Marine Ecosystems

Review of impacts of localised depletion of small pelagic fishes on predators and ecosystems

Rogers, P. J., Earl, J. and Ivey, A.

SARDI Publication No. F2013/000613-1
SARDI Research Report Series No. 852

SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

October 2013

Final Report to the Department of the Environment and the Expert Panel

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This publication may be cited as:
Rogers, P. J., Earl, J. and Ivey, A. (2013). Review of impacts of localised depletion of small pelagic fishes on predators and ecosystems. Final Report to the Department of the Environment and the Expert Panel. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2013/000613-1. SARDI Research Report Series No. 852. 44pp.

South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.pir.sa.gov.au/

Printed in Adelaide: July 2015

SARDI Publication No. F2013/000613-1
SARDI Research Report Series No. 852

Author(s): Rogers, P. J., Earl, J. and Ivey, A.

Reviewer(s): Mayfield, S. and Begg, G.

Approved by: Begg, G.
Research Chief – SARDI Aquatic Sciences

Signed: 

Date: 16 October 2013

Distribution: DEWNR, SAASC Library, University of Adelaide Library, Parliamentary Library, State Library and National Library

Circulation: Public Domain

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Executive Summary

This review was commissioned by the Department of the Environment on behalf of the Expert Panel that was established by the Minister for the Environment to assess and report on the declared Commercial Fishing Activity (i.e. which uses the mid-water trawl method; and 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). The declared Commercial Fishing Activity is prohibited for up to two years while the Expert Panel conducts an assessment of the activity and reports to the Minister for the Environment. The Expert Panel commenced its assessment in February 2013. The Expert Panel is considering all available relevant information on the nature and extent of such impacts and sought a comprehensive review of the literature on localised depletion to determine the relevance of the information to the declared Commercial Fishing Activity that is the subject of the Expert Panel's assessment.

Aims as per the review Terms of Reference (ToR):

- Provide a summary of any evidence of localised depletion of fishing activities on the ecosystem and component species;
- Provide contextual details on the information to underpin a preliminary assessment by the reviewer of the relevance of the information to the Expert Panel's assessment. That contextual information should include, as appropriate:
  - i) The scale of the localised depletion event in the context of the biomass available.
  - ii) The exploitation rate that caused the localised depletion.
  - iii) The temporal and spatial parameters of the event.
- Identify gaps in the knowledge base in relation to the issues identified above and potential areas of research to address these.

The review aims to inform the Expert Panel's assessment by identifying:

- Examples of localised depletion of small pelagic species that have resulted in a detectable impact on the ecosystem and its component species.
- Examples of localised depletion of other prey species that have resulted in a detectable impact on the ecosystem and its components.
- Any information that addresses the differential impacts on localised depletion of vessels with processing and freezing capacity and of smaller, wet boat operations.
- Management measures used to avoid and address localised depletion, particularly in relation to small pelagic species.

What is localised depletion?

- The term localised depletion is used to describe a persistent and significant reduction in the abundance/density of a target species over a defined area within the range of a population that is caused by a spatial and temporal concentration of fishing effort. Reductions in abundance at a particular location that are reflective of range contractions caused by over exploitation of the entire stock or changes in distribution caused by variations in environmental conditions are not considered as localised depletion in the context of this review.

- For localised depletion to occur, a component of the fished population or meta-populations must exhibit a degree of site fidelity. Localised depletion occurs when more fish are removed from the defined area by fishing than can be replaced by the movement/migration of fish into the area over a specified period.

- The concept of localised depletion assumes that some components of small pelagic fish populations exhibit a degree of spatial and temporal separation from the broader stock. The concept also assumes that if unmanaged, localised depletion may lead to impacts on the structure and functioning of the ecosystem and the population demographics of predators.

- Defining the spatial and temporal scales over which localised depletion may occur is critical to the overall discussion of this concept. These scales should be defined with respect to: 1) factors affecting the spatial structuring of pelagic fishes, and 2) the areas and times over which impacts on ecosystems and predators are likely to occur.

- Pelagic species are responsive to oceanographic features, such as eddies, and frontal systems (SST and primary productivity gradients) that drive food availability and determine the suitability and stability of environmental conditions for foraging, reproduction and recruitment. These features typically occur over scales of 10–100s of km and these may influence the scales at which populations of pelagic fishes may display spatial structure. However, geographical features that limit fish movements, such as headlands, embayments and straits, may also determine the spatial scale over which localised depletion could occur.

- Few studies have focussed on localised depletion of small pelagic fish species. There have been no dedicated studies of localised depletion of small pelagic fishes in Australian Commonwealth or State managed waters.

Summary of Review:

ToR 1. **Examples of localised depletion of small pelagic species that have resulted in a detectable impact on the ecosystem and its component species**

A comprehensive search of the literature revealed no documented cases of dedicated studies of localised depletion of small pelagic fishes. However, there was limited evidence available to support the concept of localised depletion, and this had largely been derived from fisheries and ecological data collected for other purposes.

a) Evidence that has been used to suggest that localised depletion may have occurred includes changes in the spatial distribution of fishery effort/catches and changes in the foraging patterns of seabirds. In the latter cases, the removal of large quantities of prey by fishing from areas in which seabirds forage combined with temporally co-incident reductions in reproductive success, increases in distances travelled and feeding behaviour during foraging have been used as indirect evidence of localised depletion.

b) One key example of where localised depletion of a small pelagic species was linked to a detectable impact on component species included the purse seine fishery for anchovy (*Engraulis ringens*) off Peru and its impacts on the spatial patterns of foraging and breeding success of seabirds within spatial scales of <50 km around breeding colonies.

c) Concerns regarding the risk of localised depletion have been described and summarised in the purse seine fishery for Atlantic menhaden (Clupeidae) (*Brevoortia tyrannus*) fishery in Chesapeake Bay.

ToR 2. **Examples of localised depletion of other prey species that have resulted in a detectable impact on the ecosystem and components**

Potential impacts of localised depletion on surrounding ecosystem and predators have been identified as key issues in the Sandeel (*Ammodytes marinus*) fishery in the North Sea (Pikitch *et al.* 2012).

ToR 3**. Information that addresses the differential impacts on localised depletion of vessels with processing and freezing capacity and of smaller, wet boat operations**

No published information was available to address the differential impacts on localised depletion of vessels with processing and freezing capacity and of smaller, wet boat operations.

