CSIRO
MARINE RESEARCH

TARGETED REVIEW OF BIOLOGICAL AND ECOLOGICAL INFORMATION FROM FISHERIES RESEARCH IN THE SOUTH EAST MARINE REGION

FINAL REPORT

B. D. Bruce, R. Bradford, R. Daley, M. Green and K. Phillips

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CSIRO Marine Research, Hobart

*** National Oceans Office**

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Introduction

As part of the South East Marine Regional Planning, and, more specifically, of the Biological and Physical Assessment, the National Oceans Office (NOO) is in the process of consolidating scientific and technical information on various aspects of ecosystems within the South East Marine Region (SEMR). The main purpose of this assessment phase of the planning process is to provide the development and evaluation of management options necessary for preparation of the regional marine plan.

Objective of review

The objective of this review has been to consolidate the broad body of literature that has arisen from fisheries research on the biological and ecological characteristics of key exploited fish populations in the region and the effects of fishing on them.

Structure of review

This review is restricted to specific fisheries and key species within those fisheries as defined by the requirements of the National Oceans Office contract (Tables 1 and 2). It is in 'dot-point' format and by necessity (both due to this format and the time frame for completion) is a first step in this process of drawing together the wealth of information available in the SEMR. Information is confined to that available for the nominated species in Australian waters. In several cases, biological, ecological and or fisheries information is available for these or related taxa in other areas of the world (e.g. for co-occurring species in New Zealand). However, reviewing this much broader, literature set was outside the scope and time frame of this review. Some existing work has compared biological parameters of SEMR species to that for similar taxa from other areas and readers are directed to publications such as that by Koopman *et al*. (2000) for such information.

The SEF is the largest of the fisheries (in terms of spatial extent, species diversity and sectorial coverage) and is largely coincident in area with the SEMR. Many of the comments within the SEF account are relevant to the SEMR in general.

Table 1: Fisheries covered within this review.

South East Fishery (incl. SE trawl and non-trawl)
Southern Shark Fishery
Southern Rock Lobster Fishery
South Tasman Rise High Seas Fishery
Abalone
Stripey Trumpeter Fishery
Beach haul & recreational fishing for Australian Salmon
Snapper Fishery
Scallop Fishery
Patagonian Toothfish Trawl Fishery (Macquarie Island)
Jack mackerel fishery
Southern bluefin tuna & East coast tuna fisheries

Table 2: Key species covered.

Common name	Species
Blue eye trevalla	*Hyperoglyphe antarctica*
Blue warehou	*Seriolella brama*
Spotted warehou	*Seriolella punctata*
Blue grenadier	*Macruronus novaezelandiae*
Orange roughy	*Hoplostethus antarcticus*
Ling	*Genypterus blacodes; G. tigerinus*
Redfish	*Centoberyx affinis*
School whiting	*Sillago flindersi*
Mirror dory	*Zenopsis nebulosus*
John dory	*Zeus faber*
Flathead	*Neoplatcycephalus richardsoni, Platycephalus bassensis, Platycephalus* spp.
Jackass morwong	*Nemadactylus macropterus*
Gemfish	*Rexea solandri*
Ocean perch	*Helicolenus percoides, H. barathri*
Silver trevally	*Pseudocaranx dentex*
Royal red prawn	*Haliporoides sibogae*
Hapuka	*Poylprion oxygeneios*
Dogfish	*Centrophorus, Deania*
Skates	*Rajidae*
School shark	*Galeorhinus galeus*
Gummy shark	*Mustelus antarcticus*
Sawshark	*Pristiophorus spp*
Elephant fish	*Calliorhinus milii*
Southern rock lobster	*Jasus edwardsii*
Oreo dories	Various
Southern bluefin tuna	*Thunnus maccoyii*
Yellowfin tuna*	*Thunnus albacares*
Skipjack*	*Katsuwonus pelamis*
Albacore*	*Thunnus alalunga*
Swordfish*	*Xiphias gladus*
Blue shark*	*Prionace glauca*
Ray's bream*	*Brama brama*
Abalone Greenlip and blacklip	*Haliotis laevigata; H. rubra*
Stripey trumpeter	*Latris lineata*
Australian salmon	*Arripis trutta*
Snapper	*Pagrus auratus*
Scallop	*Pectin fumatus, Chlamys* spp.
Patagonian toothfish	*Dissostichus eleginoides*
Jack mackerel	*Trachurus declivis*
Red bait	*Emmelichthys nitidus*
Pilchard	*Sardinops sagax, S. neopilchardus*
Blue sprat	*Spratelloidies robustus*
Octopus	*Octopus maorum, O. pallidus*
Squid	*Nototodarus gouldi, Sepioteuthis australis*
Giant crab	*Pseudocarcinus gigas*

* Species covered briefly in the SBT and ECT fisheries – see below.

Format

Where appropriate, the review provides a brief description of the fishery. Where this is not provided, it is readily available in reviews such as Kailola *et al*. (1993) or in stock assessment reports published by various agencies (e.g. Smith and Wayte 2001). General comments on key uncertainties and ecological effects of fishing are included for major fisheries (e.g. SEF, STR) in some cases, for minor fisheries (e.g. striped trumpeter fishery) such effects are unknown or undocumented.

Key species accounts follow and include (where available) the following information under specific sub-headings (with the exception of pelagic species associated with the east coast tuna and offshore fisheries – see below):

Blank fields under sub-headings indicate that no information was available for that topic.

General (including family, general distribution, how species is caught and main management objectives).

Fishery research (stock size and structure, current and pre-exploitation age/size structure, current yield and projected yield, predicted trends in stock).

Biological parameters (growth parameters, longevity, mortality, size/age at reproduction, size/age at recruitment, length-weight parameters, area for which parameters derived).

Distribution and links to physical environment (known or inferred distribution and movement patterns, links to hydrology/other physical characteristics).

Reproduction (fecundity, temporal and spatial variability, dispersal mechanisms, recruitment variability (to nursery areas and to fishery), stock recruitment relationship).

Key inter-species interactions (diet, links to other species – e.g. predation, trophic guild).

Genetics/otolith microchemistry (population structure).

Fisheries habitats (key habitats where life history stages are found (e.g. larval distribution, nursery areas, adult habitat).

Effects of fishing (gear selectivity, effects of fishing on size/age structure, ecosystem effects of habitat disturbance, effects on dependant and interacting species and ecosystem implications of by-catch).

Key uncertainties
The main uncertainties that affect ecological risk, stock assessment and management descisions and that require further research input. These have been listed with the specific species in mind but several generic themes are apparent and are summarised in the introductory section of the report for the SEMR in general.

Format for east coast tuna and offshore fishery species

The format for key species in the east coast tuna and offshore fisheries differs from the above and these species (marked by * in Table 2) are handled in a more limited way as they generally have extremely broad distributions outside the SEMR and a considerable literature base exists for them and has been reviewed or summarised elsewhere. Key species in these cases follow the following format:

General (including family, general distribution, how species is caught and main management objectives).

Fisheries Research (brief overview of stock status globally and project trends under current management).

Life history (summary of the understanding of life history).

Distribution in the SEMR (where and when the species occurs in the SEMR, movement patterns within the SEMR and between the SEMR and other areas).

References
References have been provided at the end of each section, rather than as a single block at the end of the report.

Literature overview tables.
The review also includes literature overview tables of references by fishery and key species (Appendix 1) and these (>1080 references) are also available in a *Procite* database (CD enclosed). In both cases, references are either listed or searchable based on the above sub-headings for each fishery and key species.

References

Smith, A. D. M. and Wayte, S. E. (2001). Fishery Assessment Report: The South East Fishery 2000. Australian Fisheries Management Authority, Canberra.

Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A. and Grieve, C. (1993). Australian Fisheries Resources. Bureau of Resource Sciences, Canberra, Australia.

Koopman, M. T., Punt, A. E. and Smith D. C. (2000). Production parameters from the fisheries literature for SEF-like species. Australian Fisheries Management Authority Final Report. ARF Project **R99/0308**. Marine and Freshwater Resources Institute, Queenscliff, Victoria.

General ecological/biological issues and uncertainties for the South East Marine Region

The following list summarises the basic themes that have come from the key uncertainties listed for species within this review.

- Lack of information on the basic biology for many species.
- Incorrect or at least biologically meaningless parameters cited in the literature for some species. This is apparent in age and growth data. Several species, for example, have von Bertalanffy growth parameters cited which are rather dubious. These values are listed in the biological parameters tables for completeness but their veracity is questionable. This is particularly apparent with respect to t_0 values which in many cases have been overestimated because analyses have not included small size classes of fish (which are not readily sampled). The corresponding K vales thus may also be dubious. It was outside the scope of this review to assess the veracity of these respective parameter estimates.
- Movement patterns and their determinants are poorly known for many species due to poor ability to track movements (i.e. reliance on simple point–point movement data generated by standard tagging data does not provide information on a spatial scale sufficient to understand ecological responses to environmental cues and variability).
- Taxonomic difficulties still exist for the region, specifically for deep waters of the mid to lower slope and offshore. The ability for fishers to accurately identify species, in some cases (e.g. dogfish) is also an important factor in monitoring catches.
- Progress in habitat mapping has been substantial, but still lacks information relating species distribution to habitats on a spatial scale fine enough to establish key habitats for life history stages of many of the species.
- Many of the better known areas of the SEMR have been highly impacted by human activity, but there is very little information on these habitats 'pre-impact' from which to judge the magnitude of these effects. The ecological impacts of fishing are particularly poorly understood in most cases (i.e. effects of reducing populations of key species, the effects of changing size and age structures within the framework of community dynamics and the change in habitat complexity caused, in some cases, by fishing gears. In many cases the significant declines in species (e.g. gemfish and dogfish) have probably had significant ecological ramifications.
- Lack of process-based understanding.
- Tools–ecological models that integrate oceanographic, biogeochemical and ecological processes to increase understanding of the physical links within the ecosystem and to predict how natural variability and the impacts of human use effect ecosystem processes are currently being established to examine relationships between species and communities, but there is still a lack of adequate empirical data on which to base models.
- Interannual variability in the distribution, recruitment and availability of species to commercial and recreational capture is poorly understood for most species though widely accepted as significant.
- Broad impacts of climate change.
- Teasing out differences between effects of environmentally mediated variability/change and that caused by human impact.
- Ecosystem impacts of introduced marine species (e.g. New Zealand screw shells).
- Stock structure for most species
- Limited or no fishery independent data for most species
- Stock recruitment relationship is unknown in most cases
- Key predators and trophic links.
- Relationship between catch per unit effort (CPUE) and abundance is not well demonstrated and complicated by a variety of factors including fleet dynamics/fisher behaviour, market forces, behaviour of target species and environmental influences
- Discarding and high grading
- Unstandardised or lack of catch data across all sectors (many species subject to catch by a variety of sectors).

Specific fishery and key species accounts

South East Fishery (SEF) including the South East Trawl and South East Non-trawl fisheries (SETF and SENTF).

The Southeast Fishery (SEF) is a complex multi-species, multi-fleet fishery that uses a variety of different gears and covers a broad geographic region that is essentially coincident with the SEMR (Smith and Smith 2001). The SEF covers an area of 1.27 million km^2, however much of this area is in excess of 1,000 m in depth and is rarely fished (Larcombe *et al*. 2001). There are two main sectors: the South East Trawl Fishery (SETF) and the South East Non-trawl Fishery (SENTF) which overlap in both the species targeted and the areas fished. There are number of sub-fleets determined by geographic variation, gear type and target species within each sector. Management of the SEF is primarily via Individual Transferable Quotas (ITQs) and 16 species are currently under ITQ arrangements (Table 1). However in some cases, more than one species is landed under a combined ITQ (e.g. ocean perch and flathead). The Southern Shark Fishery (SSF) is not part of the existing SEF although it is similar in its geographic extent, and management issues for both fisheries interact. Current management arrangements are under review and a more intergrated manegement approach is to be adopted for fisheries in the region. However discussion of these arrangements are outside the scope of this review. Some vessels within the SEF are also endorsed for the SSF. AFMA is developing a more integrated management plan that would introduce a common management approach for the SETF, SENTF and the SSF.

The sectors are treated separately in this review although target species accounts have not been repeated unless there were different issues of ecological significance between them.

Table 1: Quota species within the SEF.

Species	Sector
Blue eye trevalla (*Hyperoglyphe antarctica*)	SENTF, SETF
Blue warehou (*Seriolella brama*)	SENTF, SETF
Spotted warehou (*Seriolella punctata*)	SENTF, SETF
Blue grenadier (*Macruronus novaezelandiae*)	SETF
Flathead (*Platycephalus* spp., *Neoplatycephalus sp*.)	SENTF, SETF
Eastern and western gemfish (*Rexea solandri*)	SETF, SENTF
Jackass morwong (*Nemadactylus macropterus*)	SENTF, SETF
John dory (*Zeus faber*)	SENTF, SETF
Ling (*Genypterus blacodes, G. tigerinus*)	SENTF, SETF
Mirror dory (*Zenopsis nebulosus*)	SETF
Ocean perch (*Helicolenus percoides, H. barathri*)	SETF
Orange roughy (*Hoplostethus atlanticus*)	SETF
Redfish (*Centroberyx affinis*)	SETF
Royal red prawn (*Haliporoides sibogae*)	SETF
Silver trevally (*Pseudocaranx dentex*)	SENTF, SETF
School whiting (*Sillago flindersi*)	SENTF

Formal stock assessments have not been undertaken for nine quota species (only seven species were formally assessed in 2000 – blue grenadier, blue warehou, spotted warehou, eastern gemfish, ling, orange roughy and redfish) and completion of stock assessments for the remaining species remains a high priority for the fishery (AFMA 2000, Smith and Wayte 2001).

Some species within the SEF are either targeted during their spawning aggregations (e.g. blue grenadier, orange roughy and, previously, gemfish) or most commonly taken during the period of spawning (e.g. blue and spotted trevalla). Apart from the direct effects of such aggregating behaviour increasing the vulnerability of capture, there is some evidence that vessel and trawl traffic within and around the spawning aggregations can interrupt spawning behaviour. How widespread such indirect effects are, is not yet known, but they may impact the success of spawning events.

Basic biological parameters for many target species in the SEF, and the SEMR generally, are still poorly documented and results from earlier studies (particularly ageing work) are sometimes inaccurate. Most outer-shelf and slope species appear to be much older and grow more slowly than initially thought and this has significant ramifications for stock assessments and estimates of sustainability. Many species taken as part of the SEF have distributions that extend well beyond its boundaries.

Data on several low valued fisheries in the SEMR and their target species is inadequate for stock assessment purposes and will likely remain so.

Several species show stochastic and, in some cases highly episodic, recruitment patterns that are not always well accounted for in stock assessment models. Recruitment links to environmental processes are suggested for several species though the mechanisms are poorly understood. Pelagic (off-shelf) production is now widely regarded as playing a significant role in determining the productivity of the SEF (and SEMR) ecosystem and many species previously thought to be primarily demersal in habit may feed in, or occupy various levels of the water column at different times (Bax *et al.* 2001, Bulman *et al*. 2001, Prince 2001 and references therein).

Research into management tools to cope with uncertainty has increased (Punt *et al*. 2001, Smith *et al*. 2001) however, as noted by Tilzey and Rowling (2001), research into the underlying causes of these uncertainties remains poorly resourced.

There are considerable difficulties in using standardised catch rates as a surrogate for abundance and stock trends in most SEF species due to changes in fishing practices and fleet dynamics, improvements in gear technology over time and the fact that measures of effort do not include searching time (Smith and Wayte 2001). The relationship between standardised catch rates and abundance is usually assumed to be linear but this is known to be unreliable for aggregating species. In most cases there are no measures of absolute abundance and few species for which fisheries independent data on biomass are available.

Considerable changes have occurred in the species composition on trawl grounds in the SEF since the beginning of the fishery in 1915, which are more than likely a direct result of trawling activities and significant declines have occurred in several target and non-target species (Andrews *et al*. 1997, Graham *et al*. 2001, Klaer 2001).

South East Trawl Fishery (SETF)

The SETF includes inshore otter trawlers, deepwater trawlers and Danish seiners (Smith and Wayte 2001). Prior to the introduction of quota management in 1992, greater than 100 trawlers were active in the SETF. This had reduced to 85 by 1998 (Larcombe *et al*. 2001). Fishing is primarily concentrated in 200 – 1000 m depth strata with greater than 50% of these strata fished with some intensity. Trawl effort has generally increased since the introduction of the ITQ system with increases occurring primarily in small, high effort areas rather than equally across the trawl grounds. Parts of the seafloor in the major SEF trawl grounds are reportedly swept in excess of 10 times per year (Larcombe *et al.* 2001). Quota species have comprised 80 – 93% of the total catch of the SETF in recent years. The non-quota species of dogfish (several species), king dory, spikey oreo, smooth oreo, barracouta, ribbonfish (southern frostfish) and squid made up 7% of the total catch and the remaining catch comprised 75 other species (Smith and Wayte 2001). Discards of mirror dory, redfish, ocean perch and eastern gemfish are considered to be a major issue in the fishery (Smith and Wayte 2001).

South East Non-trawl Fishery (SENTF)

The SENTF includes demersal longline and dropliners, gillnetters, trappers and purse seiners (Tilzey 1999). Three quota species have comprised 70 – 80% of the catch in recent years (ling, blue warehou and blue eye trevalla). Hapuka (*Polyprion oxygeneios*), jackass morwong and spotted trevalla comprised approximately 8% of the catch with the remainder comprising some 100 other species. Hapuka, bass grouper (*P. americanus*), dogfish (various species), gemfish, ling, redfish, ocean perch, blue grenadier and Ray's bream (*Brama brama*) are commonly taken by dropliners fishing for blue eye trevalla (Smith and Wayte 2001).

Recent reviews

Annual fisheries assessment reports for the SEF are complied by the South East Fishery Assessment Group (e.g. Smith and Wayte 2001) and include information on catches, biology, quantitative stock assessments and research/management directions. The SEF was the subject of a recent special volume of *Marine and Freshwater Research* (Volume 52, 2001). This is a valuable source of management, stock assessment and biological research information for the SEF and fisheries resources within the SEMR in general. It includes papers on the history of the fishery, resource assessment, biology, habitats, food webs, the perspectives of the fishing industry, quota trading and management (see summary by Smith and Smith 2001).

Several recent reviews have also been undertaken to collate information relevant to many SEF species (e.g. production parameters – Koopman *et al.* 2000). Kailola *et al.* (1993) also provide useful information on the SEF, its various target species and other fisheries that operate within the waters of the SEMR.

Websites

Websites with information relevant to fisheries, species and research in the SEMR include:

FRDC:	http://www.frdc.com.au/
AFMA:	http://www.afma.gov.au/
BRS:	http://www.affa.gov.au
NSW Fisheries:	http://www.fisheries.nsw.gov.au/
MAFRI:	http://www.nre.vic.gov.au/
SARDI:	http://www.sardi.sa.gov.au/
TAFI:	http://www.utas.edu.au/docs/tafi/TAFI_Homepage.html
CSIRO:	http://www.marine.csiro.au/
FishBase:	http://www.fishbase.org/

General comments

Fisheries habitats in the SEF

- Fisheries habitats and fish habitat associations in shelf waters of NSW and eastern Victoria have been described by Bax and Williams (2001) and Williams and Bax (2001).
- Deepwater habitats on seamounts and rises have been described by Koslow *et al.* (2000).

Bax and Williams (2001) concluded that the south east shelf system was structured by availability of food, unlike many other ecosystems, which are structured by predation. They also hypothesized that selective reduction of predators such as tiger flathead since the beginning of the fishery may have changed the structure of the fish community on the shelf. The SEF shelf ecosystem study also concluded that demersal fisheries were strongly linked to pelagic production (Bax and Williams 2001, Bulman *et al.* 2001). There also appears to be a strong influence from regional oceanography and primary productivity on year-to-year and seasonal catches of quota species (Prince 2001). Other influences, such as the recovery of seals in the region, are also likely to be impacting the SEF ecosystem. Current proposals to reduce or even eliminate discarding in the trawl fishery are also likely to have implications for the trophic dynamics of the SEF. These could arise both through reduced provisioning of scavengers, and also through changes in the trophic level of catches – fishing down the food chain (Pauly *et al.* 2000).

There are stong correlations of community structure with depth in the SEF and the SEMR in general (Gray and Otway 1994, Connell and Lincoln-Smith 1999, Williams *et al*. 2001 and Williams and Bax

2001). This is also a feature in the size distributions of many target species with size generally increasing with depth.

Williams and Bax (2001) also noted correlations between the spatial variation in fish community structure and seabed type, latitude and hydrography.

Links between life history stages and habitats

- Spawning for several species (e.g. blue grenadier, orange roughy, oreos) often occurs over specific habitats of limited geographical extent (e.g. canyons, seamounts) and is concentrated over relatively short periods of time.
- Larvae and larval distribution is poorly known for many targeted deepwater species. Larvae may either develop in near-surface waters (where it occurs rapidly e.g. blue grenadier) or in deeper waters where developmental rates are remarkably slow (e.g. orange roughy).
- Recruitment is often episodic with some species (e.g. orange roughy) undergoing years-decades of low recruitment.
- Some species (e.g. blue grenadier) have widespread nursery areas that include estuarine, shelf and upper slope habitats. Nursery areas for several deepwater species are poorly known.
- Possible that the large aggregations of fish occurring over topographical features like seamounts may result in significant nutrient input (via rain of faecal debris) to underlying benthos and this may be an important energetic input that is reduced when target species are depleted.
- Many key species increase in size with depth as individuals move from shallow water nursery areas to deeper water with age (Jordan 1997). This results in a partitioning of habitat and food resources between size/age groups within species, may reduce predation on smaller fish (by separating them from larger individuals) and gives adults acess to the most productive foraging grounds at the outer shelf and shelf break (Bax and Williams 2001).

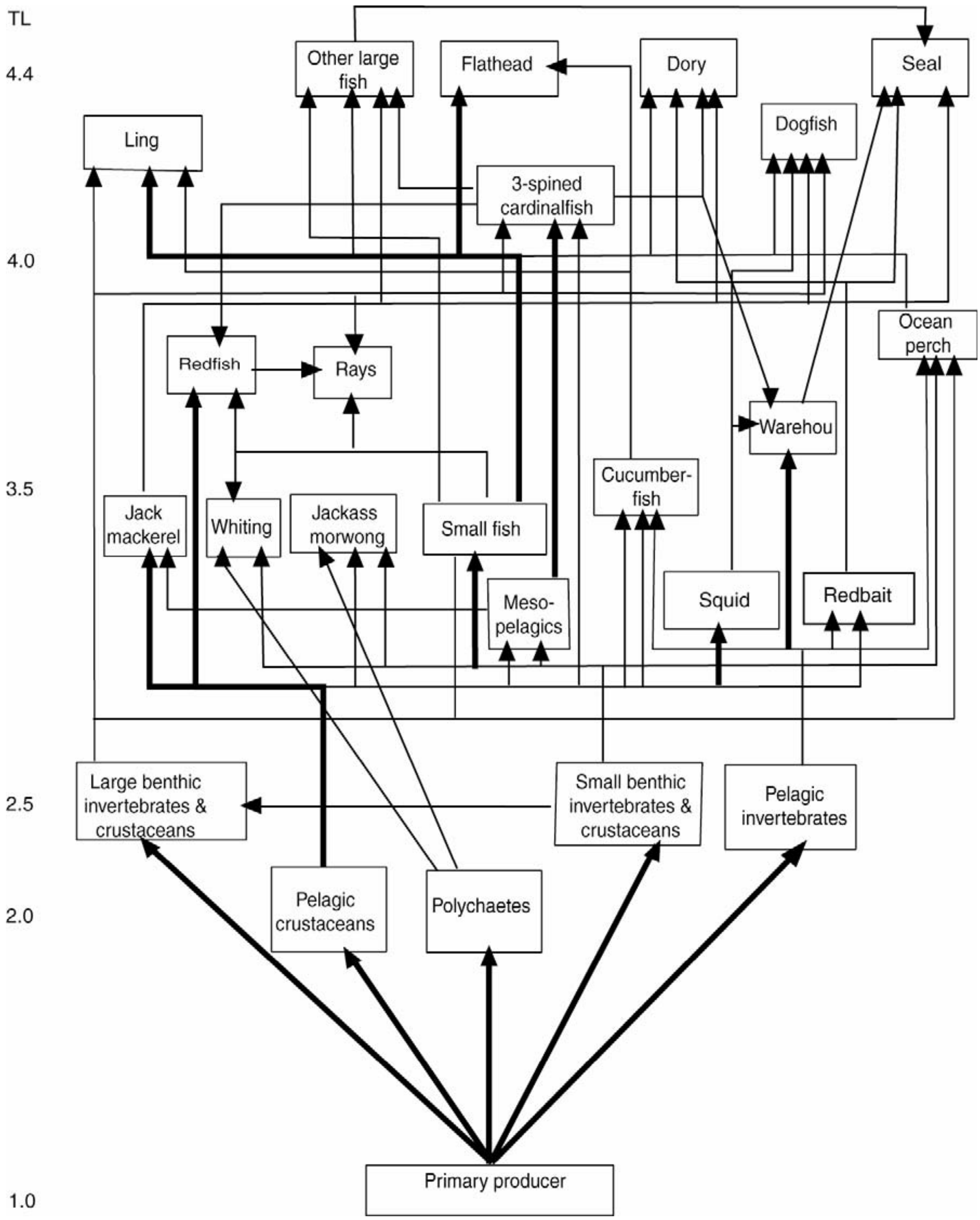
Effects of fishing

The long-term effects of fishing are poorly documented in the SEF and SEMR generally although they are likely to have been significant. Difficulties exist in interpreting trends particularly when the unexploited situation is poorly documented. Interactions between many species (both target and non-target) and other members of their associated assemblages, their habitat and how these change during different stages of their life history are poorly known for most species. This imparts considerable limitations for ecosystem-based management and requires novel ways to include uncertainty with respect to the use of such data within models (in the short term). It also requires a commitment to collect data appropriate to reducing key uncertainties in order for ecosystem-based management to be effective in the longer term. Ecosystem effects of fishing result from physical disturbance by gear, resuspension of sediments, and direct and indirect mortality of organisms (Larcombe *et al*. 2001). Impacts can manifest themselves as changes in abundance and size structure of affected populations and resultant changes in trophic structure (Gislason *et al.* 2000). Although the size structure of several exploited species is well documented for several target species in the SEMR, the implications and extent of effects of fishing are, for the most part, largely undocumented.

The SEF region contains various different habitats (see review by Bax and Williams 2001). These habitats include a mosaic of reef and non-reef areas, the former with varying degrees of habitat and biological complexity. Reef areas are vulnerable to the effects of fishing gear (removing macrobenthos and thus reducing habitat complexity) and the capacity of particular reef habitats to aggregate fish and sustain fish stocks is being reduced by these impacts (Bax and Williams 2001).

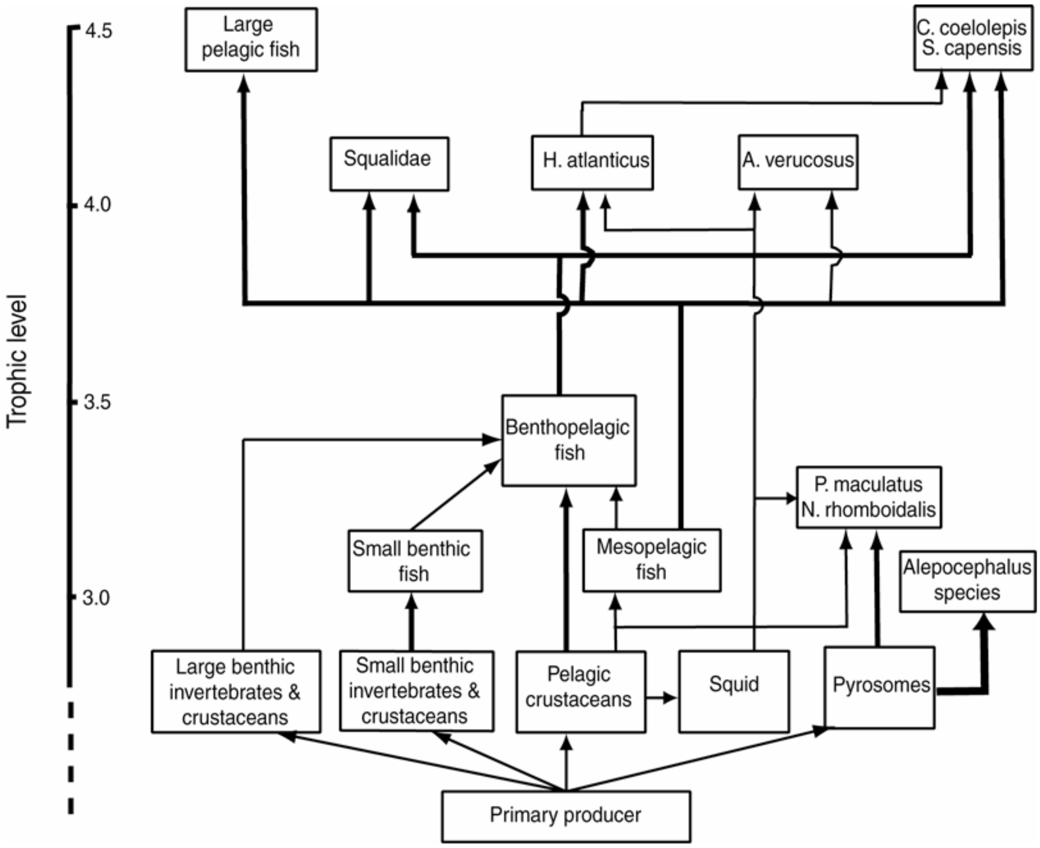
Trophic dynamics and community structure

- Apart from various studies documenting the diets of fish species in the SEF (see key species accounts for details), there have only been recent accounts of community trophic structures within the SEF (see below) by Bulman (2001), Goldsworthy *et al.* (*in press*) and He *et al*. (1999).



Community trophic structure for the SEF (from Bulman 2001)

- The primary source of productivity (both water column and benthic) for the SEF ecosystem is from pelagic, offshelf sources (plankton and micronekton) which is transported to the shelf system by upwelling (Bax and Williams 2001).
- Predation rates on commercial fish species by either other fish, mammals or birds in the system was low and Bax and Williams (2001) comment that this may be symptomatic of long term removal of predators by fishing. Productivity and the availability of prey are likely driving features of the system.



Community trophic structure for seamounts south of Tasmania ('Southern Hills'). *C. coelolepis* = Portuguese dogfish; Squalidae – dogfish; *H. atlanticus* = orange roughy; *A. verucosus* = warty oreo; *P. maculatus* = smooth oreo; *N. rhomboidalis* = spikey oreo; *Alepocephalus* = slick heads

Key knowledge gaps

- Fishing within the SEMR region has resulted in significant changes to species abundance, composition and the size composition of target and non-target species. System will change over time as other factors (e.g. increases in seal numbers) occur.
- Changes in the fish community have taken place in the past, and the consequences for current fishery production and value are unknown.
- Further changes might be expected under planned reduction or elimination of discarding in the SETF and their implications are similarly unknown.
- The implications for the fishery of current rapid recovery in seal populations.
- The reasons for, and impacts of, year-to-year variability in the SEF ecosystem (including primary productivity) on distribution and catches of quota species.
- Recruitment processes in general.
- Larval distribution and the processes that influence it are poorly known, particularly around seamounts. Larvae of many species are undescribed.
- Nursery area habitats are unknown for several species.
- Bentho-pelagic coupling processes in the deep-sea around topographical features.
- There is a need for further holistic studies to better understand the linkages between species, effects of major shifts in species abundance, species composition and size composition in the SEF and ecosystems in the SEMR in general.
- Detailed information is still lacking for trophic relationships in the SEF (and indeed the SEMR in general) and published diagramatic relationships are limited in scope, provide only for high level

taxonomic reference (at lower trophic levels) and may not capture details of some major species (e.g. blue grenadier).

- The SEF and the SEMR occur within a dynamic region of SE Australia where interannual variability in environmental forcing processes are high and our understanding of those processes (and hence the ability to distinguish between natural variability and anthropogenic effects on fisheries and ecosystems) is low.
- Habitat complexity is high in the SEF region and the effectiveness of refugia will depend on to what extent it encompasses preferred habitat for those species that inhabit it.
- The extent of refugia for species that occur over both trawlable and non-trawlable bottom (e.g. ling and redfish).
- The influence of fishing improvements that lead to targeting such refugia.

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SEF key species accounts

Blue eye trevalla (*Hyperoglyphe antarctica*)

Blue eye trevalla are members of the family Centrolophidae (Gomon *et al*. 1994). They occur in continental shelf and upper slope waters of the southern hemisphere off the coasts of southern Australia, New Zealand, South Africa, Tristan da Cunha and various seamounts. A second similar species, ocean blue eye (*Schedophilus labyrinthicus*), is sometimes caught off NSW and may occur in other areas of southern Australia. Blue eye trevalla are caught primarily by dropline off Tasmania and offshore seamounts in NSW although they are also caught in demersal trawl, particularly as by-catch in the blue grenadier fishery in 350 – 550 m (Smith and Wayte 2001). Midwater trawling has previously generated some high catch rates (e.g. 1988 – 1990).

The trawl sector of the fishery has been under quota management since 1992; followed by the non-trawl sector in 1998. Both sectors of the fishery are now managed under a global TAC with the objective to ensure spawning biomass does not significantly decline below 1994 levels and catch/catch rates remain within 1985 – 94 levels.

Fishery research

- No quantitative stock assessments have been made for blue eye trevalla and there are no estimates of virgin or current biomass. Stock assessment reports for the SEF are available for 1994, 1995 and 1997 (Smith and Wayte 2001).
- There have been noticable changes in catch rates and size composition in the non-trawl sector in all states – particularly noticeable in Tasmania where the main fishery is based (Smith and Wayte 2001).
- Declines in catch rates of older fish (> 65 cm FL) on offshore seamounts (Tas) recorded in early years of fishery prompted a shift to targeting of immature and newly recruited fish on slope

grounds and has led to belief that older fish may be more sedentary and susceptible to serial depletion (Baelde 1999).

- Baelde (1999) reviewed historical catch rates but noted that patterns for offshore seamounts were poorly documented. Catch levels and trends for continental slope areas vary between States, overall trends as follows:
    - Non-trawl catches – initially targeted large adults in slope and seamount grounds, catch rates declined rapidly from 1960s/70s and fishers moved inshore to target smaller fish. Catches stable at 200 – 300 t between 1980 – 1987, increasing to 600 – 800 t in early and mid 1990s (with the location of new grounds offshore seamount grounds off NSW). Sharp increase in 1997 followed by drop in 1998 in response to introduction of quotas.
    - Recorded annual trawl catches have ranged from 60 – 110 t since 1992.
- Three primary size classes in Tasmanian and NSW fishery – new recruits (45 – 55 cm) which dominate the fishery, young adults (55 – 65 cm) – consistently present but in low numbers and adults (> 65 cm) which are caught seasonally during spawning aggregations (Smith and Wayte 2001).
- Current size at maturity for both sexes similar to that recorded during the 1950s (Baelde 1996).
- No changes in catch composition/catch rates recorded in 1999 (Smith and Wayte 2001).
- No major concerns with current catch in short-term, although the species may be vulnerable to serial depletion in offshore regions if adult movement patterns are limited. Catch rates and size composition are influenced by gear selectivity and spatial patterns of effort.
- Recent, large catches reported on the Norfolk Ridge east of NSW, although a component of this catch (unknown) appears to be ocean blue eye (*Schedophilus labyrinthicus)* (A. Nicholls Ocean Fresh, Ulladulla, pers. comm.; A. Graham CMR, Hobart, pers. comm.).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	83.5	0.210						6-7	61			0.008657	3.1885	1 (Tas)
	90													2
									50			0.015	3.041	3 (SA)
							0.26-0.29							9 (SEF)
F	86.1	0.308	-0.38											4 (NZ)
							0.3							5 (NZ)
					0.2									6 (SEF)
														7 (Tas)
	107.0	0.08	-5.25	42			0.2	11-12	92	2-3	46-50	0.018	3.016	8 (SEF)
	96.0													
	130	0.03	-12.0	42				6	61					9 (SEF)
									71					10 (SEF)
M	81.1	0.308	-0.63									0.009626	3.173	4 (NZ)
	98.9	0.08	-5.86	39			0.2	8-9	62	2-3	46-50	0.018	3.016	8 (SEF)
	85	0.5	-14	39										9 (SEF)
									62					10. (SEF)

1. Webb (1979)
2. Winstanley and Smith (1982)
3. Jones (1988)
4. Horn (1988)
5. Horn and Massey (1989)
6. SEFAG (1998)
7. Williams (1989)
8. Baelde (1995)
9. Morrison and Robertson (1995)
10. Baelde (1996)

Distribution and links to physical environment

- Blue eye occur throughout the SEMR on outer shelf, slope and offshore seamounts and ridges.
- Depth distribution is size dependent with larger fish occurring in deeper water.
- Tagging of juveniles in New Zealand suggest juveniles (2 – 3 yrs) undertake significant movements along slope (Horn 1989) and this may also be the case in the SEMR based on tagging trials in NSW (Smith and Wayte 2001) although this is based on < 5 returns (Baelde 1999).
- Adults are believed to be more sedentary (Smith and Wayte 2001) although direct evidence for this is scant.

- Assumed movement of large fish from slope to offshore seamounts.

Reproduction
- Fecundity is determinate and high, females spawning 2 – 11 million eggs each year in 3 – 4 batches (Baelde 1996).
- Spawning is widespread in the SEMR and occurs over slope habitats and offshore seamounts in summer-autumn but its timing is regionally variable (March-April in Tasmania; April-June in NSW) (Baelde 1996, 1999, Smith and Wayte 2001).
- Recruitment to the fishery primarily occurs during spring (Nov-Dec) (Baelde 1999).
- Interannual recruitment variability unknown.
- Stock-recruitment relationship unknown.

Key inter-species interactions
- Adult blue eye trevalla are benthopelagic feeders and known to feed primarily on pyrosomes and to a lesser extent on midwater fish (*Lampanyctodes hectoris*), and squid (Winstanley 1978, Tilzey 1994). Winstanley (1978) found no evidence of benthic prey in stomach contents.
- Diets of larvae and juveniles are unknown but believed to be small pelagic fish, crustaceans and squid (Winstanley 1978).
- Key predators unknown, but catch loss occurs to marine mammals (e.g. killer whales) in some areas.

Population structure
- Genetic studies of stock structure have been conducted using allozyme techniques (Ward and Elliott 2001) and suggest a single population in Australian waters (Bolch *et al.* 1993).
- Recent genetic and otolith microchemistry testing of offshore NSW specimens (Norfolk/Lord Howe Ridge) is underway (I. Knuckey MAFRI, Queenscliff, pers. comm.).

Fisheries Habitats
- Larvae have not been described and larval distribution is unknown.
- Juveniles believed to be pelagic up to 45 cm FL with early stages associated with kelp rafts (Last *et al*. 1993).
- Young adults (55 – 65 cm) under-represented in commercial line catches (Baelde 1999) and may occur in habitats or behave in ways that reduce their vulnerability to capture by line fishing.
- Adults occur over rough ground and dropoffs over the continental slope and offshore seamounts where they form feeding and spawning aggregations (Tilzey 1994).

