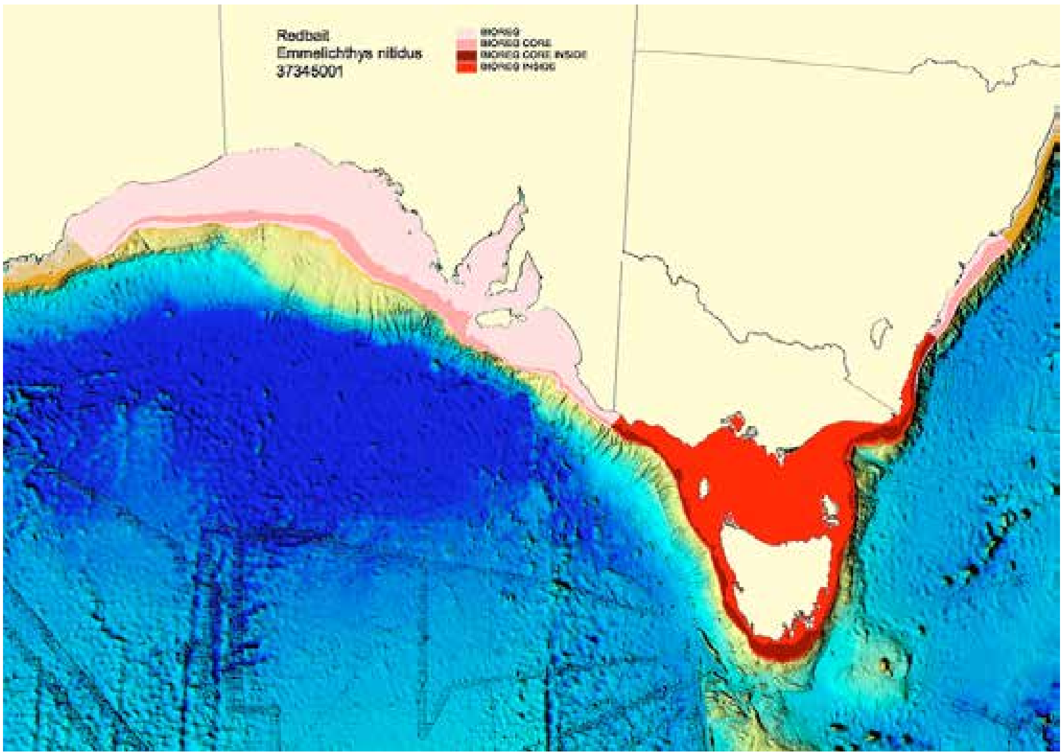
Family	**Carangidae**	
Movement	Ward *et al.* (2013) note there have been no specific studies focused on movement of jack mackerel. However, there are accounts of size classes being absent from catches: such as in the GAB where larger juveniles (16–26 cm) were caught in January 1966 but completely absent two months later (Shuntov 1969); the absence of mature fish (>30 cm) south of 39°S and fewer smaller fish north of 39°S (Stevens and Hausfeld 1984); and observation of spring-migrating fish into Tasmanian water (Jordan *et al.* 1995). Bulman *et al.* (2008) note there is a correlation between size and depth with smaller fish generally found inshore and large fish offshore based on studies from the GAB (Shuntov 1969; Stevens *et al.* 1984), Tasmania (Pullen 1994, Blaber and Bulman 1987) and eastern Bass Strait (Furlani *et al.* 2000).	
Habitat	Pelagic, continental shelf waters from surface to 500 m (Kailola *et al.* 1993, Gomon *et al.* 1994, Yearsley *et al.* 1999); generally found at less than 300 m water depth.	
Age	Longevity:	16 years (Webb and Grant 1979, Lyle *et al.* 2000)
	Age at maturity:	3–4 years (Kailola *et al.* 1993)
	Size at maturity:	31.5 cm (LD50 females) (Marshall *et al.* 1993), 27 cm FL (Kailola *et al.* 1993) but note that Stevens *et al.* (1984) observed macroscopically mature fish at 16–18 cm FL
	Recruitment to the fishery:	2 years (Moore *et al.* 2011)
Size	Maximum length:	to 64 cm TL commonly 25–40 cm (Yearsley *et al.* 1999)
	Maximum weight:	~1.6 kg commonly 0.2–0.6 kg (Yearsley *et al.* 1999)
Reproduction	Jack mackerel are serial spawners but spawning frequency in Australian waters has not been determined (Marshall *et al.* 1993). However, batch fecundity for fish from east Tasmania is estimated at ~63,000 eggs (Neira 2011). Spawning appears to progress southwards from spring to summer (Neira 2011): from October to January in NSW (Maxwell 1979, Neira 2011) and mid-December to mid-February in Tasmania (Marshall *et al.* 1993; Jordan *et al.* 1995, Neira 2011) and December–January in the GAB and Western Bass Strait (Stevens *et al.* 1984, Neira *et al.* 1998).	