ToR 4. **Management measures used to avoid and address localised depletion, particularly in relation to small pelagic species**

Although direct evidence for localised depletion of small pelagic fishes is limited, it is likely that it can and has occurred, and several fisheries have established precautionary strategies to prevent or mitigate potential impacts on the ecosystem or its predators. These strategies fall into several categories:

- Spatial management – zoning (e.g. Atka mackerel *Pleurogrammus monopterygius*, Pollock *Theragra chalcogramma* and Stellar sea lions *Eumetopias jubatus* in the Aleutian Islands and Bering Sea, Sandeel fishery and seabirds in the North Sea).
- Spatial and temporal closures to protect central place foragers (e.g. Antarctic krill fishery by the Commission for the Conservation of Antarctic Marine Living Resources; CCAMLR).
- Move on rules (e.g. Herring *Clupea harengus pallasi* fishery in Canada).

Knowledge gaps and potential research options

- Outcomes of this review were used to identify gaps in our knowledge and potential research options and monitoring priorities pertinent to informing the Expert Panel with regard to the Declared Commercial Fishing Activity.

Conclusions

We provide a brief summary of published information available on the spatial patterns of foraging of some of the key central place foragers and highly migratory (pelagic) species that target small pelagics as prey, and are distributed in southern Australian shelf and slope waters. To inform the development of a working definition of localised depletion, it should be considered that the areas over which central place foragers obtain their food resources range from hundreds to thousands of square kilometres.

There are four main options for preventing or mitigating the effects of localised depletion in the Commonwealth Small Pelagic Fishery that include: conservative exploitation rates; increased spatial management through the establishment of smaller zones (management units); spatial/temporal closures (especially for central place foragers and other species with limited home ranges); and move on rules. It is important to note that these options are not mutually exclusive and there may be costs and benefits of establishing several or all of these options in some form in the Small Pelagic Fishery.

Acknowledgements

We wish to thank Mrs Margaret Walters for assistance during the compilation of the scientific literature reviewed in this document.

This document was approved for release to the Department of the Environment and the Expert Panel by Professor Gavin Begg.

This review was funded by the Department of the Environment.

On behalf of SARDI Aquatic Sciences, the authors thank the Department of the Environment and the Expert Panel for the opportunity to contribute to this review process.

1. Introduction

Need

On 19 November 2012, the Minister for Sustainability, Environment, Water, Population and Communities (now Department of the Environment) made the Final (Commonwealth Small Pelagic Fishery) Declaration 2012 (Final Declaration), which came into force on 20 November 2012. The Final Declaration provides that a commercial fishing activity which:

1. is in the area of the Small Pelagic Fishery;
2. uses the mid-water trawl method; and
3. 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* (the EPBC Act). The Declared Commercial Fishing Activity is prohibited for up to two years while the Expert Panel conducts an assessment and reports to the Minister for the Environment on the activity. The Expert Panel commenced its assessment in February 2013.

There remains uncertainty about the likelihood and impact of localised depletion of small pelagic species in the Small Pelagic Fishery arising from the operations of large mid-water trawl vessels. The Expert Panel needs to ensure that it has considered all available relevant information on the nature and extent of such impacts and sought a comprehensive review of the literature to determine the relevance of the information to the Declared Commercial Fishing Activity that is the subject of the Expert Panel's assessment.

Aim

As per the specific guidelines outlined in the Terms of Reference (ToR), the aims of this review of the literature are to:

- Provide a summary of any evidence of localised depletion of fishing activities on the ecosystem and component species.
- Provide contextual details on the information to underpin a preliminary assessment by the reviewer of the relevance of the information to the Expert Panel's assessment. That contextual information should include, as appropriate:
    - The scale of the localised depletion event in the context of the biomass available.
    - The exploitation rate that caused the localised depletion.
    - The temporal and spatial parameters of the event.
- Identify gaps in the knowledge base in relation to the issues identified above and potential areas of research to address these.

The review aims to inform the Expert Panel's assessment by identifying:

- Examples of localised depletion of small pelagic species that have resulted in a detectable impact on the ecosystem and its component species.
- Examples of localised depletion of other prey species that have resulted in a detectable impact on the ecosystem and components.
- Any information that addresses the differential impacts on localised depletion of vessels with processing and freezing capacity and of smaller, wet boat operations.
- Management measures used to avoid and address localised depletion, particularly in relation to small pelagic species.

Scope

This literature review relates to the potential of large mid-water trawl vessels targeting small pelagic species in the Australian managed Small Pelagic Fishery to cause 'localised depletion' of stocks of those species which may affect the sustainability and predators of those stocks. Importantly, we do not include or discuss the expansive array of studies that have focused on 'overfishing' at the broad scale of the stock as this is beyond the scope of the ToR. However, we draw on salient points highlighted during those studies if they were immediately relevant to the potential broader impacts of localised depletion.

Approach

The structure of this review follows the order of the ToR (see Appendix 1), which are used as the section headings. The literature search was conducted using a number of online search engines that included Web of Knowledge, ScienceDirect, Web of Science, Scopus, Fisheries Abstracts and Google Scholar. The key words and search terms used to conduct these searches included those in Table 1. The small pelagics reference collections at the South Australian Research and Development Institute (SARDI) Aquatic Sciences were also consulted. To ensure a high level of quality and independence in the source information, we used peer-reviewed literature and scientific reports as much as possible. Where necessary, we also sourced review documents and web-based information.

Table 1. Key-words and search terms used to conduct the literature review.

Primary key-words and search terms
Localised*depletion
Small pelagics
Depletion*fisheries
Pelagic
Super-trawler
Mid-water trawler
Purse seining
Localised depletion*demersal
Reduced abundance
Fisheries
Mesoscale impacts
Surveys for depletion (acoustic, DEPM, trawl, plane-based).
Forage fish
Ecological impacts
Predator populations*impacts
Bottom up*fishing*depletion
Wasp-waist*fishing*depletion
Hydro-acoustic surveys

2. Background

Importance of small pelagic fishes to economies and ecosystems

Small pelagic fish and pelagic cephalopods each play pivotal roles in shaping the trophic functioning of marine shelf and slope ecosystems (Smith *et al.* 2011; Goldsworthy *et al.* 2013). Small pelagic fishes provide a valuable energy source for pelagic predators and support some of the world's largest high volume-low value fisheries. There is increasing public concern and awareness regarding the important role of small pelagic fishes in the functioning of marine ecosystems, and the socio-economic services that this coupling provides.

The key small pelagic fishes, including anchovies, herrings, sardines, mackerels, shads, sauries, menhaden, and capelin supported an estimated total fishery production of ~25 million tonnes in 2011, which represented ~27% of the global fishery production (FAO, 2013). Australian capture production is relatively small in comparison to other productive boundary current ecosystems, with <100,000 tonnes of small pelagic fishes landed annually. In southern Australia, much of the catch comprises Australian sardine (pilchard) (*Sardinops sagax*), which is used to feed southern bluefin tuna (*Thunnus maccoyii*) in the mariculture industry off South Australia.