Effects of Fishing
- Current size at maturity for both sexes similar to that recorded during the 1950s (Baelde 1996).
- Fish-down of populations on seamounts apparent at various stages of the fishery.
- Large adults are vulnerable to dropline fishery during spawning aggregations (Smith and Wayte 2001).
- Large catches can be taken in midwater trawls.
- No major concerns with current catch in short-term, although the species may be vulnerable to serial depletion in offshore regions if adult movement patterns are limited and the sustainability of current catches is unknown.
- Catch rates and size composition are influenced by gear selectivity and spatial patterns of effort (Smith and Wayte 2001) because different sized fish occur in different areas.

Key uncertainties
- Complex spatial and seasonal variability in size structure and availability suggest movement patterns and behaviour of fish are key uncertainties. Perceived sedentary nature of adults may lead to serial depletion of adult stock unless catch rates in discrete areas can be appropriately regulated.

- The relationship between fish in offshore (e.g. seamount, offshore rise) and continental slope regions remains unclear.
- Medium size fish (55 – 65 cm) are poorly represented in the commercial catch (all sectors) suggesting that they are either in habitats yet to be actively fished or are behaving in fundamentally different ways to other size classes.
- Estimates of biological parameters (particularly t_0 and K) are poor, influenced by a lack of data for small specimens and are thus overestimated and underestimated respectively.
- Blue eye are vulnerable to fishing pressure during spawning aggregations, but the effects on spawning success are unknown.
- Relative contribution to recruitment from spawning on offshore seamounts (specifically, the contribution of large, highly fecund fish) is unclear.
- Aggregated behaviour during spawning suggests that blue eye may be suitable for fishery independent measures of stock size (e.g. acoustics or egg surveys), however such surveys would need to be regionally specific to capture spawning in multiple localities.
- Strong gear selectivity, changes in fishing efficiency, areas fished and depth specific size composition suggests considerable caution needs to be applied to interpretation of catch composition in fishery and that there are considerable implications for shifting effort between sectors (e.g. dropline to trawl).
- Niche overlap and relative abundance of blue eye vs ocean blue eye needs identification, particularly in offshore NSW waters.

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Blue warehou (*Seriolella brama*)

Blue warehou are members of the family Centrolophidae (Gomon *et al*. 1994). They occur over continental shelf and upper slope waters of southeast Australia (NSW – SA) and in New Zealand. Blue warehou are caught by trawl (SETF) and gill-net (SENTF), primarily in depths of 50 – 300 m. Blue warehou are sometimes caught as mixed catch with closely related spotted (silver) warehou (*Seriolella punctata*).

Both sectors of the fishery are managed by global TAC with the objective of ensuring that spawning stock biomass does not fall below 1994 levels. Different TACs apply for east and west of Bass Strait and with different objectives for the Commonwealth managed portion of the fishery. The objectives are to maintain the trawl catch (CPUE) west of Bass Strait above its lowest annual average level for the 1986 – 1994 period and for east of Bass Strait so that trawl CPUE does not significantly decline below the average level for 1994 (Smith and Wayte 2001).

Fishery research

- Quantitative stock assessments have been carried out since 1998 and now use an age structured integrated anlysis model (Punt *et al*. 2001). Stock assessment reports for the SEF are available for 1994 – 2000 (Smith and Wayte 2001).
- Assessments suggest that stock biomass peaked between 1987 and 1989, then dropped markedly to 1994. The most recent assessments indicate that biomass in recent years was less than 30% of levels in 1986/87 both east and west of Bass Strait, although there are indications that a strong cohort will be entering the fishery in 2001 – 2002 (Smith and Wayte 2001).
- Stock structure is conjectural. Blue warehou are assumed to be a single stock in southeast Australia, although models that follow this assumption fit the available data extremely poorly compared to those that assume different population responses east and west of Bass Strait. For simplicity, assessments are undertaken separately for eastern and western regions (Smith and Wayte 2001).
- The trawl catch is now dominated by 2 – 4 yr age classes; gill-net catch dominated by larger 4 – 6 yr age classes due to mesh selectivity (small fish are known to occur in areas targeted by gill net fishery) (Smith and Wayte 2001).

- Catches of large/old fish in western Tasmania declined markedly from 1986 (when the fishery was considered to be in a near virgin state) to 1999, however assessments in the west are considered to be less robust than those for eastern regions.
- Catch rates have been declining since peak in availability/abundance in 1989/90.
- Catches of females exceed those of males in the commercial catch, which cannot be explained on the basis of gear selectivity (Knuckey and Sivakumaran 2001).
- The inshore scalefish catch of blue warehou in Tasmania may be significant in some years (e.g. catches exceeded 270 t in 1998 – 1999, Lyle and Hodgson 2000).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	54.65	0.370	-0.67	10 12				3-4 3-4	40 40	2-5	30-50	0.03	2.9	1 (SEF) 2 (SEF) 3 (SEF)
F														
M														

1. BWAG (1998)
2. Koopman *et al*. (2000)
3. Knuckey and Sivakumaran (2001)

Distribution and links to physical environment

- Occurs throughout SEMR from NSW to South Australia including Tasmania and Victoria
- Adults found to 500 m.
- Perceived to be a highly mobile species and believed to undertake extensive movements in relation to spawning and in response to environmental conditions (Gavrilov and Markina 1979, Knuckey and Sivakumaran 2001).
- Suggested that movements and availability linked to water temperature/hydrology (Smith and Wayte 2001).

Reproduction

- Determinate annual fecundity – three batches of eggs spawned per season (430,000 – 1,350,000 eggs per fish between 38 and 55 cm), 417 ± 99 oocytes g^{-1} (Knuckey and Sivakumaran 2001).
- Spawning occurs in winter, some regional differences in timing (May-August east of Bass Strait; June-October west of Bass Strait) (Knuckey and Sivakumaran 2001).
- Back-calculated spawning dates (from otolith microstructure) range from 21 June to 6 September (Bruce *et al*. 2001)
- Two main spawning areas, the primary currently being off western Tasmania/Victoria. Smaller spawning area off southern NSW/eastern Victoria, although it is noted that spawning in this area may well have been more significant historically.
- Maximum age approximately 10 yrs (Smith and Wayte 2001).
- Fishery (and stock assessments) subject to the effects of strong year classes recruiting to populations (1996-year class strongest to date).
- Populations east and west of Bass Strait appear to have different patterns of recruitment.
- Reasons for recruitment variability unknown.

Key inter-species interactions

- Adult blue warehou are pelagic invertebrate predators and feed primarily on pyrosomes (Bulman *et al*. 2001).
- Diets of larvae and juveniles are unknown. The occurrence of juveniles in inshore waters (coastal bays and estuaries) suggests that their diet differs from adults.

- Key predators unknown, although there are records of blue warehou in stomach contents of school sharks.

Population structure

- There have been no genetic studies to determine stock structure (Ward and Elliott 2001) and blue warehou are assumed to be a single stock in the SEMR. However, several data do not fit the single stock model and separate stock assessments are carried out east and west of Bass Strait (see *Fisheries Research* sections above).
- Distribution of larvae, geographically separate spawning areas, inferred recruitment patterns and differences in size/age compositions suggest that there may be separate populations east and west of Bass Strait or at least that populations in these areas respond differently (Bruce *et al* 2001, Knuckey and Sivakumaran 2001, Smith and Wayte 2001).

Fisheries Habitats

- Larvae from southern Australia have been described (Bruce *et al*. 1998) and occur in shelf waters. They have been recorded from southern NSW, Victoria (including Bass Strait, Tasmania and South Australia (Bruce *et al*. 2001).
- Late stage larvae and small juveniles often associated with jellyfish and flotsum in coastal and estuarine waters (Last *et al*. 1983, Bruce *et al*. 2001).
- Sub-adults inhabit coastal bays and sometimes occur in large numbers in estuaries.

Effects of Fishing

- Cui *et al*. (2001) concluded that size at maximum selectivity was not linearly proportional to mesh size for blue warehou. Gear selectivity studies are complicated by the spatial variability in abundance and size structure (particularly with depth).
- Smith (1999) noted that there were differences in the selectivity of trawl and gillnets with older and larger fish taken in the gillnet sector, particularly east of Bass Strait.
- The dynamics of the fishery have changed over the last two decades but there is no analytical means of separating changes in catch rates due to abundance with those due to fleet dynamics (Smith and Wayte 2001).
- Transfer of non-trawl quota to trawl quota could potentially reduce the reproductive capacity of the blue warehou stock. However, there have already been significant declines in the abundance of larger fish targeted by gillnets (Knuckey and Sivakumaran 2001).

Key uncertainties

- Stock structure remains a key uncertainty for blue warehou and, in particular, the relationship between populations east and west of Bass Strait.
- Recruitment variability and the influence on it of environmental forcing in assessing trends in stock and setting sustainable TACs (the current ability to estimate poorly recruited year classes is low).
- Environmental effects on distribution, movements, availability and recruitment.
- Influence of changes in fleet dynamics on catch rates.
- Blue warehou may be suitable for egg and or acoustic surveys as fishery independent estimate of biomass (fisheries independent data are currently lacking).
- The magnitude, age and size composition of discarded catch requires confirming and monitoring.
- More data on recreational catch required.
- Further trophic studies may offer some insight into the links between recruitment dynamics, movement patterns, availability and environmental forcing.

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Spotted warehou (*Seriolella punctata*).

Spotted trevalla are members of the family Centrolophidae (Gomon *et al*. 1994). They are recorded from NSW, Victoria and Tasmania and also occur in New Zealand and may occur in South America. Adults occur over the outer shelf and slope to depths of 650 m (Gomon *et al*. 1994). Spotted trevalla are caught primarily by trawling, although a small tonnage (36 t in 1999 and 5 t in 2000) is taken in the SENTF. Spotted warehou were not considered to be a target species in the SENTF in earlier years due to the market preference for blue warehou. However targeting spotted warehou has recently become more common.

Management of the trawl sector is by TAC with the objective to ensure that the spawning stock biomass does not significantly decline below the 1994 level.

Fishery research

- Quantitative stock assessment commenced in 2000 with the model currently under further development. Stock assessment reports for the SEF are available for 1994 and 2000. There are no estimates of virgin biomass (Smith and Wayte 2001).
- CPUE is spatially and interannually variable (Smith and Wayte 2001). Catches reach a seasonal peak during the spawning period in winter-spring, although there is marked interannual variability in catches.
- The availability/abundance of spotted warehou has increased over recent years – especially associated with the winter blue grenadier fishery off western Tasmania (where catches of spotted trevalla have doubled since 1998). Catch in 1998 was 2,412 t; 1999 catch was 3,253 t and the 2000 catch was 3,726 t (which was 77% of actual TAC) (Smith and Wayte 2001, SEFAG 2001).
- Mixed catches with blue warehou occur and early catch statistics combined both species under the name of "Tassie trevally".
- Industry members report no concerns with the stock status of spotted warehou.
- Discarding remains an issue due to marketing problems (Smith and Wayte 2001).
- Fishing mortality is estimated to be less than 10% (SEFAG 2001).
- The 2001 assessment concluded that the fishery has had little impact on the stock with current biomass levels similar to those in the late 1980s (SEFAG 2001).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	51.25	0.464	-0.65	14 23			 0.33	4 3	40 40					1 (SEF) 4 (SEF)
F	65 55	 0.36	 -0.2	11				3-4 3	40 40	3-6		 1.53E-5	3	2 (SEF) 3 (SEF) 4 (SEF)
M	65 55	 0.36	 -0.2	11				 3	 40	3-6				2 (SEF) 4 (SEF)

1. Central Ageing Facility - cited in Smith and Wayte (2001)
2. Smith (1989)
4. Koopman *et al*. (2000)
3. Bax and Knuckey (1998) - cited in Smith and Wayte (2001)

Distribution and links to physical environment

- Spotted trevalla occur throughout the SEMR in shelf and slope waters to a depth of 650 m (Gomon *et al*. 1994).
- Size specific patterns of movement/distribution with older and larger specimens occurring in deeper water.
- Environmental effects (e.g. water temperature) have been suggested to influence catchability and recruitment, industry comments during port visits (see Smith and Wayte 2001), although the causal factors are unknown and data are sparse.

Reproduction

- Fecundity is unknown.
- Spawning occurs in late winter-early spring (Kailola *et al*. 1993).
- Back-calculated spawning dates (from otolith microstructure) range from 1 July to 17 August with some evidence of regional variability in timing with spawning dates slightly later in Tasmanian waters compared to NSW/eastern Victoria (Bruce *et al*. 2001).
- Major spawning areas located off western Tasmania and southern NSW although the distribution of larvae suggests spawning occurs more or less continuously between these regions (Bruce *et al*. 2001).
- Recruitment is variable with a strong year class (spawned in 1993) currently passing through the fishery (Smith and Wayte 2001).

- Stock recruitment relationship is unknown.

Key inter-species interactions

- Adult spotted warehou are pelagic invertebrate predators and feed primarily on pyrosomes (Bulman *et al*. 2001).
- Diets of larvae and juveniles are unknown. The occurrence of juveniles in inshore waters (coastal bays and estuaries) suggests that their diet differs from adults.

Population structure

- There are no published genetic studies of stock structure (Ward and Elliott 2001).
- The distribution of small larvae (< 5 mm TL) is contiguous between western Tasmania around the southern Tasmanian coast to southern NSW suggesting widespread spawning and a continuous link between regions in southeast Australia (compared to blue warehou), although peak abundances of larvae are present off western Tasmania and southern NSW suggesting main spawning activity in each of those areas (Bruce *et al*. 2001).

Fisheries Habitats

- Larvae from southern Australia have been described (Bruce *et al*. 1998) and occur in shelf waters. They have been recorded from southern NSW, eastern Victoria and Tasmania (Bruce *et al*. 2001).
- Late stage larvae and small juveniles often associated with jellyfish and flotsum in coastal and estuarine waters (Last *et al*. 1983, Bruce *et al*. 2001).
- Subadults occur in large coastal embayments (Kailola *et al*. 1993).
- Adults in shelf and slope waters to depths of 650 m (Gomon *et al*. 1994).

Effects of Fishing

- Similar gear selectivity to blue warehou, but little specific data.
- The 2001 assessment concluded that the fishery has had little impact on the stock with current biomass levels similar to those in the late 1980s (SEFAG 2001).
- Other implications of stock depletion unknown.

Key uncertainties

- Reproductive biology not well documented and fecundity is unknown.
- The stock structure is still unknown but the single stock model appears to fit the current data well.
- Spatial dynamics of the population are highly complex and poorly understood on both a seasonal and interannual scale. Depth-size relationship and spatial patterns of effort needs to be taken into account when assessing size/age structure data.
- Environmental forcing of recruitment and catchability/availability is believed to be important, but the processes responsible are unknown.
- Assessments and the use of CPUE as an indicator of abundance are complicated by the interannual variability in recruitment and catchability/availability, the aggregating nature of the species, the confounding between size-depth relationship and gear selectivity and in changes in fleet dynamics.
- Stock-recruitment relationship is unknown.

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Blue grenadier (*Macruronus novaezelandiae*)

Blue grenadier are members of the family Macruronidae (Gomon *et al*. 1994). They occur in both Australia and New Zealand over continental shelf and slope waters to depths of 1,000 m (although are most common between 200 – 700 m) (Ayling and Cox 1982, Kailola *et al*. 1993). They are caught primarily by demersal trawl, but also caught by pelagic nets at night with the highest catch rates coming from winter spawning aggregations on the west coast of Tasmania. The fishery is divided into two sub-fisheries based on “spawning” and “non-spawning” fish (Punt *et al*. 2001).

The trawl fishery has been managed via TAC since 1992 (Punt *et al.* 2001) with the objective of maintaining the spawning stock biomass above 40% of its virgin (average 1979 – 1988) level.

Considerable data and assessments exist for this species in New Zealand waters.

Fishery research

- Quantitative stock assessments have been undertaken annually since 1998 using an age-structured integrated analysis model that includes catch, discards, standardised catch rates, length-at-age, catch-at-age data and estimates of absolute abundance based on the egg production method (Punt *et al*. 2001). Stock assessment reports for the SEF are available for 1994, 1995, 1997, 1998, 1999 and 2000 (Smith and Wayte 2001).
- Original estimates of at least 30,000 t for virgin stock biomass by acoustic surveys and stock reduction analyses (Smith and Wayte 2001). Subsequent estimates of spawning stock biomass 30,000 – 230,000 t with 52,000 – 104,000 t corresponding to the most plausible set of assumptions.
- Egg survey analyses estimated spawning biomass at 83,660 – 100,073 t in 1994 and 59,727 – 71,376 t in 1995 (Bulman *et al*. 1999).

- Punt *et al.* (2001) estimated that spawning biomass declined from a peak in 1989/91 to 1999 (although fishing mortality remained at < 6% for each sub-fishery) as a result of several years of poor recruitment between 1988 and 1993.
- The fishery has two main components – a “non-spawning” fishery which takes fish of primarily 4 – 5 years of age throughout the SEMR and a “spawning” fishery which targets the spawning aggregation on the west coast of Tasmania between May and September and takes fish of over 10 different year classes including large, old fish (Smith and Wayte 2001).
- Allocated TAC was 11,921 t in 1999 – 1999 SEF2 landed weight was 9,326 t (78% of the allocated TAC) (Smith and Wayte 2001). The 2000 agreed TAC was 10,000 t with an actual TAC of 11,938 t (Smith and Wayte 2001). TAC agreed in 2001 was 10,000 t (actual)/12,230t (trawl fishery only).
- An assessment of blue grenadier in May 1997 indicated that fishing had not had a major impact on the stock as a whole, and that a 10,000 t annual catch should be sustainable (Smith and Wayte 2001). Further assessments in 1998 and 1999 also indicated a TAC of 10,000 t for 20 years has a low risk of reducing the spawner biomass to below 40% virgin, but it was extremely sensitive to whether egg survey estimates were regarded as a measure of absolute or relative abundance (Smith and Wayte 2001).
- Commercial catches of the “non-spawning” fishery declined between the late 1980’s and 1997 (Punt *et al.* 2001) but improved in 1998 – 2000 due to the incoming strong year classes of 1994 – 95 (Smith and Wayte 2001).
- Growth rates in the strong 1994-year class reported to be lower than average and may influence the rate at which these fish enter the fishery (Smith and Wayte 2001). This may indicate a density dependent response of the population.
- Results of a risk analysis predict an increase in spawning biomass over the next 5 – 10 years as a result of the strong 1994- and 1995- (and perhaps the 1996-) year classes, although the extent of this increase remains uncertain (Punt *et al.* 2001). The most recent assessment indicates the peak would occur during 2001 followed by a decline as those year classes move out of the fishery (R. Thomson CMR, Hobart, pers. comm.).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	100.1	0.17	-0.38											1. (SEF)
	95.6	0.226	-1.22									0.743E-5	2.852	4. (Tas)
F	101.o	0.18	-0.58					4-7	73			3..93E-6	2.95	1. (SEF)
							0.2							2. (SEF)
				25										3. (SEF)
	99.3	0.203	-1.48									0.7528E-5	2.8498	4. (Tas)
M	95	0.2	-0.86									4.84E-6	2.89	1. (SEF)
							0.31							2. (SEF)
				25										3. (SEF)
	90.7	0.256	-1.21									1.3402E-5	2.712	4. (Tas)

1. Smith (1991)
2. Evans (1986)
3. Smith (1994)
4. Kenchington and Augustine (1987)

Distribution and links to physical environment

- Blue grenadier occur throughout the SEMR from central NSW around the south coast to the western GAB (including Tasmania).
- Adult fish migrate to and from the principle spawning area(s); however the rate of migration is unknown for either sex (Bulman *et al.* 1999), and they can be found in the spawning area year round, albeit with declining mean length through the season (Smith 1994).
- Pulses of ripe females enter the spawning fishery on the west coast of Tasmania and data suggest that these fish may not be available to the fishery after they have spawned (Smith and Wayte 2001). This is presumeably due to their movement off the spawning grounds or to a behavioural response that renders them less susceptible to capture.

- They undergo diurnal vertical migrations, moving into the water column to feed at night on lanternfish (see below) (Bulman and Blaber 1986).

Reproduction

- Blue grenadier are isochronal spawners (Gunn *et al.* 1989). Estimates of potential annual fecundity (PAF) vary between years. Regression equations for potential annual fecundity (Bulman *et al*. 1999).

1994: PAF = 502136.755 + 368934.714 x weight (kg); R^2 = 0.222, n = 40
1995: PAF = 127020.244 + 562932.612 x weight (kg); R^2 = 0.269, n = 51

- Spawning is protracted and occurs primarily off the west coast of Tasmania during winter and early spring. The onset of spawning varies between years and may be linked to water temperature during autumn and early winter (Gunn *et al*. 1989).
- Limited spawning may occur off northeast Tasmania/Victoria in some years based on the occurrence and distribution of small larvae in those areas, (Gunn *et al*. 1989, Bruce *et al*. 2001).
- Back calculated spawning dates range from 9 May to 2 October (Gunn *et al.* 1989, Bruce *et al.* 2001).
- The main transport vector for larvae from the west Tasmanian spawning grounds to eastern Tasmania nursery areas is via the Zeehan Current (Lyne and Thresher 1995).
- A persistent northern flowing current on the shelf between eastern Bass Strait and Bermagui appears to be the main transport vector for larvae in southern NSW (Bruce *et al*. 2001).
- Extended periods of low-level recruitment occur in the population (e.g. 1989 – 1993). Variability in recruitment has a marked effect on catch rates in the non-spawning fishery due to its reliance on a small number of year classes.
- Recent inclusion of discards suggest that interannual variability in recruitment is higher than previously recognised and generally under-estimated in previous stock assessments (Punt *et al.* 2001).
- The steepness of the stock recruitment relationship in current stock assessments is taken to be 0.9 (Smith and Wayte 2001).

Key inter-species interactions

- Adult blue grenadier are mesopelagic predators and feed primarily on the lanternfish (*Lampanyctodes hectoris*) and pelagic crustaceans which they target at night during vertical migrations (Bulman and Blaber 1986).
- Bulman and Blaber (1986) also noted some regional and seasonal differences in diet, possibly related to prey abundance but in all cases mesopelagic fish dominated.
- The diet of juveniles contains a higher frequency of crustaceans, than adults, in areas of the outer shelf (Bulman and Blaber 1986) but mesopelagic fish were still important. Diets of juveniles in inshore nursery areas are unknown.
- Diet of preflexion larvae off the west Tasmanian coast dominated by tintinnids (Thresher *et al.* 1992).
- Adult blue grenadier predate on juveniles during the summer months (Blaber and Bulman 1986).
- Dietary studies on adults and larvae have also been undertaken in New Zealand (see Kuo and Tanaka 1984, Murdoch 1990).

Population structure

- Genetic studies of stock structure have been conducted using allozyme techniques (Ward and Elliott 2001) and data suggest a single stock in Australian waters (Milton and Shaklee 1987) that is distinct from New Zealand where the species is represented by multiple stocks with different spawning areas (Livingston and Schofield 1996).
- Milton and Shaklee (1987) found circumstantial evidence for a differential spawning migration by fish with particular genotypes from eastern Tasmania to the west coast although the implications of this were unclear.

- The implications for stock structure of a second possible spawning area off northeast Tasmania/eastern Victoria are similarly unclear (Bruce *et al*. 2001).

Fisheries Habitats
- Larvae from southern Australia have been described (Bruce 1988, 1998) and have been recorded from northwest Tasmania around the southern Tasmanian coast to eastern Tasmania and between Bermagui (NSW) and Pt Hicks (NE Vic) (Thresher *et al.* 1988, Bruce *et al.* 2001).
- Adult blue grenadier occur on the continental slope in depths of 200 – 700 m but have been recorded as deep as 1,000 m (Kailola *et al.* 1993).
- Spawning appears to occur in the vicinity of canyons on the continental slope.
- Juveniles (20 – 30 cm) occur in estuaries in southeast Tasmania and over the outer shelf in western and eastern Tasmania, eastern Victoria and in some years off southern NSW (Gomon *et al*. 1994, Bruce *et al*. 2001).

Effects of Fishing
- Logistic gear selectivity curve parameters (trawl) were recently estimated based on field trials (X. He CMR, Hobart, pers. comm.).

Mesh	90 mm diamond		90 mm square		102 mm square		Market	
	s1	s2	s1	s2	s1	s2	s1	s2
	0.174739	40.68	0.174739	46.0	0.166855	58.77	0.0	0.0

- The inclusion of seal exclusion devices may increase the loss of fish (and decrease the survival of lost fish).
- The winter fishery targets the spawning aggregation on the west coast of Tasmania.
- An assessment of blue grenadier in May 1997 indicated that fishing had not had a major impact on the overall stock (Smith and Wayte 2001).
- Variability in age-size structure appears to be primarily driven by recruitment variability, growth rates and changes in the availability of fish as a result of movement and behaviour.

Key uncertainties
- Interactions with seals have lead to trials of Seal Exclusion Devices (SEDs) in demersal and pelagic trawls over the west Tasmanian grounds with mixed success. The development and trial of SEDs is continuing under a current project (R. Tilzey BRS, Canberra, pers. comm.). Projected increases in seal populations are likely to see an increase in seal interactions in this and other fisheries and will present significant management issues for the SEMR.
- Inclusion of discarding rates in the stock assessment model has seen an improvement in the estimation of recruitment variability and further monitoring is required. Catch loss (and mortality of fish escaping) due to SEDs may be an issue in future.
- Movement dynamics into and out of the spawning area, particularly the rate of turnover of females on the spawning ground, are unknown and have major implications for estimates of biomass based on egg survey methods.
- The confirmation and location of the possible eastern spawning area as well as its implications for stock assessments on stock require further investigation.
- Absolute biomass is still poorly determined by the assessment model and relies on egg survey data – if this is over-estimated, the risk of depletion from the current 10,000t TAC could be severely under-estimated (R. Thomson CMR, Hobart, pers. comm.). Further data required on spawning behaviour, reproductive biology and the proportion of non-spawners in order to reduce uncertainty around biomass estimates based on egg production.

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Orange roughy (*Hoplostethus atlanticus*)

Orange roughy are members of the family Trachichthyidae (Gomon *et al*. 1994). They are dominant members of the fish community at 700 – 1200 m around southern Australia and New Zealand on the continental slope, seamounts and oceanic rises (Koslow *et al*. 1994). They are also widely distributed in the Atlantic, Pacific and Indian Oceans (Gomon *et al*. 1994). Orange roughy are taken by demersal trawl in the SETF and form a major component of the fishery on the South Tasman Rise (STR) on the edge of the Australian EEZ where they form a straddling stock that is managed by both Australia and New Zealand. Small numbers of orange roughy are also taken in the Great Australian Bight and on the Lord Howe Rise.

Orange roughy are managed by TACs which are set separately within five management zones (Eastern, Southern, Western, Cascade Plateau and the South Tasman Rise), with the objective of maintaining the spawning biomass above 30% of that at the onset of significant commercial fishing in 1988 (except in the western zone where a reference year of 1985 is used) (Smith and Wayte 2001).

Considerable data and assessments also exist for this species in New Zealand waters (e.g. Francis and Smith 1995, Clark 1999, Clark 2001, Clark *et al*.2000 and references therein).

Fishery research

- Quantitative stock assessments for the Eastern Zone have been carried out in 1994 (Smith and Wayte 2001) and currently use an age-structured integrated analysis model (Punt *et al*. 2001).

Information is presented by management zone.

SEF Eastern Zone

- 2000 TAC: 2,000 t, catch 2,000 t.
- Stock size is currently estimated to be 10 – 26% of virgin (Wayte and Bax, 2001).
- Several estimates of biomass have been made for the St Helens Hill aggregation. Initial estimates of a biomass of 95,000 – 110,000 t were made by stock reduction analyses derived from catch data, trends in CPUE and annual acoustic estimates from 1990 – 1993 (Anon 1994). Koslow *et al*. (1995) reported 96,900 t as an estimate of virgin spawning stock biomass based on catch history and a mid-season stock biomass of 34,592 t and that the stock was at 28% of virgin by the end of the season in 1992. Kloser *et al*. (1996) estimated the prefishing biomass on St Helens Hill to be 98,200 t.
- Modes in age composition of aggregations at St Helens Hill have decreased from 55 yr in 1992 to 40 yr in 1995 and 40 – 45 yr in 1999. Non-aggregated modes declined from 40 yr in 1987 to 30 – 35 yr in 1999 (Smith *et al*. 1998, Smith and Wayte 2001).

SEF Southern Zone

- 2000 TAC: 700 t, catch 311 t (Wayte and Bax, 2001).
- Virgin biomass estimates of 89,000 – 148,000 (SEFAG 1995 – cited in Smith and Wayte 2001).
- Dramatic decline in catch rates after 1993 – 1994 with aggregations (non-spawning) no longer forming and fishers finding it difficult to catch fish (Smith and Wayte 2001).
- There is a greater than 50% probability that biomass in the southern zone is less than 20% of 1988 levels suggesting a zero TAC may be warranted for this area (Smith and Wayte 2001).
- Future predictions depend on rate of natural mortality used in assessment model.

SEF Western Zone

- 2000 TAC: 1,600 t, catch 192 t (Wayte and Bax, 2001).
- Catch per shot index declined from 0.24 to 0.05 between 1989 and 1999, although there has been some change in fisher behaviour that has contributed in part to this drop (Smith and Wayte 2001).
- Currently a 90% chance that biomass is less than 20% of the 1985 level suggesting a zero TAC may be warranted for this area (Wayte and Bax 2001).
- High probability (91 – 97%) that the biomass in 2004 will remain below 30% of 1985 levels even with zero TAC.

Cacade Plateau

- No quantitative stock assessments have been undertaken for the Cascade Plateau (Smith and Wayte 2001).

Biological parameters

Sex	Growth			Longevity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	42.5	0.059	-0.346	42			0.025-0.1	32	28-32					1 (NZ)
	40.05	0.044	-2.66	140+				32						2. (SEF)
							0.48-0.64			31-40				3. (SEF)
							0.049-0.071 [a]							5. (Tas)
							0.026-0.033 [b]							5. (Tas)
F												0.0351	2.97	4. (Tas)
	31	0.048												5. (Tas)
M												0.0383	2.942	4. (Tas)
	40	0.064												5. (Tas)

1. Mace *et al.* (1990)
2. Fenton *et al.* (1991)
3. Smith and Wayte (2001)
4. Lyle (1991) - cited in Smith and Wayte (2001)
5. Smith *et al.* (1995)

(a) East coastTasmania (winter)
(b) South coast Tasmania (summer)

Distribution and links to physical environment

- Orange roughy occur throughout the SEMR at mid-slope depths, on seamounts and offshore rises. They are dominant members of the fish community at 700 – 1200 m (Koslow *et al*. 1994).
- Movement patterns are complex and poorly understood but some movement between southern and eastern zones appears to occur based on otolith shape analysis and seasonal size structure of adults (Smith *et al.* 1995).
- Other studies have inferred little movement between zones based on parasite analysis (Lester *et al*. 1988) and otolith chemistry (Edmonds *et al*. 1991).
- Adults form both spawning and non-spawning aggregations.
- Spawning occurs in specific localities in the vicinity of topographical features such as seamounts.

Reproduction

- Orange roughy are group synchronous, single batch spawners with determinate fecundity (Pankhurst 1988, Koslow *et al*. 1995).
- Koslow *et al*. (1995) reported that fecundity (adjusted for standard length) varies significantly between localities: NSW 42,787 eggs/female; SA 35,339 eggs/female; Tas 31,085 eggs/female.
- Annual fecundity estimates in New Zealand range from 11,000 – 180,000 eggs/female (Clark *et al*. 1994).
- Orange roughy form large spawning aggregations and spawning occurs in winter but the exact timing varies between different fishing grounds (Wayte and Bax, 2001). Spawning occurs on the Cascade Plateau in early June, off St Helens and Patricks Head (eastern Tasmania) during July and August and on the South Tasman Rise from late July to mid August.
- Limited spawning has also been reported off western and southernTasmania (Lyle *et al*. 1989), western Victoria and southeast South Australia (Smith and Wayte 2001). Spawning is complete off NSW by mid-June (Bell *et al*. 1992).
- Little is known of larvae or juveniles. Jordan and Bruce (1993) described a 26 mm juvenile from a midwater trawl fished at 400 – 950 m off St Patricks Head, eastern Tasmania and small juveniles have been taken in deep water grounds off New Zealand (P. Grimes NIWA, Wellington NZ, pers. comm.).
- Recruitment is variable and probably episodic, where recruitment to the adult population may be extremely low for periods of up to or greater than a decade (Smith *et al*. 1995, Koslow *et al*. 2000, Koslow and Tuck unpublished manuscript). Some analyses have suggested that recruitment has been declining over the last 60-80 years (i.e. prior to fishing).
- Stock-recruit steepness was estimated to be 0.75 for 1995 – 1997 assessments (Smith and Wayte 2001).

Key inter-species interactions
- Juveniles feed mainly on benthopelagic and mesopleagic crustaceans; adults feed mainly on mesopelagic fish and squid (Bulman and Koslow 1992).
- Daily food consumption rates were estimated by Bulman and Koslow (1992) to be 0.91% body weight and 1.15% body weight for juveniles and adults, respectively.

Population structure
- Genetic studies of stock structure have been conducted by a variety of researchers using allozyme, mtDNA and nuclear DNA techniques (Black and Dixon 1989, Ovenden *et al*. 1989, Ward *et al*. 1992, Smolenski *et al.* 1993, Oke *et al*. 1999) with a variety of conclusions drawn regarding stock structure. Some results suggested sub-populations whilst others did not and in some cases (e.g. Smolenski *et al.* 1993) there was evidence that different stocks occurred in the same location in different years. However, the overall picture is still inconclusive and there are no consistent patterns of genetic substructuring (Ward and Elliott 2001).
- Elliott *et al*. (1994) also concluded that there was little differentiation between Australian and North Atlantic populations.
- Several other techniques have been used to examine stock structure in orange roughy. Morphometric data suggests several stocks (Elliott *et al*. 1995); Otolith microchemistry analysis found evidence of separation within Australian and Tasman Sea stocks relatively weak (Edmonds *et al*. 1991, Thresher *et al*. 1997); Otolith shape analysis suggested eastern and southern zones are common migratory stock (Smith *et al*. 1998); Parasite data suggested five Australian stocks (Lester *et al*. 1988).
- Recent otolith shape data suggests that spawning eastern zone roughy and southern zone non-spawning roughy may comprise a common stock which is distinct from an eastern non-spawning and southern winter-caught stock (Smith *et al*. 1995, Robertson *et al*. in prep).

Fisheries Habitats
- Larvae have not been described and only small numbers of yolksac larvae have been recorded in vertical drop net samples targeting eggs during spawning surveys (C. Bulman CMR, Hobart, pers. comm.). Small numbers of more advanced larvae have been recorded in New Zealand waters in deep tows in the vicinity of spawning grounds (P. Grimes NIWA, NZ, pers. comm.).

- Juvenile habitat is unknown. Juveniles have been recorded from deep (400 – 950 m) midwater tows (Jordan and Bruce 1993).

Effects of Fishing

- Exceptionally long-lived, deepwater species that is highly vulnerable to overfishing. Vulnerability stems from 'K-selected' life history strategies (see above), highly predictable aggregating behaviour (during spawning) and flee response to approaching trawl whereby individuals descend to the bottom when alarmed. Huge catches (> 50 t per shot) have been taken and aggregations present essentially fixed targets when located. Sustainable yield believed to be only a few percent of virgin biomass. Species has declined in other areas of the world where it is fished (Koslow *et al.* 1997, Koslow and Tuck unpublished manuscript).
- Initial estimates of virgin biomass (based on acoustic and egg surveys) approx. 100,000 t. Depletion currently believed to be 20 – 30% or less of virgin biomass depending on stock structure analyses, the results of which are inconclusive (Koslow *et al*. 1997).
- Significant increase in mean fecundity of 20% in fish off eastern Tasmania during the period 1987 – 1992, suggesting a possible compensatory response to stock depletion. Also an increase in the proportion of females spawning during the same period from 54% to 71% (Koslow *et al*. 1995).
- Serial depletion of population recorded during life of the fishery as operations target successively unfished seamounts and grounds (Koslow *et al*. 1997).
- Suggestions that vessel and trawl activity around spawning aggregations may disrupt spawning behaviour (A. D. Smith CMR, Hobart; M. Clarke, NIWA, Wellington NZ, pers. comm.).
- Vulnerability of stock also increased by likely episodic recruitment patterns where recruitment to the adult population may be extremely low for periods of up to or greater than a decade. Highly episodic recruitment appears to drive size structure of fished population rather than fishing impacts per-se. This recruitment variability may considerably influence risk of stock collapse and is generally not well handled in stock assessment models (Koslow *et al*. 2000, Koslow and Tuck unpublished manuscript).

Key uncertainties

- Assessment results are highly dependent on the rate of natural mortality used.
- Generally accepted to be late maturing (20 – 30 years) and long lived (100 + years) (Fenton *et al*. 1991) but this has been disputed (Gauldie and Cremer 1998). A review of ageing, age validation is required.
- Stock structure remains uncertain and a full review of available data is required (Smith and Wayte 2001).
- Uncertainty regarding stock structure creates considerable uncertainty in biomass estimates.
- Acoustic estimates of biomass are sensitive to errors in estimates of community composition due to the low target strength of orange roughy (Kloser *et al*. 1997).
- St Helens biomass estimates by themselves may not provide a consistent index for the eastern zone spawning biomass as a significant number of spawning fish were present at St Patricks Head in 1996 and 1999.
- No biomass estimates or formal assessment of Cascade Plateau or South Tasman Rise – some results from industry surveys may become available in late 2001.
- Information on recruitment variability required.
- Information on the impact of disturbance by trawls to spawning fish required.

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Pink ling (*Genypterus blacodes*)

Pink ling are members of the family Ophidiidae (Gomon *et al*. 1994). They are distributed from Newcastle (NSW) to Busselton (WA) including Tasmania, on the continental shelf and slope in 40 – 700 m). They are also recorded from New Zeland and South America (Gomon *et al*. 1994). Ling were initially a by-catch species of the gemfish and blue grenadier fisheries in the SETF (Smith and Wayte 2001) but they are now targeted in both the trawl and non-trawl sectors. In the latter, they are caught by longline, drop-line, traps and mesh nets. The related rock ling, *Genypterus tigerinus,* is also caught in the SEMR but is restricted to inshore waters in depths of less than 60 m.

The trawl catch has been regulated by ITQ since 1992. ITQ's were introduced for the non-trawl sector in 1998. The current management objectives are to maintain the recruited biomass at the 1995 level and maintain CPUE at or above its lowest annual average level from 1986 to 1994 (Smith and Wayte 2001).

Fishery research

- Quantitative assessments for ling in the SEF were completed in 1999 and 2000 using the integrated assessment method, but the model does not reconcile the stable or slightly increasing standardised CPUE series with catch-at-age and catch-at-length data (Smith and Wayte 2001, Thomson and He 2001). Stock assessment reports are available for 1994 and 1995 (Smith and Wayte 2001).
- Wankowski and Moulton (1986) estimated the mean annual biomass of pink ling in eastern Bass Strait was 3,200 t (SE 63 t) during 1992 and 1994.
- Smith (1995 - cited in Smth and Wayte 2001) estimated the annual standing stock of pink ling in western Bass Strait to be 1,055 t in 1987 – 88.
- The 1999 assessment estimated the size of the overall stock to be between 6 – 48% of virgin biomass depending on the weighting given to catch-at-age and length-at-age data (Smith and Wayte 2001).
- The current stock status estimated to be 20 – 70% of the unfished biomass (taken as the 1977 biomass level).
- Commercial catches in the SEF increased from 790 t in 1984 to 1,972 t in 1999 generally following the increase in TACs. However, catch rates have been stable since 1997. The agreed 2000 TAC was 2,905 t (trawl) and 305 t (non-trawl) (Smith and Wayte 2001).
- Independent catch rates off NSW were similar in 1976/77 and 1996/97 (Graham *et al.* 1997).

