

A conservation perspective on demersal fishing in Australia

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Executive Summary

Demersal fishing targets marine organisms which live on or close to the seafloor, including scallops, prawns, scalefish and sharks. The methods used include dredging, trawling, gillnetting and longlining. They are among the most destructive used in Australia due to their direct physical damage to the seafloor, and/or their indiscriminate capture of hundreds of species, including threatened and protected species and endemic species.

There are more than thirty Commonwealth, State and Territory managed demersal fisheries, spread across the Australian Exclusive Economic Zone. In many cases they overlap. This report focuses on the South-west, North-west and North Marine Regions (see Figure 1).

Direct physical impacts

The extent of the direct physical impacts by demersal fishing gear on benthic habitats has been increasingly documented over the past fifteen years in Australia and around the world. Trawling and particularly dredging can significantly modify benthic environments, with attached invertebrates (e.g. sponges and corals) being ploughed from the bottom or crushed, often with unknown recovery times. The total area trawled in a fishery can be hard to ascertain, but trawling in the Northern Prawn Fishery, for example, has occurred over at least 130,000 square kilometres. Fished habitat can be quite variable, and more than twenty distinct high-risk habitats have been identified in the GAB Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF). It is estimated that millions of sponges per year are removed by the Pilbara Fish Trawl Fishery which coincides almost precisely with a hotspot for sponge diversity in north-western Australia. There is now emerging evidence that other demersal fishing gear (gillnets and longlines), that often overlap trawl fisheries, may also be having a destructive influence on delicate benthic habitats.

Status of stocks

Many of the target or byproduct scalefish and sharks are long-lived, late maturing and have few offspring, making them particularly susceptible to over-fishing. Nevertheless, as for most Australian fisheries, they are typically fished down to 20-40% of their unfished biomass, well below a threshold of 75% recommended on the basis of fundamental conservation principles. A number of over-fished species have been listed or are undergoing assessment (e.g. whaler and gulper sharks) as threatened species under the EPBC Act 1999.

Demersal fisheries are indiscriminate in nature. Management is complicated by the multi-species nature of the catch, as less well understood species can become a significant part of the catch before their stocks have been adequately assessed (e.g. ocean jackets in the GAB Trawl fishery and red endeavour prawns in the Northern Prawn Fishery). Even for some of the main target species, stock assessments can be based on little or poor information.

Bycatch

Trawling is one of the least selective fishing methods, producing only 2% of the world's wild harvest but up to one third of its bycatch. The Northern Prawn Fishery has historically had a bycatch to catch ratio of about 9:1. Bycatch reduction devices (BRDs) have potentially halved the amount of bycatch, but uncertainty remains over the survival of species, whether escaping through BRDs or being discarded after

landing. Hundreds of scalefish and shark species are caught in trawl fisheries, including species with the vulnerable life history characteristics described above.

Gillnetting is a less indiscriminate method but can nevertheless have a significant impact, particularly when the cumulative impact of multiple fisheries is taken into account. The South-west marine region contains 150 shark and ray species, including many endemic species. It contains more than half a dozen fisheries. Just the WA South Coast Shark Fishery and GAB Trawl fishery catch at least 34 and 50 shark and ray species, respectively, of which about one third are discarded. Ecological risk assessments identified 14 species at high risk in more than one fishery, including the dusky shark (nominated as Vulnerable under the EPBC Act 1999), greeneye dogfish (endemic), and white shark (Vulnerable under the EPBC Act 1999). Flaws have been identified in the additional ecological risk assessments that resulted in a downgrade of some of these risks. In the WA South Coast Shark Fishery, recommendations for bycatch monitoring have not been implemented despite evidence that fishers do not accurately report shark bycatch species.

Threatened and protected species

There are a number of significant outstanding threatened and protected species issues in Australian demersal fisheries. The Australian sea lion is endemic to the south and west coasts of Australia, and is listed as Vulnerable under the EPBC Act and Endangered on the IUCN Red List. Tens of thousands of kilometres of net are set each year in south-western shark fisheries, but very few sea lion interactions have historically been reported. However, a recent observer-based study of the SESSF gillnet sector in South Australia estimated that 374 sea lions were killed per 18 month breeding cycle, threatening to drive a number of subpopulations to extinction.

In the two years from 2008-09, one dolphin was killed for every 87 tonnes of fish caught in the Pilbara Fish Trawl. Despite evidence of under-reporting, observer coverage levels have declined and have never achieved the recommended level. Mortalities have been halved by the use of exclusion grids, but further work is needed.

Based on projections from two northern case study fisheries, thousands of sea snakes and hundreds if not thousands of pipefish (Listed Marine Species under the EPBC Act) are also killed each year within Australian trawl fisheries.

Food chain impacts

Demersal fishing also impacts food chains through the removal of a high diversity and abundance of carnivores, and scavenging of discarded bycatch by dolphins, seabirds and demersal species. There is a general lack of data to adequately assess food chain effects and support assumptions made by fishery management agencies about a low risk. It is not unusual for reassessment of a fishery under the EPBC Act 1999 to occur without significant progress against recommendations on food chain studies from previous assessments.

Conclusion

Irrespective of the level of environmental damage considered acceptable by Governments based on the multiple environmental and economic criteria of 'ecologically sustainable development', it is clear that the methods described above are not compatible with areas dedicated to marine conservation. Demersal trawling, longlining and gillnetting have all been assessed as incompatible with the conservation values in all areas being assessed as potential multiple-use marine reserves in the South-west region, let alone highly protected zones within them.

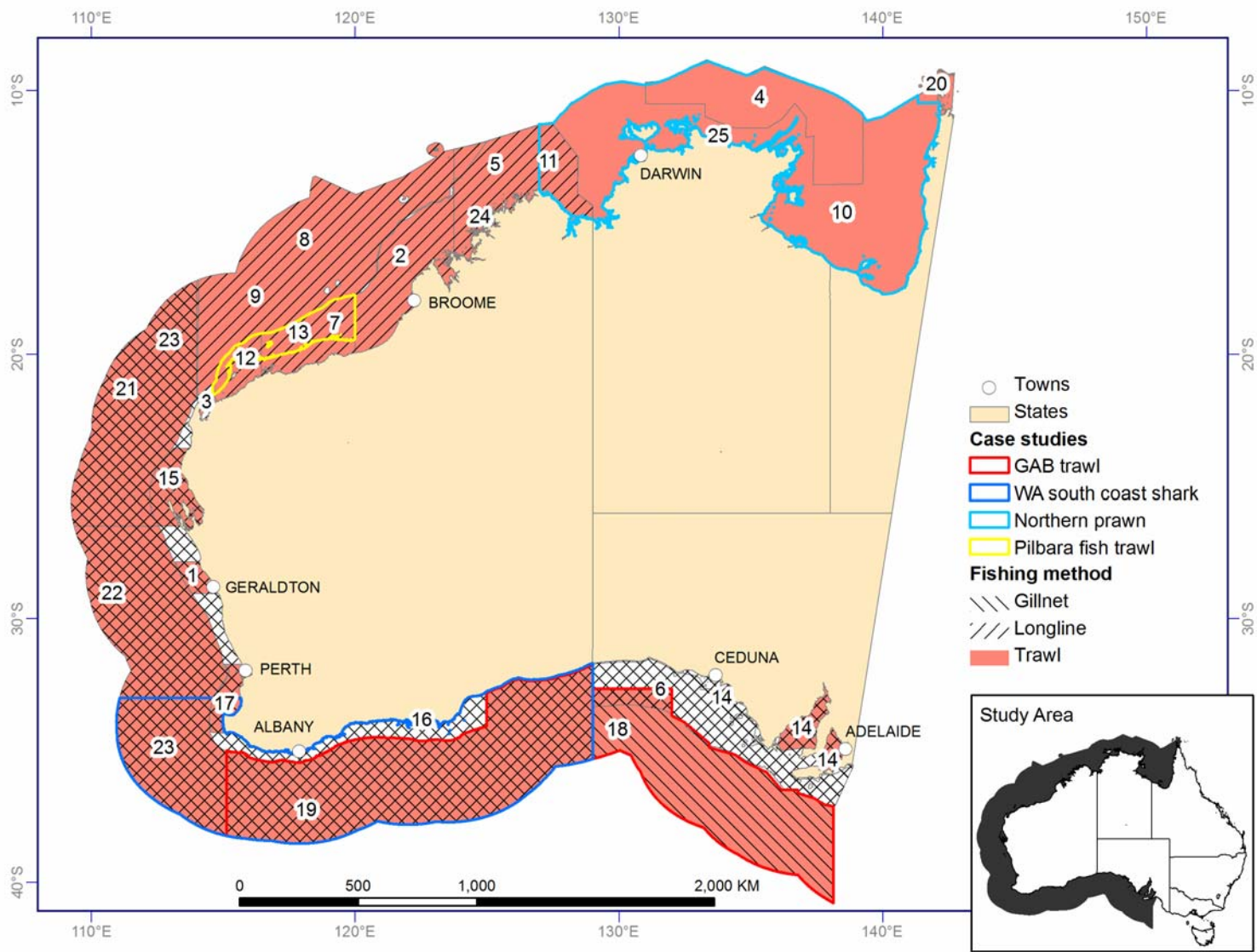


Figure 1. Demersal fisheries in the South-west, North-west and North marine regions of the Australian Fishing Zone

Note: the map shows the entire area by which each fishery is defined and does not generally exclude fishing closures or unfished areas. Examples showing the spatial extent of fishing effort within these boundaries are provided by Figure 4 and Figure 5. The numbers providing a cross-reference to the fisheries listed in Appendix 1, are located within or near the boundaries of each fishery but only provide an approximate location.

Introduction

This report examines demersal fishing in Australia from a conservation perspective, providing a general overview and four case studies.

What is demersal fishing?

Demersal fishing refers to the fishing of marine organisms which live on or close to the seafloor. It typically targets scallops, prawns and other crustaceans, scalefish and sharks. This report explores some of the demersal fishing methods used in Australia that are most prone to impacting marine ecosystems, namely: dredging, trawling, gillnetting and longlining (see Table 1 for summary). Various other gear types that have some interaction with the physical benthic environment and demersal species - including droplines, pots, and traps - are not discussed in this report. Furthermore, for gillnets, the focus is on wide-mesh (15 cm mesh) gillnets spanning several kilometres in offshore fisheries using (e.g. see the WA South Coast Demersal Shark Fishery case study), rather than the smaller haul nets (tens to hundreds of metres) used in inshore fisheries (e.g. OceanWatch Australia 2010a, 2010b).

How does demersal fishing affect the environment?

Demersal fishing impacts the environment, including threatened, endangered and protected (TEP¹) species in a number of ways, including:

- direct physical damage to the benthic environment
- overfishing of target or byproduct stocks
- bycatch
- food chain effects

Direct physical impacts

The physical impacts of demersal fishing methods on benthic habitats have been well documented (e.g. Dayton et al. 1995, Jennings and Kaiser 1998; Turner et al. 1999, Thrush and Dayton 2002, Kaiser et al. 2006, Nellemann et al. 2008 and Australian examples: Svane et al. 2009; Tanner 2003). Trawling and particularly dredging can significantly modify benthic environments with marine flora and sessile invertebrates (e.g. sponges and corals) being ploughed from the bottom or crushed. These communities may be long-lived and slow growing and therefore take a long time to recover. There are examples of sponge communities with individuals of 100 years old (Hogg et al. 2010). Resuspension of sediments can also affect marine flora indirectly through increased turbidity, and sessile invertebrates by smothering (Hogg et al. 2010). The direct or indirect loss of filter feeding organisms such as sponges can result in further effects on water quality (Wulff 2006; Bell 2008).

Demersal longlining and gillnetting have generally been considered to have a relatively low impact on marine habitats compared with other demersal fishing techniques (e.g. GoodFishBadFish 2011). However, this is only now being scientifically tested (Constable et al. 2007, cited by DEWHA 2010), with preliminary results showing that previous studies may have underestimated the impact (Welsford

¹ It is recognised that this term includes a tautology ('threatened' typically includes 'endangered') but has been adopted here due to its common use by fisheries management agencies in Australia

and Kilpatrick 2008, cited by DEWHA 2010). Furthermore, several habitat types with erect, often delicate benthic (seafloor) fauna have been identified as potentially at high risk of damage from demersal longline gear in the Southern and Eastern Scalefish and Shark Fishery (SESSF) (Daley et. al. 2007a). Similarly, deepwater hard and soft bottom habitats with slow-growing seafloor invertebrates have been identified as potentially at high risk from gillnet fishing in the SESSF (Walker et. al. 2007).

