Chapter 3 Assessments of new scientific information to support Commonwealth marine reserve zoning and management decisions

The Expert Scientific Panel (ESP) terms of reference included providing advice on options for zoning and allowed uses consistent with the Goals and principles for the establishment of the National Representative System of Marine Protected Areas in Commonwealth waters (the Goals and Principles). Noting the extensive scientific process that underpinned the design of the Commonwealth marine reserves (CMRs) proclaimed in 2012, as outlined in chapter 2, and mindful of work of the Bioregional Advisory Panel (BAP) to identify possible new zoning boundaries for the CMR estate, the ESP focused its work on this term of reference on new science directly relevant to the needs of the BAP.

The BAP referred a number of matters to the ESP for advice. These matters related to areas of contention identified through the BAP consultation process. They are listed in table 3.1 and are addressed in this chapter. The associated findings were communicated to the BAP for consideration in formulating recommendations on zoning options. Broadly, these matters related to:

- concerns about the applicability of Fishing Gear Risk Assessment (FGRA) findings to certain gear types in certain areas of the CMR estate (section 3.1)
- concerns about the impact of recreational fishing (section 3.2)
- concerns about the effectiveness of different zone types (section 3.3)
- the need to have up-to-date scientific information for particular marine features and particular CMRs (sections 3.4 and 3.5).

Table 3.1 Issues referred by the Bioregional Advisory Panel to the Expert Scientific Panel for advice

Advice request	**CMR and/or network to which the request related**	**Relevant section of ESP report**
Evaluate the process used to determine fishing gear risk for CMRs.	Estate-wide	2.3.5
Review the FGRA rating for demersal automatic longline gear in the Southern and Eastern Scalefish and Shark Fishery.	Central Eastern CMR Coral Sea CMR	3.1.1
Review the FGRA rating for demersal (prawn) trawl in the Northern Prawn Fishery.	Gulf of Carpentaria CMR North CMR Network	3.1.2
Review the FGRA for the former Northern Territory Finfish Trawl Fishery in relation to semi-demersal trawl.	Oceanic Shoals CMR Arafura CMR	3.1.3
Review the FGRA rating for Western Australian trawl fisheries in relation to demersal (scallop) trawl.	Bremer CMR Geographe CMR	3.1.4

Advice request	CMR and/or network to which the request related	Relevant section of ESP report
Assess recreational fishing in relation to CMRs.	Estate-wide	3.2
Assess how different CMR zone types contribute to achieving conservation objectives and the potential merits of split zoning over coral reefs in the Coral Sea.	Estate-wide	3.3
Assess the value of specific marine features, systems and processes, including: • connectivity • the pelagic system • the continental shelf and slope • canyons and seamounts.	Estate-wide	3.4
What new information is there on the conservation values of the: • Coral Sea CMR • Geographe CMR • Bremer CMR • Perth Canyon CMR • Oceanic Shoals CMR	Coral Sea CMR Geographe CMR Bremer CMR Perth Canyon CMR Oceanic Shoals CMR	3.5

3.1 Fishing Gear Risk Assessment reviews

As discussed in chapter 2, a series of FGRAs were undertaken to assess the risk of fishing gears to biodiversity in marine regions. The ESP assessed that the process which underpinned the 2010 FGRAs drew on the best information available at the time and was appropriate in the circumstances. However, new scientific information relevant to several of the 2010 FGRAs—specifically for trawling in areas of the North, North-west and South-west CMR Networks and demersal longline in the Temperate East—is available. At the request of the BAP, the ESP reviewed this new information against the original FGRA outcomes to assist the BAP's development of recommendations on zoning options.

3.1.1 Review of the Fishing Gear Risk Assessment rating for demersal automatic longline gear specifically in relation to operations in the Coral Sea Commonwealth Marine Reserve and the Central Eastern Commonwealth Marine Reserve

Description of the location and habitat[9]

The Coral Sea and Temperate East Regions cover deepwater tropical and sub-tropical ecosystems which are dominated by the East Australian Current (EAC). With its associated eddy fields, the EAC forms large-scale, spatially predictable and ecologically important pelagic features off the east coast of Australia. The flow of these localised features is thought

[9] DEWHA (2009a) except where otherwise indicated by in-text references.

to create a barrier to larval dispersal, thus contributing to the high endemism and localised distribution of species in the region.

The majority of the eastern side of the Coral Sea CMR is deepwater, between 500 m and 2000 m, but has a significant number of seamount/guyot and saddle features which are part of the northern extent of the Tasmantid seamount chain. This chain of submerged volcanoes extends for 2000 km from the southern Coral Sea to the Tasman Basin, running north–south at approximately 155°E longitude. In the Coral Sea CMR it includes Kenn, Wreck, Cato and Fraser seamounts (DNP 2014a). Further south in the Central Eastern CMR are the Queensland and Brittania guyots and the Stradbroke, Derwent–Hunter, Barcoo and Taupo seamounts. None of these southern seamounts breaks the surface and the tops of the seamounts range in depth from around 130 m at Taupo to approximately 1800 m at Stradbroke (DNP 2014b).

The Tasmantid seamount chain is shown in figure 3.1. Taupo seamount is the largest seamount at 60 km in diameter at its base. It rises from 4800 m to a flat top only 130 m below sea level. This shallow platform, with relief of less than 10 m, is approximately 40 km north to south and up to 15 km wide. In addition to those seamounts mentioned above, many smaller unnamed and unsurveyed seamounts occur along the chain as well as subsidiary cones on the flanks of larger eminences (DNP 2014b).

The slopes on the sides of the seamounts are commonly in the range of 10 to 20 degrees but locally can be much steeper or form flat terraces cut at historical sea levels. These slopes consist of rugged rock outcrops, with boulders and blocks covered by a relatively thin layer of sediment. The seamounts shed sediment to the adjacent seabed to form an apron at their base. In some cases, this apron is removed by bottom currents to form a moat.

The seamounts have been found to have different morphologies supporting a diverse range of habitats in temperate and subtropical waters, with high levels of endemism. They comprise a unique deep-sea environment characterised by substantially enhanced currents and a fauna that is dominated by suspension feeders such as corals. Seamounts form distinctive marine habitats that provide topographical structure across the continental slopes and abyssal plains of the deep sea, altering oceanic circulation patterns with local upwellings, turbulent mixing and closed circulation cells. Topographically-induced upwelling at seamounts and the interaction between eddies and seamounts can create conditions that lead to concentration of pelagic productivity around seamounts and conditions conducive to the establishment of deep-reef communities dominated by filter feeders. Flow acceleration is favourable for recruitment and growth of passive suspension feeders, as shown by the relatively high abundance of corals on seamount peak edges where periods of flow acceleration have been observed.

The Tasmantid seamount chain is a key ecological feature (KEF) of both the Coral Sea and Central Eastern CMRs (DNP 2013b, 2013c). The major conservation values in the Coral Sea and Central Eastern CMRs are described in tables 3.2 and 3.3.

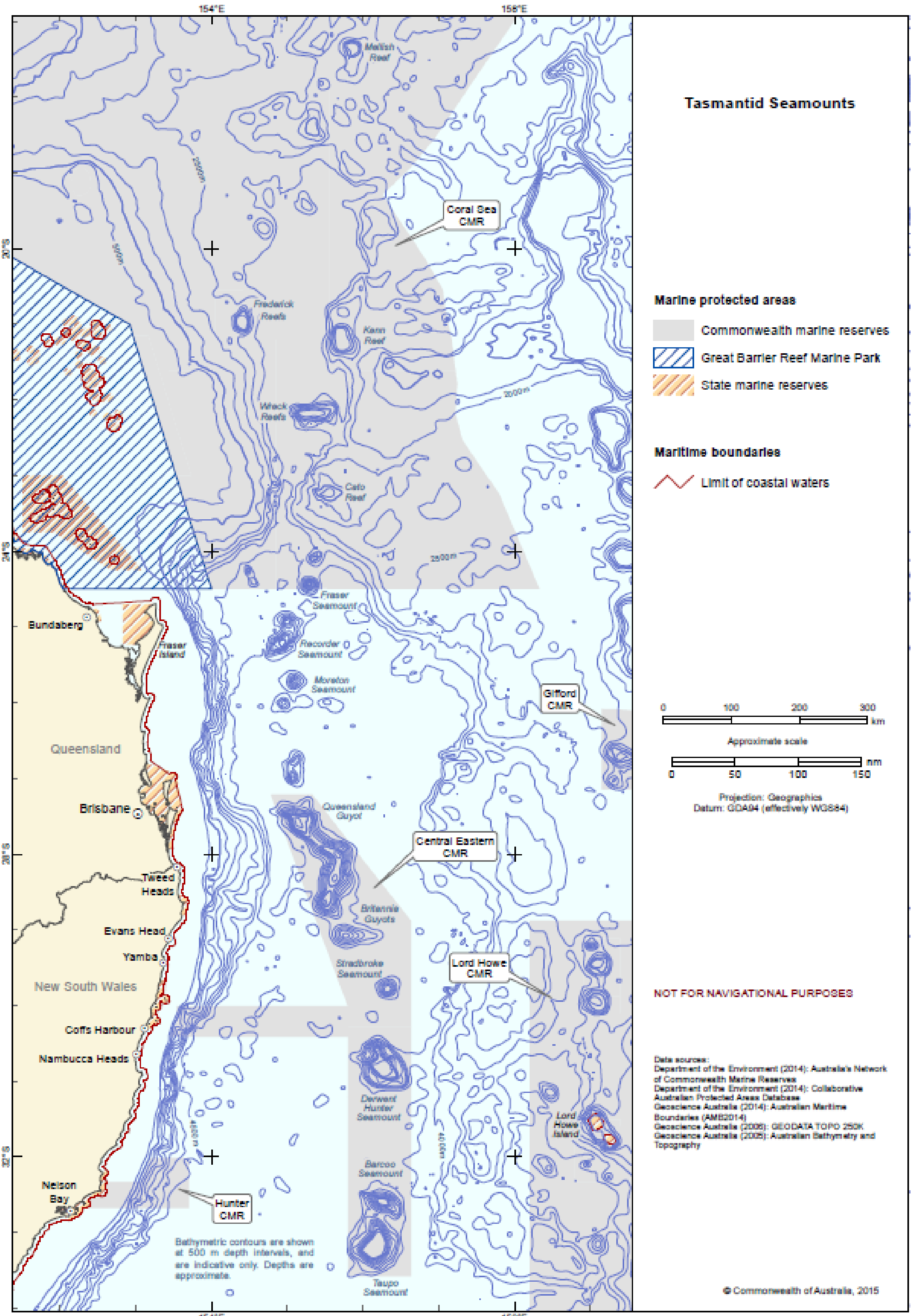

Figure 3.1 The Tasmantid seamount chain and its relationship to the Coral Sea and Central Eastern Commonwealth Marine Reserves

Table 3.2 Conservation values of the Coral Sea Commonwealth Marine Reserve* (after DNP 2014a and 2013c)

Conservation values	Description
Depth	15–5000+ m.
Seafloor features	Abyssal plain / deep ocean floor; apron / fan; basin; canyon; continental rise; deep/hole / valley; knoll / abyssal hill / hill / mountain / peak; pinnacle; plateau; reef; ridge; saddle; seamount/guyot; slope; terrace; trench / trough.
Key ecological features	Reefs, cays and herbivorous fish of the Marion Plateau. Reefs, cays and herbivorous fish of the Queensland Plateau. Tasmantid seamount chain.
Species	The reserve supports: • populations of large pelagic fish, including blue trevally, barracuda and tunas, as well as grey reef, silvertip and whitetip reef sharks • populations of highly migratory pelagic species, including small fish schools • manta rays and other fish, including humphead maori wrasse, yellowfin and bigeye tuna, and potato cod. Black marlin undergo seasonal movements into the Queensland Plateau area • high sponge diversity and endemic demersal sponge communities that are distinct from those found on the Great Barrier Reef • communities of shallow and deepwater corals, as well as crabs, echinoderms and cephalopods. Habitats and important areas for species in the reserve include: • breeding and calving grounds for humpback whales during their annual migration along the east coast of Australia • nesting and inter-nesting sites for green turtles • likely foraging grounds for hawksbill turtles • an aggregation site for whale sharks • breeding and foraging areas for a number of seabirds, including masked booby, black noddy, black-naped tern, brown booby, common noddy, crested tern, lesser frigatebird, red-footed booby, red-tailed tropic bird, sooty tern and wedge-tailed shearwater.

* Representing the Cape Province, Central Eastern Transition, Kenn Province, Kenn Transition, North-east Province, North-east Transition provincial bioregions.

Table 3.3 Conservation values of the Central Eastern Commonwealth Marine Reserve* (after DNP 2014b and 2013b)

Conservation values	Description
Biological seascapes	Represents two seabed assemblages (which are derived from sediment and depth data). Cluster 7: 137–235 m depth; very low range of seabed oxygen; very low range of water temperature at the seabed; low range of benthic irradiance. Cluster 8: 275–357 m depth; very low range of benthic irradiance.
Depth	120–6000 m.
Seafloor features	Abyssal plain / deep ocean floor; canyon; knoll / abyssal hill / hill / mountain / peak; pinnacle; seamount/guyot; slope.
Key ecological features	Canyons on the eastern continental slope (part of one of three shelf-incising canyons occurring in the region). Tasmantid seamount chain (known breeding and feeding areas for a number of open ocean species such as billfish and marine mammals).
Species	The reserve contains biologically important areas for the protected humpback whale, vulnerable white shark and a number of migratory seabirds.

***** Representing the Central Eastern Province, Central Eastern Shelf Transition and Tasman Basin Province provincial bioregions and the Tweed–Moreton meso-scale bioregion.

Gear type and relevant fisheries

Automatic longline (auto-longline) refers to the fishing method also known as demersal or bottom longline, whereby automatically baited lines are set horizontally on or in close proximity to the seafloor and held in place with anchors and floats (see figure 3.2). Longlines can be many kilometres in length and can incorporate as many as 15 000 hooks, but they typically involve one to four magazines, with each magazine storing 1500 hooks. The gear usually comprises a main line with hooks spaced every 1.3 m on 40 cm monofilament or braided cord lines called ‘snoods’. The main line is anchored at each end and attached to a downline which is buoyed with a dan pole and flag for ease of location. Auto-longline differs from other demersal longline fishing in that hooks are baited by a machine rather than by hand.

Gear is often deployed at dusk and normally left to ‘soak’ for around six to eight hours before being hauled. The main line is lowered over the stern of the vessel, where tori lines[10] are used to deter birds from diving on the baits. Hauling is done from one end over a roller mounted on the gunnels using hydraulic winches (Daley *et al.* 2007).

[10] Bird-scaring lines used to minimise seabird bycatch while fishers are setting longline gear (AFMA a).

Auto-longlines are deployed to catch finfish on or near the seafloor, typically in waters between 200 m and 800 m deep along Australia's continental shelf break and slope.

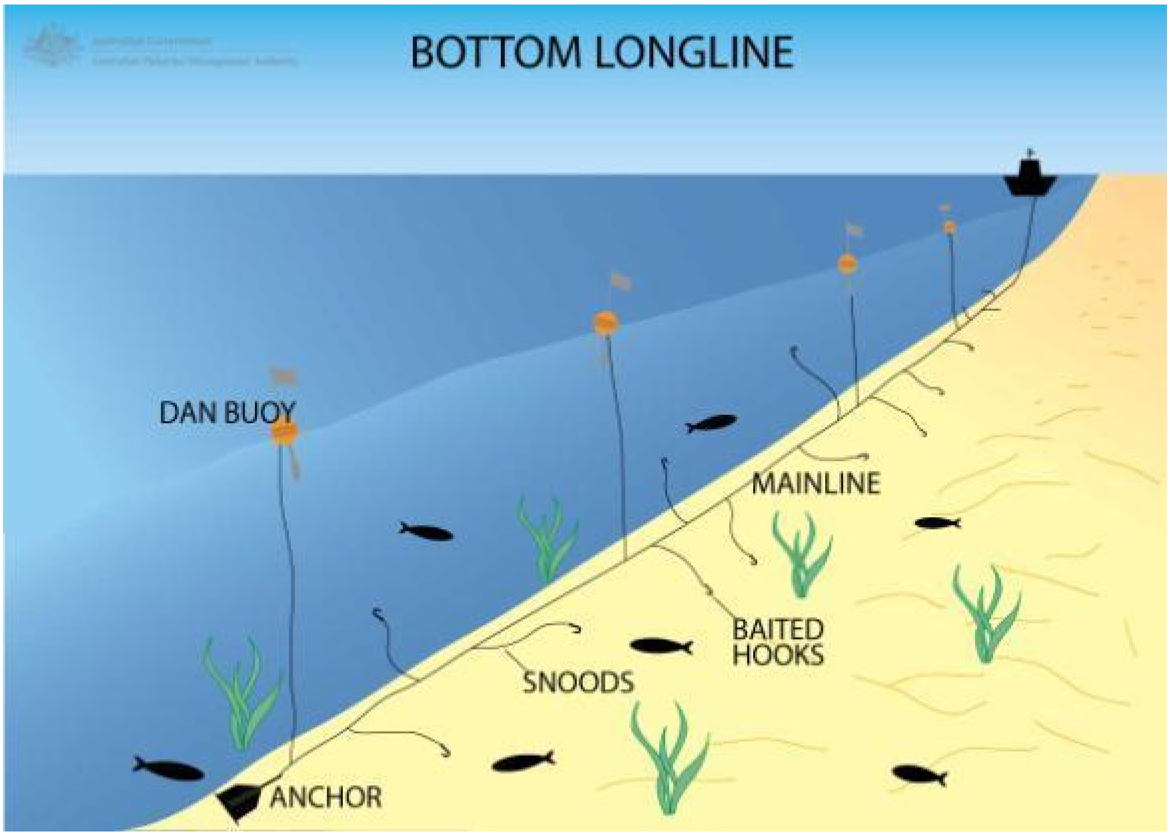

Figure 3.2 Bottom (demersal) longline fishing gear (AFMA)

In the Temperate East Region demersal longlining is part of the Gillnet, Hook and Trap Sector of the larger Commonwealth Southern and Eastern Scalefish and Shark Fishery (SESSF). This is a multi-sector, multi-species fishery that occurs in almost half of the Australian fishing zone (AFZ). It stretches south from Fraser Island in southern Queensland, around Tasmania, to Cape Leeuwin in southern Western Australia. The auto-longline fishery includes all Commonwealth waters of the AFZ off South Australia, Victoria and Tasmania that are deeper than 183 m. It also includes waters off southern Queensland (south of Sandy Cape) and New South Wales from approximately the 4000 m depth contour (60–80 nm from the coast) to the extent of the AFZ. Waters inside this line off the New South Wales and Queensland coasts, and inside 3 nm around South Australia, Victoria and Tasmania, are managed under the jurisdiction of the state governments (AFMA 2014a).

Current management arrangements in the SESSF restrict fishing by scalefish auto-longline vessels to waters deeper than 183 m to prevent targeting of school and gummy shark. The main target species are blue-eye trevalla (*Hyperoglyphe antarctica*), pink ling (*Genypterus blacodes*), with ribaldo (*Mora moro*), hapuku (*Polyprion oxygeneios*) and ocean perch (*Helicolenus barathri* and *H. percoides*) being other important commercial species.

The major markets for the scalefish auto-longline sector are in southern and eastern Australia. The amount of effort in this sector peaked in 2005 at 9 776 448 hooks set, decreasing to 4 280 916 hooks set in the 2011–12 season.

In the Coral Sea CMR, demersal longlining (including auto-longlining) is part of the Line, Trap and Trawl Sector of the Commonwealth Coral Sea Fishery, which targets finfish and shark species. The fishery extends from Sandy Cape, Fraser Island, to Cape York and east of the Great Barrier Reef Marine Park (GBRMP) outer boundary through to the edge of the AFZ. There is a small focus on the Northern Plateau edges, with most fishing on localised areas of the seamounts. Fishing occurs between 30 m and 600 m, but observer coverage indicates that 50 per cent of lines are set at depths greater than 200 m. Because of small numbers of vessels, confidentiality agreements prohibit disclosure of catch and effort. Reef and seamount species are targeted: this includes a broad range of finfish, including tropical snappers and emperors (*Lethrinidae*, *Pristipomoides* or *Lutjanidae*), eyeline snapper (*nemypterids*), coral cod (*Epinephelus* spp., *Serranidae*), jobfish (*Lutjanidae*) and coral trout (*Plectropomus leopardus*). Depending on the area being fished, other species, such as blue-eye trevalla and shark (Furlani *et al.* 2007), may also be targeted.

East Marine Region[11] Fishing Gear Risk Assessment

Demersal longline (including auto-longline) was assessed as part of the East Marine Region FGRA (Morison and McLoughlin 2010). This assessment noted several fisheries that were entitled to use this method, including the Coral Sea Fishery, the SESSF, the New South Wales Ocean Trap and Line Fishery and several Queensland line fisheries.

The fisheries of interest here are the SESSF Scalefish Hook Sector, which uses auto-longline gear in the Central Eastern CMR; and the Line, Trap and Trawl Sector of the Coral Sea Fishery, which uses demersal auto-longline.

Morison and McLoughlin (*op. cit.*) noted that the majority of effort by line fishing methods takes place in waters to the south of the East Marine Region, though there had been a small amount of exploratory activity in the Tasmantid – Lord Howe Area for Further Assessment. They noted that the SESSF auto-longline Level 2 Ecological Risk Assessment (ERA) (Daley *et al.* 2007) examined 149 habitat types and found 17 at high risk, predominantly on the upper continental slope (200–700 m). This risk arose partly from ability of auto-longline fishing to target bottom types not fishable by trawling. A key uncertainty was the effect of movement of the main line itself on large, erect and fragile epifauna. The Level 2 ERA found 56 species to be at high risk, mostly shark and seabird species (two target species, 13 by-product species, 14 bycatch species and 27 TEP species). By taxa, 21 were chondrichthyans, 26 were marine birds, eight were teleosts and one was a marine mammal.

[11] The Coral Sea CMR and Central Eastern CMR are located within the former East Marine Region, which was used as a planning region in the marine bioregional planning process.

Residual risk assessment and the Level 3 Sustainability Assessment of Fishing Effects (SAFE) ERA identified nine species (two teleosts, two skates and five deepwater sharks) at high ecological risk. These species, high priorities for ecological risk management (ERM), were blue-eye trevalla, hapuku, bight skate, grey skate, blackbelly lantern shark, Harrisson's dogfish, greeneye dogfish, platypus shark and southern dogfish (AFMA 2010a).

Morison and McLoughlin (*op. cit.*) describe two key issues that emerged from the available analyses of demersal longline fisheries in the East Marine Region which they state were consistent with the findings for risk analyses in other regions. Both were related to direct impacts from fishing:

- potential damage to seafloor habitats by the longline gear
- potential impacts on turtles and impacts on sharks and rays (in particular, deepwater shark species).

The ERA for the auto-longline sector of the SESSF identified high risks to both hard and soft bottom habitats on the outer shelf (100–200 m) and the upper slope (200–700 m) and in upper slope canyons (100–1500 m). Many of these habitats were also accessible to trawl. Morison and McLoughlin (*op. cit.*) noted that the Coral Sea Fishery ERA acknowledged the potential risks to habitats from demersal longlines, but the assessment was silent on risks to seamounts. All six species of turtle are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and appendix 1 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), but data on interactions with turtles by auto-longline is limited.

Morison and McLoughlin (*op. cit.*) noted that chondrichthyans were a common component of demersal longline catches in the East Marine Region. Catches of shark were often poorly documented and limited information was available detailing where shark catches were taken and which species were taken. Several species have been identified at high risk in assessments across the East Marine Region demersal longline fisheries and the risks assessed for chondrichthyans using the Level 3 SAFE method (Zhou *et al.* 2007) were thought to have been underestimated (Zhou *et al.* 2009).

Based on their assessment, demersal longline gear (including auto-longline) was rated as an 'Unacceptable' level of risk (pending further assessment). This assessment took into account:

- the high risk findings for benthic habitat impacts by the ERA for auto-longline gear
- a lack of information about the nature and extent of the grounds fished by these methods
- the high risk findings for several chondrichthyan species, including deepwater shark, which are considered to be least sustainable; and potential interaction with grey nurse shark.

<u>Review of the assessment of the East Marine Region Fishing Gear Risk Assessment</u>

A review of the FGRA undertaken by Daley (2010) suggested that the FGRA for the East Marine Region was largely accurate for the gear types considered in terms of their current use and foreseeable use in fisheries in the medium term (10 years). In part this time frame was constrained by use of ERA reports based on current effort footprints.

Overall the methodology was supported, but it cautioned against the use of ERA results from other fisheries in assessing risk in the East Marine Region. There was also concern that data limitations could lead to an underestimation of risk, especially to chondrichthyans.

While the review of the FGRA for the East Marine Region by Bodsworth and Knuckey (2011) considered aspects of the broader FGRA process, it did not address issues of direct relevance to auto-longline in the Central Eastern CMR or Coral Sea CMR.

Ecological Risk Assessment

Southern and Eastern Scalefish and Shark Fishery:

The Australian Fisheries Management Authority (AFMA) continues to update detailed ERAs for all major and minor Commonwealth managed fisheries as a key part of the move towards ecosystem-based fisheries management. A Level 2 Probabilistic Safety Analysis (PSA) Residual Risk Analysis for non-teleost and non-chondrichthyan species in the auto-longline sector of the SESSF was completed (AFMA 2012a). This assessment focused on species assessed as at high risk in 2010 (AFMA 2010a). Overall, 29 high risk species were reassessed, including 27 seabird species and two marine mammals. All of these had their risk scores reduced, as a Threat Abatement Plan (TAP) had been introduced for all bird species, which has a high level of compliance within the scalefish auto-longline sector of the Gillnet, Hook and Trap Sector. The Australian fur seal was added to the assessment because of 59 interactions in 2009; however, no interactions have been recorded since. For this reason, based on the number of interactions in the fishery, both Australian fur seal and Hector's beaked whale had their risk scores reduced (AFMA 2014a).

The Level 3 SAFE methodology was updated to include the most recent fishery distribution and effort data, and new species from logbook and observer data. The analysis was applied to all teleost and chondrichthyan species for six major methods in the SESSF, including auto-longline in the Gillnet, Hook and Trap Sector (Zhou *et al.* 2012).

The Level 3 SAFE analysis was applied to all teleost and chondrichthyan species in the SESSF regardless of their Level 2 PSA scores. However, without application of the residual risk guidelines, it was likely that a number of the high risk species were false positives, as management arrangements and bycatch mitigation strategies were not considered. AFMA in consultation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) agreed that it would be appropriate to apply residual risk guidelines and expert overrides to some of the 2012 risk scores. This allows management measures and interaction levels to be taken into account to determine the risk level (AFMA 2014a).