Table A4.4 Peruvian jack mackerel *Trachurus murphyi* (Nichols, 1920)

Family	**Carangidae**
Distribution	Widespread throughout the south Pacific, along the shelf and oceanic waters adjacent to Ecuador, Peru and Chile and across the south Pacific to New Zealand and southeastern Australia (South Pacific Regional Fisheries Management Organisation (SPRFMO) 2014b); expanse described by Elizarov *et al.* (1993) as the "Jack mackerel belt" from the coast of Chile to New Zealand within a 35° to 50°S variable band across the South Pacific, which varies with season as "spawning groups concentrate mainly in the north of 40°S in spring and summer and south of 40°S in autumn and winter to feed" (SPRFMO 2014b). In Australia, it is reported throughout the fishery (Moore *et al.* 2011), but see map below.  Figure A4.3. Distribution (presumed) of Peruvian jack mackerel (based on catch data). Bioreg = range determined by the Bioregionalisation project, Core = preferred depth range, Inside = unverified core distribution range. Source: Bulman *et al.* (2008), reproduced with permission of the CSIRO and FRDC.
Stock structure	In the south Pacific, up to five stocks have been suggested; a Chilean stock which is a straddling stock with respect to the high seas; a Peruvian stock which is also a straddling stock with respect to the high seas; a central Pacific stock which exists solely in the high seas; a south-west Pacific stock which exists solely in the high seas; and a New Zealand-Australian stock which straddles the high seas and both the New Zealand and Australian Exclusive Economic Zones (SPRFMO 2014b). Bulman *et al.* (2008) concluded that it is probable that fish caught in Australia belong to a large south-west Pacific Ocean basin stock.

Family	Carangidae
Movement	No information is available on movement of Peruvian jack mackerel in Australian waters. Elsewhere: • a seasonal migration has been described between coastal and oceanic waters for the Chilean subpopulation, and is related to 'reproductive and trophic processes' (SPRFMO 2014b) • in Chilean fisheries waters, large jack mackerel tend to be distributed toward the south; a similar tendency for larger fish in southern waters is also seen in New Zealand fisheries waters (SPRFMO 2014b) • Russian researchers detected several geographically isolated groupings of jack mackerel within the species belt; these groupings were attached to zones having stable hydrological conditions; each one makes circular seasonal migrations (SPRFMO 2014b) • in oceanic waters, beyond 120°W, a migratory pattern has been described whereby jack mackerel move from productive, cold southern waters, northward into subtropical waters where they spawn, and then return (SPRFMO 2014b) • in New Zealand, *T. murphyi* appeared in catches in the mid-1980s, increasing and extending westwards (to Australia) until the mid-1990s, then contracting as the range contracted eastwards (SPRFMO 2014b).
Habitat	Pelagic neritic and oceanic (SPRFMO 2014b) Depth: 10–306 m; diurnal migratory behaviour has been identified, with fish being found deeper during the day (50–180 m) than at night (10–40 m) (SPRFMO 2014b)
Age	Longevity: 20–30 years (SPRFMO 2014b); 30 years (Moore *et al.* 2011) Recruitment to the fishery: not determined Maximum reported age: 16 years (Smith-Vaniz 1995 in Froese and Pauly 2011); in Chile the maximum recorded age is 19 years (whole otoliths); in Peru max age of 11 years; in New Zealand age of 35 years (sectioned otoliths). Some of the difference in these estimates can be explained by New Zealand specimens being larger, and therefore older than those in Chile, as would be expected for an animal near the extreme of its range, but may be due to differing ageing methodologies. Chilean estimates have been validated using the bomb radiocarbon method (SPRFMO 2014b)
Size	Maximum length: ~81 cm TL (Moore *et al.* 2011); 70 cm TL male/unsexed (Smith-Vaniz 1995 in Froese and Pauly 2011) Common length: 45 cm FL male/unsexed (Smith-Vaniz 1995 in Froese and Pauly 2011)
Reproduction	Age at maturity (50%): 3 years (Moore *et al.* 2011); 2–3 years (SPRFMO 2013) Length at maturity: at first maturity in Chile 21.6–30 cm (Cubillos 2008 in SPRFMO 2014b); in Peru 26.5 cm FL (Perea *et al.* in SPRFMO 2014) Indeterminate batch spawner. Spawns when water temp above 15°C and currents are low; evidence that occurs along subtropical convergence. *T. murphyi* spawns throughout its whole distribution range in austral spring and summer, with the main spawning season from October to December. In Peruvian waters *T. murphyi* has a single relatively extended spawning period with a maximum in November each year. The reproductive activity of *T. murphyi* has a greater variability off Peru and the spawning period has peaks of lesser magnitude but extend longer than observed in the spawning occurring off Chile (SPRFMO 2014b).