Biological parameters

Sex	Growth	Long-evity	Mortality	Reproduction	Recruitment	Length-weight	Author (area)

	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
												2.93E-03	3.1390	1. (SEF)
							0.18							2. (NZ)
				28			0.16							5. (SEF)
F	125.7-	0.076-	-1.05											2. (NZ)
	160.1	0.113	0.7											
								4-5	72					3. (Tas)
	126	0.151	-0.79											4. (SEF)*
	117.8	0.14	-2.19											4. (SEF)**
	135.5	0.095						3	60					5. (SEF)
M	95.1-	0.087-	-1.24											2. (NZ)
	146.1	0.194	0.28											
	112.5	0.167	-0.77											4. (SEF)*
	96.2	0.198	-1.83											4. (SEF)**
	135.5	0.095												5. (SEF)

1. SEFAG (1999) – cited in Smith and Wayte (2001)
2. Horn (1993) - ranges cover various areas in NZ
3. Lyle and Ford (1993)
4. Morrison *et al.* (1999)
5. Koopman *et al.* (2000)

* data from 1970s; ** data from 1990s

Distribution and links to physical environment

- Ling occur throughout the SEMR on the outer shelf and slope to depths of 900 m but are mainly caught in 300 – 600 m (Daley *et al*. 2000).
- Some movements associated with spawning have been reported (inshore to shallow water off western Tasmania and to sites off eastern Bass Strait and southern NSW (Tilzey 2000). However, apart from this, ling are believed to be relatively sedentary (Tilzey 1994).

Reproduction

- Spawning aggregations have been reported by commercial fishers off Strahan (Tas), Lakes Entrance (Vic) and Gabo Island (NSW) during spring (Tilzey 2000) although the occurrence of larvae suggests a more protracted spawning period.
- Dispersal and mixing is belived to occur in the early life history stage as adults are believed to be sedentary. *Genypterus* larvae are widely distributed in the SEMR (see *Fisheries Habitats* below).
- Ling have been aged using otoliths and the maximum reported age in Australia 28 years (Withel and Wankowski 1989, Smith and Wayte 2001).
- Recent ageing studies have been carried out by Morison *et al.* (1999) and Smith *et al*. (1996).

Key inter-species interactions

- Ling are primarily epibenthic feeders and feed on fish (Coleman and Mobley 1984, Blaber and Bulman 1987, Bulman *et al*. 2001).
- Juveniles are prey species of tiger flathead (Bulman *et al*. 2001).

Population structure

- Genetic studies of stock structure have been conducted using allozyme and nuclear DNA techniques (Ward and Elliott 2001) and the data, combined with morphological results, suggest that there is a single stock (Daley *et al*. 2000, Ward *et al*. 2001).

Fisheries Habitats

- Larvae of pink ling have been described from southeast Australian waters (Furlani 1998) and have been recorded in shelf and slope waters of NSW from April to September (CMR unpublished data, A. G. Miskiewicz Wollongong, pers. comm., Gray 1995). *Genypterus* larvae have been recorded from Tasmanian waters in all months except June (Kailola *et al*. 1993) with peak abundances in September-October and January-February, however the specific identity of these larvae were not confirmed and may include the related rock ling (*G. tigerinus*).
- Juvenile and adult ling inhabit a variety of substrates from rocky ground to muds.
- Recent video footage has shown considerable numbers of ling on low relief rocky reefs in south east Australian shelf waters and these areas may currently provide refuge for the species (CMR, Hobart, unpublished data).

Effects of Fishing

- Logistic gear selectivity curve parameters (trawl) were recently estimated based on field trials (X. He CMR, Hobart, pers. comm.).

Mesh	90 mm diamond		90 mm square		102 mm square		Market	
	s1	s2	s1	s2	s1	s2	s1	s2
	0.319683	42.93	0.2	52.4	0.348487	57.07	0.353294	35.18

- The proportion of trawl landings from western Tasmania, western Bass Strait has been steadily increasing and the median ages and sizes of ling in these western areas are both older (3 years vs 2 years) and larger (by 15 cm) than that in the east (Thomson 2000) suggesting that the fishery has impacted eastern populations.

Key uncertainties

- Time series for non-trawl logbook data is too short for reliable assessment.
- Catch rates appear to be affected by changes in fishery practices, environmental factors, or other extraneous factors such that CPUE is not a reliable indicator of abundance trends.
- Limited fishery independent data.
- Basic biology, reproduction and movements are poorly known.

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Redfish (*Centroberyx affinis*)

Redfish are members of the family Berycidae (Gomon *et al*. 1994). They occur in southeast Australia from Morton Bay (Qld) to western Bass Strait including northeast Tasmanian waters and on offshore ridges (e.g. Nolfolk and Lord Howe) (Kailola *et al*. 1993). Redfish also occur in New Zealand, most commonly within the northern waters around the North Island. A related species (*Centroberyx gerrardi*) occurs in the GAB (Gomon *et al*. 1994). Redfish are most abundant off NSW and this region constitutes the main fishery (Rowling 1994). They are caught primarily by trawling and the fishery has developed through various periods where discarding and high grading has been a consistant feature (Smith and Wayte 2001).

The fishery is managed by quota with the objective of ensuring that spawning biomass does not significantly decline below the 1994 level and that CPUE in the fishery is above its lowest annual average level from 1986 – 1994.

Fishery research

- Quantitative stock assessments are currently carried out using an integrated analysis model (Thomson 2001). A comprehensive stock assessment was carried out in 1993 (Chesson 1995) and stock assessment reports are available for the years 1993, 1994, 1995, 1997, 1998, 1999 and 2000 (Smith and Wayte 2001).

- Redfish have been fished since 1915, however there was little or no market demand at that time (Rowling 1994) and discarding was common in the early years of the fishery. Peak landings occurred in 1949 and again in 1980 (2,400 t), followed by a steady decline in catch to about 850 t in 1989; slight increase between 1989 and 1993 to ~2,100 t (1993 TAC set at 600 t) (Rowling 1994).
- Chesson (1995) concluded that the stock biomass in the late 1980s was less than 20% of that in 1969 but that increases in recruitment occurred from 1990 – 1993, which was reflected in increased CPUE.
- The current and unexploited biomass are uncertain with Smith and Wayte (2001) reporting that the best estimates are 5,000 – 6,000 t and 30,000 – 50,000 t, respectively. Recent modelling suggests that biomass stabilised during the 1990s (R. Thomson CMR, Hobart, pers. comm.).
- 1999 and 2000 TAC agreed at 1,750 t, actual allocated TAC was 1,932 t and 2,097 t in 1999 and 2000, respectively (Smith and Wayte 2001). Agreed TAC in 2001 = 1,570 t (actual = 1,989 t, trawl fishery only) (SEFAG 2001).
- A substantial amount of catch is recorded as coming from State waters and therefore not subject to Commonwealth TAC; however, less than 10% of the catch is from waters less than 100 m depth (Rowling 1994).
- Most of the catch is taken off the NSW south coast between Sydney and Eden – in recent years ~65% of catch has been taken from trawl grounds during winter and spring (Rowling 1994).
- Discarding and high grading have been significant features of the fishery, although discard rates dropped from an estimated 50% by weight to less than 10% between 1993 and 1995. The recent closure of the Sydney surimi processing plant may lead to an increase in the discard of small redfish (Smith and Wayte 2001).
- Small size classes dominate the current catch and may be useful as a surrogate recruitment index.
- Significant numbers of redfish are also taken by recreational fishers (Rowling 1994).
- Available data and recent quantitative stock assessments indicate that the redfish resource is significantly depleted and may continue to decline under current TAC levels (Rowling 2001).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	38.8	0.031	-16.6	35										1. (SEF)
				40			0.115							6. (SEF)
F												0.0477	2.8213	2. (SEF)
							0.15							3. (SEF)
	38.8	0.031	-16.6	35			0.1	5-7	17-21	5-7	17-21	0.0477	2.8213	4. SEF)
				44										5. (SEF)
	26.5	0.24	-0.47					4	20					
M												0.0626	2.7233	2. (SEF)
	38.8	0.031	-16.6	35			0.01	5-7	17-21	5-7	17-21	0.0626	2.7233	4. (SEF)
				37										5. (SEF)
	23.9	0.26	-0.52											

1. Smith and Robertson (1992)
2. Rowling (1992)
3. Redfish Assesment Group 1999 - cited in Smith and Wayte (2001)
4. SEFAG 1994 - cited in Smith and Wayte (2001)
5. Morison and Rowling (2001)
6. Koopman *et al*. (2000)

Note: Recent tagging studies and analysis of sectioned otoliths indicates that growth is slow – with maximum recorded age of 44 years (females) and 37 years for males, (Rowling 1994, Kalish 1995, Morison and Rowling 2001, R. Thomson CMR, Hobart, pers. comm.). A recently collected redfish from the Norfolk Ridge was estimated at 50 years (K. Rowling NSW Fisheries, Sydney, pers. comm.).

Distribution and links to physical environment

- Distribution suggests an offshore movement as length increases (Rowling 1994, Chen *et al*. 1997).
- Industry reports that catch rates may decrease during warm water periods (Rowling 2001).
- There are suggested links between catch rates and Southern Oscillation Index (SOI) although correlations are poor when data are disaggegated to monthly strata (Rowling 2001).

Reproduction

- The annual fecundity of redfish is unknown (study currently underway K. Rowling NSW Fisheries, Sydney, pers. comm.).
- Spawning occurs in late summer/autumn in shelf waters throughout their geographical range (Rowling 1994, Smith and Wayte 2001).
- The occurrence of larvae off NSW from November to May suggests that spawning may occur somewhat earlier than indicated by previous observations based on adults (Miskiewicz *et al.* 1998). Earlier spawning is also suggested by recent adult sampling (R. Thomson CMR, Hobart, pers. comm.).
- Back-calculated spawning dates have not been determined for redfish.
- No studies on biological factors affecting recruitment strength (but an inverse relationship between SOI and CPUE has recently been noted (Prince 2001).

Key inter-species interactions

- Redfish are benthopelagic feeders and feed primarily on benthopelagic fish and pelagic crustaceans (Coleman and Mobley 1984, Bulman *et al*. 2001).

Population structure

- There are no published genetic studies of stock structure (Ward and Elliott 2001) and redfish are assumed to be a single stock within the SEMR. However, growth rates vary between areas suggesting further research is required (possible northern and southern stock with a boundary between Ulladulla and Eden) (Morrison and Rowling 2001, Smith and Wayte 2001).

Fisheries habitats

- Larvae from southern Australia have been described and have been recorded in NSW coastal waters from November to May (Miskiewicz *et al*. 1998).
- Juvenile redfish often aggregate in estuaries and shallow coastal waters; adult fish also aggregate, forming large demersal schools in shelf and slope waters to a depth of about 500 m (Rowling 1994).
- Adults most abundant along outer shelf and upper slope in depth range of 150 – 250 m (Smith and Wayte 2001). They occur over rocky reefs and muddy substrate.
- Redfish form dense schools over the bottom at dawn and dusk and disperse through the water column at night (Tilzey 1994).

Effects of Fishing

- Recruitment to the commercial trawl fishery appears to be largely determined by the selectivity of the codend mesh size (Rowling 1994) but studies on the selectivity of current gear are lacking.
- There is strong evidence for growth overfishing (Smith and Wayte 2001).

Key uncertainties

- Stock-recruitment relationship is unknown (Rowling 1994).
- Stock structure and the dynamics leading to regionally variable growth.
- Selectivity studies are required on existing trawl gear and ways to increase the size at first capture need identifying to protect smaller fish currently taken by the fishery.
- Reproductive biology is poorly known.
- Estimates of biological parameters (particularly t_0 and K) are poor, influenced by a lack of data for small specimens and are thus overestimated and underestimated respectively.

- Variability in the availability of (sub) populations in response to movements and fishing strategies (targeting rougher ground or new areas) may drive interannual differences in catch rates and this needs to be examined.
- The links between CPUE and abundance have been challenged as redfish are a schooling species, variability in CPUE may reflect variability in the factors leading to the formation of aggregations rather than abundance trends.
- No fishery independent estimate of biomass is available, although acoustics may offer some promise.
- The current stock size, recruitment levels and whether or not continuing catch rates of 1,500 – 2,000 t per year are sustainable is the subject of considerable debate within the fishery. Recent stock assessment modelling gives a more positive outlook (R. Thomson CMR, Hobart, pers. comm.), however there are considerable concerns regarding the effects of growth overfishing (K. Rowling NSW Fisheries, Sydney, pers. comm.).
- Validation of age and growth estimates required.
- Processes leading to recruitment variability are unknown.

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School whiting (= red spot) (*Sillago flindersi*)

School whiting are members of the family Silliginidae (Gomon *et al*. 1994). They are distributed from southern Queensland to Kangaroo Island (SA). The closely related sand whiting, *Sillago bassensis*, is also taken in small quantities at the western edge of the range. Sand whiting are taken by both the SETF and the SENTF but the bulk of the catch is taken by Danish seiners in eastern and central Bass Strait, operating from Lakes Entrance and San Remo (Smith and Wayte 2001). School whiting are also an important recreational species.

School whiting are managed by TAC with the objective to ensure that the spawning stock biomass does not significantly decline below the 1994 level and that CPUE in the fishery is above its lowest annual average level from 1986 to 1994 (Smith and Wayte 2001).

Fishery research

- Several different stocks exist in the SEMR region (see genetics section) and the boundaries between the stocks are not well defined (Smith 1994). The Jervis Bay to Portland stock is the primary fished population (Smith and Wayte 2001) and stock assessment work (below) refers to that stock.
- A quantitative stock assessment was conducted in 1999 using an integrated analysis model (Punt *et al.* 2001, Smith and Wayte 2001). Stock assessment reports are available for 1994, 1999 and 2000 (Smith and Wayte 2001).
- Annual landings have ranged from close to zero in the early 70s (from 1947 to 1970 annual catches ranged from 30 – 270 t (Smith 1994), rising to 2,000 t by 1986 (Wankowski *et al.* 1986) and remaining over 1,500 t in the early 1990s (SEFAG 2001) followed by a decline in recent years. The annual catch has been largely dictated by export demand and changed fishing practices to suit market demand (e.g. a decline in targeting fish during summer since 1993).

- In 2000 the landed weight of school whiting was 759 t, which was 41% of the allocated TAC of 1,870 t (SEFAG 2001).
- Agreed TAC 2001 = 1,500 t / actual TAC = 1,899 t (SEFAG 2001).
- The biomass of eastern Bass Strait stock estimated to be 20,500 t in 1986 (Wankowski *et al.* 1986).
- Length frequency distributions in the catch are uni-modal with fish ranging in length from 12 to 25 cm with most between 16 and 20 cm (Smith and Wayte 2001).
- There appeared to be a slightly greater proportion of older fish in catches in 1991 and 1992; while 1-year old fish were more numerous in the 1995 catch than in other years (SEFAG 2001). Strong catches of small whiting in 1999 suggest a good recruitment during that year (Smith and Wayte 2001).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
								2	14-15		16-17	1.32E-5 5.56E-3	2.93 3.188	4. (SEF) 5. (Tas) 6. (Tas)
F	23.9	0.513	-0.3	7	1.1		0.9-1.1	2		2-3	10-26	7.23E-3	3.1	1. (Bass St) 3. (SEF) 5. (Tas)
M	23.1	0.507	-0.26	7	1.5			2		2-3	10-26	8.16E-3	3.063	2. (Bass St) 5. (Tas)

1. Hobday and Wankowski (1986)
2. Wankowski *et al.* (1986)
3. Smith (1994)
4. Bax and Knuckey (1998) - cited in Smith and Wayte (2001)
5. Lyle and Ford (1993)
6. Jordan (1997)

- Hobday and Wankowski (1986) noted that school whiting from central Bass Strait have a significantly different growth rate to those from eastern Bass Strait.

Distribution and links to physical environment

- School whiting are distributed throughout the SEMR in coastal waters.
- There is no direct evidence of migration by eastern school whiting (Smith 1994), but age classes increase with depth (Wankowski *et al.* 1986) suggesting an ontogenetic movement from shallow inshore nursery areas to deeper waters.

Reproduction

- Eastern school whiting are multiple spawners (Hobday and Wankowski 1987).
- The following relationships (Hobday and Wankowski 1987) between potential fecundity and
    - Age: $\text{fecundity} = 19.72 \times 10^3 \times \text{Age}^{1.03}$
    - Length: $\text{fecundity} = 10.00 \times \text{Length}^{2.93}$
    - Weight: $\text{fecundity} = 819.37 \times \text{Gutted Weight}^{1.01}$
- Mean potential fecundity ranged between 39,000 eggs for 2-year old females to 115,000 eggs for 6-year old females (Hobday and Wankowski 1987).
- Spawning is regionally variable in its timing and occurs from October to March in eastern Bass Strait (Hobday and Wankowski 1986, 1987), late summer in Tasmania (Jordan 1997) and during winter in northern NSW (Smith 1994).
- Little is known regarding recruitment but it is thought to be interannually variable (Smith and Wayte 2001).

Key inter-species interactions

- School whiting are benthic omnivores and feed primarily on polychaetes and benthic crustaceans and molluscs (Coleman and Mobley 1984, Bulman *et al.* 2001).

Population structure

- Dixon *et al*. (1987) concluded that there were four stocks - north of Newcastle, Jervis Bay to Portland, west of Portland to southeast South Australia, and Tasmania.

Fisheries habitats

- Larvae have not been formally described but can be distinguished from the similar *Sillago bassensis* on the basis of pigment (Bruce 1995). They have been recorded from shelf waters throughout the SEMR, particularly in Bass Strait (F. J. Neira AMC, Beauty Point, pers. comm., CMR, Hobart, unpublished data).
- Juveniles are generally found inshore of the adults (Wankowski *et al.* 1986, Smith *et al.* 1987, Smith 1994).
- Adults prefer clean sandy substrate from the surf zone to depths of about 55 – 60 m (Hobday and Wankowski 1987, Smith and Wayte 2001).

Effects of Fishing

- Differences in sizes of fish caught between trawl and Danish seine indicate strong sampling bias in selectivity of the different gear types. Danish seines have smaller mesh than trawl codends and retain a broader size composition that includes small juveniles (5 – 10 cm) (Lyle and Ford 1993).
- Catch rates and targeting have been influenced by increases in the occurrence of weed on fishing grounds (Smith and Wayte 2001).
- Results of assessments suggest that the spawning stock biomass and the size and age compositions have been reasonably stable over the last decade (Smith and Wayte 2001).

Key uncertainties

- Eastern school whiting are targeted by recreational fishers; the size of the recreational catch is unknown, but undoubtedly significant (Smith 1994). Recent studies on recreational fishing will assist in defining the catch in this sector.
- Because of the stock structure and apparent lack of large-scale migration, there is a risk of localised depletion if fishing pressure is increased (Smith 1994).

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Mirror dory (*Zenopsis nebulosus*)

Mirror dory are members of the family Zeidae (Gomon *et al.* 1994). They occur in shelf and upper slope waters off the coasts of Australia, New Zealand, Japan, Hawaii, Korea, California and Chile (Gomon *et al.* 1994). In Australia they are distributed from New Soutrh Wales, around the south coast to northwest Western Australia. Mirror dory are caught primarily by trawl in the SETF but are also a component of the catch in the Danish seine sector of the SENTF (Smith and Wayte 2001).

Mirror dory are managed by TAC (trawl sector only) which, in the absence of a quantitative assessment, is based on catch history. The objective is to maintain CPUE above its lowest annual average level from 1986 to 1994 (Smith and Wayte 2001).

Fishery research

- No quantitative assessments are available for mirror dory. Stock assessment reports are available for 1994, 1996 and 1997 (Smith and Wayte 2001).
- Mirror dory are assumed to comprise a single stock for management purposes in the SEF (Rowling 1994).
- No reliable biomass estimates are available.
- The recorded catch of mirror dory in 1999 was 352 t, which was 37% of the allocated TAC of 960 t (1999 landings were 17% lower than the 1998 landings at 426 t) (Smith and Wayte 2001).
- The 2000 agreed TAC was 800 t, with actual TAC being 977 t (Smith and Wayte 2001).
- TAC agreed 2001 = 800 t / actual = 996 t (trawl fishery only) (SEFAG 2001).
- Mirror dory occur in the same depths as gemfish and the closure of the eastern gemfish fishery has impacted annual catches (Smith and Wayte 2001). Effort has shifted to slightly deeper strata to avoid gemfish. The 400 – 450 m depth strata is now the most important depth strata in terms of recorded mirror dory catch (Smith and Wayte 2001).

- Since 1996, catches of mirror dory have been boosted by increased catches to the west of Bass Strait (Smith and Wayte 2001).
- In 1996 mean unstandardised catch rates dropped below 20 kg/h, triggering AFMA's catch rate performance criterion (4th year in a row), and have since remained stable at around this level (Smith and Wayte 2001).
- Length frequency distributions and mean length-at-age of the catch differ significantly between areas east of Bass Strait and areas west of Bass Strait with western caught fish being older, larger and slower growing (Knuckey and Curtain 2001). These authors suggest that stock assessments should be conducted separately for eastern and western regions.
- No yield estimates can be made for mirror dory due to the lack of biological information, in particular age and growth data (Rowling 1994) and a lack of a suitable index of abundance (Smith and Wayte 2001).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	60.94	0.2	0.18	12				5						1. (SEF)
	65.25	0.160	-0.38	12										2. (SEF)
				13										3.
				14										4. (SEF)
(a)	49.71	0.13	-5.05											5. (SEF)
(b)	66.91	0.1	-5.11											5. (SEF)
F														
M														

1. Smith and Stewart (1994)
2. Central Ageing Facility - cited by Smith and (Wayte 2001)
3. Parin *et al*. (1988)
4. I. Knuckey MAFRI, pers. comm.
5. Knuckey and Curtain (2001)

(a) Eastern fish
(b) Western fish

Distribution and links to physical environment

- Mirror dory are distributed throughout the SEMR in mid-shelf and upper slope depths.
- Rowling (1994) reported that there was no apparent migration associated with spawning activity, however, Prince (2001) noted that (based on a cursory examination of gonadal status) there appeared to be a northern movement along the NSW coast associated with spawning.

Reproduction

- Fecundity is probably low with the possibility of serial spawning (Rowling 1994).
- Spawning aggregations occur from May to September (Kailola *et al*. 1993).
- Spawning occurs over a wide geographical area in central and southern NSW (Rowling 1994).
- Length frequency distributions are extremely variable between trawl shots and years suggesting interannually variable recruitment and a strong size structuring in their distribution (Smith and Wayte 2001).

Population structure

- No published genetic studies of stock structure (Ward and Elliott 2001), however, age and size structure as well as length-at-age are significantly different between eastern and western regions of the SEF (Smith and Wayte 2001).

Key inter-species interactions

- Mirror dory feed primarily on benthopelagic and pelagic fish and are major predators of jack mackerel (Coleman and Mobley 1984, Bulman *et al*. 2001).

Fisheries habitats

- Larvae have not been described and their distribution is unknown.
- Adults are recorded as deep as 800 m, but more usually caught in depths between 50 and 600 m (Kailola *et al.* 1993).

Effects of Fishing

- Mirror dory are fully vulnerable to capture by trawl gear with 90 mm codend mesh at sizes well below 30 cm (2 – 3 yr) (Knuckey and Curtain 2001).
- Logistic gear selectivity curve parameters (trawl) were recently estimated based on field trials using New Zealand dory as a surrogate (X. He CMR, Hobart, pers. comm.).

Mesh	90 mm diamond		90 mm square		102 mm square		Market	
	s1	s2	s1	s2	s1	s2	s1	s2
Mirror dory	0.416	14.00	0.416	14.00	0.416	14.00	0.472909	30.48

- The size range of the landed catch of mirror dory has remained stable over the last decade (Smith and Wayte 2001).

Key uncertainties

- Factors governing recruitment are unknown.
- Stock structure is unknown.
- Estimates of biological parameters (particularly t_0 and K) are poor, influenced by a lack of data for small specimens and are thus overestimated and underestimated respectively.
- Discarding remains a major issue for the species. Discarding of mirror dory in the eastern zones is high – between 50 and 80% by weight being discarded in previous years (Liggins 1996). Since 1997, discarding has decreased in the eastern zones A and B to about 8% (Smith and Wayte 2001). High levels of discarding occurred off eastern Tasmania (44%) in 1999 (Smith and Wayte 2001). In 1999, about 20% of the mirror dory catch was discarded (by weight) across the fishery (Smith and Wayte 2001).
- Off NSW and NE Victoria, mirror dory abundance peaks during winter in the same depth strata as the winter gemfish spawning run and thus by-catch of gemfish when targeting mirror dory is problematic (Rowling 1994, Smith and Wayte 2001).

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John Dory (*Zeus faber*)

John dory are members of the family Zeidae (Gomon *et al*. 1994). They are widely distributed in coastal and continental shelf waters of Australia, the eastern Atlantic Ocean, Mediterranean Sea, Japan and New Zealand. In Australian waters they occur from Moreton Bay (Qld) around the south coast to Cape Cuvier (WA) (Gomon *et al*. 1994). They are caught largely as by-catch in the SEF when trawling for tiger flathead and jackass morwong, although some targeting occurs on inshore trawl grounds (Smith and Wayte 2001). They are also caught by several sectors outside the SEMR (particularly between Sydney and southern Qld).

John dory are managed by TAC (trawl sector only) with the objective of ensuring the spawning biomass does not fall significantly below its 1994 level and that CPUE is maintained above its lowest annual average level from 1986 to 1994 (Smith and Wayte 2001).

Unless otherwise referenced, the following information comes from the review by Smith and Wayte (2001).

Fishery research

- John dory are assumed to be a single stock throughout the SEMR.
- Biomass estimates during 1986 for eastern Bass Strait ranged from 800 t in winter to 2,400 t in autumn but these data are not considered reliable.
- Catch rates in SETF have varied between 6 kg/h and 12 kg/hr; 7.4 kg/hr in 1999 with little seasonal variation.
- Catches highest (for SETF) within the 150 – 200 m depth zone although this largely reflects the distribution of trawling effort for flathead and morwong rather than distribution of John dory.
- Significant declines in catch rate recorded from 1994 to 1998 with a slight increase in 1999 in SETF, however it is unknown if this reflects changes in abundance or changes in fishing practices. Generally considered that this reflects declining abundance.
- Discarding levels believed to be low and probably restricted to small fish (reflecting the high market value of the species).
- Length frequencies off NSW coast ranged between 17 and 45 cm with a mode of 25 cm in 1999.
- John dory are also taken by recreational fishers, but the extent of catch and effects on the population are unknown.

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	53.2	0.15	-1.0	12				3-5	28					1. (SEF)
F														
M														

1. Smith and Stewart (1994)

Distribution and links to physical environment

- Abundance believed to be lower south of NSW.

Reproduction

- Fecundity is not known for Australian fish.
- John dory are serial spawners – spawning occurs from December to April in New Zealand.
- John dory are a widely dispersed species on fishing grounds within the SEMR; aggregations are rare.
- Recruitment (or catchability) is interannually variable with fishers reporting good and bad years (e.g. 1996 was a good year whereas 1997 was considered to be poor).

Key inter-species interactions

- John dory are piscivores and feed primarily on benthopelagic fish. They are major predators of small redfish (Bulman *et al*. 2001).

Population structure

- There are no published genetic studies of stock structure (Ward and Elliott 2001) and assumed to be a single stock (although differences between size-at-age in New Zealand and Australia suggests some separation across the Tasman Sea).

Fisheries habitats

- Larvae have been described in various regions of the species distribution (e.g. New Zealand – Crossland 1982 - and the Mediterranean Sea) but have not been identified in Australian waters and their distribution in the SEMR is unknown.

Effects of Fishing

- Abundance appears to have declined (based on catch rate data) but environmental effects (on recruitment) are considered to be a more likely cause than the effects of fishing (although this appears to be largely speculative in the absence of further data).

Key uncertainties

- No fisheries independent data for species and insufficient data to allow conclusive stock assessment.
- Biological data poorly known (e.g. age validation, size-at-age, age-at-maturity, growth rate, mortality).
- Environmentally driven recruitment variability suggested as a factor in the species decline in abundance but there are little data available to substantiate this.

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Flatheads (*Neoplatycephalus spp*., *Platycephalus spp*.)

Flathead are members of the family Platycephalidae (Gomon *et al*. 1994). Flatheads are targeted using both Danish seine and trawl. Most (over 90%) of the flathead catch taken in the SEF are tiger flathead (*N. richardsoni*) but include toothy flathead (*N. aurimaculatus*), sand flathead (*P. bassensis*), blue spot flathead = yank flathead (*P. caeruleopunctatus*) and southern flathead (*P.speculator*). These species are all now regulated within the SEF. Other flathead species are unregulated. All are Australian endemics.

Tiger flathead and toothy flathead occur from central NSW to Tasmania, including Bass Strait (Yearsley *et al*. 1999). They are taken by trawl and Danish seine. Tiger flathead were one of the original target species of the SETF (Klaer 2001).

Sand flathead occur from southern NSW to southwest Western Australia including Tasmania. They are caught by trawl, Danish seine, gillnet, beach seine and handline. They are also an important recreational species in Tasmania and Victoria (Yearsley *et al.* 1999).

Blue-spot flathead occur from southern Queensland to north eastern Victoria. They are taken by trawl and by recreational anglers fishing in mid-shelf waters (Yearsley *et al.* 1999).

Southern Flathead occur from eastern Bass Strait to southwest Western Australia. They are caught in beach seines, gillnets and haul nets, rarely by trawl (Yearsley *et al.* 1999).

Most available information refers to tiger flathead and sand flathead.

Fishery research

Tiger flathead (*N. richardsoni)*:

- Stock assessment reports are available for 1994 and 1996 (Smith and Wayte 2001). A preliminary quantitative stock assessment using the integrated analysis method (using length, age, catch, discards, catch rate) was conducted in 2001 (Cui *et al.* 2001). However no conclusions about stock status could be made due to various data issues.
- There were cases of localised, almost complete, depletion during the period of steam trawl operations in the NSW region (e.g. 1930s) but no indications of localised recovery (Klaer 2001). Recruitment overfishing caused collapse of the stock in NSW in 1940s (Rowling 1994).
- Overall catches were stable between 1986 and 1992 but increased between 1993 and 1999.
- The 2000 landed catch was 3,325 t and all but 103 t was taken in Commonwealth waters (Smith and Wayte 2001).

- The sustainable yield is estimated at 2,500 – 3,000 t (Montgomery 1985, Wankowski 1986a) and the resource is considered fully exploited (Rowling 1994).
- Proportion of total population numbers represented by adult fish (> 7 years) has been steadily falling from 26.4% in 1991 to 8.8% in 1994. Mean ages also declined from 5.73 years to 5 years over the same period (Smith and Wayte 2001).
- Catch rates in both trawl and Danish seine sectors suggest that the abundance of tiger flathead has been declining in eastern Bass Strait since the late 1980s (Smith and Wayte 2001). However Cui *et al*. (2001) reported no strong trends in catch rates over the past 15 years for either trawl or non-trawl sectors.

Biological parameters (tiger flathead)

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F	76.6	0.178	-0.65	12	1.1					3-4	33			1. (NSW)
	58.8	0.178	-1.22		0.6-0.8									2. (Vic)
	74.51	0.116	-2.46							4	30			3. (SEF)
				12	0.27				30					4. (Tas)
M	58.9	0.122	-0.63	8	1.1					3-4	33			1. (NSW)
	48.2	0.16	-1.69	10	0.6-0.8									2. (Vic)
	59.54	0.095	-2.14							4	25			3. (SEF)
				9	0.46				25					4. (Tas)

1. Montgomery (1985)
2. Wankowski *et al*. (1986a)
3. CAF; Bax and Knuckey (1997) – cited in Smith and Wayte (2001)
4. Jordan (1997)

Biological parameters (sand flathead)

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	38.46	0.23	-0.63											1. (Tas)
F	40.45	0.23	-0.52	16				2	23.5					1. Tas)
M	36.6	0.22	-0.79	17				2	21					1. (Tas)

1. Jordan *et al*. (1998)

Distribution and links to physical environment

Tiger flathead (*N. richardsoni)*:

- Tiger flathead occur from northern NSW to western Bass Strait including Tasmania (Daley *et al.* 1997); demersal in 10 – 400 m (more typically 30 – 160 m).
- Most recaptures of tagged fish indicate movements of less than 50 km suggesting there are no broad scale geographic movements but understanding is limited. (Fairbridge 1951, Rowling 1994).
- Tiger flathead retain their swim bladder (Gomon *et al.* 1994) and may move into the water column to feed on benthopelagic species (Bulman *et al*. 2001).
- Mature adults move inshore to spawn (Fairbridge 1951).

Sand flathead (*P. bassensis*):

- Sand flathead occur from the central coast of NSW to eastern South Australia but are most abundant in southern NSW, Victoria and Tasmania (Gomon *et al*. 1994).

Reproduction

Tiger flathead (*N. richardsoni)*:

- Fecundity is high with up to 2.5 million eggs per female (Colefax 1938, Hobday and Wankowski 1987).
- Spawning occurs over an extended period from October to May in NSW (Fairbridge 1951) and from December to February in Bass Strai and southern Tasmania (Hobday and Wankowski 1987, Jordan 1997).
- Cui *et al*. (2001) set the steepness in the stock-recruitment relationship to 0.9 in assessments.

Sand flathead (*P. bassensis*):

- Spawning is regionally variable in sand flathead. It is protracted in Tasmanian waters, occurring from October to March with a peak between October and December. Spawning occurs in both coastal embayments and waters of the inner continental shelf (Jordan 2001). Spawning occurs from August to October in Port Phillip Bay (Brown 1987) and larvae have been recorded from December to February in Victorian waters (Neira *et al*. 2000)

Key inter-species interactions

Tiger flathead (*N. richardsoni)*:

- Tiger flathead are benthopelagic piscivores and feed on a variety of fish including juvenile ling (Bulman *et al*. 2001).
- Predators of juvenile tiger flathead include John dory and larger tiger flathead (Smith and Wayte 2001).

Sand flathead (*P. bassensis*):

- Sand flathead are benthic piscivores (Bulman *et al*. 2001).

Toothy flathead (*N. aurimaculatus*):

- Toothy flathead feed on cephalopods (Coleman and Mobley 1984).

Population structure

- There have been no genetic studies of stock structure in any of the four species of flathead (Ward and Elliott 2001).
- Rowling (1994) concluded that there was little evidence of more than one stock of tiger flathead and they are thus assumed to be a single stock for management purposes.

Fisheries habitats

Tiger flathead (*N. richardsoni)*:

- There is no published information on larval development, distribution or early juvenile development (Smith and Wayte 2001) but recent work has identified tiger flathead larvae, although they have yet to be described (A. Miskiewicz, A. Jordan TAFI, Hobart, pers. comm.).
- Jordan (1997) suggested that tiger flathead utilised shallow inshore nusery areas (based on the absence of small juveniles in shelf waters). Small juveniles were not recorded in a more recent and extensive sampling of such areas in Tasmania (Jordan 2001). Jordan also suggested that they either have discrete nursery areas outside the southeast Tasmanian region, the abundance of juveniles was low during their study period or they have an extended pelagic juvenile phase. The later is suggested by the retention of a swim bladder (which is unusual in platycephalids – Gomon *et al.* 1994) and the capture of small juvenile tiger flathead in midwater trawls in shelf and slope waters (CMR, Hobart, unpublished data).

Sand flathead (*P. bassensis*):

- Larvae have been described from southern Australian waters and have been recorded in Tasmanian coastal waters during spring and summer (Jordan 2001).
- Settlement to unvegetated subtidal areas in coastal bays of south eastern Tasmania occurs over a protracted period and at a size of about 2 cm (Jordan 2001).

Effects of Fishing

Tiger flathead (*N. richardsoni)*:

- Danish seine and demersal trawl catches differ in size composition and small individuals are likely to be under-estimated in trawl catches (Lyle and Ford 1993).
- Mesh selectivity trials indicate that the length at 50% selection occurs at 27 cm for 42 mm mesh and 38 cm for 110 mm mesh (Wankowski 1986b).
- Significant declines occurred in the abundance of tiger flathead in the early years (pre 1950s) of the fishery off NSW and in some cases localised almost complete depletions occurred with little indications of recovery (Klaer 2001).

Key uncertainties

- The effects of fishing on minor species is unknown.
- Biological data poorly known for some species. Estimates of biological parameters (particularly t_0 and K) are poor, influenced by a lack of data for small specimens and are thus overestimated and underestimated respectively.
- The interpretation of catch is confounded by inadequate information on catch rates, size/age composition, changes in fishing practices, redistribution of trawl effort, fluctuations in rates of high grading and discarding and the species composition of catches between sectors.
- Increased catches of smaller flathead could represent unregulated species.
- There are some concerns over quality of logbook data and its suitability for assessment, including lack of species breakdown.
- Catch rates are unstandardised between seine and trawl sectors.
- Stock structure is unknown.
- Movements are poorly documented.
- Location and habitat requirements of juveniles poorly documented.
- Size of the recreational catch unknown (but currently being assessed).

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Jackass morwong (*Nemadactylus macropterus*)

Jackass morwong are members of the family Cheilodactylidae (Gomon *et al*. 1994). They occur from Moreton Bay (Qld) to Perth (WA), including Tasmania. Also found in New Zealand, South America, southern Africa and the Amsterdam and St Paul Islands in the Indian Ocean (Elliott and Ward 1994, Grewe *et al.* 1994). A related, undescribed, larger species occurs on offshore rises (King terakihi, *Nemadactylus* spp.) and has occasionally been recorded in mainland waters of the SEMR (Clive

Roberts Wellington, NZ, pers. comm.). Jackass morwong are caught mainly by trawl and Danish seine; other methods include: fish traps, line fishing, and, occasionally, gill nets (Smith 1994).

Jackass morwong are managed by TAC with the objective of ensuring that the spawning stock biomass does not fall significantly below the current (1994) level and that CPUE is above its lowest annual average level from 1986 to 1994 (Smith and Wayte 2001).

Fishery research

- A quantitative assessment was carried out in 1997. Stock assessment reports are available for 1994, 1995, 1997 and 2000 (Smith and Wayte 2001).
- Jackass morwong are currently managed as a single stock.
- Biomass in the eastern sector of the fishery was estimated to be 10,000 t in the mid-1980s (Smith and Wayte 2001). However there are no estimates of either current or virgin biomass.
- Jackass morwong have a long catch history. The 1947 catch was 1,800 t; catches peaked at 2,200 t in 1981 (Smith 1994); average 1,400 t between 1981 and 1993 (Smith and Wayte 2001).
- Unstandardised catch rates (since 1986) have declined steadily from a peak in 1989 of approximately 90 kg/h to below 40 kg/h in 1996, but have been relatively stable at about 40 kg/h since. Total annual catches have been relatively stable since 1992 (Smith and Wayte 2001).
- AFMAs catch rate performance criterion triggered in 1995, 1996 and 1998. Catch rates in 1999 above the criterion, but reached a record low in 2000. Market forces also have an effect on catch rates and there is competition on the domestic market with imports from New Zealand (Smith and Wayte 2001).
- In 2000 the catch in the SEF was 882 t (57% of allocated TAC) (SEFAG 2001).
- The agreed TAC in 2001 was 1,185 t, with an actual TAC of 1,413 t (SEFAG 2001).
- Seasonal and depth variations in catch rate occur across the entire SEF, with abundance highest in the 100 – 149 m stratum in summer (Smith 1994).
- The size of fish in the catch (landed at Lakes Entrance) between 1992 and 1996 ranged from 25 to 45 cm with a mode of 31 to 33 cm, although the mean size decreased from 34.4 cm to 31.7 cm during the period. Fish caught in NSW range from 25 to 40 cm between 1993 and 1999 with a mode of 30 cm, with some evidence of a strong cohort (26 – 27 cm) entering the fishery (Smith and Wayte 2001).
- Biological indicators do not raise concerns about the current state of jackass morwong stocks (SEFAG 2001), some industry members have expressed concerns regarding the status of the stock, although most believe that reduced catch rates are a result of environmental influences.