Australian temperate and subtropical small pelagic fishes

The small pelagic fish assemblage that occurs in Australia's temperate and sub-tropical shelf and slope ecosystems comprises nine species in six families. Members of the Clupeidae predominate and the species include Australian sardine, scaly mackerel (*Sardinella lemuru*), Australian anchovy (*Engraulis australis*), and round herring (*Etrumeus teres*). The remainder of the assemblage comprises larger bodied species, such as jack mackerel and yellowtail scad (*Trachurus declivis and T. novaezelandiae,* Carangidae), blue mackerel (*Scomber australasicus,* Scombridae), redbait (*Emmelichthys nitidus,* Emmelichthyidae) and saury (*Scomberesox saurus*, Scomberesocidae). These species exhibit a range of life history characteristics and have different productivity levels. For example, jack mackerel attain ~64 cm and live for 16 years; yellowtail scad reach 50 cm and live for 14 years (Gomon *et al.* 1994; Lyle *et al.* 2000; Stewart and Ferrell 2001); blue mackerel grow to ~50 cm and live for at least 8 years (Ward and Rogers 2007); redbait grow to ~36 cm and live for up to 21 years (Gomon *et al.* 1994; Welsford and Lyle 2003; Neira *et al*. 2008); scaly mackerel grow to ~24 cm and live for 6–7 years (Gomon *et al.*

1994; Gaughan and Mitchell 2000); Australian sardines grow to ~25 cm and live for 9 years (Rogers *et al.* 2007); and Australian anchovy grow to ~15 cm and live for 5 years (Dimmlich and Ward 2006). There are significant gaps in the information available on the stock sizes, resilience to fishing, distribution patterns, recruitment dynamics, stock structure and movement patterns of these species.

What is localised depletion?

There have been various interpretations in the literature of how localised depletion is defined and this varies slightly depending on whether target species are essentially pelagic or demersal. In the context of this review, the term localised depletion is used to describe 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 effort. Reductions in abundance at a particular location that result from changes in distribution caused by variations in environmental conditions or range contractions caused by over-exploitation of the stock are not considered as localised depletion in the context of this review.

For localised depletion to occur, a component of the fished population or meta-population must exhibit a degree of fidelity to the fished area. Localised depletion occurs when more fish are removed from a defined area by fishing than can be replaced by movement/migration into the area over a specified period. The concept of localised depletion also assumes that some components (e.g. aggregations, size/age classes or sub-stocks) of small pelagic fish populations exhibit a degree of spatial and temporal separation from the broader stock over a particular time scale. Defining the spatial and temporal scales over which localised depletion may occur for small pelagic species is critical to the discussion of this concept. These scales should be defined with respect to: 1) factors affecting the spatial structuring of pelagic fish populations, and 2) the areas and times over which impacts on ecosystems and predators are likely to occur.

Pelagic species are responsive to oceanographic features, such as eddies, sea surface temperature and Chl-*a* fronts that border upwelling systems, enhance food availability and determine the suitability and stability of environmental conditions for growth, reproduction and recruitment. These features typically occur over scales of 10–100s of kilometres (meso-scale) and may influence the scales at which populations of pelagic fishes display spatial structuring. Geographical features and barriers that limit fish movements, such as headlands, embayments and straits may also play a role in determining the spatial scales over which localised depletion could occur.

To place this review into a global context, it is useful to consider some important points highlighted in previous studies and reviews, as well as to highlight that the operational definition of localised depletion has varied depending on the situation/fishery/ecosystem being investigated.

BOX 1: Definitions of localised depletion of small pelagic fishes

Haddon (2009) wrote, "*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".*

Pikitch *et al.* (2012) suggested "*Forage fish [small pelagics] are vulnerable to localised depletion, which is a reduction, through fishing, in abundance or biomass in a specific area. Localised depletion occurring in key foraging areas and at critical feeding times may have a major effect on predators [e.g. central place foragers] that have little ability to find more distant patches of abundant prey."*

Maguire (2009) stated, "*Localised depletion in the Chesapeake Bay is defined as a reduction in menhaden 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*."

Spatial foraging patterns of marine predators

An array of central place foragers and highly migratory pelagic species are distributed off the Australian coastline within the region where the Small Pelagic Fishery operates. The Great Australian Bight region has recently been recognised as an internationally significant “hot-spot” for predatory species (Goldsworthy *et al.* 2013), with shelf ecosystems off eastern Australia, Bass Strait and western Australia also supporting key predator assemblages (Griffiths *et al.* 2010; Smith *et al*. 2011). Central place foragers are predominantly land-breeding predator species that bring resources back to a particular site for a mate or offspring. These species are particularly vulnerable to the effects of localised declines in prey abundance because of their limited capacity to adjust their search areas when prey abundance is reduced in areas adjacent to colonies and haul-outs (e.g. Santora *et al*. 2009).

Published spatial foraging details for predators that focus on small pelagic prey in Australian shelf and slope waters where the Small Pelagic Fishery (Commonwealth managed waters) operates are shown in Table 2. Land breeding species for which there is published data on spatial patterns in movement and foraging dynamics, and which are most likely to be directly impacted by reductions in availability of small pelagic prey include the crested tern (*Sterna bergii*), little penguin (*Eudyptula minor*), Australasian gannet (*Morus serrator*), short-tailed shearwater (*Puffinus tenuirostris*), Australian fur seal *(Arctocephalus pusillus doriferus*) and New Zealand fur seal (*A. forsteri*) (Table 2). Detailed discussion of indirect ecological impacts of reductions of small pelagic prey is beyond the scope of this review. Dietary dynamics, trophic guilds, spatial distribution of consumption effort and trophodynamic modelling scenarios for key regions are provided at various spatial scales by Bulman *et al*. (2011), Goldsworthy *et al*. (2011; 2013) and Smith *et al*. (2011). Highly migratory species that include pelagic sharks, large teleosts (e.g. Scombrids) and some non-breeding seabirds (e.g. albatrosses) tend to have larger or multiple foraging areas where they search for and obtain their prey. The mobility of highly migratory species may partly offset the potential impacts of variability in prey availability attributed to changes in the distribution, abundance and movement of the small pelagics or localised depletion by fishing. However, reduced prey abundance in critical foraging habitats could impact the movement schedules of highly migratory species and/or have a cumulative impact on reproductive output, fitness and survival of populations.