The cumulative effects of fisheries operating in the same area also need to be considered (DEWHA 2010).

Overfishing of stocks

Demersal fishing methods have resulted in a number of stocks (orange roughy, eastern gemfish and school shark) being overfished to the point that they are now listed as Conservation Dependent under the EPBC Act 1999. This category is typically applied to fished species that require specific management action to stop decline and to support their recovery to maximise their chances of long-term survival in nature.

Other species with similar life history characteristics (long-lived, late maturing and with few offspring) are also depleted to levels that may affect recruitment, e.g. dusky and sandbar sharks in the WA South Coast Shark Fishery (McAuley and Leary 2010), and three species of gulper sharks in south-eastern Australian fisheries (Wilson et al. 2010).

It is also important to understand that stocks reported as having an acceptable status by management agencies can nevertheless be fished down to quite low levels. For example, many Commonwealth managed stocks are not reported as 'overfished' until they are below 20% of their unfished biomass (DAFF 2007; Wilson et al. 2010). The implications of this level of fishing go beyond the target species (see also *Food chain effects* below). Ward (2009) recommended that populations should be maintained around or above 75% of the unfished biomass, based on fundamental species and ecosystem conservation principles. The conservation benefits would include greater stability and resilience of the stocks, reduction or elimination of some of the more pervasive impacts of fishing (e.g. local depletions, reductions in the geographic distribution of a species, changes to size at first maturity and disruption of food chains) (Ward 2009).

Automatic longlining, which uses a machine to bait and set the hooks, can apply a high level of effort by relatively few fishers, potentially causing local depletion of fish, shark and ray populations.

Management of demersal stocks is complicated by the multi-species nature of the catch, as less well understood species can become a significant part of the catch before their stocks have been adequately assessed (e.g. ocean jackets in the GAB Trawl fishery and red endeavour prawns in the Northern Prawn Fishery).

Furthermore, cumulative impacts may occur if species targeted by one method of fishing are also caught as byproduct by other fishing methods (e.g. in the SESSF).

Bycatch (including TEP species)

The indiscriminate nature of the demersal fishing methods described in this report results in significant amount of bycatch, including TEP species and other species with vulnerable life-histories (long-lived, late-maturing and with few offspring), including:

- marine mammals (e.g. dolphins in the Pilbarra Trawl Fishery and Australian sealions in the shark gillnet fisheries, with evidence of under-reporting in both cases)
- sharks. The South-west marine region contains 150 shark and ray species, many of which are endemic. Four of these are acknowledged as overfished, including the school shark (Conservation Dependant under the EPBC Act 1999) and three species of gulper shark (two of which are being assessed under the EPBC Act 1999), and 14 species considered to be at high risk in more than one fishery, including the dusky shark (nominated as Vulnerable under the EPBC Act 1999), greeneye dogfish (endemic), and white shark (Vulnerable under the EPBC Act 1999) (DEWHA 2010).
- deep-sea fish species (e.g. orange roughy and Patagonian toothfish).

Trawling can be considered as one of the least selective fishing methods (Alverson 1994; Haywood et al. 2005). Nevill (2008) noted that prawn trawling, in particular, produces only 2% of the world's wild harvest but estimates of its global share of bycatch range from one fifth (Zhou 2008) to one third (Aish et al. 2003). It has the highest ratio of bycatch to catch of any fishing method (Haywood et al. 2005). Many species are unlikely to survive the barotrauma associated with being brought to the surface from depth (e.g. see St John and Syers 2005). Broadhurst (2008) found considerable variability among the immediate and short-term fate of the various bycatch species after being trawled or gillnetted in estuarine fisheries.

Although there have been significant improvements in bycatch reduction devices (BRDs) for some fisheries, the survival of bycatch species that escape through BRDs is still largely uncertain in Australian trawl fisheries (DEH 2003a). This is concerning given that the ratio (by weight) of bycatch to catch in the Northern Prawn Fishery (for example) was up to 9:1 prior to the introduction of BRDs (DEH 2003a). There is a general lack of clarity in bycatch reporting, with a focus on any reduction in bycatch ending up on the deck but few explicit assessments of the overall mortality arising from interactions of fishing gear with non-target species.

Risks to bycatch species within Commonwealth fisheries are assessed (along with other ecological risks) using a multi-stage risk assessment process that progressively screens out lower risk species during increasingly quantitative stages (Hobday et al. 2007). The case studies in this report have placed greater emphasis on the results of the more precautionary semi-quantitative stages, due to a number of concerns about the subsequent, fully quantitative stage. These include underestimation of sustainable rates of sharks and rays, consideration of other bycatch species, lower resilience to future changes in fishing effort, and applicability in some habitats (DEWHA 2010).

Food chain effects

Demersal fishing impacts food chains through the removal of target and by-product species, capture of bycatch species, and the reintroduction of bycatch species through discarding. For example, prawns are significant prey of some sharks and fish (DEH 2003a), but there has been no assessment of the impact of the fishery on such species. Sharks and deep-sea species are commonly long-lived and slow growing, making them particularly susceptible to mortality through bycatch. In the case of top-order predator sharks, this can have subsequent impacts at the ecosystem level. Floating discarded bycatch (e.g. from trawler) may impact dolphins, sharks and seabirds, while sinking discards are later scavenged by other species on the seafloor. Provisioning of

animals, including seabirds, has also been identified as an issue of concern, including suggestions that increasing populations of some species beyond their natural capacity may have implications for the ecosystem as a whole (DEH 2003a).

In general, there is a lack of data to adequately assess food chain effects. Fishery agencies typically present the view that fished species are generalist carnivores and therefore the impact of their removal will be spread over many species; or that there are unfished species that play a similar role in the ecosystem. However, these arguments are rarely backed up by ecological data, and a proper assessment is generally deferred pending further study. It is not unusual, however, for reassessment of a fishery (under the EPBC Act 1999) to occur without significant progress on recommendations from previous assessments.

Further discussion

Based on many of the general impacts described above, and interactions with a number of threatened or potentially threatened species, demersal trawling (and Danish seining) in the South East Trawl Fishery (a sub-fishery of the SESSF) has been nominated as a key threatening process under the EPBC Act 1999, but the deadline for assessment has been extended to July 2012 to align with the assessment of gulper sharks relevant to that fishery (SEPWC 2011).

Irrespective of the level of environmental damage that is considered acceptable by Governments based on the multiple environmental and economic criteria of 'ecologically sustainable development', it is clear that the methods described above are not compatible with areas dedicated to marine conservation. For example, demersal trawling, longlining and gillnetting have all been assessed as incompatible with the conservation values in all areas being assessed as potential multiple-use Marine Protected Areas in the South-west region, let alone highly protected zones within them (DEWHA 2010). A similar finding was made for demersal trawl, Danish seine and scallop dredging for the South-east region (E-Systems, 2005).

Where does demersal fishing occur?

Generally speaking, demersal fishing occurs in some form in most regions of the Australian Fishing Zone (AFZ) (See Figure 1):

- Dredging (for scallops) occurs mainly between Victoria and Tasmania
- Trawling for prawns occurs throughout tropical Australia, south-western Australia, and in the South Australian gulfs
- Fish trawls occur around most of the coastline
- Demersal gillnetting and longlining extend across the most of the southern and western coasts, offshore from the north-east coast (longlining) and along the northern coast (gillnetting).

Some specific examples of the various fisheries (by gear) are provided in Table 1 and a full list of demersal fisheries within the AFZ is provided in Appendix 1.

Four of these fisheries have been selected as case studies and are discussed below.

Table 1. Summary of demersal methods

Method	Description (AFMA 2011a; GoodFishBadFish 2011)	Target species	Physical impacts	Selectivity	Example fisheries (see Appendix 1)
Dredging	A typical dredge is constructed of a heavy steel frame covered with a steel mesh cage open on the front side (with rigid teeth attached to the base). As the dredge is towed behind the vessel, the catch is dug or ploughed from the seafloor and collected in the cage.	Scallops and clams	Very high	Very low	Bass Strait Central Zone Scallop (AFMA), and adjacent fisheries (Vic and Tas).
Demersal trawling (including Danish Seine)	Demersal (seafloor) trawling is the general term for a number of trawling methods targeting bottom dwelling species, where the hauled net maintains contact with the seafloor as the vessel is underway. This is achieved by weighting the bottom edge of the net entrance, whilst floating the top edge with the use of buoys. These weights also assist in disturbing buried organisms up into the water column. Danish seines are similar to a small trawl net but long wire warps rather than otter boards to herd fish towards the central net.	Fish including flathead, flounder and orange roughy; crustaceans including prawns	High	Low – some species selectivity through bycatch reduction devices (e.g. turtle exclusion devices), with varying levels of effectiveness	GAB Trawl, Commonwealth Trawl and East Coast Trawl sectors of the SESSF (AFMA), Antarctic (AFMA) (fish), Pilbara Fish Trawl (WA). Northern Prawn (AFMA), Western deepwater trawl (AFMA) (fish and crustaceans).
Demersal gillnet	Demersal (seafloor) gillnets are lengths of netting set in place vertically along the seabed, with the use of weights and buoys. They possess a predefined mesh size which results in the target size of fish being entangled in the net, whilst allowing some smaller fish to swim escape. Demersal gillnet fisheries target a range of shark and scale-fish species such as snapper and barramundi.	A range of shark and scalefish species including gummy sharks, snapper and barramundi	Variable – can damage fragile habitats	Low – some size selectivity through mesh sizes and species selectivity through bycatch reduction devices (e.g. acoustic pingers), with varying levels of effectiveness	Gillnet, hook and trap sector of the SESSF (AFMA); Southern Demersal Gillnet and Demersal Longline Fishery (AFMA/WA) and other shark fisheries (WA).
Demersal longline	Demersal longlines are fixed along the seafloor using anchors, at depths as little as a few hundred metres down to many thousands of metres. Demersal longlines often have shorter, more frequent branching lines (snoods) as well as shorter mainlines compared to pelagic longlines. Note that automatic longlining is another type of longlining – it is basically demersal longlining except that some of the functions (for example baiting the hook) are automated.	Bottom dwelling sharks and scalefish species including ling and Patagonian toothfish	Variable – can damage fragile habitats	Low – some size selectivity through hook size, bait type, and species selectivity through bycatch reduction devices (e.g. acoustic pingers)	Antarctic fishery (AFMA), Southern Demersal Gillnet and Demersal Longline Fishery (AFMA/WA) and other shark fisheries (WA).

Case Studies

WA South Coast Demersal Shark Fishery²

Fishery profile

Gear

Demersal gillnets and demersal longlines with power-hauled reels are used in this fishery, although most fishers have traditionally used gillnets (WADF 2005, DEWHA 2009). The mesh size of the nets (at least 162.5 mm) has been set with the intention that only a narrow size range of sharks be targeted, comprising mainly juveniles of the long-lived species or adults of the faster growing species are caught (WADF 2005). However, long-lived scalefish species are increasingly being caught (see below).

Historically, nets have been typically between one and three kilometres long (McAuley and Simpfendorfer 2003) but can be up to eight kilometres (Government of WA 2011). Nets may be set in close proximity to each other or separated by distances of several kilometres. Most vessels deploy their gear overnight (the mean observed 'soak time' for nets in these fisheries is 17 hours) but some operators deploy and recover their gear more than once per day (McAuley and Simpfendorfer 2003).

Area of operation

The fishery extends from Cape Bouvard (near Mandurah) to the South Australian border. The fishery is divided into two regions; the westernmost region (Zone 1) extends from Cape Bouvard to Chatham Island (near Walpole), and the second region (Zone 2), from Chatham Island to the South Australian border (WADF 2005).

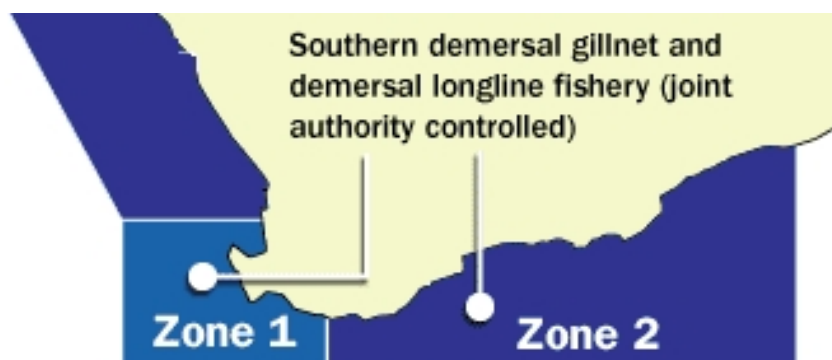


Figure 2. Location of the south coast demersal shark fishery

Source: adapted from WADF 2005

There are similar fisheries to the north (West Coast demersal shark fishery) and east (Gillnet, Hook and Trap Sector of the SESSF).