The following methodology was used:

1. For all species scored as high risk in the 2012 Level 3 SAFE analysis, record the Level 2 PSA risk score from 2007. The productivity and susceptibility scores are unlikely to have changed.
2. Apply the residual risk guidelines to the Level 2 PSA risk scores from 2007.
3. Those species which have had their risk scores downgraded will be removed from the list of priority species to be addressed in the Ecological Risk Management response.

This assessment found that five species had an estimated fishing mortality rate greater than F_{crash}—the minimum unsustainable fishing mortality rate that will lead to population extinction in the long term. When uncertainty in both estimated fishing mortality rates and reference points are included in the analysis, 15 species were assessed as at least precautionary high risk. However, when a Residual Risk Analysis was performed on this group, the number of species that remained as high risk was reduced to seven. They were Harrisson's dogfish, southern dogfish, greeneye spurdog, grey skate, sawtail catshark, bight ghost shark and hapuku.

A recent comparison of fish assemblages off south-east Australia based on automatically baited longlines and baited remote underwater video (BRUV) revealed that longlines were particularly effective in catching chondrichthyans (McLean *et al*. 2015). Their study also revealed an expected fishing mortality of greater than 50 per cent for gulper sharks, as only 43 per cent were in a condition suitable for tagging.

Coral Sea Fishery:

For the Coral Sea Fishery, the preliminary Level 1 ERA and a semi-qualitative Level 2 ERA for chondrichthyans and TEP species has been undertaken (AFMA 2010b). No ecological components were eliminated at Scoping or Level 1 (there was at least one risk score of 3—moderate—or above for each of the components). Most hazards (fishing activities) were eliminated at Level 1 (risk scores 1 or 2). Six issues emerged from the ERA Level 1 analysis of the Coral Sea Fishery auto-longline sub-fishery (Furlani *et al*. 2007):

- Fishing capture was identified as a hazard to Target, By-product, Habitat and Communities components, largely as a result of repeated effort on fairly limited fishing grounds and the consequent risk of localised depletion. Information on target and bycatch species is limited.
- Fishing activity without capture was identified as a habitat hazard due to the nature of the gear set and the lack of regeneration information for tropical-water habitats. Erect, inflexible and fragile fauna are at risk, especially during setting and recovery if currents are strong. Regeneration times for most deepwater species are thought to be long.
- Gear loss without capture was identified as a hazard to species components, with Fishing Activity Reports noting the regular occurrence of gear loss. The absence

of data, or mitigating measures, has produced a low confidence score in the assessment of this moderate hazard.

- Translocation of species was identified as a moderate hazard to Target, By-product and TEP components and a major risk hazard to Habitat and Community components. This risk arises through hull fouling and bilge water as well as the use of imported baits.
- Provisioning was identified as a hazard to the TEP component. Birds are known to be attracted to baited hooks, and the hazard presented by auto-longline fishing has been well documented in other fisheries. For the Coral Sea Fishery, the use of tori lines is a permit condition as a means of mitigating this risk.
- Gear loss impact, through the addition of non-biological material, was identified as a hazard to species components. Remaining lines and hooks continue to present an entanglement hazard. The lack of data to assess this risk has resulted in a low confidence score.

Additionally, for the Coral Sea Fishery line sector, three main groups—turtles, bathyl sharks (at water depths greater than 200 m) and reef sharks—were identified through the semi-qualitative Level 2 ERA process. The greatest bycatch issue identified to date in the Coral Sea Fishery is considered to be the potential interaction of TEP species such as turtles and sharks (AFMA 2010b).

Information on this fishery is sparse. Williams *et al.* (2012) highlighted the lack of data in relation to protected shark species for the Fraser Seamount, noting it is within the distribution range of the Harrisson's dogfish. There is no bycatch action plan currently in place for the Coral Sea Fishery, with the Coral Sea Fishery Bycatch and Discarding Workplan 1 July 2010 to 30 June 2012 (AFMA 2010b) being on hold pending finalisation of the Coral Sea CMR and any associated industry adjustment (AFMA 2013). Monitoring of all catches of target species has been recommended for this sector to allow consideration of trends and develop management responses (Furlani *et al*. 2007) Under the 2010–2012 bycatch and discarding workplan, a fisheries monitoring programme was in place. This programme required verification of catch logbooks and deployment of observers (AFMA 2010b).

AFMA continues to monitor the catch of target species, which is reported in its annual fishery status reports (Patterson *et al.* 2015).

Provisions to limit catches in the Coral Sea Fishery include trip limits for deepwater sharks (introduced in 2010) and limits (in kilograms per permit, similar to those used in the SESSF as part of the stock-rebuilding strategy for the upper-slope dogfish) for all deepwater sharks that occur in the Coral Sea Fishery, believed to be about 19 species (AFMA 2010b).

The diverse range of species in the Coral Sea Fishery, frequent exploratory and variable fishing undertaken in the fishery, generally low level of fishing activity and limited opportunity to undertake research and collect data means that differentiating target species from bycatch and discard species can be difficult (AFMA 2010b).

Ecological Risk Management

There is no ERM strategy for the Coral Sea Fishery. The ERM strategy for the SESSF (AFMA 2015) sets out the management actions necessary to support the objectives of the *Fisheries Management Act 1991* and Commonwealth Policy on Fisheries Bycatch 2000—in particular:

> *ensuring that the exploitation of fisheries resources and the carrying on of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development (which include the exercise of the precautionary principle), in particular the need to have regard to the impact of fishing activities on non-target species and the long term sustainability of the marine environment.*

To pursue this, the objectives of this ERM strategy are to:

- implement management arrangements to minimise fishing impact on non-target species and habitats, with a particular focus on high-risk species and habitats assessed through AFMA's ERA process
- minimise interactions with species listed under the EPBC Act, excluding conservation dependent species.[12]

The ERM strategy describes a number of management tools, which broadly fall into two categories: input controls and output controls. Input controls limit the amount of effort in a fishery, indirectly controlling interactions with target, by-product, bycatch and threatened, endangered or protected (TEP) species. Output controls directly limit the number of species which can be taken from the water or interacted with.

Key to this ERM strategy is addressing the seven high-risk species as assessed through the ERA process (AFMA 2014a); however, it also addresses broader aspects of bycatch and habitat interactions, with a number of measures aimed at mitigating impacts as outlined below (AFMA 2015).

Marine mammals

While no marine mammals were identified at high risk from auto-longline, mitigation strategies include:

- spatial closure
- hook limitations
- anchorage of gear to the seafloor
- electronic monitoring on all vessels.

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[12] Some key commercial species are listed under the EPBC Act in the category of conservation dependent. However, these species are managed in accordance with the Commonwealth Fisheries Harvest Strategy Policy under species-specific rebuilding strategies and therefore do not fall under the ERM framework, with the exception of school shark, which is currently assessed as high risk under the ERA.

Sharks, skates and rays

Mitigation strategies include:

- size limits and trigger limits
- fishers must not retain Harrisson's dogfish, southern dogfish, endeavour dogfish and greeneye dogfish
- mandatory handling practices for species of the family *Centrophotidae* (excluding *Deania* spp.) and *Squalidae*
- regulations in relation to finning and shark livers
- gear restrictions (hook limits and prohibition of wire trace)
- anchorage of gear to the seafloor
- spatial and temporal closures:
    - restriction of auto-longline gear to waters deeper than 183 m
    - closures under the Upper-slope Dogfish Management Strategy
- bycatch and discarding workplan (AFMA 2009)
- chondrichthyan guide for fisheries managers (Patterson and Tudman 2009)
- upper and lower reference limits for species of concern
- National Plan of Action for the Conservation and Management of Sharks (DAFF 2012)
- Upper-slope Dogfish Management Strategy (AFMA 2012b).

Industry has also implemented a code of conduct aimed at improving the handling practices and the release of live sharks. The bycatch working group has noted that most sharks reach the surface alive and there is thus the potential for them to be released.

Seabirds

Seabirds are no longer identified as a high-risk group in the most recent ERA re-evaluation. This is primarily due to strict management arrangements through the TAP (AAD 2014) process.

Teleosts

Mitigation strategies for teleosts include:

- hook limits
- anchoring longlines to the seafloor
- depth restrictions
- spatial closures
- electronic monitoring on all vessels.

Habitat

Several habitats are at least potentially at risk from auto-longlining operations. A key uncertainty remains the effect of movement of the main line itself on large, erect and fragile epifauna. This risk is mitigated through the several closures in the fishing area, including CMRs.

Upper-slope Dogfish Management Strategy[13]

Harrisson's dogfish have been shown to be present on the Tasmantid Seamounts and that area closures and gear restrictions would significantly enhance protection and recovery of the species. Noting that trawl was not permitted on the seamounts, it was proposed that line fishing be limited to hydraulic reel drop-line fishing only (this method also called power-handline fishing or minor-line fishing). Using this method, lines are always attended, fewer hooks are used and soak times are short. As a consequence, gulper sharks are brought to the surface in a vigorous condition, may be quickly released and are expected to have survival rates greater than 90 per cent (Williams *et al.* 2013). Bycatch using this method was negligible.

This strategy was revised in 2012 to promote the recovery of two species of dogfish: Harrisson's dogfish (*Centrophorus harrissoni*) and southern dogfish (*C. xeehaani*). The strategy relies primarily on a network of spatial closures (see figure 3.3) complemented by a range of non-spatial operational measures. The network builds on existing closures by implementing new closures, extending existing closures and revising existing closures (see table 3.4). It also provides some protection to endeavour dogfish (*C. moluccensis*) and greeneye spurdog (*Squalus chloroculus*).

The types of management arrangements which apply under the strategy include:

- a prohibition on the take of Harrisson's dogfish and southern dogfish
- area closures
- monitoring obligations through observers or electronic monitoring
- a limit for bycatch of Harrisson's dogfish and southern dogfish when undertaking permitted types of line fishing in specific areas
- handling practices to improve post-capture survival for released sharks.

[13] AFMA 2012b, except where otherwise referenced.

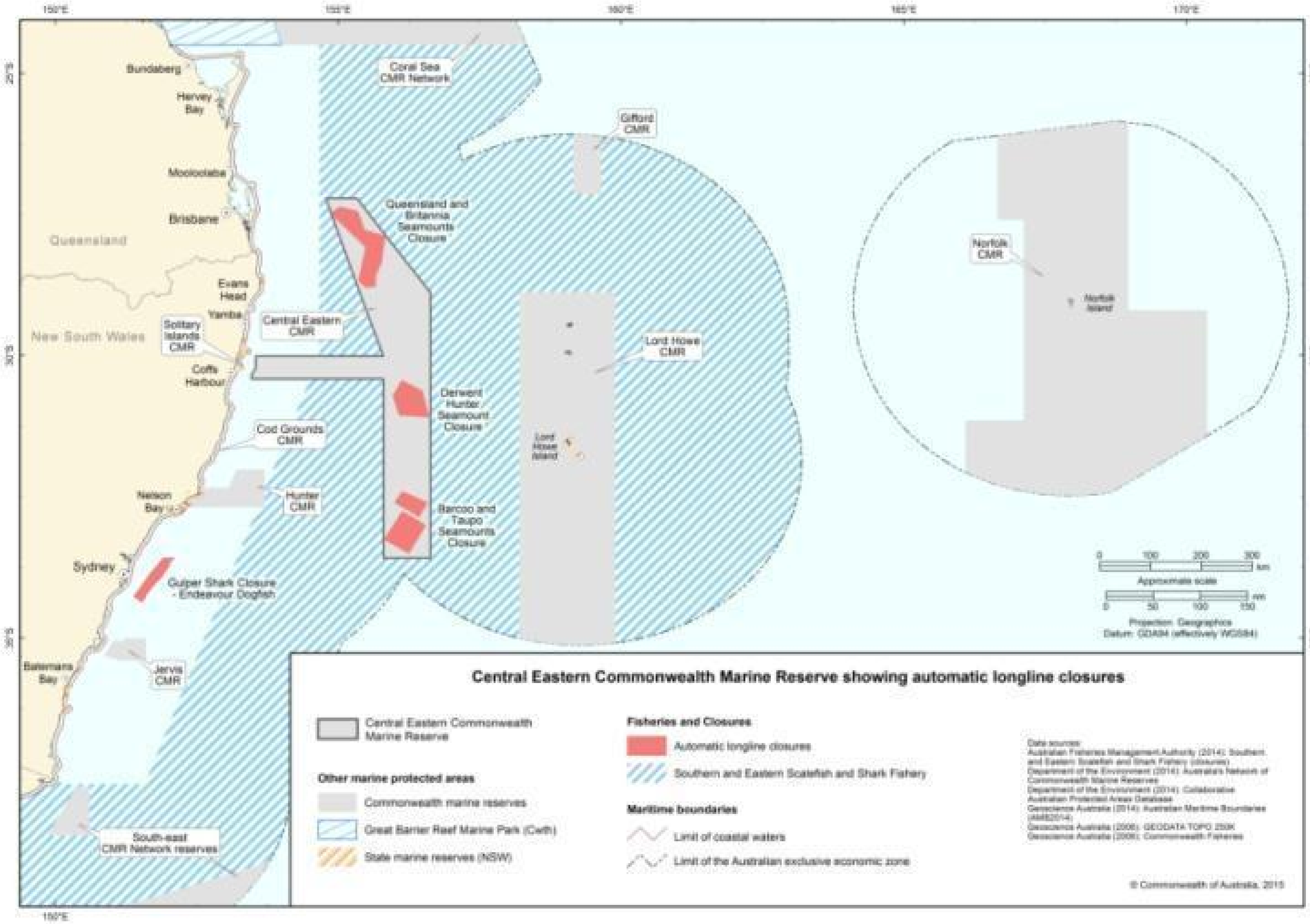

Figure 3.3 The Temperate East CMR network showing the extent of the SESSF and auto-longline closures

Table 3.4 Closures under the Upper-slope Dogfish Management Strategy that are relevant to the Central Eastern Commonwealth Marine Reserve (after AFMA 2015)

Spatial closures	Details	Complementary management arrangements where fishing is permitted inside closures
Extended closures		
Extended endeavour dogfish closure off Sydney	Extended closure to all methods of fishing across the core depth range	Fishing is not permitted, so complementary measures are not applicable
New closures		
Derwent Hunter Seamount	Closed to all fishing methods	Fishing is not permitted, so complementary measures are not applicable
Queensland and Brittania Guyots	Closed to demersal longline (including trotline and auto-longline) Open to hydraulic hand reel drop-lining only	Line fishing subject to regulated handling practices, interaction limit per boat and 100% monitoring* Vessel interaction limit of three gulper sharks. If limit is reached, the closure will apply to that boat for 12 months Trigger limit removed for power handline method
Revised Closures		
Barcoo Seamount and Taupo Seamount	Will remain closed to all trawl methods Will be open to line fishing	Line fishing subject to regulated handling practices and 100% monitoring* Vessel interaction limit of three gulper sharks. If limit is reached, the closure will apply to that boat for 12 months Trigger limit removed for power handline method

* 100 per cent monitoring by an approved AFMA method.

Impacts on the benthos

The global expansion of deep-sea fisheries has raised alarm about its sustainability (Norse *et al*. 2012; Watson and Morato 2013; Watling 2013), especially because it has predominantly been through trawl. Mobile gears such as dredge and trawl have been shown to cause significant reductions in the heterogeneity of habitats (Pitcher et al. 2000; Glover and Smith 2003; Clark and Rowden 2009). Static gear such as demersal longlines have been less well studied, but research is emerging to suggest that demersal longlining has a significantly lower footprint than trawling and may be viewed as a sustainable alternative for deep-sea fisheries. Pham *et al.* (2014) showed that demersal longline fishing had little impact on vulnerable marine ecosystems in the Azores, less impact than trawl on deepwater coral species and limited damage to benthic communities. However, earlier work, including that of Munoz *et al*. (2011), reached a different conclusion and suggested that, although bottom longlines are expected to be much less damaging than trawls to deepwater coral and other erectile benthos, they may still represent a threat if fishing intensity is high. In a detailed study of the impact of demersal fishing gear on deepwater benthic ecosystems in the Heard Islands and MacDonald Islands toothfish and icefish fisheries, Welsford *et al*. (2014)

showed that longlines were static on the benthos but exhibited significant lateral movement during hauling. Bycatch, although less in quantity, was taxonomically similar to trawl.

ESP finding

Recent management arrangements implemented by the Australian Fisheries Management Authority, particularly those relating to spatial closures, together with use of tori lines and industry codes of practice designed to improve the survival of bycatch, have significantly mitigated the threat of demersal longline fishing to vulnerable chondricthyans and seabirds in the Central Eastern Commonwealth Marine Reserve. In addition, current fishery closures limit demersal longline fishing on most of the seamounts in this reserve.

Information on the impact of the auto-longline sector of the Coral Sea Fishery in relation to target species, bycatch species and habitat is poor, but closer monitoring of logbooks and placement of observers has been recommended.

The impact of demersal longline fishing on deepwater habitats such as those found in the Central Eastern and Coral Sea Commonwealth Marine Reserves remains uncertain, as to date no research has specifically assessed this risk.

In some circumstances and under appropriate management arrangements, demersal longline may be a more sustainable method relative to trawl for deepwater fisheries off the continental slope and on seamounts. However, this will depend largely on the habitat characteristics of the area fished and the intensity of fishing.

Spatial closures appear to offer the best protection where catch rates of non-target species are high.

Until such time that these relationships can be properly understood, a precautionary approach to deepwater fishing should be maintained. For this reason, demersal longline fishing (including auto-longlines) should remain a method that is incompatible with the conservation values of the Central Eastern and Coral Sea Commonwealth Marine Reserves, particularly those relating to seamounts.

3.1.2 Review of the Fishing Gear Risk Assessment rating for the Northern Prawn Fishery, specifically in relation to the Gulf of Carpentaria Commonwealth Marine Reserve

<u>Description of the location and habitat</u>

The Gulf of Carpentaria CMR covers the marine environment from waters adjacent to the Wellesley Islands into the Gulf of Carpentaria Basin (DNP 2014c). The Gulf of Carpentaria is a large, shallow, muddy marine bay with marked seasonality in temperature, rainfall, salinity and wind regimes. The dominant weather feature is a seasonal summer monsoon, with associated northerly winds and rain, and a very dry winter period with south-east trade winds (Delaney 2012).

It has a diversity of land forms, including offshore islands, fringing coral reefs, sandy, muddy and cliff-lined coastal topographies and extensive mud/sand tidal flats. Extensive open coastline seagrass communities have been reported in the southern Gulf in the past, mainly of the genera *Halodule* and *Halophila* intertidally, and *Syringodium* and *Cymodocea* subtidally (Roelofs *et al.* 2005)

Sediments throughout the Gulf of Carpentaria are predominantly fine muds (Long *et al*. 1995), and these are easily resuspended due to the shallow bathymetry resulting in increased turbidity. Cyclones and storms also readily disturb and shift sediments in this shallow environment (Roelofs *op. cit*.), affecting benthic distributions (Post *et al*. 2006).

The Gulf of Carpentaria is unique in that it is the largest tropical epicontinental sea in the world. The gulf basin functions as a predominantly closed ecosystem, with biological productivity strongly dependent on benthic nutrient cycling and mixing of nutrients through the water column. The benthos (the assemblage of organisms inhabiting the seafloor) is dominated by deposit feeders and scavengers, including echinoids (heart urchins and sand dollars), bivalve molluscs, polychaete worms, prawns and demersal fish (sharks and rays). Sponges, sea pens, solitary corals and ascidians are common in areas where the seafloor is exposed to stronger currents. Dugongs, marine turtles, dolphins and large numbers of birds migrate through the basin waters to internationally significant breeding, nesting and feeding sites on the Gulf of Carpentaria coastline. Rich assemblages of schooling fish feed on diverse and abundant plankton and in turn attract aggregations of higher order predators (for example, sharks, mackerels, snappers, seabirds, cetaceans and sea snakes) (DEWHA 2008a).

The conservation values of the Gulf of Carpentaria CMR are summarised in table 3.5.

Table 3.5 Conservation values of the Gulf of Carpentaria Commonwealth Marine Reserve* (after DNP 2014c and DNP 2013d)

Conservation values	Description
Biological seascapes	Represents eight seabed assemblages (which are derived from sediment and depth data). Cluster 1: Moderately high variation in seabed oxygen, moderately low chlorophyll A, moderately low turbidity, primarily sandy, deep mid-shelf. Cluster 4: High sediment mud content, low sediment sand content, low chlorophyll A, low turbidity, high salinity average, high variation in seabed oxygen, mid-shelf depth. Cluster 7: High variation in sea surface temperature, very high salinity average, high variation in water temperature at the seabed, inner-shelf depth range. Cluster 12: Low sediment mud content, moderately high sediment sand content, inner-shelf depth range. Cluster 13: Very high variation in sea surface temperature, very high benthic irradiance, very shallow, high sediment sand content, very high average seabed oxygen, high chlorophyll A, low sediment carbonate, relatively low average sea surface temperature, high turbidity. Cluster 14: Very low sediment mud content, high sediment sand content, high sediment gravel content, high sediment carbonate, relatively low average sea surface temperature, very high variation in salinity, very high variation in bottom stress, very high bottom stress, moderately shallow. Cluster 16: Moderately high salinity average, moderately high variation in seabed oxygen, depth range. Cluster 20: Very high sediment sand content, low sediment mud content, low sediment gravel content, relatively low sediment carbonate, high average seabed oxygen.
Depth	The reserve covers a depth range of approximately 10–55 m. It represents the coast to shallow shelf transition of the Northern Shelf Province.
Seafloor features	Plateau, saddle, shelf, canyon, deep hole / valley, reef, specifically submerged coral reefs that support large plate corals (*Turbinaria* spp.), abundant hard corals and a large proportion of soft corals.
Key ecological features (KEFs)	The Gulf of Carpentaria CMR represents four KEFs: - the Gulf of Carpentaria coastal zone, recognised as a unique seafloor feature with an important ecological role and for its feeding and breeding aggregations of species - the plateaux and saddle of the Wellesley Islands, made up of living patch reefs that support reef fish that are unique within the Gulf of Carpentaria. Octocorals, sponges, acsidians and gorgonians are also likely to occur in the area - submerged coral reefs of the Gulf of Carpentaria - the Gulf of Carpentaria Basin.

cont’d overleaf

* Containing representative examples of the Northern Shelf Province provincial bioregion and the Carpentaria, Karumba–Nassau and Wellesley meso-scale bioregions.

Table 3.5 Conservation values of the Gulf of Carpentaria Commonwealth Marine Reserve* (after DNP 2014c and DNP 2013d) cont'd

Conservation values	Description
Species	Important inter-nesting habitat for threatened green and flatback marine turtles preparing successive egg clutches for laying on nearby coasts. Important foraging habitat for breeding aggregations of migratory birds, including the lesser frigatebird, brown booby and roseate tern, and for the listed marine crested tern. Large aggregations of dugong. Breeding and aggregation habitats for many fish species, refuges for sea snakes and apex predators (such as sharks), and important habitat for invertebrates such as crustaceans and polychaete worms. Heart urchins and sand dollars, sponges, solitary corals and sea cucumbers, as well as top predators such as snappers.

* Containing representative examples of the Northern Shelf Province provincial bioregion and the Carpentaria, Karumba–Nassau and Wellesley meso-scale bioregions.

Gear type and fisheries in the Northern Prawn Fishery

Trawl nets are designed to be towed by a boat along the seafloor (bottom trawl). They are shaped like a cone or funnel with a wide opening to catch fish or crustaceans and a narrow, closed 'cod-end'. Bottom trawls use trawl doors known as otter boards to keep the mouth of the net open (AFMA b).

Vessels in the Northern Prawn Fishery may tow a range of nets in a variety of configurations that are regulated by the *Northern Prawn Fishery Management Plan* 1995 (AFMA 2014b). These include multiples of two, three or four nets, with long arms (or booms) extending out from each side of the boat to allow the nets to fully open. Prawn trawl nets use ground chain for weight, which skims the seabed and encourages prawns living on the sea floor up into the trawl mouth. In addition to the main fishing gear, smaller 'try-nets' are used to test the potential of catches in a given area (Banks *et al.* 2012).

Physical devices, such as excluder and bycatch reduction devices within trawl nets, are used by fishers to divert unwanted species out of the net. This is important, as it allows small fish, larger animals and protected species to escape the net (Eayrs *et al.* 1997).

The fishery targets several species in three distinct sub-fisheries (Banks *op. cit.*). These are:

- the banana prawn sub-fishery (usually from 1 April and up to mid-June, but may be shortened using applied input control rules), targeting white banana prawns (*Fenneropenaeus merguiensis*) in water depths less than 20 m
- the tiger prawn sub-fishery (usually from 1 August and to 30 November but may be shortened using applied input control rules), generally (but not exclusively) comprising mixed catches of adult brown tiger prawns (*Penaeus*

esculentus) between 10 m to 20 m, grooved tiger prawns (*P. semisulcatus*) over fine mud and often in deeper water, and blue endeavour prawns (*Metapenaeus endeavouri*) and red endeavour prawns (*M. ensis*), usually between 30 m and 45 m
- the Joseph Bonaparte Gulf sub-fishery, targeting red-legged banana prawns (*Fenneropenaeus indicus*), which historically has operated in both seasons but has been closed in the banana prawn season from 2007 to 2010 inclusive as a trial to improve the economic return from the fishery. Fishing takes place in deeper water at depths of 45 m to 85 m.

Although the gear is the same in each sub-fishery, the method of deployment changes depending on the type of prawn targeted.

In the tiger prawn sub-fishery, the trawl is generally lowered to fish as close as possible to the seabed and towed for three to four hours. The white banana prawn sub-fishery gear is lowered for less than an hour on aggregations in the water column identified by an echo sounder, whilst in the red-legged prawn sub-fishery the gear is towed above the seabed. Both are considered to have a lighter ‘touch’ than that of the tiger prawn fishery (Banks *et al.* 2012).

Therefore, most of the benthic impacts from Northern Prawn Fishery operations are likely to be associated with the tiger prawn sub-fishery and to a lesser extent the banana and Joseph Bonaparte Gulf sub-fisheries. The impacts of the banana prawn sub-fishery are likely to be water column or pelagic impacts and not benthic impacts.

In recent years in the Northern Prawn Fishery, fishing effort has declined significantly from 286 vessels in 1981 to 52 vessels in 2009. Although intensity and frequency of trawling are fisheries management issues and therefore outside the purview of an FGRA, it is worth noting that surveys show only about three per cent of the fisheries management area is trawled (Brewer *et al.* 2007). Furthermore, the large number of spatial and temporal closures adopted by the Northern Prawn Fishery serves to protect vulnerable habitats such as seagrass beds and coral and rocky reefs (Kenyon *et al.* 2005).