Table 2. Spatial foraging details for predators of small pelagic fishes in shelf and slope waters. BUR – Bonney Upwelling Region; GAB – Great Australian Bight, NBUR – Northern frontal area of Bonney Upwelling Region, SG – Spencer Gulf, South Australia, GSV – Gulf St Vincent, South Australia, STF – Sub-tropical Front; IO – Indian Ocean, PO – Pacific Ocean, subscript A – Austral autumn; subscript W – Austral winter; subscript O – oceanic; subscript S – shelf; NSTF – Northern sub-tropical front; RDD – regionally deficient; Ad M– adult male; Ad F – adult female and Juv – juvenile.

Group/species	Foraging mode	Spatial extent of foraging distance from colony (km) (Average ±se, *range)	Core foraging area (km)	Reference
Central place foragers				
New Zealand fur seal (*A. forsterii*)	Shallow and deep diving	$^{Ad\ M}$108.0±73.9; $^{Ad\ F}$188.6±106.9; ^{Juv}1012.8±357.2; ^{A}114±44; ^{W}460±138	NBUR; STF	Page *et al.* (2006) Baylis *et al.* (2008)
Australian fur seal (*A. pusillus doriferus*)	Benthic/pelagic	<100	Bass St – W Tas shelf	Arnould and Hindell (2001)
Crested tern (*S. bergii*)	Shallow surface feeding	*2.3–38.9	Chl-*a* fronts close to colonies	McLeay *et al.* (2010)
Little penguin (*E. minor*)	Shallow and deep diving	GAB Shelf: 39±27 GSV, Gulf: 13±5	22.9±17.0 7.0±2.0	Wiebkin (2012)
Australasian gannet (*M. serrator*)	Shallow diving	?	?	RDD
Short-tail shearwater (*P. tenuirostris*)	Shallow diving	Short trips shelf: 14±5; Long-trips shelf: *500–1000; Oceanic: *1000–3600	Shelf; Oceanic, frontal systems	Einoder *et al.* (2011)
Highly migratory species				
Southern bluefin tuna (*T. maccoyii*)	Pelagic	NA	GAB–BUR W Tasman Sea	Bestley *et al.* (2008) Patterson *et al.* (2008)
Small petrels and prions	Pelagic/Shallow surface feeding	Shelf and southern gulf waters	?	RDD
Shy albatross (*Thalassarche cauta*)	Pelagic	*9–88	SW-W Bass St	Hedd *et al.* (2001)
Dusky shark (*Carcharhinus obscurus*)	Pelagic/Benthic	NA	SG	Rogers *et al.* (2012)
Dolphins/toothed whales	Deep diving/Pelagic	NA	?	RDD

3. ToR 1. Examples of localised depletion of small pelagic species that have resulted in a detectable impact on the ecosystem and its component species

Localised depletion of small pelagic fishes is a largely untested concept due to the dynamic and highly variable movement patterns and population structures of these taxa, and the logistical difficulties associated with measuring changes in distribution and abundance in response to fishing pressure. A comprehensive search of the literature revealed no documented cases of dedicated studies of localised depletion of small pelagic fishes. The lack of clear evidence for localised depletion makes it difficult to make generalised statements about the levels of exploitation that may lead to localised depletion and/or the temporal or spatial scales over which events may occur. Much of the limited evidence available to support the concept of localised depletion has been largely derived from fisheries and ecological data collected for other purposes. Empirical evidence that has been used to suggest that localised depletion has occurred includes:

- Expansions in the spatial distribution of fishing effort and catches.
- Changes in the foraging patterns of predators.

In this section, we provide case-study examples of where localised depletion of small pelagic species has been identified as an issue for ecosystems and/or its component species (i.e. central place foragers and or pelagic predators).

Purse seine fishery for sardines, scad and mackerels, off Java, Indonesia

Fishery catch rate data were used to assess patterns of spatial depletion in an unregulated small pelagic purse seine fishery off Java, Indonesia (Cardinale *et al*. 2011). This fishery is economically and socially important, has existed since the 1970s, and represents ~27% of Indonesia's total fishery production (Cardinale *et al*. 2009). Species targeted in this fishery include scads (*Decapterus russelli* and *Decapterus macrosoma*), bigeye scad (*Selar crumenopthalmus*) and Indian mackerel (*Rastrelliger kanagurta*) (Cardinale *et al*. 2009). Population genetic studies have suggested that there is heterogeneity in genetic population structuring in the scad *D. macrosoma* at scales that suggest that sub-population structuring exists between the Indian Ocean and Sunda Shelf where the fishery operates (Arnaud *et al.* 1999). No movement data are currently available. For *D. russelli*, mitochondrial and nuclear-DNA data suggested the existence of three geographically distinct populations driven by homing behaviour and spawning habitat in the Makassar Strait and Sulawesi Sea, in the Arafura Sea, and western region of the Indo-Malay Archipelago (Rohfritsch and Borsa 2005). Spatial patterns of decline in catch rates in the fishery between 1990 and 2010 were interpreted to represent evidence of localised and serial depletion of several small pelagic stocks. It was suggested that the temporal and spatial dynamics of this depletion over the 20-year time series indicated that fishing areas were sequentially depleted with distance from the main port (Cardinale *et al*. 2011). The dynamics of this pattern varied with the commercial importance of the species. The initial unexploited biomasses of the stocks and exploitation rates as a proportion of biomass associated with these localised depletions were unknown. Ecological impacts of this long-term depletion scenario were also unknown.

Purse seine fishery for anchovy in the Humbolt Current and Peruvian boobies

The purse seine fishery for anchovy (*Engraulis ringens*) in the Humbolt Current off Peru is recognised as being the world's largest single species fishery. The commercial total allowable catch (TAC) for the fishery has been fairly stable since 1993 (~6 million t, except for reduced quota in 1997–1998), and management is based on two seasonal closures to sustain spawning stock and recruitment year classes (Chavez *et al*. 2008; Bertrand *et al.* 2012). Recently, the foraging patterns of Peruvian boobies (*Sula variegata*) have been used to provide evidence of ecological impacts of localised prey depletion by this fishery. Stock assessment surveys between 2000–2006 estimated anchovy biomasses of up to 1.77 million ± 320,106 t in the study area (Bertrand *et al.* 2012). These authors used tracking methods and data from Vessel Monitoring Systems (VMS) to investigate the spatial movements of the fleet and the seabirds during the commercial fishing season. Boobies exhibited significant differences in the range of foraging trips and distances of dives from the colony, directly following intensive fishing (350,000 t) near the colony (Bertrand *et al.* 2012). In general, as more anchovies were removed by the fishery, breeding seabirds had to travel and dive further from the colony. Bertrand *et al*. (2012) estimated the fishery took 1,115,424 t of anchovy and 519,121 t during the tracking experiment in the study area, which equated to ~30% of the available anchovy biomass, and 63% of what was landed during the fishing season. The fishing season and area directly overlap with breeding seasons and foraging areas of several seabirds (Bertrand *et al.* 2012).