² Officially known as the (Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery

Species fished

The main shark species targeted by fishers on the south coast are dusky sharks in Zone 1, where whiskery sharks are also an important component of the catch, and gummy sharks in Zone 2 (McAuley and Leary 2010, WADF 2005). Other target species include hammerhead sharks, wobbegongs, longnose grey sharks, tiger sharks and shovelnose rays (DEWHA 2009).

Catches by species in this fishery in 2002-03 season were 182 tonnes of dusky whaler, 380 tonnes of gummy, 133 tonnes of whiskery, 30 tonnes of sandbar and 150 tonnes of other shark (WADF 2005), but in recent years dusky whaler and sandbar shark catches have dropped below 150 tonnes and 10 tonnes respectively, whiskery shark catches have been relatively stable, and gummy shark catches have increased to more than 600 tonnes. The catch of scalefish has progressively increased from 130 tonnes in 2002-03 to 187 tonnes in 2008-09 (WADF 2005; McAuley and Leary 2010)

Management approach

Because some of the species caught in this fishery are shared with other states, it is managed jointly by WA and the Commonwealth. The Department of Fisheries WA is responsible for the day-to-day management and research (WADF 2005).

The fishery is managed by a suite of input controls, including the type and amount of gear, and the period and duration in which it can be operated (as transferable time/gear effort units). Effort levels have been periodically reduced since 1992 in response to overfishing (WADF 2005), have now been capped at 2001-02 levels and processes put in place to remove latent effort from the fishery (McAuley and Leary 2010).

Other fishing controls restrict mesh and hook sizes, net height ('drop') and maximum net length, and the following additional measures were introduced during the 2006-07 season:

- a two month closure of Zone 1 to protect near-term pregnant whiskery sharks
- a maximum size limit for dusky sharks to protect their breeding stock
- a prohibition of metal trace wire and large hooks previously used to target large whaler sharks

A commercial ban has been introduced to prevent targeting of sharks in other fisheries, as well as a maximum size limit for recreational fishing of whaler sharks (McAuley and Leary 2010).

Fishing season

Fishing occurs year-round (season from 1 June to 31 May), apart from the closure from 16 August – 15 October in Zone 1 (DEWHA 2009).

Value of fishery

The estimated annual commercial value for 2005-06, 2006-07 and 2007-08 was \$6.4 million, \$4.9 million and \$6 million respectively (DEWHA 2009, McAuley and Leary 2010).

The catch was exported after processing to Asian markets (DEWHA 2009), although some is used to supply the local restaurant trade.

Number of licences and boats

In 2005-06, there were 57 licences: 24 in Zone 1 and 33 in Zone 2 (see Figure 2 for zone locations).

The estimated employment (skippers and crew) from 2006-07 to 2007-08 was between 49 and 65 (McAuley and Leary 2010).

Ecological sustainability

Direct physical damage

The fishery status report states that gillnets and longlines are deployed infrequently over approximately 40% of the fisheries area and under normal circumstances the physical impact of the gear on the bottom is minimal (McAuley and Leary 2010). However, this assumption has not been tested scientifically, and is not consistent with the identification of habitat types potentially at risk of damage from demersal longlines and gillnets in the SESSF (Daley et al. 2007a; Walker et al. 2007) and recent research on demersal gear (Constable et al. 2007, cited by DEWHA 2010).

Status of stocks

The breeding stock levels of the main target species have been assessed as follows in the most recent fisheries status report (McAuley and Leary 2010):

- gummy shark: fished to just above 40% of its unfished biomass, but is classed as adequate (considered to have sufficient spawning biomass assuming there are no adverse environmental conditions)
- whiskery shark: recovering after its significant depletion during the 1980s and continued gradual decline through the 1990s, but is nevertheless fished to 35-50% of its unfished biomass. The stock recovery is expected to accelerate when sharks born during the closed season begin to reach reproductive age in 2012
- dusky shark (and sandbar shark): depleted to levels that may affect recruitment, with some measures of catch rate showing further decline. The population is particularly susceptible to small increases in mortality of older sharks (which can occur in other fisheries) (McAuley and Leary 2010). The dusky shark has been nominated for listing as Vulnerable under the EPBC Act 1999 (based on its susceptibility to fishing) and is due for assessment by 30 September 2011.

Although a variety of management changes have been introduced to address the depleted stocks (see above), increased monitoring is required to support and assess the effectiveness of these measures (McAuley and Leary 2010).

Although catches of the scalefish indicator species pink snapper and dhufish were reasonably consistent over the three year period to 2008-09, they are depleted in the West Coast Bioregion (Mackie et al. 2009), which overlaps the western zone of this fishery. Catches for queen snapper and western blue groper, which are not assessed, increased by 35% and 60% respectively (McAuley and Leary 2010). This is a concern for western blue groper which is particularly susceptible to increased fishing pressure due to its life history characteristics (long-lived, late maturing and sex changing) (Coulson et al. 2007). A more general concern is the implication of increased targeting of reef-associated scalefish that can be prone to local depletion. In the

adjacent West Coast fishery, declines in demersal scalefish resulted in management actions which aim to reduce both the commercial and recreational catch levels by 50%. To date there has been no stock assessment of demersal scalefish, nor any precautionary management response in the South Coast fishery.

Bycatch

An observer-based survey of catch composition during the period 1994-99 reported 44 scalefish and 34 elasmobranch species or groups (in the latter case twice the number reported by fishers). Many of these species are classified as target or byproduct species but (unsaleable) bycatch includes saw sharks, wobbegongs and rays (McAuley and Simpfendorfer 2003).

The fishery status report (McAuley and Leary 2010) notes that an ecological risk assessment conducted in 2002, based on this study, indicated a low to negligible risk for bycatch species. It predicts that current bycatch levels will be lower based on a one-third reduction in fishing effort since that period, but is silent on the vulnerability of current populations (which have not been assessed) to this level of catch. Although the DEH (2006a) assessment of the fishery considered that the fishery was not likely to threaten bycatch species, it expressed concern about the lack of bycatch monitoring and imposed a condition that a bycatch monitoring program be implemented in the fishery. This was changed to be a recommendation in the final approval (Minister for Environment and Heritage 2007), and has not yet been implemented.

A recent multi-fisheries bycatch risk assessment has been undertaken by WADF for the West Coast Bioregion, which includes Zone 1 of the fishery (Evans and Maloney 2010). The outcome for the Port Jackson shark, which was assigned the highest risk score, is illustrative. This species had moderate to high abundances in all fishery bycatch data used for the assessment (and has the highest abundance of bycatch species in the South Coast Shark Fishery), and was given a high risk ranking for its reproductive characteristics. It was nevertheless assigned a risk category of low-moderate, based on apparently high natural abundance (although it was suggested that more information on this should be gathered), resilient life history parameters relative to other elasmobranchs and low capture mortality rates (Evans and Maloney 2010).

TEP species

There have been few interactions with marine turtles, mammals and seabirds (DEH 2006a, McAuley and Leary 2010), with sea lion captures observed at a rate of 1 per 100,000 km gillnet hours, other marine mammal captures at 1 per 10,000 km gillnet hours, seabirds at 1 capture per 25,000 km gillnet hours and turtles at 1 capture per 100,000 km gillnet hours (McAuley and Simpfendorfer 2003).

DEH (2006a) expressed concern about the level of interaction with protected white sharks and grey nurse sharks, and imposed conditions to improve the reporting of TEP species interactions. The most recent fishery status report classifies the risk to TEP species as low to negligible, stating that low numbers of sharks (an annual mean of 11 white sharks and 66 grey nurse sharks – both Vulnerable under the EPBC Act 1999) have been reported in fisher logbooks since 2006-07, with an (unquantified) minority of mortalities (McAuley and Leary 2010). There was no apparent observer program to support these findings.

Risks to Australian sea lions from demersal gillnet captures in this fishery (and the West Coast shark fishery) have been highlighted (Evans and Maloney 2010), with several colonies in south east of the state among those at greatest risk (McAuley and

Leary 2010). The Australian sea lion is endemic to the south and west coasts of Australia, and is listed as Vulnerable under the EPBC Act and Endangered on the IUCN Red List. During recent years in the adjacent SESSF Gillnet, Hook and Trap Sector, an average of 18,000 km of net was set per year (up to 6 km per net), offshore from SA (Goldsworthy et al. 2010) - enough to cover the length of SA waters ten times over, or go half the way around the world. It is estimated that there were 374 sea lion mortalities per 18 month breeding cycle, threatening to drive a number of genetically distinct subpopulations to extinction (Goldsworthy et al. 2010). However, in the adjacent South Coast shark fishery, near a comparable number of colonies and with a higher level of gillnet effort, only a single sea lion mortality was recorded from an observer program with 7% coverage over five years (McAuley and Simpfendorfer 2003). It is possible that observers failed to record dead sea lions that 'drop out' of the net as it is being hauled over the side (Goldsworthy et al. 2010). Further independent work is required to estimate actual levels of sea lion bycatch (or verify the low capture rate observed previously), noting that there has been significant under-reporting of sea lion mortalities and ongoing compliance issues in the SESSF (Goldsworthy et al. 2010; AFMA 2011b, 2011c). It should be noted that gear modification options are limited, and spatial management of fishing effort based on minimum core foraging areas of females or minimum depth ranges has been identified as the most practical solution (Goldsworthy et al. 2010).

Food chain effects

DEH (2006a) noted the generalist carnivore theory put forward by the Department of Fisheries WA (see Introduction) but recommended that the uncertainty due to the lack of monitoring be addressed in the longer term. DEWHA (2009) further recommended research on the effects of removing large quantities of juvenile sharks on food chains. This does not yet appear to have occurred, and the effect of the fishery on food chains was not assessed for the most recent fishery status report (McAuley and Leary 2010).

Conclusions

The key management issues are the depleted stocks of dusky, sandbar and whiskery sharks, increased catch of long-lived scalefish species, potential risks to Australian sea lions, and a general lack of data to assess ecological impacts.

Management changes have been introduced to address the depleted shark stocks but their effectiveness has not yet been assessed. There are strong indications from adjacent fisheries that further, precautionary management measures are required to address: bycatch of Australian sea lions threatening the survival of breeding populations; and potential overfishing of scalefish species that have increased catches, are biologically susceptible to fishing, and have yet to undergo stock assessment.

Further information is also required to adequately assess risks to benthic habitats, bycatch species and effects on food chains.

If management changes aimed at reducing latent effort are not successful then there is potential for impacts of this fishery to be exacerbated.

Pilbara Fish Trawl Fishery

Fishery profile

Gear

The current fish trawl fishery operates with standard stern trawling gear – a single net with extension sweeps and two otter boards. The net towed by the vessel must be of mesh size not less than 100 mm, with a head rope length not exceeding 36.58 metres, and with the overall trawl gear (including sweeps, bridles, and headrope) not exceeding 274.32 metres (WADF 2010a, Newman et al. 2010).

There is a maximum size (diameter) limit on rubber ground-gear discs which restricts trawling activity to flatter/softer regions of seabed (WADF 2010a).

There is a grid in the net to reduce the take of large fauna and flora, and a top opening net configuration is being developed to reduce the incidental bycatch of protected species (WADF 2010a).

Area of operation

The Pilbara Fish Trawl Fishery is situated in the Pilbara region in the north west of Australia, seaward of the 50 m isobath and landward of the 200 m isobath (see Figure 4). The Fishery consists of two zones: Zone 1 in the south west of the Fishery is closed to trawling; and Zone 2 in the north consists of six management areas, of which Areas 3 and 6 are closed.

The total area available for trawling is 14,980 square nautical miles (Newman et al. 2010). The open areas of the Trawl Fishery are trawled with varying intensity due to the variable effort allowed within different areas, the substrate composition and economic considerations (e.g. distance from port) (Newman et al. 2010).

Species fished

Targeted species are typically long-lived and include the bluespotted emperor, red emperor, spangled emperor, rosy threadfin bream, brownstripe snapper, crimson snapper, saddletail snapper, goldband snapper, frypan snapper and Rankin cod (Newman et al. 2010).