Table A4.5 Redbait *Emmelichthys nitidus* (Richardson, 1845)

Family	**Emmelichthyidae**
Distribution	Redbait is widely distributed throughout the southern hemisphere. It is found off the western Cape coast in South Africa, St. Paul and Amsterdam Islands, throughout southern Australia and New Zealand. In Australia, they have been caught from northern NSW (south of 30S), Victoria, SA, Tasmania and WA (Bulman *et al.* 2008).  Figure A4.4. Distribution of redbait in Australia. Bioreg = range determined by the Bioregionalisation project in CAAB database, CSIRO. Core = preferred depth range, Inside = unverified core distribution range (P. Last, CSIRO pers. comm. 2007). **Source:** Bulman *et al.* (2008), reproduced with permission from CSIRO and FRDC.
Stock structure	"There have been no targeted stock structure studies on redbait in Australia. However, on the weight of evidence, Bulman *et al.* (2008) concluded that redbait from eastern Australia and eastern Tasmania were likely to be a single stock. The situation for western Tasmania and the GAB is less clear but the observation that fish off eastern and south-western Tasmania exhibit some biological differences (Neira *et al.* 2008) provides some evidence for separation into eastern and western stocks" (Ward *et al.* 2013).
Movement	No studies have investigated redbait movement (Ward *et al.* 2013).
Habitat	Pelagic, forms surface or mid-water schools over the continental shelf but common in 20–100 m (Kailola *et al.* 1993, Yearsley *et al.* 1999). Mostly recorded from mid-water trawl in 100–400 m water (Ward *et al.* 2013).

Family	Emmelichthyidae	
Age	Longevity:	21 years (females) and 18 years (males) (Ewing and Lyle 2008); they note that much larger redbait (>49.3 cm) from South Africa suggest that the maximum age may be higher than indicated from Tasmanian or Victorian samples and that growth is highly variable by region
	Recruitment to the fishery:	~2 years (Moore *et al.* 2011)
Size	Maximum length/weight:	to 36 cm TL and 0.4 kg (commonly adults 20–34 cm and 0.1–0.3 kg) (Yearsley *et al.* 1999); Ewing and Lyle (2008) note that the maximum reported size from Tasmania is 31.7 cm FL (female) and 30.4 cm FL (males); off eastern Victoria 33.5 cm FL and 356 g (Furlani *et al.* 2000); 34.4 cm SL off Chile and up to 49.3 cm TL in South Africa.
Reproduction	Age at maturity (50%):	2–4 years (Welsford and Lyle 2003, Neira *et al.* 2008, Ewing and Lyle 2009)
	Size at maturity:	Female: 14.7 cm east, 24.4 cm FL south-west; male: 15.7 cm east, 26.1 cm south-west, Ewing and Lyle 2009); noticeable regional differences in size and age at sexual maturity, southwestern Tasmania fish maturing at ~10.0 cm larger and two years older compared to eastern Tasmania fish (Ewing and Lyle 2009)
	Redbait is an asynchronous batch spawner with indeterminate fecundity similar to other clupeids, engraulids and scombrids (Ewing and Lyle 2009). Batch fecundity of 186 per g of gonad-free weight lower than for sardines (~500) but similar to carangids and scombrids (~150–200) (Ewing and Lyle 2009). Spawns off southeastern Australia during October/November but could extend into February/ March (Neira *et al.* 2008). Spawn along a narrow 2.5 nautical mile corridor either side of the shelf break when mid-water temperatures are 12.0–15.2°C (Neira *et al.* 2008).	