Purse seine fishery for Atlantic menhaden in Chesapeake Bay, Virginia

Concerns regarding the risk of localised depletion have been described and summarised for the purse seine fishery for Atlantic menhaden (*Brevoortia tyrannus*) in Chesapeake Bay, Virginia, United States (Maguire 2009; Pikitch *et al.* 2012). This small pelagic purse seine fishery has historically taken >100,000 t per year (Smith 1999). A TAC of 109,020 t was implemented in 2006. The Atlantic menhaden stock is not considered to be over-fished based on available assessment data for the 1999–2007 period; however over-fishing occurred in 2008 (NOAA webpage: chesapeakebay.noaa.gov).

The Atlantic menhaden stock undergoes an annual migration and spawning occurs off the mid-Atlantic coast followed by recruitment of larvae into nearby bays. A stock structure study showed that there was connectivity among the aggregations within the different regions of the bay, which was consistent with expectations based on their vagility (Lynch 2008). Haddon (2009) suggested that this species also exhibited site-fidelity (based on otolith chemistry data and indicators of larval/juvenile abundance), which is an important trait when trying to investigate localised depletion. Following this, Haddon (2009) suggested that the coastal stock assessment concludes that the broader stock was not over-fished, but that it cannot be used to assess localised depletion due to the spatial disjunct between the coastal waters where the program is conducted, and the area of the fishery inside Chesapeake Bay. Pikitch *et al.* (2012) also suggested that the current coast-wide stock assessment did not directly consider localised depletion, as there was no spatially explicit estimate of abundance to inform management procedures for the fishery.

Maguire (2009) reviewed the National Oceanic and Atmospheric Administration (NOAA) research program designed to assess localised depletion inside Chesapeake Bay. The operational definition of localised depletion in this program was "*the threshold of abundance that is sufficient to maintain its basic ecological (e.g. forage base, grazer of plankton), economic and social/cultural functions*". The aims of this program were to determine the abundance of Atlantic menhaden inside Chesapeake Bay; assess removal by predators; evaluate exchange between the bay and outside coastal region; and determine larval recruitment. However, it was not clear from the reviews of Maguire (2009), Haddon (2009) or Pikitch *et al*. (2012) what evidence the Atlantic Menhaden Research Program used to identify and assess localised depletion. We could not find any information on the initial unexploited biomass of the proportion of the coastal stock inside Chesapeake Bay, and exploitation rates as a proportion of that biomass are unknown.

Information on broader ecological impacts relating to localised depletion were not available. However, negative effects on striped bass (*Morone saxatilis*), bluefish (*Pomotomas saltatrix*) and osprey *Pandion haliatetus*) have been attributed to localised depletion of Atlantic menhaden in Chesapeake Bay (Haddon 2009; Pikitch *et al*. 2012), although no empirical evidence for localised depletion has been documented. Haddon (2009) suggested that requirements of key predators in the Chesapeake Bay ecosystem had been estimated at ~16,000 t of Atlantic menhaden per annum.

4. ToR 2. Examples of localised depletion of other prey species that have resulted in a detectable impact on the ecosystem and its components

In this section, we provide an example of where localised depletion of other small prey species resulted in detectable impacts on the ecosystem and predators.

North Sea sandeels, seabirds and predatory fish

The sandeel-seabird and predatory fish inter-relationships in the North Sea provide a case study in relation to potential impacts of localised depletion. Sandeels (Ammodytidae) are small, energetically valuable bony fish that burrow in the seabed and form aggregations in the water column which are influenced by bottom temperature and seabed habitat (van der Kooij *et al.* 2008). Their presence in the water column makes sandeels an important forage source for marine predators (Camphuysen *et al.* 2006). In the North Sea, sandeels are exploited by industrial fisheries for fishmeal and fish-oil, with annual landings of ~425,000 t in the past decade. Engelhard *et al.* (2013) suggested that sandeel densities explained observed variation in body condition indices of five predatory fish species, including whiting (*Merlangius merlangus*), lesser weever (*Echiichthys vipera*), grey gurnard (*Eutrigla gurnardus*), plaice (*Pleuronectes platessa*) and haddock (*Melanogrammus aeglefinus*) and pointed out that this may reflect localised depletion of sandeels by commercial fishing. Seabird mortalities were linked to low prey availability and competition with the fishery in 1983, and reproductive success of Arctic terns (*Sterna paradisaea*) (Monaghan *et al*. 1989) and black legged kittiwake (*Rissa tridactyla*) were correlated with sandeel abundance (Rindorf *et al*. 2000; Furness 2002). It was suggested that the sandeel stock needed to be ~50,000 t for the kittiwake population to have a breeding success of >0.5 chicks per nest (Furness 2006). Following scientific advice from the ICES Study Group on Effects of Sandeel Fishing regarding the ecological importance of sandeels, spatial catch limits were implemented along the coast of Scotland to protect seabird breeding populations which were heavily or totally reliant on sandeels (Dunne 2003). This action followed the occurrence of seabird mortality events and pressure from media and non-government organisations. Fishing for sandeel was closed in an extensive inshore area between eastern Scotland and north-eastern England that was named the ‘sandeel box’, in response to a precautionary ecological indicator (if the breeding success of kittiwakes in adjacent colonies declined below 0.5 chicks per pair for three successive years) (Frid *et al.* 2005).

5. ToR 3. Information that addresses the differential impacts on localised depletion of vessels with processing and freezing capacity and of smaller, wet boat operations

No published information was available to specifically address and compare differential impacts on localised depletion of vessels with processing and freezing capacity and of smaller, wet boat operations.

6. ToR 4. Management measures used to avoid and address localised depletion, particularly in relation to small pelagic species

A key component of ecosystem-based fisheries management (EBFM) of small pelagic species is that exploitation should be managed as part of the broader ecosystem, with key consideration of marine predators and their trophic linkages. This includes the identification of spatial and temporal management units that are critical foraging and breeding habitats. Tools that are available to protect predators from the potential impacts of competing with small pelagic fisheries include spatial and temporal restrictions and ecological allocations. Spatial closures can be implemented to temporarily or permanently restrict fishing operations in key foraging areas of predators. Ecological allocations refer to the reservation of a proportion of the catch of prey species, e.g. commercial TAC, to meet energetic needs of predators. Information required to establish spatial closures includes the distribution of predator species and their foraging ranges, overlap with the range of the fishery, prey consumption rates, and the effects of oceanographic and climatic processes on prey distribution and abundance. Much of the concern regarding localised depletion stems from the potential impacts on the trophodynamic functioning and bottom-up impacts within marine systems.