Management approach

The Pilbara Fish Trawl Interim Managed Fishery is managed through a combination of area closures, gear restrictions, and by allocating different levels of effort for each fishing area, monitored by a satellite-based vessel monitoring system. This Interim Management Plan was implemented for the fish trawl fishery in the Pilbara in 1998, with effort levels determined to achieve the best yield from the Fishery while keeping exploitation rates of the indicator species at sustainable levels (Newman et al. 2010). Effort reductions have taken place in the fishery to address sustainability issues (see below).

The fishery is currently being assessed to determine whether it can be moved to “managed” fishery status (Newman et al. 2010).

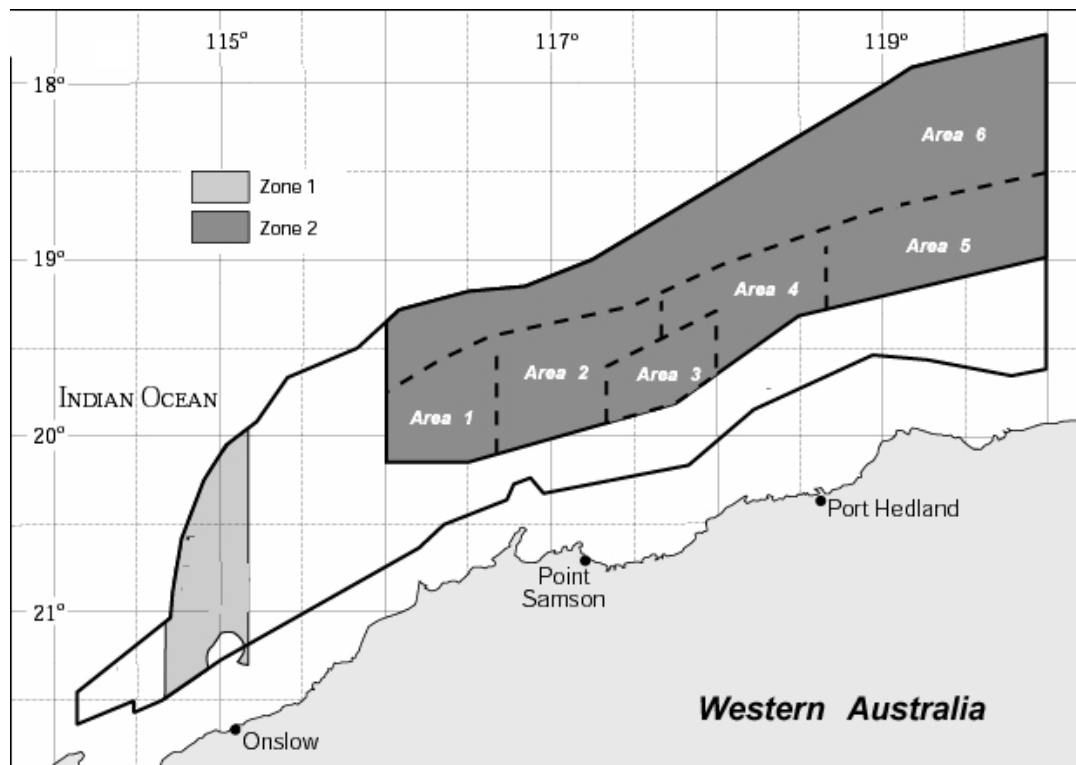


Figure 3. Fishing zones in the Pilbara Trawl fishery

Source: adapted from Newman et al. 2010

Fishing season

Trawling is permitted all year but due to inclement weather there is reduced effort between December to March (i.e. the cyclone season). Trip duration is generally between five and nine days. The shot duration can be anywhere from a half-hour to five hours with an average time of three hours (WADF 2010a).

Value of fishery

The gross value of production of the fishery was \$7.3 million in 2009. The catch from the Pilbara fisheries dominates the WA metropolitan markets and supports the local fish-processing sector. Exports have been minimal in the years preceding 2009 due to the increased value of the Australian dollar (Newman et al. 2010).

Number of licences and boats

There are 11 permits for the fishery, with the combined effort allocations being consolidated over time onto 3-4 full-time vessels (Newman et al. 2010).

18 fishers on 4 vessels were directly employed during 2008 (Newman et al. 2010).

Ecological sustainability

Direct physical damage

The substrate of the main fishing grounds is variable and includes limestone ridges, coarse sand, mud and gravel bottoms. The major vegetation types in the trawl grounds are sparse beds of macroalgae and encrusting algae associated with some of the harder substrates. A diverse range of sponges, gorgonians, sea whips, and soft corals also occurs and provides structurally complex habitat that is used by many of the target species caught by the fishery (WADF 2010b). The region between Point Samson and Port Hedland has been described as a hotspot for sponge biodiversity (Hooper & Ekins 2004).

Habitat impact is considered to be moderate in the most recent fishery status report (Newman et al. 2010). Impacts to the habitat are limited to those of the fish trawl fishery, which is restricted to around 7% of the North-west shelf (see Figure 3), although plots of trawl activity indicate that the actual area trawled is less than this (Newman et al. 2010).

Within the areas trawled, past research has indicated that 0.5-20% of the sessile benthic fauna (e.g. sponges) is detached per year, and 15% of larger organisms (>20 cm) are removed in a single trawl (Moran and Stephenson 2000). It is estimated that the annual bycatch includes more than 115,000 sponges and 20,000 sea fans (WADF 2010b). However, given that Moran and Stephenson (2000) found that only 4% of such organisms ended up in the net, the total number of removed species could be in the millions. It is not known whether the detachment rate exceeds the rate of regrowth (Newman et al. 2010).

Status of stocks

The breeding stock levels of the fishery were assessed in the most recent fishery status report as being acceptable, based on a weight of evidence approach using three methods to assess several indicator species (slow and fast growing) deemed to represent the entire demersal suite of species. The indicator species include red emperor, Rankin cod, goldband snapper and bluespotted emperor (Newman et al. 2010).

The mean trawl catch rates of indicator species and the total catch have been decreasing annually since about 2004 (although they were higher in 2009 for some areas). It is questioned whether this is due to changes in stock levels or reduced gear efficiencies following the introduction of bycatch reduction devices (Newman et al. 2010). The declining catch rates, and the high fishing mortality of red emperor in some areas resulted in a reduction of effort of up to 16% in some areas. The current 'acceptable' status of the fishery is based on an assessment of the spawning biomass levels of the target species in 2007, which could be as low as 30% of the unfished level (Newman et al. 2010), including more long-lived species such as the Rankin cod.

Bycatch/TEP Species

Bycatch and TEP impacts have been classified as moderate in the most recent fishery status report, meaning they are acceptable with the risk control measures currently in place (Newman et al. 2010).

Bycatch in the fishery is predominantly unmarketable scalefish, sharks and rays and sessile species such as sponges and corals. Neither a list of species nor a summary of the number of species caught have been provided by fishery status and assessment reports (e.g. WADF 2004, Newman et al. 2010). As for the sponge communities (see above), the fish communities are highly diverse and a number of fish biodiversity hotspots have been identified between Onslow and Port Hedland (Fox & Beckley 2005).

In addition, the fishery catches TEP species including bottlenose dolphins, marine turtles, sea snakes, Syngnathids and sawfish. These species are all protected in Western Australia and are Listed Marine species under the EPBC Act 1999 (except dolphins, which have stronger protection as Cetaceans under the EPBC Act 1999). Species with threatened status are noted below.

Reducing dolphin interaction has been the key bycatch issue since the inception of the fishery (WADF 2010b). In the two years from 2008-09, one dolphin was killed for every 87 tonnes of fish caught (WADF 2010a, Newman et al. 2010). Dolphins associate with trawlers more than 90% of the time they are within the fishery, and are generally caught throughout the fished areas (Allen and Loneragan 2010). Independent observer coverage has yielded dolphin capture rates that are typically 1.6 to 3.7 times higher than those reported in fisher's logbooks. Despite recognition by WADF that a minimum observer coverage of 22% is required, it has dropped progressively from 17% in 2006-07 to 8% in 2010 (Allen and Loneragan 2010).

The high mortality rate is despite significant reductions in response to new measures, in particular the implementation of exclusion grids in trawl nets since 2005 (WADF 2010a) - previously more than twice as many dolphins were killed. Significant work to research and evaluate potential solutions has been undertaken (Stephenson and Wells 2008, Allen and Loneragan 2010), with the latter study recommending:

- the installation of top opening escape hatches to potentially further reduce dolphin capture rates
- resolution of the taxonomic uncertainties surrounding the dolphin population(s) impacted by the fishery (some dolphins may be the oceanic bottlenose dolphin)

Following the implementation of bycatch exclusion grids, the bycatch of larger sharks and rays (>150 cm length) was reduced. Other large sharks (>1 metre) are generally alive and in good condition when they are returned to the water, while small sharks are generally dead. Based on their abundance, distribution, and biological characteristics, the green and narrow sawfish are at highest risk. The green sawfish is listed as Vulnerable under the EPBC Act. In the two years from 2008 to 2009, 39 green sawfish (five dead) and 59 narrow sawfish (11 dead) were discarded (WADF 2010b).

A total of 24 turtles were reported as caught in the five years from 2005 to 2009 in nets with grids, compared with 42 in 2005 and 2006, without grids. Data from 2008 and 2009 showed that most were green turtles (Vulnerable under the EPBC Act), with one loggerhead turtle (Endangered under the EPBC Act) in each year, and all turtles from these years were reported as alive on release (WADF 2010a³).

³ It is assumed that the Dead and Alive columns have been accidentally reversed by WADF (2010a, Tables 2 and 3).

A total of 265 sea snakes were reported as caught over 2008 and 2009, of which 80% were released alive. The most common species was the bar bellied sea snake.

A total of 333 pipefish were reported as caught in 2008 and 2009, of which 26% were released alive. Sixteen seahorses were also reported as caught, with half released alive. The two most common Syngnathids captured in the fishery were the pallid pipefish, and the western spiny seahorse, both listed as data deficient on the IUCN Red List (Morgan et al. 2006, Project Seahorse 2002).

Food chain effects

The most recent fishery statement report assessed this impact as low, meaning 'acceptable, with no specific control measures needed' (Newman et al. 2010). No definition or criteria for this classification were provided. The WADF (2004) submission on the ecological sustainability of the fishery stated that:

- because most species in the scalefish catch are generalist carnivores and consume a wide range of fish and invertebrates, the impact of any reduction in scalefish predator abundance would be spread across many prey species.
- other species of medium-sized carnivores not caught by the fishery would compensate for the effect of removals by the fishery.
- Stability of scalefish catch rates suggests that scalefish recruitment to the Pilbara region has not been affected by removals and that generalist carnivores in the region are being maintained at a level sufficient to maintain food chains.

However, there was no ecological data on food chains provided to support this assessment.

Conclusions

The key management issue for the Pilbara fish trawl is the bycatch of dolphins. Further work is required to evaluate potential gear-based solutions, and the recommended level of independent observer coverage should be provided. This would also improve the monitoring of a number of other TEP species killed in the hundreds as bycatch of the fishery.

The direct physical impacts of trawling over the sponge biodiversity hotspot identified within the fishery area have not been given sufficient attention. There are possibly millions of sponges removed each year, with unknown regeneration times.

Management intervention has been required due to previous declines in targeted species, including species biologically susceptible to fishing such as Rankin cod, and there is uncertainty over the reasons for declining catches in recent years.

There is inadequate information to assess the impact of the fishery on food chains.

Northern Prawn Fishery⁴

Fishery profile

Gear

Fishers catch the prawns by towing two or four nets with a chain on their bottom edge which is dragged to force prawns to swim out of the muddy bottom and into the net. Each net must have a turtle excluder device as well as bycatch reduction device (see below).

The nets are towed behind purpose-built, steel hulled vessels ranging in length from 14 metres to 29 metres (AFMA 2008a). Trawlers unload product to a mothership, (which usually rendezvous with the trawlers every two/three weeks), or directly at ports including Darwin and Karumba (AFMA 2008a; Larcombe and Perks 2010).

Area of operation

The Northern Prawn Fishery (NPF) covers an area of 771,000 square kilometres off Australia's northern coast, and extends from the low water mark to the outer edge of the Australian Fishing Zone (AFZ) in the area between Cape York in Queensland and Cape Londonderry in Western Australia (see Figure 4). Haywood et al. (2005) found that 17% of this area (130,000 square kilometres) was trawled over a five year period. The most intense fishing (accounting for 83% of the prawns) came from an area of approximately 18,000 square kilometres (Haywood et al. 2005).