<u>North and North-west Fishing Gear Risk Assessment</u>

This assessment for the North and North-west CMRs was based on risks that commercial fishing methods posed to the conservation values identified in the AFAs in the North and North-west Marine Regions (Lack 2010).

Lack’s 2010 assessment relied on the outputs of the AFMA ERAs for Commonwealth fisheries (Griffiths *et al.* 2007). ERAs are determined using the Ecological Risk Assessment for Effects of Fishing (ERAEF) methodology developed by the CSIRO (Hobday *et al.* 2007). ERAs were supplemented by qualitative Ecologically Sustainable Development Assessments (ESDAs) for state and territory fisheries, DEWHA EPBC Act assessment reports and available information on the management and status of fisheries published by state, Northern Territory and Commonwealth fisheries management agencies.

Level 3 ERAs (using the fully quantitative SAFE method), which calculate *absolute* levels of risk, have been conducted for teleosts and chondrichthyans in all Commonwealth managed fisheries authorised to operate in the North and North-west Marine Regions (Brewer *et al.* 2007; Zhou *et al.* 2009). Level 2 assessments, which lead to an assessment of *potential* risk, have been carried out for target species and in most cases for by-product/bycatch, TEP species and habitats, although in some cases some of these elements were eliminated from further analysis in Level 1 (see table 3.6). Both Level 2 and Level 3 ERAs were used in the FGRA. This results in a mixture of 'potential' and 'actual' risks being assessed; however, it ensures that the best available information is used to inform the assessment (Lack *op. cit.*).

Table 3.6 Authorised fisheries / main methods and key information available (after Lack 2010)

North Marine Region		**North-west Marine Region**	
Fishery	Risk assessment information	Fishery	Risk assessment information
Northern Prawn Fishery (AFMA)	ERA: Level 1—communities eliminated Level 2—target, by-product/bycatch and TEP species and habitats Residual Risk Analysis of the 28 high-risk species Level 2.5 (earlier version of Level 3) analysis of 26 high residual risk species Level 3 SAFE for sea snakes	Northern Prawn Fishery	ERA: Level 1—communities eliminated Level 2—target, by-product/bycatch and TEP species and habitats Residual Risk Analysis of the 28 high-risk species Level 2.5 (earlier version of Level 3) analysis of 26 high residual risk species Level 3 SAFE for sea snakes

The outcome of Lack's (*op. cit.*) assessment was that demersal trawl (prawn trawl) posed an unacceptable level of risk to sawfishes and habitat types in the Gulf of Carpentaria. In summary, two areas of concern were raised from the analysis of demersal and/or semi-demersal trawl on the Conservation Values of the North Marine Region:

1. risks associated with impacts on benthic habitats
2. risks posed to sawfishes and other chondrichthyans.

Benthos

Lack (*op. cit.*) reported that the banana prawn sub-fishery of the Northern Prawn Fishery targeted aggregations in waters generally less than 20 m, was very selective and used smaller trawl gear and shorter shots than the tiger prawn sub-fishery. This fishery, which trawls at night in waters of more than 20 m in depth, was less selective and used heavier/larger gear and longer shots. As a consequence, the tiger prawn sub-fishery was thought to pose a higher risk to seabed habitat than did the banana prawn sub-fishery.

Lack (*op. cit.*) noted that the Level 1 scoping results for the ERA, as reported in Griffiths *et al*. (2007), confirmed the uncertainty about the recovery of erect, rugose and inflexible octocorals (which are associated with soft, muddy substratum) that are damaged through interaction with trawl gear, particularly the heavier and more intensive use of gear in the tiger prawn sub-fishery. The results indicate the need for data on resilience and recovery times of mud-based habitats. The ERA report notes that regeneration times of damaged tissues will vary between species and that, while in coastal margin depths (0–25 m) and inner shelf depths (25–100 m) regeneration can be expected to be reasonably rapid as fauna are likely to be well adapted to frequent and considerable disturbance regimes (for example, strong currents, run-off and cyclones), more structurally complex forms/communities may take more than one year to recover. Therefore, it might be inferred that, in areas where trawling is conducted annually, there is potential for the gear to impede the recovery of more complex forms/communities.

However, Lack (*op. cit.*) notes that, since the ERA was conducted, the results of the Great Barrier Reef Seabed Biodiversity Project (Pitcher *et al*. 2007) were released. These results suggest that less than seven per cent of the 850 species (bycatch and benthic species) were significantly affected by trawl effort. However, Pitcher (2014) notes that the impact was related to trawl effort and that uncertainty in the distributions, relative catch rates and natural mortality rates of several species required a precautionary response. Nevertheless, Lack (*op. cit.*) suggested that these findings, if they are transferable to the areas fished by the Northern Prawn Fishery, may suggest that trawling poses less of a risk to benthic habitats and communities than implied by the qualitative assessment of the Level 1 ERA.

Lack (*op. cit.*) noted that the Level 2 ERA for the Northern Prawn Fishery assessed 157 habitats, none of which were found to be at high risk. Sixty-five habitats were assessed to be at medium risk and 92 were at low risk. Of the medium-risk habitats, 48 were inner shelf habitats (0–100 m) dominated by flat to highly irregular unconsolidated sediments of mud to coarse grained biogenic gravels, with large erect sponges, hard and soft corals, complex communities of mixed fauna, and individual animals. The remaining 17 medium-risk habitats were coastal margin habitats (0–25 m), which also include several soft sediment seabed types but which were dominated by seagrass communities not identified from the inner shelf.

However, Lack (*op. cit.*) notes that the ERA report by Griffiths *et al.* (*op. cit.*) cautions that:

> *A complication of the construction of the PSA model means that no NPF habitats can appear at high risk from prawn trawling. This is largely because of the way that the PSA calculation is influenced by the scoring of the Productivity attributes, with shallow habitats assumed to be quite productive with good recovery rates.*

Therefore, Lack concludes that further analysis is required to validate the Level 1 and Level 2 ERA findings on the impact of demersal trawl gear on benthic habitats in the North Marine Region to ensure that there are no high-risk impacts.

Sawfishes and chondrichthyans

A key component of the initial FGRA for the North/North-west was consideration of the potential impact of fishing gear on TEP species. It identified risks posed to sawfishes and other chrondrichthyans as an area of concern.

All trawl nets in the Northern Prawn Fishery are required to be fitted with approved turtle excluder devices (TEDs) and bycatch reduction devices (BRDs) and it was one of the first fisheries to explicitly focus research on bycatch reduction and implement measures to mitigate impacts on bycatch (AFMA 2011). For example, the mandatory use of TEDs since 2000 has been shown to reduce turtle bycatch by 97 per cent, reduce the capture of large sharks and rays by 86 per cent and 94 per cent respectively, and reduce the narrow sawfish bycatch by over 93 per cent.

Lack (*op. cit.*) noted that the refinement of the SAFE methodology had led to the application of a more conservative relationship between reference points and life history. Sawfishes were identified as a draft conservation priority in the North Marine Region. Lack noted that three of the five species were listed as vulnerable under the EPBC Act and all five species were listed (four species on Appendix I and one species—freshwater sawfish—on Appendix II) on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Lack (*op. cit.*) noted that, while TEDs had been successful in reducing elasmobranch bycatch, they were not effective in excluding sawfish species, specifically the green and freshwater sawfish. Level 2 ERA results rate sawfishes at high risk due to low fecundity and high susceptibility to being caught in nets (AFMA 2008); however, the Gulf of Carpentaria ESDA found sawfish to be at a medium risk in the Gulf of Carpentaria Demersal Finfish Trawl Fishery (Zeller and Snape 2006). Brewer *et al.* (2007) did not find sawfishes to be at risk from the Northern Prawn Fishery alone, as they were widely distributed and subject to being caught in other fisheries. They recommended that a precautionary approach be adopted because they were subject to cumulative risk.

Lack (*op. cit.*) noted that the SAFE assessment for the Northern Prawn Fishery, and subsequent incorporation of expert opinion, had resulted in the blotched fantail ray and the porcupine ray being assessed as at extreme high risk in the Northern Prawn Fishery. Patterson and Tudman (2009) provide some guidance on potential mitigation measures for the blotched fantail ray, but note that there are no proven mitigation measures available to specifically reduce interactions with the blotched fantail ray and the porcupine ray.

In summary, Lack's analysis led to a finding of 'Unacceptable' risk for demersal (and semi-demersal) gear based on:

- the need to apply the more precautionary, high-risk findings of the Level 2 assessment for sawfish species given the acknowledgement that the Level 3 Northern Prawn Fishery assessment for chondrichthyans was not sufficiently conservative and the lack of proven measures to mitigate this impact
- the lack of proven measures to mitigate the impact on the high-risk species of blotched fantail ray and porcupine ray
- uncertainties arising from the application of the PSA model to habitats in the Northern Prawn Fishery.

Use of the Fishing Gear Risk Assessments

The FGRA findings were an input into the zoning matrices for the draft and final proclaimed North and North-west CMR Networks. The Gulf of Carpentaria CMR was proclaimed with two zones—Marine National Park Zone and Multiple Use Zone. Demersal trawl is excluded from these zones.

Subsequent consultation on the draft management plan for the North CMR Network resulted in a change to the zones for the Gulf of Carpentaria CMR, replacing the Multiple Use Zone with a General Use Zone (Carpentaria) to allow demersal trawling to continue. This confirmed the consistent application of the International Union for Conservation of Nature (IUCN) categories across CMRs and allowed for the continuation of additional or existing commercial fishing activity. The Director of National Parks report concerning responses to public comments on the North Commonwealth Marine Reserves Network Management Plan (2013) (DNP 2013f) made the following observation:

> *This amendment reflects consideration of information in a submission on the economic significance of this area to the Northern Prawn Fishery, the long history and more recent results of research and monitoring on the environmental impacts of bottom trawling in this specific area, the fishery's focus on long-term sustainability, and its accreditation by the Marine Stewardship Council.*

Additional information

In 2012 the Northern Prawn Fishery received certification against the strict environmental standards set by the Marine Stewardship Council (MSC). As part of this certification process, an assessment was done of all relevant literature, including the ERAs, against the criteria of the MSC. Principle 2 is specifically relevant to this process in that it examines five components (retained species, bycatch species, TEP species, habitats, ecosystems) which are considered to cover the range of potential ecosystem elements that may be impacted by a fishery, taking into account the status, management strategies and information relevant to each of these components (Banks *et al.* 2012).

Impacts on benthos

Key environmental concerns related to trawling usually focus on the physical disturbance to the benthic habitat and ecological impacts to the associated communities, with the key effects being a combination of mortality, short-term damage and long-term modification impacts.

In the MSC assessment, Banks *et al.* (*op. cit.*) refer to a study by Haywood *et al.* (2005) as follows:

> *Detailed analyses of the impacts of trawling on the benthos in the NPF are provided by a 2005 study conducted near Mornington Island and a more recent study focused on the sedimentary shelves and submerged river beds of the southwestern Gulf of Carpentaria. Based on these studies, there are no known unique, exclusive habitats in either area.*
>
> *The majority of the ecologically important habitats are located in untrawlable ground. However, there are some areas of high biodiversity, such as marginal reefs and sponge gardens, within trawlable areas and it is not known whether these are permanent structures or whether they form and are dispersed in response to natural environmental disturbance. In the 2005 study, experiments simulating commercial fishing operations through repeated intensive trawling of study sites showed that most benthic assemblages were primarily influenced by seasonal factors rather than trawling. Recovery in a number of sessile or slow moving taxa was found to occur within 6-12 months.*
>
> *While these studies did not examine habitat per se, findings indicating that trawling has little effect on the infaunal community suggest that trawling also has relatively little effect on benthic habitat.*

The ERA (AFMA 2012c) also addresses this issue, noting that regeneration times of damaged tissues will vary between species and that, while in the coastal margin (0–25 m) and inner shelf depths (25–100 m) regeneration can expect to be reasonably rapid because fauna are likely to be well adapted to frequent and considerable disturbances of regimes (for example, strong currents, run-off and cyclones), more structurally complex organisms may take more than a year to recover. Banks *et al.* (*op. cit.*) also considered the impact of the Northern Prawn Fishery on ecosystem structure and function, noting that:

> *Previous research has characterized the NPF ecosystem as driven by land-sea interactions, particularly freshwater input which triggers productivity in the form of benthic diatoms and tropical plankton. These studies found no evidence that the fishery affects this ecosystem in a significant way*.

Previous findings were re-examined in a recent study focused on the tiger prawn sub-fishery, which had the highest diversity and quantity of bycatch of the three Northern Prawn Fishery sub-fisheries (Bustamante *et al.* 2010). This study confirmed that the effects of trawling at the current scale of the Northern Prawn Fishery do not affect overall biodiversity and cannot be distinguished from other sources of variation in community structure. In particular, recent analyses showed that the composition and density of demersal fish, epibenthic invertebrates and infauna in the Gulf of Carpentaria were more strongly related to region and, in some cases, time of day than to the intensity of trawling as mapped by Northern Prawn Fishery vessel monitoring system (VMS) data.

Despite the finding that the benthic impacts of trawling may not be as severe as first thought, there can be no doubt that commercial fishing can have a profound impact on marine ecosystems (Thrush and Dayton 2002). Various habitats with different histories of disturbance may be expected to exhibit a variety of responses (Thrush and Dayton 2010). Also important is the intensity of fishing. Dell *et al*. (2013), for example, found differences in the benthic diet of predatory fish between areas of high and low fishing intensity, suggesting shifts in benthic communities with the intensity of prawn trawling in the Gulf of Carpentaria.

Sawfishes and chondrichthyans

The MSC assessment noted that:

> *Subsequent to the quantitative Level 2.5 ERA, Level 3 SAFE assessments were carried out for elasmobranch species which included the five species of sawfishes identified as being at high risk in Level 2.5, i.e., Pristis zijsron (green sawfish), Anoxypristis cuspidata (narrow sawfish), P. pectinata (wide sawfish), P. microdon (freshwater sawfish) and P. clavata (dwarf sawfish). Applying the results of the Level 3 SAFE, and taking into consideration the EPBC Act TEP species, three sawfishes (dwarf, green and narrow) were included in the NPF priority species list for monitoring although they were considered not to be at high risk given the SAFE findings. Monitoring for some TEP sawfish species is required under the EPBC Act, but it has been recommended that all sawfish species continue to be monitored as they are highly vulnerable to the impacts of fishing. A recent update to the SAFE assessment was undertaken for the period 2007-2009 but the assessed risk levels for sawfishes remained unchanged, i.e. they are not considered to be at high risk.* (Banks *op. cit.*)

National recovery plan for sawfish and river sharks[14]

A draft recovery plan for sawfish and river sharks has been published by the Department of the Environment (DoE 2014). This plan applies to the largetooth sawfish (*Pristis pristis*), green sawfish (*Pristis zijsron*) and dwarf sawfish (*Pristis clavata*) that can be present in the Oceanic Shoals and/or Arafura CMRs.

The recovery plan notes:

> *[The] Commonwealth marine reserves network protects habitats important for threatened species. Their location outside of state waters (three nautical miles off the coast) means they relate to solely marine environments and therefore would support adult sawfish and river sharks once they mature and utilise offshore areas. There are 21 Commonwealth Marine Reserves in the North and North-west Commonwealth Marine Reserve Network that sawfish and river shark species may utilise.*

The primary objective of the recovery plan is to assist the recovery of sawfish and river sharks in Australian waters, including through reducing and, where possible, eliminating adverse impacts of commercial fishing on sawfish. Additional management measures other than those contained in the recovery plan are being implemented through a number of agencies (AFMA, Department of Agriculture, Fisheries and Forestry, and state and territory governments). These measures include area and seasonal closures, compulsory recording of incidental capture, mechanisms to encourage recreational fishers to report interactions and a number of observer programmes that provide independent measures of mortality in state and Commonwealth waters.

Other threatened, endangered or protected species

The other group of TEP species requiring further action based on the Level 2.5 ERA was the sea snakes. A study dedicated to this topic was completed in 2008. It found that catch rates for the 10 most common species have remained stable since 1976. This study also concluded that trawl mortality was below reference points and no species appear to be at risk based on current levels of fishing effort in the fishery. Since sea snakes are protected species under the EPBC Act, interactions with the Northern Prawn Fishery will continue to be monitored as required through logbook and observer reporting; however, there are currently no sea snakes on the list of Northern Prawn Fishery priority species as a result of concerns based on risk assessment (Banks *et al.* 2012).

New BRDs have recently been trialled in the Northern Prawn Fishery which, unlike previous BRDs, appear to significantly reduce the capture of small bycatch and

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[14] DoE 2014.

particularly those species of concern—sawfish, sea snakes and, potentially, rays. The report (Burke *et al.* 2012) notes that:

> *Trials of the Popeye Fishbox and Witches Hat BRD Enhancer both demonstrated the greatest potential for reduction in small bycatch of all BRD designs trialled in the NPF to date. These devices have been tested and found to be successful in the tiger prawn season, though their effectiveness in the banana prawn season remains unknown.*

Further trials are planned, with mechanisms for adoption by industry in development. The Northern Prawn Fishery also has a Bycatch Action Plan, the aims of which are to develop strategies that will:

- respond to high ecological risks assessed through AFMA's ERAEF and other assessment processes
- avoid interactions with species listed under the EPBC Act
- reduce discarding of target species to as close to zero as practically possible
- minimise overall bycatch in the fishery over the long term (AFMA 2011).

ESP finding

Recent research and better identification of the conservation values suggest that the Northern Prawn Fishery operations (demersal trawling) may not impact as significantly on the benthic environment in the Gulf of Carpentaria Commonwealth Marine Reserve as previously thought, particularly as operations avoid ecologically important habitats such as sponge gardens and reefs, which are located in what is considered untrawlable ground and which are protected within fishery spatial closures.

More recent evaluations of the risks to elasmobranchs suggest that none were at risk from trawling because of widespread distributions and/or low overlaps with the fishery.

It is highly likely that a similar situation may apply to other areas of the North and North-west, such as the Wessels Commonwealth Marine Reserve and the Joseph Bonaparte Gulf Commonwealth Marine Reserve. However, consideration must be given to ensuring that sufficient areas are protected from the impacts of trawl, especially where there is an absence of Marine National Park Zones.

3.1.3 Review of the Fishing Gear Risk Assessment for the former Northern Territory Finfish Trawl Fishery (now amalgamated into the Northern Territory Demersal Fishery) specifically in relation to the Oceanic Shoals and Arafura Commonwealth Marine Reserves

Description of the location and habitat

Oceanic Shoals Commonwealth Marine Reserve[15]

The Oceanic Shoals CMR lies within the Timor Sea, with its north boundary on the edge of Australia's Exclusive Economic Zone (EEZ). East of the reserve are Bathurst and Melville islands (Tiwi Islands).

The reserve represents a significant area of the Bonaparte Basin and includes some of the deepest waters found in the North Marine Region, at approximately 300 m. The reserve contains a number of shoals, channels and valleys that are found in the carbonate bank and terrace system of the Van Diemen Rise and Sahul Shelf. These KEFs support rich sponge gardens, octocorals, pelagic fish, sharks and sea snakes. The reserve also includes the Pinnacles of the Bonaparte Basin, which are a KEF and are presumed to support high biodiversity, including hard and soft corals, sponges, and aggregations of demersal fish. Threatened flatback, olive ridley and loggerhead turtles are known to forage around the pinnacles, and whale sharks and other shark species occur in the area. The reserve also covers part of the shelf break and slope of the Arafura Shelf, which supports at least 284 demersal fish species.

The waters within the Oceanic Shoals CMR provide important inter-nesting habitat for flatback and olive ridley turtles that are preparing successive egg clutches for laying on nearby coasts. Marine communities dominated by beds of *Halimeda* algae occur in the reserve and these algae play an important role in fixing carbon at rates that are amongst the highest known.

The Oceanic Shoals CMR lies near the Tiwi Islands—an area recognised by the Northern Territory Government as a Site of Conservation Significance.

The conservation values of the Oceanic Shoals CMR are summarised in table 3.7.

[15] DNP 2013c.

Table 3.7 Conservation values of the Oceanic Shoals Commonwealth Marine Reserve* (after DNP 2014c and DNP 2013d)

Conservation values	Description
Biological seascapes	Represents 14 biological seascapes (a combination of physical and biological information). Cluster 1: Moderately high variation in seabed oxygen, moderately low chlorophyll A, moderately low turbidity, primarily sandy, deep mid-shelf. Cluster 2: High average water temperature at the seabed, low silicate average, high turbidity, high chlorophyll A, sandy–muddy sediments with high gravel, high variation in bottom stress, inshore depth range. Cluster 3: Moderately high sediment mud content, low sediment sand content, high variation in seabed oxygen, low salinity average, mid-shelf depth range. Cluster 5: Very low average water temperature at the seabed, low variation in sea surface temperature, very low benthic irradiance, upper slope depth range, very high silicate average, very low chlorophyll A, very low average seabed oxygen, very low turbidity, very high nutrients. Cluster 6: High sediment carbonate, high average sea surface temperature, low variation in water temperature at the seabed, moderately high variation in bottom stress, mid-shelf depth range; Cluster 8: Very high average sea surface temperature, low variation in sea surface temperature, low benthic irradiance, outer-shelf depth range, moderately low average seabed oxygen, moderately high silicate average, moderately high sediment mud content. Cluster 10: Low average water temperature at the seabed, low benthic irradiance, shelf-break depth range, high silicate average, low chlorophyll A, low average seabed oxygen, low turbidity, high sediment mud. Cluster 11: Low sediment carbonate, very high sediment mud, very low sediment sand content, very low sediment gravel content, low sediment carbonate, low salinity average, moderately high average water temperature at the seabed, depth. Cluster 12: Low sediment mud content, moderately high sediment sand content, inner-shelf depth range. Cluster 14: Very low sediment mud content, high sediment sand content, high sediment gravel content, high sediment carbonate, relatively low average sea surface temperature, very high variation in salinity, very high variation in bottom stress, very high bottom stress, moderately shallow. Cluster 15: High average water temperature at the seabed, high benthic irradiance, low silicate average, very low salinity average, shallow depth. Cluster 16: Moderately high salinity average, moderately high variation in seabed oxygen, depth range. Cluster 17: Low average water temperature at the seabed, high silicate average, low average seabed oxygen and very high variation in seabed oxygen, high nutrients and very high variation in nitrate, outer-shelf depth range. Cluster 19: High average sea surface temperature, very low variation in sea surface temperature, very high sediment carbonate, high bottom stress with high variation, typical depth range with shoals to around 20 m.
Depth	To approximately 300 m.

cont'd overleaf

* Containing representative examples of the North-west Shelf Transition and Timor Transition provincial bioregions and the Bonaparte Gulf, Oceanic Shoals and Tiwi meso-scale bioregions.

Table 3.7 Conservation values of the Oceanic Shoals Commonwealth Marine Reserve* (after DNP 2014c and DNP 2013d) cont'd

Conservation values	Description
Seafloor features	Banks/shoals, basin, deep/hole/valley, pinnacle, reef, shelf, slope, terrace, tidal sandwave/sandbank.
Key ecological features	Carbonate bank and terrace system of the Van Diemen Rise. Carbonate bank and terrace system of the Sahul Shelf. Pinnacles of the Bonaparte Basin. Shelf break and slope of the Arafura Shelf.
Species	Important foraging and resting area between egg-laying (inter-nesting area) for the threatened flatback turtle and olive ridley turtle. Area of high biodiversity supporting at least 284 fish species, whale sharks and other shark species.

* Containing representative examples of the North-west Shelf Transition and Timor Transition provincial bioregions and the Bonaparte Gulf, Oceanic Shoals and Tiwi meso-scale bioregions.

Arafura Commonwealth Marine Reserve[16]

The Arafura CMR is located in the Timor Sea and extends from north-west of Croker Island to the tributary canyons of the Arafura Rise. The Arafura CMR includes a continuous transect from the edge of Northern Territory waters (three nm) to the limit of Australia's EEZ (200 nm).

The reserve incorporates four of the eight Tributary Canyons of the Arafura Depression. These canyons are the remnants of a drowned river system that existed during the Pleistocene era and are a KEF. The steep topography of the canyons, their diverse current regimes, nutrient enrichment and entrapment, detritus funnelling and diverse substrate types form widely divergent ecosystems which, in combination with the regional setting and geological origins of the area, strongly influence species biodiversity.

At least 245 macroscopic species have been recorded from the canyons, including a diverse variety of invertebrates such as sponges, corals, sea anemones, tunicates, worms, crustaceans, brittle stars and feather stars.

The waters within the Arafura CMR provide important foraging and inter-nesting habitat for threatened flatback, green, hawksbill and olive ridley marine turtles that are preparing successive egg clutches for laying on nearby coasts. Waters within and adjacent to the southern boundary of the reserve are also important foraging habitats for breeding aggregations of migratory roseate terns.

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[16] DNP 2013d.

The Northern Territory Garig Gunak Barlu National Park lies approximately 30 km from the Arafura CMR and the Croker Island Group Site of Conservation Significance lies adjacent to the reserve. The conservation values of the Arafura CMR are summarised in table 3.8.

Table 3.8 Conservation values of the Arafura Commonwealth Marine Reserve* (after DNP 2014c and DNP 2013d)

Conservation values	Description
Biological seascapes	Represents 12 biological seascapes (a combination of physical and biological information). Cluster 1: Moderately high variation in seabed oxygen, moderately low chlorophyll A, moderately low turbidity, primarily sandy, deep mid-shelf. Cluster 3: Moderately high sediment mud content, low sediment sand content, high variation in seabed oxygen, low salinity average, mid-shelf depth range. Cluster 5: Very low average water temperature at the seabed, low variation in sea surface temperature, very low benthic irradiance, upper slope depth range, very high silicate average, very low chlorophyll A, very low average seabed oxygen, very low turbidity, very high nutrients. Cluster 6: High sediment carbonate, high average sea surface temperature, low variation in water temperature at the seabed, moderately high variation in bottom stress, mid-shelf depth range. Cluster 8: Very high average sea surface temperature, low variation in sea surface temperature, low benthic irradiance, outer-shelf depth range, moderately low average seabed oxygen, moderately high silicate average, moderately high sediment mud content. Cluster 10: Low average water temperature at the seabed, low benthic irradiance, shelf-break depth range, high silicate average, low chlorophyll A, low average seabed oxygen, low turbidity, high sediment mud. Cluster 11: Low sediment carbonate, very high sediment mud, very low sediment sand content, very low sediment gravel content, low sediment carbonate, low salinity average, moderately high average water temperature at the seabed, depth. Cluster 12: Low sediment mud content, moderately high sediment sand content, inner-shelf depth range. Cluster 14: Very low sediment mud content, high sediment sand content, high sediment gravel content, high sediment carbonate, relatively low average sea surface temperature, very high variation in salinity, very high variation in bottom stress, very high bottom stress, moderately shallow. Cluster 15: High average water temperature at the seabed, high benthic irradiance, low silicate average, very low salinity average, shallow depth. Cluster 16: Moderately high salinity average, moderately high variation in seabed oxygen, depth range. Cluster 17: Low average water temperature at the seabed, high silicate average, low average seabed oxygen and very high variation in seabed oxygen, high nutrients and very high variation in nitrate, outer-shelf depth range.
Depth	5–250 m.

cont’d overleaf

***** Containing representative examples of the Northern Shelf and Timor Transition provincial bioregions and the Arafura and Coburg meso-scale bioregions.