Perhaps the most relevant example of the development of spatially explicit EBFM approaches for managing localised impacts of pelagic fishing on marine predators is that from the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) (Constable and Nicol 2002). This initiative originated to ensure the sustainable management of the Antarctic krill (*Euphausia superba*) fishery and extended to manage the potential negative impact on land breeding and pelagic marine predators (Constable 2011). Importantly, the development of spatial management approaches that form the foundation of CCAMLR's approach are explicitly precautionary in reference to the importance of the ecosystem, and account for absences of available scientific evidence with regard to potential impacts of localised depletion on central place foragers and pelagic predators in the Southern Ocean ecosystem.

Box 2. CCAMLR and the Antarctic krill fishery

In the case of CCAMLR and the Antarctic krill fishery, Constable and Nicole (2002) wrote "*In general, the early acquisition of information on the distribution of local populations of krill and the potential foraging densities of predators from within a harvesting unit (i.e. abundance of predators, distribution of colonies and foraging range) will provide a means of circumscribing predator units as well as undertaking an assessment of long-term annual yield. It is proposed that the early development of the fishery could be concentrated in a small number of units in such a way that the relative fishing intensities in those units are equivalent, although not necessarily equal, to the intensity expected across all units once the catch limit had been reached. Other units in which fishing was not occurring could be monitored as well. This process could help determine whether or not the catch limit is likely to cause undesirable effects on predators in any of the predator units. In this way, it is possible to determine, well in advance of the catch limit being reached, whether or not local restrictions on harvesting are necessary, as well as the overall requirements for the monitoring program*".

Conservative exploitation rates

Smith *et al*. (2011) suggested that maintaining the biomass >75% of the unfished level has been shown to prevent ecological impacts in most fisheries for low trophic level species. Other fisheries, including the Antarctic krill fishery and the Small Pelagic Fishery have also established explicitly conservative exploitation rates to reduce risks of ecosystem effects through fishing. However, conservative exploitation rates may not be sufficient to prevent effects on predatory species when fishing is sufficiently concentrated in an area to cause localised depletion of the target species, and there is still uncertainty regarding this issue.

Spatial and temporal closures

An important case study in relation to managing localised depletion is the fishery for sandeels and seabird populations in the North Sea (Pikitch *et al.* 2012). Through a program of targeted research on seabird foraging dynamics, spatial catch limits were implemented to protect breeding populations following a substantial body of scientific evidence that suggested black legged kittiwakes (*Rissa tridactyla*) were particularly sensitive to declines in prey availability linked to industrial scale fishing.

Spatial allocation and other protection measures have been implemented and recently re-drafted in response to localised impacts of fishing of Atka mackerel (*Pleurogrammus monopterygius*) and groundfish, including pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*) on the Endangered (*US Endangered Species Act*, ESA) Stellar sealion (*Eumetopias jubatus*) in the Aleutian Islands and Bering Sea, Alaska. It has been suggested that depletion of these key prey by these fisheries can impact the condition, growth, reproduction, and ultimately the survival of Stellar sealions through competition and disturbance (Witherell *et. al*. 2000; Balsiger 2013).

In November 2010, existing seasonal, spatial and fishery effort provisions for the Bering Sea and Aleutian Island Management Areas were reviewed when the National Marine Fisheries Service (NMFS) conducted an assessment of the effects of these fisheries on *Endangered Species Act* listed species and implemented alternative closures and protection measures (Balsiger 2013). These new restrictions predominantly focused on the Atka mackerel and Pacific cod fisheries in the Aleutian Islands, with only a minor change made to the Atka mackerel fishery in the Bering Sea. A detailed impact statement suggested the fisheries were likely to impact Steller sealions and their designated critical habitat. This situation was highly controversial and ended in a US District Court hearing in December 2010 that required the NMFS to work in consultation with the North Pacific Fishery Management Council to develop a draft Environmental Impact Statement and provided five alternatives for spatial closures, catch and participation limits in three main fishery regions of the Bering Sea and Aleutian Islands that are to be supported by compliance and VMS (Balsiger 2013). The draft Environmental Impact Statement was open for public comment from May-July 2013 and is scheduled to be finalised by March 2014 (alaskafisheries.noaa.gov).

In situations where genetic sub-structuring is apparent in targeted stocks of small pelagic species, or where predictable spawning aggregations form on an annual basis, implementation of management zones provides an option for mitigating the potential ecological and single-species impacts of localised depletion. On this topic, Gaughan *et al.* (2002) made the point that under the tenets of precautionary management principles, when a fishery depletes part of a breeding stock that is spatially separated due to ecological, physical or oceanographic factors, then areas may need to be managed separately to reduce the likelihood of localised depletion.

Informing spatial management: the role of predator studies

A critical part of the aims of CCAMLR is to compare and analyse overlapping information on the critical foraging ranges and habitats of a suite of central place foragers and to a lesser extent, pelagic (or highly migratory species) predator populations, Antarctic krill distribution, movement and abundance, and the spatial behaviour of the krill fishery to develop small scale management or 'predator units' (Constable *et al*. 2000; Constable and Nicol 2002; Constable 2011). Similar strategies could be applied to fisheries targeting small pelagic fishes and cephalopods, and would be least disruptive to fishery production if the challenge of meeting the requirements of multiple predator species could be achieved concurrently (Constable 2011) through identification of shared areas of ecological significance (AES) as has been achieved in some ocean basins/ecosystems, including the northeast Pacific, Patagonian Shelf, and Kerguelen Plateau (Falabella *et al*. 2009; Block *et al.* 2011; Hindell *et al.* 2011). These regions incorporate multiple critical habitats for predators and Hindell *et al*. (2011) defined them as areas used for foraging by multiple predator species and many individuals. A similar large scale approach to identifying shared AES for predators was developed by the Atlas of the Patagonian Seas Project by Falabella *et al.* (2009) who assessed use of the Patagonian Sea by sixteen predator species.

Historically, this approach has tended to lean more toward central place foragers and predators that are restricted in their flexibility to move to alternate areas following depletion of prey in their focal foraging region. However, the extensive telemetry studies conducted by various research groups and integrated by Block *et al.* (2011) demonstrated that central place foragers and highly migratory pelagic species (23 species) exhibited various degrees of fidelity in areas of the California Current large marine ecosystem (CCLME), which suggested that they focused their foraging effort within the CCLME or the Gulf of Alaska, the North Pacific transition zone (NPTZ) (female elephant seal *Mirounga angustirostris*, salmon shark *Lamna ditropis* and Laysan albatross *Phoebastria immutabilis*), the subtropical gyre and north equatorial current (leatherback turtles *Dermochelys coriacea*, blue shark *Prionace glauca* and shortfin mako *Isurus oxyrinchus*), or the offshore oceanic 'Cafe´ region of the eastern Pacific and the Hawaiian Islands (black-footed albatross, albacore *Thunnus alalunga* and white shark *Carcharodon carcharias*). This information could potentially be used to inform spatially explicit management of fisheries in the future.