Species fished

The three main species targeted are the grooved and brown tiger prawns and the white banana prawn, which make up 80% of the annual catch. The remaining 20% is composed of blue and red endeavour prawns, red-legged banana prawns, giant tiger prawns, western king prawns and red spot king prawns (DEH 2003a). The brown tiger prawn is endemic to Australia, but the other species have a broad tropical distribution. Squid, scampi scallops and bugs are also caught in the trawl net and retained as byproduct.

⁴ It should be noted that Nevill (2008) provides a comprehensive discussion of the Northern Prawn Fishery, providing background on the fishery, discussion of destructive fishing issues, benchmarks the fishery against adaptive, precautionary and ecosystem-based management, and discusses the re-accreditation of the fishery under the EPBC Act 1999.

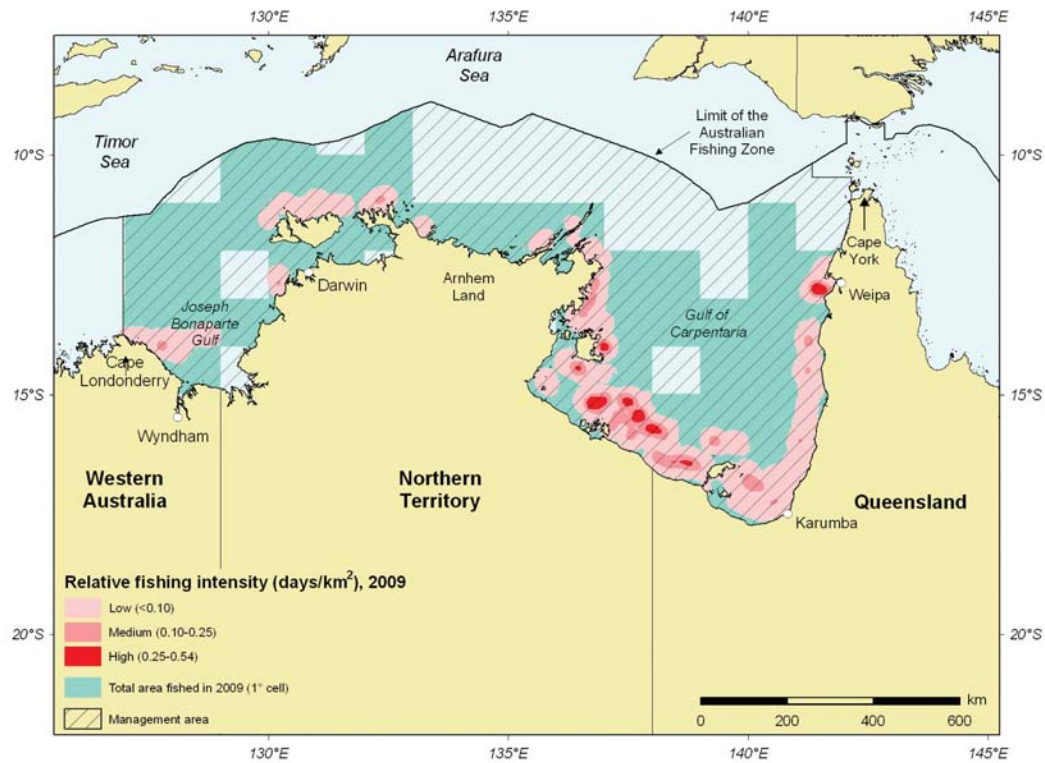


Figure 4. Distribution of fishing effort in the Northern Prawn Fishery

Source: Larcombe and Perks (2010)

Note that the relative fishing intensity area marked in pink/red shades covers only effort for five or more boats, while the green area shows all areas fished.

Management approach

The NPF has been historically managed through a combination of input controls (limited entry, seasonal closures, permanent area closures, gear restrictions and operational controls). The fishery is now, however, in the process of moving to a quota management system.

Fishing season

The NPF has two distinct fishing seasons, falling between March and June (banana prawns) and between August and November (tiger prawns). Closures coincide with spawning and recruitment phases of prawns (DEH 2003a). Trawling is banned during daylight hours during the tiger prawn season to reduce bycatch and the catch of egg-bearing females. The tiger prawn season is dependant on catch rates and a reduced season may be applied (AFMA 2008a).

Value of fishery

The annual gross value of production (GVP) of the fishery has varied between \$65 million and \$185 million (in 2000-01) since opening in the 1970s. This can be attributed to the fluctuating annual catch, season lengths, market conditions and foreign exchange rates. The GVP in 2008-09 was \$74 million (Larcombe and Perks 2010). Management costs in that year were \$2.5 million.

Number of licences and boats

In 2008-09 there were 52 fishing permits, and 55 active vessels (Larcombe and Perks 2010). The median age of vessels in the fleet is around 25 years. Between 2005 and 2008 there was a decrease of 45% in the number of boats used and a decrease of 35% in the total amount of gear-related effort used by the fishery (based on headrope length) (AFMA 2008a).

Typically there are 5-6 crew on each vessel (AFMA 2003), and therefore up to 300 persons working directly in the fishery. Other commercial enterprises associated with the NPF fleet include the land-based fishing companies, agents and mothership operators, prawn buyers, processors and exporters, transport operators, shipyards and maintenance yards and service industries (AFMA 2003).

Ecological sustainability

Direct physical damage

The disturbance and mortality of the benthic communities are considered to be the main impact of the fishery due to the otter boards and ground-chain contact with the seabed (DEH 2003a). As discussed above, up to 130,000 square kilometres may be affected, with the majority of the effort over 18,000 square kilometres). The areas trawled most intensely are shown in Figure 4.

Studies in the NPF and a nearby fishery have found that a single pass of a prawn trawl removed on average 10-15% of the seabed biota, with 5-6 trawls required to remove half of it (Haywood et al. 2005; Poiner et al. 1998). Intensive commercial trawling would result in much higher rates of repeated trawling over small areas (Haywood et al. 2005).

The ecological risk assessment did not classify any NPF habitats as being at high risk, based on their assumed productivity and hence good recovery rates (Griffiths et al. 2007). Analysis of several sessile or slow moving groups (bryozoans, corals, urchins and algae) showed recovery from trawling impacts within 6-12 months (Haywood et al. 2005).

Status of stocks

The most recent publicly available assessment of the status of target stocks (Larcombe and Perks 2010) found that most species were neither overfished nor subject to overfishing. However, it was uncertain whether red endeavour prawns were overfished or subject to overfishing, and whether both species of king prawns remained overfished. Blue endeavour prawns may have been fished down to 20-40% of their unfished biomass (Larcombe and Perks 2010).

Bycatch

Trawling in this fishery has historically resulted in a high proportion (up to 9:1) of bycatch relative to product (Raudzens 2007), and there are further interactions with ground chain and nets. A diverse array of marine species is affected, including:

- the green sawfish (Vulnerable under the EPBC Act 1999) and three other species. Salini et al. (2007) found that the cumulative bycatch from all northern fisheries was unsustainable for each of the four species

- more than 50 other sharks and rays, with the highest risk species being the banded wobbegong, blotched fantail ray and porcupine ray (AFMA 2008a, 2009a). One quarter of the sharks are killed (AFMA 2008a)
- more than 450 scalefish species (Stobutzki et al. 2000), with the highest risk species being the dwarf lionfish and raggy scorpionfish (AFMA 2009a)
- more than 200 invertebrate species (Stobutzki et al. 2000), with several byproduct species being at the highest risk (AFMA 2008a, 2009a)
- 12 sea snake species (Milton et al. 2008) making up the bulk of TEP species interactions in the NPF, with more than 40,000 reported as caught in 2004-07 with at least 11% mortality (AFMA 2008a)
- at least two Syngnathid species (Stobutzki et al. 2000)
- six marine turtle species (Stobutzki et al. 2000), although turtle exclusion devices (TEDs) have reduced mortality with an average one mortality reported each year during 2004-08 (AFMA 2008a).

Bycatch reduction devices (BRDs) can reduce the bycatch ratio to 5:1 (Larcombe and Perks 2010; Raudzens et al. 2007), but the survival of bycatch species that escape through BRDs is still largely uncertain. Survival rates of bycatch after release are variable, but generally low for fishes and higher for some invertebrates (Brewer et al. 2007).

The semi-qualitative ecological risk assessments identified 26 high risk species, mostly sea snakes and sawfish (AFMA 2008b). The fully-quantitative risk assessment retained a high risk rating for seven species (two rays, two scalefish, and three byproduct crustaceans) but did not take into account cumulative impacts from other fisheries in the region and may therefore underestimate the number of species at risk (Larcombe and Perks 2010, Brewer et al. 2007).

Food chain effects

Food chains can be affected by the NPF through the removal of target and by-product species, capture of bycatch species, and the reintroduction of discard species (DEH 2003a). Prawns are significant prey of some sharks and fish (DEH 2003a), but no assessment of the impact of the fishery on such species is apparent. Floating discards may impact on dolphins, sharks and seabirds, while sinking discards are later scavenged by fish and invertebrate species on the seafloor. Provisioning of animals, including seabirds, is an issue of concern. The impacts of increasing populations of some species, beyond their natural capacity may have implications for the ecosystem as a whole (DEH 2003a).

TEP species

Impacts on TEP species have been discussed above.

Conclusions

More than 500 fish and shark species are caught as bycatch in the Northern Prawn Fishery. One quarter of the sharks are returned dead. More than a thousand sea snakes are killed each year. Bycatch reduction devices (BRDs) have approximately halved the bycatch to catch ratio from 9:1 to 5:1. However, this reduction refers to fish and sharks landing on the deck, and the survivability of BRD escapees has not been assessed.

Trawling could remove 10-15% of the seabed biota across 130,000 square kilometres. More intensely trawled areas (covering 18,000 square kilometres) would lose more than half of their seabed biota) and barely recover by the following season.

The status of king prawn and endeavour prawn stocks is uncertain, and some byproduct species may be at risk. There is inadequate information to assess the impact of the fishery on food chains.

Great Australian Bight Trawl Sector

Fishery profile

Gear

Demersal trawl consisting of a pair of otter boards, a chain ground-rope with rubber bobbins and discs (to reduce impacts on the seafloor) and a net with minimum 90 mm mesh (AFMA 2002, AFMA 2010b).

Area of operation

The GAB Trawl Sector management area extends from Cape Leeuwin (WA) to Cape Jervis (SA), covering area of approximately 789,000 square kilometres (see Figure 5).

Fine scale information on the areas fished is collected but is not readily available (except as shown in Figure 5). Reporting at the level of one degree grid squares showed that approximately one quarter of the grid squares were fished in 2008-09. However, caution should be used when equating this to a number of square kilometres as only part of each grid squares is fished.

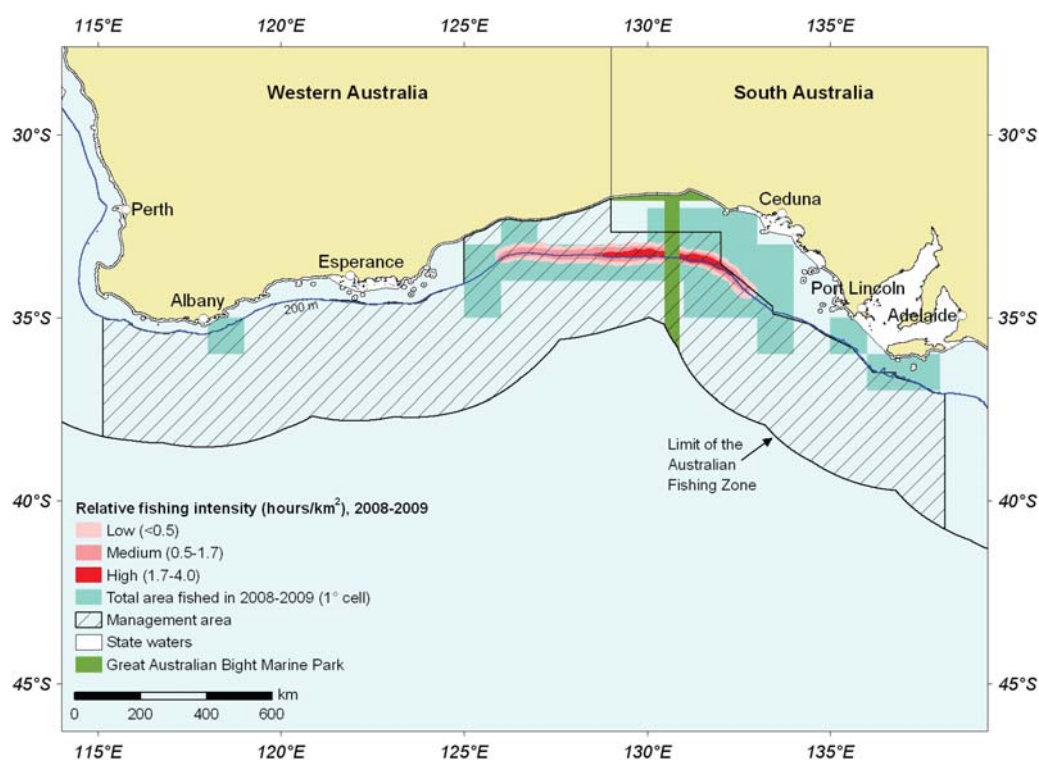


Figure 5. Distribution of fishing effort in the GAB Trawl Sector

Source: Moore et al. (2010). Note that the relative fishing intensity area marked in pink/red shades covers only effort for five or more boats, while the green area shows all areas fished.