Table 3.8 Conservation values of the Arafura Commonwealth Marine Reserve* (after DNP 2014c and DNP 2013d) cont'd

Conservation values	Description
Seafloor features	Apron/fan, banks, shoals, canyon, deep/hole/valley, ridge, shelf, terrace.
Key ecological features	Tributary canyons of the Arafura Depression.
Species	Important foraging and inter-nesting areas for the threatened flatback, green, hawksbill and olive ridley turtles. Important foraging habitat for breeding aggregations of the migratory roseate tern.

***** Containing representative examples of the Northern Shelf and Timor Transition provincial bioregions and the Arafura and Coburg meso-scale bioregions.

<u>Gear type and fisheries in the former Finfish Trawl Fishery</u>

Semi-demersal trawl (also called semi-pelagic otter trawl or high-aspect semi-pelagic trawl) is a form of trawling that fishes close to the seabed, with only the trawl boards, wing-end weights and chain droppers coming in contact with the seabed (FRDC 2014).

The semi-demersal trawl gear used in the previous Finfish Trawl Fishery was described as having a semi-demersal net separated by two otter boards with mesh that must exceed 110 mm and a footline that must not exceed four kg per linear metre (Wendy trawl net) (DEWHA 2009b). Additionally, a system comprising grids and rails on the fish hopper to enable sharks and rays to be returned to the water via a chute in a timely manner must be in place (DEWHA 2009b). Square mesh codends and BRDs which have a similar design to TEDs were being used on a voluntary basis (DEWHA 2009b).

<u>North and North-west Fishing Gear Risk Assessment</u>

This assessment for the North and North-west CMRs was based on risks that commercial fishing methods posed to the conservation values identified in the Areas for Further Assessment (AFAs) in the North and North-west Marine Regions (Lack 2010).

Lack (*op. cit.*) noted that there were no specific risk assessments of the habitat impacts of semi-demersal trawl gear and that the success of the gear in minimising benthic impacts relied in part on the skill and experience of the operator in deploying and using the gear. As a consequence, information on habitat impacts in the Northern Prawn Fishery was used to assess the impacts of both demersal trawl methods.

Benthic habitat impact assessment

The assessment of the benthic habitat impacts of the Northern Territory Finfish Trawl Fishery was based on information available about habitat impacts in the Level 2 ERA for the Northern Prawn Fishery (Lack *op. cit.*). The assessment determination was that there was an 'Unacceptable' impact from semi-demersal trawl gear on benthic habitats in the Northern Prawn Fishery (see section 3.1.2).

Sawfishes and other chondrichthyans impact assessment

In accordance with the application of the precautionary approach, the Level 2 Northern Prawn Fishery risk ratings for chondrichthyans, as well as the outcomes of the Level 2.5 SAFE findings for chondrichthyans, as further refined in the Northern Prawn Fishery's Ecological Risk Management Report, were taken into account in FGRA analysis. Taking into account the precautionary approach, the FGRA contained a finding of 'Unacceptable' for semi-demersal trawl gear (Lack 2010).

<u>Reviews of the Fishing Gear Risk Assessment</u>

A review of the FGRA by CSIRO (Griffiths 2010) made the following observations:

- From available datasets it may be assumed that gear used in the Northern Territory and Queensland fish trawl fisheries may have lower impact on benthic habitats than the Northern Prawn Fishery tiger prawn fishery since the fish trawl gear is intended to fish above the sea floor. However, anecdotal accounts from scientific observers indicate that fish trawl gear is often fished hard along the seafloor, to the extent where entire coral shelves are caught in the trawl gear. It is therefore reasonable to make the precautionary assumption that the fish trawl fisheries have the same impact as the Northern Prawn Fishery tiger prawn fishery.
- More recent studies have questioned the uncertainty surrounding the recovery of erect, rugose and inflexible octocorals after interaction with trawl gear (Pitcher 2007). Anecdotal evidence suggests that the blotched fantail ray and porcupine ray are rarely encountered in northern Australian fisheries, probably because their primary habitats are outside the high-effort fished regions.
- The biology of sawfish species is poorly understood and more research on sawfishes is critical for understanding how they might respond to fishing pressure.

A second independent review of the FGRA (Bodsworth and Knuckey 2011) commissioned by the National Seafood Industry Alliance noted:

- The FGRA process did not identify a specific risk assessment for habitat impacts of this method and used a precautionary approach also informed by assessment of habitat impacts from demersal trawl gear used in the Northern Prawn Fishery.
- A brief literature search identified two directly relevant examples supporting an assessment that semi-demersal trawl has significantly less impact on the benthos than demersal trawl. Brewer *et al.* (1996) compared the relative performance difference between this gear and standard demersal trawl gear, reporting convincingly fewer (number and biomass) of unwanted species normally taken in trawls.
- Similar research comparing performance of semi-demersal and standard demersal trawl gear in the waters of the North West Slope Trawl Fishery (NWSTF) found that fishing with the semi-pelagic trawl (about 15 cm off the seabed) had no measurable effect on the benthos (Moran and Stephenson 2000).
- Queensland Gulf of Carpentaria Development Finfish Trawl Fishery observer data suggests a very low proportion of benthos in the catch (0.03 per cent of bycatch by weight) (DEEDI 2010).
- Semi-demersal trawl gear was assessed as ‘Unacceptable’ under the North Marine Region FGRA due to assumed levels of risk on sawfish and habitats in the Van Diemen and Arafura AFAs.

Additional information

Fishery amalgamation

The Finfish Trawl Fishery was amalgamated with the Demersal Fishery in February 2012 (DPIF 2012). Traps and lines are permitted across the whole fishery, and finfish trawl (that is, semi-demersal) gear is permitted in two defined zones (Demersal Multigear Areas) as shown in figure 3.4 (DPIF 2012).

The fishery operates in waters from 15 nm from the coastal baseline to the outer limit of the AFZ, excluding the area of the Timor Reef Fishery (DPIF 2014a).

The Northern Territory Fisheries Joint Authority, through the Northern Territory Fisheries Act, manages all finfish taken in the Demersal Fishery, while the day-to-day management of the fishery is conducted by the Fisheries Division of the Department of Primary Industry and Fisheries (DPIF 2012).

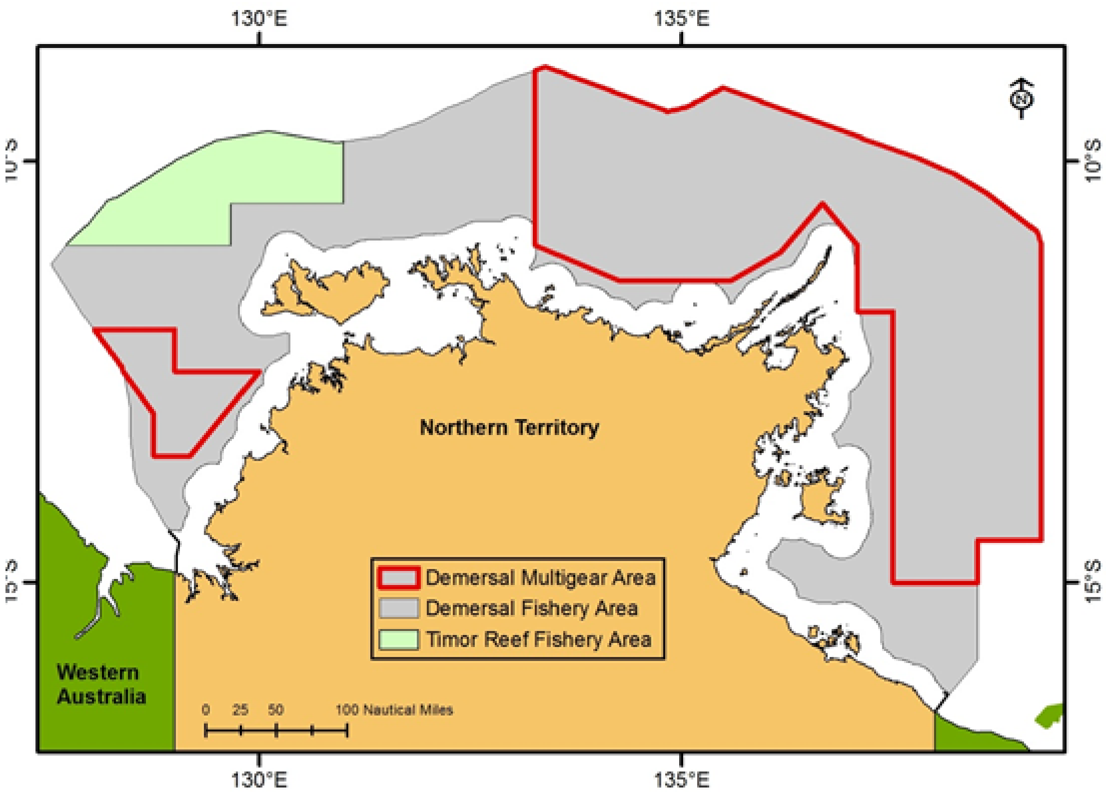

Figure 3.4 Northern Territory Demersal Fishery and Timor Reef Fishery Development Fishery (DPIF 2012) © Copyright, Department of Primary Industries and Fisheries

Gear type and deployment

The semi-demersal trawl net was developed cooperatively between government and industry. It is designed to minimise seabed disturbance and reduce the amount of bycatch and environmental impact in the fishery (DPIF 2012; NTSC 2012). The use of high-aspect trawl boards reduces bottom contact by as much as 80 per cent compared to traditional otter boards used for fish trawling in the past (NTSC 2012). The use of a BRD in conjunction with the square-mesh funnel/codend is stated to further reduce some of the broader ecosystem impacts (DPIF 2012). Semi-demersal trawl gear is permitted only within two defined zones in the Demersal Fishery, neither of which intersect with the Oceanic Shoals CMR.

The Timor Reef Fishery operates in remote offshore waters of the Northern Territory and harvests demersal fish species using traps and lines. Total allowable catches and individual transferable quotas allow for the sustainable harvest of goldband snappers, red snappers, and all other retained fish (‘group’ species) targeted in the fishery. Currently a development permit has been issued to trial finfish trawl gear in the Timor Reef Fishery (DPIF 2014a).

Four precautionary methods are described for the Timor Reef Fishery Developmental Fishery (Australia Bay Seafoods 2015):

'Semi Demersal Trawl Nets

Fishing operations are conducted using a semi-pelagic demersal trawl. The trawl net was developed cooperatively by Australia Bay Seafoods and the NT government to minimise habitat disturbance whilst ensuring commercial catch rates were maintained.

Bycatch Reduction Device (BRD)

Different styles of aluminium grids are used in many prawn trawl fisheries to allow larger bycatch such as sharks to escape unharmed. Unfortunately these grids are simply unusable in trawling for fish as they would have to be wound onto a net drum which simply cannot occur. To overcome this problem Australia Bay Seafoods have developed a large grid made from stainless steel wire rope which while successfully allowing larger bycatch to escape unharmed can also be wound onto the vessels net drum. A significant drop in shark catches has been seen since the grids implementation and again the quality of retained catch has improved.

Hopper release system

To assist in reducing release mortality, Australia Bay Seafoods has developed a system comprising grids and rails on the fish hopper to enable sharks and rays to be returned alive to the water via a chute with minimal handling. The hopper system is now being evaluated by other trawl fisheries interstate with the intention of incorporating its use as standard operating practice.

Square Mesh Net

This is used to allow small fish to escape. As the Cod end fills with fish there is more tension on the meshes of the net, this tension reduces the size of normal netting and causes excess catch of unwanted small fish. To minimise the catch of small fish, Australia Bay Seafoods utilise a square mesh (T90) Cod end extension. As the tension increases this section of netting stays open and allows small fish to escape.'

Recent descriptions of the habitat in the Oceanic Shoals Commonwealth Marine Reserve[17]

In 2012, four areas in the western sector of the Oceanic Shoals CMR were surveyed, including a range of seabed geomorphic features in water depths from 30 to 180 m, such as carbonate banks, terraces and pinnacles, as well as soft sediment plains and valleys. The survey provides new information about the range of seabed environments occurring on the banks and terraces of the Oceanic Shoals CMR.

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[17] Nichol *et al.* 2013.

Key observations of this survey were that:

- the geomorphic diversity of the Oceanic Shoals CMR is well represented in the western part of the reserve, with numerous banks and terraces providing hard substrate for benthic communities
- the epibenthic biodiversity on banks appears to vary as a function of water depth and related light and turbidity conditions, with shallower banks (less than 45 m) supporting more biodiversity than deeper banks, including hard corals
- species richness and endemism of sponges in the western sector of the Oceanic Shoals CMR may not be as high as those in the eastern sector, with sponges from the west comparatively dominated by species that are common across northern Australia (to be confirmed by taxonomic analysis)
- spatial gradients in epibenthic biodiversity exist as a possible function of marked changes in substrate, light and turbidity levels along the depth transition from bank to terrace to plain
- tidal currents play an important role in regulating levels of suspended sediment (turbidity) and in redistributing sediment across the plains and around banks and terraces, with some smaller banks partly buried by sediment
- demersal fish communities respond to spatial patterns in benthic biodiversity, occurring in larger and more diverse populations on the shallower, less turbid banks
- a wide variety of high-order pelagic fish species occur in these waters.

The preliminary results and conclusions of Nichol *et al.* (2013) are described below:

- Common biological and habitat characteristics were found across all survey areas. Banks and scarps were characterised by coarse, muddy sand with occasional gravel inclusions, whereas plains, terraces and mounds were composed of softer silt or sandy silt. Two different types of depressions were characterised—deep, steep-sided depressions (muddy, silty gravel) and shallower depressions (inferred to have a silt or sandy silt composition). Associations were identified between the geomorphology and substrate types and the distribution of epibenthic and infaunal communities. The survey found that epifauna was rare over the terraces and plains, although in particular areas there were very common burrows and mounds, indicating that abundant or rich infaunal communities were present in the unconsolidated sediments of some plains and terraces. In one deep depression there was evidence of a hard substrate and higher epifaunal biodiversity (sponge and octocoral gardens) compared to the surrounding plains. Moderate to dense biological coverage was found more frequently on banks than on plains or terraces and reef-forming corals were restricted to banks.

- While taxonomic identifications are pending, on board observations suggest that sponges in the survey areas were predominantly common northern Australian species. This is in contrast to results from previous surveys in the eastern sector (Przeslawski *et al*. 2011), which indicated that species richness and endemism of sponges in the western sector of the Oceanic Shoals CMR were probably less than in the eastern sector.

Industry environmental management

The Northern Territory Seafood Council has established a Demersal Fishery Environmental Management System—a voluntary, industry-driven environmental initiative (NTSC 2012). The environmental management systems for the former Finfish Trawl Fishery and the Demersal Fishery were originally developed in 2006 by the Northern Territory Demersal Fishermen's Association and the Finfish Trawl Licensee Committee with assistance from the Northern Territory Seafood Council and the Fisheries Research and Development Corporation (NTSC 2012). These documents were revised in 2011 to cover the amalgamated Demersal Fishery (NTSC 2012).

The goals of the environmental management system include identifying and assessing potential environmental impacts and risks concerning the fishery, their likelihood of occurrence and predicted consequences; providing fishery operators with a defined set of actions to reduce those risks and improve the fishery; and providing an ongoing process for the environment management system and the environmental performance of the fishery, to be continually reviewed and improved (NTSC 2012).

In 2012, bycatch was reported to be less than 20 per cent of the total trawl catch in the Demersal Fishery (DPIF 2012). The presence of larger species, including sharks and rays, was noted to have declined, coincidental with the use of BRDs (DPIF 2012).

It was reported that a small number of interactions with TEP species was recorded by onboard observers in 2012 (DPIF 2014b). The number of interactions was reduced with the improvement of the BRD technology as the fishery developed through the year (DPIF 2014b).

Ongoing research into the impacts of trawl on bycatch species and benthic habitats is encouraged, particularly longer-term monitoring, as the cumulative impacts may be found to be significant (Foster *et al.* 2015).

National Recovery Plan for Sawfish and River Sharks[18]

A draft recovery plan for sawfish and river sharks has been published by the Department of the Environment. This plan applies to the largetooth sawfish (*Pristis pristis*), green sawfish (*Pristis zijsron*) and dwarf sawfish (*Pristis clavata*) that can be present in the Oceanic Shoals and/or Arafura CMRs.

The recovery plan notes:

> *Commonwealth marine reserves network protects habitats important for threatened species. Their location outside of state waters (3 nautical miles off the coast) means they relate to solely marine environments and therefore would support adult sawfish and river sharks once they mature and utilise offshore areas. There are 21 Commonwealth Marine Reserves in the North and North-west Commonwealth Marine Reserve Network that sawfish and river shark species may utilise.*

The primary objective of the recovery plan is to assist the recovery of sawfish and river sharks in Australian waters, including through reducing and, where possible, eliminating adverse impacts of commercial fishing on sawfish. Additional management measures other than those contained in the abatement plan are being implemented through a number of agencies (AFMA; Department of Agriculture, Fisheries and Forestry; and state and territory governments). These measures include area and seasonal closures, compulsory recording of incidental capture, mechanisms to encourage recreational fishers to report interactions, and a number of observer programmes that provide independent measures of mortality in state and Commonwealth waters.

ESP finding

Recent research, an improved understanding of the habitat, a better identification of the conservation values of the area and improvements in gear type and management suggest that Demersal and Developmental Fishery operations (semi-demersal trawling) may not impact as significantly on the benthic environment as previously thought.

More recent evaluations of the risks to elasmobranchs suggest that none were at risk because of widespread distributions and/or low overlaps with the fishery. A national recovery plan is being developed to address threats to these species.

It is highly likely that a similar situation may apply to other areas of the North and North-west Commonwealth Marine Reserves. However, consideration must be given to ensuring that sufficient areas are protected from the impacts of trawl, especially where there is an absence of Marine National Park Zones.

[18] DoE 2014.

3.1.4 Review of the Fishing Gear Risk Assessment rating for Western Australian Trawl Fisheries, specifically demersal scallop trawl in Bremer and Geographe Commonwealth Marine Reserves

Description of the location and habitat

Geographe Commonwealth Marine Reserve

The Geographe CMR lies within and adjacent to Geographe Bay south of Perth, Western Australia, and has a depth range of 15 m to 70 m.

It is an area of high benthic productivity and high biodiversity, where extensive seagrass meadows support habitat for a wide variety of fish and invertebrates (Westera *et al.* 2007). It is also recognised as being an important foraging area for several threatened and migratory seabirds and falls within the migratory pathways of several cetaceans, including both humpback and blue whales (DNP 2014d).

In nearshore waters (2–18 m), seagrass meadows have been well described (Walker *et al.* 1987; McMahon *et al.* 1997; Westera *et al.* 2007) and are dominated by *Posidonia sinuosa* (60 per cent cover), with *Amphibolis antarctica* and other species found around the edges of *P. sinuosa* meadows and on limestone outcrops (McMahon and Walker 1998). In recent tow video footage in deeper water (15–40 m) in the western portion of the area, *Zostera* has also been identified, as well as patchy distributions of dense epiphytes (Van Niel *et al.* 2009). Seagrass contributes large amounts of wrack (detached leaves and stems) to the local beaches, predominantly during winter storms (Oldham *et al.* 2010).

Westera *et al.* (2007) show clear changes with increasing distance from shore with the cover of the seagrasses, *A. antarctica* and *P. sinuosa* decreasing, while *A. griffithii* and the number of rocky reefs increase. Changes in seagrass species composition have been correlated with increasing depth of water, which is typical of other seagrass meadows in the region. Westera *et al.* (*op. cit.*) suggest it is very likely that increases in the number of rocky reefs with distance from shore would have important ecological influences on assemblages of fishes, invertebrates and algal assemblages.

More recent surveys conducted by the National Environmental Research Program have used BRUV drops in deeper water across the CMR. This sampling, using a Generalised Random Tessellated Stratification survey design, indicates that seagrass habitat is more extensive across Geographe Bay and appears to be one of the largest continuous seagrass beds recorded in Australia. BRUV surveys also confirm that fish assemblages differ by depth and between seagrass, reef and sand habitats (Bax and Hedge 2015).

Westera *et al.* (2007) consider that the natural marine habitats of Geographe Bay face potential impacts from increases in population; growth in tourism; recreational and commercial fishing; introduced marine pests; and climate change. Observed decreases in seagrass cover have coincided with extensive land clearing and drain construction during the 1950s, which may have resulted in increased sediment loads and smothering of seagrasses. More recent concerns have centred on high levels of nutrients entering Geographe Bay from agricultural and urban run-off. However, Westera *et al.* (*op. cit.*) conclude that there is insufficient current information to detect current impacts or predict future impacts.

The conservation values of the Geographe CMR are summarised in table 3.9.

Table 3.9 Conservation values of the Geographe Commonwealth Marine Reserve* (after DNP 2014d and DNP 2013e)

Conservation values	Description
Biological seascapes	Represents five seabed assemblages (which are derived from sediment and depth data). Cluster 7: Moderately small variation in sea surface temperature, relatively high sediment carbonate, moderate salinity average, mid-shelf depth range. Cluster 11: High sediment carbonate, high intermediate salinity average, outer-shelf depth range. Cluster 13: Relatively low sediment carbonate, mid-shelf depth range, some areas of high sediment mud content. Cluster 14: Very high sediment carbonate, moderately high salinity average, shelf depth range, moderate average water temperature at the seabed. Cluster 17: Low carbonate, low surface water temperature average and variation, inner shelf depth range.
Depth	15–70 m.
Seafloor features	Shelf.
Key ecological features	The Commonwealth marine environment within and adjacent to Geographe Bay (high benthic productivity, high biodiversity, feeding, resting, breeding and nursery aggregations).
Species	Important foraging areas for the threatened soft-plumaged petrel. Important foraging areas for the migratory wedge-tailed shearwater. Important pre-migration aggregation area for the migratory flesh-footed shearwater. Important migratory habitat for the protected migrating humpback and blue whales. Western rock lobster habitat (species with an important ecological role).

* Containing representative examples of the South-west Shelf Province on the continental shelf as well as the Leeuwin–Naturaliste meso-scale bioregion.

Bremer Commonwealth Marine Reserve

The Bremer CMR extends from the state water boundary close to the terrestrial Fitzgerald River National Park. It covers a depth range from about 15 m at the northern boundary to depths of 5000 m or more at the southern edge of the reserve.

The Bremer CMR covers most of the Bremer Canyon—a major feature in the region and one of nine shelf-incising canyons in the south-west. Shelf-incising canyons provide more diverse marine habitat and intersect major ocean boundary currents on the Australian margin. Associated hydrodynamics such as upwelling enhance the horizontal and vertical exchanges of water and materials between the slope and shelf (Huang *et al*. 2014).

The Bremer CMR is known as an area that supports diverse feeding aggregations of megafauna such as killer whales, southern right whales, sperm whales and sharks (De Barros *et al*. 2013). The area is also a foraging area for Australian sea lions and a range of seabirds, including the Indian yellow-nosed albatross. Hovland and Riggs (2014) have suggested that hydrocarbon seepage in the vicinity of the Bremer Canyon may support a productive phytoplankton feedstock for bait species, higher-order predators and marine mammals.

The conservation values of the Bremer CMR are summarised in table 3.10.

Table 3.10 Conservation values of the Bremer Commonwealth Marine Reserve* (after DNP 2014d and DNP 2013e)

Conservation values	Description
Biological seascapes	Cluster 7 (mid-shelf): Moderately small variation in sea surface temperature, relatively high sediment carbonate, moderate salinity average, mid-shelf depth range. Cluster 10 (shelf): Shelf depth range, moderately high average water temperature at the seabed and surface, moderate low variation in sea surface temperature, intermediate low oxygen average at the seabed, moderately high sediment carbonate. Cluster 11 (outer shelf): High sediment carbonate, high intermediate salinity average, outer-shelf depth range. Cluster 15 (outer shelf and break): Very low surface water temperature average and variation, moderately low average seabed water temperature, high average seabed oxygen, relatively low silicate average and variation, outer-shelf/break depth range. Cluster 18 (upper slope): Very low salinity average, very low average seabed water temperature, very high nutrients, high average seabed oxygen, high silicate average, upper-slope depth range.
Depth	15–5000 m.
Seafloor features	Shelf.
Key ecological features	The Albany Canyons group (high productivity, feeding aggregations).
Species	Foraging areas for the threatened white shark, Australian sea lion, Indian yellow-nosed albatross, soft-plumaged petrel and flesh-footed shearwater. Migratory areas for protected humpback whales. Seasonal calving habitat for the threatened southern right whale. Known aggregation site for sperm whales and killer whales.

* Containing representative examples of the Southern Province and the South-west Shelf Province on the continental shelf and the Western Australia South Coast meso-scale bioregion.

Target species, gear type and relevant fisheries

Target species

While several scallop species are known in Western Australian waters, only the saucer scallop *Amusium balloti* supports a commercial fishery (Harris *et al.* 1999). Saucer scallops tend to be restricted to sandy substrates in sheltered environments and the lee of islands and reef systems and, although saucer scallops are found between Broome in the north to Esperance in the south, the fishery is concentrated in Shark Bay and around the Abrolhos Islands (Joll 1989). The species has been reported in depths from 10 m to 75 m (Dredge 1988). Saucer scallops develop rapidly, growing to a size of 90 mm in just six to 12 months, and are characteristic of short-lived species with high natural mortality, making them susceptible to a ‘boom and bust’ life history. Recruitment of scallops to the west coast of Australia is highly variable and not thought to be dependent on the density of spawning biomass. As a result, catch rates and annual tonnage vary dramatically from year to year (Caputi *et al*. 1996). Because saucer scallops are capable of flight swimming, fisheries target them using low-opening otter trawls (Sporer *et al.* 2014).

Gear type

Saucer scallops are targeted using twin-rigged otter trawls, each with a 10 mm ground chain and 100 mm mesh size. Twin gear otter trawls are also used to catch scalefish; however, mesh sizes may be larger. These trawl nets are towed along the seabed and are held open by a pair of otter boards on either side attached to the wings of the net. All vessels are required to fish with a BRD and a secondary fish exclusion device (FED) in each net (DSEWPaC 2013). When searching for scallops, fishers test the viability of an area by towing a smaller try-net.