Move on rules

The best example of adaptive real-time spatial management of localised depletion is that provided in Dunn *et al.* (2013) for the herring (*Clupea harengus pallasi*) fishery in the Gulf of St. Lawrence, Canada, where vessels have to move from a management area for five days when the juvenile component of the catch exceeds 25% of retained catch per trip (Dunn *et al*. 2013). Dunn *et al.* (2013) also provide a useful summary of the use of 'move on rules'. Move on rules have some advantages over spatial and temporal closures that are coarse management measures, being fixed and not directly sensitive to triggers or encounter rates. Dunn *et al.* (2013) defined move on rules as guidelines that trigger closure of areas within a fishery for a temporary period when a catch (or bycatch) threshold is reached. This set of rules identifies the distance and time over which fishing must be displaced. Move on rules have also been used to limit the take of juvenile cod (*Gadus morhua*) in the North Sea.

Move on rules have potential as a targeted management measure in pelagic fisheries that overlap with critical foraging, breeding and migratory habitats of central place foragers and highly migratory marine predators; valuable discussion of this management option is provided by Dunn *et al.* (2011). The benefits of this approach include minimising recruitment over-fishing by stipulating triggers based on catch rates of juveniles, reducing discards and bycatch of threatened, endangered and protected species, and improvements in the economic efficiency of fisheries by potentially reducing time spent in unproductive areas.

7. Discussion

- This review identified that there are limited published studies designed to directly address the topic of localised depletion in pelagic fisheries.
- We identified examples of fisheries where indirect evidence suggested that localised depletion may have occurred.
- No published information was available to address potential differential impacts of localised depletion of small pelagic fish species by vessels with processing and freezing capacity and of smaller, wet boat operations.
- We provided published examples where changes in the foraging patterns and breeding success of predatory species have been linked to localised depletion of key prey.
- We highlighted examples where precautionary management responses have been developed to prevent ecosystem effects of localised depletion.
- The current lack of empirical evidence of localised depletion of pelagic fish species in Australian-managed waters should not prevent the further development of conservative management arrangements to prevent and/or mitigate the risk of this from occurring.
- A key point underscored during this review was a need to identify and evaluate existing and required information to assess localised depletion, and to differentiate indicators of localised depletion from those used to assess the status of stocks.
- This review also identifies options for preventing and/or mitigating the potential effects of localised depletion in the Small Pelagic Fishery, and acknowledges that some are currently in place.

Localised depletion of small pelagic fishes

A thorough search of the primary literature indicated there was a lack of published research that directly investigated localised depletion of small pelagic fish populations in a dedicated framework, and over a pre-determined timeframe that had built-in ecological and economic considerations. However, there was evidence that research and monitoring were being undertaken that could inform future management processes for small pelagic fishes and the supporting ecosystems within discrete fishery areas (e.g. Chesapeake Bay, Peru, and Alaska). It should also be considered that there are logistical challenges involved in assessing localised depletion of vagile small pelagic species, especially in cases where stock structure and movement dynamics, and links between environmental variability and pelagic habitat dynamics are poorly understood.

One published example of utilisation of existing data series to investigate localised depletion of small pelagic fishes was Carindale *et al*. (2011), who summarised information on the spatial patterns of the small pelagic fishery off Java. During this study, the authors interpreted sequential long-term declines in catch rates as serial depletion with distance from port and suggested that spatial expansions by fleets can mask detectable impacts of regional depletion. This suggests that assessing fine scale spatial patterns in behaviour of fishing fleets may be worthy of further consideration. For example, spatial models integrating VMS data have been used to assess fine scale patterns in fishing behaviour and could, in-turn, inform managers with regard to movement and re-distribution patterns of commercially targeted small pelagic fish species (Bertrand *et al.* 2007; Vermard *et al*. 2010).

Importantly, this review process highlighted the value of examining a range of precautionary management options for mitigating the potential economic, ecological, and social impacts of localised depletion of highly mobile, small pelagic fish species. The inherent difficulties and high costs of establishing empirical evidence for localised depletion, coupled with high levels of community concern about potential impacts of fisheries for low trophic level species suggests that the Small Pelagic Fishery should continue to adopt precautionary approaches that are consistent with “world’s best practice”. Direction in this concept is provided by the CCAMLR which implemented a range of precautionary management arrangements, including conservative exploitation rates and spatial management to prevent ecological impacts of localised depletion on predators.

Options to prevent potential ecological effects of localised depletion in the Small Pelagic Fishery

There are four main options for preventing or mitigating the effects of localised depletion in the Small Pelagic Fishery that include: conservative exploitation rates; increased spatial management through the establishment of smaller management units; spatial/temporal closures (especially for central place foragers); and move on rules. It is important to note that these options are not mutually exclusive and there may be benefits in establishing several or all of these options to complement the existing management strategies that have been established in the Small Pelagic Fishery.

Conservative exploitation rates

A research project currently being led by Dr Tony Smith (CSIRO) is explicitly assessing whether the current exploitation rates in the Small Pelagic Fishery are sufficiently conservative. The need to review the current harvest strategy for the fishery may need to be reassessed upon evaluation of the findings of that study. It is important to note that estimates of spawning biomass obtained for small pelagic species using the fishery-independent daily egg production method (DEPM) are typically conservative (negatively biased) because of the logistical constraints associated with surveying the spatial extent of the zones for which TACs are established. One option for addressing this logistical issue would be to develop predictive spawning habitat models (e.g. Webber and McClatchie 2010) to augment biomass estimates from stock assessment surveys used to recommend biological catch for quota species. Spawning habitat models have the potential to allow improved planning of survey areas prior to surveys (e.g. for sardine), as well as to improve our understanding of the ecological interactions between predators and small pelagic prey species (Webber and McClatchie 2010). It would be beneficial to assess the benefits of incorporating this type of information into population modelling processes for some quota species.

Spatial and temporal closures

Establishing spatial and/or temporal closures that include the foraging areas of central place foragers would significantly reduce the risk of the Small Pelagic Fishery causing trophic impacts on these species through localised depletion. For some central place foraging predators, spatial and temporal closures would act to minimise the risk of high bycatch levels (i.e. not target areas where there is a high density of that predator species in key foraging areas). The large spatial extent of the Small Pelagic Fishery suggests such closures would have a relatively minor impact on the available fishing area. Spatial and temporal closures could also be established to mitigate potential impacts on recreational fishers and/or their target species.