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
												4.29E-5	3	3. (SEF)
					0.18	0.09	0.09							4. (SEF)
F	42	0.12		35				3		3-7	25			1. (SEF)
	36.39	0.34	-0.45	38				3	22					2. (SEF)
	38.4	0.36	-0.07	41										5. (Tas)
M	38.5	0.12		30			0.2	3		3-5	25			1. (SEF)
	35.18	0.41	-0.2	31				3	22					2. (SEF)
	36.2	0.42	0.15	30										5. (Tas)

1. Smith and Robertson (1995) – cited in Smith and Wayte (2001)
2. Central Ageing Facility – cited in Smith and Wayte (2001)
3. Bax and Knuckey (1998) – cited in Smith and Wayte (2001)
4. Smith and Wayte (2001)
5. Jordan (2001a)

Distribution and links to physical environment

- Jackass morwong occur throughout the SEMR in shelf and upper slope waters.

- There may be some movement of adult fish from eastern Tasmania into eastern Bass Strait during autumn (Jordan 2001b).
- The dispersal of long-lived larval stages is linked to offshore mesoscale oceanographic processes within the SEMR (Bruce *et al*. 2001).

Reproduction
- Jackass morwong are serial spawners. The relationships between fecundity and length, age and weight are as follows (Hobday and Wankowski 1987):

Length:	Fecundity = 0.84 x Length - 3.72;
Age:	Fecundity = 117,210 x Age - 194,518;
Gutted Weight:	Fecundity = 851 x Gutted Weight - 104,211

- The timing of spawning varies regionally. In eastern Bass Strait spawning occurs in summer and autumn, with 80% of spawning activity occurring between April and June (Hobday and Wankowski 1987). Off eastern Tasmania, spawning peaks in summer (Jordan 1997).
- Back-calculated spawning dates (from otolith microstructure) range from 16 March to 21 May (Bruce *et al*. 2001), although, due to the seasonal nature of sampling, this does not cover the entire spawning period.
- Recruitment of pelagic post-larvae to shelf waters of Storm Bay and the east coast of Tasmania occurs over an extended period during spring and early summer (September-January) (Jordan 2001b).
- Recruitment highly variable with evidence of a particularly strong 1988-year class (Jordan 2001a). Smith and Wayte (2001) reported evidence over the last 20 years of stronger recruitment every 4 – 5 years.

Key inter-species interactions
- Jackass morwong are benthic feeders and feed primarily on polychaetes and benthic crustaceans (Coleman and Mobley 1984, Bulman *et al*. 2001).

Population structure
- Genetic studies of stock structure have been conducted using both allozme and mtDNA techniques (Ward and Elliott 2001) and suggest that there is a single panmictic population of jackass morwong in Australia, with no convincing evidence of genetic structuring in the population (Richardson 1982, Elliott and Ward 1994, Grewe *et al.* 1994).
- Australian and New Zealand populations were genetically distinct, the degree of differentiation corresponding to an estimate of ~80 migrations per generation (Elliott and Ward 1994).
- Otolith microchemistry studies, however, indicated differences between Tasmania and NSW/Vic fish (Thresher *et al.* 1994) and larvae from NSW/Vic have significantly different otolith microstructure to Tasmanian caught larvae (Bruce *et al* 2001) however, it is unclear if such differences indicate separate stocks.

Fisheries habitats

Links between life history stages and habitats
- Larvae have been described from southern Australia (Bruce 1998) and have been recorded from southern NSW to southern Tasmania, including Bass Strait (Bruce *et al*. 2001, CMR Hoabrt, unpublished data).
- Jackass morwong have a protracted pelagic larval period (~8 – 12 months) (Tong and Vooren 1972, Vooren 1972, 1975) with larvae occurring at the surface in offshore waters to at least 250 km from the shelf break (Bruce *et al*. 2001).
- There is some evidence for discrete nursery areas in south-eastern Australia – juveniles are restricted to coastal waters of Bass Strait and Tasmania, rarely caught in eastern Victoria, NSW or the GAB (Lyle and Ford 1993, Jordan 2001b).

Effects of Fishing
No information currently available.

Key uncertainties

- Generally believed to be a single stock, although further clarification required.
- Environmental influences on recruitment variability.
- The extent to which recruitment variability or environmental factors influence stock availability and catch rates.

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Gemfish (*Rexea solandri*)

Gemfish are members of the family Gempylidae (Gomon *et al.* 1984). They occur from northern NSW around the south coast to Western Australia. Gemfish also occur in New Zealand. There are two Australian stocks, eastern and western, and each are dealt with separately in this account.

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Eastern gemfish (*Rexea solandri*)

Eastern gemfish have been caught primarily by trawling in depths of about 400 m (during the winter pre-spawning migration along the NSW coast). They have also been caught by droplining and gillnet (Smith and Wayte 2001).

The fishery has had a targeted TAC of zero since 1993 with the exception of 1997. A zero targeted TAC will remain in force until the spawning biomass has a 50% probability of exceeding 40% of the 1979 biomass level (EGAG 2000).

Fishery research

- Cohort analyses were undertaken in 1988 and a variety of other analyses have been undertaken since (Smith and Punt 1998, Punt and Smith 1999, Smith and Wayte 2001). Assessments are now undertaken by the integrated analysis method (Punt *et al*. 2001).
- Virgin (1979) biomass was estimated to be 13,500 – 19,400 t (EGAG 1998 – cited in Smith and Wayte 2001). Current stock assessment results suggest that the eastern gemfish stock is between 4 and 26% of the 1979 biomass level. However, relative abundance data has not been available since the last year of targeted survey data and this has increased the level of uncertainty in assessments.

- The fishery, when open, targets the winter pre-spawning migration on the southeast coast of Australia between latitudes of 40°S and 33°S and in a narrow depth zone of 350 – 400 m on the continental slope (Rowling 1990).
- Catches of eastern gemfish peaked in 1978 – 1980 at 5,000 t, declining to ~3,000 t per year (a second peak of 4,200 t in 1987); a TAC was set at 3,000 t in 1988 (Rowling 1994).
- From 1988 to 1992 TAC was progressively reduced from 3,000 t to 200 t, culminating in a TAC of zero being set since 1993, with the exception of 1997 when a TAC of 1,000 t was set (Rowling 1994, 2001, SEFAG 2001).
- Monitoring of size composition identified a decline in mean length of the catch. A subsequent decline in spawning stock biomass of 60 – 70% by the late 1980s (Rowling 1990) was confirmed by stock assessments by the Eastern Gemfish Assessment Group (EGAG 2000) which indicated that the mature population had declined to 35 – 40% of the unexploited level by the mid 1980s.
- There are major concerns about low stock size resulting from an extended period of low recruitment (Prince and Griffin 2001, Rowling 2001).
- The strong 1990-year class is under-represented in the most recent assessments and it has been suggested that a mortality event in 1999 may have reduced numbers, but a general consensus has not yet been reached regarding the validity of such an event. Stock assessments incorporating a 1999 mortality event provide a better fit to the available data. An alternative explanation is that data collected in 1999 and 2000 were not representative of the spawning population (SEFAG 2001).
- Stock projections for eastern gemfish are not encouraging. Only under a single scenario is there a recovery to a level above the AFMA threshold of 40% of the 1979 biomass level (assuming no mortality event in 1999); all other scenarios show only limited recovery (but not to the reference level) or further long-term decline (SEFAG 2001).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
										5-6				3. (SEF)
				13										4. (SEF)
F	109.4	0.18	-0.61	16		0.3-0.41	0.44-0.58							1. (SEF)
								4-6						2. (SEF)
					0.59			4-6	60-75	4-6	60-75			3. (SEF)
M	97.5	0.21	-0.52	11		0.3-0.41	0.44-0.58					1.43E-6	3.39	1. (SEF)
								3-5						2. (SEF)
					1.22			3-5	50-65	3-5	50-65			3. (SEF)

1. Punt (1998)
2. Rowling (1994)
3. Smith and Wayte (2001)
4. Withell and Wankowski (1989)

Distribution and links to physical environment

- Eastern gemfish are distributed from northern NSW to Tasmania on the east Australian coast (Rowling 1994). In summer they are scattered around the eastern Tasmanian shelf break and aggregate around canyons (Prince and Griffin 2001).
- Mature gemfish aggregate prior to spawning and migrate north along the NSW continental slope during winter from June to August (Rowling *et al*. 1990).
- Prince and Griffin (2001), using catch information on the southern NSW coast, have suggested that winter spawning aggregations of eastern gemfish have evolved in response to subsurface plumes of nutrient-rich deep Sub-Antarctic mode water that result in enhanced productivity and hence larval survival. However, gemfish larvae have only been located in northern and central NSW waters between Crowdy Head and Sydney (Gormon *et al.* 1987), typically north of the winter fishery region investigated.

- It has also been suggested that spawning occurs at the location of the Tasman Front on the NSW central coast, although supporting data are sparse.
- Rowling (2001) suggested that pre-spawning aggregations are determined in general by a combination of time of season and latitude and that they form a similar pattern between years that is not consistent with the Prince and Griffin hypothesis.

Reproduction

- Fecundity is closely related to fish weight, the majority of females producing 1 – 1.5 million eggs (Rowling 1994).
- Spawning occurs in northern and or central NSW during winter and there is a suggested link to the location of the Tasman Front. Spawning fish have been recorded off Crowdy Head (Rowling 1994).
- Stock assessment results suggest that there was a period of good recruitment from the early 1970s to the mid 1980s after which recruitment was poor with the exception of the 1990-year class and perhaps the 1996-year class (Rowling 1994, 2001, Prince and Griffin 2001, SEFAG 2001).
- A variety of stock-recruitment relationships have been applied to gemfish including Beverton-Holt, depensatory and regime-shift (Smith and Wayte 2001).

Key inter-species interactions

- Gemfish feed primarily on benthopelagic fish (Bulman *et al*. 2001).

Population structure

- Genetic studies of stock structure have been conducted using allozyme and mtDNA techniques (Ward and Elliott 2001) and concluded that the eastern gemfish stock was distinct from the western gemfish although some limited mixing occurs off western Tasmania (Colgan and Paxton 1997).
- Some similarity between eastern gemfish and the gemfish population in New Zealand were suggested by Colgan and Paxton (1997).
- Examination of parasite loads also supports a separate eastern stock (Sewell and Lester 1995).

Fisheries habitats

- Larvae have been described from eastern Australia (Miskiewicz and Trnski 1998) and have been recorded in coastal and offshore waters of northern and central NSW from August to September (Gorman *et al.* 1987) and in coastal waters off Sydney from July to September (Gray *et al*. 1992).

Effects of Fishing

- Logistic gear selectivity curve parameters (trawl) were recently estimated based on field trials (X. He CMR, Hobart, pers. comm.).

Mesh	90 mm diamond		90 mm square		102 mm square		Market	
	s1	s2	s1	s2	s1	s2	s1	s2
Gemfish	0.252031	28.13	0.137676	49.13	0.189678	53.331	0.344971	37.28

- The fishery has had a major impact on the biomass, age structure and size structure of the eastern stock. The ecosystem implications of this are undocumented, but the significant decline of what was undoubtedly an important predator in slope regions suggests they have probably been significant.

Key uncertainties

- Many of the issues surrounding eastern gemfish now revolve around the difficulty in obtaining estimates of relative abundance and representative sampling of age classes.
- Environmental forcing of recruitment variability and the influences on the spawning migration are still conjectural.
- Implications of highly depleted stock levels on spawning dynamics and population reponses are poorly understood.

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Western gemfish (*Rexea solandri*)

The western gemfish occurs in outer shelf and slope waters from western Tasmania/western Bass Strait across the GAB to the west coast of WA extending as far north as 23º 25’ S (Gomon *et al*. 1994). They are taken by trawling as part of multi-species catches, usually with blue grenadier and ling, rather than by targeting.

Western gemfish are managed by TAC with the objective of ensuring that the recruited biomass does not significantly decline below the 1994 level (Smith and Wayte 2001).

Many of the comments on the biology of the eastern gemfish can be extrapolated to the western stock. Important differences have been highlighted below.

Fishery research

- There are no quantitative assessments for western gemfish and the status of the stock is unknown (Smith and Wayte 2001). Smith (1995) estimated a standing stock biomass of 1,481 t for western Bass Strait in 1988/89.
- Agreed western gemfish TAC 2001 = 329 t / actual western gemfish TAC = 306 t (SEFAG 2001).
- Catch rates indicate a decline in western gemfish abundance and/or catchability from the mid-1980s to the mid-1990s (SEFAG 2001).
- The fishery showed an improvement in 1996, with catches containing predominantly 40 – 60 cm LCF fish (2 – 4 year olds) compared with the 1995 catch of proportionately more larger, older fish (SEFAG 2001).
- Length frequencies generally ranged between 40 and 85 cm in 1999 with a mode between 45 and 50 cm. Significant numbers of small western gemfish (20 – 40 cm) were recorded in catches in 2000 (Smith and Wayte 2001).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				16	0.41			3-6						1. (SEF)
F														
M														

1. Smith and Wayte (2001).

Distribution and links to physical environment
No information currently available.

Reproduction

- Spawning of the western gemfish appears to occur in summer in the west of the GAB (Smith and Wayte 2001).
- Recruitment appears to be interannually variable but the causes are unknown.

Key inter-species interactions

- Gemfish feed primarily on benthopelagic fish (Bulman *et al*. 2001).

Population structure

- Genetic studies of stock structure have been conducted using allozyme and mtDNA techniques (Ward and Elliott 2001) and concluded that the western gemfish stock was distinct from the eastern gemfish although some limited mixing occurs off western Tasmania (Colgan and Paxton 1997).
- Examination of parasite loads suggests that the western gemfish may comprise two stocks (Sewell and Lester 1995).

Fisheries habitats

- Larvae have not been collected from western areas.

Effects of Fishing
No information currently available.

Key uncertainties

- Spawning dynamics, spawning migrations and spawning location are not understood for western gemfish.
- Recruitment dynamics are unknown but there is evidence of variable interannual rates.
- Possible two stocks (based on parasite loads).

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Ocean perch (*Helicolenus percoides* and *H. barathri*).

Ocean perch are members of the family Scorpaenidae (Gomon *et al.* 1994). They occur in both Australia and New Zealand. Two species occur in Australia (the "inshore" *H. percoides* and "offshore" *H. barathri*) which are similar in form and overlap in their depth distribution. They occur from 29^{o}S in NSW to 26^{o}S in WA at depths of 50 to 750 m (Smith and Wayte 2001). They are primarily caught by the SETF while targeting other species (although minor catches are reported in the SENTF). The majority of the catch is *H. barathri* although the species are not separately logged.

Both species of ocean perch are managed by a common TAC with the objective of ensuring that the spawning biomass does not significantly decline below the 1995 level and that CPUE is maintained above its lowest annual average level from 1986 to 1994 (Smith and Wayte 2001).

Fishery research

- There are no quantitative assessments of ocean perch. Stock assessment reports are available for 1994 and 1996 (Smith and Wayte 2001). The status of stocks is uncertain.
- High levels of discarding occur, particularly inshore. Discarding of fish less than 23 – 25 cm occurs in both species representing fish less than or equal to 4 years and 10 years for *H. percoides* and *H. barathri*, respectively (Knuckey and Curtain 2001).
- Andrew *et al*. (1997) noted a significant decline in catch rates between 1976/77 and 1979/81 (associated with a fish down of the virgin stock) and further declines between 1979/81 and 1996/97. The reasons for particularly the latter decline are uncertain.
- Estimated catches have ranged from 187 to 464 t since 1977. The 2000 TAC was 500 t (Smith and Wayte 2001).
- Length frequency data showed a peak of 35 cm in 1976/77 with a marked reduction in the proportion of fish greater than 30 cm by 1996/97 (Andrew *et al*. 1997).
- The interpretation of size distributions is complicated by the mix of the two species in the catches. In 1999, the size composition of *H. percoides* ranged between 10 and 30 cm with a mode of 22 cm; the size composition of *H. barathri* ranged between 15 and 40 cm with a mode between 25 and 30 cm (Smith and Wayte 2001). Smith and Wayte (2001) noted some evidence of a decrease in the size of *H. barathri*.

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	43.72	0.114		42										1. (SEF)
H. p.	34.7	0.16	-0.78											3. (SEF)
H. b.	42.87	0.07	-5.96											3. (SEF)
F									31			1.81E-2	2.997	2. (Tas)
M									30					2. (Tas)

1. Withell and Wankowski (1988)
2. Lyle and Ford (1993)
3. Knuckey and Curtain (2001)

Distribution and links to physical environment

- Ocean perch occur in shelf and upper slope waters in depths of 50 – 750 m.

Reproduction

- Ocean perch are viviparous, have a low brood size and, based on studies of adults, spawning occurs in late winter/early spring (Park 1993). However, larvae have been recorded from coastal waters around Tasmania from mid winter to late summer suggesting a more protracted period of spawning (Furlani 1997).

- Fecundity is poorly documented in Australian specimens. A New Zealand study by Mines (1975), reported that 30 cm FL female ocean perch produce between 150,000 and 200,000 eggs during a breeding season, of which 40,000 to 50,000 were fertilised and developing embryos.

Key inter-species interactions

- Ocean perch are benthopelagic omnivores and feed on megabenthos and benthic crustaceans (Bulman *et al*. 2001).

Population structure

- There have been no genetic studies of stock structure (Ward and Elliott 2001).

Fisheries habitats

- Larvae have been described from southern Australian waters (Furlani 1997) and have been recorded in Tasmanian shelf waters from July to January (Marshall and Jordan 1992, Furlani 1997), off the NSW south coast in August (CMR, Hobart, unpublished data) and off Sydney, NSW from May to December (Gray 1995).

Effects of Fishing

- Logistic gear selectivity curve parameters (trawl) were recently estimated for *H. barathri* based on field trials (X. He CMR, Hobart, pers. comm.).

Mesh	90 mm diamond		90 mm square		102 mm square		Market	
	s1	s2	s1	s2	s1	s2	s1	s2
H. barathri	0.454229	18.55	0.8	25.47	3.060085	27.64	0.787749	23.35

- Andrew *et al*. (1997) noted a significant decline in catch rates between 1976/77 and 1979/81 (associated with a fish down of the virgin stock) and further declines between 1979/81 and 1996/97. The reasons for particularly the latter decline are uncertain.

Key uncertainties

- Stock status is uncertain.
- Estimates of biological parameters (particularly t_0 and K) are poor, influenced by a lack of data for small specimens and are thus overestimated and underestimated respectively.
- Gear selectivity.
- Impacts of high levels of discarding of small fish.

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Silver trevally (*Pseudocaranx dentex*)

Silver trevally are members of the family Carangidae (Gomon *et al*. 1994). They occur throughout southern Australia from North West Cape (WA) to northeast Queensland, including Tasmania and the Lord Howe and Norfolk Islands (Tilzey 1994, Trnski 1998). They are also found in New Zealand and the subtropical to temperate waters of the Atlantic, Indian and Pacific Oceans (Kailola *et al*. 1993, Gomon *et al*. 1994). They are caught primarily in the SETF but are also taken by trap, line recreational and estuarine sectors (Rowling and Raines 2000).

Silver trevally are managed by TAC with the objective to maintain CPUE above its lowest annual average level from 1986 to 1994 (Smith and Wayte 2001).

Fishery research

- Silver trevally are treated as a single stock for management purposes in the SEF (Tilzey 1994).
- There have been no quantitative assessments of silver trevally. Stock assessment reports are available for 1994 (Smith and Wayte 2001).
- Recorded catches increased from < 200 t in the 1960s to around 1,500 t in the late 1980s. Significant declines in catches occurred in the late 1990s. The 1999 commercial catch was 340 t (Rowling 2000).
- Recreational catches of approximately 120 t per annum have been reported for NSW ocean waters and similar amount believed taken by recreational fishers from NSW estuarine waters in the early 1990s (Rowling 2000).
- Age structure of pre-exploited population could not be determined by Rowling (2000) due to lack of data from the early years of the fishery but probably contained a greater proportion of fish in the 10 to 25 years age classes.
- Recent commercial catches contained a high proportion (50%) of fish < 5 years of age; fish > 10 years of age estimated to make up 7% of catch (Rowling 2000).
- Preliminary modelling by Rowling (2000) suggests optimum size at first capture to be in excess of 30 cm; size at first capture is currently 20 – 25 cm.

- Data currently suggests that the stock is "growth overfished" and may continue to decline under current fishing pressure (Rowling 2000).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F	63.16	0.051	-6.47	>20			0.05-0.15	5-6	26-28	2	18-22			1.
M														

1. Rowling (2000)

Distribution and links to physical environment
- Tagging studies in New Zealand suggest limited movements (James 1984).

Reproduction
- Silver trevally are a partial spawner, releasing several batches of eggs over a period of several weeks (James 1978, Rowling 2000); fecundity is estimated at 220,000 eggs for a 37 cm female; fecundity in larger females may range up to 1,000,000 eggs (Rowling 2000).
- Silver trevally in spawning condition were reported off the north coast of NSW from October to December by Roughly (1951), however, the distribution and occurrence of larvae suggest that spawning is widespread, protracted and regionally variable in its timing within the SEMR. Recent work by Rowling (2000) concluded that silver trevally in NSW spawn from spring to autumn.

Key inter-species interactions
- Silver trevally are benthopelagic piscivores and feed on benthopelagic fish and to a smaller extent, megabenthos and benthic crustaceans (Bulman *et al*. 2001).

Population structure
- No published genetics studies on stock structure in Australian waters (Ward and Elliott 2001).

Fisheries habitats
- Silver trevally are a shallow water species (maximum depth approximately 120 m) (Trnski 1998).
- Larvae have been described from southern Australian waters (Trnski 1998) and have been recorded entering Lake Macquarie on the NSW central coast from December to February (Misckiewicz 1987), in coastal waters off Sydney from August to May (Gray *et al*. 1992), off southern NSW in May and off northeast Tasmania in March (CMR, Hobart, unpublished data) and off Portland (Vic) in January (F. Neira AMC, Beauty Point, pers. comm.).
- Juveniles usually inhabit estuaries, bays and shallow continental shelf waters, while adults form schools near the seabed on the continental shelf (Kailola *et al*. 1993, Tilzey 1994). Larger adults have been found over deeper shelf waters (Last *et al*. 1983).

Effects of Fishing
- There are indications that the fishery has had a significant effect of size structure of the stock. Average sized fish in commercial catches during 1997 – 99 was 28.4 cm and 500 g (Rowling 2000).

Key uncertainties
- Stock structure is unknown.
- Estimates of biological parameters (particularly t_0 and K) are poor, influenced by a lack of data for small specimens and are thus overestimated and underestimated respectively.
- Gear selectivity.

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Royal red prawn (*Haliporoides sibogae*)

Royal red prawn are members of the family Solenoceridae (Baelde 1991). They are widely distributed on the edges of continental shelves and the continental slopes around the Indo-west Pacific between 100 – 1,460 m (Ohtomi and Matsukoa (1998). In Australia, they occur from northern Queensland to northwest Western Australia. They are a quota species within the SETF and are caught primarily in NSW between Sydney and Ulladulla (Yearsley *et al.* 1999).

Fishery research

- No estimates of spawning stock biomass area available and no formal stock assessments have been made.
- Commercial exploitation of Royal red prawn developed in SA Australian waters in the mid 1970s (Smith and Wayte 2001).
- Catches were initially small in the mid 1970s (< 100 t) but increased to 322 t by 1979. Thereafter, catches were relatively steady at 300 – 350 t but with the exception of a peak of 700 t in 1984, but this peak appears to be a result of increased effort as the southern NSW grounds were targeted (Baelde 1991).
- Catches along the northern NSW/southern QLD region (north of the SEMR) were initially 90 – 166 t per year until 1984 and then declined substantially.
- Most of the fishing effort is targeted between 34^{o}S and 35^{o}S and in the depth range of 400 – 500 m (Baelde 1991).
- Standardised CPUE did not vary markedly between seasons within the fishing area for the years 1985 to 1988. However, there are several limitations to using CPUE as an indicator of abundance and it is difficult to determine the impact of the fishery on the abundance of the royal red prawn stock (Baelde 1991).
- Most of the catch is of prawns aged between 2 and 3 years and below the size at maturity, however most spawning appears to occur north of the fishing area, hence adults are under represented in the catch (Baelde 1994).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf} (mm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (mm)	Age (y)	Size (mm)	a	b	
F	48.3	0.37			1.6		0.6-0.7		30.8					1. (NSW) 2. (NSW)
M	33.5	0.49			1.2		0.4-0.8		25.8					1. (NSW) 2. (NSW)

1. Baelde (1994) (note – length refers to carapace length)
2. Baelde (1992)

Distribution and links to physical environment

- Latitudinal size distribution of prawns suggests movements from a southern recruitment ground to a northern spawning ground along the NSW coast (Baelde 1994).
- Most of the spawning appears to occur north of the prime fishing areas and outside the SEMR.

Reproduction

- Females breed several times during their life as apposed to males which probably only breed once (Balede 1992).
- Individual fecundity ranges from approximately 58,000 to 140,000 oocytes (Baelde 1992).
- Two restricted spawning seasons (February-April and July-August) occur.

Key inter-species interactions

No information currently available.

Population structure

No information currently available.

Fisheries habitats

- Royal red prawns are widely distributed in Australian waters. In NSW they occur along the entire coast from 270 – 820 m but appear to be more abundant in depths of 350 – 550 m (Graham and Gorman 1985).

- They are fished over well established muddy grounds (Baelde 1994) but may also occur over untrawlable bottom.

Effects of Fishing

- Impacts on stock of current fishing pressure are unknown although catch rates appear to be relatively stable.
- Small mesh size used when targeting royal red prawns provides the potential for bycatch of juveniles of various finfish species.
- Matsuoka *et al*. (1996) assessed the trawl selectivity of royal red prawns in the East China Sea and concluded that codend mesh selectivity was not representative of the gear as a whole, as considerable loss occurred through the wings of the net.

Key uncertainties

- Stock structure.
- Extent of stock in areas not currently fished.

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Hapuka (*Polyprion oxygeneios*)

Hapuka are members of the family Polyprionidae (Francis *et al*. 1999). They are distributed throughout southern Australia from Sydney (NSW) to Rottnest Island (WA), including Tasmania (Kailola *et al.* 1993, Gomon *et al.* 1994). Elsewhere they occur off New Zealand and Chile (Gomon *et al.* 1994). Hapuka make up a small portion of the by-catch of the blue eye trevalla fishery in southern Australia and are caught primarily by dropline, although they are also taken by trawl, gillnet and longline (Baelde 1999) although have been the subject of recent targeting by dropline off the Norfolk Rise. In New Zealand it is targeted in the long-line fishery (Roberts 1989). They are not landed in large numbers in Australia (Yearsley *et al*. 1999). Catches of the closely related bass grouper, *Polyprion americanus*, were initially included in NSW catch statistics (until 1998) and hapuka were initially included in blue eye trevalla catch statistics in Tasmania (Baelde 1999).

Hapuka are a non-quota species in the SEF.

Fishery research

- No stock assessments are available for hapuka.
- NSW dropline catches of bass grouper and hapuka combined ranged from 30 to 40 t in the mid-1980s, increasing to 50 to 70 t in the early 1990s and subsequently decreased to 30 t. When first separated from bass grouper in 1998 catch statistics, hapuka catch was recorded at 6 t (Baelde 1999).
- Trawl catches ranged from 3 to 9 t from 1986 to 1994 and then increased to 18 to 26 t from 1995 to 1998 (Baelde 1999) with the increase coming from offshore seamount fishing.

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F	133	0.0698	-4.3	50-60				10-13	85	3-4	50			1. (NZ)
M	129	0.0618	-5.75	50-60				10-13	85	3-4	50			1. (NZ)

1. Francis *et al*. (1999)   2. Baelde (1999)

Distribution and links to physical environment

- Tagging studies of hapuka in New Zealand have demonstrated that this species is capable of long-distance migrations, up to ~1,350 km (Beentjes and Francis 1999).

Reproduction

No information currently available.

Key inter-species interactions

No information currently available.

Population structure

- In a study of the population structure of the closely related wreckfish (*Polyprion americanus*), a small sample of *P. oxygeneios* were used as an out-group. Only a small number of hapuka from New Zealand and Australia were analysed, however no genetic difference was detected (Ball *et al*. 2000).

Fisheries habitats

- Larvae are undescribed. Juvenile hapuka are thought to live a pelagic existence in surface waters well offshore and often in association with flotsam (Roberts 1996). Juvenile hapuka switch to a demersal habitat at about 50 cm TL and an estimated age of 3 – 4 years (Francis *et al*. 1999).
- Adults are often associated with deep reefs on the continental shelf as well as canyons of the continental slope to a depth of about 450 m (Yearsley *et al*. 1999).

Effects of Fishing

- Industry have noted that small hapuka, 2 – 5 kg, form seasonal aggregations that can be targeted by trawl and non-trawl methods.

Key uncertainties

- Little is known about hapuka in Australian waters.
- Estimates of biological parameters (particularly t_0 and K) are poor, influenced by a lack of data for small specimens and are thus overestimated and underestimated respectively.

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Dogfishes (Squalidae)

At least 16 species are taken as target, by-product and by-catch species. The meat is marketed as flake and the liver oil is refined and exported. Members of this diverse group occur in three distinct habitats: continental shelf (*Squalus acanthias*, *Squalus megalops*), upper-slope (*Centrophorus* spp., *Squalus mitsukurii*.) and mid-slope (*Centroscymnus* spp., *Deania* spp. and *Etmopterus* spp.). These ecological groups differ in their reproductive biology and vulnerability to fishing.

Fishery research

- Australian dogfish fisheries have recently been reviewed (Daley *et al*. 2001).
- Currently the largest targeted catches are mid-slope species taken in the SET (Daley *et al*. 2001).
- Previously the largest targeted catches were upper-slope species taken in the SET and SSF (Johnson 1997, Walker *et al.* 1999, Daley *et al*. 2001).
- The current estimated total catch is between 790 – 1,430 t (whole weight) (Daley *et al*. 2001).
- Catches are not limited by TAC or ITQ.

Biological parameters (*Centrophorus harrissoni*)

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F									100			0.0013	3.3	1. (NSW, Tas)
M									80–85			0.0011	3.4	1. (NSW, Tas)

1. Daley *et al*. (2001)

Biological parameters (*Centrophorus uyato*)

Sex	Growth			Longevity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				46				9–15						2. (SSF)
F									100			0.0010	3.4	1. (NSW)
M									80			0.0009	3.3	1. (NSW)

1. Daley *et al*. (2001)
2. Fenton (2001)

Biological parameters (*Centroscymnus crepidater*)

Sex	Growth			Longevity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F				13				7	80			0.0098	3.8	1. (NSW, Tas), 3. (W. Vic)
M				13				4	63			0.0017	3.2	1. (NSW, Tas), 3. (W. Vic)

1. Daley *et al*. (2001)
3. Irvine (2000)

Biological parameters (*Centroscymnus owstoni*)

Sex	Growth			Longevity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F									95			0.0030	3.2	1. (NSW, Tas)
M									75			0.0059	3.0	1. (NSW, Tas)

1. Daley *et al*. (2001)

Biological parameters (*Deania calcea*)

Sex	Growth			Longevity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F				17				11	93–104			0.0044	23.0	1. (NSW, Tas) 3. (W. Vic)
M				20				4	73–80			0.0031	3.0	1. (NSW, Tas) 3. (W. Vic)

1. Daley *et al*. (2001)
3. Irvine (2000)

Biological parameters (*Etmopterus granulosus*)

Sex	Growth			Longevity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F				14					61			0.0024	3.2	1. (Tas) 3. (W. Vic)

M				19					50			0.0042	3.0	1. (Tas) 3. (W. Vic)

1. Daley *et al.* (2001)
3. Irvine (2000)

Biological parameters (*Squalus acanthias*)

Sex	Growth			Long - evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				78										5. (Tas)
F								36	69					4. (Tas) 5. (NE Pacific)
M									55					4. (Tas)

4. Scott (1993)
5. Saunders and McFarlane (1993)

Biological parameters (*Squalus megalops*)

Sex	Growth			Long - evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F				32				15	50			0.0056	3.0	6. (NSW) 7. (W. Indian O.)
M				29				9	39			0.008	2.88	6. NSW 7. (W. Indian O.)

6. Graham (1997) unpublished data
7. Watson and Smale (1999)

Biological parameters (*Squalus mitsukurii*)

Sex	Growth			Long - evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
F									80					1. (NSW)
M									65					1. (NSW)

1. Daley *et al.* (2001)

Distribution and links to physical environment

- Geographic distribution varies between species (Last and Stevens 1994, Daley *et al.* 2001).
- At least one species (*Centrophorus harrissoni*) is thought to be endemic (Last and Stevens 1994), however, there are taxonomic problems within the group and other species may also be endemic (P. Last CMR, Hobart, pers. comm.).
- Market data suggests *Centrophorus* spp. may move northward during colder months and southward during warmer months (Daley *et al.* 2001).
- Upper-slope species have been targeted throughout their depth range making them most vulnerable to capture (Daley *et al.* 2001).
- Mid-slope species extend deeper than fishing operations, deep waters may offer some refuge from commercial fishing operations (Daley *et al.* 2001).

Reproduction

- Dogfishes have low fecundity compared to teleosts and a stronger link between adult stock size and recruitment (litter sizes 1 – 32, some species probably breed less than once per year) (Hanchet 1988, Scott 1993, Wetherbee 1996, Girard and Du Buit 1999, Daley *et al.* 2001).

Key inter-species interactions

- *Squalus megalops* and *Squalus acanthias* feed mainly on demersal teleost fishes as well as crustaceans and cephalopods (squid and octopus) (Scott 1993, Graham 1997 unpublished data).
- *Centrophorus* spp. and *Squalus mitsukurii* feed mainly on vertically migrating fishes, such as lantern fishes (Myctophidae) and may be important in the vertical transfer of energy in the upper-slope ecosystem. They also feed on cephalopods, crustaceans and teleosts that are common in commercial trawls (Daley *et al.* 2001).
- *Centroscymnus crepidater* and *Deania calcea* are mid-slope species that feed mainly on myctophids. Other mid-slope species have different feeding strategies. Teleost fishes are the key component of the diet of *Centroscymnus coelolepis* while cetacean (whale) blubber is important in the diet of *Centroscymnus coelolepis* (Blaber and Bulman 1987, Bulman *et al*. 2002, Daley *et al*. 2001).

Population structure

- There have been no stock structure studies in Australia.
- Stock structure studies are unlikely to be undertaken until taxonomic problems are resolved.

Fisheries habitats

- Mid-slope species differ in their adaptations for particular bathymetric features. *Etmopterus granulosus* are caught most frequently near the peaks of seamounts, whereas *Centroscymnus crepidater* and *Deania calcea* are more common in catches taken on flat ground (Daley *et al.* 2001).

Effects of Fishing

- There is little evidence of declines in shelf species (*Squalus acanthias* and *Squalus megalops*).
- Fishery, scientific and market data indicate major declines in some upper-slope species (*Centrophorus* spp.) (Graham *et al*. 1997, Daley *et al.* 2001, Graham *et al*. 2001) and such declines have undoubtedly had major ecosystem ramifications. These effects are, however, poorly documented. *Centrophorus harrissoni* has been nominated for Endangered listing under the EPBC Act; *C. uyato* and *C. moluccensis* have been nominated as Vulnerable. If these species are listed then recovery plans will be required. Such recovery plans are likely to require fishery restrictions.
- Fishery and independent data suggest mid-slope species are at lower risk (Graham *et al*. 1997, Daley *et al*. 2001, Graham *et al*. 2001).

Key uncertainties

- Insufficient knowledge of movements, home range and critical habitat for appropriate recovery plans for upper-slope species.
- Previous under-reporting of discarded catches, poor fishery data.
- Limited independent data.
- Limited knowledge of reproduction, age and growth.
- Taxonomic problems, possibly more than one endemic species. Correct species indentification is difficult for fishers and presents a problem for monitoring catches.
- Stock structure is unknown.

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Skates (*Rajidae*)

Skates are members of the family Rajidae. They are distributed worldwide on the continental shelf and slope (Last and Stevens 1994). There are at least six by-product and by-catch species taken in the SEMR, mainly within SETF (Daley 2001). Almost nothing is known of Australian skate biology or stock size and catches are unregulated. Skates are extraordinarily vulnerable (Musick *et al*. 2000) and are considered one of the most threatened groups of all marine species worldwide. There have been local and near extinctions overseas (Dulvey *et al*. 2000, Stevens *et al.* 2000). Concerns are also held for other batoids including stingarees (Urolophidae) and stingrays (Dasyatididae).

Fishery research

- There have been no fishery-based assessments in Australia.
- There have been only a few assessments of skate fisheries overseas and most of these are not species specific (Agnew *et al.* 2000).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				15–18 9–24 7–12 12–13			 0.10–0.35	7–9 6–11						1. (W. Indian O.) 2. (NZ) 3. (E. Atlantic) 4 (NE Pacific)
F								6–13 17						2. (NZ) 5. (Mediterranean)
M								4–8 15						2. (NZ) 5. (Mediterranean)

1. Walmsley-Hart *et al.* (1999)
2. Francis *et al*. (2001)
3. Ryland and Ajayi (1984)
4. Zeiner and Wolf (1993)
5. Abdel-Aziz (1992)

Distribution and links to physical environment

- Skates are benthic, demersal species (Last and Stevens 1994).
- They primarily occur on the continental slope, also shelf, from 50 – 2,300 m in Australian waters (Last and Stevens 1994).
- Some species within the SEMR are thought to be endemic with localised distributions (Last and Stevens 1994).

Reproduction

- Skates are oviparous (egg layers).
- Fecundity is low compared to teleosts therefore recruitment is dependent on adult stock size.
- Some overseas fisheries target mating concentrations (Rio and Junquera 2000).

Key inter-species interactions

- Skates have a variety of feeding strategies which differ between species. Diet may include crustaceans, small demersal fishes, polychaete worms and cephalopods (Ebert *et al*. 1991, Orlov 1998).

Population structure

- There are at least 14 species in Australian waters and there are taxonomic problems within the group (Last and Stevens 1994).
- Nothing known of stock structure in Australia.

Fisheries habitats

- Skates are caught primarily on flat ground and are most vulnerable to trawling (Daley 2001).
- The structure of skate communities differs with depth (Ebert *et al*. 1991).

Effects of Fishing

- Independent surveys off southern NSW show catch rates have declined by 83% for skates and by 66% for stingarees (Graham *et al.* 1997, Graham *et al*. 2001).
- There have been declines in several regions overseas: Irish Sea, Celtic Sea, northwest Atlantic, North Sea (Brander 1981, Casey and Myers 1998, Walker and Hislop 1998, Stevens *et al*. 2000).

- Overses studies show larger, later maturing skates tend to decline under fishing pressure but smaller, earlier maturing species may increase (Agnew *et al*. 2000).