Vessels generally tow two low-opening demersal otter trawl nets at a speed of around 2.5 to 3.5 knots, as this is the most effective speed when targeting scallops. Shot durations can vary from around 20 minutes up to 150 minutes, depending on scallop abundance. The ground chain travels across the sea floor and disturbs scallops so that they swim up from the seafloor and into the path of the oncoming net. Low-opening nets have the headrope set in front of the footrope (which creates a net ‘veranda’), ensuring that scallops disturbed by the ground chain do not usually pass over the headrope. The ground chain is designed / set to make it skim over the sand without digging into the sea floor (WA DoF 2005). Figure 3.5 shows the standard twin otter rig and try gear used by trawlers targeting scallops in the South Coast Trawl Fishery.

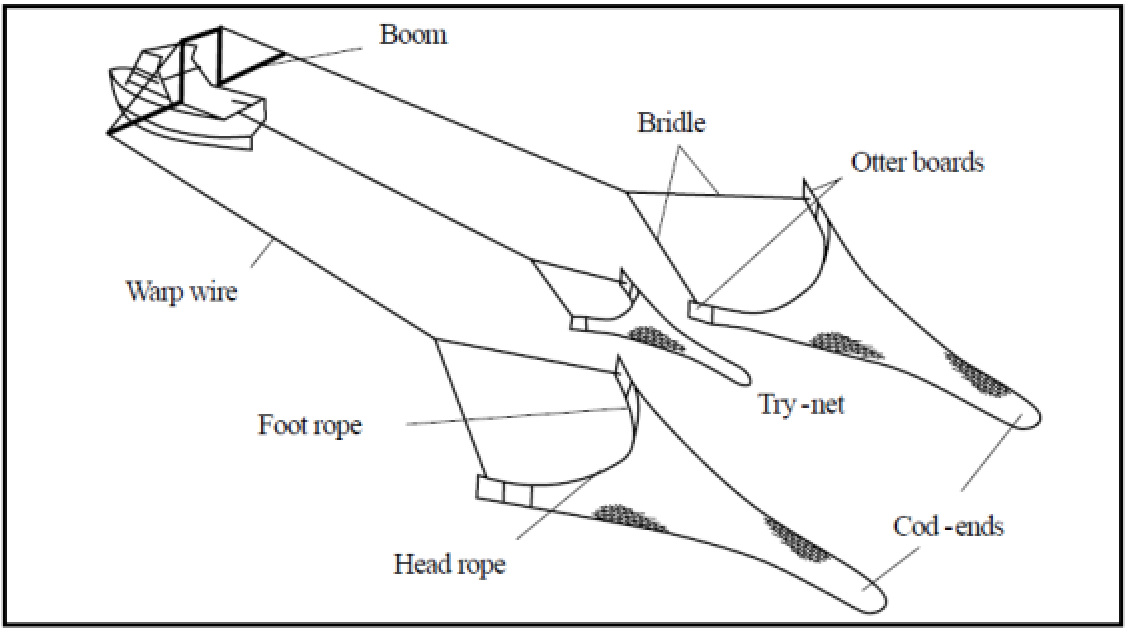

Figure 3.5 Rig and gear used by trawlers targeting scallops in the South Coast Trawl Fishery (WA DoF 2005). Note that the twin otter rig and try-net are shown on the same diagram but used separately as described above © Copyright, Department of Fisheries (Western Australia)

South West Trawl Managed Fishery (covering Geographe Commonwealth Marine Reserve)

The South West Trawl Managed Fishery (SWTMF) includes two of the state's smaller scallop fishing grounds—Fremantle and north of Geographe Bay (WAFIC 2015). It is a multi-species fishery including scallops (*A. balloti*), western king prawns, mixed whiting species, blue swimmer crabs and other mixed fish. Good scallop landings were taken in 1990 and 2010, but catches are generally low due to variability in recruitment (Sporer *et al.* 2014).

The SWTMF is a gear-based managed fishery that operates under an input control system that limits boat numbers, gear sizes, fishing areas and season. The management plan also includes large closures to protect sensitive coastal habitats (including seagrass beds) and nursery areas such as Cockburn Sound, Warnbro Sound and inshore Geographe Bay (Sporer *et al.* 2014).

A total of 13 licences operate. This is seen as a comparatively small, low-activity fishery in which effort is related to the abundance of scallops in any given year, which can be highly variable (Kangas and Zeller 2014).

South Coast Trawl Fishery (covering Bremer CMR)

The South Coast Trawl Fishery (SCTF) principally targets scallops (*A. balloti*) and associated by-product species, although in years of low scallop catches licensees may use other trawl gear to target finfish species. Scallop landings in the fishery are variable, depending primarily on the strength of recruitment (Sporer *et al.* 2014). While the boundaries of the fishery cover a large section of the south coast, the operations of the fleet are effectively restricted to very small areas of higher scallop abundance—mainly the waters of Bremer Bay, the Recherche Archipelago and Israelite Bay (WA DoF 2005).

The SCTF is managed primarily by limited entry, with only four licences permitted to operate in the fishery. Additional management arrangements for the SCTF are set by conditions within the Instrument of Exemption and are aimed at ensuring the stock and environment are protected via gear restrictions and seasonal closures. The Department's VMS monitors the activities of all boats, including compliance with the spatial closures. The Department of the Environment has assessed the SCTF under the provisions of the EPBC Act and granted a three-year export approval for the fishery until 6 May 2016.

South-west Fishing Gear Risk Assessment

The Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) conducted a desktop FGRA for the South-west Marine Region (DSEWPaC 2010). The assessment was undertaken to determine the potential risks posed by fishing methods to the conservation values and marine biodiversity identified within AFAs.

The South-west Marine Region FGRA was completed in two stages:

1. identification of elements of the South-east Marine Region FGRA (E-Systems 2005) that could be transferred to the South-west Marine Region, as well as gaps that existed in terms of fishing methods or conservation values of the South-west Marine Region
2. assessment of the risks posed by the methods found to be of medium- to high-risk in the south-east FGRA.

The two (south-east and south-west) FGRAs differed in that the south-west FGRA applied the Australian Government's quantitative ERAs for the effects of fishing (ERAEFs) findings rather than risk ratings agreed through a workshop, noting that these ERAs had been undertaken in consultation with relevant industry representatives and that these assessments were based on the best available science and expert input (DSEWPaC 2010).

The south-east FGRA finding of 'Incompatible Risk' for demersal/bottom trawl was considered transferable to the south-west based on similar gear types and habitats within which demersal trawl operates. In addition, the ERAs for both the Commonwealth bottom trawl fisheries operating in the South-west Marine Region identified seafloor habitat degradation and mortality rates of non-target species as key concerns, with numerous seafloor habitats and by-product and bycatch species rated as being at potentially high risk (Wayte *et al.* 2007; Daley *et al.* 2007).

However, state managed fisheries had not been assessed under the Commonwealth's quantitative ERA process, including three fisheries that operate demersal trawl within Commonwealth waters of the South-west Marine Region:

1. Abrolhos Islands and Mid West Trawl Managed Fishery (MWTMF)
2. the SWTMF
3. the SCTF.

Due to key differences in target species and the localised nature of these fisheries, specific information was sought for each of these fisheries (DSEWPaC 2010). ESD reports submitted to the Department of Environment, Water, Heritage and the Arts (DEWHA) for assessment found negligible impacts on bycatch, negligible to low impacts on protected species, and low impacts on benthic habitats in the MWTMF, SWTMF and SCTF (WA DoF 2004; WA DoF 2005). The 2008/09 Western Australian State of the Fisheries Report stated that these fisheries also have a low impact on bycatch, protected species and ecosystems (Fletcher and Santoro 2009).

DEWHA (2008b) noted the lack of species-specific identification of small elasmobranches caught in the MWTMF—something that has also been identified as a key issue in the National Plan of Action for the Conservation and Management of Sharks (DAFF 2012).

In the absence of detailed information about bycatch or by-product mortality on shark species, and consistent with a precautionary approach, these fisheries were considered incompatible with the conservation objectives of CMRs (DSEWPaC 2010).

Reviews of the South-west Fishing Gear Risk Assessment

Reviews of the South-west FGRA were conducted by Smith (2010) and Knuckey *et al.* (2011). Both concluded that, given the policy context, the conservation values of interest and the purpose of the paper, the general approach and the methods applied in this analysis seemed appropriate and the conclusions were reasonable given the stated objectives. However, Knuckey *et al.* (2011) criticised the assumption that gear risk ratings could be transferred from one bioregion to another, not only in terms of gear but also in terms of habitat similarity (both extent and composition) between each bioregion. They argued that, although the assumptions about gear can be fairly readily verified, a bioregion, by definition, is characterised by distinctive flora and fauna, so the validity of the second assumption should be scrutinised carefully before the transfer of risk ratings is made. Even within a single bioregion, there can be extensive areas of certain habitat types for which the risk ratings of certain gears may be quite different than other habitat types. Potentially, such areas of habitat type could be captured within a particular AFA or reserve but not in another.

Additional information

Marine Stewardship Council certification

The pre-assessment phase for the MSC approval system is under way for the South West Trawl Managed Fishery and the SCTF (Fletcher and Santoro 2014); however, this information was not available for scrutiny.

Impacts on the benthos

In general, the Western Australian saucer scallop fisheries are considered to have a low risk of adverse habitat effects, with trawling usually occurring over a small proportion of the designated trawl area. The physical impact of this gear on the sandy habitats within these areas is regarded as negligible (Kangas and Zeller 2014).

For example, in Geographe Bay, sampling and underwater observations before and after depletion trawling failed to detect any impact on the benthic communities of existing trawl grounds. In this study the area was completely swept by the trawl gear on four successive occasions during a single night, with one sweep over the area consisting of four trawls (Laurenson *et al*. 1993). Geographe Bay is dominated by seagrass, rock and rubble habitats and is largely untrawlable. The limited availability of suitable ground for trawling for scallop habitats in this sector indicates that further expansion of the area trawled is unlikely (Laurenson *op. cit.*) .

Similarly in Shark Bay, Kangas *et al*. (2006) note that scallop trawling occurs mostly over the sand and shell habitats and has the effect of flattening this otherwise rippled and three-dimensional substrate—and this may also indirectly affect the species that inhabit this area by changing the nature of their habitat—but that the potential impact on the sand and shell habitat as a result of the scallop trawling operations was considered to be of minor consequence. Kangas *et al.* (*op. cit.*) argue that this is due to the small percentage of the area actually trawled as well as the length of the period in which trawling occurs (it usually only occurs for about two months of the year).

These findings are consistent with similar findings in scallop trawl fisheries elsewhere (Dignan *et al.* 2014).

Impacts on threatened, endangered or protected species

The risk of TEP species interactions in the SWTMF and SCTF is assessed as ‘Low’. TEP species do not occur regularly in the fishing areas despite frequenting the surrounding waters and there were no recorded captures of listed species in 2013 for either of these fisheries (Fletcher and Santoro 2014).

The DSEWPaC assessment for the SCTF stated that there has been little evidence of interactions with protected species recorded in the fishery. An ERA for the fishery was completed in 2005, which identified the incidental capture of syngnathids in trawl nets as low risk. Given the low number of boats in the fishery and the limited area trawled, the risk presented by the fishery to protected species is still considered to be low (DSEWPaC 2013).

Impacts on bycatch

The Government of Western Australia's Department of Fisheries has also assessed the impacts on bycatch as 'Low' (Fletcher and Santoro 2014). In the SWTMF trawling for scallops is focused on a few small offshore areas, while the prawn catch is mainly taken from Comet Bay (Zone D). The large-mesh (100 mm) trawl gear used in the SCTF takes minimal bycatch.

For the SCTF, DSEWPaC found that the risk to bycatch species in the fishery was low. The large minimum net mesh sizes (100 mm or greater) used in trawl nets for scallops and demersal scalefish trawling combined with the low number of licenses (four) and the actual area trawled within the fishery (area trawled is much smaller than the extent of the fishery) contributes to a low risk to bycatch species. All trawl nets in the fishery are also required to have BRDs in the way of grids, which also lowers the risk to bycatch species (DSEWPaC 2013).

Impacts on the food chain and ecosystem

The Government of Western Australia's Department of Fisheries has also assessed the impacts on the food chain as 'Low' (Fletcher and Santoro 2014). The total biomass taken by these fisheries is generally very small. Moreover, due to the high natural variability of scallop stock abundance, it is unlikely that any predators are highly dependent on this species.

For the SCTF, the DSEWPaC assessment was that the variable recruitment, resultant fluctuating biomass of the scallops and the low retained catch of scalefish species suggests the fishery is likely to have a minor impact on the general food chain in the region. Scallops have a high natural variability and therefore trophic impacts on the fishery's removal of scallops are likely to be low (DSEWPaC 2013). DSEWPaC also notes that vessels in the fishery operate over a small proportion of the licensed area and therefore benthic impacts are contained to this small area. In addition, trawling is restricted to areas of high scallop abundance, which is predominantly sand-based habitat and resilient to impacts from trawling.

ESP finding

The South-west Fishing Gear Risk Assessment for demersal/bottom trawling, which had been transferred from the South-east Fishing Gear Risk Assessment, was not applicable to demersal scallop trawling in Western Australia.

For this reason, the fishing risk was assessed against ecologically sustainable development reporting conducted by the Western Australian Department of Fisheries. It concluded that demersal scallop trawl was incompatible with the conservation objectives of Commonwealth marine reserves, based primarily on the lack of information on the impact of these fisheries on small shark species.

More recent research on the impact of scallop trawling on soft substrates in Western Australia in both the South West Trawl Managed Fishery and the South Coast Trawl Fishery, together with state Ecologically Sustainable Development Assessments, suggest that the habitat impacts are both localised and minor. Similarly, current ecologically sustainable development reporting suggests that impacts on bycatch and threatened, endangered and protected species is low.

This suggests that scallop trawl fisheries operating on soft sediment substrates in the Bremer and Geographe Commonwealth marine reserves should be considered as being 'Compatible' with respect to the conservation values of these areas.

These findings may be applicable to all scallop trawl operations in Western Australia; however, care should be exercised when transferring risk assessments between areas of similar geomorphology but inherently different biodiversity assemblages.

3.2 Assessment of recreational fishing in relation to the Commonwealth marine reserve estate

In this section, we examine aspects of recreational fishing that relate to zoning and management arrangements within the CMR estate and discuss specific issues, including no-take catch-and-release, consume-on-site and pelagic fishing.

Unlike a number of commercial fishing gears, FGRAs were not specifically undertaken for different recreational fishing gear types with respect to CMRs. This was primarily because all recreational fishing gear types (see below) are similar to equivalent commercial gear types and all are allowed in IUCN zones IV and VI subject to recreational fishing restrictions such as size and bag limits (see also chapter 2).

3.2.1 Recreational fishing methods

Recreational fishing methods include hook and line (either using a rod and reel or handline), netting (set and throw nets), hand collecting, trapping and spearfishing.

Line fishing may include the use of live or dead baits as well as a wide variety of lures that may be cast and retrieved or towed (trolled) behind a moving boat. Single hooks are normally used for bait fishing, while double or treble hooks are often used with lures. Fishing reels are normally wound by hand, but mounted electric reels may also be used when fishing in deep water.

Cast nets are legally used by recreational fishers in some states, as are gillnets in others. Underwater spearfishing by speargun or handspear is another form of recreational fishing, but spearfishing while using scuba or surface air supply (‘hookah’) gear is not permitted by any state or territory. A variety of nets and traps are used by recreational fishers to catch prawns, crabs and crayfish, while specifically designed jigs are used to catch squid.

Recreational fishing may be undertaken from the shore, including rock platforms, beaches and jetties; and from boats ranging in size from kayaks to large long-ranging game fishing vessels. Recreational fishing also takes place from charter boats, but this is generally regarded as a form of commercial fishing and/or tourism operation in that operators of the charter business charge a fee from recreational fishers to fish from their vessels.

3.2.2 Management of recreational fishing

Management of recreational fishing, especially in relation to CMRs, is detailed in appendix 2. Reiterating two pertinent points from that summary:

- The relevant provision of the EPBC Act means that ‘take’ includes catching and releasing fish.
- Recreational fishing, like other extractive activities, is not allowed in Sanctuary Zones (IUCN Ia) or Marine National Park Zones (IUCN II).

Some additional aspects of management of recreational fishing are as follows.

While Commonwealth regulations determine whether or not recreational fishing may take place in CMRs, state-determined size limits, bag limits, closed seasons, gear restrictions and other regulations governing recreational fishing apply in areas zoned to allow recreational fishing. Recreational fishers fishing in salt water are required to hold a licence to fish in New South Wales and Victoria. In Western Australia, fishing in salt water from a powered boat requires a licence. In most state and territory jurisdictions, charter operators must maintain logbooks and also when fishing in permitted zones of marine reserves such as the GBRMP. Private recreational fishing vessels are not required to maintain logbooks. It is illegal in all states and territories for recreational fishers to sell their catch. This also applies to fish caught on charter vessels.

While state and territory regulations of recreational fishing apply to state and Commonwealth waters, appendix 2 of this report also notes that, in addition to management plan prescriptions, the Director of National Parks' powers under the EPBC Act in relation to recreational fishing in CMRs include the ability to specify:

- the number, species and size of fish that can be taken and/or possessed
- the type of gear and bait that can be used
- spatial and temporal closures.

However, as also stated in appendix 2, the Director of National Parks does not commonly apply additional restrictions.

3.2.3 Recreational fishing surveys

There has been only one national survey of recreational fishing participation and catch in Australia (Henry and Lyle 2003), although a repeat survey every five years is being planned. This National Recreational and Indigenous Fishing Survey, undertaken in 2001, was a comprehensive diary-based survey that ran for 12 months and covered all states and territories. The study estimated the total catch of finfish by recreational fishers in 2000–2001 to be at least 27 000 t, plus an additional 3000 t of invertebrates (molluscs and crustaceans). Estimated catches were based on reported numbers of organisms caught, which were then transformed to weights, with inherent errors in different jurisdictions. Nevertheless, the results are thought to be reasonable 'order of magnitude' estimates of total recreational catches. Removing freshwater fish from these totals (since these are not relevant to CMRs) results in a nationwide estimate of about 23 000 t of marine finfish harvested by recreational fishers in 2000–2001, most of which would have been taken in nearshore waters.

Recreational catches of marine finfish were greatest in Queensland (about 7500 t), followed by New South Wales (5100 t), Western Australia (4700 t) and South Australia (2900 t).

Complementing this national survey, there have been several statewide surveys conducted from time to time, the most recent being, for Western Australia, in 2012 (Ryan *et al.* 2013); for Queensland, in 2010 (Taylor *et al*. 2012); for South Australia, in 2007 (Jones 2009); for the Northern Territory, in 2009–2010 (West *et al*. 2012); and, for Tasmania, in 2012–2013 (Lyle *et al.* 2014). A statewide survey is currently under way in New South Wales.

It is important to note that, with respect to CMRs, while results of these surveys are usually broken down into smaller geographic regions (for example, Ryan *et al.* 2013), there is limited specific information on previous or current recreational fishing catches or fishing effort within the boundaries of the CMRs.

Relevant to this report is the general perception that recreational fishing participation, and therefore catches, are growing through time. In fact, this is not the case, with many studies indicating continuing declines in participation rates in recreational fishing in Australia (for example, Henry and Lyle 2003; Jones 2009; Taylor *et al.* 2012).

ESP finding
Previous national recreational fishing surveys provided substantial information on recreational fishing catches, but this information is dated, although individual jurisdictions continue to conduct surveys. The Expert Scientific Panel notes that the spatial scope of these surveys is not directly applicable to Commonwealth waters or specific to Commonwealth marine reserve zones.

3.2.4 Comparisons and interactions with commercial catches

A relative indication of effects of recreational fishing on biodiversity may be derived by considering relative catches of the recreational and commercial fishing sectors. Considering Australian commercial catches in 2000–2001 (the same period as the National Recreational Survey), the commercial wild seafood catch was of the order of 190 000 t (Dundas-Smith and Huggan 2006). This figure includes non-finfish (molluscs, crustaceans and other invertebrates), so it would compare with the total estimated recreational catch (including invertebrates) of about 26 000 t. It should be noted in such comparisons, though, that there may be little overlap in species caught by either sector. For example, the current annual commercial catch of Australian sardine is of the order of 33 000 t, but recreational catch of the same species would be very small.

In South Australia, Jones (2009) estimated some relatively high percentages of total catches taken by recreational fishers. These included (with recreational percentage of total catch in brackets), flathead (88 per cent), mulloway (67 per cent), King George whiting (49.6 per cent), Australian salmon (45 per cent) and southern calamari (40.5 per cent). On the other hand, the recreational percentages of total catches were less for many of the targeted commercial species, including blue swimmer crab (29.8 per cent), yellowfin whiting (22 per cent), snapper (19 per cent), gummy shark (16 per cent), southern rock lobster (2.6 per cent) and abalone (less than 0.5 per cent). Care needs to be taken in making some of these comparisons, since the total commercial catch may actually be quite small. In the above, the commercial component of the total catch of flathead represents just 2.5 t, so is clearly not an important target species of that sector.

In Queensland, Taylor *et al.* (2012) estimated the catches of some selected species taken by recreational fishers in 2010 (recreational catch as a percentage of total catch) to be: barramundi (10.4 per cent), Spanish mackerel (48 per cent), spotted mackerel (56.6 per cent), whiting (38 per cent), tailor (66.5 per cent) and pink snapper (65.8 per cent).

In Western Australia, estimates of recreational catches in 2011–2012 were made for the whole coast, divided into four regions (Ryan *et al.* 2013). The comparative catches by species for commercial and recreational sectors were not presented in this report, but, as a result of the study, explicit resource allocations between commercial and recreational fisheries were subsequently determined as follows: Western rock lobster (five per cent recreational, 95 per cent commercial), Roe’s abalone (quotas—40 t recreational, 36 t commercial), and the West Coast demersal scalefish fishery (36 per cent recreational, 64 per cent commercial).

The majority of the recreational catches cited above were taken in state waters. However, as noted, state-managed recreational fishing may extend much further offshore and does overlap with some Commonwealth fisheries to varying degrees. Griffiths and Pepperell (2006) developed a matrix of such interactions, or shared species, in each of the Commonwealth fisheries. These do not inform directly on the recreational fishing impact or importance in the CMRs but do provide information on the species of fish of importance to the recreational sector that might be found in CMRs covering parts of the geographic range of each of the Commonwealth fisheries.

The main Commonwealth commercial fisheries in which the interaction with recreational fisheries was identified as being significant were the Eastern and Western Tuna and Billfish Fisheries (ETBF, WTBF), the Southern Bluefin Tuna Fishery (SBTF) and some parts of the Southern and Eastern Scalefish and Shark Fishery (SESSF). The tuna and billfish fisheries are relevant to all CMRs. The southern bluefin tuna and components of the SESSF are both relevant in the Temperate East and South-west CMRs.

The potential significance of recreational fishing on pelagic species is underscored in an assessment of catch and effort in the pelagic sport fishery off eastern Australia, which concluded that the catch estimates for the seven most commonly caught species varied between 27 per cent and 206 per cent of total commercial catch (Zischke *et al*. 2012). This study noted that catch-and-release rates varied between species, with sport species like billfishes released in every instance but species favoured for eating commonly retained and less than 10 per cent of desirable table fish (for example, Spanish mackerel and wahoo) being released. Only five per cent of respondents in the study tagged and released fish. The authors conclude that, given the significance of recreational catch for some pelagic species, future stock assessments require reliable estimates of catch and catch rates by recreational fishers.

Relevant to future planning and monitoring for CMRs, Griffiths and Pepperell (2006) recommended species in three broad categories for inclusion in long-term monitoring of recreational fishing in Commonwealth fisheries (which would also apply to monitoring in the CMRs). These include: pelagic fishes (tunas, billfishes, mackerels, and sharks); demersal slope and shelf species (trevallies, snapper, elephantfish, gummy shark, flatheads, trevallas, warehous, gemfish, morwongs, trumpeters and barracouta); and tropical reef species (emperors and snappers, coral trouts and cods, and amberjacks). They also identified numerous existing and potential data sources which may be useful for monitoring recreational fishing in Commonwealth fisheries, including state fisheries agencies, universities and community programs—noting, however, that many have inadequate spatial and temporal coverage. The most useful data sources suggested were studies from state fisheries agencies where on-site surveys collected catch, effort, and size composition of recreational catches across relatively large spatial and/or temporal scales. Some novel methods for estimating catches and catch per unit effort (CPUE) in specialised recreational fisheries, which would have relevance to future monitoring within the CMRs, have subsequently been tested. These include chain-referral sampling as a form of respondent-driven sampling (Griffiths *et al.* 2010a) and time–location sampling as more efficient and cost-effective than access point surveys (Griffiths *et al.* 2010b; Griffiths *et al.* 2013).

ESP finding

Recreational catches of fish can be significant components of total catches of fish, often of the same order of magnitude and sometimes exceeding commercial fishing on the same species. At the spatial level of Commonwealth marine reserves, and for specialised fishing, such as for pelagic fish, research and monitoring is needed to quantify recreational catch and effort. The Expert Scientific Panel notes that recently-developed novel methods may show promise in this regard.

3.2.5 Effects of recreational fishing on biodiversity

As indicated above, specific FGRAs were not deemed to be necessary for recreational fishing activities with respect to CMRs. The opportunity is taken here to examine some aspects of recreational fishing activities that may have impacts on the biodiversity conservation values of the CMR network or individual reserves.

While recreational anglers may target desirable species of fish, non-target or bycatch species are also often caught in the process of fishing with rod and line or other gear (nets, traps). In the recreational fishing surveys discussed above, retained bycatch is regarded as ‘harvest’, whereas discarded bycatch would be included in the category ‘released’. Commonly discarded bycatch (undesirable species) would include toadfish, pufferfish, rays, rabbitfish, moray eels, wirrah or any species that is regarded as dangerous, poisonous or of dubious eating quality. Post-release survival of key recreationally targeted fish species is discussed in detail in a paper written to inform the ESP’s review (Pepperell 2015).

Survival of routinely discarded species is not well studied or quantified, and few studies have been undertaken in relation to survival rates of fish commonly targeted by recreational fishers in Commonwealth waters. In Australia there has been only one major study on post-release survival of tropical reef species (Brown *et al.* 2008). That study recorded survival rates of over 75 per cent for coral trout, redthroat emperor, red emperor and crimson snapper, while saddletailed snapper survival was below 50 per cent.