Move on rules

Move on rules have been established in several fisheries to prevent spatial and temporal concentration of fishing effort and reduce the risk of localised depletion occurring (Dunn *et al.* 2013). Move on rules could be implemented in the Small Pelagic Fishery in several alternative forms. For example, each of the current zones could be sub-divided into grid-squares (e.g. 10 by 10 nm) and the proportion of the zonal TAC (e.g. 5–10%) that could be taken from that grid square over a specified time period (e.g. month) could be constrained. Alternatively, the spatial distribution of catches could be monitored in “near or real-time” (e.g. using VMS and or logbook data) and if fishing was highly concentrated (i.e. providing potential for localised depletion to occur) fishers could be directed to move fishing operations to another location.

Key knowledge gaps

This review highlighted factors to be considered to understand the potential ecological impacts of localised depletion of small pelagic fishes and provided an opportunity to identify topics for consideration for research and monitoring. Knowledge gaps relating to these factors are followed by potential research and monitoring options:

- Biomass and recruitment dynamics of small pelagic species in key fishing areas.

This gap could be addressed via fine scale assessment of changes in size structure of fish in catches, and egg abundance as an index of spawning stock status. This option could potentially integrate existing data streams.

- Species-specific information on fishery fleet behaviour and movement patterns of small pelagic fish species has the potential to provide valuable insights into localised depletion and the recovery dynamics of localised aggregations.

This gap could be addressed via an evaluation of the use of spatial modelling approaches and high resolution VMS data to assess patterns in fleet behaviour (see Bertrand *et al*. 2007; Vermand *et al*. 2010). Spatially and temporally stratified hydro-acoustic studies could be evaluated as a means of assessing the fine-scale movements of small pelagic fish species (and recovery from depletion). This could be achieved by using commercial and fishery-independent vessels in key Small Pelagic Fishery areas that overlap with the critical habitats of central place foraging predators. This option could integrate an economic assessment of fishing in different regions.

- Stock structure of small pelagic fish species targeted by the Small Pelagic Fishery;

Stock structure questions could be addressed using modern genetic techniques to delineate boundaries and connectivity in small pelagic fish populations targeted by the Small Pelagic Fishery. This would allow spatial comparisons with the fishing areas of small pelagic fisheries, known foraging ranges of predators and current and potential stock and ecosystem-based management options.

- High resolution information on the foraging dynamics of key central place foragers and pelagic predators: ecological impacts of overlaps with fishery areas.

Questions specific to the foraging dynamics of predators of small pelagic species can be addressed through multi-disciplinary approaches that combine high spatial resolution biotelemetry and dietary analyses in pre- and post-fished areas over a range of space and time scales. Ecological impacts of competition between fisheries and central place foraging predators could potentially be assessed using a combination of individual-based and ecological modelling approaches at the spatial scale of fishery areas.

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Appendix 1.

Purpose

Background

1.1 On 19 November 2012, the Minister for Sustainability, Environment, Water, Population and Communities made the Final (Small Pelagic Fishery) Declaration 2012 (**Final Declaration**), which came into force on 20 November 2012.

1.2 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* (the EPBC Act).

1.3 The Declared Commercial Fishing Activity is prohibited for up to two years while the Expert Panel conducts an assessment and reports to the Minister on the activity. The Expert Panel commenced its assessment in February 2013.

Need

1.4 There remains uncertainty about the likelihood and impact of localised depletion of small pelagic species in the Small Pelagic Fishery arising from the operations of large mid-water trawl vessels. The Expert Panel needs to ensure that it has considered all available relevant information on the nature and extent of such impacts and is seeking a comprehensive review of the literature. The literature review must ensure that sufficient information is provided to allow the Expert Panel to determine the relevance of the information to the Declared Commercial Fishing Activity that is the subject of the Expert Panel's assessment.

1. Services

1.1 The Service Provider must:

(a) compile a report synthesising the literature identified. The report must:

(i) provide a summary of any evidence of localised depletion of fishing activities on the ecosystem and component species;

(ii) provide contextual details on the information to underpin a preliminary assessment by the reviewer of the relevance of the information to the Expert Panel's assessment. That contextual information should include, as appropriate:

(A) the scale of the localised depletion event in the context of the biomass available;

(B) the exploitation rate that caused the localised depletion; and

(C) the temporal and spatial parameters of the event; and

(iii) identify gaps in the knowledge base in relation to the issues identified above and potential areas of research to address these.

(b) provide the Expert Panel with an electronic copy of all the identified literature;

(c) provide a draft of the literature review (**Draft Literature Review**) to the Department in accordance with the timeframe specified in Schedule 2;

(d) meet with the Expert Panel prior to the commencement of the review and following the Expert Panel's consideration of the draft report. These discussions may be conducted as face-to-face meetings or by teleconference;

(e) provide a final version of the literature review (**Final Literature Review**) to the Department in accordance with the timeframe specified in Schedule 2; and

(f) if required by the Department or the Expert Panel, meet with the Expert Panel following submission of the Final Literature Review.

1.2 The Service Provider acknowledges that the Expert Panel will require a reasonable amount of time to review the Draft Literature Review and Final Literature Review.

1.3 If the Department or the Expert Panel requests amendments to the Draft Literature Review or Final Literature Review, the Service Provider must make the required amendments and resubmit the relevant review to the Department.

1.4 The literature review must seek to inform the Expert Panel's assessment by identifying:

(a) examples of localised depletion of small pelagic species that have resulted in a detectable impact on the ecosystem and its component species;

(b) examples of localised depletion of other prey species that have resulted in a detectable impact on the ecosystem and component;

(c) any information that addresses the differential impacts on localised depletion of vessels with processing and freezing capacity and of smaller, wet boat operations; and

(d) management measures used to avoid and address localised depletion, particularly in relation to small pelagic species.

Scope

1.5 The literature review relates to the potential of large mid-water trawl vessels targeting small pelagic species in the Small Pelagic Fishery to cause localised depletion of stocks of those species which may affect the sustainability of those stocks and predatory species for those stocks.

1.6 The Expert Panel acknowledges that 'localised depletion' is not a consistently defined term and that its interpretation is likely to vary across the relevant literature. It is important, therefore, that in reporting the results of the literature review that the various interpretations and/or definitions used are clearly identified.

1.7 The Expert Panel anticipates that examples of detectable localised depletion in Australian waters resulting from mid-water trawling, and from other fishing methods, for any marine species will be very limited. It is expected that the review will include a global search of the literature on localised depletion arising as a result of a range of fishing methods, and across a range of species. However, particular attention should be paid to identification of localised depletion of small pelagic species that arises from mid-water trawl and purse seine operation