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Southern Shark Fishery

The Southern Shark Fishery extends from the Western Australian/South Australian Border east to the Victorian/NSW border and has been operating since the 1920s. Two species of shark are the primary target: school shark (*Galeorhinus galeus*) and gummy shark (*Mustelus antarcticus*), although other species of elasmobranchs and finfish are also taken. Longlines were initially used to target school sharks in the fishery but it expanded during the late 1960s and early 1970s with the introduction of gillnets, whereupon gummy shark assumed greater importance (Punt and Walker 1998). The fishery has a long research history (since the 1940s) and a management plan was introduced in 1988 that includes limited entry, minimum legal lengths, gear controls restricting effort in the net and hook sectors, nursery (and some inshore) area closures and mesh size limitations (Olsen 1954, 1984, Walker 1992, 1994, Walker *et al*. 1995, Stevens *et al*. 1996). The SSF is limited entry with permits issued to endorsement holders. Endorsements were initially allocated on the basis of catch history. Gill-net effort in the SSF is based on a net unit, with each net unit currently 420 m. Licence holders are constrained to the number of net units they can have under their endorsement (Walker *et al*. 1997), with the maximum being 10 (Table 2) and then 6 under A-Class endorsement. B-Class endorsements are generally owned by fishers that concentrate on other fisheries such as crayfish, but who take shark in the “off-season”. Some of these endorsements are not active.

Table 2. Number of vessels with Commonwealth shark permits as at 1 September 1997 (from Walker *et al.* 1999).

State	Net permit						Hook permit		
	A10	A6	B5	B4	B3	B2	H2000	H1000	Total
Vic	25	14	17	0	0	2	2	12	71
Tas	2	4	10	1	1	2	3	14	37
SA	13	10	20	1	1	1	0	4	51
Total	40	28	47	2	2	5	5	30	159

During 1998, 124 entitlement holders were issued Commonwealth permits to catch shark with gill-net. Sixty-eight of these were A-class permits (40 A10, 28 A6). Hook permits were issued to 37 long-liners. Four vessels hold both hook and gill-net permits. Ninety vessels were responsible for 80% of the catch (Walker *et al.* 1999).

Current input controls include the maximum length of net (4,200 m) that can be set during a single fishing operation, and constraints on mesh size and net height. The length of time a net is set (soak time) is to some extent restricted by natural processes. The longer a net is set, the more spoilage and wastage due to sea-lice and other fish (including sharks and leatherjackets) damaging catch. In January 2001, output controls in the form of Individual Transferable Quotas (ITQs) were introduced for the fishery. However, the current input controls are also still in place.

There are 11 ports that vessels primarily operate out of, but are not restricted to. The four main ports are San Remo, Port Lincoln, Lakes Entrance, and Robe, closely followed by Thevenard, Streaky Bay, Victor Harbour and Port Albert.

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Key species accounts

School shark (*Galeorhinus galeus*)

School sharks are members of the family Triakidae (Last and Stevens 1994). They are widespread in temperate waters of both the northern and southern hemispheres. In Australia they occur from Brisbane (Qld) around the south coast to Perth (WA) including Tasmania and Lord Howe Island (Last and Stevens 1994). School sharks are taken by gillnet and bottom set longlines in the Commonwealth managed Southern Shark Fishery off Victoria, Tasmania and South Australia. They are also taken as by-catch in other fisheries within the SEMR (e.g. SETF, Victorian Bay and Inlet Fishery, by recreational fishers and in the SBT longline fishery – pre 1998) (Walker and Punt 1998).

Catches have been regulated by global TAC and ITQ since 2001 with the objective to ensure that there is an 80% probability of the mature biomass exceeding the 1996 level by 2011. Descriptions of the fishery can be found in Olsen (1954, 1959, 1984), Walker (1993), McLoughlin and Walker (1995) and McLoughlin *et al*. (1998) and references therein.

Fishery research

- School shark assessments have been undertaken using a variety of models over the history of the fishery, see Walker and Punt (1998) for review.
- The most recent assessments are based on a spatially structured model that includes movement rates between southern Australia and New Zealand, sex structure, tag loss/tag mortality, catch, length-frequency data and sex ratio data and includes the possibility of more than one stock (Punt *et al*. 2000, Punt and Pribac 2001).
- A less complex model assuming a single stock around southern Australia but with different age and sex-specific availability between areas was recently explored by Punt (2001). The model fit was relatively good and provided further confirmation of the highly depleted nature of the resource.
- Catch declined from 3,893 t in 1970 to 1,200 t in 1996 (Stevens 1999).
- 1998 assessment estimated biomass 13 – 45% of virgin, suggested reduced catches needed.
- 2000 assessment estimates pup production at 12 – 18% of virgin.
- 2001 assessment suggests that rebuilding of stocks to 1996 level may not be achievable under any level of TAC (SharkFAG 2001).
- Currently assessed as over-exploited and severely overfished, particularly in Bass Strait. Extremely high exploitation rate indicated by high frequency of recapture of tagged sharks (> 30%) (West and Stevens 2001).

- An estimated reduction in fishing mortality of 19% is needed to stabilise school shark populations at their current size and a reduction of 42% to have an 80% probability that the level of mature biomass is above the 1996 level by the year 2011 (Punt and Walker 1998).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	160.4	0.1639	-1.27	60			0.1 0.3 0.1					0.6561E-9	3.2815	1. (SSF) 2. (SSF) 3. (SSF) 4. (SSF) 6. (SSF)
F	161.83	0.16	-1.28					10				0.5187E-9	3.3206	1. (SSF) 2. (SSF) 5. (SSF)
M	158.33	0.1675	-1.25					8				1.0629E-9	3.2067	1. (SSF) 2. (SSF) 5. (SSF)

1. Grant *et al.* (1979)
2. T. Walker (unpublished data) - cited in Punt *et al.* (2001)
3. Dow (1986)
4. Walker *et al.* (2000)
5. Moulton *et al.* (1992)
6. Anon (1991).

Distribution and links to physical environment

- Movements are complex and vary spatially by sex and size (Walker and Punt 1998). A current hypothesis is that they may home to natal mating and puping grounds.
- Large seasonal movements across southern Australia (distances travelled of over 1,400 km recorded) and between Australia and New Zealand (distances in excess of 3,500 km) based on the movements of conventionally tagged specimens (Olsen 1954, Coutin *et al*. 1992, Stevens and West 1997).
- Archival tagging has provided more detailed information of movements. More restricted movements and complex movements suggested than that given by conventional tagging but time at liberty (up to 1.2 years for archival tags vs up to 42 years for conventional tagging) probably accounts for this. Archival-tagged specimens favoured four areas in southern Australia. The outer GAB and Tasmanian east coast were favoured during summer, whereas fish in those regions moved to Kangaroo Island and the west Tasmanian coast during winter. Major movements occur during March-April and October-November in Tasmania but occur over a wider time period in South Australia (West and Stevens 2001).
- Depth diving behaviour variable between specimens. Most stay over continental shelf depths where ascents towards or to near the surface at night are common except during full moon periods when this behaviour is suppressed. Those recorded in deeper waters also moved vertically in the water column and including regular ascents to near the surface at night (West and Stevens 2001).
- Size generally increases from inshore to offshore (Olsen 1984).
- Sexes and sizes segregate into separate schools (Olsen 1954, 1984).
- Pregnant sharks move from eastern areas to South Australia and later move back eastward to give birth (Walker *et al*. 1989a).

Reproduction

- School sharks are ovoviviparous (internally fertilized eggs develop in utero without a placenta) and do not develop uterine compartments during gestation (Walker and Punt 1998).
- Litter sizes average approximately 30 (range 15 – 43), with only a weak correlation between number of embyos carried and maternal size (Walker *et al*. 1989b).
- 12 months gestation period (Walker and Punt 1998).
- Pupping frequency 2 – 3 years (Stevens *et al*. 1997).
- Close relationship between parent stock and recruitment.

Key inter-species interactions

- School shark feed primarily on teleosts (47% by weight) and cephalopods (37%) (Walker 1989). That study identified the four most important prey items as barracouta (*Thysites atun*), Gould's squid (*Notodarus gouldi*), Octopus (*Octopus* spp) and calamary (*Sepioteuthis australis*).
- New born and juvenile school sharks feed on benthic invertebrates (Olsen 1954).

Population structure

- Large seasonal movements across southern Australia have led to inference of a single stock (Olsen 1954).
- Genetic evidence (although weak) suggests that there is restricted gene flow across the Tasman Sea (Ward and Gardner 1997). However, school sharks tagged in New Zealand have been recaptured in Australia indicating some mixing (Coutin *et al*. 1992, Hurst *et al*. 1999). It is believed that the stocks between Australia and New Zealand are essentially separate but that the fish mix on common feeding grounds (Stevens 1999).

Fisheries habitats

- Pupping and nursery areas have been confirmed in certain estuaries, protected embayments and ocean beach habitats of eastern Bass Strait, eastern Victoria and eastern and southern Tasmania (Olsen 1954, Stevens and West 1997, Stevens 1999).
- Suggestions that pupping is more widespread than above confirmed localities (e.g. within the GAB – Prince 1966).
- School sharks occur on the bottom on the shelf and slope from intertidal areas to 800 m depth (Last and Stevens 1994), but they range through the water column, particularly at night and also occur in the oceanic zone where they may behave pelagically (Stevens 1999).

Effects of Fishing

- The selectivity pattern for gill-nets is assumed to follow a gamma function (Kirkwood and Walker 1986). Gill-net selectivity parameters for the 2001 assessment are given below (T. Walker unpublished data – cited in Punt *et al*. 2001):

Mesh size	α	β
6-inch	23.79	47.49
7-inch	32.05	41.13
8-inch	41.57	36.24

- Some evidence of increased growth rate of juveniles in nursery areas that may be related to declining abundance (density dependent growth effect) (Stevens and West 1997).

Key uncertainties

- The extent of discarding and unaccounted for fishing (e.g. recreational fishing, small mesh trawlers, drop-out and predation in nets) is not well documented.
- Regional pupping and recruitment is not well understood.
- More knowledge of movements required, particularly associated with reproduction as well as the age-specific distribution and movements when on the continental shelf (the latter to assist with an understanding of spatial patterns in fishing mortality from tag returns).
- Lack of fishery independent data will make future stock assessments difficult (a newly funded fishery independent survey at fixed sites will commence in 2002).
- Recent changes in management are likely to affect fishery data more than abundance.
- Stock assessments are sensitive to movements of sharks between Australia and New Zealand.
- The extent of movements on and off the continental shelf and the size of the population "offshore" where they are unavailable to the fishery.
- Interannual variability in environmental factors.
- Stock structure still not clear, global TAC will not be appropriate for multiple stocks.
- The influence of degredation of inshore pupping grounds is poorly understood.

- The extent to which inshore open sandy beach habitats act as nursery areas (e.g. eastern Victoria) is unknown but may be extensive.
- Initial tag loss rates and tagging mortality are disputed.
- The extent to which catch rates are proportional to abundance is unknown and likely to be spatially variable.
- CPUE is also complicated by:
  - changes in fishing method from longline to gill-nets in the late 1960s/early 1970s,
  - differences in mesh-size and gear types between regions of the fishery,
  - progressive changes in mesh-size of gill-nets since the early 1970s, and
  - differences in targeting pratices by fishers operating primarily in gummy shark areas compared with fishers operating over a wide area targeting school sharks.

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Gummy shark (*Mustelus antarcticus*)

The gummy shark (*Mustelus antarcticus*) is endemic to Australian waters and is broadly distributed over areas of southern Australia from Geraldton (WA) around the south coast to as far north as Townsville (Qld) (Last and Stevens 1994, Ward and Gardner 1997). The species has a long history of targeted fishing using bottom set long-lines and gill-nets in the SSF where catches are regulated by ITQ and TAC. It is also the subject of a small recreational fishery and gummy sharks are taken as by-catch in inshore scale fisheries and in the SETF.

Management objectives aim to stabilise gummy shark stocks at the 1994 level. Descriptions of the fishery can be found in Walker (1993), McLoughlin and Walker (1995) and McLoughlin *et al*. (1998) and references therein.

Fishery research

- Gummy shark assessments have been undertaken using a variety of models over the history of the fishery, see Walker (1998a) for review.
- Stock assessments are currently conducted for three broad areas (South Australia, Bass Strait and Tasmania) on the basis that multiple sub-stocks probably occur in southern Australia (Punt *et al*. 2000, SharkFAG 2000). Further sub-structuring of stocks within these areas is suggested by other work (see Walker 1998a) but the details are uncertain and the present assessment strategy minimises the complexity of the model required for the fishery.
- Annual catch overall increased from 860 to 1,520 t between 1970 and 1998.
- Catches increased to 1,945 t in 1989, declined to 1,720 t in 1991 and then peaked at 2,300 t in 1993 (Walker *et al.* 1996).
- 1991 and 1992 assessments concluded gummy sharks were over exploited, however current catches of gummy shark appear to be sustainable (Walker 1998b).
- The 1999 assessment estimated that the pup production in Bass Strait was 45 to 78% of the virgin level and in South Australia, 72 to 89% of virgin. There are insufficient data to formally assess the population in Tasmania but available data suggests the levels are similar to Bass Strait (SharkFAG 2000).
- Current catch rates appear to be sustainable and catch predictions based on assessment results are reviewed in SharkFAG (2000).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf} (mm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				16			0.197							2. (SSF) 3. (SSF)
F	2109 2019	0.123 0.086	-1.55 -3.01					5				1.22E-9	3.18	1. (SSF) 2. (SSF) 3. (SSF) 4. (SSF)
M	1387 1417	0.253 0.17	-0.9 -2.08					4				4.38E-9	2.97	1. (SSF) 2. (SSF) 3. (SSF) 4. (SSF)

1. Stevens (1999)
2. Moulton *et al*. (1992)
3. Walker (1992)
4. Walker (1994)

Distribution and links to physical environment

- Gummy shark occur from Geraldton (WA) around the southern coast to Townsville (Qld) (Gardner and Ward 1998).
- Some records of long distance movements across southern Australia with females probably more mobile than males. Most movements more restricted - average 35 km, (Walker 1983).
- Frequent movements of tagged fish bewteen Bass Strait, Tasmania and South Australia (Gardner and Ward 1998).

Reproduction

- Gummy sharks are considered to be one of the more productive of sharks. They are ovoviviparous (internally fertilized eggs develop in utero without a placenta) and develop uterine compartments where the embryos develop (Walker 1998).
- Average litter size of 14 but, unlike school shark, there is a strong relationship between litter size and female size with larger females having up to 40 pups (Walker 1992).
- 12 months gestation period.
- Pupping frequency varies regionally; every year in WA (Lennaton *et al*. 1990) but every two years in southeast Australia (Walker 1992).
- Current assessments suggest that recruitment has been relatively stable over the last 30 years (SharkFAG 2000).

Key inter-species interactions

- Gummy sharks are benthic carnivors and prey on a wide range cepahlopods, crustaceans and fish, with cephalopods and crusctaceans forming the majority of the diet (Coleman and Mobley 1984). Walker (1989) reported that octopus and squid comprise 36% by weight of stomach contents, crustaceans 25% and fish 11%.

Population structure

- Several studies suggest the entire Australian population structure is complex and consists of more than the single stock concluded by MacDonald (1988) – including studies of reproductive biology (Lennaton *et al.* 1990) and mercury content (Walker 1976).
- Most recent allozyme and mtDNA studies suggest two and maybe three stocks in Australian waters: Bunbury (WA)-Eden; Newcastle – Clarence River (NSW) and possibly off Townsville (Qld) (Gardner and Ward 1998). The SSF thus is believed to target a single genetic stock (Ward and Gardner 1997).

Fisheries habitats

- Gummy sharks do not have restricted and well defined nursery areas (as is the case with school sharks). Pups are usually born in shallow coastal areas and pups and juveniles aggregate in many areas across southern Australia (Walker 1998).
- Adults are demersal on the continental shelf from inshore to about 80 m, but are sometimes encountered on the upper-slope to 400 m. Most (84%) of commercial catch taken in 25 – 75 m (Kailola *et al.* 1993).

Effects of Fishing

- The selectivity pattern for gill-nets is assumed to follow a gamma function (Kirkwood and Walker 1986). Gill-net selectivity parameters for the 1997 assessment are given below (Walker 1998).

$$\varnothing_1 = 1.843$$
$$\varnothing_2 = 29739$$

- There is no evidence that years of heavy fishing on 3 – 4-year age classes have had a detectable impact on recruitment (SharkFAG 2000). However targeting of adults is low due to legislated gill

mesh size and dynamics of fishery. The consequent ‘protection’ offered to the adults may have facilitated the stable recruitment observed to the fishery.
- No evidence of change in reproductive rate or growth rate as a result of fishing (for comparisons between 1973 – 76 and 1986 – 87) (Moulton *et al*. 1992, Walker 1992).
- Gear competition is likely to be important, with high levels of effort not necessarily resulting in large increases in catch (Punt 2000, Punt *et al*. 2000).

Key uncertainties
- Movement associated with reproduction need further examination.
- Interpretation of length frequency data (as a surrogate data for year class strength) requires finer spatial resolution (e.g. shot by shot data) rather than current combined data on landing.
- Links between catch rate and abundance uncertain.
- Targeting practices by fishers, which are generally unknown, have impacts on catch rates.
- Gummy shark fishing may have unsustainable impact on school sharks as by-catch.
- Lack of independent data.
- Changes in fishery management are likely to influence catch data more than abundance.
- Several sectors (e.g. recreational) are not included in current assessments.

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Sawsharks (*Pristiophorus spp*)

Pristiophorids (sawsharks) are a marine, bottom dwelling shark species (Yearsley *et al*. 1999). There are two sawsharks commonly found throughout the southern waters of Australia: *Pristiophorus cirratus* (common sawshark) and *P. nudipinnis* (southern sawshark). A third species, *Pristiophorus* sp. A (eastern sawshark) occurs off New South Wales. Sawsharks are the most poorly known of the commercial elasmobranchs in the SEMR. There have been no published biological studies of sawsharks in Australia and very little published world-wide.

Fishery research

- Sawsharks are a by-catch of the SSF and the SEF.
- They were the third most important shark catch in the SSF in 2001 representing 8.3% of the annual harvest (Walker *et al*. 2001).

- Catches in commonwealth waters are limited by ITQ.
- Aggregated SSF catch data shows total catch was 359 t (carcass weight) in 1995 and around 200 t in 2001 (Walker *et al*. 2001).
- There have been no formal catch assessments or CPUE analysis to date.

Biological parameters

- Very few biological parameters are available.The biology of sawsharks is currently under examination by MAFRI as part of an FRDC Project (99/103); published findings are expected in early 2002

Biological parameters (*Pristiophorus cirratus*)

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf} (cm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	A	b	
	134													1. (SSF)
F														
M									97					2. (Sthn Aust)

1. R. Hudson (MAFRI, Queenscliff, pers. comm.)
2. Last and Stevens (1994)

Biological parameters (*P. nudipinnis*)

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf} (cm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	A	b	
F														
M									90					1. (Sthn Aust.)

1. Last and Stevens (1994)

Biological parameters (*Pristiophorus sp.* A)

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf} (cm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	A	b	
F														
M														

Distribution and links to physical environment

Pristiophorus cirratus

- The common sawshark is endemic to Australia, occurring from roughly Caloundra (Qld) to Jurien Bay (WA), including Tasmania (Gomon *et al*. 1994; Last and Stevens 1994).
- Occurs throughout the continental shelf in depths between 40 and 310m (Last and Stevens 1994).

P. nudipinnis

- The southern sawshark is endemic to Australia, occurring from Wilsons Promontory (Vic) to the Bunbury (WA), including Tasmania (Gomon *et al*. 1994, Last and Stevens 1994).

- They are largely restricted to the inner continental shelf to depths of about 70m (Last and Stevens 1994), but extending to about 200m (Gomon *et al*. 1994).
- Small southern sawshark are known to enter shallows (Gomon *et al*. 1994).

Pristiophorus sp. A
- The eastern sawshark is distributed in warm temperate waters from Coffs Harbour (NSW) to Lakes Entrance (Vic) (Last and Stevens 1994).
- They are restricted to the continental shelf and upper slope in depths between 100 and 630m (Last and Stevens 1994).

Reproduction
- Sawsharks are aplacental viviporous (live-bearers).
- Fecundity is low compared to teleosts and recruitment is strongly linked to adult stock size
- Common and southern sawsharks have around 20 pups per litter and probably breed only every second year (R. Hudson, MAFRI pers. com. 2002)

Pristiophorus cirratus
- Size at birth for the common sawshark is about 38cm (Last and Stevens 1994).

P. nudipinnis
- The southern sawshark grows to at least 99cm (Last and Stevens 1994) and possibly up to 120cm (Gomon et al 1994).
- Size at birth for the southern sawshark is about 25cm (Last and Stevens 1994).

Pristiophorus sp. A
- The female eastern sawshark grows to at least 107cm – no male eastern sawsharks were examined (Last and Stevens 1994).

Key inter-species interactions
- The diet includes small teleosts and cephalopods (R. Hudson, MAFRI, Queenscliff, pers. comm.).

Population structure
- There have been no stock structure studies in the SEMR.

Fisheries habitats
- The southern sawshark occurs most commonly on sandy bottoms inshore (R. Hudson, MAFRI, Queenscliff, pers. comm.)
- The common sawshark is caught to 300 m mainly by trawlers on flat ground.

Effects of Fishing
- There is no evidence of adverse effects of fishing (Walker *et al*. 2001).

Key uncertainties
- Limited knowledge of biology (all species).
- Limited fishery data.
- No stock assessments.
- Trends for individual species may be masked by aggregation of data.
- Lack of independent data.
- Stock structure is unknown.

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Elephant fish (*Callorhinchus milii*)

Callorhinchus milii, elephant fish, is a marine, demersal shark species that grows to about 120 cm in length and 9 kg (Last and Stevens 1994, Yearsley *et al*. 1999). Elephant fish are largely a by-catch of the Southern Shark Fishery (SSF) and the South East Fishery (SEF) (Kailola *et al*. 1993). The biology and population dynamics of elephant fish are poorly known.

Fishery research

- In 1991 the catch from the SSF was about 50 t, however the by-catch from trawl and Danish seine was unknown (Kailola *et al.* 1993).
- Declining catch rates from gill nets suggests that this species may be fully, if not over, exploited (Kailola et al 1993).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf} (mm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				15-20										2+3. (SSF?NZ)
F														
M									70					1.

1. Kailola *et al*. (1993)
2. Coutin 1992
3. Francis 1997.

Note: In New Zealand some researchers have reported a fast growth rate and young maximum age, while others have reported slow growth and a greater maximum age (see McClatchie and Lester 1994 and references therein).

Distribution and links to physical environment

- Elephant fish are distributed throughout the continental shelves of cool and temperate regions of Australia and New Zealand in depths to at least 200m (Last and Stevens 1994).
- In Australia, they are distributed from Sydney (NSW) to Esperance (WA) including Tasmania, with abundance increasing south of Bass Strait (Gomon *et al*. 1993; Last and Stevens 1994).
- Adult elephant fish migrate into the shallower waters (generally less than 40m depth) of estuaries and bays in spring to breed (Last and Stevens 1994).

Reproduction

- Elephantfish are oviparous, and lay two egg cases on sandy or muddy bottoms (Cox and Francis 1997).
- In New Zealand, females are thought to deposit several egg pairs over the breeding season, possibly as frequently as every two weeks (Didier 1992). Embryos take as long as 8 months to

develop and they hatch at about about 15cm in length (Last and Stevens 1994; Cox and Francis 1997).

Key inter-species interactions
No information currently available.

Population structure
No information currently available.

Fisheries habitats
No information currently available.

Effects of Fishing
No information currently available.

Key uncertainties
- There is a lack of biological and population dynamic information for this species.
- A large part of the by-catch from the trawl and Danish seine fisheries is either discarded or not recorded to species, adding to the uncertainty.
- Recruitment variability is unknown.

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Southern Rock Lobster Fishery

The main region of the commercially fishery ranges from the western GAB through South Australian, Victorian and Tasmanian waters, with smaller fisheries in Western Australia (primarily around Esperance) and southern New South Wales. Southern rock lobster (SRL) also forms a major fishery in New Zealand waters where they are known as red rock lobster. The fishery in southern Australia is divided into seven functionally independent management zones. However it is likely that zones are connected via dispersal/transport of long-lived larvae although the source and destination of larvae entering and leaving each zone is unknown. Given this absence of knowledge on connectivity between zones, the precautionary approach is adopted of attempting to maintain reasonable egg production in each.

There are also significant recreational fisheries for SRL in, particularly, South Australian and Tasmanian waters.

Priority species accounts

Southern rock lobster (*Jasus edwardsii*)

Southern rock lobster (SRL) are distributed from Coffs Harbour (northern NSW) around the south coast to Dongara (WA) (Brown and Phillips 1994).

Considerable differences occur between management zones (and, in some cases, within management zones) in growth, age at maturity, sex ratio, mortality, catch rates and spawning biomass. For these reasons, information (where it is available) is reviewed by State or management zone.

Note: Settlement is used below in reference to puerulus settling from their pelagic phase (at the end of the larval period) to the substrate where they take up a benthic existence. Recruitment is used in reference to when rock lobsters first enter the fishery.

Fishery research

General comments

- CPUE data can be hard to interpret as a measure of stock abundance due to variations in catchability of rock lobster, selectivity of pots, fleet dynamics and fisher behaviour (Addison 1997, Frusher and Haddon 2000).
- For these reasons, each state uses additional measures of abundance ranging from model estimates of biomass (which use CPUE data, but also estimates of monthly catchability, selectivity and fleet dynamics), to independent measures such as Change-In-Ratio techniques (e.g. Frusher *et al.* 1998).

South Australia

- The fishery in South Australia is divided into two management zones (Northern and Southern) which comprise 58 statistical reporting blocks (McGarvey *et al*. 1999).

Tasmania

- The Tasmanian fishery is divided into eight regions for stock assessment purposes due to regional differences in growth, mortality, size at maturity and catch rates (Punt and Kennedy 1997), however the fishery itself is not separately zoned and fishers are free to move between zones and management controls act globally.
- During the 1980s and early 1990s the fishery was considered to be over-exploited (Frusher 1996) and catch rates have been declining since the 1980s (Frusher 1997), although some recent improvements in catch rates have been recorded (Buxton 2000).
- The 2000/2001 season saw stable catch rates and improving legal-sized biomass (Gardner *et al.* 2002). Catch rates, legal-sized biomass and egg production were all well above the levels of reference years (Gardner *et al.*2002).

- Estimates of the abundance of legal sized animals has improved by 54% since the year of lowest statewide legal-sized biomass in 1993. Industry and management has expressed their intent to increase the size of the annual harvest in the future while still maintaining the process of stock rebuilding (Gardner *et al.* 2001).
- Annual catch rates declined in Tasmanian waters from 1.6 to 0.82 kg/pot lift between 1980 and 1994 but have since risen back above 1.00 (Punt and Kennedy 1997, Gardner *et al.* 2001). It should, however, be noted that the relatively low catch rates currently are also a reflection of changes to quota management in 1998. As a result, fishers now concentrate more of their effort during the winter when prices are higher, but catchability of lobsters is lower (Gardner *et al.* 2001). For this reason, the estimates of legal-size biomass provide a more useful measure of the state of the stocks.
- Spawning stock biomass varies markedly across the range of the fishery from as low as 13% of the unexploited equilibrium level in the north west to greater than 100% in the south west (Punt and Kennedy 1997, Gardner *et al.* 2001). This estimate of greater egg production in the south west currently, than would occur under unfished conditions may be merely a function of the modelling process, although it may also have an underlying biological basis. The fishery in this region is based almost entirely on males, so the removal of some males through fishing may have made more resources available for females.
- Frusher (1997) estimated that a total allowable catch of 1,500 t was required to rebuild the stock. This prediction has proved to be correct with an estimated 54% increase in legal-size biomass compared to 1993 under a regime of a 1,500 t TAC since 1998.
- The assessment process in Tasmania utilises data from a range of sources other than commercial catch and effort, including recreational catch surveys (Lyle 2000), monitoring of future recruitment to the fishery from larval settlement indices (Gardner *et al.* in press), research fishing surveys (Frusher *et al.* 1998), and effort distribution patterns by the commercial fleet (Gardner *et al.* 2001).
- Recent research to refine estimates of catchability has been conducted in Tasmania (C. Gardner, TAFI, Hobart, pers. comm.).
- Fleet dynamics models have been used since 1996 and have been the subject of intense research in Tasmania for the last 2 years. The latest assessment report (Gardner *et al.* 2002) includes a revised model.

Victoria

- The Victorian fishery is divided into western and eastern management zones; 80% of the catch is taken in the western zone (Hobday and Ryan 1997).
- Catch rates declined from 2.5 kg/pot lift in the 1950s to 0.3 and 0.5/pot lift in the eastern and western zones, respectively, by the mid 1990s (Hobday and Smith 1996).
- Egg production in both Victorian zones is estimated to be at 6 to 20% of the virgin, unfished stock.

Distribution and links to physical environment

- Growth rate differs markedly between regions and depth, probably as a result of water temperature (as well as, food availability, density dependence) (Punt *et al.* 1997).
- Links believed to occur between physical processes and settlement of puerulus including fequency of wind and storm events and offshore presence of particular water masses (Bruce *et al*. 2000, McGarvey and Mathews 2001).
- Movement of adults is generally small scale (less than 2 km over periods of several years), with no directional migration paths detected in Tasmania.

Reproduction

General

- Mating occurs during autumn and early winter (MacDiarmid 1988). Eggs hatch from September to January, the timing varying slightly with latitude (Kailola *et al*. 1993, Bruce *et al*. 2000, C. Gardner TAFI, Hobart, pers. comm.).

- SRL have long-lived (up to 24 months), widely dispersed pelagic larvae that occur in offshore waters and have been found right across the Tasman Sea to New Zealand. However, it is generally believed that larvae retained within 500 km of the coast contribute to settlement back to the Australian fishery (Bruce *et al*. 2000, Booth and Phillips 1994).
- Larvae develop through a series of 11 stages before metamorphosing into a non-feeding puerulus stage, which settles on coastal reefs (Booth and Phillips 1994).
- Early stage larvae occur in shelf waters; mid and late stage larve are found almost exclusively offshore where they occur primarily in waters of the subtropical front, STF (Bruce *et al*. 2000).
- Circulation processes within the STF are thought to play a primary role in larval transport and supply (Bruce *et al.* 2000).
- The magnitude of settlement is interannually variable but shows some correlation between regions. The timing of settlement is generally consistent within regions although may vary between them. Main settlement peaks are usually in summer or winter or both. The magnitude of the summer or winter peak(s) varying regionally and low-level settlement may occur year-round in some areas (Kennedy *et al.* 1994, Frusher *et al*. 1997).
- The similarities in settlement trends across southern Australia suggest that broadscale physical processes have a controlling influence on settlement patterns (Bruce *et al*. 2000, McGarvey and Mathews 2001).
- Recruitment to the fishery is complicated by variable growth rates between regions and comprises multiple year classes in areas of slow growth (e.g. southwest Tasmania) or single year classes in areas of more rapid growth (e.g. north east Tasmania) (Gardner *et al.* in press).
- SRL cannot be aged directly and growth is incremental (by moulting), thus differing from that assumed in conventional fish models - although growth is adequately described by the von Bertalanffy relationship (McGarvey *et al*. 1999). SRL are known to live for at least 20 years (based on tag recaptures) and grow to at least 23 cm carapace length (Kailola *et al.* 1993).

South Australia

- Puerulus settlement is interannually variable with summer and winter peaks in the Southern Zone (Prescott *et al.* 1998) and a winter peak in the Northern Zone (McGarvey and Mathews 2001).
- Links suggested between puerulus settlement and upwelling events, southeasterly storms and northwest coastal currents in south east regions of the state (Frusher *et al.* 1997).
- Derived recruitment indicies for the Northern Zone suggest correlations between the strength of westerly winds and settlement during the July-September settlement period with a 5 – 7 year time lag. Westerly wind strength (and recruitment) shows a 10 – 12 year cycle (McGarvey and Mathews 2001).

Tasmania

- Size at maturity varies regionally, from 65 mm carapace length at L50% in southern Tasmania to 110 mm carapace length at King Island (northern Tasmania) (Kailola *et al*. 1993, Punt *et al*. 1997).
- Fecundity increases with female size: 69,000 to over 600,000 eggs for females with a 74 and 155 mm carapace length, respectively (Annala and Bycroft 1987, Brown and Phillips 1994).
- Growth rate of males exceeds females (Kennedy and Tarbath 1992, Punt *et al.* 1997).
- Puerulus settlement is interannually variable, some links suggested with the seasonal north-south movement of the subtropical front (Bruce *et al*. 2000). Large peak in settlement in 1995 which was subsequently reflected in increased catch rates of recruits to the fishery in 1999 (East Coast waters) (Gardner *et al.* in press).

Victoria

- Fecundity (F) increases with size (carapace length, CL) as follows (Hobday and Ryan 1997)
  $F = 0.0316CL^{3.359}$ ($r^2 = 0.8539$; n = 571).
- Size at onset of maturity (females) varies between eastern and western zones. Western zone = 90 mm CL; Eastern zone = 112 mm CL (Hobday and Ryan 1997).
- Growth rate of males higher than females and growth rates highest in the eastern Zone (Hobday 1997).

Key inter-species interactions

- Interactions occur with octopus in some areas and octopus are a by-catch of the fishery and contribute to mortality of rock lobster in pots (J. Prescott, SARDI, Mt Gambier, pers.comm.).
- Current research in Marine Protected Areas in Tasmania may provide further information on species interactions and habitats (C. Gardner, TAFI, Hobart, pers. comm.).

Population structure

- Studies suggest a single genetic stock spanning Australia and New Zealand (Ovenden *et al.* 1992, Ovenden and Brasher 1994) although this may not reflect effective management sub-units.

Fisheries habitats

No information currently available.

Effects of Fishing

- Egg production in the northern region of Tasmania is currently less than the 25% target of an unharvested population – no predictions of the TAC scenarios indicate that egg production in this region will reach the 25% target by 2004 (Gardner *et al.* 2002).
- The number of recreational licences continues to increase in Tasmania and the recreational catch is approaching the 10% of commercial catch trigger point (Gardner *et al.* 2002).

Key uncertainties

- Interactions between rock lobster, sea urchins and macroalgae and their role in sea urchin barrens.
- Ecological effects of depleted abundance and reduced size frequency in fished areas (although studies within MPA's are currently addressing some of these issues: C. Gardner TAFI, Hobart, pers. comm.).
- Further work required on defining catchability.
- Current management aims to have high egg production in all areas. Better information on larval dispersal patterns may allow these targets to be modified to increase both yield (i.e. reduce management focus relating to egg production in areas of low importance for eggs), and increase egg supply (in areas of high importance).
- Stock structure may be better defined by adult movements, dispersal of larvae or analyses of catch statistics (Addison 1997).
- Linkages between management zones via larval dispersal and the extent to which spawning within a zone contributes to recruitment in other zones is unclear.
- Several population and biological parameters vary markedly over the geographic area of the fishery and either finer scale resolution of these parameters may be necessary in order to refine models for stock assessment purposes or just improve precision of estimates for current assessments.

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South Tasman Rise Fishery (including offshore deepwater fisheries)

Several areas in the SEMR have commercial fishing operations targeting off-shelf demersal habitats. These include areas of the continental slope off NSW, Victoria, Tasmania, Macquarie Island and seamounts, primarily off southern and south-eastern Tasmania. Deepwater fish species that form fisheries in these areas are often highly unproductive (low fecundity, long lived – often extremely, slow growing, late age at maturity and have very low natural mortality). This life history strategy is termed “K-selected”. Examples include orange roughy and oreo dories which can exceed 100 years in age. With these characteristics, such species are highly vulnerable to stock depletion and overfishing. Most fished deepwater stocks around the world currently suffer from these impacts. Several species aggregate (often to spawn) in restricted geographic areas around particular topographic features and are highly vulnerable to targeted trawling.

Note: orange roughy is the primary target species in the STR fishery however its detailed species account is included in the SEF above. Aspects of the fishery which are of specific relevance to fisheries habitat and effects of fishing are referred to under those sections.

General comments

Effects of fishing

- Stock depletion of slow growing, long-lived slope/seamount/deepwater species is well documented world-wide (Koslow and Tuck unpublished manuscript). In the SEMR, significant depletions have occurred in several species including orange roughy, and some deepwater dogfish species (Graham *et al*. 2001, Smith and Wayte 2001).
- Some species may be susceptible to serial depletion as fishing activity shifts from one ground (e.g. seamount) to the next. Thus overall catch rates may show successive peaks or remain relatively stable as stocks decline.
- Some behavioural traits significantly enhance species vulnerability to targeting (e.g. aggregating behaviour and descending from midwater to the bottom if disturbed, e.g. by an approaching trawl).
- Fishing has obvious effects on stock size of deepwater species through direct removal. Effects on size structure can be less apparent than for shallow water species. This appears to be due to the episodic nature of recruitment. Size structure may not significantly shift towards smaller sizes if recruitment has been poor for decadal periods (Koslow *et al. 1997*, Koslow and Tuck unpublished manuscript).

Ecosystem effects

- Trawling has significant impacts on deepwater benthos which is often of diverse physical structure (e.g. corals), fragile and similarly long-lived and slow growing (Koslow *et al.* 2000, Koslow *et al*. 2001).
- By-catch of other fish species can be low in targeted deepwater fisheries but impact on benthos (damage) may be high.
- Endemisim is high on offshore seamounts and rises. Recovery rates of disturbed/damaged communities are unknown but believed to be slow (Richer de Forges *et al.* 2000).
- High degree of endemism and localised distributions have major ramifications for conservation. Networks of protected areas may be required to adequately conserve species and habitats.
- Many of the targeted species dominate the mid-upper trophic levels in slope/seamount/deepwater environments and both their depletion and changes in size structure of the population may have long-term ecological impacts, however the nature of these impacts is unknown.

Key uncertainties

- Ecological impacts of removal of dominant species from mid-upper trophic levels.
- Life history parameters of many target species.
- Life history parameters for benthos.

- New species and their degree of endemism (taxonomic and at-sea identification challenges for both scientists and fishers).
- Interactions between target species and benthic community.
- Recovery rates of disturbed benthic communities.

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Key species accounts

Orange Roughy (*Hoplostethus atlanticus*)

See account under SEF.

Oreos (*Allocyttus niger*, *A. verrucosus*, *Neocyttus rhomboidalis*, *Pseudocyttus maculatus*)

Oreos are distributed from NSW to WA, including Tasmania, but the main commercial fishery area is to the south of Tasmania including the Cascade Plateau and the South Tasman Rise (Kailola *et al*. 1993, Daley *et al.* 1997, Lyle and Smith 1997). They are taken as a by-catch of orange roughy but are becoming increasingly targeted, especially around southern Tasmania. The fishery is managed by the Commonwealth within the SEF but there are no TACs or ITQs. Oreos are also taken in the GAB trawl fishery.

Fishery research

- *N. rhomboidalis* and *P. maculatus* were the main species landed in 1997 (Tilzey 1998).
- Annual catches in the SEF have increased from 60 t in 1985 – 1988; 900 t in 1989 – 1990; approximately 2000 t in 1997 (Kailola *et al*. 1993, Tilzey 1998).
- GAB Trawl catches are highly variable ranging from 30 – 200 t/year (Kailola *et al.* 1993).

Biological parameters

Sex	Growth	Long-evity	Mortality	Reproduction	Recruitment	Length-weight	Author (area)

	L_{inf} (mm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	B	
				130 20										1. (NZ) 2. (
F								28						1. (NZ)
M								24						1. (NZ)

1. Stewart *et al.* (1995)
2. George *et al*. (1998)

Distribution and links to physical environment

- Oreos are demersal on the mid-slope and seamounts.