Studies in Australia and overseas using pop-up satellite tags on marlin caught on recreational gear estimated survival rates of between 74 per cent and 100 per cent (Domeier *et al.* 2003; Horodysky and Graves 2005; Musyl *et al.* 2005; Graves and Horodysky 2008; Pepperell and Kopf 2011; Domeier and Speare 2012). A single study of 60 tuna caught in south-eastern Australia estimated post-release survival between 80 per cent and 90 per cent (Tracey *pers. comm.*). One study recorded a 100 per cent survival rate for 20 white marlin caught on circle hooks and a 65 per cent survival for 21 fish caught on more traditional 'J' hooks (Horodysky and Graves 2005).

Recreational fishers also harvest bait. In inshore areas, this includes ghost shrimp, prawns, beachworms and other polychaetes, and many species of small fish. The latter would include mullet, scad (yellowtail), mackerel (*Scomber* spp.), pilchards and, for game fishing, larger scombrids and carangids such as skipjack tuna, mackerel tuna, double-lined mackerel, queenfish and rainbow runner. Many of the recreational fishing surveys mentioned above do record catches of such organisms but not necessarily in a category defined as 'bait'.

Importantly, catches of recreational fishing need to be taken into account as part of stock assessments since they are part of the total fishing mortality to which a stock of fish may be subjected. The level of fishing mortality caused by recreational fishing can vary from very light to significant depending on the number of fishers and their catch rates. As well as these direct effects of recreational fishing on fish populations, there are also potential indirect effects of the activity. McPhee *et al.* (2002) considered a broad range of such indirect effects, which are discussed below.

McPhee *et al.* (2002) cite some overseas examples of trophic interactions caused by selective removal of carnivorous fish, for instance, an increase in populations of some invertebrate prey species. They speculated a high likelihood of such effects in some Australian cases (for example, mulloway, coral trout and tailor) but did not provide any evidence to support this contention. They also cite a number of references regarding entanglement of marine animals in fishing line or recreational crab pots and note that boat strike is the leading cause of mortality of turtles in Queensland, although this would include all forms of boats, not just recreational fishing boats. While many of these aspects of recreational fishing may occur, it is important to note that the actual level of impact of most have not been quantified in any meaningful way.

ESP finding

While recreational fishing can have significant impacts on target species of fish, these impacts and the possible indirect effects of recreational fishing on biodiversity are not well understood or quantified, especially in Commonwealth waters. Risks to biodiversity need to be better understood.

3.2.6 Relative risks of recreational fishing

In a CMR, the relative risk of recreational fishing to fish populations—and therefore to some aspects of biodiversity—will be directly proportional to the level of fishing effort and efficiency of that effort. The impacts of fishing on reef-associated species are well understood, especially for long-lived, slow-growing and sex change species (referenced below). Proximity to the coast and/or to urban or major holiday centres would be the strongest correlates of recreational fishing effort and therefore potential impacts (Buxton 1993; Mapstone *et al*. 1997; Mapstone *et al.* 2003). Conversely, the more remote a given location, the less likely that there would be visitations by recreational fishers, although the attraction of pristine, remote reefs may result in some targeting of such locations by long-distance charter and private operators. However, as noted, recreational fishing data has usually been gathered on broad geographic scales not directly applicable to the scale of CMRs. Some localised studies of recreational catch and effort have been carried out from time to time, but none with respect to the specific zoning as indicated in the CMRs.

In Australia, effects of recreational fishing within MPAs has usually been studied by comparing ‘populations’ of fish within no-take zones with those in comparative areas that are open to fishing. Relative abundance is estimated by means of visual counts along transects by divers, either by surface swimming, deeper scuba swimming or manta board towing. Some studies have also made use of baited remote underwater video gear. Estimates of the sizes of some species of observed fish may also be made during such censuses.

The GBRMP has been studied in greatest detail in this regard, especially since the zoning there allowed comparisons between large numbers of no-take areas and areas open to fishing following creation of the park in 1975 and after significant expansion of no-take zones in 2004. Many of the studies have focused on a key group of species caught by recreational and commercial fishers—for example, the coral trouts, *Plectropomus* spp.

Evans and Russ (2004) noted that earlier studies on the effects of no-take reserves on the abundance of coral trouts in the GBRMP were somewhat contradictory. Some studies showed higher densities in protected versus fished zones around Heron Island (Goeden 1978; Craik 1981), while others found no differences in other paired comparisons (for example, Ayling and Ayling 1984; 1986—unpublished reports to GBRMPA cited in Evans and Russ 2004; Ayling *et al*. 1993; Mapstone *et al*. 1997). Further studies showed increased densities of coral trouts in no-take zones in some, but not a majority of comparisons (Mapstone *et al*. 2003). On the other hand, Williamson *et al*. (2004) found almost five times the biomass of coral trouts in inshore no-take zones compared with open, presumably heavily fished areas. Evans and Russ (2004) found variable results with respect to density of coral trouts in no-take versus open areas, resulting in an overall non-significant difference between protected and fished zones. However, when size of fish was taken into account, highly significant differences in estimated biomass of observed fish were found between fished and not-fished reefs across the study area. This is similar to work done on temperate reefs in Tasmania (Barrett *et al.* 2007).

Such studies evolved over time. In a follow-up study to those above, Russ *et al.* (2008) found significant increases in density of coral trout in both inshore and offshore areas within two years of expansion of no-take zones within the GBRMP. And Miller *et al.* (2010) systematically surveyed coral trout over a six-year period on more than 20 pairs of more offshore reefs open to and closed to fishing since 2004, when no-take areas were expanded considerably within the GBRMP. The study area stretched from north of Cairns to south of Rockhampton—a distance of over 1000 km. The results showed that coral trout populations on no-take reefs were significantly higher than on reefs open to fishing and that populations on open reefs combined declined over the period of the study but were stable on the no-take reefs.

It is important to note in reviewing this series of case studies on coral trout densities and biomass in no-take versus fished zones that the areas open to fishing are open to both recreational and commercial line fishing. The coral trouts are highly sought commercial species and, while it is true that the commercial fishery tends to operate further offshore than the recreational fishery, confounding effects of commercial fishing on all open reefs cannot be discounted.

Another example of this is shown in the study of Nardi *et al.* (2004), who monitored the abundance of two commercially and recreationally important fish species—baldchin groper or bluebone (*Choerodon rubescens*) and, again, coral trout (*Plectropomus leopardus*) in protected and open areas off the Houtman Abrolhos Islands, Western Australia, between 1995 and 2002 (protection had been established in 1994). Populations of baldchin groper were similar in no-take versus open areas and, for the first three years of the study, coral trout populations were also similar between the two areas. However, after eight years, coral trout populations were significantly higher in no-take areas. Again, this study showed that removal of line fishing can have beneficial effects on stocks of some but not all target species, but it could not discriminate between recreational and commercial fishing as to the degree of impact caused by either.

Boaden and Kingsford (2015) compared numbers and biomass of a number of piscivorous fish species (including coral trouts) and herbivorous fish on reefs within the GBRMP that were closed to fishing, open to fishing and with 'limited fishing'. In general, biomass and numbers of predatory fish were greater on the reefs that were closed to fishing and, to a lesser extent, on reefs open to limited fishing. In addition, there was evidence of ‘prey release’ (an increase in some prey species due to depletion of predators) in some open reefs but not others.

Reefs that were open to ‘limited fishing’ appear to be reefs where only recreational fishing was assumed to occur (because they were ‘inshore’) but, in fact, may have been fished commercially since they were not closed to commercial fishing.

In fact, there are few studies in which only recreational fishing effects have been considered in comparing no-take with fished zones within Australian MPAs. In one such study, Westera *et al.* (2003) compared no-take and open areas at four inshore sites within the Ningaloo Marine Park, Western Australia. Importantly, only recreational fishing was permitted in the open areas, not commercial line fishing. Using surface visual survey and BRUV, they found significant differences in the composition of fish families/genera targeted by fishers (*Lethrinidae*, *Lutjanidae*, *Haemulidae*, *Serranidae* and the genus *Choerodon* of the family *Labridae*) in terms of biomass between no-take and open reefs.

ESP finding

There is good evidence that line fishing does have impacts, if not always on numbers of fish then on biomass per unit area of targeted relatively sedentary species. It is important to note, though, that these studies have been primarily conducted on reef habitats and, with respect to effects of recreational fishing per se, are often confounded by the additional impact of commercial line fishing on the same areas that are open to fishing. There is a good case for investment in specific experiments on effects of solely recreational fishing on fished versus no-take areas, including on non-sedentary species.

3.2.7 Catch and release fishing

This topic is covered in detail in Pepperell (2015) and a summary is provided here. A considerable volume of quantitative data has been accumulated on post-release survival of a range of fish species caught and released using typical recreational hook-and-line fishing methods. In Australia, many studies in which released fish are confined for subsequent observations of mortalities have been conducted on inshore marine species, but relatively few have been conducted on reef species. Pop-up archival tags have been used in increasing numbers to derive post-release mortality data on pelagic species—in particular, the billfishes.

The overall conclusions across these studies are that post-release survival of recreationally caught fish is generally high (as a ‘rule of thumb’, usually between 65 per cent and above 95 per cent—sometimes even 100 per cent) under the conditions of the experiments. Pelagic fish—in particular, billfish, but also pelagic sharks and tunas—have high post-release survival (86 per cent to more than 90 per cent), especially if shark predation on released fish is minimal. On the other hand, studies on catch and release of several reef fish and deepwater species show that mortality can be significant, even with a range of handling techniques to minimise impacts such as barotrauma.

A number of these studies were also designed to quantify predictors of mortality and therefore how post-release mortality might be mitigated. These include how to deal with barotrauma, the use of certain hooks that reduce tissue damage, cutting the line if the hook is swallowed and, more recently, not removing some species from the water (minimising air contact). Some studies also provide data on predation events by sharks on released fish, indicating that in some cases this can be a significant factor in post-release mortality. Again, some of these results suggest ways of mitigating predation immediately after release.

Catch-and-release provisions in some areas could have the added potential benefit of encouraging citizen science based research on aspects of the biology of the fish caught and released—from studies of movements and post-release behaviour to refining information on factors that increase post-release survival to the provision of biological samples from released fish for a wide variety or research purposes. A recent example of the value of citizen science in recreational fishing was a successful broad-scale population genetics study of black marlin utilising finclips taken from fish released by recreational fishers on both the Pacific and Indian ocean coasts of Australia (Williams *et al.* 2015a; Williams *et al.* 2015b).

ESP finding

The Expert Scientific Panel notes that post-release survival for some pelagic species may be high. However, for others, especially reef-associated species which are subject to barotrauma, survival may be considerably reduced, especially when caught from deep water. The prospect of post-release mortality and the unknown impact of capture on the physiology of survivors makes this form of fishing incompatible with Marine National Park protection. It is likely that post-release survival of most species can be further enhanced by encouraging experimentally-determined gear and handling techniques.

The voluntary practice of catch-and-release and the willingness of the recreational sector to assist research is a good basis for future beneficial citizen science studies.

The Expert Scientific Panel believes that investment in the monitoring of the levels of catch-and-release by recreational fishers in key regions of the Commonwealth marine reserve estate, especially in remote areas, and further engagement of recreational fishers in regulated and supervised citizen science activities will be an important component of Commonwealth marine reserve management into the future.

3.2.8 Effects of recreational fishing on pelagic fish

The potential effects on pelagic species targeted by recreational fishers is dependent on the species, fishing techniques used and intensity of effort. As noted, much of the research on effects of recreational line fishing in no-take versus fished areas has focused entirely on reef-associated species. Relatively sedentary reef species such as coral trout, which rarely move between reefs (Davies 2000, cited in Miller *et al.* 2010) are far more susceptible to targeted site fishing by line fishing (both recreational and commercial) than offshore pelagic species such as billfish, tuna and pelagic sharks, which have extensive ranges, are highly mobile and are capable of moving large distances in short periods (Pepperell 2010). Furthermore, the method of recreational fishing for pelagic fishes is confined to surface waters, minimising physical effects of gear on substrate-based habitat and where the proportion of pelagic fish surviving catch and release can be high (Pepperell 2015).

While no studies were found comparing the effects of recreational and/or commercial hook-and-line fishing between no-take and fished areas on pelagic species, one Western Australian study, using pelagic stereo BRUVs, found no differences in numbers of pelagic fish (mainly carangids, mackerels and sharks) in a 22 km^2 area closed to fishing when compared with nearby open areas (Santana-Garcon *et al.* 2014).

ESP finding

While recreational fishing for pelagic species at low levels of effort would be unlikely to impact on the populations of these species, especially for catch-and-release fishing, the limited studies on catch and effort suggest reserve managers should adopt a cautious approach to recreational fishing for pelagic species until better data is available and there is an improved understanding of impacts on populations, particularly of targeted species.

3.2.9 Consume-on-site

The concept of ‘consume-on-site’, whereby fish caught within a reserve must not be taken away but, rather, must be consumed while on-site, is relatively novel.

It appears that this activity was initially permitted within the vast United States Papahanaumokuakea Marine National Monument, encompassing the north-western Hawaiian Islands, but this is no longer the case. Subsistence fishing by native Hawaiians is permitted and some provision is made for consuming fish in this area for vessels in distress.

In Australia, a form of consume-on-site regulation exists in the Lalang-garram / Camden Sound Marine Park—the largest in Western Australian state waters. Within the Jungulu Special Purpose Wilderness Conservation Zone, a low level of recreational fishing is permitted, but a possession limit of one fish per person (or two fillets) applies, and the fish must be consumed on site. Possession of baitfish species above this limit is allowed (DPW 2013).

No specific studies of relative effects of consume-on-site versus normal recreational fishing activity were found. Such effects would depend on the prevailing bag and possession limits for taking fish away, the number of boats visiting and the number of fish of given species each boat took for consume-on-site.

Even in the absence of specific studies, it is reasonable to assume that zoning which stipulated consume-on-site would result in less fishing mortality within the zone than a fully open area since existing bag and possession limits are generally higher than an individual would consume in one day. This suggests a reduction of impact on vulnerable species, especially slow-growing, long-lived and sex change reef-associated species.

Taking Queensland as an example, in that state an individual recreational fisher is permitted to have considerable numbers of fish in his or her possession at any point in time. For example, an angler fishing on an offshore reef would be permitted to possess up to 20 coral reef finfish. This could include, for example, seven coral trout, eight snappers, and/or combinations of other species, including emperors, parrotfish, tuskfish, sweetlips and fusiliers. The same angler, using trolling techniques in the same area, could also catch and have in his or her possession 23 mackerels (*Scomberomorus* spp.), five mahi mahi, two wahoo, various combinations of other species and an unlimited number of tuna or billfish of any species (QLD DAF 2015).

Since there are no boat limits in Queensland, these numbers could be multiplied by the number of anglers on a given vessel, including a charter boat. Thus, a boat with, say, five anglers could legally have on board 100 coral reef finfish, 115 mackerels, 50 shark mackerel, 25 cod/grouper, 25 mahi mahi, 10 wahoo, five sharks or rays and unlimited numbers of tuna and billfish. Furthermore, the possession limit for coral reef finfish per angler on a charter boat would increase from 20 to 40 if the charter is longer than 72 hours, and to 60 if the charter is longer than seven days (QLD Government 2008).

In contrast, consume-on-site zoning would mean that one angler may have only one or two fish in possession or, in the case of a party of anglers on a boat and for larger fish over several kilograms in weight, less than one fish per person. Similar calculations can be made for other state jurisdictions, but the principle would remain—that consume-on-site regulations would greatly reduce the potential recreational take of fish from a given site.

ESP finding

Consume-on-site provisions for recreational fishing in some areas, especially remote reefs, have the potential to minimise impacts while allowing limited fishing to occur in such areas. Controlled experiments could be conducted on effects and practicality of consume-on-site arrangements (if implemented) on pairs of more remote reefs within the Commonwealth marine reserve estate.

3.3 Zonation

In a system of marine reserves designed to achieve biodiversity conservation while simultaneously accommodating a range of other uses, zoning plays a key role by prohibiting, constraining and spatially allocating different activities, particularly extractive uses across a reserve or network. To help inform specific zoning recommendations and the matrix of allowable uses in each zone, the ESP examined how different zone types contribute to achieving conservation objectives. The evaluation in this chapter also informs the identification of research needs to inform future zoning decisions (see chapter 4).

This section provides a discussion of the conservation value of different zone types used in the CMR estate, each of which is assigned to one of the IUCN Protected Area Categories, based on their management objective (see section 2.3.4 for more detail on Australia’s approach to zoning). They include:

- Sanctuary (IUCN Ia)
- Marine National Park (IUCN II)
- Habitat Protection (IUCN IV)
- Multiple Use and Special Purpose (IUCN VI).

The terminology and definitions for IUCN Protected Area Categories were articulated by Day *et al*. (2012) with the aim of providing greater consistency in the use of these zoning categories in marine areas.

The primary purpose of CMRs is the protection and conservation of biodiversity and other natural and cultural values. Secondarily, they provide for ecologically sustainable use of natural resources where this is consistent with the primary objective. CMRs have specifically not been proposed for fisheries management purposes. While considerable debate exists over the use of marine protected areas as a fisheries management tool (Gell and Roberts 2003; Jones 2007; Hilborn *et al.* 2006; Gaines *et al.* 2010) or as an approach to mitigate threats to the marine environment (Kearney *et al*. 2012; Kearney and Farebrother 2014), their conservation benefit is generally accepted. It is also widely accepted that reserves play an important role as research reference sites.

3.3.1 Marine National Park Zones (International Union for Conservation of Nature Category II)

Terminology on MPAs varies considerably in the literature. For example, the terms ‘no-take MPA’, ‘marine reserve’ and ‘marine sanctuary’ are often interchanged and used to denote the same thing. ‘No-take’ is used in the CMR for areas where extraction of biological or physical resource is prohibited. In accordance with Australian Government practice, no-take zones may either be Sanctuaries (where non-extractive and extractive uses are generally prohibited) or Marine National Parks (where non-extractive activities like nature-based tourism and recreation uses and research activities are allowed). These two zone types are assigned to IUCN Categories I and II respectively and have the most restrictions on human usage (Day *et al.* 2012).

In the CMR context, a Marine National Park Zone was defined in the set-aside management plans as an area protected and managed to preserve its natural condition. Marine National Park Zones are intended to provide a high level of protection for the ecosystems, habitats and biodiversity within the area and, as such, activities involving the taking or harvesting of either living or non-living resources will generally be prohibited. Areas where harvesting of living resources is prohibited are a key component of any conservation planning, as recognised in the Goals and Principles (Principle 18).

The greatest concentration of scientific effort in examining the effects, value and utility of ‘no-take’ has been focused on inshore and coastal ecosystems. While this may partly be due to ease of access and cost for researchers, there is also a much longer history of MPAs closer to shore and on coral reefs than in remote, deeper waters. In evaluating the role of Marine National Park Zones, consideration was given to the latest scientific literature; however, few studies are available on offshore reserves and most of the discussion refers to near-shore no-take reserves.

There is a large body of published research that illustrates the importance and value of no-take areas from a conservation perspective, including the protection and/or recovery of species, habitats and ecosystems from the effects of exploitation. Some of this work, particularly longer-term studies, also demonstrates changes in ecological processes and food webs. Key differences between exploited and ‘no-take’ areas include increases in species richness, abundance, biomass and body size of target fish, although effects on non-target fish or benthic assemblages vary (Stobart *et al*. 2009; Barrett *et al.* 2007; Barrett *et al.* 2009; Lamb and Johnston 2010; Miller *et al*. 2012; Wing and Jack 2013; Williamson *et al*. 2014; Emslie *et al*. 2015; Starr *et al*. 2015).

Response to protection in no-take areas can be slow, complex and species-specific (for example, Barrett *et al*. 2007; Edgar *et al*. 2009), but the benefits associated with ‘no-take’ include:

- stable populations of targeted fish inside no-take reserves contributing to resilience of these species (Babcock *et al*. 2010)
- greater stability in the food web due to the presence of large omnivorous fish (Wing and Jack 2013)
- contribution of 'no take' areas to recruitment in reef-associated species (Wen *et al*. 2013; Harrison *et al*. 2012)
- spillover to adjacent areas and improved catch per unit effort, particularly where the area adjacent to the reserve is overfished (Buxton *et al.* 2014)
- recovery of kelp forest as a consequence of increased predation by large lobsters and fish on destructive herbivorous grazers such as urchins (Babcock *et al*. 1999; Edgar *et al*. 2009; Leleu *et al.* 2012; Alexander *et al.* 2014; Costello 2014)
- increased resilience against climate change or large-scale disturbance events such as floods or cyclones (Williamson *et al*. 2014; Emslie *et al*. 2015).

In a global assessment of marine reserves, Edgar *et al*. (2014) showed that 'no-take' is one of five key features—no-take, enforced, old, large and isolated (NEOLI)—that derive the most effective conservation outcomes for marine reserves in terms of the mean size and abundance of exploited species. The extent of changes in no-take zones also depends on the site history, with previously disturbed or heavily utilised zones displaying more substantial changes than zones located in areas of no or little prior disturbance or human use (Edgar *et al*. 2009; Edgar *et al*. 2014). Conservation benefits, including for fish of commercial value, were more apparent with increasing age of no-take zones (Claudet *et al*. 2008; Molloy *et al*. 2009; Edgar *et al*. 2014). Coral reef fish targeted by fishers in the Philippines increased in densities inside no-take reserves with the age of no-take protection, while non-targeted fish responded more to habitat changes inside reserves (Russ *et al*. 2015).

Value of no-take areas for research and reference

Against a backdrop of a worldwide decline in marine biodiversity (Pimm 2012; McCauley *et al.* 2015) and low recovery success recorded so far for marine species and ecosystems (Lotze *et al.* 2011), no-take zones are important reference areas to inform management and conservation (Rice and Houston 2011). Reduction of human impacts (reduced or no exploitation, habitat protection and pollution control) is the most obvious driver of recovery in marine animal populations and ecosystems (Lotze 2011). No-take areas allow insight into natural relationships and are the best way to understand what 'natural' ecosystems are, including the full functional extent of habitats (Thrush and Dayton 2010; Sheehan *et al*. 2013; Costello 2014).

Assessing recovery can be impossible when the 'normal state' or historical base lines of populations or ecosystems are unknown (Manez *et al*. 2014) due to shifting base lines and controversial methods to reconstruct historical reference points (Lotze *et al*.

2011). For example, three decades of protection in New Zealand led to changes in benthic habitats and communities, which showed that habitats that had been perceived as natural when reserves were established were in fact modified by the lack of large predators (Costello 2014).

Reference areas are also needed to distinguish between natural variability and other (non-fishing) human-induced fluctuations in marine ecosystems (Rice and Houston 2011; Costello 2014). Comparing monitoring data within and outside of no-take zones thus allows specific patterns of variation occurring only in unprotected areas to be attributed to human uses (Edgar *et al*. 2009; Rice and Houston 2011; Alexander *et al*. 2014). Marine reserves provide for experimental Before-After-Control-Impact (BACI) designed studies on otherwise experimentally uncontrolled human activities, including fishing (Barrett *et al.* 2009; Leleu *et al.* 2012; Costello 2014).

Size of no-take areas

The science underpinning the adequacy of size of no-take areas is still a matter of debate. For example:

- In a global synthesis of nearly 150 peer-reviewed publications on effects of no-take zones, Lester *et al.* (2009) showed that the magnitude of effects (increase in size, biomass, density and species richness) appeared irrespective of the size of the no-take zone.
- Sciberras *et al*. (2015), in a study which included no-take areas of between 0.13 and 30 km^2, noted that size of no-take areas relative to partially protected areas did not explain variations in target species density among MPAs. But they did note that size is one of a number of factors of interpretation that are of more general relevance in interpreting MPA studies.
- Edgar *et al*. (2014) showed that larger no-take areas (over 100 km^2) achieved greater biodiversity outcomes, especially when they were well enforced, old and isolated (three of the NEOLI key features).

- For commercial fish, a review of data from 12 marine reserves in Europe showed overall increases in fish densities with size and age of no-take zones and time since reserve establishment accounting for some variability between reserves (Claudet *et al*. 2008). The review indicated that the positive effect on densities of small and large commercial fish was scaled with increasing size of no-take areas. However, the size of the buffer zone had a negative effect on fish density, possibly because of fishing pressure (Claudet *et al*. 2008).

- The required size for conservation outcomes is also subject to the species to be protected as, for example, rock lobster populations can benefit from protection, even from small no-take areas (Barrett *et al.* 2009*;* Bevacqua *et al*. 2010), whereas highly mobile pelagic fish may not benefit from small-sized closures (Santana-Garcon *et al*. 2014). Rice and Houston (2011) proposed that no-take MPA sizes be large enough to meet management objectives and maintain key ecosystem processes structuring pelagic and benthic communities, which mostly require tens or hundreds of square kilometres.

ESP finding
The Expert Scientific Panel (ESP) recognises the significant body of scientific literature that demonstrates the effectiveness of Marine National Park Zones (no-take zones) in achieving conservation outcomes and for their role as scientific reference areas. The ESP notes the emerging consensus that, to attain and preserve natural condition, no-take, size, configuration, enforcement and length of time the area has been protected all need to be considered.

The ESP considers that, because Marine National Park Zones are important scientific reference sites for monitoring change within and outside reserves, each reserve should include at least one Marine National Park Zone and that a significant sample of each primary conservation feature and each provincial bioregion be included in at least one Marine National Park Zone of an appropriate configuration and size to meet conservation objectives.

The ESP also recognises the relative paucity of research on offshore Marine National Park Zones, including most of the Australian estate, and proposes future research to test the applicability of patterns emerging from shallow water no-take zones to their offshore equivalents (see chapter 4).

3.3.2 Habitat Protection Zones (International Union for Conservation of Nature Category IV)

While the primary management objective for all zones in MPAs is the conservation of biodiversity, zones that allow for some economic and social uses and activities that are compatible with the primary objective are often referred to as providing 'partial protection'. This section focuses on Habitat Protection Zones, which in the Australian marine context have been characterised by the exclusion of activities that physically damage or seriously compromise the conservation values associated with the particular habitat in question. Habitat Protection Zones aim to maintain habitat and to secure and maintain habitat conditions necessary to protect significant species, communities or physical features (EPBC Regulations Schedule 8) (CoA 2015). These zones are assigned as IUCN Category IV. Here, we discuss habitat considerations and review literature findings on the effectiveness of IUCN Category IV.

The importance of protecting benthic habitat has a policy basis. For example, the Goals and Principles specifically identify seafloor features and key ecological features like canyons and seamounts as conservation value to be represented in the CMR estate (see section 3.4). Benthic habitats considered for Habitat Protection Zones include significant seafloor and geomorphic features such as pinnacles, seamounts and canyons but may also include habitat such as seagrass.

Protection of benthic habitats also provides for the protection for organisms that build or create structures that provide habitat for other organisms (ecosystem engineers). A review of cold-water corals, for example, observed they provide niches for many species, with over 1300 species reported as having been found living on cold-water coral reefs in the North-East Atlantic (Roberts *et al*. 2006). Further importance for protection arises from the ecological role played by the benthos in the marine environment (for example, nutrient cycling, primary productivity, source of prey and hosting of critical life stages for pelagic species) (Levin and Sibuet 2012; Snelgrove *et al*. 2014) and from their uniqueness as species and communities (for example, endemism and rarity).