Stock assessment and status

Table A4.6 Stock assessment and status, SPF target species

SPECIES	NATURE OF ASSESSMENT	MOST RECENT ASSESSMENT	SPAWNING BIOMASS (T)	STOCK STATUS (2012)	HARVEST STRATEGY TIER, RBC, STATE CATCH ALLOWANCE AND TAC (2013–14)	HARVEST STRATEGY TIER, RBC, ESTIMATED STATE CATCH[1] ALLOWANCE AND TAC (2014–15)
Australian sardine (east)	DEPM	July 2004 A DEPM is being conducted for this species in 2014	DEPM: 29,000 t Estimate used to set RBC: 40,000 t	Not overfished Not subject to overfishing	Tier: 2 RBC: 3000 t State catch: 2735 t TAC: 270 t	Tier: 2 RBC: 3000 t Est. state catch: 1070 t TAC: 560 t
Blue mackerel (east)	DEPM	2004	DEPM: 23 000 t Estimate used to set RBC: 40,000 t	Not overfished Not subject to overfishing	Tier: 2 RBC: 3000 t State catch: 315 t TAC: 2700 t	Tier: 2 RBC: 3000 t State catch: 172 t TAC: 2660 t
Blue mackerel (west)	DEPM	2005	DEPM: 56,000 t Estimate used to set RBC: maximum permissible for blue mackerel (west) under Tier 2 in SPF Harvest Strategy	Not overfished Not subject to overfishing	Tier: 2 RBC: 6500 t State catch: 30 t TAC: 6500 t	Tier: 2 RBC: 6500 t State catch: 28 t TAC: 6500 t
Jack mackerels (east)	2011 using samples collected off southeastern Australia in 2002	A DEPM is being conducted for this species in 2014	DEPM: 141,000 t Estimate used to set RBC: 141,000 t	Not overfished Not subject to overfishing	Tier: 2 RBC: 10,600 t State catch: 800 t TAC: 9800 t	Tier: 2 RBC: 10,600 t Est. state catch: 80 t TAC: 10,230 t
Jack mackerels (west)	No assessment, some catch history data available		DEPM: n.a. Estimate used to set RBC: maximum permissible for jack mackerel (west) in SPF Harvest Strategy	Not overfished Not subject to overfishing	Tier: 2 RBC: 5000 t State catch: confidential TAC: 5000 t	Tier: 2 RBC: 5000 t State catch: confidential TAC: 5000 t
Redbait (east)	DEPM	2005 and 2006	DEPM: 86,990 t (2005) and 50,782 t (2006) Estimate used to set RBC: 68,886 t (average of DEPM estimates)	Not overfished Not subject to overfishing	Tier 2 RBC: 5200 t State catch: 0 TAC: 5200 t	Tier 2 RBC: 5200 t State catch: 0 TAC: 5000 t
Redbait (west)	No DEPM survey, some catch history data available	None	DEPM: n.a. Estimate used to set RBC: maximum permissible for redbait (west)	Uncertain Not subject to overfishing	Tier 2 RBC: 5000 t State catch: 0 TAC: 5000 t	Tier 2 RBC: 5000 t State catch: 0 TAC: 5000 t

1. State catches taken from SEMAC (2014). However, AFMA (2014b) notes that information on state catches was subsequently revised and the revised figures were used in setting the TACs.
Sources: Ward *et al.* (2013), Moore *et al.* 2013, AFMA (2013g), SPFRAG (2014b), AFMA (2014b); SEMAC (2014)