Reproduction

- Oreos have lower fecundity than most teleosts which could contribute to susceptibility to overfishing (Conroy and Pankhurst 1989). *P. maculatus* females have a maximum fecundity of 84,000 eggs , *A. niger* 62,000 eggs (Conroy and Pankhurst 1989, Lyle, Kitchener *et al.* 1991).
- Spawning appears to be widespread throughout the SEMR. *N. rhomboidalis* spawn in August–October and *A. verrucosus* spawn in May–June (Lyle and Smith 1997); *P. maculatus* and *A. niger* spawn in late spring/early summer (Pankhurst *et al.* 1987).
- Spawning is synchronous in *A. niger* (Pankhurst *et al.* 1987).
- Oreos are slow growing and long-lived (Lyle *et al.* 1992).

Key inter-species interactions

- A trophodynamic model for oreos is currently under development (Bulman *et al*. in press).

Population structure

- Genetic (allozyme) evidence suggests that spikey oreos from New Zealand, Western Australian and south Australia are from different stocks and that gene flow is restricted between different depths (Elliott *et al*. 1998).
- Genetic (allozyme and mtDNA) studies suggest that smooth oreos from Western Australia, Tasmania and New Zealand are from a common stock (Ward *et al.* 1998).
- Genetic (allozyme and mtDNA) studies provisionally identified warty oreos from Tasmania as separate from a Western Australia/New South Wales stock. (Ward *et al.* 1998).
- Genetic (allozyme and mtDNA) studies provisionally identified black oreos from Tasmania and New Zealand as separate stocks (Ward *et al.* 1998).

Fisheries habitats

- Adults live near the bottom, typically from 750 – 1200 m where they form large shoals over seamount pinnacles and near canyons (Kailola *et al*. 1993).
- Smaller oreos often distributed over smooth ground (Kailola *et al.* 1993).
- Eggs, larvae and juveniles are pelagic (Stewart and Smith 1992, Kailola *et al*. 1993).

Effects of Fishing

- Longevity and low fecundity of oreos suggests that they are as similarly vulnerable to overfishing as orange roughy.

Key uncertainties

- There have been no detailed stock assessments.
- The discarding rate is unclear making it difficult to determine accurate catch rates.
- Declines in orange roughy catches could lead to increased targeting of oreos.

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Southern Bluefin and East Coast Tuna Fisheries (within the SEMR)

The east coast tuna fishery and in particular, the southern bluefin tuna fishery, extend well beyond the region covered by the SEMR. In both cases, the highest catches are not within the SEMR. Most of the SEMR tuna catch is taken by longline, pole and line and in some cases, purse seine. The main species targeted within the SEMR within the east coast tuna fishery are yellowfin tuna, skipjack tuna, albacore and swordfish. Big eye tuna and striped marlin are also targeted but mainly north of the SEMR (although striped marlin are caught within the SEMR as far south as northern Tasmania during late summer) (Campbell 1999).

The primary fishing areas for southern bluefin tuna are west of the SEMR in the Great Australian Bight and most of the Australian quota (e.g. 95% of the 1999-2000 catch) is now caught and transported live to holding/grow-out facilities in the Port Lincoln region of South Australia. Management of the SBT fishery has previously been under a trilateral arrangement (between Australia, New Zealand and Japan – tripartite agreement was ratified in May 1994 as the Convention for the Conservation of Southern Bluefin Tuna, CCSBT) which were responsible for annual stock assessments (Campbell *et al*. 2000). However, due to the recent dispute between Australia/New Zealand and Japan regarding assessments and catches, the CCSBT has not met since 1998 and the Southern Bluefin Tuna Management Authority Committee (SBTMAC) has since reviewed available information in the absence of catch information pending from the Japanese long-line fleet (SBTFAG 2000).

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Key species accounts

Southern bluefin tuna (*Thunnus maccoyii*)

Southern bluefin tuna (SBT) are members of the family Scombridae (Gomon *et al*. 1994). SBT are highly migratory and occur throughout temperate and colder areas of the Southern Hemisphere mainly between 30° and 50°S, to nearly 60°S, although they enter tropical waters of the eastern Indian Ocean to spawn (Froese and Pauly 2001).

Tuna fisheries in Australia date back to 1938, but a significant effort in the SBT fishery did not begin until the early 1960s (Murphy and Majkowski 1981). Individual transferable catch quotas were introduced to the SBT fishery in 1984 (Campbell *et al.* 2000).

Fishery research

- SBT are believed to form a single stock throughout their range (Proctor *et al*. 1995, Grewe *et al*. 1997).
- Murphy and Majkowski (1981) reported in 1981 that the SBT fishery was fully exploited.
- Efforts were made in the early 1980s to reduce total catches; in 1983-84 an interim management plan adopted including a TAC of 21,000 t. This was subsequently reduced to 14,500 t in late 1984 and further reduced in subsequent years in response to continuing decline in the SBT parental stock. Since 1990 the global TAC has been limited to 11,750 t (Campbell *et al*. 2000).

- Trends in estimates of SBT parental biomass exhibit a long and continuous decline as a consequence of intensive fishing. The 1997 parental biomass was estimated to be approximately 7 – 15% of 1960 levels (SBTFAG 2000).
- Recent re-evaluation of age at maturity (most recent estimates 11 – 12 y, J. Farley, CMR, Hobart pers. comm.) based on Indonesian catches, indicate parental biomass has continued to decline (SBTFAG 2000).
- Current recruitment to the fishery is low and most recent estimates suggests recruitment levels of about one third of 1960 levels (SBTFAG 2000).
- Stock projections assessed by Australian/New Zealand are disputed by Japanese assessments. Australian/New Zealand projections suggest a low probability (< 14%) of recovery to the 1980 level by 2020 whereas Japanese projections estimate a high (76 – 87%) probability of recovery (SBTFAG 2000).
- The value of the Australian SBT fishery has fluctuated over the period 1982 to 1996, however the trend has been one of increase, while the quanitity has decreased.
- Lowest value was obtained in 1983-84 at 12.6 million dollars (15.8 ktonnes); highest in 1994-95 season at 86.3 million dollars (5.2 ktonnes) (Campbell *et al*. 2000).
- The mean lengths of 2+, 3+, and 4+ year old fish, and the increment from age 1 to age 3, have increased substantially over the history of the fishery, probably a density dependent response to the decline in larger fish due to heavy fishing pressure (Leigh and Hearn 2000).
- Listed under the IUCN Red List of Threatened Species as *critically endangered* (Hilton-Taylor 2000).
- No clear trends were apparent in the monthly longline catch rates of SBT in the east coast fishery from 1994 to 1999 and there are considerable difficulties in interpreting catch rates as a measure of SBT abundance in the SEMR because of fishing practices (SBTFAG 2000).
- Lyne *et al*. (1999) reported a sharp decline in the mean weight of SBT caught in SE Australia from 1989 to 1995 and, specifically, a decline in the capture and intensity of aggregations of larger fish (> 80 kg) from 1989 onwards.
- Lyne *et al*. (1999) also report a negative correlation between yearly catch rates and average weight of SBT and the Southern Oscillation Index (SOI) off eastern and southern Tasmania.

Life history
- Spawning occurs entirely outside the SEMR. The only known spawning area is in the tropical east Indian Ocean (Yukinawa and Miyabe 1984, Yukinawa 1987) where fish in spawning condition are found on the spawning ground during every month of the year except July (Farley and Davis 1998).
- SBT have an asynchronous pattern of oocyte development; once a females begins to spawn, it spawns daily. Batch fecundity of SBT estimated to be 57 oocytes per gram of body weight (Farley and Davis 1998).
- As soon as individuals have finished spawning they quickly depart from the spawning ground (Farley and Davis 1998).
- Juveniles leave the spawning grounds within a few months of hatching and move south along the continental shelf of WA. Juveniles first appear in the GAB as one-year-olds in summer and then disperse along the West Wind Drift in winter (Farley and Davis 1998).

Distribution in SEMR
- SBT of various sizes are found throughout the SEMR. Distribution (as measured by CPUE in the fishery, is influenced by spatial variability in temperature and topographical features that influence movements of the Sub-tropical Convergence Zone (Lyne *et al*. 1999).
- Juvenile SBT form large schools in the surface waters off southern and south eastern Australia, while mature SBT are dispersed throughout the southern oceans (Campbell *et al*. 2000).
- Catches of larger fish occur off south-western Tasmania and southern NSW and in the latter case, the distribution of fish are believed to be related to the increased productivity associated with deep stirring of cooler waters by eddies in the area (Lyne *et al*. 1999).

Key uncertainties

- The extent to which SBT are targeted or caught as by-catch within the fishery operating in the SEMR.
- Impact of the availability of quota and the extent of discarding
- The influence on catch rates and abundance in the SEMR of fishing activities outside the SEMR and in particular the surface fishery west of the region.

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Yellowfin tuna (*Thunnus albacares*)

Yellowfin tuna are members of the family Scombridae (Gomon *et al.* 1994). They inhabit all tropical and subtropical seas, except the Mediterranean Sea, between about 40ºN and 40ºS (Kailola *et al.* 1993). The primary fishing method for yellowfin in the Australian Fishing Zone (AFZ) is longline although they are a by-catch of the skipjack tuna fishery off southern NSW which fishes by pole-and-line, purse seine and trolling (Campbell 1999a).

Fishery research

- Otolith microchemical and genetic analysis indicate there are at least two reproductively isolated stocks in the Pacific (western/central, and eastern) (Gunn and Ward 1994, Ward *et al.* 1994).
- In 1994 ~ 380,000 t of yellowfin was harvested in commercial fisheries across the western Pacific (Lawson 1995).
- Stock structure and the relationship of yellowfin tuna in the eastern AFZ to the western and central Pacific stock (WCPO) is unclear. Campbell (1999b) reported that declines in catch rates evident post 1985 in the WCPO were not reflected in the Australian catch suggesting that mixing between the two areas was not as high as would be expected if they were a homogeneous stock. However differences in targeting practices over time in the WCPO makes the comparisons difficult. Pepperell and Diplock (1989) found some evidence that yellowfin remain in the eastern Australian region for periods of at least two years. Smith *et al.* (1988) found some genetic substructuring between north and south coasts of eastern Australia but similarities with fish from Hawaii. It is possible that recruitment to the eastern AFZ is sourced from spawning in the Coral Sea in some years (i.e. AFZ self recruiting) interspersed with recruitment over wider areas of the western Pacific (Gunn and Grewe 1998, Campbell 1999b).
- Detailed stock assessments have not been made due to uncertainties in population dynamics for yellowfin in the eastern AFZ (including stock structure, length-at-age, movement patterns) (Campbell 1999b).
- There is considerable interannual variability in catches but no evidence for a long term decline in abundance in the eastern AFZ. Interannual variability may be a result of large scale variations in oceanographic conditions that influence distribution or recruitment (Campbell 1999b).
- Japanese longliners have been fishing for yellowfin and bigeye in the AFZ between Cape York and south-eastern Tasmania since the 1950s (Suzuki *et al*. 1978).
- The domestic fishery off the eastern coast began in the mid 1980s following the demise of the NSW southern bluefin fishery (Hampton and Gunn 1998) and is confined to within 100 nautical miles of the coast, with 64% of domestic effort occurs within 50 nm of the coast (Campbell and McIlgorm 1997).
- Annual catches of yellowfin in the eastern AFZ have ranged between several hundred tonnes to almost 5,000t since 1979, with an average of 28% of the catch being taken by the Australian fleet since 1987 (Hampton and Gunn 1998). The domestic catch in the eastern AFZ was 1,844 t in 1998 (Campbell 1999). However, most of the catch is taken north of the SEMR.
- Effort and catch increased dramatically for the area south of 34ºS between 1986 and 1989 (Campbell and McIlgorm 1997):

	1986	1987	1988	1989
Effort (1,000s hooks)	7.5	138.5	220.5	402.4
Catch (t)	2.6	47.0	94.1	298.0

- High catches (> 240 t) were taken over the shelf break between 36^{o}S and 37^{o}S in May 1996 and 1997 as a result of favourable oceanographic conditions in the area (Young *et al.* 2001).

Life history

- Yellowfin are multiple spawners. Spawning in the Coral Sea commences in October and finishes in March, becoming less protracted with increasing latitude (McPherson 1991).
- Yellowfin spawning in the western Coral Sea may be a major source of recruits to the longline fishery in the eastern AFZ (McPherson 1991).
- Average interval between spawning (spawning frequency) of yellowfin in the Coral Sea was 1.54 days (McPherson 1991).

- There is strong evidence of spawning-site specific chemical signals in yellowfin otoliths (Gunn and Ward 1994).
- Numbers of yellowfin larvae reach a peak in the southward flowing EAC during November-December (Cole 1980).
- Yellowfin larvae in the AFZ between July and September suggests some recruitment of yellowfin to the AFZ occurs from the north and east of the Coral Sea (McPherson 1991).
- Estimated length at which 50% of yellowfin reached maturity is ~108 cm in the handline fishery and 120 cm in the Japanese longline fishing area off north-eastern Australia (McPherson 1991).
- Yellowfin inhabiting coastal waters may attain sexual maturity at a smaller size than did those in offshore waters of the Pacific (McPherson 1991).

Distribution in SEMR

- In Australia, yellowfin occur from the Torres Strait to as far south as eastern Tasmania (~43ºS) and from south-western Australia at about 128ºE to Northern Territory waters at about 136ºE Kailola *et al*. 1993). Most catches in the SEMR are off southern NSW between April and July and between 36^{o}S and 38^{o}S (Young *et al*. 2001).
- Yellowfin appear to concentrate at thermal discontinuities in regions of enhanced productivity and prey availability (Young *et al*. 2001).
- Only during out-of-the-ordinary intrusions of warm water are yellowfin taken in any numbers off eastern Tasmania (Young 1998).

Key uncertainties

- Stock structure.
- Reasons for interannual variability in catches and links to oceanographic processes.
- Movement dynamics.

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Skipjack tuna (*Katsuwonus pelamis*)

Skipjack tuna are members of the family Scombridae (Gomon *et al*. 1994). They are widely distributed throughout all tropical and subtropical waters except for the Mediterranean Sea and the Black Sea (Blackburn and Serventy 1981) where they prefer water temperatures of between 20 and 30ºC; however, they are sometimes found in waters as cold as 15ºC (Forsberg 1980, Collette and Nauen 1983). In Australian waters, skipjack occur from Lady Elliot Island in Queensland, south to Storm Bay in Tasmania; from Kangaroo Island in the GAB west and north to beyond Broome, WA (Kailola *et al.* 1993). Skipjack are caught primarily by pole-and-line and purse seine (Campbell 1999).

Fishery research

- Total standing stock in the west and central Pacific Ocean (WCPO) was estimated to be 3 million tonnes in late 1970s/early 1980s during which time annual skipjack catches rose from less than 5,000 t to about 220,000 t (Kleiber *et al*. 1987). Catches increased substantially thereafter and in 1991 exceeded 1,100,000 t. The WCPO catch was estimated at 1,168,861 t in 1998 (Campbell 1999).
- Stock structure is uncertain. Two hypotheses currently lead in support:
    1. At least 5 subpopulations are present within the Pacific, including two in the western Pacific (Sharp 1978)
    2. There are no distinct subpopulations, however the probability of skipjack schools interbreeding is proportional to the distance separating schools (Richardson 1983, South Pacific Commission 1984).
- In Australia, skipjack have been a part of the SBT fishery in the GAB since the 1950s. However, the main fishing area for skipjack within the SEMR is from Ulladulla to just south of Gabo Island. Between 1985/86 and 1991/92 catches rose from an estimated 150 t to about 6,000 t (Kailola *et al*. 1993).

- Reported catches are highly variable between years as a result of interannual differences in the availability and distribution of fish (related to environmental conditions), under-reporting, changes in the number of vessels targeting them and, more recently the closure of the Eden Cannery (Campbell 1999).
- The skipjack fishery takes a relatively small tonnage (< 30 t) of yellowfin tuna as by-catch (Campbell 1999).
- No formal stock assessments have been conducted on skipjack tuna in Australian waters.

Life history

- Skipjack are short-lived, fast-growing, highly fecund species (Kleiber *et al*. 1987).
- Spawning is widespread and occurs year-round in equatorial waters (where it reproductively active females may spawn almost daily – Hunter *et al*. 1986), but is appears to be restricted to summer/autumn in subtropical waters (Kailola *et al.* 1993). Skipjack probably spawn, in Australian waters, in the Coral Sea and off north-western Australia (Collette and Nauen 1983).
- Estimates of the number of eggs released at each spawning range from 100,000 (small females) to 2 million eggs (large females) (Matsumoto *et al*. 1984).
- Larvae have been recorded off eastern Australia and are transported southwards into subtropical waters via the EAC (Wild and Hampton 1991).

Distribution in SEMR

- Skipjack occur throughout the SEMR where they are primarily targeted in the southern NSW between 35^{o}S and 38^{o}S during spring and summer (Campbell 1999) and the GAB (Kailola *et al*. 1993).

Key uncertainties

- There are no estimates of sustainable yield or stock size for skipjack in Australian waters

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Albacore (*Thunnus alalunga*)

Albacore are members of the family Scombridae (Gomon *et al.* 1994). They are widely distributed from about 45ºN to 50ºS in all tropical, subtropical and temperate oceans, including the Mediterranean Sea (Kailola *et al*. 1993). They are largely a by-catch species in Australian waters as part of the southern bluefin, yellowfin and big eye tuna fisheries although recent targeting via trolling has increased catch levels (Chapman *et al*. 1993, Harper 1993).

Fishery research

- Albacore are though to comprise a discrete stock in the Pacific Ocean south of the equator (Murray 1994, Yeh and Wang 1996) which is significantly different to the Atlantic Ocean stock (Chow and Ushiama 1995, Hauser and Ward 1998).
- They are fished throughout their range. Prior to start of the drift gillnet fishery surface catches were less than 2,500 t. Between 1983/84 (start of commercial-scale drift netting) and 1985/86 (start of Subtropical Convergence Zone troll fishery), total surface catches were less than 5,300 t. Rapid expansion of gill netting resulted in historically high catches of 29,000 – 58,000 t in 1988/89. Reductions in drift gill netting resulted in a decline of the surface catch to 9,419 t in 1990/91. Since 1991, no drift gill netting has taken place and the surface troll fishing catch is not likely to exceed 10,000 t (Murray 1994). Total longline catches increased with expanding effort from 1952 to 1967 to reach the historical peak of 40,572 t. However, since 1967 total longline catch has ranged between 21,000 and 39,000 t, but usually less than 35,000 t (Murray 1994).
- Albacore stocks are considered to be under-utilised in Australian waters (Caton 1991). From 1984 to 1988 an annual average of 1300 t of albacore was caught by Japanese longliners working in Australian waters (Caton and Ward 1989).

Life history

- Spawning appears to take place primarily in the November-February period north of the 20ºC isotherm (Murray 1994).
- In the South Pacific Ocean, larvae are distributed from northeast Australia - east through French Polynesia between 5 – 25ºS (Nishikawa *et al*. 1985). Larvae are mostly caught during October to December, although present in most other months except January, March and April (Murray 1994).

Distribution in SEMR

- It is possible that albacore from the east coast move around southern Tasmania and mix with the Indian Ocean stock, although the interchange is probably low (Caton 1991, Murray 1994).
- Off southern Australia and New Zealand, albacore appear to prefer sea surface temperatures of 16 – 22ºC in association with temperature fronts (Garvey 1991). Although they have been recorded in waters ranging between 9.5 – ~25ºC (Foreman 1980, Collette and Nauen 1983).

- Albacore catches off eastern Tasmania were strongly associated with eddies and frontal zones during 1991 and 1992 (Reddy *et al.* 1995) and those authors derived an algorithm that identified the most productive fishing areas based on SST.
- Albacore feed at the surface, but otherwise live at the thermocline; which in the Tasman Sea in summer tends to vary between 50 – 150 m depth. Albacore have been found at least as deep as 500 m in the Pacific Ocean (Kailola *et al*. 1993).
- Juveniles move from the tropics into temperate waters and then eastwards along the subtropical convergence zone. At maturity they return to the tropics, but go back to temperate waters after spawning (Jones 1991).

Key uncertainties

No information currently available.

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Broadbill swordfish (*Xiphias gladius*)

Broadbill swordfish are members of the mono-specific family Xiphiidae (Gomon *et al.* 1994). They are widely distributed in all tropical, subtropical and temperate seas between approximately 50^o N and 50^o S but may occur to 60^o N in areas where warm currents extend (Ward and Elscot 2000). They can tolerate a wide range of temperatures (5^{o}C – 27^{o}C) (Nakamura 1985) and undergo diurnal vertical migrations associated with movements of the deep scattering layer (Carey 1992). Swordfish are caught by longline and driftnet (the latter in high seas fisheries outside the Australian region) as both a target species and as a by-catch species in tuna and billfish fisheries. The status of world swordfish fisheries was recently reviewed by Ward and Elscot (2000).

Fishery research

- There are at least four genetically distinct populations of broadbill swordfish world-wide – in the Pacific Ocean, North Atlantic Ocean, South Atlantic Ocean, and the Mediterranean Sea (Alvarado Bremer *et al.* 1996, Rosel and Block 1996).
- Based on CPUE trends in the Japanese longline fishery, four stock units were inferred: i) off Japan, in the north western and central Pacific, ii) off Baja California Peninsula, iii) off the western coast of South America, iv) off the eastern Australian coast and north of New Zealand (Sosa-Nishizaki and Shimizu 1991).
- The high market value for swordfish has stimulated a global commercial fishery that harvests more than 50,000 t annually (Sakagawa 1989). World broadbill swordfish landings in 1997 were ~97,698 t (Ward and Elscot 2000).
- Current Pacific-wide catches of broadbill swordfish exceed the estimates of MSY from production-model-based assessments (Punt *et al*. 2001).
- There is limited knowledge regarding key biological parameters and stock structures (Punt *et al.* 2001).
- Some fisheries targeting broadbill swordfish in other regions of the world have shown initial rapid expansion followed by substantial decline (Ward and Elscot 2000).
- Japanese longliners harvested an average of 660 t of swordfish per year in the AFZ from the 1950s until 1997 (Caton *et al.* 1998).
- Swordfish catch by the Australian longliners has increased from < 30 t on average before 1996 to 1,754 t in 1997 (Ward and Elscot 2000; Punt *et al*. 2001). Landings increased to 2,373 t in 1998 and 2,513 t of swordfish were reported taken from the AFZ in 1999 (Ward and Elscot 2000).
- Although broadbill swordfish are a by-catch of the tuna fisheries, in 1996/97 many longliners relocated from NSW to southeast Queensland where they used night-set, squid baits to target broadbill swordfish and bigeye.

Life history

- Swordfish do not appear to have discrete spawning grounds but spawn in waters of more than 20^{o}C, year round in equatorial waters but progressively limited to spring-summer in higher latitudes (Palko *et al.* 1981).
- Broadbill swordfish larvae occur in all tropical seas including the Atlantic, Pacific, and Indian Oceans and the Mediterranean Sea (Grall *et al*. 1983). Larvae have been recorded off the NSW mid and north coasts in summer (B. Bruce CMR, Hobart, pers. comm.).
- Growth is initially extremely rapid with individuals reaching 90 cm and 15 kg after one year (Ehrhardt 1992) with females growing faster than males thereafter (Kume and Joseph 1969).

Distribution in SEMR

- Broadbill swordfish inhabit all Australian waters beyond the edge of the continental shelf (Kailola *et al.* 1993). However, most of the eastern Australian catch is currently taken north of the SEMR in an area bounded by 24° S – 32° S and 152° E – 162° E, although distribution data suggest that there is potential for Australia's longliners to expand fishing operations to waters south of Lord Howe Is. at 34° S – 40° S and around Norfolk Is. (Ward and Elscot 2000).
- Acoustically-tagged broadbill swordfish have been recorded to respond to bottom topography – bottom features that result in turbulent flow may concentrate prey organisms and attract broadbill swordfish (Carey and Robison 1981).
- Broadbill swordfish migrate vertically in response to light: being near the surface at night, at maximum depth (> 600 m) at local noon, and rapidly migrating up or down in the water column during sunset and sunrise, respectively (Carey and Robison 1981).
- Broadbill swordfish are able to easily penetrate thermoclines and are not limited in depth distribution by them (e.g. a 19° C temperature change in 2.5 h) (Carey and Robison 1981).
- Broadbill swordfish concentrate in areas where food is abundant, commonly along frontal zones where ocean currents or water masses intersect to create turbulence and sharp gradients in temperature and salinity (Sosa-Nishizaki and Shimizu 1991).

Key uncertainties

- Quantitative stock assessments for the Australian east coast fishery are unlikely in the short term due to inadequate data and limited information on stock structure.
- Biological data on swordfish is inadequate for the Australian region, although a recent project is targeting the species off the east coast (J. Young, CMR Hobart, pers. comm.).

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Blue shark (*Prionace glauca*)

Blue sharks are members of the family Carcharhinidae (Last and Stevens 1994). They are a cosmopolitan species, and have the most extensive distribution of any chondricthyan species occurring in temperate and tropical waters of both Hemispheres. They are an oceanic pelagic species occurring from the surface to 350 m (Last and Stevens, 1994).

Blue sharks are one of the principle shark by-catch species of Japanese and domestic tuna and billfish longline fisheries. They are also the target of a small sport fishery (mainly off NSW) (Stevens 1984).

Fishery research

- Little is known regarding stock structure and biology of blue sharks in Australian waters (Stevens 1992).
- The most recent assessment was undertaken in (1998) based on logbook returns and observer catch monitoring (Stevens and Wayte 1999).
- Japanese longliners have previously taken up to 1100 t/year from Australian waters (Stevens and Wayte 1999), although the total catch within the SEMR is somewhat less. Total (retained) catch in Tasmanian waters by the Japanese longline fleet averaged about 34,000 sharks (275 t) from 1982 to 1992, although the actual number and tonnage caught was no doubt higher as a proportion of those caught are released (but often damaged) (Stevens 1992).
- Domestic longliners reported a total catch of 45 t in 1997 but this catch is thought to be under-reported.
- The majority of blue sharks caught in Tasmanian waters are immature and sub-adult females and it is unclear if removals at this rate presents a risk to the stock (Stevens 1992).
- There is no evidence of a decline in Australian waters.
- Other areas have shown small (20%) declines.

- Assessments need a broad geographic (Pacific Ocean) focus due to the wide distribution of blue sharks.
- Blue sharks have a high natural abundance and are more productive than many sharks. It is likely to be more resilient than many other sharks and ray species (Stevens and Wayte 1999).

Life history
- Females move into coastal NSW to mate and give birth between September and December; males are present throughout the year (Stevens 1984).
- Blue sharks are viviparous and reproduction is via a yolk-sac placenta (Stevens and Wayte 1999).
- Gestation lasts 9 – 12 months (Pratt 1979, Stevens 1975). However, the full length of the female cycle is unclear and therefore annual fecundity is not known.
- Litters of up to 157 (average 32 – 35) are nourished by yolk-sac placenta (Castro and Mejuto 1995, Stevens 1975, Stevens 1984).

Distribution in SEMR
- Blue sharks occur throughout the SEMR in shelf and offshore waters.
- Broad-scale movements occur between SEMR and international waters (e.g. a blue shark tagged off southern Tasmania was later recaptured in Madagascar (J. Stevens CMR, Hobart, pers. comm.).
- Blue sharks are seasonal visitors to southern Tasmania where they occur in summer and early autumn, although their abundance is interannually variable and may have some links to the abundance of squid (J. Stevens CMR, Hobart, pers. comm.).
- The main catches of blue sharks within the SEMR have been taken by the Japanese tuna longline fleet in offshore waters of southwest, southern and eastern Tasmania. Smaller catches are also taken along the NSW coast (Stevens and Wayte 1999).

Key uncertainties
- Highly migratory, complex movement patterns, stock structure and scale of appropriate management units not well defined.
- Pelagic sharks such as blue sharks are likely to be key species in oceanic ecosystems and the ecological effects of removing sharks as top predators is poorly understood.
- Annual fecundity unknown.

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Ray’s bream (*Brama brama*)

Ray’s bream are members of the family Bramidae (Gomon *et al.* 1994). They are widely distributed in oceans of the Southern Hemisphere and a similar form (which appears to be another species) occurs in the Northern Hemisphere (Yearsley *et al.* 1999). Other bramid species are taken in the SEMR (e.g. the big-scale pomfret, *Taractichthys longispinnus*, and the golden pomfret, *Xenobrama microlepis*), but they are easily distinguished based on body shape, fin shape and colour (Yearsley *et al.* 1999). Ray’s bream is caught primarily as a by-catch species in long-line fisheries for tuna, but has also been taken via pelagic trawling.

Fishery research

- The current and pre-exploitation age/size structure is unknown for Australian waters.
- Current yield is unknown, however Last and Baron (1994) estimated the catch of Ray’s bream to have been in excess of 250 t between October and December 1993.
- Highest average catch rates, in excess of 40 fish per 1,000 hooks, were obtained in November south of 40˚ S, with the majority coming from areas south of 44˚ S (Last and Baron 1994).

Life history

- Larvae have been described from Australian waters by Moteki and Neira (1998) and have been caught off Sydney, NSW, from May to August (Gray 1995).

Distribution in SEMR

- In Australia Ray’s bream is distributed throughout southern waters from Narooma (NSW) to Israelite Bay (WA), including Tasmania (Gomon *et al.* 1994), probably linked to the 9 – 13˚ C isotherm (Last and Baron 1994).
- They commonly inhabit the upper 200 m of the water column (Last and Baron 1994).

Key uncertainties

- The biology and ecology of Ray’s bream in Australia has been poorly studied.
- The population stock structure of Ray’s bream in Australia is unknown.

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Abalone Fishery

A considerable research literature exists for abalone in Australian waters. Reviews are provided by Shepherd *et al.* (1992) and further literature is available via researchers in SARDI, TAFI and MAFRI.

The abalone fishery in southern Australia is a diver based fishery and extends from approximately Port Stephens in NSW to Perth in Western Australia (Kailola *et al*. 1993) and covers broad areas of the SEMR. Abalone are managed on a State basis by individual quotas and a total allowable catch. The main areas of the fishery are in Tasmania and South Australia where the fishery is subdivided into various zones. The fishery in South Australia is divided into three management zones which are further subdivided into fishing areas. Management is based on both input (number of licences, minimum legal size) and output (quota) controls. The fishery is subdivided into State based management zones which have differences in quotas and legal sizes. There are currently 35 licence holders in SA (Mayfield *et al*. 2001). Abalone occur as metapopulations (a result of their short larval life, limited dispersal and limited movements) and management of the fishery is generally aimed at maintaining metapopulations at sustainable levels, allowing adequate recruitment and maintaining genetic diversity (Mayfield *et al*. 2001).

The fishery is based on two species, the greenlip abalone (*Haliotis laevigata*) and the blacklip abalone (*H. rubra*). However, small numbers of a third species (*H. roei*) are also taken (Mayfield *et al*. 2001).

Both species are taken by recreational fishers, although blacklip is the main target due to its generally shallower distribution. Both species are also the target of illegal fishing, however, the extent of the illegal catch is difficult to determine. Recent work on genetic fingerprinting of abalone species has assisted in identifying components of the illegal catch (N. Elliott CMR, Hobart, pers. comm.).

Biological parameters (e.g. growth rates, size at maturity, fecundity) are highly variable across the range of both species and references/data specific to the area of interest should be consulted. Not all data are given in the biological parameters tables as a result and ranges for regions have been given where appropriate. The range in growth rates are a result of differences in food availability, water temperature, reduced abundance as a result of fishing (i.e. density dependent effects), differences in techniques used to estimate parameters (e.g. mark-recapture vs length-at-age data) and, in some cases, genetic differences.

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Key species accounts

Greenlip abalone (*Haliotis laevigata*)

Greenlip abalone are members of the family Haliotidae (Geiger 1999) and are endemic to Australian waters (Shepherd 1973). They occur from Corner Inlet (Vic) across southern Australia to Cape Naturaliste (WA), including Tasmania, primarily in depths of 10 to 30 m.

Fishery research

South Australia

- Catches declined from 1,200 t in 1968 to approximately 250 t in 1974; increased slightly to 500 t in 1984. Catches have been stable at approximately 400 t since 1990 (Mayfield *et al*. 2001).
- The annual recreational catch is estimated to be approximately 13 t (4.6% of TAC) (Mayfield *et al*. 2001).
- Fishery independent diver surveys suggest a significant decrease in abundance at two of the four sites regulary surveyed in SA and significant decreases in juvenile abundance at some sites. No trends in abundance were apparent at other sites (Mayfield *et al*. 2001).
- Declines in the percentage of sub-legal sized abalone (suggestive of sustained low recruitment levels) have been detected at most survey sites (Mayfield *et al*. 2001).

Tasmania

- Current TAC is 140 tonnes for Tasmanian waters. Declines in catch rates in Furneaux Is. group (Bass Strait) stabilised after recent manegement intervention. Stock may be rebuilding in this area (Tarbath *et al*. 2000).
- Recent increase in effort on Tasmanian mainland (resultling, in part, from catch restrictions in Furneaux group) (Tarbath *et al*. 2000).

Biological parameters

Sex	Growth*			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}* (mm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (mm)	Age (y)	Size (mm)	a	b	
*	143.86 - 169.02	0.357-0.583	0.85-1.34	14-19				2.5-3.0 3	80-90 70-90 70-120	5-6	140	1.02-6.75E-5	0.085-0.183	1. (SA) 2. (Tas) 3. (SA)
F														
M														

1. Rodda *et al*. (1997)
2. Officer (1999)
3. Shepherd and Laws (1974)

* ranges for different regions in Tasmania
Note: Growth parameters vary regionally in abalone and stunted populations occur in most States (e.g. see Nash 1992 and Shepherd 1988).

Distribution and links to physical environment

- Greenlip are patchy in their distribution and tend to cluster in areas of suitable habitat such that populations can be separated by tens of kilometres (Shepherd 1973, Mayfield *et al*. 2001).
- Movements are limited in adults (in the order of 10s of metres) (Shepherd and Brown 1993).

Reproduction

- Greenlip are broadcast spawners and spawn once per year from late October to March-April (Shepherd and Laws 1974, Rodda *et al*. 1997). However spawning can be more restricted in some regions (e.g. Eyre peninsular SA where it occurs from November to December, Shepherd *et al*. 1992).
- Fecundity can vary between individuals, populations and years (Shepherd *et al.* 1992) and may be related to food supply (Shepherd 1987). Wells and Mulvay (1995) reported the following ranges for a fecundity-length relationship in greenlip in WA. Parameters varied by region.

$$\text{Fecundity} = a(\text{Length})^b$$
where a = 1.33E-3 to 4.95E-5; b = 4.29 to 4.99

- Larval life is short (5 – 10 days) and influenced by water temperature (Shepherd and Brown 1993).
- Local hydrodynamics play a major role in dispersal of larvae and stock structure (Shepherd and Brown 1993).

Key inter-species interactions

- Newly settled abalone feed on diatoms and other microscopic algae (Shepherd and Daume 1996).
- Diet changes to, predominantly, drift algae by 2 – 3 years of age (Shepherd and Cannon 1988, Shepherd and Steinberg 1992).
- Juvenile abalone are preyed upon by fish (usually wrasse), crabs, octopus, rays and rock lobster (Shepherd and Godoy 1989).

Population structure

- Genetic studies of stock structure have been conducted using allozyme techniques (Ward and Elliott 2001); the data suggest significant substructuring of the population on small spatial scales (Brown and Murray 1992). Aggregations of greenlip abalone have been reported to be genetically discrete with genetic variation increasing with geographic distance between populations (Shepherd and Brown 1993).

Fisheries habitats

- Larvae settle preferentially on areas of crustose coralline algae (Shepherd and Turner 1985, Shepherd and Daume 1996) although post settlement survival may be higher in such habitats and mask more widespread settlement patterns (McShane 1995).

Effects of Fishing

- Removal of aggregations during spawning may decrease fertilization success (Shepherd 1986).
- Fishing pressure may change sex ratios from 1:1 in some areas (Wells and Mulvay 1995).

Key uncertainties

- Ageing.
- Effects of regionally variable condition and growth on fecundity and implications for stock assessments.
- Error introduced by variation in catching efficiencies over life of fishery (by divers) on assessments of stock abundance.
- Defining ecosystem effects of depletion of abalone on ecosystem - including abalone-urchin dynamics.
- Natural mortality and recruitment variability in several areas.
- Scale of management may not match scale of stocks and this presents special challenges for management at possibly “micro-scales” – see Prince *et al*. 1998).

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Blacklip abalone (*Haliotis rubra*)

Blacklip abalone are members of the family Haliotidae (Geiger 1999) and are endemic to southern Australia (Shepherd 1973a). They occur from Coffs Harbour (NSW) around the south coast to Rottnest Island (WA), in primarily shallow waters to 10 m in depth.

Fishery research

South Australia

- Blacklip catches increased from 270 t to over 500 t from 1968 to 1972. Catches then declined steadily to 250 t in 1975 and 1978. Catches have been relatively stable at 500 t since 1981 (Mayfield *et al*. 2001).
- There have been no significant trends in CPUE across the South Australia fishery since quotas were introduced (Mayfield *et al.* 2001).

Tasmania

- Total catches have fluctuated over the course of the fishery. Peak catches occurred in 1984 (4,500 t) prior to introducing individual quotas and a TAC. The TAC was originally set at 3,806 t but was progressively reduced to 2,100 t in 1989 (Tarbath 1999a).
- Regional differences occur in the susceptibility of populations to fishing pressure as a result of regional variability in recruitment success (Nash 1991, Nash *et al*. 1995).
- Aggregations occur in areas of preferred habitat and these are targeted by the fishery (Douros 1987, Prince and Shepherd 1992, Shepherd and Partington 1995). Aggregations at the same sites reform after fishing via movements to preferred habitat by larger individuals. Catch rates and size structure of catch can thus remain relatively stable masking depletion of stock and thus making interpretation of catch statistics difficult (Breen 1992, Nash *et al*. 1994, Gorfine *et al*. 1998).
- Highly significant differences in growth rates between north and south of State (abalone growing faster and larger in the south) leading to large differences in size at maturity and harvesting of some immature fish although they are above the minimum size limit in the south and stunted populations that do not reach the size limit in the north (Nash 1992, Tarbath 1999a).
- Tarbath *et al*. (2001) noted that size limits on the east coast of Tasmania were too small to allow abalone to reach a size where they have two breeding seasons prior to entering the fishery. This led to a recent size limit change.

Biological parameters

Sex	Growth*			Long-evity	Mortality			Reproduction		Recruitment**		Length-weight		Author (area)
	L_{inf} (mm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (mm)	Age (y)	Size (mm)	a	b	
								3	75-120					1. (SA)
	116.9-146.4	0.13-0.4	0.3-4.2						74.9-94.6			1.216E-4	2.98	2. (Tas)
	183	0.13		20				4.5-6.2	75-95	8-11				3. (SA)
	133.4-157.7	0.16-0.37	-0.49-0.05		0.29-0.51									4. (Tas)
								6-10	90-110					5. (Tas)
	152.6-182.2	0.4-0.52												6. (east coast Tas)
F														
M														

1. Shepherd and Laws (1974)
2. Tarbath (1999b)
3. Mayfield *et al*. (2001)
4. Tarbath (1999a)
5. Nash (1990)
6. Tarbath *et al.* (2001)

* Note that although VBF parameters are given by several authors, Prince *et al.* (1988) recommended modelling juvenile growth separately to adult growth as abalone growth does not conform to the von Bertalanffy model).