Activities allowed in IUCN Category IV may include selective and/or low-impact harvesting of benthic or demersal species, such as hand collection of sea cucumbers or line fishing (see, for example, the set aside management plan for the South-west CMR Network, which was to exclude demersal gillnet, demersal longline, fish traps, lobster pots, octopus traps and crab pots from Habitat Protection Zones). Activities that are prohibited in IUCN Category IV damage habitat and cause the destruction, disturbance or fragmentation of substrates and organisms that support marine life, including ecosystem engineering structures like corals and sponges (Thrush and Dayton 2002). These damaging activities include a range of demersal fishing practices (Althaus *et al.* 2009; Clark and Rowden 2009; Heifetz *et al.* 2009; Williams *et al.* 2010) and mining and oil and gas exploration and production (Roberts *et al.* 2006; Clark *et al.* 2012; Levin and Sibuet 2012).

While it is not specified in the EPBC Regulations whether 'habitat' refers to benthic or pelagic habitat, Habitat Protection Zones are most commonly focused on protecting the benthic and demersal habitats and species assemblages. It is worth noting, however, that in the Macquarie Island CMR, there are two Habitat Protection Zones that protect benthic and pelagic habitat, in part for their importance as foraging areas for seabirds and seals. Further reasons for protecting processes in the pelagic system are evaluated in section 3.4.2. The corollary of protecting the benthos and associated seafloor features is that activities in the water column that damage the habitat will also be regulated.

An evaluation of the effectiveness of Habitat Protection Zones is constraint by the scientific literature on partial protection in marine reserves, in zones where some extractive use or uses are allowed, which is much less extensive than that for 'no-take'. Drawing generalisations from this literature is challenging because of differing applications of the term 'partial protection' and a wide variety in the nature, intensity and frequency of allowed uses (Lester and Halpern 2008). For example, some studies considered the exclusion of commercial fishing but allowing recreational fishing as 'partial protection' (for example, Coleman *et al.* 2013), as was banning of spearfishing but allowing other forms of recreational fishing (Curley *et al.* 2013). In another study, excluding recreational fishing but allowing commercial fishing was regarded as partial protection (Di Franco *et al.* 2009).

Few studies report on the efficacy of partial protection and even fewer on management regimes that protect benthic habitats. Most studies investigated fish—in particular, targeted species. From comparisons between no-take zones, partial protection zones and areas open to fishing, the following patterns emerge:

- Biomass increases significantly with higher protection—for example, a threefold higher biomass in the no-take zone than partial protection (Di Franco *et al.* 2009; Ban *et al*. 2014a; Guidetti *et al*. 2014)—as size of fish was larger in no-take zones than in Habitat Protection Zones (Coleman *et al*. 2015).
- Species richness and functional richness were not significantly different between no-take zones and partial protection zones or between all three zones (Di Franco *et al.* 2009; Ban *et al*. 2014a; Coleman *et al*. 2015).
- Abundance was not consistently different between no-take zones and partial protection zones or between all three zones (Di Franco *et al.* 2009; Ban *et al*. 2014a; Coleman *et al*. 2015), depending on habitat (Coleman *et al*. 2015) or type of fish (for example, trophic level) (Guidetti *et al*. 2014; Boaden and Kingsford 2015).
- Top-down control by predatory fish was most pronounced in the no-take zone, less so in partially protected areas (Guidetti *et al*. 2014; Boaden and Kingsford 2015).
- There were distinct fish assemblages with a gradient of effects from no-take (highest benefit) to some effects (partial protection) (Boaden and Kingsford 2015).
- The ecological effectiveness of IUCN Category IV was 60 per cent (confidence intervals from 34 per cent (lower) to 89 per cent (upper)), compared to 100 per cent for no-take areas and 0 for no protection (Ban *et al*. 2014a, based on global meta-analysis).
- Variability in the response to protection can be high and the analysis of species responses challenged by large spatio-temporal variations occurring in species assemblages across the systems (Coleman *et al.* 2013: Ban *et al*. 2014a).

Some studies discussing the importance and effectiveness of protecting benthic habitats have identified habitat dependencies, specialisations and life history characteristics of benthic species as important attributes of demersal species assemblages (for example, Fitzpatrick *et al.* 2012). An additional value of benthic protection will arise from the extent to which benthic habitats—for example, nursery areas, spawning and feeding grounds—and associated demersal communities provide ecosystem services and play a significant role in the life history of pelagic and other mobile species (Levin and Sibuet 2012).

ESP finding

The Expert Scientific Panel (ESP) recognises the value of Habitat Protection Zones to protect habitat, biological diversity and associated ecosystem services and structure. Areas of high conservation value should be captured in Habitat Protection Zones across the Commonwealth marine reserve estate, where socio-economic factors prevent designation as a Marine National Park Zone. Allowed uses in Habitat Protection Zones must be compatible with the conservation of biodiversity and maintenance of the integrity of ecological processes.

The ESP considers that there is a high conservation benefit from zoning areas as Habitat Protection Zones to protect benthic and demersal habitats by excluding damaging activities while allowing activities such as regulated fishing in the water column, including take of pelagic species that do not compromise conservation values and management objectives for these areas.

The ESP notes the general paucity of studies on the value and effectiveness of Marine Protected Area zoning that protect specific habitats and that many studies that have been undertaken were not in Australia. This indicates a need for scientific study on the efficacy and benefits of Habitat Protection Zones and comparisons with Marine National Park Zones, Multiple Use Zones and controls outside of Commonwealth marine reserves. Investments in research and monitoring on this issue should be a priority in the future. This is discussed further in chapter 4.

3.3.3 Multiple Use Zones (International Union for Conservation of Nature Category VI)

The vast majority of global MPAs are managed for multiple use. Of 17 802 MPAs analysed from the World Database on Protected Areas, 93 per cent (or 82 per cent by area) were managed for multiple use. Of the 1124 sites managed for no-take, nearly three-quarters are smaller than 10 km^2 and their median size is 1.7 km^2 (Thomas *et al.* 2014). By contrast, the multiple use component of Australia's CMR estate proclaimed in 2012 (that is, excluding the South-east CMR Network), including Habitat Protection Zones, is 64 per cent by area, with a median size of no-take areas (Sanctuary Zones and Marine National Park Zones) of 907 km^2.

Multiple Use Zones in Australian CMRs allow some extractive uses and are assigned as IUCN Category VI under the EPBC Act and Regulations. This requires their primary purpose to be the protection and maintenance in the long term of the biological diversity and other natural values of the reserve or zone while being managed mainly for the sustainable use of natural ecosystems.

In a recent thorough global meta-analysis that drew on 40 studies of 63 MPAs, Sciberras *et al*. (2015) evaluated the conservation benefits of partially protected areas (that restrict some extractive activities) and no-take reserves against open areas. They subdivided partial protection regimes into those that excluded fishing activities that are damaging to bottom habitats and non-target species, like bottom trawling and scallop dredging; and those that prohibited fishing that affected particular species but not the surrounding environment, like seine nets and pelagic longlines. Their analysis showed that, while partially protected areas had significantly enhanced fish density and biomass compared to open areas and mainly of species targeted by fishers, fish density and especially biomass (92 per cent on average) were much higher in the no-take areas due largely to the response of target fish species that were protected in the no-take area only. Their analysis showed fishery gear-specific effects in the partially protected area, with the key determinant of the efficacy of partial protection being the specific protection regime (that is, gear exclusion). They found the larger response when commercial fishing using mid-water gear, like seine nets and pelagic longlines, was excluded but recreational fishing allowed.

Using the data provided by Sciberras *et al*. (2015), Ban *et al*. (2014a) assigned IUCN categories and reanalysed the same 40 studies for their ecological effectiveness following methods by Sciberras *et al*. (2015). This global meta-analysis revealed a lower effectiveness of IUCN Category VI than IUCN Category IV or no-take areas (see figure 3.6).

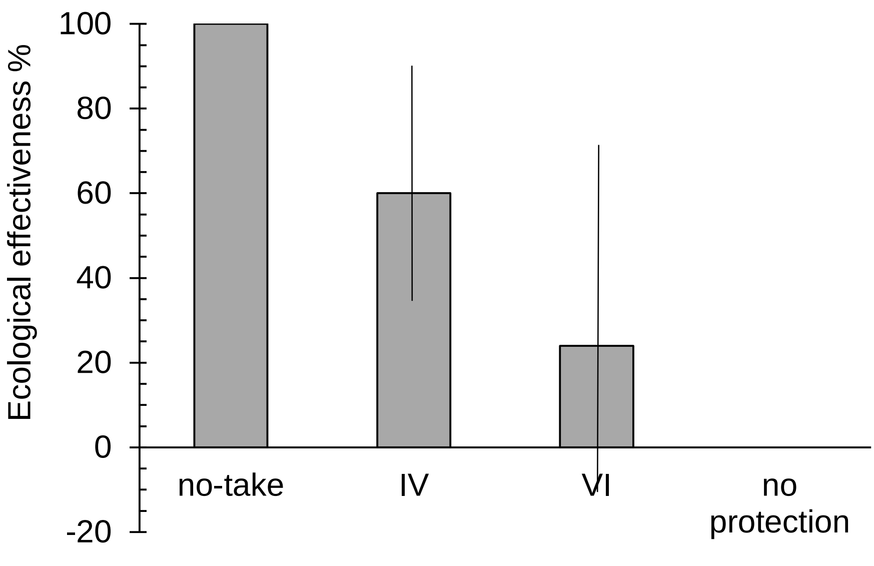

Figure 3.6 Ecological effectiveness of marine protected areas under IUCN Categories IV and VI, rescaled between full protection (no-take) and areas open to all uses (no protection). Error bars indicate upper and lower limits of 95 per cent confidence intervals. Based on meta-analysis of 40 studies worldwide (data from Sciberras *et al*. 2015). Figure adapted from Ban *et al*. (2014a)

Sciberras *et al*. (2015) detected complex and variable effects of size and age of the protected areas. They concluded that MPAs may meet their objectives in a number of ways without necessarily excluding all extractive activities. They observed that the effectiveness of partially protected areas was decreased the larger the size of this zone, possibly from non-compliance and infringement going unnoticed inside large areas. The authors conclude their study suggests that no-take areas provide benefit over less protected areas; nevertheless, the significant ecological effects of partially protected areas relative to open areas suggest that partially protected areas are a valuable spatial management tool, particularly in areas where exclusion of all extractive activities is not a socio-economically and politically viable option (Sciberras *et al*. 2015). The authors raise a number of issues of interpretation that are of more general relevance in interpreting MPA studies: differences in age and size of MPA; effectiveness of compliance; history of exploitation prior to MPA establishment; exploitation intensity inside and outside the MPA; temporal and spatial variability of ecosystem processes; and the need for and frequent lack of strong experimental design in MPA studies.

The study of partial protection zones and no-take zones across a network of MPAs in New South Wales state waters (Kelaher *et al.* 2014) found significant differences between no-take zones and fished areas in the structure of fish assemblages and in fish abundance. In comparing the two partial protection zones—habitat protection and general use—they found no differences between them in the structure of fish assemblages, but the fish assemblage in the Sanctuary Zones was significantly different to both fished zones. Similar findings emerged from the Mediterranean, where fish assemblages in sanctuary zones were distinct, while a greater similarity in fish assemblages and biomass occurred between partial protection and fished area (Guidetti *et al*. 2014). Buffer zones did not achieve a stabilisation of the fish assemblage in the Mediterranean, presumably as they attracted higher fishing effort (Seytre and Francour 2014). Kelaher *et al*. (2014) reported significantly greater species richness in the general use zones than in the Habitat Protection Zone, while richness was not significantly different between Sanctuary Zones and the two fished zones. However, the paper does not report any comparison between either of these two partial protection measures and the fished control sites outside the MPAs. They suggest that management strategies that result in shifting recreational fishing effort towards partially protected areas, which they speculate may have occurred, could limit the conservation benefits of these two areas (Kelaher *et al.* 2014).

ESP finding

While the strongest biodiversity and conservation benefits are delivered by excluding extractive activities from marine reserves, less restrictive management regimes can also deliver biodiversity benefits. The inclusion of some extractive activities in Multiple Use Zones can be compatible with biodiversity conservation as long as the intensity, extent and impact of the activities are known and well managed.

Multiple Use Zones should be used in conjunction with other regulatory controls, such as permits, quotas, bag limits and anchoring and fishing gear restrictions, for managing social, economic and recreational activities (see appendix 2 for discussion of these controls) where conservation objectives are not compromised by the inclusion of these activities.

3.3.4 Split zoning over coral reefs in the Coral Sea

Split zoning involves using two or more different zone types for different areas of a single reef or reef complex. This allows users of an MPA, such as fishers, to continue to access part of the reef while also ensuring that other parts are highly protected. To help inform specific zoning and allowed use recommendations in the Coral Sea, the ESP examined the benefits and risks of this approach for conservation objectives.

Coral reefs are complex ecosystems with a high degree of dependency between the many marine organisms that create, maintain and inhabit them. They support a very high diversity of species and life forms. While covering less than 1 per cent of the world's oceans, they host an estimated 25 per cent of known marine species. The coral reefs represented in the CMR estate are almost all oceanic coral reefs rather than the barrier and coastal reef systems that are closer to shore. Similar to other findings in this report, most experience and scientific research has come from these more coastal reef systems. Oceanic reefs are generally more isolated, with a much higher exposure to waves and storms, than more coastal reef systems. This isolation means they are more dependent on self-seeding for recruitment. Edgar *et al*. (2015) suggest that this raises the risk of local extinctions.

The concept of applying different zones (and hence management objectives) to reefs has been adopted by some park management agencies, but there is little detailed consideration in the scientific literature of the consequences and value of this approach. The Great Barrier Reef Marine Park Authority (GBRMPA) adopted a split zoning approach to a number of reefs in early zoning of the GBRMP (mostly between Marine National Park Zones and Habitat Protection Zones), but many were rezoned as Marine National Park Zones in the 2003 rezoning. Day (2002) noted that, in the GBRMP experience, split zoning had caused problems in public understanding, compliance and enforcement. He also questioned their ecological value, particularly for some of the smaller areas developed in earlier zoning plans. The recommended approach was, as far as practicable, to have single zones or regulatory provisions over areas of a discrete geographical description (for example, single islands or reefs).

The expert scientific committee that developed the Biophysical Operational Principles for the GBRMPA's Representative Areas Program advised that reefs are integral biological units with high levels of connectivity amongst habitats within them and thus they should not be subject to 'split zoning' (Fernandes *et al.* 2009). They recommended a minimum size of no-take areas of at least 20 km in length on the smallest dimension to be adequate for providing the area needed for population maintenance and to ensure against edge effects from use in surrounding areas (Fernandes *et al.* 2009). Despite this, a number of split-zoned reefs remain in the GBRMP (for example, Moore and Opal Reefs) because of social and economic impediments to single zoning. In these and other similar cases, they are substantially smaller that the recommended minimum size of 20 km on their smallest dimension.

The consequence and relative value of different zones on reefs in the GBRMP have not been scientifically evaluated; however, Reef Check Australia surveys of Opal and Moore reefs show that coral cover has increased in both the Marine National Park (green) and Conservation Park (yellow) zones on these reefs (Bauer 2014a; Bauer 2014b). These data suggest that the reefs are in good health despite different levels of protection.

The complexity of coral reef communities is influenced by abiotic factors such as exposure to wind and waves, depth and reef morphology parameters (Fitzpatrick *et al.* 2012; Graham *et al.* 2014; Jankowski *et al*. 2015) as well as by biotic factors such as recruitment success and a range of other life history characteristics. The latter may vary widely, including species with very narrow ecological niches and home ranges, highly mobile generalists that forage and/or migrate considerable distances, species with very limited dispersal capabilities and species whose juveniles or larvae disperse widely (Green *et al*. 2014). Coral trout, for example, have home ranges of 200 m to 1000 m but migrate up to 5 km to form spawning aggregations or to forage on schools of baitfish (Miller *et al.* 2012).

Marine reserve zonation, management objectives and allowed uses should recognise this complexity and the high degree of dependency between many of the constituent species and Green *et al*. (2014) propose the home range of focal species as a starting point for the determination of reserve (or zone) size.

Clearly, split reefs will impact on species with different life history characteristics in different ways. They may be more effective for highly resident and sedentary species than for more mobile ones. This complexity gave rise to the recommendation that management zones in the GBRMP be at least 20 km across.

One risk associated with split zoning is that fishing effort and other impacts may become more concentrated in the less protected part. Emslie *et al.* (2015) found no indication that the displacement and concentration of fishing effort reduced coral trout populations on fished reefs. However, physical damage to the reef can occur from anchor damage and breakage (Kininmonth *et al.* 2014; Lamb *et al*. in press).

ESP finding

The Expert Scientific Panel recognises the integrity of coral reefs, which are structurally and ecologically complex ecosystems with a high degree of dependency between habitat forming and associated species. Given this complexity, different management regimes across reef systems should not be applied across small reefs (less than 20 km across).

Splitting reef systems into more than one zone type should only be considered on reef systems that are large enough to ensure that:
(i) each zone covers a sufficient area to deliver conservation outcomes
(ii) the allowable activities undertaken in one zone are not of a type, scale or intensity to impact on adjacent zones
(iii) one zone type is a Marine National Park Zone.

Individual reefs often form part of larger reef systems which may offer a better opportunity to manage different areas for different objectives if biodiversity objectives are not compromised. The impacts of allowable activities in one zone need to be well managed and monitored to ensure that their impacts do not compromise the management objectives of other zones, particularly Marine National Park Zones.

Split zones and paired sites offer an opportunity to study the effectiveness of different management approaches and can provide useful information to inform and improve future reserve management.

3.4 Values of specific marine features, systems and processes

Marine reserves play an important role in protecting specific marine features, systems and processes, including seamounts, submarine canyons, pelagic ecosystems, connectivity and benthic–pelagic coupling. These features are often integral to the interests and activities of marine users and are therefore important in the consideration of zonation and allowable uses, as recognised in the Goals and Principles. This section summarises recent information on these values to assist future zoning revisions under CAR principles. The section also illustrates the availability of data for planning processes in the CMR network as well as knowledge gaps for consideration of research priorities (discussed further in chapter 4).

3.4.1 Connectivity

Many marine species occur in metapopulations, where spatially separate populations or different life history stages of the same species occur in different areas. Ecological connectivity, which encompasses the dispersal of larvae or propagules as well as the movement of adults, is an important mechanism underlying the persistence of these populations and is therefore relevant to marine reserve design (Magris *et al.* 2014; Berumen *et al.* 2012).

Physical oceanographic processes largely determine the degree to which planktonic stages disperse and hence the connectivity and exchange of genetic material between sessile or relatively sedentary adults stages (Coleman *et al.* 2011). Improved understanding and modelling of ocean currents and oceanographic processes is helping to understand and predict factors affecting connectivity. Major current patterns can be characterised by remote sensing, and more localised effects like upwellings, downwellings and eddies are being studied more intensively to help understand and predict biodiversity distribution and abundance (for example, Rennie *et al*. 2009; Feng *et al.* 2010; Currie *et al.* 2012; Holliday *et al.* 2012; Matis *et al.* 2014; Scales *et al.* 2014).

Entrainment in frontal eddies of boundary currents has been shown to be important for dispersal and retention of fish larvae and hence cross-shelf and latitudinal connectivity (Feng *et al*. 2010; Holliday *et al*. 2012; Mullaney and Suthers 2013; Matis *et al*. 2014). The main two boundary currents around Australia differ in their local retention and cross-shore transport, as the Leeuwin Current promotes much more onshore transport than the EAC (Condie *et al*. 2011). While the Leeuwin Current provides important alongshore transport, meso-scale features like eddies and upwellings, such as those occurring in the Perth Canyon (Rennie *et al.* 2009), create areas where shelf-to-ocean connectivity is high. The strengths of boundary currents determine the connectivity of kelp and other seaweeds around southern Australia (Coleman *et al.* 2011; Wernberg *et al.* 2013), and it is suggested that extreme weather such as cyclones can enhance connectivity by increasing the distance that larvae are advected (Radford *et al*. 2014).

Much of the understanding of connectivity comes from the fisheries literature that illustrates the importance of connectivity for the dispersion and recruitment of fish (Geffen 2009, Condie *et al.* 2011, Bode *et al.* 2012). Tagging has been a traditional approach to understanding movements of individuals, but advances in ocean observation, genetic analyses and modelling have greatly improved the understanding of connectivity in recent years (Berry *et al*. 2012). Growing understanding includes the spatial and temporal dynamics of populations, and recovery potential after disturbances in habitat-forming species such as kelp (Coleman *et al*. 2011), coral (Underwood *et al*. 2009; Radford *et al*. 2014) and seagrass (Sinclair *et al.* 2014) and can inform considerations of resilience in conservation planning.

Harrison *et al*. (2012), using genetic parentage analyses, showed that larval export from no-take reserves in the GBRMP was occurring and influencing the recruitment for coral trout and snapper in areas outside of the reserves. They also found larval retention within reserves and connectivity between neighbouring reserves, which may be important for single, isolated reserves or reefs for which there are no other reliable sources of larvae (Berumen *et al*. 2012). Protecting recruitment hotspots can thus improve the performance of reserves (Wen *et al*. 2013). Recent research has also shown that localised recruitment and long-distance dispersal are not mutually exclusive and that an understanding of connectivity patterns subject to dispersal capabilities of species and hydrodynamic conditions will improve the design of protected areas (Underwood *et al*. 2012). Linking knowledge of larval stages and dispersal with population models could improve reserve design (White *et al*. 2014).

Other approaches used to detect connectivity for protected area networks include hydrodynamic models with particle tracking or biophysical models linked with metapopulation models (Condie and Andrewartha 2008; Berglund *et al*. 2012; Puckett *et al*. 2014; Soria *et al* 2014). Using a four-dimensional biophysical dispersal model for larval connectivity off the north and west coast of Australia (Kool and Nichol 2015) demonstrates the potential for complex and varying degrees and directions of simulated larval connectivity which also shifted with seasons. Patterns emerging included southerly transport of larvae from the Gascoyne CMR with the Leeuwin Current, seasonal shifts in the direction of larval transport, low connectivity between the Oceanic Shoals and Kimberley CMR, corridors for marine larvae between several CMRs and high levels of self-connectivity among the CMR network.

Based on field data of plankton sampled off the Kimberleys, McKinnon *et al*. (2015) detected along-shore metacommunities with weaker cross-shelf connectivity, which varied seasonally for mesopelagic fish larvae. However, Underwood *et al*. (2012) found restricted connectivity and low dispersal of coral reef fish between coral atolls off the Kimberley coast. Genetic analyses of damselfish (*Chromis margaritifer*) revealed a lack of panmixia across the study region, including genetic discontinuity between adult damselfish from Rowley Shoals and Scott Reef.

Integrating the underlying physical processes as well as the functional and structural aspects of connectivity in conservation planning for the size and placement of protected areas has received recent attention, and objective quantitative measures for connectivity are emerging (Treml and Halpin 2012; Gerber *et al.* 2014; Lagabrielle *et al*. 2014; Magris *et al*. 2014). Criteria for improving the inclusion of connectivity considerations in conservation planning could include proximity of habitat features, juxtaposition of sources and destinations, and functional aspects of connectivity, including spatial and temporal dynamics (Magris *et al*. 2014).

ESP finding

Connectivity is integral to the functioning of marine ecosystems. Recent studies illustrate the complexity and dynamics of dispersal processes and the need for further research. However, scientific understanding of connectivity in marine systems is steadily improving. The movements of species during one or more of their life stages are complex and not yet well described for the vast majority of species, especially in Commonwealth marine reserves. Computer modelling of ocean currents and oceanographic processes is increasingly being used to improve understanding and facilitate better predictions of how marine species are connected, reproduce, disperse, forage and migrate.

The identification of sink or source areas for recruitment can support reserve design and known patterns of connectivity should be included in conservation planning.

Further research into connectivity will benefit future improvements of the Commonwealth marine reserve network. Future research will also need to address how connectivity might be affected by changing current strengths and other effects of global warming.

3.4.2 Pelagic ecosystems

Pelagic ecosystems, defined as the physical, chemical and biological features of the marine water column of the open oceans or seas, constitute 99 per cent of the biosphere volume, supply more than 80 per cent of the fish consumed by humans and account for half of the photosynthesis on Earth (Game *et al.* 2009). Deep ocean ecosystems, including the high seas, generate ecosystem services that include commercial and recreational activities (fishing and wildlife tourism) and ecological functions (oxygen production and carbon capture and storage) (Rochette *et al.* 2014). Less than three per cent of the world's oceans are found in MPAs and fewer protected areas exist in the pelagic ocean than any other ecosystem on Earth (Rochette *et al.* 2014). Pelagic ecosystem protection has been termed the missing dimension in ocean conservation (Game *et al.* 2009); however, the need for pelagic marine reserves has been increasingly recognised around the world and extends to areas beyond national jurisdictions (Rochette *op. cit.*, Selig *et al*. 2014).

Conservation planning for a representative network is based on the distribution of biodiversity and key habitats, which is challenging for pelagic ecosystems because of the highly dynamic nature of oceanographic processes and constantly moving boundaries and features (Maxwell *et al*. 2014; Marchese 2015). However, dynamic physical processes can be used as surrogates for pelagic biodiversity (Game *et al.* 2009; Grantham *et al*. 2011). Areas where physical conditions promote high biological activity, such as upwelling, meso-scale eddies and fronts, are equivalent hotspots with aggregations of primary and secondary consumers and increased prey for top predators (Marchese 2015). Such areas are becoming increasingly better understood through ocean observation programs and remote sensing (Game *et al*. 2009).

Hobday *et al*. (2011) were able to characterise seven different pelagic habitats off the eastern Australian coast that varied both spatially and temporally. Some oceanographic processes may be linked to geomorphic features such as seamounts or shelf breaks and are thus spatially fixed, while others may be spatially predictable (for example, coastal upwelling) but temporarily variable (Game *et al*. 2009). Upwelling and downwelling in meso-scale circulation features generated by boundary currents are examples of highly dynamic pelagic processes (Matis *et al*. 2014). Reserve networks should capture features such as fronts or upwellings, particularly networks of representative MPAs (Rice and Houston 2011).