Shortened forms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ACAP	Agreement on the Conservation of Albatrosses and Petrels
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AMCS	Australian Marine Conservation Society
ASL	Australian sea lion
Atlantis-SE	Atlantis South East model
B_{MSY}	Biomass at maximum sustainable yield
BRD	Bycatch reduction device
CAAB	Codes for Australian Aquatic Biota
CCAMLR	Commission/Convention for the Conservation of Antarctic Marine Living Resources
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CED	Cetacean excluder device
CFP	Certified Fishing Practice
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CM	Conservation measure
CPF	Central place forager
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTS	Commonwealth Trawl Sector
DAFF	Department of Agriculture, Fisheries and Forestry (Commonwealth)
DCFA	Declared Commercial Fishing Activity
DDD	Dolphin dissuasive device
DEPM	Daily egg production method
DPIPWE	Department of Primary Industries, Parks, Water and Environment (Tasmania)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth)
EAC	East Australian Current
EBFM	Ecosystem-based fisheries management
EBS	Eastern Bass Strait
ECDWT	East Coast Deepwater Trawl
EEZ	Exclusive Economic Zone
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
EPI	Ecological Performance Indicator
ERA	Ecological risk assessment

ERAEF	Ecological Risk Assessment for the Effects of Fishing
ERIN	Environmental Resources Information Network
ERM	Ecological risk management
ETP	Eastern Tropical Pacific
EwE	Ecosim with Ecopath
F	Fishing mortality
FAO	Food and Agriculture Organization of the United Nations
FL	Fork length
FM Act	*Fisheries Management Act 1991* (Cwlth)
FRDC	Fisheries Research and Development Corporation
FRML	Fishery-related mortality limit
GAB	Great Australian Bight
GABT	Great Australian Bight Trawl
GCM	Global Climate Model
GDSG	Genetically distinct spawner groups
GHAT	Gillnet, hook and trap (fishery)
HCR	Harvest control rule
HCS	Humboldt Current System
HIMI	Heard Island and McDonald Islands
ICES	International Council for the Exploration of the Seas
IMAS	Institute of Marine and Antarctic Studies
ISMP	Integrated Scientific Monitoring Program
ITQ	Individual transferable quota
IUCN	International Union for Conservation of Nature and Natural Resources
IWC	International Whaling Commission
LOA	Length overall
LTL	Low trophic level
MALFiRM	Maximum allowable level of fishing related mortality
MEY	Maximum economic yield
MMED	Marine mammal excluder device
MMOP	Marine Mammal Operational Procedures
MMPA	Marine Mammal Protection Act of 1972 (USA)
MNPL	Maximum net productivity level
MoU	Memorandum of understanding
MSC	Marine Stewardship Council

MSE	Management strategy evaluation
MSY	Maximum sustainable yield
NMFS	National Marine Fisheries Service (USA)
NRC	National Research Council (USA)
NSW	New South Wales
OCS	Offshore Constitutional Settlement
OSP	Optimum sustainable population
PBR	Potential biological removal
PCB	Polychlorinated biphenyls
PFTIMF	Pilbara Fish Trawl Interim Managed Fishery
PIRSA	Primary Industries and Regions, South Australia
PSA	Productivity-susceptibility analysis
PSWG	Pelagic Scientific Working Group, (South Africa)
RBC	Recommended biological catch
SA	South Australia
SAP	Seal avoidance practices
SARDI	South Australian Research and Development Institute
SASF	South Australian Sardine Fishery
SBT	Southern bluefin tuna
SED	Seal excluder device
SEMAC	South East Management Advisory Committee
SESSF	Southern and Eastern Scalefish and Shark Fishery
SET	South East Trawl
SETFIA	South East Trawl Fishing Industry Association
SD	Standard deviation
SFR	Statutory Fishing Right
SL	Standard length
SLED	Sea Lion Excluder Device
SPF	Small Pelagic Fishery
SPFMAC	Small Pelagic Fishery Management Advisory Committee
SPFRAG	Small Pelagic Fishery Resource Assessment Group
SPRFMO	South Pacific Regional Fisheries Management Organisation
SSB	Spawning stock biomass
SSC	Species Survival Commission (IUCN)
SSL	Steller sea lion

SSMU	Small-scale management unit
SST	Sea surface temperature
STF	Subtropical Front
SURF	Supportive role for fishery ecosystems
TAC	Total allowable catch
TACC	Total allowable commercial catch
TAFI	Tasmanian Aquaculture and Fisheries Institute
TARFish	Tasmanian Association for Recreational Fishing Inc.
TL	Total length
TEPS	Threatened, endangered and protected species
USA	United States of America
VIT	Victorian Inshore Trawl
VMS	Vessel monitoring system
VMP	Vessel management plan
WA	Western Australia
WTO	Wildlife trade operation
WWF	World Wide Fund for Nature

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