Species fished

The main target species on the continental shelf are deepwater flathead and bight redfish. Blue grenadier and gemfish are targeted on the upper continental slope (depths >200 m), but comprise only a few percentage of the overall catch in this

fishery. Orange roughy was formerly targeted in deeper water (>700 m) but is no longer targeted since the closure of most of the historical grounds for this species (Moore et al. 2010). Ocean jackets are a key byproduct species.

Management approach

The fishery is managed through a number of input controls (limited entry, area closures and gear restrictions), and a quota management system for deepwater flathead and bight redfish as well as four species targeted mainly in other fisheries (Moore et al. 2010).

Fishing season

The shelf fishery operates year round, but deepwater flathead catches and catch rates peak in October–December and those of Bight redfish in February–April (Moore et al. 2010).

Value of fishery

The gross value of production in 2007–08 and 2008–09 was \$12.8 million and \$9.0 million, respectively (Moore et al. 2010).

Number of licences and boats

There were ten fishing permits and four active vessels in 2009-10 (down from seven vessels in 2008-09) (Moore et al. 2010).

Ecological sustainability

Direct physical damage

The most recent fishery status report states that most shelf trawls are on soft, sandy substrates with little sessile fauna or flora, but some ‘exploratory’ shots near the established grounds contain substantial benthos (Moore et al. 2010). Nevertheless, the ecological risk assessment identified 21 habitat types at high risk from the outer shelf and mid to upper slopes, including seamounts, canyons, and soft and hard bottom habitats characterised by corals, sponges, bryozoans and sedentary animals. Williams et al. (2011) identified highly vulnerable habitats overlapping with approximately 10% of the historical trawl footprint (with half in current closures).

Status of stocks

The main target species (bight redfish and deepwater flathead) are currently being fished down (Moore et al. 2010). Bight redfish have been classified as one of the more vulnerable fish species based on life history characteristics (long-lived and slow-growing) (Saunders et al. 2010). Neither species has been reported as overfished or subject to overfishing, being at 77% and 49%, respectively, of their unfished biomass. Bight redfish are therefore currently fished at the level recommended by Ward (2009), while deepwater flathead is now approaching the management target level for this species, which equates to the maximum sustainable yield (Wilson et al. 2010).

The status of ocean jackets is uncertain (with no formal assessment undertaken). The orange roughy is no longer subject to overfishing (zero catch in 2008-09 and 2009-10), but its current status is nevertheless uncertain (Moore et al. 2010).

Bycatch

Information gathered by the onboard observer program has shown modest discarding of commercial species, but substantial discarding (about 44% by weight of the overall catch) of non-commercial species in continental-shelf waters (Moore et al. 2010). More than 282 different species have been caught over the past decade, many of which were caught rarely or in low numbers (Moore et al. 2010, AFMA 2010b). The bulk of the discarded catch by weight comprised small latchet, sponges, stingarees and ocean jackets⁵ (AFMA 2010b).

The semi-qualitative ecological risk assessments identified 40 shark and scalefish species at high risk, including several large skates, the greeneye dogfish, wide stingaree, and ornate angel shark. The latter three are endemic shark species with restricted ranges (Daley et al. 2007b, AFMA 2008c).

Limited interactions with TEP shark species are currently reported in logbooks (Moore et al. 2010), and there has been an observer program since 2000 (AFMA 2008c). Nevertheless, the grey nurse shark (Vulnerable on the west coast under the EPBC Act 1999) was included among the high risk species, as was the school shark (Conservation Dependent under the EPBC Act 1999). There is a closure which aims to protect gulper sharks (AFMA 2009b).

As a result of the fully-quantitative risk assessment, which downgraded the risk for all species, bycatch management focus has shifted from a species specific to a general bycatch reduction approach (AFMA 2010b). This may be inappropriate given concerns raised by DEWHA (2010).

TEP Species

Apart from the sharks discussed above, few TEP species are currently known to interact with this fishery (AFMA 2010b, Phillips et al. 2010).

A key focus for bycatch management is to minimise seabird interactions (AFMA 2010b). Seabirds are known to interact with trawling activities and are vulnerable to warp strike, predominantly during hauling (Phillips et al. 2010).

Food chain effects

The AFMA (2002) submission on the ecological sustainability of the fishery suggested that the range of species available to fill a particular role in the ecosystem and the generally low impact of the fishery on lower order (oceanic) sources of production to the system would result in ecologically related species and communities remaining viable.

There is however a lack of data to adequately assess this impact. Furthermore, DEH (2003b) recommended that the role of redfish in the diets of many species, and the increasing competition from top order predator species such as whales and seals for species targeted by the fishery were key areas for risk assessment and response.

It has also been suggested that if developmental midwater trawling for small pelagic species such as jack mackerel, blue mackerel and Gould's squid in the Great Australian Bight were to progress to commercial operations then the implications of harvesting key prey species of predators such as southern bluefin tuna, marine mammals and seabirds should be considered (Moore et al. 2010).

⁵ Not all operators retain this species as byproduct, and it may be discarded at a small size but retained at a larger size.

Conclusion

A risk assessment identified 21 habitat types at high risk from trawling, and a separate study has found the highly vulnerable habitats overlap with approximately 5% of the current trawl footprint.

The main target species are lightly fished in comparison with other species examined in this report. The bight redfish stock is currently above the threshold of 75% of unfished biomass recommended based on conservation principles, which is appropriate given its high biological susceptibility to fishing. Orange roughy has not been caught in the fishery for two years, but its recovery from earlier depletions is not being monitored. The status of ocean jackets (the third highest catch in the fishery), has not been assessed.

Several hundred scalefish and shark species are caught, with a bycatch to catch ratio of approximately 1:1. Forty high risk species, including endemic species, were identified from the semi-quantitative (more precautionary) risk assessment, but were downgraded by the fully-quantitative risk assessment for which flaws have been identified. Management focus for TEP species bycatch is on minimising seabird mortality.

There is inadequate information to assess the impact of the fishery on food chains.

Overall conclusions

Direct physical damage

Fished substrates are quite variable, and some of the fisheries examined occur over areas with diverse and/or fragile attached invertebrates. The overlap of fisheries with sensitive habitats can vary. It has been estimated that vulnerable habitats overlap with approximately 5% of current GAB Trawl fishery footprint (Wilson et al. 2011). A similar assessment has not been undertaken for the Pilbara Fish Trawl, but it is estimated that millions of sponges per year are removed from a hotspot for sponge diversity in north-western Australia that is co-located with that fishery (see Pilbara Fish Trawl Fishery case study). The recovery rates of benthic habitats from trawling are not well understood but to be seem highly variable. There are estimates of 6-12 months for bryozoans, corals, urchins and algae in the Northern Prawn Fishery (Haywood et al. 2005), but there are also examples from elsewhere of sponge communities with individuals 100 years old (Hogg et al. 2010).

Trawling and dredging have historically been regarded as the most destructive demersal fisheries. However, there is now also emerging evidence that gillnetting and longlining, that often overlap trawl fisheries, may also be having a destructive influence on delicate benthic habitats (Constable et al. 2007, cited by DEWHA 2010; Daley et al. 2007a).

Status of stocks

Many of the target or byproduct scalefish and sharks are long-lived, late maturing and have few offspring, making them particularly susceptible to over-fishing. Demersal fisheries are indiscriminate in nature.

Nevertheless, as for many Australian stocks, they are typically fished down to 20-40% of their unfished biomass, well below a threshold of 75% recommended on the basis of fundamental conservation principles (Ward 2009). As a result of this threat from fishing mortality there has been a number of species listed or undergoing assessment (e.g. whaler and gulper sharks) as threatened species under the EPBC Act 1999. Trawling in the South East Scalefish and Shark Fishery (SESSF) has been nominated as a key threatening process.

Management is complicated by the multi-species nature of the catch, as less well understood species can become a significant part of the catch before their stocks can be adequately assessed (e.g. ocean jackets in the GAB Trawl fishery and red endeavour prawns in the Northern Prawn Fishery). Even for some of the main target species, stock assessments can be based on poor or little information.

Bycatch

Trawl bycatch is typically composed of hundreds of scalefish and shark species, including endemic species and species with the vulnerable life history characteristics described above. Reported bycatch to catch ratios in the case studies varied from about 1:1 to 5:1. There have been improvements with the use of bycatch reduction devices, but mortality of both escapees from these devices and caught species that are subsequently discarded have not been well assessed or documented..

Gillnetting is a less indiscriminate method but can nevertheless have a significant impact, particularly when the cumulative impact of multiple fisheries is taken into account. The South-west marine region contains 150 shark and ray species, including

many endemic species. It contains more than half a dozen fisheries. Just the WA South Coast Shark Fishery and GAB Trawl fishery catch at least 34 and 50 shark and ray species, respectively, of which about one third are discarded (McAuley and Simpfendorfer 2003, Darley et al. 2007a). Ecological risk assessments identified 14 species at high risk in more than one fishery, including the dusky shark (nominated as Vulnerable under the EPBC Act 1999), greeneye dogfish (endemic), and white shark (Vulnerable under the EPBC Act 1999) (DEWHA 2010). Flaws have been identified in the additional ecological risk assessments undertaken by AFMA resulting in a downgrade of some of these risks (DEWHA 2010). In the WA South Coast Shark Fishery, recommendations for bycatch monitoring have not been implemented despite evidence that fishers do not accurately report shark bycatch species (McAuley and Simpfendorfer 2003).

TEP species

There are a number of significant outstanding TEP species issues in Australian demersal fisheries. The Australian sea lion is endemic to the south and west coasts of Australia, and is listed as Vulnerable under the EPBC Act and Endangered on the IUCN Red List. Tens of thousands of kilometres of net are set each year in south-western shark fisheries, but very few sea lion interactions have historically been reported (McAuley and Simpfendorfer 2003, Goldsworthy et al. 2010). However, a recent observer-based study of the SESSF gillnet sector in South Australia estimated that 374 sea lions were killed per 18 month breeding cycle, threatening to drive a number of subpopulations to extinction (Goldsworthy et al. 2010).

In the two years from 2008-09 in the Pilbara Fish Trawl, one dolphin was killed for every 87 tonnes of fish caught (WADF 2010a, Newman et al. 2010). Despite evidence of under-reporting, observer coverage levels have declined and have never achieved the recommended level. Mortalities have been halved by the use of exclusion grids, but further work is needed.

Based on projections from two northern case study fisheries, thousands of sea snakes and hundreds if not thousands of pipefish (Listed Marine Species under the EPBC Act) are also killed each year within trawl fisheries (AFMA 2008a, WADF 2010a).

Food chain effects

Demersal fishing also impacts food chains through the removal of a high diversity and abundance of carnivores, and scavenging of discarded bycatch species by dolphins, seabirds and demersal species. There is a general lack of data to adequately assess food chain effects and support assumptions made by fishery management agencies about a low risk. It is not unusual for reassessment of a fishery under the EPBC Act 1999 to occur without significant progress against recommendations on food chain studies from previous assessments.

Cumulative impact on biodiversity

This report concludes that the cumulative effects of ubiquitous, and sometimes overlapping demersal fisheries can be significant and present serious issues for the objective of biodiversity conservation.

Irrespective of the level of environmental damage considered acceptable by Governments based on the multiple environmental and economic criteria of 'ecologically sustainable development', it is clear that the methods described above are not compatible with areas dedicated to marine conservation.