** Dependent on minimum legal size and growth rates which vary regionally – see area specific references for details.

Distribution and links to physical environment

- Movements of abalone are limited. Aggregations occur in preferred habitat (e.g. in regions of coralline algal covered boulders - Tarbath 1999b) and abalone may reaggregate at such sites after periods of fishing (Prince and Shepherd 1992, Shepherd and Partington 1995).

Reproduction

- Spawning is regionally variable in its timing ranging from autumn-winter to spring and autumn in some areas (Shepherd and Laws 1974).
- Blacklip abalone become sexually mature at age rather than size (Nash *et al*. 1994).
- A positive correlation between abundance of adults and recruitment was observed over small spatial scales (10s of metres) by Prince *et al*. (1988).
- Larval life is short (5 – 10 days) and influenced by water temperature (Shepherd and Brown 1993).
- Local hydrodynamics play a major role in dispersal of larvae and stock structure (Shepherd and Brown 1993).
- Recruitment can vary both regionally and interannually. This has been linked to reductions in coraline algal cover as a result of habitat changes (Tarbath 1999b) but recruitment failure has also been observed in unfished populations (Shepherd 1990).

Key inter-species interactions

- Newly settled abalone feed on diatoms and other microscopic algae (Shepherd and Daume 1996).
- Juvenile abalone are preyed upon by fish (usually wrasse), crabs, octopus, rays and rock lobster (Shepherd and Godoy 1989).
- Abalone and sea urchins may play an interdependent role in structuring the algal habitat in their environment (see Tarbath 1999b and Shepherd and Turner 1985)
- Various parasites and commensals may influence the growth rate and mortality of abalone (Shepherd and Breen 1992).

Population structure

- Genetic studies of stock structure have been conducted using allozyme, mtDNA and nuclear DNA techniques (Ward and Elliott 2001); the data suggest significant substructuring of the population on small spatial scales and a significant relationship between geographic and genetic distance (Brown 1991, Huang *et al.* 2000). However, little sub-structuring has been detected in the Tasmanian population.

Fisheries habitats

- Larval settlement is highest on coralline algae (Shepherd and Daume 1996, McShane and Smith 1988).

Effects of Fishing

- Catchability of abalone may vary between mature and immature abalone as immature specimens tend to be more cryptic (Nash *et al.* 1994, Gorfine *et al*. 1998). However, this behaviour may vary both regionally and temporally (Shepherd 1973a).
- Regional differences occur in the susceptibility of populations to fishing pressure as a result of regional variability in recruitment success and growth trates (Nash 1991, Nash *et al*. 1995).
- Concentrated fishing effort may have considerable effects on local recruitment due to the limited larval dispersal of the species (Prince *et al*. 1987, Prince *et al.* 1988).
- Depletion of stock can cause localised increases in growth rates and increases in size at maturity (due to density dependent effects) (e.g. see Tarabath 1999a).
- Links believed to occur between overfishing and the abundance of sea urchins - leading to habitat change (Tarbath 1999b). Overfishing may cause an incease in algal growth resulting in a more

favourable environment for sea urchins (particularly *Centostephanus*) (Shepherd 1973b). Urchins may then denude algae leading to urchin barrens (Tarbath 1999b).
- Urchins may also decrease the cover of coralline algae and this, in turn, may decrease the recruitment of abalone (Shepherd and Turner 1985).

Key uncertainties

- Defining ecosystem effects of depletion of abalone on ecosystem - including abalone-urchin dynamics.
- Reasons for behavioural differences leading to non-emergent (cryptic) and emergent specimens.
- Effects of regionally variable condition and growth on fecundity and implications for stock assessments.
- Error introduced by variation in catching efficiencies over life of fishery (by divers) on assessments of stock abundance.
- Natural mortality and recruitment variability in several areas.
- Scale of management may not match scale of stocks and this presents special challenges for management at possibly “micro-scales” – see Prince *et al*. 1998).

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Striped Trumpeter Fishery

Key species accounts

Striped trumpeter (*Latris lineata*)

Striped trumpeter are members of the family Latridae (Gomon *et al*. 1994). They are distributed throughout southern Australia from Sydney (NSW) to Kangaroo Island (SA) including Tasmania (Kailola *et al*. 1993). Striped trumpeter are taken by a variety of methods including hook and gillnet (in Tasmanian State waters), they are targeted in the SENTF, are caught as by-catch in demersal trawling on the shelf (SETF) and as by-catch in the SSF (Lyle and Hodgson 2000). Striped trumpeter are also taken by recreational fishers - juveniles are taken in graball (gill nets) on coastal reefs and adults are taken by hook and line on offshore reefs.

Fishery research

- Striped trumpeter are assumed to be a single stock in Australian waters (Lyle and Hodgson 2000).
- Current catches are approximately 100 t per annum (Lyle and Hodgson 2000).
- CPUE has generally increased in handline and dropline sectors of the fishery but trends in CPUE are influenced by variations in the strength of year classes entering the fishery (Lyle and Hodgson 2000).
- Significant increases in annual catch in late 1990s due mainly to increasing effort in the handline and dropline sectors (Lyle and Hodgson 2000).
- Age and size composition have not been documented but they are also influenced by interannual variability in recruitment.
- Sustainability of current catches uncertain.
- No formal stock assessments (but catch and effort trends are examined annually by TAFI in Tasmania).

Biological parameters

Sex	Growth			Longevity	Mortality		Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				31									3. Tas)
F	72.9	0.89	-1.258				5	43.8	5		0.034	2.77	1 (Tas) 2 (Tas)
M	72.9	0.89	-1.258				8	53.4			0.034	2.77	1 (Tas) 2 (Tas)

1. Lyle and Hodgson (2000)
2. Hutchinson (1993)
3. Jordan (2000)

Distribution and links to physical environment

- Depth distribution is size based, with larger fish in deeper waters indicating ontogenetic pattern of movement from inshore nursery areas to adult habitat on mid and outer shelf reefs.
- Movements within the SEMR occur based on the recapture of a Tasmanian tagged fish in southern NSW (Lyle and Hodgson 2000).
- Broadscale oceanic movements occur based on the return of a Tasmanian tagged individual from the St Paul/Amsterdam Island group in the South Atlantic Ocean (J. Lyle TAFI, Hobart, pers. comm.).

Reproduction

- Striped trumpeter are multiple spawners, fecundity increases with fish size (100,000 – 400,000 eggs are produced by females weighing 3.2 kg and 5.2 kg, respectively) (Hutchinson 1993).

- Spawning occurs on deep reef habitats from July to early October. Timing of spawning is regionally variable with spawning occurring earlier in the northern part of the species distribution (Ruwald *et al*. 1991, Jordan 2000).
- There is evidence of marked recruitment variability with very strong cohorts spawned in 1993 and 1994 (Murphy and Lyle 1999) and, perhaps, the 1996 cohort (Jordan 2000).

Key inter-species interactions

- Adult striped trumpeter are benthopelagic piscivores and prey on a variety of benthic and benthopelagic fish including ocean perch (*Helicolenus percoides*) (Bulman *et al.* 2001).

Population structure

- There have been no genetic or otolith microchemistry studies of stock structure.

Fisheries habitats

- Larvae have been described from reared material (Furlani 1998). They are long-lived and believed to have a similar pelagic juvenile phase to that of morwongs (cheilodactylids), although the distribution of larvae in the wild is poorly known and no latrid larvae greater than 8 mm have been recorded in samples from southern Australia. Latrid larvae have been recorded from shelf waters of western Tasmania in September and October, although the species identification is uncertain.
- Juveniles occur on shallow reefs throughout south east Tasmania and remain relatively site attached for several years (Murphy and Lyle 1999). Larger juveniles gradually move to deeper offshore reefs.
- Adult striped trumpeter occur mainly on the continental shelf over rocky reefs in depths to 300 m.

Effects of Fishing

No information currently available.

Key uncertainties

- Little information is available about the size of the resource or the sustainability of current catches.
- No fishery independent biomass estimates but species may be suitable for fisheries independent (egg) surveys.
- Age composition of the commercial catch is poorly documented.
- Movements of juveniles and adults are poorly known and the extent to which larvae/pelagic juveniles disperse is also unknown. The recent recapture of a Tasmanian tagged fish from oceanic islands in the South Atlantic indicates movements can be extensive and that stock structure may be complex.
- Basic population parameters (growth, mortality, reproductive biology) poorly known.
- Determinants of recruitment variability unknown but suspected to be environmentally driven and linked to processes occurring during the long-lived larval stage.

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Beach Haul and Recreational Fishery for Australian Salmon

Key species accounts

Australian salmon (*Arripis trutta* and *Arripis truttaceus*)

Australian salmon are members of the family Arripidae (Gomon *et al*. 1994). There are two species (Paulin 1993). The eastern Australian salmon (*Arripis trutta*) occur from Brisbane (Qld) to Port Phillip Bay (Vic), including Tasmania and Lord Howe and Norfolk islands. *A. trutta* also occur in New Zealand. The western Australian salmon (*Arripis truttaceus*) is confined to the southern and western coasts of Australia from central Victoria, including Tasmania, to Geraldton (WA) (Gomon *et al.* 1994).

Eastern Australian salmon are the predominant species caught in the Tasmanian and New South Wales commercial fisheries; western Australian salmon make up the bulk of the Western Australian and South Australian fishery; a roughly equal mix of eastern and western Australian salmon is caught in the Victorian commercial fishery (Stanley 1978).

Fishery research

- The total catch of Australian salmon has remained steady at about 4,000 t per annum since 1997/98.

Australian salmon production statistics by state (ABARE 2001).

	1997 / 98		**1998 / 99**		**1999 / 00**	
	tonnes	**$ '000**	**tonnes**	**$ '000**	**tonnes**	**$ '000**
NSW	296	284	157	175	295	274
Vic	718	717	689	805	803	787
WA	2,608	1,252	1,753	841	2,558	1,279
SA	632	809	527	672	461	569
Tas	476	671	385	554	346	572
Total	**4,730**	**3,733**	**3,511**	**3,047**	**4,463**	**3,481**

*Note that this table includes both subspecies of Australian salmon: The predominant age classes caught in the commercial fishery vary with region (Table 2).

Age classes caught in the commercial fishery by region (Stanley 1978).

Region	**Subregion**	**Age Class**
Tasmania		
	Tasmania coastline	2+ to 4+, 5+ (~3%)
	Flinders Island	2+ to 3+, 5+ (~7%), some 6+
Victoria		
	Gippsland Lakes	0+ to 2+
	Western Port and Port Phillip Bay	0+ to 5+
	Lakes Entrance	1+ to 5+
	Mid Victoria	1+ to 3+
	Western Victoria	2+ to 5+
NSW	2+ to 7+	2+ to 7+

Biological parameters

Sex	Growth			Longevity	Mortality		Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	

A.trutta A. truttaceus	22.07-58.7 32.07-69.91	0.2909-1.6952 0.2609-0.694	-0.16 to –0.0001 -0.236 to 0.0	10									1. (SE Aust) 2. (SE Aust) 1. (Vic-WA)
F													
M													

1. Nicholls (1973)
2. Stanley (1980)

Distribution and links to physical environment

- Between November and February, adult eastern *A. trutta* migrate to waters between the Gippsland Lakes (Vic) region and Bermagui (NSW) for spawning (Stanley and Malcolm 1977, Stanley 1980). Some also disperse northwards along the New South Wales coastline. *A. truttaceus* migrate westwards to southwest Western Australia to spawn.
- Recruitment strength in South Australia is correlated with strength of the Leeuwin Current/El Nino signature (G. K. Jones SARDI, Henley Beach, pers. comm.).

Reproduction

- Eastern Australian salmon are serial batch spawners (Stanley 1980).
- Spawning takes place between December and January in the Lakes Entrance region, between January and February in the Eden region and between November and February in the Bermagui region (Stanley and Malcolm 1977).
- Eggs, larvae and juveniles of eastern Australian salmon disperse, initially by drifting aided by the East Australian Current, from the NSW spawning grounds to Tasmania and Victoria (Nicholls 1973).

Key inter-species interactions

No information currently available.

Population structure

- Each species is considered to be represented by a single genetic stock in Australian waters. Genetic studies have also shown that the New Zealand population of eastern Australian salmon forms a further discrete breeding population, however, they are not sufficiently divergent to be considered a separate species (MacDonald 1983).

Fisheries habitats

- Adult eastern Australian salmon occur in shelf waters, commonly inhabiting bays and estuaries to a depth of about 30 m. They are also sometimes found in large schools over seagrass beds and in mangrove-lined creeks (Kailola *et al*. 1993).

Effects of Fishing

No information currently available.

Key uncertainties

- Unvalidated scale readings which may cause inaccurate age-based demographics.
- Batch fecundity is uncertain.
- Lack of a useful effort measure and fishery-independent data.
- Unknown utility of recruitment indices and environmental correlates.

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Snapper Fishery

Key species accounts

Snapper (*Pagrus auratus*)

Snapper are members of the family Sparidae (Gomon *et al*. 1994). Snapper occur throughout southern Australia from Hinchinbrook Island (Qld) to Barrow Island (WA), including northern Tasmanian waters (Kailola *et al*. 1993). They also form an important fishery in New Zealand. A similar species, *Pagrus major*, occurs in the northern hemisphere in waters of Japan, China, Taiwan, Indonesia, and the Philippines and was classified as a reproductively isolated population of *P. auratus* by Paulin (1990). They are an important commercial and recreational species across their range and are also important in aquaculture (Yearsley *et al*. 1999). Commercial catches in Tasmania are negligible compared to the other States. They are primarily caught by handline, longline, dropline and mesh nets but are also taken as by-catch in inshore trawling, prawn trawling and in the SSF. The largest fish are taken by longline and variability in catches reflect variations in recruitment and the passage of strong and weak year classes through the sectors of the fishery. Growth rates are highly variable between stocks and regions (Coutin 2000).

Fishery research

Snapper production statistics for SEMR states – excluding Tas (ABARE 2001).

	1997 / 98		1998 / 99		1999 / 00	
	tonnes	**$ '000**	**tonnes**	**$ '000**	**tonnes**	**$ '000**
NSW	272	2,400	286	2,411	262	2,333
Vic	62	470	84	566	47	326
SA	394	1,980	447	2,238	576	3,247

South Australia

- Catches peaked at 528 t in 1971 (Knight and Tsolos 1999). During the 1990s, catches in South Australia ranged between 223 and 456 t, ranking SA behind NSW (450 – 650 t, Ferrell and Sumpton 1997) and WA (725 – 944 t, McGlennon *et al*. 2000), but ahead of Qld (80 – 110 t, Ferrell and Sumpton 1997) and Vic (50 – 185 t, Coutin 1997).
- Poor recruitment lead to a decline in catch rates in the handline fishery from 1990/91 to 1994/95, with a recent increase for 2000 (projected to 2004) as the strong year classes from 1990 and 1991 recruit to the fishery (McGlennon and Jones 1997).
- Similar declines in catch rates also occurred in the longline fishery as the 1979-year class was fished down, improvements are expected in 2004 – 2006 as the 1990- and 1991-year classes recruit to the fishery, although this will depend on the impact on stocks of the handline fishery (McGlennon and Jones 1997).

Victoria

- The Victorian commercial snapper catch has been consistently declining since 1978/79 and the 1996/97 catch of 49 t was the lowest since records began in 1914 - catches improved slightly to 60 t in 1997/98 (Coutin 2000).
- There was a high abundance of 0+ – 1+ snapper in Port Phillip Bay during 1995 – 1997 providing forecasts of higher levels of recruitment to the fishery in the next few years.
- The size frequency of the commercial catch is bimodal with a dominant mode of 65 to 67 cm and a lesser mode of 50 to 53 cm in 1996 – 97 (Coutin 2000).
- Coutin (1997) noted that inspite of declines in catches, the size and age structure of commercial catches in Port Phillip Bay was not significantly different in the early 1990s to that in the early 1970s and there was no evidence of a decline in the average size of snapper or in the number of age classes represented in the catch.

Biological parameters

Sex	Growth			Longevity	Mortality		Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	B	
	93	0.144	0.8285	 34-39									1. (SA) 2. (SA)
F													
M													

1. McGlennon and Jones (1997)
2. McGlennon *et al.* (2000)

Distribution and links to physical environment

- Recruitment variability has been correlated with autumn water temperatures in New Zealand (Scott and Pankhurst 1992, Francis 1993).
- Tagging in Victoria has revealed extensive stock specific movements (see Sanders 1974 for details).

Reproduction

- Snapper, like many sparids, change sex. Francis and Pankhurst (1988) found that in New Zealand, 0+ aged fish had gonads that were undifferentiated, all 1+ age fish were immature females, 2+ to 4+ aged fish had gonads that were either ovary, ovo-testis or testis, and older fish were either male or female.
- Snapper are a serial spawning species in which spawning occurs on a daily basis in the majority of individuals with batch fecundity of about 100,000 eggs per kg weight (Scott and Pankhurst 1992, Scott *et al.* 1993, Hobby and Pankhurst 1997).
- McGlennon and Jones (1997) estimated fecundity of snapper from South Australia to range between 8,700 and 760,000 eggs per batch.
- The timing of spawning varies between regions. In southern Australia, spawning occurs between late October and early March (Lenanton 1974); in more northern waters, spawning occurs during winter between late May and August (Kailola *et al.* 1993). Spawning throughout the year in NSW waters is suggested by the year round distribution of larvae in coastal and some estuarine waters (Miskiewicz 1987, Gray 1995).
- Recruitment is highly variable in snapper, in South Australia years of strong recruitment include 1968, 1969, 1973, 1979, 1991 whereas 1980 to 1987 were years of poor recruitment (McGlennon and Jones 1997). The 1991-year class was extremely strong and is currently moving through the fishery in SA (A. Fowler SARDI, Henley Beach, pers. comm.). Recruitment is highly variable in the two Victorian stocks with a large number of 0+ – 1+ fish present in 1995 – 1997 (Coutin 2000).
- Indirect influences on recruitment may occur to some NSW estuarine systems as a result of acid sulphate soil drainage (K. Frederieke NSW Fisheries, Cronulla, pers. comm.).
- Otolith microchemistry studies are currently underway in SA and Vic to look at relative importance of nursery areas and movements between nursery areas and adult stock (current studies by A. Fowler, SARDI, and G. Jenkins, MAFRI).

Key inter-species interactions

- Snapper are benthic omnivores. Juveniles feed on polychaetes, molluscs and crustaceans (Winstanley 1983). Adults feed on crustaceans, molluscs and sea urchins (Coleman and Mobley 1984, Winstanley 1983).
- White sharks are key predators of snapper (Malcolm *et al.* 2001).

Population structure

- Both tagging and genetic studies indicate that snapper form discrete stocks or breeding units in Australian waters with considerable overlap in the distribution of these populations (MacDonald 1982, Francis and Winstanley 1989).

- Two stocks exist in Victorian waters: a western stock that extends into SA (to the Murray mouth), and an eastern stock that extends into northern NSW with the dividing point at Wilsons Promontory (Sanders 1974, MacDonald 1980, Donnellan and McGlennon 1996).

Fisheries habitats

- Larvae from southern Australia have been described (Miskiewicz and Neira 1998) and have been recorded in Port Phillip Bay from December to March (Jenkins 1986), entering estuaries in central NSW in all months with a peak in September (Miskiewicz 1987, Marsden 1986) and in coastal waters off Sydney throughout the year (Gray 1995).
- Juvenile and small adult snapper inhabit bays, estuaries and inlets, often over mud and seagrass (Kailola *et al.* 1993, Gomon *et al*. 1994, Miskiewicz and Neira 1998).
- At about 1 year of age, snapper move from these sheltered habitats to coastal rocky reefs at depths up to 300 m, but more commonly to depths of about 35 m (Kailola *et al*. 1993, Gomon *et al*. 1994, Miskiewicz and Neira 1998).

Effects of Fishing

- Strong behavioural influences (movement patterns) influence availability of fish to fishery (A. Fowler, SARDI, Henley Beach, pers. comm.).
- Release mortality of line caught fish may be significant in deeper water regions (> 30 m) – (current studies by St John and Moran – WA Fisheries).

Key uncertainties

- The reliance on few (or even single) year classes in the South Australian stock(s) is cause for concern.
- Further protection of spawning fish to improve the likelihood for more frequent recruitment successes may be required in some areas.
- Determinants of recruitment variability unknown for Australian waters.
- Movement dynamics and their relationship to the availability of fish to fishing gear are largely unknown and appear to be important in various areas.
- Uncertainty about the relative contributions of fishing pressure, natural fluctuations in reproductive success (combined with uncertainties regarding movements) make it difficult to interpret trends in fisheries data.

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Scallop Fishery

Key species accounts

Scallops

The scallop fishery in southern Australian waters is based on a number of species: *Pecten fumatus*, *P. alba*, *P. meridionalis* (which are considered to be clinal variations of the one species) *P. modestus*, *Chlamys (Mimachlamys) asperrimus*, and *C.* (*Equichlamys*) *bifrons* (Young and Martin 1989). Scallops are taken primarily by dredge but also on SCUBA (Young and Martin 1989). *P. fumatus* occurs from central New South Wales to roughly the border between South Australia and Western Australia (western limit unclear), including Tasmania (Young and Martin 1989). *C. asperrimus* is distributed from New South Wales to Geographe Bay (WA), including Tasmania (Macpherson and Gabriel 1962). *C. bifrons* is distributed from New South Wales to South Australia, including Tasmania (Macpherson and Gabriel 1962).

The scallop fishery is based on animals in a roed (reproductive) state ("roe-on fishery") and fishing is concentrated in a period when the gonad is most fully developed and condition and meat yield are highest – in Port Phillip Bay this is between July and October (Coleman 1998).

Scallop fisheries have a history of sequential depletion of newly discovered beds and subsequent fishery collapse and this has been recorded in all SEMR scallop fisheries with various fishing areas remained closed in several years. Such problems appear to stem from balancing catch rates, damage to stock that is not retained by fishing gear and leaving sufficient spawning biomass to maintain a sustainable level of recruitment.

Recent management plans for SEMR based scallop fisheries

Fishery research

- *Pecten* species have historically been the most important species in the scallop fisheries of southern Australia (Young and Martin 1989).
- In the past commercial quantities of *Pecten* species were taken throughout southern Australia, including New South Wales. By 1985 the main scallop beds were depleted, with the last major bed being fished out in 1986 (Young and Martin 1989).
- The fishery is now based primarily in Tasmanian and Victorian waters, with smaller fisheries operating in Jervis Bay (NSW) and Coffin Bay and Spencer Gulf (SA) (Yearsley *et al.* 1999). The *Pecten* fishery reached a peak in 1983, with a record catch of 4,136 t of meat (Young and Martin 1989).
- The commercial fishery for *Chlamys* species was limited to the D'Entrecasteaux Channel in southern Tasmania (Young and Martin 1989). Hoever, commercial fishing no longer occurs in this area.

Tasmania

- Fishery for *P. fumatus* began in the upper Derwent estuary in the early 1900s. By 1920 the fishery had moved to the D'Entrecasteaux Channel having exhausted the upper Derwent; catches rose steadily until 1947, following which the fishery declined (Fairbridge 1953).
- Fishing for *P. fumatus* in Great Oyster Bay began in 1953, halting the decline in the fishery; discovery of the scallop beds in Norfolk Bay in 1955 boosted production – in 1956 Norfolk Bay supplied 369 t (flesh weight) of the 534 t Tasmanian catch (Anon 1956).
- By 1960 the Norfolk beds were completely depleted and have not since contributed significantly to the Tasmanian catch (Young and Martin 1989).
- 1964 saw the discovery of new beds along the east coast of Tasmania, but they did not contribute substantially to the catch.; by 1967 the D'Entrecasteaux Channel beds were exhausted and closed (Dix 1982).
- In 1970, Tasmania recorded no landings of scallops (Dix 1982).

- New beds were subsequently discovered further and further offshore on the east and northeast coasts (St Helens, Banks Strait, Sisters Islands) during the 1980s.
- The Tasmanian commercial scallop fishery was closed between 1988 and 1994. Catches in 1995 and 1996 were 1,609 and 250 t shell weight, respectively (ScallopMAC 2001). The fishery was closed in 1997, reopened for 1998 (3,500 t shell weight) and 1999 (4,555 t shell weight), closed in 2000 (ScallopMAC 2001).

Victoria

- The exploitation of scallop beds began in Port Phillip Bay in 1963 (Young and Martin 1989).
- By 1966 most of the Australian catch of 2,008 t was caught in Port Phillip Bay (Dix 1982).
- Following the Tasmanian pattern, the Port Phillip Bay scallop fishery collapsed and by 1969 the catch was 286 t (Young and Martin 1989).
- In 1970 only 18 t were produced (Coleman *et al*. 1996).
- Since 1970 yield has fluctuated widely from about 1,650 t in 1985 to zero in 1989 and 1990 (Coleman *et al*.1996). Dive surveys were conducted annually in Port Phillip Bay to assess scallop abundance (Coleman 1998). Port Phillip Bay fishery was closed to commercial scallop fishing in 1997 and thw Victorian government entered a commercial licence buy-back scheme.

Estimated abundance of scallops, yield from the fishery and opinions on the fishery in Port Phillip Bay based on dive surveys (from Coleman 1998).

Year	Estimated Number Available To Fishery in Millions (± 95% CL)	Yield (tonnes)	Fisher's Comments
1982	489 (363)	894	very good
1983	195 (95)	440	fairly poor
1984	312 (101)	868	good
1985	321 (108)	1,672	very good
1986	135 (24)	160	poor
1987	268 (123)	645	good
1988	92 (26)	35	very poor
1989	20 (11)	0	no fishing
1990	51 (39)	0	no fishing
1991	390 (225)	529	good
1992	2,654 (1,164)	189	poor (very high mortality)
1993	1,200 (495)	312	poor (very high mortality)
1994	212 (132)	133	poor
1995	330 (318)	368	poor
1996	232 (189)	75	poor

- Following their discovery in 1970, the scallop beds off Lakes Entrance entered the fishery – in their first year these beds produced 641 t of scallop meat (Sturgess *et al*. 1982).
- From 1989 to 1991 less than 650 t shell weight of scallops were taken from Lakes Entrance each year (ScallopMAC 2001).
- In 1992 and 1993 catches improved, averaging 8,600 t shell weight per year, falling to an average of 220 t shell weight per year between 1994 and 1996, in 1998/99 only 19 t shell weight of scallops were taken (ScallopMAC 2001).

South Australia

- Fisheries for scallops in South Australia followed the same sequential discovery and depletion pattern as for the Tasmanian and Victorian fisheries (Young and Martin 1989).
- Coffin Bay fishery: 22 t in 1972, 105 t in 1973, 20 t in 1974, followed by zero catch (Jones 1976).

New South Wales:

- Jervis Bay: 184 t in 1971, steady decline for the following three years, ceased in 1975 (Anon 1984).

- Scallops reappeared in Jervis Bay in 1978; landings peaked at 367 t in 1981, but by 1983 the beds were depleted (Anon 1983). Small catches have since been taken (Yearsley *et al.* 1999).

Biological parameters (*P. fumatus*)

Sex	Growth			Longevity	Mortality		Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	92.5 85.9	0.59 1.57		14 16									1. (Bass St)* 1. (Bass St)** 2. (Tas) 3. (SE Aust)
F													
M													

1. Gwyther and McShane (1988): * 1964 – 1967; ** 1983 – 1985
2. Fairbridge (1953)
3. Coleman (1998)

Distribution and links to physical environment

Pecten fumatus

- Bed orientation is influenced by the strength and direction of tidal flow (Young and Martin 1989).
- In Bass Strait, the seasonal cycle in gonad development is correlated with the time of lowest water temperatures and highest nutrient conditions (Young *et al.* 1999).
- Fishery areas tend to be concentrated around hotspots of primary productivity and are thus patchy in their distribution.

Reproduction

- Fluctuations in recruitment are characteristic of scallop populations, and the sequential depletion of fishing areas suggests both considerable stock structure and a demonstratable stock-recruitment relationship. However little work has been done to study the form of this relationship.

Pecten fumatus

- *P. fumatus* is a functional hermaphrodite that matures as both male and female in their second year (Young and Martin 1989).
- The timing of spawning varies throughout the range of the species.

Region	**Spawning time**	**Author**
Southern Tasmania	Aug – Oct (peak in spring)	Harrison (1961)
Port Phillip Bay	Jun – Nov (peak in spring)	Sanders and Lester (1981), Sause *et al.* (1987)
Jervis Bay	late winter, early spring, early summer, late autumn	Jacobs (1983)

- Fertilised eggs hatch into trochophores after 2 days at 13 – 15˚ C, and become straight-hinged veligers at 3 days (Young and Martin 1989).
- Metamorphosis occurs at about 31 days after fertilisation (Dix and Sjardin 1975).
- Young *et al.* (1999) found maximum gonad development to precede spatfall by about 1 month.
- The timing of settlement varies throughout the range of the species.

Region	**Settlement Time**	**Author**
East coast Tasmania	peak in Sep; minor amts in late spring/early summer	Dix (1981), Hortle and Cropp (1987)
Port Phillip Bay	Oct – Dec (peak in Dec)	Sause *et al.* (1987)
Eastern Bass Strait	spring/summer	Hortle (1983)

Jervis Bay	early winter/late spring	Jacobs (1983)

- Spat settlement appears to be highest in midwater (Dix 1981, Hortle 1983).
- Off eastern Tasmania growth of spat held in bags averaged 1.5 mm per week (Hortle and Cropp 1987); spat attained 60 mm shell height after their first year of post-settlement growth when held in lantern cages off eastern Tasmania and Port Phillip Bay (Dix 1981, Sause *et al*. 1987).

Chlamys species:

- Both *Chlamys asperrimus* and *C. bifrons* are gonochores (Young and Martin 1989).
- In the D'Entrecasteaux Channel *C. asperrimus* and *C. bifrons* are in full roe in early April, spawning is believed to take place late June (Grant 1971, Zacharin 1986).
- Zacharin (1994) reported spawning of *C. asperrimus* occurs between September and December; with a second partial spawning occurring late December – early January.
- Eggs of *C. asperrimus* reached trochophore stage one day following fertilisation, straight-hinged veliger by day 2, fully developed pediveliger by day 19, larvae metamorphosed at day 20 (17 – 18˚ C) (Rose and Dix 1984).
- *C. bifrons* developed into straight-hinged veligers on day 3 at 12 – 18˚ C, metamorphosis occurred between days 17 and 20 following fertilisation for larvae maintained at 14 – 18˚ C (Dix 1976).
- Settlement of *C. asperrimus* larvae has been observed in late April in Tasmania, and between February and April in South Australia (Hortle 1983, Chernoff 1987).
- Zacharin (1994) observed settlement of *C. asperrimus* between September and April in the D'Entrecasteaux Channel, with a peak in December.
- Growth characteristics of *C. asperrimus* and *C. bifrons* have not been described (Young and Martin 1989).
- In Bass Strait *C. asperrimus* reach 80 mm shell height, while in the D'Entrecasteaux Channel they may exceed 100 mm (Grant and Alexander 1973, Zacharin 1986).

Key inter-species interactions

No information currently available.

Population structure

- *Pecten fumatus*, *P. alba*, *P. meridionalis* are considered to be clinal variations of the one species (Young and Martin 1989).

Fisheries habitats

- Scallops inhabit enclosed embayments as well as exposed oceanic environments (Young and Martin 1989).
- *P. fumatus* tend to congregate in discrete beds from depths of 1 to 120 m (Yearsley *et al*. 1999).
- *Chlamys* spp. live on a variety of substrates (attached by an byssus) in depths between 7 and 69 m (Olson 1955, Grant and Alexander 1973).
- They are most commonly found on coarse bottom substrates in water depths from 2 to 40 m (Olson 1955, Grant and Alexander 1973) and on silt and mud.

Effects of fishing

- Fishing pressure has resulted in changes to growth rates (see biological parameters table).
- Dredges have been modified and developed over the years in order to reduce the damage caused to both the catch and those scallops not retained in the dredge. However damage rates are still generally high.
- The Baird dredge (Baird 1955) was banned from the D'Entrecasteaux Channel because fishers believed it to be damaging to the scallops and the beds – it remained in use on the east coast of Tasmania (Young and Martin 1989).
- Since 1961 the Digby or Lip dredge with a width of 1.3 m has been the only approved dredge for the D'Entrecasteaux Channel (Anon 1981).

- The Baird dredge (Baird 1955) was initially used in the Port Phillip Bay fishery but was rapidly modified into the mud or box dredge that is in use today (Young and Martin 1989).
- In Jervis Bay, dredging was estimated to damage 25 – 33% of the catch and a further 10% of the scallops which were not retained by the gear (Butcher *et al*. 1981).
- In Bass Strait, under conditions of high scallop density up to 41% of live scallops in a catch may be damaged by dredging; a further loss of 68% of scallops not caught was estimated to occur – thought to be as a result of bacterial contamination resulting from the decay of dead and damaged scallops left on the bottom (McLoughlin *et al*. 1991).
- Catching efficiency of the Australian scallop mud dredge was estimated by McLoughlin *et al*. (1991) to be about 11.6%.

Key uncertainties

- Scallop fisheries experience high natural variability in abundance, growth, mortality and meat yield making traditional stock assessment difficult.
- Form of stock-recruitment relationship. Further information on the contribution of the area, size of beds and the minimum level of breeding stock required to maintain recruitment is needed.
- There are major information deficiencies in scallop biology that affect yield estimates in stock assessment models – growth, mortality, age and condition.
- The potential effects of introduced species to the scallop fishery are unknown (starfish are attracted to scallops damaged by dredging and lead to increased incidental mortality due to dredging effects).
- Very little information on by-catch.

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Patagonian Toothfish Fishery (Macquarie Island)

Various aspects of the Macquarie Island toothfish fishery have been recently reviewed in Xi and Furlani (2001). The fishery commenced in November 1994 with fishing activity primarily occurring in the spring/summer months in the area (Williams and Lamb 2001). Small fishing grounds were gradually discovered over the next few years that initially provided high catches. However, catches have since declined and aggregations are now difficult to locate (Williams and Lamb 2001). Despite extensive searching over the entire Macquarie Ridge within the Australian Fishing Zone, no further fishing grounds have been located.

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Key species accounts

Patagonian toothfish (*Dissostichus eleginoides*)

Patagonian toothfish are members of the family Nototheniidae (DeWitt *et al*. 1990). They are widely distributed in the higher latitudes of the Southern Hemisphere around the southern coast of Chile, the Patagonian shelf, and the sub-Antarctic islands of Kerguelen, South Georgia, and Macquarie (Kock *et al.* 1985, DeWitt *et al.* 1990). The fishery for Patagonian toothfish operates south of the Polar frontal zone (Inchausti and Weimerskirch 2001) where they are caught by trawl and longline (although longlining for toothfish is not allowed within the Australian EEZ in order to minimise the by-catch of albatross and other seabirds). The fishery for Patagonian toothfish began in the Australian sector around Macquarie Island in 1994 (Moore *et al.* 1998).

Patagonian toothfish are currently managed by TAC in the Australian sector.

Fishery research.

- Since mid 1980s the total world catch of toothfish has ranged from 2,804 t to about 75,500 t in 1996/1997 (including illegal catch) although estimates of up to 82,200 t are recorded (Agnew 2000).
- There is a high illegal catch with estimates that more than 80% of the total toothfish catch (estimated annual value of US$500 million) is taken by illegal means (Clark and Hemmings 2001).
- Several fishing grounds exist around Macquarie Island including the Aurora Trough, Colgate Canyon, Grand Canyon and Beer Garden (Williams and Lamb 2001). CPUE has declined in all grounds around Macquarie Island since 19998/99 (Williams and Lamb 2001).
- Results of tagging and CPUE have seen a progressive reduction in TAC (Aurora Trough) from 750 t in 1996/97 to 200 t in 1997/98. Since 1999, the Aurora Trough has been closed to fishing with the exception of a 40 t research quota (Williams and Lamb 2001).
- At the close of the 2000 season, tag-recapture models for the Aurora Trough show a decline to approximately 30% of the available pre-tagging biomass with declines to less than 30% possible in other grounds (Tuck *et al.* 2001).
- The catch at Macquarie Island consists primarily of immature fish (Constable *et al*. 2001).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment*		Length-weight		Author (area)
	L_{inf} (cm)	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	1855 221.7	0.042 0.025	-0.781 -2.42	35-50 43			>0.2	12-15	97.5*			4.4E-9	3.14	1. (Mac. Is) 3. (Mac. Is)
F	1951	0.038	-1.184					9-12	90-100			5.4E-9	3.11	2. (Atl. Ocean) 1. (Mac. Is.)
M	1542	0.054	-0.434					7-11	64-94			5.0E-9	3.12	2. (Atl. Ocean) 1. (Mac. Is.)

1. Constable *et al*. (2001) *Heard Is. data
2. DeWitt *et al*. (1990)/Zhivov and Krivoruchko (1990)
3. Kalish *et al*. (1999)

Distribution and links to physical environment

- 4,564 fish been have tagged off Macquarie since 1995/96 with an 11.5% recapture rate and little movement/migration noted (Williams and Lamb 2001).

Reproduction

- Toothfish spawn large pelagic eggs (4.3 – 4.7 mm dia) and spawning is thought to take place on the continental slope at about 500 m depth. Hatching occurrs between August and November in the Patagonian region (Kock 1993). Spawning at Herd Island occurs in June (Duhamel 1991).
- Fish caught at Macqarie Island are almost entirely juveniles or adults in resting stage of gonad development and there is no information on spawning in the area (Constable *et al*. (2001).

Key inter-species interactions

- Toothfish are opportunistic predators and prey on a wide range of species including fish, cephalopods and crustaceans. The most important prey species in these groups are the benthopelagic fish (*Bathylargus antarticus*), squid (*Gonatus antarcticus*) and prawns (Goldsworthy *et al*. 2001a).
- Goldsworthy *et al.* (2001b) noted little predation on toothfish by seals or seabirds, or prey competition between toothfish and other marine predators and concluded that the trophic linkages between toothfish, sea birds and mammals around Macquarie Island were weak.

Population structure

- There are significant genetic differences between populations of Patagonian toothfish. In the Southern Ocean, there are genetic differences among the isolated populations around sub-Antarctic islands – little long-distance gene flow with each small, localised population considered to be a separate stock (Smith and Gaffney 2000).
- Genetic differences were significant for two samples (~60 km apart) off Macquarie Island (at 5% level) suggesting the presence of different stocks (Reilly and Ward 1999).
- In most recent studies by Reilly *et al*. (2001), mtDNA and nuclear DNA (microsatellites) were used to investigate the population structure of Patagonian toothfish at Macquarie Island, Heard/McDonald Islands and from Shag Rocks/South Georgia. Significant mtDNA heterogeneity was detected among the three locations; spatial and temporal collections within the same fishing location were not significantly different. There was weak and inconsistent heterogeneity at several microsatellite loci, and no overall differentiation among the three locations. The mtDNA heterogeneity suggests that gene flow between the two Australian fishing locations and more generally among the three locations within the Southern Ocean is restricted.
- Significant differences in otolith core C-14 from different regions also supports the presence of several stocks in the Southern Ocean (Kalish *et al*. 1999, Constable *et al*. 2001).

Fisheries habitats

- Adult fish live in deep waters on the continental slope from 700 – 2,500 m (Yau *et al.* 2001).

- Juveniles probably remain pelagic for a year until they reach 15 – 20 cm TL when they become demersal (Kellermann 1990).
- Spawning occurs in areas defined by slope position (between 800 and 1,200 m) around South Georgia (Agnew *et al*. 1999).