References

- AFMA 2002, *Southern and Eastern Scalefish and Shark Fishery Assessment Report*
- AFMA 2003, *Northern Prawn Fishery – Draft Assessment Report*
- AFMA 2008a, *Status Report for Re-assessment for Export Approval Under the EPBC Act – Northern Prawn Fishery.*
- AFMA 2008b, *Residual risk assessment of the level 2 ecological risk assessment species results, report for the Northern Prawn Fishery.*
- AFMA 2009a, *Ecological risk management. report for the Northern Prawn Fishery – tiger and banana prawn sub-fisheries*
- AFMA 2009b, *Southern and Eastern Scalefish and Shark Fishery Wildlife Trade Operation Re-assessment 2009*
- AFMA 2010a, *Upper-Slope Dogfish Management Strategy - Commonwealth-managed Fisheries.*
- AFMA 2010b, *Great Australian Bight Trawl Fishery Bycatch and Discarding Workplan*
- AFMA 2011a, *About fishing methods and devices.* <http://www.afma.gov.au/resource-centre/teachers-and-students/about-fishing-methods-and-devices/>
- AFMA 2011b, *Changes in the Gillnet, Hook and Trap Sector of the Southern and Eastern Scalefish and Shark Fishery*
- AFMA 2011c, *AFMA Update Volume 8, Issue 8, May 2011.*
- AFMA, 2008c, *Residual risk assessment of the level 2 ecological risk assessment species results: report for the Great Australian Bight trawl sub-fishery of the Southern and Eastern Scalefish and Shark Fishery*, AFMA, Canberra.
- Aish, A, Trent, S & Williams, J 2003, *Squandering the seas: how shrimp trawling is threatening ecological integrity and food security around the world*, Environmental Justice Foundation, London.
- Allen S and Loneragan N 2010. *Reducing Dolphin Bycatch in the Pilbara Finfish Trawl Fishery. Report to the Fisheries Research and Development Corporation (FRDC) on Project No. 2008/048.*
- Alverson, D.L.; Freeberg, M.H.; Pope, J.G.; Murawski, S.A. 1994, *A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper No. 339.* Rome, FAO. 1994. 233p.
- Bell JJ, 2008, *The functional role of marine sponges. Estuarine Coastal and Shelf Science* 79, 341-353.
- Brewer, DT, Griffiths, S, Heales, DS, Zhou, S, Tonks, M, Dell, Q, Taylor, BT, Miller, M, Kuhnert, P, Keys, S, Whitelaw, W, Burke, A & Raudzens, E 2007, *Design, trial and implementation of an integrated, long-term bycatch monitoring program, road tested in the Northern Prawn Fishery, final report on FRDC project 2002/035*, CSIRO, Cleveland.

- Broadhurst M, 2008, *Maximising the survival of bycatch discarded from commercial estuarine fishing gears in NSW. Final report to the Fisheries Research & Development Corporation for Project No. 2005/056*. NSW Department of Primary Industries – Fisheries Final Report Series No. 107. 194pp. ISSN 1449-9967.
- Constable, A. J., D. C. Welsford, S. J. Doust and R. Kilpatrick, 2007, *Demersal fishing interactions with marine benthos in the Southern Ocean: an assessment of the vulnerability of benthic habitats to impact by demersal gears*. CCAMLR Document: SC-CAMLR-XXVI/BG/30.
- Coulson P, Potter I, Hesp S & Hall N, 2007, *Biological parameters required for managing Western Blue Groper, Blue Morwong and Yellowtail Flathead FRDC Report 2004/57*.
- Currie, D.R., Dixon, C.D., Roberts, S.D., Hooper, G.E., Sorokin, S.J. and Ward, T.M., 2009, *Fishery independent by-catch survey to inform risk assessment of the Spencer Gulf Prawn Trawl Fishery. Report to PIRSA Fisheries*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.
- DAFF (Department of Agriculture, Fisheries and Forestry), 2007, *Commonwealth Fisheries Harvest Strategy: Policy and Guidelines*.
- Daley RK, Stevens JD and Graham KJ, 2002, *Catch analysis and productivity of the deepwater dogfish resource in southern Australia*. FRDC Final Report 1998/108. Fisheries Research and Development Corporation, Canberra.
- Daley, R, Knuckey, I., Dowdney, J., Williams, A., Bulma, C., Sporcic, M., Fuller, M., Smith, T., 2007b, *Draft Ecological Risk Assessment for the Effects of Fishing. Report for the Great Australian Bight trawl sub-fishery of the Southern and Eastern Scalefish and Shark Fishery. Report for the Australian Fisheries Management Authority*. Canberra, Australia
- Daley, R., Webb, H., Hobday, A., Timmiss, T., Walker, T., Smith, T., Dowdney, J. and Williams, A., 2007a, *Ecological Risk Assessment for the Effects of Fishing. Report for the automatic longline sub-fishery of the Southern and Eastern Scalefish and Shark Fishery*. Report for the Australian Fisheries Management Authority, Canberra.
- Dayton PK, Thrush SF, Agardy MT, Hofman RJ 1995, *Environmental effects of marine fishing*. *Aquat Conserv* 5:205–232
- DEH 2003a, *Assessment of the Northern Prawn Fishery*.
- DEH 2003b, *Assessment of the Southern and Eastern Scalefish and Shark Fishery*
- DEH 2006a, *Assessment of the Western Australian Temperate Shark Fisheries*
- DEH 2006b, *Assessment of the New South Wales Ocean Trawl Fishery*
- DEWHA 2009, *Assessment of the Western Australian Temperate Shark Fisheries*
- DEWHA 2010, *Assessment of risks that commercial fishing methods may pose to conservation values of the South-west Marine Region: Discussion Paper*.
- E-Systems 2005, *Fishing Risk Assessment for the Development of a Representative System of Marine Protected Areas in the South-east Marine Region*, Report of the Technical Working Group, prepared for the Department of Environment and Heritage, Canberra.

- Evans, R. and Malony, B. W. 2010, *Ranked Risk Assessment for Bycatch in Multiple Fisheries: a Bioregional Risk Assessment Method*. Fisheries Research Report No. 212. Department of Fisheries, Western Australia. 88pp.
- Fox, N.J. & Beckley, L.E., 2005, 'Priority Areas for Conservation of Western Australian Coastal Fishes: A Comparison of Hotspot, Biogeographical and Complimentary Approaches', *Biological Conservation* 125:399–410.
- Goldsworthy, S.D., Page B, Shaughnessy, P.D and Linnane A, 2010, *Mitigating Seal Interactions in the SRLF and the Gillnet Sector SESSF in South Australia*. Report to the Fisheries Research and Development Institute. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000613-1. SARDI Research Report Series No. 405.
- GoodFishBadFish 2011, *Fishing technique*. viewed online: http://goodfishbadfish.com.au/?page_id=31
- Government of WA, 2011, *Joint Authority Southern Demersal Gillnet and Demersal Longline Limited Entry Fishery Notice 1992*, as amended to 6 May, 2011, [http://www.slp.wa.gov.au/statutes/subsidiary.nsf/0/C47FE58A11B271914825788B00261A5B/\\$file/15+southern+demersal+gillnet+&+longline+06-05-11.pdf](http://www.slp.wa.gov.au/statutes/subsidiary.nsf/0/C47FE58A11B271914825788B00261A5B/$file/15+southern+demersal+gillnet+&+longline+06-05-11.pdf)
- Griffiths, S., Kenyon, R., Bulman, C., Dowdney, J., Williams, A., Sporcic, M. and Fuller, M., 2007, *Ecological Risk Assessment for the Effects of Fishing: Report for the Northern Prawn Fishery*. Report for the Australian Fisheries Management Authority, Canberra.
- Haywood, MDE, Hill, J, Donovan, AG, Rochester, WA, Ellis, N, Welna, A, Gordon, S, Cheers, SG, Forcey, K, McLeod, IM, Moeseneder, CH, Smith, GP, Manson, FJ, Wassenberg, TJ & Thomas, S., 2005, *Quantifying the effects of trawling on seabed fauna in the Northern Prawn Fishery; volumes 1 and 2*, CSIRO, FRDC project 2002/102, Canberra.
- Hobday, A. J., A. Smith, H. Webb, R. Daley, S. Wayte, C. Bulman, J. Dowdney, A. Williams, M. Sporcic, J. Dambacher, M. Fuller, T. Walker, 2007, *Ecological Risk Assessment for the Effects of Fishing: Methodology*. Report R04/1072 for the Australian Fisheries Management Authority, Canberra.
- Hogg, M.M., Tendal, O.S., Conway, K.W., Pomponi, S.A., van Soest, R.W.M., Gutt, J., Krautter, M. and Roberts, J.M., 2010, *Deep-sea Sponge Grounds: Reservoirs of Biodiversity*. UNEP-WCMC Biodiversity Series No. 32. UNEP-WCMC, Cambridge, UK.
- Hooper, J. & Ekins, M., 2004, *Collation and Validation of Museum Collection Databases related to the Distribution of Marine Sponges in Northern Australia (Contract National Oceans Office C2004/020)*, Unpublished Report to the National Oceans Office, Brisbane: Queensland Museum.
- Jennings, S. and Kaiser, M.J., 1998. *The effects of fishing on marine ecosystems*. *Advances in Marine Biology*. 34: 203-314.
- Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J., Karakassis, I., 2006, *Global analysis of response and recovery of benthic biota to fishing*. *Mar. Ecol. Prog. Ser.* 311, 1–14.

Larcombe J and Perks C, 2010, Northern Prawn Fishery. In Wilson DT, Curtotti R, & Begg GA (eds), *Fishery status reports 2009: status of fish stocks and fisheries managed by the Australian Government*, Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences, Canberra.

Macbeth, W.G., Johnson, D.D., and Gray, C.A. 2008, *Assessment of a 35-mm square-mesh codend and composite square-mesh panel configuration in the ocean prawn trawl fishery of northern New South Wales*.

Mackie, M.C., McCauley, R.D., Gill, H.S. and Gaughan, D.J. 2009, *Management and Monitoring of Fish Spawning Aggregations within the West Coast Bioregion of Western Australia. Final report to Fisheries Research and Development Corporation on Project No. 2004/051*. Fisheries Research Report No. 187. Department of Fisheries, Western Australia.

McAuley R and Leary T., 2010, *Demersal Gillnet and Longline Fisheries Status Report*. In: *State of the Fisheries and Aquatic Resources Report 2009/10* eds. W.J. Fletcher and K. Santoro, Department of Fisheries, Western Australia, pp. 39-48.

McAuley, R. and Simpfendorfer, C. 2003, *Catch composition of the Western Australia temperate demersal gillnet and demersal longline fisheries, 1994 to 1999*. Fisheries Research Report No. 146, Department of Fisheries Western Australia. 78 pp.

Milton, D.A., Zhou, S., Fry, G.C. Dell, Q., 2008, *Risk assessment and mitigation for sea snakes caught in the Northern prawn Fishery. Final report on FRDC Project 2005/051*. CSIRO Cleveland, pp. 123.

Moore A, Patterson H and Pham T, 2010, Great Australian Bight Trawl Sector. In Wilson DT, Curtotti R, & Begg GA (eds), *Fishery status reports 2009: status of fish stocks and fisheries managed by the Australian Government*, Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences, Canberra.

Moran MJ and Stephenson PC 2000, *Effects of otter trawling on macrobenthos and management of demersal scalefish fisheries on the continental shelf of north-western Australia*. *ICES J Mar Sci* 57:510-516.

Morgan, S., Pogonoski, J., Pollard, D. & Paxton, J. 2006. *Solegnathus hardwickii*. In: IUCN 2011. *IUCN Red List of Threatened Species. Version 2011.1*. www.iucnredlist.org Downloaded on 09 July 2011.

Nellemann, C., Hain, S. and Alder, J. (Eds), 2008, *In Dead Water – Merging of Climate Change with Pollution, over-Harvest, and Infestations in the World's Fishing Grounds*, United Nations Environment Programme, GRIDArendal, Norway.

Nevill J, 2008, *Benchmark appraisal: Australia's northern prawn trawl fishery*.

Newman SJ, Wakefield C, Stephenson P, Skepper C. Moddington D, Cliff M, Mitsopoulos G and Rome B 2010, *North Coast Demersal Fisheries Status Report*. In: *State of the Fisheries and Aquatic Resources Report 2009/10* eds. W.J. Fletcher and K. Santoro, Department of Fisheries, Western Australia, pp. 39-48.