Effects of Fishing

- Selectivity parameters were estimated by Constable *et al.* (2001) (see their Table 10.4, Figure 10.6) and their estimation of Bertalanffy parameters that take into account selectivity. Results suggest that L_{inf} may be over-estimated for toothfish populations at Heard Is and South Georgia in analyses where selectivity is not taken into account.
- Long-lining activity has resulted in significant seabird by-catch in the toothfish fishery (Nel *et al.* 2000, Clark and Hemmings 2001). Estimated by-catch of seabirds from illegal fishing for 1995 – 1999 was 105,900 to 257,000 birds (Clark and Hemmings 2001). Seabird by-catch has been reduced, however, by setting lines at night (Nel *et al*. 2000). However, seabird mortality is low in the Macquarie Is. fishery as a result of a ban of the use of netsonde cables (Williams *et al*. 2001) which cause most fatalities in other fishing areas (Weimerskirch *et al*. 2000).
- Sub-adult fish (< 50 cm) are often caught in trawls as an incidental by-catch on the Patagonian shelf (DesClers *et al.* 1996).
- By-catch rates are generally low in established fishing grounds averaging 8.48% of total catch. The majority of fish species taken as by-catch are common and widely occurring species and by-catch rates are not considered a threat to their populations either locally or globally (Williams *et al*. 2001).
- Most fishing is concentrated in deep sediment filled valleys where benthos is not very abundant and consists of widely spaced species of low conservation concern (Butler *et al*. 2000).

Key uncertainties

- The extent of illegal catch is unknown but considered to be large. Clarke and Hemmings (2001) noted that if illegal fishing continues at its present rate, toothfish will be commercially extinct in three years.
- The rough terrain around Macquarie Island has precluded a trawl survey that could provide a fishery-independent estimate of biomass.
- Rates of mixing of otherwise separate stocks confuses stock structure.
- Natural mortality.
- The degree of localisation suggested by the current genetics results suggests that, if confirmed, that assessments of the fishery will need to occur at a finer spatial scale.

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Jack Mackerel Fishery

Key species accounts

Jack mackerel (*Trachurus declivis*)

Jack mackerel are members of the family Carangidae (Gomon *et al*. 1994). They occur throughout southern Australia from Wide Bay (Qld) to Shark Bay (WA), including Tasmania (Gomon *et al.* 1994). Jack mackerel are taken predominantly by the SENTF although they are also taken in the SETF. The fishery is mostly concentrated in Tasmanian waters where it is based on large seasonal surface and subsurface schools that occur on the shelf in east coast waters from November to May (Williams *et al.* 1987). A second species, the Peruvian jack mackerel (*Trachurus murphyi*) has been recorded in catches in recent years (Pullen *et al*. 1989).

Fishery research

- Various fishery trials have occurred dating back to the 1940s off NSW and eastern Bass Strait (Maxwell 1979).
- Annual landings are highly variable and range from 9,000 – 42,000 tonnes with the largest catches taken in the mid-late 1980s (Kailola *et al.* 1993, Lyle et al. 2000). Current TAC set at 42,000 tonnes.

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
	47 46.3 36.2	 0.23 0.267	 0.1 -1.21	16 25				3-4	27					1. (SEF) 2. (SEF) 3. (Tas)
F														
M														

1. Webb (1976)
2. Webb and Grant (1979)
3. Lyle *et al.* (2000)

Distribution and links to physical environment

- In Tasmania, spawning fish move to the shelf break during spring and summer where they are not available to the inshore fishery (Williams *et al*. 1987, Jordan *et al.* 1995).
- Movements of adult fish may also be in response to the summer peak abundances of the lantern fish *Lampanyctodes hectoris*, a major prey species, in the shelf break region (Blaber and Bulman 1987, May and Blaber 1989). Adults return inshore where they re-enter the fishery in April-May (Williams *et al*. 1987, Williams and Pullen 1993).
- Some movement of fish from NSW to Tasmanian waters was initially suggested by Maxwell (1979) based on the timing of appearance of surface schools, however this may be an artifact of a change in behaviour of resident demersal schools rising to feed on seasonally available schools of the krill, *Nyctiphanes australis* (Williams and Pullen 1993).

Key inter-species interactions

- Jack mackerel are pelagic crustacean feeders and omnivores (Bulman *et al*. 2001), feeding on krill *Nyctiphanes australis* (Williams and Pullen 1993) and pelagic fish (*Lampanyctodes hectoris*) (Young *et al.* 1993).
- Jack mackerel are an important prey sepecies for many larger fishes in the SEMR.

Reproduction

- Spawning is thought to occur throughout the species' range in southern Australia, although it is regionally variable in its timing. Spawning occurs in the GAB in summer (Stevens *et al.* 1984); between October and January off NSW (Maxwell 1979); between November and February along the east coast of Tasmania, where spawning activity decreases through the season (Jordan 1994, Jordan *et al.* 1995).
- The timing and spatial extent of spawning off eastern Tasmania appears to be consistent despite significant interannual changes in hydrography as a result of La Nina events. However reproductive output may be influenced by the availability of food in the year prior to spawning (Young *et al.* 1993, Jordan *et al.* 1995).
- Spawning is thought to occur in the vicinity of the shelf break in eastern Tasmania (Jordan *et al.* 1995).

Population structure

- Richardson (1982) suggested there were multiple stocks or sub-populations within eastern Australia. This was supported by a more limited study by Smolenski *et al.* (1994), however, further data are required to elucidate stock structure.

Fisheries habitats

- Larvae from southern Australia have been described (Trnski 1998) and have been recorded in shelf waters of eastern Tasmania from December to April and in southern NSW and Victorian waters (including Bass Strait) Tasmania and South Australia (F. J. Neira AMC, Beauty Point, pers. comm., CMR, Hobart, unpublished data). Concentrations of larvae in excess of 500 per m^3 were reported by Jordan *et al.* (1995) off eastern Tasmania in January.
- Both adults and juveniles usually inhabit continental shelf waters where they form dense schools (Kailola *et al*. 1993).

Effects of fishing

- Age/size structure of catch has changed over time. 50% of fish were 6 years or older in 1985/86 falling to less than 4% in 1994/95 with length frequencies suggesting a catch more typical of early years in 1995/96 (Lyle *et al*. 2000).
- Blue mackerel and redbait are known bycatch species.

Key uncertainties

- Stock structure in southeast Australia requires further investigation.
- Regional patterns of movement poorly documented.
- Changes in age structure of the fishery are complex and reasons for variability are unclear.
- The extent of catches of the Peruvian jack mackerel (*Trachurus murphyi*) is unknown.

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Redbait (*Emmelichthys nitidus*)

Redbait are members of the family Emmelichthyidae (Gomon *et al*. 1994). They occur throughout all southern Australian waters south of 30˚ S and they also occur in New Zealand, South Africa, Chile and oceanic islands in the same latitude (Gomon *et al*. 1994). They are largely a by-catch of the jack mackerel purse seine fishery; however, when they also form independent schools that may be targeted (Kailola *et al*. 1993, Yearsley *et al*. 1999). Redbait are used largely for fish meal, but have the potential for greater use as bait in the tuna industry (Yearsley *et al*. 1999).

Fishery research

- Annual landings may exceed 1,000 t (Yearsley *et al*. 1999).
- Peak landings in 1987/88 at 1,280 t (Kailola *et al.* 1993).

Biological parameters

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
									21					1. (SEF)
F														
M														

1. Kailola *et al.* (1993)

Distribution and links to physical environment

- Found throughout the continental shelf region, but more common in water depths between 20 and 100 m (Gomon *et al*. 1994, Yearsley *et al*. 1999).

Key inter-species interactions

- Pilchards are an important baitfish species for several predators (fish and other taxa) in the SEMR and the impacts of reducing their abundance is unknown.

Reproduction

- Spawning takes place in Tasmanian waters between October and January (Williams *et al*.1987, Kailola *et al.* 1993).

Population structure

- No studies on stock structure have been undertaken.

Fisheries habitats

No information currently available.

Effects of fishing

No information currently available.

Key uncertainties

- Very little is known regarding biology or stock structure.
- Ecosystem effects of reducing abundance is unknown.

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Other Selected Key Species Accounts

Pilchard (*Sardinops neopilchardus* /*S. sagax*)

Pilchards are members of the family Clupeidae (Gomon *et al*. 1994). The main commercial fishing areas are in South Australia and Western Australia with a smaller fishery in Victoria. They are distributed from Hervey Bay (Qld) throughout the southern region of Australia to Red Bluff (WA), including Tasmania (Fletcher 1990). The species is also widespread throughout the temperate waters of most continents (Fletcher 1990). Pilchards are also caught in NSW and Queensland, although the amount taken is negligible compared to the other States. There is no recreational fishery for pilchards in Australia, although small quantities may occasionally be collected for bait (Kailola *et al.*1993).

Fishery research

- The fishery for pilchards began in the 1800s but remained underdeveloped until the 1970s when fishing intensified (Fletcher 1990).

Pilchard production statistics for Victoria and South Australia (ABARE 2001)

	1997 / 98		**1998 / 99**		**1999 / 00**	
	tonnes	**$ ‘000**	**tonnes**	**$ ‘000**	**tonnes**	**$ ‘000**
Vic	790	926	277	679	144	244
SA	6,041	3,846	4,465	2,500	3,836	2,685

- The average size of pilchard caught varies between locations, however, in general, fish are between 14 and 16 cm and 2 to 5 years old (Kailola *et al.*1993).

Biological parameters

Sex	Growth			Long evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	T_0	A_{max}	Z	F	M	Age (y)	Size (cm)	Age (y)	Size (cm)	a	b	
				9	0.43			2	12.0-13.0					1. (WA)
F	17.4	0.584	0.95											2. (WA)
M	16.4	0.805	1.02											2. (WA)
F								2	14.8					3. (SA)
M								2	14.2					3. (SA)
F								2	15.1					3. (Vic)
M								2	12.9					3. (Vic)
	18.58	0.546	-0.233											4. (†Spencer Gulf/Coffin Bay, SA)
F	18.40	0.609	-0.043											4. (†Spencer Gulf/Coffin Bay, SA)
M	18.81	0.469	-0.537											4. (†Spencer Gulf/Coffin Bay, SA)
*	22.96	0.318	-0.637											4. (†† Lakes Ent / Port Phillip Bay)
**F	24.12	0.287	-0.736											4. (†† Lakes Ent / Port Phillip Bay)
**M	21.20	0.379	-0.483											4. (†† Lakes Ent / Port Phillip Bay)
	18.67	0.440	-1.380											4. (†Coffin Bay, SA)
	19.53	0.372	-0.973											4. (†Spencer Gulf, SA)
	24.61	0.237	-1.189											4. (††Port Phillip Bay, Vic)

1. Fletcher (1995) * includes immature fish

2. Fletcher and Blight (1996)	**	includes half of immature fish
3. Kinloch *et al.* (1998)	†	Mar 1995 – Mar 1997
4. Morison and Hall (1998)	††	Dec 1994 – Feb 1997

Distribution and links to physical environment

Reproduction

- Pilchards are synchronous multiple-batch spawners (i.e. they spawn more than once per year) (Fletcher *et al*. 1996).
- Batch fecundity estimates for the pilchard range from about 10,000 eggs in females of about 13 cm to roughly 47,000 eggs in females of about 18 cm in length (Joseph 1981, cited in Fletcher 1990).
- Fecundity (F) is related to body weight (W) and gonad weight (G) as follows (from Fletcher *et al.* 1996):

$$F = 2.629 \times 100W^{1.1081}$$
$$F = 10870 \times G^{0.91}$$

- Batch fecundity of pilchards from south eastern Australia has been estimates at 15,366, 16,422 and 13,947 eggs for the years 1995, 1996 and 1997, respectively (Kinloch *et al.* 1998).
- Fecundity was only weakly related to weight in the south eastern region by the equation (Kinloch *et al.* 1998):

$$F = 192.02 \times W^{1.139} \qquad r^2 = 0.167$$

- The timing of spawning varies throughout the range of the pilchard (Fletcher *et al*. 1997). In Western Australia spawning occurs during autumn and winter; in South Australia, between summer and autumn; in Victoria and Tasmania between spring and summer, and along the New South Wales/Queensland coast from autumn to spring (Blackburn 1950, Blackburn 1951, Fletcher 1990, Neira *et al*. 1999).
- Spawning in the Great Australian Bight is thought to extend over the summer and autumn period based on gonad condition (Stevens *et al.* 1984).
- Spawning in general appears to occur inshore on the continental shelf (Fletcher 1990).

Key inter-species interactions

- SBT feed on a range of prey including clupeoids in eastern waters, and predominatly on clupeoids in South Australia and Western Australia (Sheard 1950, Serventy 1956, Young *et al.* 1997).
- The western Australian salmon (*Arripis truttaceus*) in SA may consume about 13,500 t of pilchards annually (Jones *et al.* 1995) – more than the 1998 TAC for the SA pilchard fishery (Ward and Jones 1998).
- In Bass Strait, clupeoids are an important item in the diets of arrow squid, *Nototodarus gouldii* (O'Sullivan and Cullen 1983).
- The major component of the diet of little penguins, Eudyptula minor, consists of clupeoids (Gales and Pemberton 1990, Cullen *et al.* 1992) – in Bass Strait, little penguins consume about 25,000 t of clupeoids per annum (Gales and Green 1990). The breeding success of little penguins is related to annual variations in clupeoid abundance (Cullen *et al.* 1992, Hobday 1992).
- The proportion of clupeoids in the diet of Australian fur seals, *Arctocephalus pusillus*, in Australian waters is unknown; however, in South Africa they make up about 50% of the Australian fur seal diet (Ward and Jones 1998).
- Overseas studies have indicated that annual consumption rates by clupeoid predators commonly match fisheries catches (Ward and Jones 1998).

Population structure

- In Western Australia there is considered to be a degree of mixing of pilchards throughout the region, however, distinct sub-populations and stocks can be recognised (Cochrane 1999).
- Based on otolith microchemistry (Edmonds *et al.* 1995), catch-at-age (Fletcher 1995) and cycles of gonad activity pilchards in the Albany region are considered to be a separate stock from those 150 km to the east at Bremer Bay (Fletcher *et al.* 1996).

- Blackburn (1951) suggested there were three distinct stocks, eastern, southeast, and south-western, of pilchard based on the differences between spawning seasons and growth rates for the various areas.

Fisheries habitats

- Both adult and juvenile pilchards occur on the continental shelf to a depth of about 200 m (Fletcher 1990).
- In South Australia there is some evidence to suggest that juveniles may remain in bays, inlets and estuaries until they reach about 8 – 12 months of age before moving further offshore to join schools of adult fish (Mackie 1995).
- In South Australia preliminary evidence suggests that spawning of pilchards in exposed areas is associated with upwelling regions (Mackie 1995).

Effects of fishing

No information currently available.

Key uncertainties

- The genetic relationship between pilchards from different areas is unknown, leading to uncertainty in the number and size of stocks in Australia.
- The long term effects of the massive 1995 pilchard kill throughout the range of the pilchard are unknown.
- There have been no published data on the effects of clupeoid stock depletion on the stocks of predatory fish in Australia.

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Blue sprat (*Spratelloides robustus*)

Blue sprat are members of the family Clupeidae (Gomon *et al*. 1994). They are distributed throughout southern Australia from southern Queensland to the Dampier Archipelago (WA), including Tasmania (Yearsley *et al*. 1999).

Fishery research

- Blue sprat is a minor by-catch of other clupeiod fisheries (Miskiewicz and Neira 1998).
- Potential for a fishery based on this species as a substantial resource possibly exists (Yearsley *et al.* 1999).

Biological parameters

No information currently available.

Distribution and links to physical environment

- In South Australia there is some evidence to suggest that juveniles may remain in bays, inlets and estuaries until they reach about 8–12 months of age before moving further offshore to join schools of adult fish (Mackie 1995).

Reproduction

- Little is known of the biology of this species.
- Larvae have been found entering Wilson Inlet (WA) in December and January (Neira and Potter 1992), entering Lake Macquarie (NSW) from September to April (peaking in February – March) (Miskiewicz 1987), and in coastal waters off Sydney (NSW) from November to April (Gray 1995).

Key inter-species interactions

No information currently available.

Population structure

No information currently available.

Fisheries habitats

No information currently available.

Effects of fishing

No information currently available.

Key uncertainties

- Biology is poorly known.
- Stock structure is unknown.
- Resource size is unknown.
- Spawning and egg development is unknown.

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Octopus (*Octopus maorum* and *Octopus pallidus*)

The most commonly fished species of octopus in the South East marine region are *Octopus maorum* and *O. pallidus*, both members of the family Octopodidae (Orbigny 1840). Octopus is commercially fished on a small scale in Tasmania, Victoria and South Australia using octopus pots, barrier nets, baited hooks and gaffs. There are no commercial quotas for octopus, although recreational fishers in Tasmania are restricted to a possession limit of 5 octopuses.

O. maorum is the largest species of octopus in the Southern Hemisphere and reaches a maximum mantle length (ML) of 30cm and an average weight of 10 kg (maximum 15 kg). *O. pallidus* attains a maximum of 15 cm ML and weighs < 2 kg (Cephbase 2003).

Fishery research
- Fine scale movements of *Octopus maorum* in relation to the Tasmanian Eaglehawk Neck fishery are currently being researched by Dr Jayson Semmens, a postdoctoral fellow based at the Tasmanian Aquaculture and Fisheries Institute (TAFI).
- There has been little research of stock sizes, life history, fecundity or recruitment.

Biological parameters
- No information currently available.

Distribution and links to physical environment
- *O. maorum* is distributed in temperate waters in southern Australia and temperate to sub-Antarctic regions of New Zealand (Anderson 1999).
- *O. pallidus* is restricted to temperate waters in South East Australia.
- *O. maorum* is a benthic octopus that is found sub-tidally to depths >50 m. It is commonly associated with soft-sediment shellfish beds and seagrass (Anderson 1999).
- *O. pallidus* is also associated with shallow waters and soft-sediment shellfish beds but is also fished in deeper waters in Bass Strait.

Reproduction
- Octopuses reach sexual maturity within 12 months and die shortly after spawning.
- *O. maorum* spawns during the spring-summer, when females attach up to 7000 eggs individually to the substratum. Eggs take approximately 2 months to hatch (Anderson 1999).
- *O. pallidus* reaches maturity in 7 months in captivity, possibly 8-12 months in the field, and is also dies shortly after spawning.

Key inter-species interactions

- Interactions occur with the Southern Rock Lobster in some areas, and octopuses are a by-catch of the lobster fishery and contribute to mortality of rock lobsters in pots.

Population structure
- Females represent approximately 60% of the population in study areas.

Fisheries habitats
- Shallow inlets and bays with soft sediment shellfish beds or seagrass.

Effects of fishing
- *O. maorum*: all animals captured by the Tasmanian fishery are reproductively mature, thus there is some potential for recruitment over-fishing. However, research to date suggests that this is not happening given the current size of the fishery (J. Semmens unpublished data).

Key uncertainties
- Movement related to spawning aggregations,
- life history, and
- age structure of populations (there are currently no techniques available to age octopus).

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Squid (*Nototodarus gouldi* and *Sepioteuthis australis*)

Two species of squid are fished commercially in South East Australia: Gould's arrow squid *Nototodarus gouldi* (family Ommastrephidae Steenstrup 1857); and Southern calamary *Sepioteuthis australis* (family Loliginidae Lesueur 1821). The main species fished is the arrow squid (AFMA 2003). Females arrow squid reach a mantle length of 40 cm and weigh up to 1.6 kg, while males attain a maximum mantle length of 35 cm (AFMA 2003). For the Southern calamary, females have a maximum mantle length of 40 cm and weight of 2 kg, while males attain a maximum mantle length of 53 cm and weight of 3.6 kg (PECL 2000).

Fishing for squid in South eastern Australian waters was developed sporadically by both foreign and local vessels up until 1987 (Larcombe *et.al* 2002). From 1988, the fishery matured to a soley domestic concern. The fishery, which is managed by AFMA beyond 3NM (either through the Southern Squid Jig Fishery or the South Eastern Trawl Fishery) is most activley concentrated off the Victorian coastline between Queenscliff and Portland, although fishers also operate along the coast from Ulladulla (NSW) to Whyalla (SA) including Tasmania (mainly in the Storm Bay region). AFMA manages the fishery through limited entry. Between 1995 and 1999 there was an average of 35 active operators within the Commonwealth fishery. In 2000 the annual catch from the Commonwealth fishery was around 1600 tonnes (Larcombe *et.al.* 2002)

Southern calamary form the basis of small commercial fisheries in South Australia, Victoria (principally Port Phillip Bay) and discrete areas along the East Coast of Tasmania. Fishers predominantly use jigs but also trawls, seine nets, dip nets and spears or jigs. The fishery is managed under both limited entry and input control. For instance, the fishery off the East Coast of Tasmania is closed twice a year during spawning seasons to protect egg production (Moltschaniwskyj *et.al.* 2002) Recreational landings may exceed commercial landings, particularly in Port Phillip Bay.

Fishery research
- There has been little research of Australian squid populations since the commencement of commercial exploitation. However, researchers at the University of Tasmania have recently begun to study the life histories, population structures and movement of both the arrow squid and the southern calamary.

Biological parameters (*Sepioteuthis australis*)

Sex	Growth			Long-evity	Mortality			Reproduction		Recruitment		Length-weight		Author (area)
	L_{inf}	K	t_0	A_{max}	Z	F	M	Age (m)	Size (cm)	Age (m)	Size (cm)	a	b	
F												0.00042	2.56	
M												0.00049	2.50	

Distribution and links to physical environment

- *N. gouldi* forms aggregations over the continental shelf between Geraldton, Western Australia and southern Queensland (in addition to northern waters in New Zealand), and is found at depths from 50 to 200 m. It is distributed in waters with sea surface temperatures ranging from 11°C to 22°C, with best catches obtained in 17°C. Sea surface temperatures greater than 18°C are generally unproductive for the fishery. (AFMA 2003)
- *S. australis* is distributed in coastal waters, inlets and bays between Brisbane (QLD) and Dampier (WA) including Tasmania, and is commonly fished in waters less than 10 m deep. It is associated with seagrass beds and patchy reefs, particularly during the spawning seasons (Moltschaniwskyj *et.al*. 2002).

Reproduction

- *N. gouldi* spawns throughout the year, with 2-3 peaks in spawning activity.
- *N. gouldi* reaches sexual maturity within 12 months and dies shortly after spawning (McGrath & Jackson 2002).
- *S. australis* also spawns throughout the year with peaks in both winter and spring/early summer. Spawning has only been observed in waters less than 15 m deep, and egg masses are attached to seagrass, algae or rocky substrates (PIRSA 2003).
- *S. australis* reaches sexual maturity as early as 4-5 months and may live up to 12 months (Pecl 2000)

Key inter-species interactions

- Squid are essential dietary components for many pelagic predators, including numerous species of fish, seabirds and marine mammals (Nowra & Walker 1998).
- There are almost no species interactions associated with jig fisheries, which target squid very specifically. Occasionally, other species of squid such as *Ommastrephes bartramii* and *Todarodes* spp. may be collected as by-catch from the *N. gouldi* jig fishery.
- *N. gouldi* is a by-product of the South Eastern Trawl Fishery (AFMA 2003)

Population structure

- No information currently available.

Fisheries habitats

- *S. australis*: shallow inlets and bays with extensive seagrass beds (Moltschaniwskyj *et.al*. 2002).

Effects of fishing

- *S. australis*: fishing is likely to target spawning aggregations of sexually mature squid, and may affect spawning dynamics and thus recruitment success of populations.
- Vessels and fishing gear may also damage seagrass habitats (Pecl 2003).

Key uncertainties

- Migration/movement of populations.
- Resource status.
- Stock structure
- Reproductive dynamics.
- Habitat requirements.
- Impacts of environmental variability on recruitment success.

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Giant crab (*Pseudocarcinus gigas*)

The giant crab (*Pseudocarcinus gigas*, family Xanthidae) was originally caught as by-catch of rock lobster, shark and trawl fisheries. Since the early 1990's the fishery has developed as a small yet lucrative commercial fishery in southern Australia. Approximately half of the catch is exported live to the Asian market, with the remainder supplying restaurants in Sydney and Melbourne. Management of the giant crab fishery is allocated to the states, and TACs and closed seasons vary according to state jurisdiction — however, the majority of the catch landed is under Tasmanian jurisdiction. The fishery, in Tasmania, experienced rapid expansion from 1990/91 until 1994/95 (from 1 tonne in 1990/91 to 290 tonnes in 1994/95). The TAC in Tasmania is presently 100 tonnes (Levitt 2002).There is very little recreational fishing for this species.

Male giant crabs grow to more than double the size of females, and can reach a maximum carapace length of 260 mm and weigh 13 kg.

Fishery research

- There has been limited research of the larval and reproductive biology of giant crabs collected from Tasmanian waters, based on field and laboratory studies (Gardner & Quintana 1998; Gardner & Williams 2002).
- FRDC has contributed to research into biology of the giant crab (FRDC 2003).

Biological parameters

- No information currently available.

Distribution and links to physical environment

- Giant crabs are distributed on the continental shelf from Perth, Western Australia to Victoria (including Tasmania) within a temperature range of 11°C – 17°C.

- They are found at depths from 18 m to 400 m, but are predominantly fished between 140 m and 270 m.

Reproduction

- Males become sexually mature at a carapace length of approximately 90 mm – a size considerably less than the minimum catch size (carapace length 150 mm or 140 mm in WA).
- In the laboratory, females can produce successive annual broods without moulting and can store viable sperm for up to four years (Gardner & Williams 2002, McGarvey *et.al.* 2002).

Key inter-species interactions

- Several tonnes of giant crabs are taken as by-catch of the benthic trawl industry.
- The extent of this bycatch is unknown as is the effect of trawling operation on sub-legal animals and giant crab habitat.
- A small bycatch of a few hundred kg is taken each year by the rock lobster fishery.

Population structure

- No information currently available.

Fisheries habitats

- Discrete areas on the edge of the continental shelf in southern Australia.
- Females are generally captured in bryozoan rich substrates at a minimum depth of approximately 120 m.
- Males are captured from a broader depth range.

Effects of fishing

- Larger males may fertilize many more broods than smaller males, as observed for other exploited crab species, and thus removal of large males (in accordance with the minimum catch size of 150 mm carapace length) may affect the reproductive success of giant crabs (Gardner & Williams 2002).

Key uncertainties

- Most of the fishery is based off Tasmania. Although growth has been described in other areas, there is little information from this state.
- There is also a lack of historical data on size structure, which contributes to uncertainty in the trends in biomass of populations.
- Trawling effort over giant crab habitat has undergone large increases since 2000 off western Tasmania and Victoria. The effect of this on giant crab habitat and stocks is unclear.

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Appendix 1

South East Fishery (including South East Trawl and South East Non-Trawl)

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Hyperoglyphe antarctica	Blue eye trevalla	138, 157, 773	138, 772, 773	138, 771, 772, 773, 774, 776, 777, 779, 780, 782, 783, 785	138, 157, 773, 775, 781	138, 157, 771, 772, 773	138, 781, 784	75, 138, 173	138, 157, 773, 778, 781	138, 772	138
Seriolella brama	Blue warehou	138, 157, 791	138, 792, 795	138, 789, 792, 793, 794	138, 157, 792	138, 157, 787, 792	138, 788	138, 173, 787, 792	40, 138, 157, 786, 787	138, 790, 792, 796	138
Seriolella punctata	Spotted warehou	138, 157, 640	138, 640, 797	138, 179, 640, 793	138, 157, 640	138, 157, 640, 787, 797	138, 788	138, 173, 787	40, 138, 157, 640, 786, 787	138, 640, 797	138, 640
Macruronus novaezelandiae	Blue grenadier	139, 145, 157, 640	139, 142, 148, 640	141, 142, 640, 800, 802	104, 141, 157, 854, 860	139, 142, 147, 148, 157, 640, 803	104, 148, 801, 804	105, 162	148, 157, 640, 798, 799, 808	640	640
Hoplostethus atlanticus	Orange roughy	132, 138, 157, 795, 813, 814, 815, 820	138, 795, 809, 823, 825, 829, 835, 838	138, 819, 831, 835	109, 132, 138, 157, 835	138, 157, 810, 816, 822, 825, 826, 827, 829, 830, 833, 835, 838	138, 812	108, 109, 110, 138, 173, 240, 250, 811, 817, 818, 832, 834, 835, 836, 837	138, 157, 822, 827	138, 836, 827, 828, 829	138, 819, 821, 824
Genypterus blacodes & G. tigerinus	Ling	138, 157, 640, 788, 793	130, 138, 140, 640	100, 123, 138, 640, 793, 842, 843	50, 120, 138, 157, 640, 781, 839	80, 120, 123, 138, 157, 640, 841, 843	27, 138, 781, 788, 839	50, 138, 173, 845	100, 138, 157, 640, 781, 788, 840, 841	100, 138, 640, 844	138, 640
Centroberyx affinis	Redfish	35, 138, 157, 170, 640, 788, 793	35, 138, 170, 259, 640, 797, 846, 848, 1064	35, 138, 149, 154, 640, 793, 797, 847, 1064, 1065	35, 138, 157, 640, 781, 848	35, 138, 150, 157, 640, 797, 1083	27, 138, 781, 788	138, 173, 847	35, 138, 150, 157, 640, 781, 788	35, 138, 640, 797	35, 138, 640

Sillago flindersi	School whiting	138, 157, 788, 795	138, 176, 184, 795, 797, 856	100, 138, 176, 177, 184, 797, 856	138, 157, 176, 177, 184	138, 157, 175, 177, 184, 797, 856	27, 138, 788	138, 183	100, 138, 157, 176, 177, 184, 185, 356, 788, 856	100, 138, 797, 862	138, 184
Zenopsis nebulosus	Mirror dory	25, 138, 157, 640, 788	138, 160, 640, 797, 849	138, 161, 640, 797, 849, 850	25, 138, 157, 160, 640	138, 157, 160, 640, 797	27, 138, 788	138, 173	25, 138, 157, 640, 788	138, 640, 797, 849	138, 159, 640
Zeus faber	John dory	138, 157, 788	138	138, 850	138, 157	138, 157	138, 788	138, 173	99, 138, 157, 788	138	138
Platycephalus sp., Neoplatycephalus sp.	Flathead	30, 138, 157, 788, 858, 863, 1066	138, 853, 856, 858, 859, 860, 861	100, 138, 856, 857, 859	30, 138, 157, 854, 860	72, 138, 157, 851, 852, 853, 854, 855, 856	27, 138, 788	138, 173, 860	72, 100, 138, 157, 788, 856, 863	100, 138, 858, 862	138
Nemadactylus macropterus	Jackass morwong	101, 102, 138, 157, 194, 788	138, 194, 797, 856	100, 138, 186, 797, 856	138, 157, 187	138, 157, 178, 186, 187, 797, 856, 865	27, 138, 788	101, 102, 103, 138, 173, 191, 865	100, 138, 157, 187, 192, 195, 196, 197, 788, 856, 864, 865	100, 138, 797	138
Rexea solandri	Eastern & western gemfish	138, 157, 788, 795, 1067	115, 120, 121, 138, 165, 795, 797, 869, 871, 872, 1067	123, 138, 165, 797, 868	120, 138, 157, 165, 866, 870	120, 123, 138, 157, 797, 841	138, 788	117, 138, 163, 173	138, 157, 788, 841, 866, 867	138, 797	138
Helicolenus percoides & H. barathri	Ocean perch	138, 157, 788, 873	138, 849, 873	100, 138, 346, 849	138, 157	138, 157, 347, 841, 875, 876	138, 788	138, 173	100, 138, 157, 347, 788, 841, 874	100, 138, 849, 873	138
Pseudocaranx dentex	Silver trevally	138, 157, 640, 788, 879, 881, 1069	138, 640, 879	138, 640, 879	138, 157, 640, 1068	66, 138, 157, 640, 877, 878	138, 788	138, 173	33, 40, 66, 138, 157, 640, 788, 881	138, 640	138, 640
Haliporoides sibogae	Royal red prawn	138, 863, 1070, 1075	138, 1070, 1072, 1073	138, 1071, 1072	138, 1072	138, 1071, 1075	138	138	138, 863, 1072, 1073	138, 1074	138

Polyprion oxygeneios	Hapuka	157, 640, 773, 863, 883, 884	640, 773	640, 773, 883	157, 640, 773, 916	157, 640, 773, 884		882	157, 640, 773, 863, 883, 885	640	640
Centrophorus sp. & Deania sp.	Dogfish	320, 640, 650, 890	320, 640, 887, 889, 890, 892	640, 650	640, 650, 887	640, 650, 886, 887, 888, 891, 893, 894, 895		650	640, 650	640, 889, 890	640
Rajidae	Skates	650, 710, 890, 1002, 1003, 1006	730, 889, 890, 1007	650, 1001, 1005, 1008, 1010, 1011	650	650, 740	1004, 1007	650	650, 1002, 1004	710, 720, 730, 750, 889, 890, 1009	

Southern Shark Fishery

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Galeorhinus galeus	School shark	270, 320, 370, 640, 650, 896, 904, 905, 913	320, 480, 530, 640, 906, 907, 909, 913	260, 600, 610, 640, 650, 903, 908	270, 640, 650, 896, 902, 913	640, 650, 913	270, 912	270, 550, 650, 924	270, 640, 650, 1084	260, 350, 640, 908	640
Mustelus antarcticus	Gummy shark	300, 450, 640, 650, 898, 904, 905, 911	640, 910, 919, 920, 921, 922, 925	260, 450, 640, 650, 903, 910, 923	310, 500, 520, 640, 650	450, 640, 650, 917, 920, 921, 922	27, 912	300, 310, 510, 650, 910, 917, 924	520, 640, 650, 910, 921, 922	260, 350, 450, 640, 918, 919, 920	640
Pristiophorus spp.	Sawshark	157, 640, 650, 863	640	640, 650	157, 640, 650	157, 640, 650, 926		650	157, 640, 650, 863	640	640
Calliorhinus milii	Elephant fish	157, 640, 650, 863	640	280, 640, 650, 928, 929	157, 640, 650	157, 180, 640, 650		650	157, 640, 650, 863	640	640

Southern Rock Lobster Fishery

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Jasus edwardsii	Southern rock lobster	640, 933	181, 640, 930, 935, 936, 937, 938, 940, 941, 943, 944, 947, 949, 953, 1076	640	252, 640, 934, 954	252, 640, 931, 932, 933, 939, 941, 942, 943, 945, 946, 948, 949, 952, 954		950, 951	640	640, 930, 1076	640

South Tasman Rise High Seas Fishery

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Various	Oreo dories	30, 640, 956	640	640, 957	30, 640	200, 210, 220, 230, 640	955		640, 958	640	640

Southern Bluefin Tuna & East Coast Tuna Fisheries

Species	Common Name	General	Fishery Research	Life History	Distribution in SEMR	Key Uncertainties
Thunnus maccoyii	Southern bluefin tuna	157, 168, 235, 238, 1062	167, 168, 232, 234, 236, 238, 1062, 1063	237, 257, 258	157, 168, 1063	
Thunnus alalunga	Albacore	267, 278, 640, 1012, 1013	264, 265, 266, 267, 268, 276, 640	267, 275, 278, 640	267, 268, 272, 277, 278, 279, 640, 1014	640
Thunnus albacares	Yellowfin tuna	157, 288, 640, 1015	26, 245, 281, 285, 291, 292, 640, 1015, 1016, 1017, 1018, 1019	245, 254, 286, 640	26, 157, 287, 640, 1015	640
Katsuwonus pelamis	Skipjack tuna	157, 278, 293, 298, 640, 1015	290, 295, 299, 316, 640, 1015	256, 278, 290, 293, 300, 301, 640	157, 278, 640, 1015	640
Xiphias gladus	Swordfish	157, 320, 323, 640, 1022	304, 307, 309, 312, 320, 321, 326, 640	315, 322, 640, 1023, 1024, 1025	157, 309, 310, 320, 640	640

Prionace glauca	Blue shark	650, 960	700, 961	670, 690, 959, 960, 961	961	
Brama brama	Rays bream	157, 863	863, 962	841, 1020	157, 962	

Abalone

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Haliotis laevigata	Greenlip abalone	45, 53, 55, 1081	45, 1081	45, 48, 57, 63, 64, 86, 1080	45, 55, 58	58, 60, 63, 64, 83, 86	49, 59, 62, 84	47, 58, 76	54, 62, 84	55, 56, 62, 64	
Haliotis rubra	Blacklip abalone	53, 55, 1081	50, 51, 52, 70, 71, 77, 78, 80, 81, 85, 1081	48, 63, 69, 80, 81, 82, 1082	52, 55, 58, 82, 85	58, 63, 72, 73, 75, 79, 82	49, 59, 62, 84	47, 58, 65, 66, 76	62, 68, 84, 85	55, 62, 70, 71, 74, 78, 79, 82	67, 81

Striped Trumpeter Fishery

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Latris lineata	Striped trumpeter	157, 640, 788, 967	640, 967	640, 965, 966, 967	157, 640, 967	157, 332, 640, 965, 966, 968	788		157, 332, 640, 788, 964	640	640

Beach Haul & Recreational Fishing for Australian Salmon

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Arripis trutta and *A. truttaceus*	Eastern & western Australian salmon	41, 43, 157, 640	43, 640, 969	40, 44, 640	42, 44, 157, 640	40, 42, 44, 157, 640		37	157, 640	640	640

Snapper Fishery

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Pagrus auratus	Snapper	157, 373, 640, 863, 990	383, 640, 969, 970, 971, 978, 990, 1077	383, 640, 978	157, 379, 640, 980, 1078	66, 157, 374, 375, 379, 381, 640, 841, 978, 986, 990	27, 977, 994	972, 976, 980, 991, 993	66, 157, 640, 841, 863, 979, 987, 992	640	640

Scallop Fishery

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Pecten fumatus, Chlamys sp.	Scallop	16, 31, 40	10, 12, 13, 16, 17, 21, 22, 30, 38, 39, 40	16, 22, 25	40, 41	15, 18, 19, 20, 23, 24, 26, 27, 28, 29, 34, 35, 36, 37, 40, 41, 42, 43		40	23, 33, 40	14, 32, 40, 44	

Patagonian Toothfish Trawl Fishery (Macquarie Island)

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Dissostichus eleginoides	Toothfish	211, 214, 217, 218	198, 208, 227, 228, 231	217, 219, 226, 228	227	216, 225, 228	997, 998	199, 226, 228, 229, 230	207, 222, 995, 1000	208, 213, 220, 228, 996, 999, 1000	208

Jack Mackerel Fishery

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Trachurus declivis	Jack mackerel	96, 157, 640, 788, 881, 984	89, 640, 1085	94, 95, 640	85, 89, 96, 130, 157, 640, 839, 988	62, 85, 87, 89, 157, 640, 989	788, 839, 988, 989	90, 91	85, 157, 640, 788, 881	640, 1085	640
Emmelichthys nitidus	Redbait	96, 157, 640, 863	640, 863	640	96, 157, 640, 863	96, 157, 640			157, 640, 863		

Other Selected Key Species

Species	Common Name	General	Fishery Research	Biological Parameters	Distribution & Movement	Reproduction	Trophic Links	Population Structure	Habitat	Effects of Fishing	Key Uncertainties
Sardinops neopilchardus/S. sagax	Pilchard	50, 157, 640	50, 640, 969	52, 640, 1027, 1032, 1033	157, 640	47, 48, 50, 53, 54, 61, 62, 65, 157, 640, 1027, 1032	1026, 1028, 1029, 1030, 1031, 1034, 1035, 1036, 1037, 1038	48, 49, 52, 54, 67	50, 65, 157, 640	640, 1037	640
Spratelloides robustus	Blue sprat	157, 863	69, 863		65	66, 841, 985					