OceanWatch Australia 2010a, *Where does seafood come from: inshore net fishing*. <http://www.youtube.com/watch?v=M-Gy2RhPC2w>

OceanWatch Australia 2010b, *Where does seafood come from: barramundi netting*. <http://www.youtube.com/watch?v=zyuTILpweaw>

Phillips, K, Giannini, F, Lawrence, E and Bensley, N 2010, *Cumulative assessment of the catch of non-target species in Commonwealth fisheries: a scoping study*, Bureau of Rural Sciences, Canberra

Poiner I, S Blaber, D Brewer, C Burrridge, D Caesar, M Connell, D Dennis G Dews, N Ellis, M Farmer, J Glaister, N Gribble, B Hill, R O'Connor, R Pitcher, J Salini, T Taranto, M Thomas, P Toscas, Y Wang, S Veronise and T Wassenberg., 1998, *Final report on effects of prawn trawling on Far Northern Section of Great Barrier Reef*. CSIRO Division of Marine Research and Queensland Department of Primary Industries, 750 pp.

Project Seahorse 2002, *Hippocampus angustus*. In: *IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1.* www.iucnredlist.org Downloaded on 09 July 2011.

Raudzens, E 2007, *At sea testing of the popeye fishbox bycatch reduction device onboard the FV Adelaide Pearl for approval in Australia's Northern Prawn Fishery*, AFMA, Canberra.

Salini, JP, McAuley, R, Blaber, SJM, Buckworth, RC, Chidlow, J, Gribble, N, Ovenden, J, Peverell, S, Pillans, RD, Stevens, JD, Stobutzki, I, Tarca, C & Walker, TI, 2007, *Northern Australian sharks and rays: the sustainability of target and bycatch species, phase 2 report*, CSIRO, Cleveland Queensland.

Saunders, R.J., Bryars, S.R. and Fowler, A.J, 2010, *Preliminary consideration of the biology of several of South Australia's marine fish species that have conservation or management interest*. Report to the Department for Environment and Heritage. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000693-1. SARDI Research Report Series No. 426. 41p.

SEWPC 2011, *Threatened Species and Ecological Communities - Extensions to EPBC Act nomination timeframes*. Viewed online, 26/07/2011, <http://www.environment.gov.au/biodiversity/threatened/nominations-fpal-extensions.html>

St. John, J., and Syers, C.J. 2005, *Mortality of the demersal West Australian dhufish, *Glaucosoma hebraicum* (Richardson 1845), following catch and release: the influence of capture depth, venting and hook type*. *Fish. Res.* **76**: 106–116.

Stephenson, P. C. and Wells, S., 2008, *Evaluation of the effectiveness of reducing dolphin catches with pingers and exclusion grids in the Pilbara trawl fishery. Final report to Fisheries Research and Development Corporation on Project No. 2004/068*. Fisheries Research Report No. 173, Department of Fisheries, Western Australia, 44p.

Stobutzki, I., Balber, S., Brewer, D., Fry, G., Heales, D., Miller, D., Miller, M., Milton, D., Salini, J., Van der Velde, T., Wassenberg, T., Jones, P., Wang, Y., Dredge, M., Courtney, T., Chilcott, K., and Eayrs, S., 2000, *Ecological sustainability of bycatch and biodiversity in prawn trawl fisheries. FRDC Project 96/257*.

Svane, I., Hammett, Z. and Lauer, P., 2009, *Impacts of trawling on benthic macro-fauna and flora of the Spencer Gulf prawn fishing grounds*. *Fisheries Research.* **90**: 158-169.

Tanner, J.E., 2003, *The influence of prawn trawling on sessile benthic assemblages in Gulf St. Vincent, South Australia*. *Canadian Journal of Fisheries and Aquatic Sciences.* **60**: 517-526.

- Thrush, S.F. and Dayton, P.K., 2002, *Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity*. *Annual Review of Ecology and Systematics* 33: 449-473.
- Turner, S.J., Thrush, S.F., Hewitt, J.E., Cummings, V.J., and Funnell, G.A. 1999, *Fishing impacts and the degradation or loss of habitat structure*. *Fish. Manag. Ecol.* 6: 401–420.
- WADF 2004, *Application to the Department of Environment and Heritage (DEH) on the Pilbara Fish Trawl Interim Managed Fishery, against the Australian Government Guidelines for the Ecologically Sustainable Management of Fisheries*.
- WADF 2005. Southern Demersal Gillnet and Demersal Longline Joint Authority Fishery. [http://www.fish.wa.gov.au/docs/cf/Sharks/Comm SharkPage03.php?0206](http://www.fish.wa.gov.au/docs/cf/Sharks/Comm%20SharkPage03.php?0206)
- WADF 2010a, *Application to the Department of the Environment, Water, Heritage and the Arts on the Pilbara fish trawl interim managed fishery against the Guidelines for the Ecologically Sustainable Management of Fisheries – 2007*.
- WADF 2010b. *A bycatch action plan for the Pilbara fish trawl interim managed fishery*. *Fisheries Management Paper No. 244*. ISSN 0819-4327
- Walker, T., Dowdney, J., Williams, A., Fuller, M., Webb, H., Bulman, C., Sporcic, M., Wayte, S., 2007, *Ecological Risk Assessment for the Effects of Fishing: Report for the Shark gillnet component of the Gillnet Hook and Trap Sector of the Southern and Eastern Scalefish and Shark Fishery*. Report for the Australian Fisheries Management Authority, Canberra.
- Ward T, 2009, *A brief review and commentary on the marine conservation effectiveness of the Commonwealth's Guidelines for the ecologically sustainable management of fisheries*. Prepared for the Australian Conservation Foundation by Greenward Consulting, Perth.
- Welsford, D.C. and Kilpatrick, R., 2008, *Estimating the swept area of demersal longlines based on in-situ video footage*, CAMLR Document: WG-FSA-08/58.
- Williams A, Daley R, Fuller M and Knuckey I., 2011, *Supporting sustainable fishery development in the GAB with interpreted multi-scale seabed maps based on fishing industry knowledge and scientific survey data*. FRDC Project No. 2006/036
- Wilson DT, Curtotti R, & Begg GA (eds) 2010, *Fishery status reports 2009: status of fish stocks and fisheries managed by the Australian Government*, Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences, Canberra.
- Wilson DT, Patterson HM, Summerson R and Hobsbawn PI, 2009, *Information to support management options for upper-slope gulper sharks (including Harrison's dogfish and southern dogfish)*. Final Report to the Fisheries Research and Development Corporation Project No. 2008/65. Bureau of Rural Sciences, Canberra.
- Wulff JL, 2006, *Ecological interactions of marine sponges*. *Canadian Journal of Zoology* 84, 146-166.
- Zhou, S, 2008, *'Fishery by-catch and discards: a positive perspective from ecosystem-based fishery management'*, *Fish and Fisheries*, vol. 9, pp. 308-15.

Appendix 1. Demersal fisheries in the South-west, North-west and North marine regions

Note: * = case study fishery

Jurisdiction	Fishery name	Fishing method	Target species	Coastline extent	Figure 1 reference
AFMA	North West Slope Trawl	Demersal trawl	Scampi and prawn	South of Port Hedland to Ashmore Reef	15
AFMA	Northern Prawn*	Demersal trawl	Nine commercial species of prawns	North coast (WA, NT)	16
AFMA	GAB Trawl Sector* (SESSF)	Demersal trawl	Bight redfish and flathead	Cape Leeuwin (WA) to Cape Jervis (SA).	22
AFMA	Gillnet, Hook and Trap Sector (SESSF)	Demersal gillnet	Sharks	Southern Queensland to the SA border, offshore to 200 nm	23
AFMA	South Tasman Rise	Demersal trawl (currently closed)		South of Tasmania	n/a
AFMA	Torres Strait	Demersal trawl	Tiger and endeavour prawns	Torres Strait	32
AFMA	Western Deepwater Trawl	Demersal trawl	Fish and crustaceans	East of Albany to north of Port Hedland	34

Jurisdiction	Fishery name	Fishing method	Target species	Coastline extent	Figure 1 reference
WA	Shark Bay Scallop Fishery and Shark Bay Prawn Fishery	Demersal trawl	Scallops and prawns	Shark Bay and adjacent waters, to a depth of 200 m	28
WA	Other northern prawn fisheries, including: Broome Prawn Fishery Exmouth Gulf Prawn Fishery Kimberley Prawn Fishery Nickol Bay Prawn Fishery Onslow Prawn Fishery	Demersal trawl	Prawns	Exmouth to WA border	4, 7, 10, 13, 19
WA	Southern and western trawl fisheries, including: South West Trawl Fishery Abrolhos Island and Mid West Trawl Fishery South Coast Trawl Fishery	Demersal trawl	Prawns and scallops. South Coast Trawl Fishery also takes some whiting and crabs	Isolated areas around Abrolhos, Fremantle, Geographe Bay and Esperance	31, 1, 29
WA	Pilbara Fish Trawl Fishery*	Demersal trawl	Scalefish	Exmouth to East of Port Headland, within 50-200 m depths	20

Jurisdiction	Fishery name	Fishing method	Target species	Coastline extent	Figure 1 reference
WA	Shark fisheries, including: Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery* West Coast Demersal Gillnet and Demersal Longline Fishery Western Australian North Coast Shark Fishery Joint Authority Northern Shark Fishery	Demersal Gillnet and Demersal Longline	Sharks and scalefish	Collectively extend around WA coast except for closure between Shark Bay and Exmouth.	26, 27, 14, 17
WA	Kimberley Gillnet and Barramundi Fishery	Demersal gillnet	Barramundi and other scalefish	WA/NT border to south of Broome.	35
NT	Scalefish trawl	Demersal trawl (semi-pelagic)	Two scalefish species	Offshore waters east of Darwin, including northern Gulf of Carpentaria.	8
NT	Barramundi	Gillnet		Northern Territory waters, except various closures	36

Jurisdiction	Fishery name	Fishing method	Target species	Coastline extent	Figure 1 reference
SA	Marine scalefish fishery	Gillnet and longline	Whaler sharks, school and gummy sharks, snapper	South Australian coast offshore to 150 m depth	12
SA	Prawn (Gulf St Vincent) Fishery Prawn (Spencer Gulf & West Coast) Fishery	Demersal trawl	Western king prawns	Gulf St Vincent, Spencer Gulf and West Coast	21

Appendix 2. Glossary

Adaptive Management	A structured, iterative process that incorporates monitoring and evaluation to improve decision-making in uncertain environments. It is, in essence, “learning by doing.”
Australian Fishing Zone	Waters adjacent to Australia and its external territories (excluding Torres Strait and the Antarctic Territories) which extend from defined baselines to 200 nm seawards, but not including coastal and excepted waters. Agreed boundaries apply where these zones intersect the 200 nm zones of other nations. Within the Australian Fishing Zone, Australia exercises jurisdiction over all fishing by Australian and foreign boats
Benthic	Living on or under the seafloor substrate (see also Demersal)
Bycatch	Non-target species captured in a fishery, usually of low value and often discarded (see also Target species).
Byproduct	Non-target species captured in a fishery, but it may have value to the fisher and be retained for sale (see also Target species).
Demersal	Living on or near the bottom and feeding on benthic organisms (see also Benthic)
Ecosystem-based management	Ecosystem-based management (EBM) is a place-based approach to natural resource use that aims to restore and protect the health, function and resilience of entire ecosystems for the benefit of all organisms.
Endemic	Unique to a particular geographical region.
Input controls	Restrictions placed on the amount of effort input into a fishery e.g. by restricting types and size of fishing gear and boats and the amount of fishing time.
Interaction	Any occurrence of fishing gear having an effect on species.
Latent effort	The potential for effective effort within a fishery to increase over time (i.e. inactive fishing licences that may be used in the future).
Offshore Constitutional Settlement	An agreement between the State(s) and the Commonwealth whereby the State or the Commonwealth is given jurisdiction for a particular fishery occurring in both coastal waters and the Australian Fishing Zone. Without such an agreement the fishery remains under the jurisdiction of the State out to 3 nm, and the Commonwealth from 3 to 200 nm.
Output controls	Restrictions imposed on the quantity of fish that can be taken from a fishery within a specified period of time, e.g. see Quota management system.
Quota management system	A method of management based on output controls whereby the TAC is allocated among eligible operators and allocated as shares in the annual TAC.

Recruitment	The addition of fish to the exploitable stock each year due to growth and/or migration into the fishing area.
Recruitment overfishing	The rate of fishing above which the recruitment to the exploitable stock becomes significantly reduced.
Sessile	Attached to the seafloor.
Spawning biomass	The total weight of all adult fish in a population
Substrate	The substance forming the bottom of the sea or ocean floor
Syngnathid	Member of the Syngnathidae family of fish which includes seahorses, seadragons and pipefishes.
Target species	A species or group of species whose capture is the goal of a fishery, sub-fishery, or fishing operation.