Pelagic ecosystems are also three-dimensional in space and trophic structures in the water column and sediment are linked through benthic–pelagic coupling (Graf 1989; Graf 1992; Cummings *et al*. 2013; Bulman and Fulton 2015). A detrital nutrient flux, consisting of marine snow (particulate organic carbon (POC), faecal pellets, dead plankton) or larger carcasses that sink to the seafloor provide a food source for organisms at greater depths, including deposit feeders and scavengers. Large episodic pulses of particulate organic matterflux have been shown to affect the structure and function of deep sea communities, highlighting that conditions in the surface ocean cannot be seen in isolation from the deep sea and benthic environments underneath (Marchese 2015).

Benthic–pelagic coupling through detrital flux is stronger on the shelf and upper slope than in offshore environments. In the former, it can determine the abundance of benthic fauna (Cummings *et al*. 2013; McCallum *et al*. 2014; Kopp *et al*. 2015). Along the ‘Central-Western Transition Zone’ (IMCRA v4.0), species archetypes were found to be matched with unique environmental signatures and driven by the flux of particulate organic carbon, which was higher over the shelf than slope (Woolley *et al*. 2013). Regional differences in pelagic productivity are reflected in the degree of benthic–pelagic coupling and condition of benthic megafauna on the seafloor underneath (Cummings *et al.* 2013). Patterns of sediment infauna on the continental margin of Western Australia were strongly correlated with productivity, indicating the importance of benthic–pelagic coupling (McCallum *et al.* 2015). Yet, for decapods alone, species richness decreased with high and variable POC flux (McCallum *et al.* 2013). With greater depth, the connectivity between surface productivity and benthic systems becomes more distant, and trophic connections for deep-sea abyssal plains are poorly understood. In deep-sea sediments, signs of activity of benthic organisms (‘Lebensspuren’) increased with higher freshness of organic matter in the sediments (Przeslawski *et al.* 2012). Such dependence on surface production for the benthic fauna in sediments on the shelf and deep sea further emphasises the need for three-dimensional protection.

A further trophic biological flux links the pelagic and benthic realms. The main primary production occurs through phytoplankton in the surface waters of the oceans, which is consumed by zooplankton, including gelatinous plankton and fish larvae. These are in turn preyed upon by small planktivorous pelagic fish or squid (Bulman and Fulton 2015*)*. This micronekton can be directly preyed upon by bentho-pelagic feeding demersal fish or it is preyed upon by piscivorous fish, which are in turn becoming prey to benthic–pelagic feeding fish (see figure 3.7).

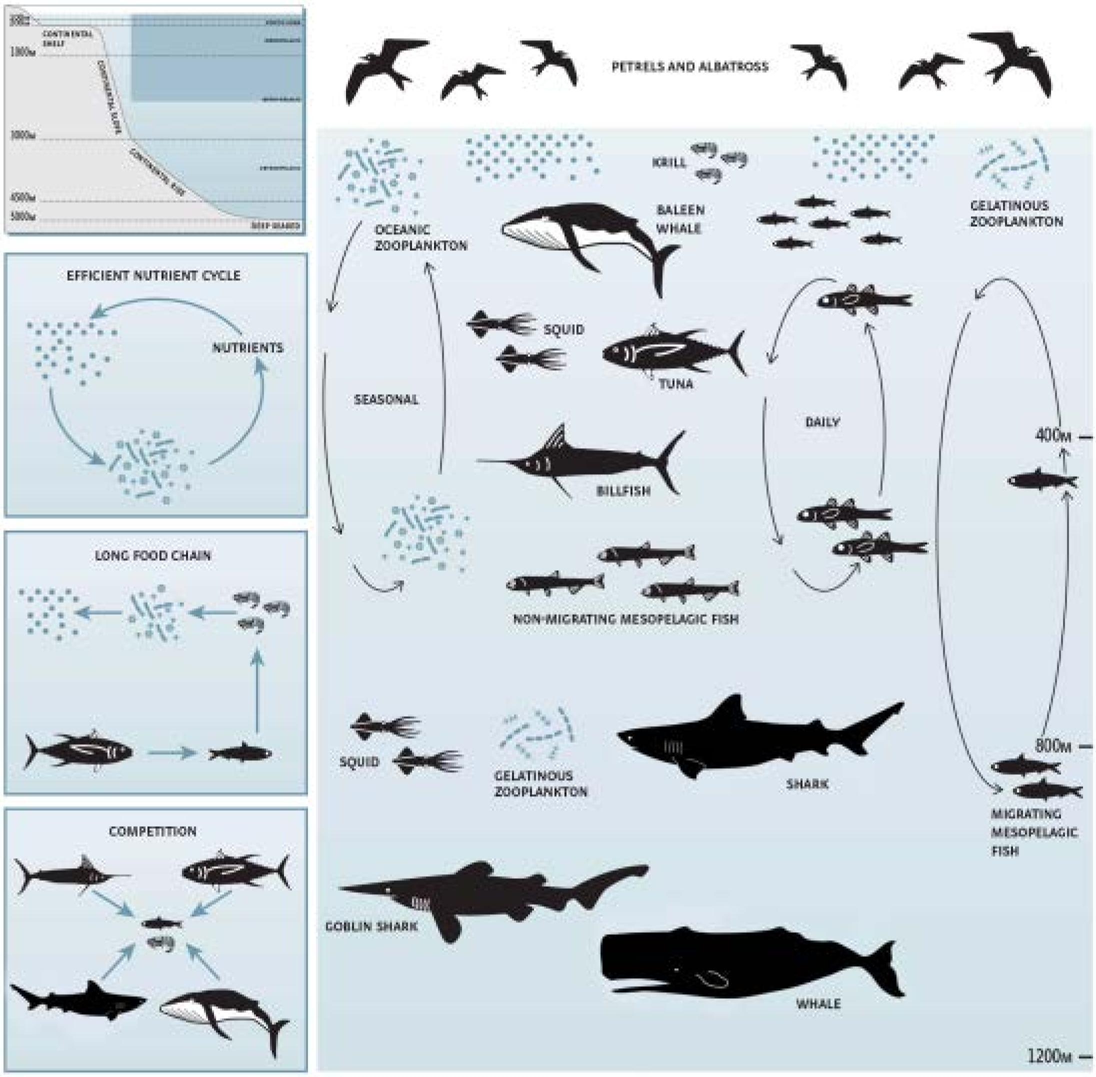

Figure 3.7 Conceptual model of offshore pelagic ecosystem in the South-east Marine Region (NOO 2002)

Bulman and Fulton (2015) note:

> *Our best available knowledge suggests that in shallow systems (like reefs) pelagic and benthic pelagic production flows in both directions, mediated through invertebrates and fish and their predators. In upper slope waters the linkages are more one way (at least at shorter time scales) where pelagic production filters to depth through physical settling as well as via trophic links mediated by horizontal and some vertical movement of epipelagic species such as jack mackerel, and by*

micronekton like mesopelagic fish, squid and gelatinous species. At deeper depths on seamounts and the rugged terrain of steep slopes, the return of pelagic production from overlying waters via settling diminishes even further and the dense populations of demersal fishes found in these can only be supported by advected allochthonus production originating from probably quite some distance away. On longer time scales physical and chemical linkages also operate, where deep water nutrients are brought to the surface by current systems and upwellings – though we have put less attention on such linkages here. Comparing what is known around Australia with similar depths elsewhere suggests that these general patterns seem to hold fairly broadly.

The design of marine reserves for the conservation and protection of pelagic habitat and highly mobile species requires a different approach to that taken for benthic habitats and site-attached fish (Game *et al*. 2009; Ban *et al*. 2014b; Breen *et al*. 2015). In general, larger home ranges will require larger reserves for them to be effective from a conservation perspective (Breen *et al*. 2015). However, protecting highly mobile species covering their entire distribution range, short of protecting entire ocean basins, is not feasible (Game *et al.*, 2009) and requires other approaches. This was illustrated by Santana-Garcon *et al*. (2014), who found no benefits to highly mobile fish from small reserves at the Houtman Abrolhos Islands off Western Australia.

Although the protection of migratory, mobile and far-ranging species presents major challenges for spatial management (Game *et al.* 2009), species are not equally vulnerable over their entire range. Instead, protection could focus on particular habitats linked to life-cycle stages, such as breeding grounds or feeding grounds (Grüss *et al*. 2011; Breen *et al*. 2015). For many species, further studies and time series data are needed to identify the location of such critical habitats (Grantham *et al.* 2011), but progress is being made. For example, the Perth Canyon has been identified as an important foraging habitat for migratory blue whales due to the high diversity and abundance of krill in the canyon (Rennie *et al*. 2009).

Seasonal or inter-annual variation in benthic–pelagic coupling can contribute to variability in foraging efforts, abundance and distribution of top predators such as tuna or fur seals (Hoskins and Arnould 2014; Menkes *et al.* 2015). For example, seasonal spawning aggregations of mesopelagic lanternfish in the Coral Sea provide a foraging resource for concurrent spawning aggregations of tuna (Flynn and Paxton 2012). Spatial and temporal protection would be an obvious approach to the conservation of this feature.

Game *et al.* (2009) note that protected areas are not a panacea for the conservation of pelagic biodiversity and will need to be complemented by other forms of management. In this context, it becomes important to identify areas or situations where pelagic protected areas offer benefits that other regulatory mechanisms cannot. They suggest that a good place to start would be to encourage the protection of representative examples of all pelagic habitats in line with international conventions for biodiversity conservation (CBD 2008) and that such representation could be based on available biogeographic classifications.

ESP finding

Our knowledge of pelagic ecosystems is in its infancy relative to benthic and coastal realms, especially in relation to offshore regions. Clearly there are many geographic gaps. Added to this is the uncertainty associated with broader environmental shifts associated with climate change.

Despite this, much is known about the oceanographic processes in pelagic ecosystems around Australia and it is clear that they play an important role in connectivity (migration and dispersal of marine species) and trophic dynamics, not just in the water column but in terms of benthic–pelagic coupling across the marine environment.

For these reasons, pelagic ecosystems need to be adequately represented and protected through the network of Commonwealth marine reserves.

However, the Expert Scientific Panel recognised that pelagic ecosystems are dynamic and there are challenges for the design and location of pelagic reserves. To be effective in contributing to the conservation of pelagic and associated species and the ecological processes on which they depend, Commonwealth marine reserve design and management must recognise this dynamism and the importance of complementary measures taken in the management of surrounding waters.

3.4.3 Continental shelf and slope

The continental shelf and slope comprise two-thirds of Australia's EEZ, with a depth profile ranging from less than 200 m on the shelf to more than 3000 m in the deep ocean (Heap and Harris 2008). Patterns of biodiversity are influenced by seabed and substrate type (Williams *et al.* 2010; Anderson *et al.* 2011a), exposure and habitat features such as rocky reefs (Saunders *et al.* 2014), geomorphic features and structures such as seamounts and canyons (see section 3.4.4), nutrient and food availability, oxygen concentration, and temperature. Many of these variables vary with water depth and many studies report a strong stratification of species assemblages by depth (Williams *et al*. 2010; Anderson *et al.* 2011a; Schlacher *et al*. 2010).

Shelf environments are generally characterised by warmer temperatures than the deep sea, higher light levels, and nutrients from land-based sources as well as primary production in the ocean. Australia's continental slope is dissected by numerous canyons, many with complex structures (Huang *et al*. 2015) and drainage patterns that can play significant roles in nutrient and sediment transport from the shelf to deep ocean (Porter-Smith *et al.* 2012) and vice versa through upwellings associated with these structures and oceanic currents.

Depth has emerged as the key defining variable in large-scale differentiation on benthic habitat classifications, with nutrients in the water column, bottom water temperatures and seafloor properties explaining smaller scale classifications (Huang *et al*. 2011). The gradients in environmental conditions at the upper slope and shelf define unique faunal communities (McCallum *et al*. 2013). The upper slope and shelf are characterised by high habitat diversity and dynamic oceanographic environments, with gradients in temperature and oxygen, upwelling events and seasonally varying currents and undercurrents affecting biota and their dispersal at a larger scale (Williams *et al*. 2010; Huang *et al*. 2011; McCallum *et al*. 2013). Seabed type, which is used as a surrogate, appeared more important for megabenthic diversity at smaller scales (Williams *et al.* 2010), and patterns of decapod species richness (McCallum *et al*. 2013). Benthic biodiversity patterns on the Carnarvon Shelf, where the highly diverse macrofaunal and infaunal assemblages occur with many rare species, showed no strong relationship with environmental variables, with the authors suggesting that abiotic surrogates maybe a limited value at small spatial scales (tens of kilometres) (Przeslawski *et al.* 2013).

Globally, depth-related gradients vary and various taxa show unique patterns, as deep sea habitats are highly heterogeneous (Ramirez-Llodra *et al*. 2010; Danovaro *et al*. 2014). This lack of consistent patterns across the world is also illustrated in Australia in comparison to the Atlantic, where diversity increases with depth. Examples from Australia indicate a decrease of diversity with depth, as benthic species richness was higher on the continental shelf than the slope off Western Australia (Williams *et al*. 2013; McCallum *et al*. 2015) and, similarly, in the Great Australian Bight (Currie *et al*. 2009). Both fish and macrofauna species richness around Australia was highest on the shelf, shelf break and upper slope and decreased with depth, especially below 1000 m (Coleman *et al*. 1997; Ward *et al*. 2006; Currie *et al*. 2009; Last *et al*. 2010; Dunstan *et al*. 2012; Fromont *et al*. 2012; McCallum *et al*. 2013; McCallum *et al.* 2015; Conlan *et al*. in revision). However, diversity has been found to be increase with depth around some seamounts and within some canyons around Australia (O'Hara *et al*. 2011; Poore *et al*. 2015). Further research in this area would be valuable.

Studies in Australia and elsewhere show that shallow water fauna is always very distinct from deep sea fauna and that major shifts in species assemblages occur in the upper slope and again at the lower slope transition (Ramirez-Llodra *et al*. 2010; O'Hara *et al*. 2011; Levin and Sibuet 2012). While the shelf and bathyal biomes are always fundamentally different, they can each share more similarity across latitudes or longitudes (O'Hara *et al*. 2011). For example, ophiuroid fauna from temperate shelf regions of Australia and New Zealand were very different, whereas bathyal species of ophiuroids had widespread longitudinal ranges within both temperate and tropical regions (O'Hara *et al*. 2011). Using a modelling approach based on the common species found in the surveys, four species archetypes were defined by latitude and depths (Woolley *et al*. 2013). The latitudinal distinction of archetypes aligned with the 'Central-Western Transition Zone' (IMCRA v4.0) at about 21ºS in accordance with findings from other taxon-specific studies and a high degree of rarity in this region, characterised by the Carnarvon Terrace (O'Hara *et al*. 2011; Dunstan *et al*. 2012; McCallum *et al.* 2013). The depths for transition between archetypes varied with latitude and for some taxonomic groups, occurring at approximately 150 m deep north of 20ºS, and around 300 m to 400 m deep south of 20ºS (Woolley *et al*. 2013).

A recent study of benthic invertebrate diversity off the deep continental margin of Western Australia reported a largely novel and endemic fauna, with most species either new to science or not previously reported in Australia (Poore *et al.* 2015). In some regions, the Australian shelf and deep-sea fauna are also characterised by a high proportion of apparently rare species (Coleman *et al*. 1997; Fromont *et al*. 2006; Schlacher *et al*. 2007; Dunstan *et al*. 2012). A similar high proportion of rare species has been predicted to occur in depths of 200 m to 400 m (Dunstan *et al*. 2012). High levels of endemicity are reported for the deepwater fish assemblages of the Coral Sea (Last *et al.* 2014). Decapod crustaceans occurred in very narrow depth ranges (McCallum *et al*. 2013), and bathymetry also defined patterns of sponges (Fromont *et al*. 2012). Some of these studies caution on drawing too firm a conclusion on rarity and endemicity without more extensive sampling, as many of the collections include single samples of species (singletons) (for example, Last *et al.* 2014). However Fromont *et al.* (2012) report a range of studies on the distribution of sponge species in the Australian shelf and slope environment that consistently report finding many rarely occurring species with limited distributions.

Recent surveys along the continental margin of Western Australia have yielded important insight into biodiversity patterns along and across the shelf and slope, which will allow refinement of future biogeographic regionalisation (Woolley *et al*. 2013). Benthic diversity is very high in sediments off Western Australia, with a high degree of rarity (for example, 65 per cent of 890 species of decapods occurred once or twice only) (McCallum *et al*. 2013; Fromont *et al*. 2012; Poore *et al*. 2015). Regions and depths for greatest species turnover vary for different benthic invertebrate taxa and fishes (O'Hara *et al*. 2011; McCallum *et al*. 2013; Woolley *et al*. 2013). Depth-related patterns have been found to vary with distance from shore and habitat-forming benthos have been found for fish assemblages off Australia's east coast (Harvey *et al*. 2013; Malcolm *et al*. 2011; Schultz *et al*. 2014).

Many of Australia's deepwater benthic environments have not been extensively sampled and are consequently not well characterised or understood. Studies over the last decade have progressively improved knowledge on biodiversity patterns on the shelf and continental slope. Findings from these studies have informed and supported conservation planning for the CMR estate. For example, an analysis of macrobenthic species collected from a range of habitats on the deep continental margin off southern Tasmania found highly variable species composition and assemblages and concluded that large areas at a range of depths would be needed to adequately represent these species within reserves (Dunstan *et al.* 2012). These studies have provided additional support for the general approach taken in designing the CMR estate.

ESP finding
Species assemblages vary with latitude, depth and substrate type. Across the range of organisms studied so far, some species appear to be widely distributed, while others appear to have very limited distributions. While knowledge and understanding of patterns of biodiversity distribution have improved and will continue to improve with further sampling of less studied parts of Australia's ocean environment, the evidence so far supports the general approach adopted in the design and planning of the Commonwealth marine reserves, which is to include representative samples of all depth ranges in regional networks that include a wide range of seafloor features and substrates.

3.4.4 Canyons and seamounts

<u>Canyons</u>

Canyons are a common geomorphic feature found on the margins of all continents. They are typically complex in their morphology and interact with ocean currents, tides and internal waves to influence ecosystems and habitats on the shelf, slope and deeper ocean. Canyons are recognised as features associated with enhanced primary productivity, benthic biomass and biodiversity (Huang *et al*. 2014 and references therein).

A comprehensive remapping of submarine canyons on the Australian margin (excluding Norfolk Island and Cocos Island Territories) was completed by Geoscience Australia (GA) in 2014 through the National Environmental Research Program (NERP) (Bax and Hedge 2015). A total of 713 submarine canyons were identified and classified—a substantial increase (76 per cent) from the 405 canyons previously mapped in 2008. Figures 3.14–3.16 in section 3.5 show this mapping for three CMRs (Bremer, Perth Canyon and the South-west corner) in the South-west bioregion. Of the 713 canyons, 254 (36 per cent) are wholly or partly in a CMR (Nichol *et al*. 2015).

The project generated a nationally consistent map and a new classification for submarine canyons on the Australian margin (Huang *et al*. 2014).

Of the canyons mapped and classified, 95 canyons extend onto the continental shelf as shelf-incising canyons that play an important role in connecting the deep ocean and the shelf via upwelling and downwelling. Some shelf-incising canyons in Australia have been shown to harbour high biodiversity. The south-west region has nine shelf-incising canyons (including Perth Canyon and Bremer Canyon, which are discussed in more detail at sections 3.5.3 and 3.5.4). The Perth and Bremer canyons intersect the Leeuwin Current (and Leeuwin Undercurrent). The Huang *et al*. study (2014) classifies both canyons as topographically complex and describes these examples in greater detail as a proof of concept of the value of the mapping. The north-east region has seven unnamed shelf-incising canyons (including in the Coral Sea) (Nichol *et al*. 2015).

Ongoing work by Geoscience Australia is producing a comprehensive assessment of Australian canyons as habitat for benthic and pelagic species. This assessment is using biodiversity surrogates, (such as seafloor rugosity, upwelling strength and current velocity) to classify habitat complexity, productivity and disturbance. Geomorphometrics (measures of seafloor complexity), such as canyon distribution and seafloor rugosity, have an important influence on the movements of large fish predators over macro-ecological scales (Nichol *et al*. 2015).

A new acoustic methodology that consistently differentiates hard from soft substrate was developed to classify potential benthic habitats associated with canyons. A uniform scoring method (developed by the Marine Biodiversity Hub, called Collaborative and Automated Tools for the Analysis of Marine Imagery (CATAMI)) was used to classify epibenthic fauna in these habitats from seafloor video imagery (656 649 records from 12 voyages). Hard-ground habitats in the 150 m to 700 m depth range were both infrequent and quite highly variable between canyons for the 60 shelf-incising canyons for which data were available. Video imagery showed benthic epifauna abundance to be depth stratified and higher inside canyons. Seabed hardness was an important habitat classifier for a large subset of the fauna. Based on the video imagery, the shelf-incising canyons did not support significantly different epibenthic macrofauna when compared to other upper slope hard and soft substrate (Nichol *et al*. 2015)

The NERP project developed an individual-based dispersal model to simulate the movement and connectivity of marine larvae to help understand and predict their collective behaviour and to identify priority areas for future observations and sampling. Canyons with ‘high source capacity’ (typically topographically complex) have a high potential to contribute to resilience of the protected area network by exporting larvae to other connected locations (Nichol *et al*. 2015). The modelling can also explore connectivity patterns between marine regions and interdependent geographic regions and reveal areas that may have a relatively high role in maintaining the biodiversity of the area. It is not only applicable to canyon connectivity. For example, the models predict strong ophiuroid connectivity between the Oceanic Shoals and Kimberley CMRs (Nichol *et al*. 2015).

In a study of two canyons in south-eastern Australia, species richness and megafaunal biomass declined with depth (Currie and Sorokin 2014). Three distinct community assemblages were identified stratified by depth. The canyons showed significant differences in trophic structure. Differences in faunal diversity and biomass between the two canyons were attributed in part to the location of du Couedic Canyon (with higher diversity and biomass) near the Spencer Gulf—a source of rich organic material (Currie and Sorokin 2014).

In a recent review of studies on the use of submarine canyons by cetaceans, Moors-Murphy (2014) found some evidence that cetaceans are more likely to be associated with large canyons but cautions that potential sampling bias militates against drawing clear conclusions with wider application.

Seamounts

Seamounts are a common feature in the oceans around the world and are among the physical ocean features used as proxies for biodiversity in designing and managing networks of marine reserves. A considerable literature is available on the global distribution and characteristics of seamounts and seamount ecology (for reviews, see Clark *et al*. 2010; Rowden *et al*. 2010; Schlacher *et al*. 2010; Clark *et al*. 2011; Kvile *et al*. 2014) and, in the Australian context, for the east and south-east regions (Williams *et al*. 2010; Williams *et al*. 2011). The seamount field project of the Census of Marine Life has provided the framework and data for a number of recent papers on seamount biodiversity (Schlacher *et al*. 2010; Clark *et al*. 2012; Stocks *et al*. 2012).

Ocean currents displaced by seamounts create turbulent upwelling of deepwater nutrients supporting elevated planktonic and consumer productivity and benthic communities dominated by slow-growing sponges and corals (Kvile *et al*. 2014). Reported geographic differentiation among seamount communities has suggested limited larval dispersal, local speciation and geographic isolation or a combination of these processes. However, genetic studies have documented complex patterns of connectivity that depend on spatial scale and life history characteristics (Schlacher *et al*. 2010).

Earlier hypotheses about seamounts supporting endemic species and diverse and distinct assemblages, being biomass hotspots and acting as biogeographic stepping stones are being increasingly tested and challenged (Rowden *et al*. 2010; Clark *et al*. 2012; Kvile *et al*. 2014). A range of studies have concluded that there are no consistent differences between species assemblages on seamounts and other deep sea habitats at similar depths, at least in the same region (Howell *et al*. 2010; Clark *et al*. 2012). However, differences in hydrothermal activity can modify patterns of benthic species assemblages within a seamount chain (Boschen *et al*. 2015). Recent studies now show that seamounts can have comparable levels of benthic diversity and endemism to continental margins, with many species widely distributed within their preferred depth range, but their communities may also include a distinct composition of species with higher biomass (Rowden *et al*. 2010).

A small number of the world's seamounts have been well studied (Kvile *et al*. 2014). Seamounts support higher biomass than adjacent waters, especially by aggregating pelagic and bentho-pelagic species (review by Clark *et al*. 2010) and are targeted for a range of commercially exploited fish species. There is a widely held view that the biological components of seamounts are sensitive and vulnerable to disturbance, especially from bottom contact fishing (Rowden *et al*. 2010; Williams *et al*. 2010;

Stocks *et al*. 2012) and are particularly vulnerable to trawl fisheries (Pham *et al*. 2014).

Global, climate-driven changes in ocean chemistry and changes to the aragonite saturation horizon suggest that seamounts and canyons, because of their vertically continuous habitat, will offer refuge to deep ocean fauna that are forced out of existing depth ranges (Tittensor *et al*. 2010).

Some confidence is emerging in the use of physical variables, from mapping and acoustic technologies, video and biological sampling, to infer, predict and validate biological patterns (for example, Anderson *et al*. 2011a). Physical characteristics of the seabed, particularly geomorphology, were found to be good predictors of biological assemblage composition and cover of key taxa (Anderson *et al*. 2011a).

ESP finding

Submarine canyons and seamounts are major geomorphic features that hold significant implications for distribution, abundance, dispersal and persistence of a wide variety of marine organisms. While some areas have been well studied, there remain big gaps in the knowledge and understanding of oceanographic dynamics, drivers of productivity and the role played by canyons and seamounts in the structuring and functioning of marine ecosystems and as potential refugia in a climate-driven, changing environment.

Given the role and significance of seamounts and canyons in the functioning of deep sea, continental shelf and pelagic ecosystems and growing concern about the impacts of human activities, it would be prudent to protect representative samples of both and to support further studies that improve understanding and effective conservation of these features and the management of sustainable uses.

3.5 Recent science on specific components of the Commonwealth marine reserves estate

Since the proclamation of the new CMRs in 2012, new scientific information has become available on the conservation values of a number of the reserves and hence to the work of the BAP. This section summarises information on the Coral Sea, Geographe Bay, Bremer, Perth Canyon and Oceanic Shoals CMRs.

3.5.1 Coral Sea Commonwealth Marine Reserve

Reef Life Survey surveyed 160 sites on 17 Coral Sea reefs between September 2012 and July 2013 (see figure 3.8). The objectives were to:

(i) improve knowledge of the state of current biodiversity and the likely species or processes important for ongoing monitoring of the ecosystem health of the Coral Sea CMR

(ii) place the Coral Sea CMR in the context of the broader region

(iii) provide a baseline that can assist in distinguishing future natural ecological change from that arising from management status (Stuart-Smith *et al.* 2013; Edgar *et al.* 2015).

There was a clear distinction in the reef fish communities between the northern (north of Marion Reef) and southern reefs, not just in terms of species composition but also at the level of functional groups. Analysis of Reef Life Survey dataset showed that Coral Sea reefs host faunal communities that are unique to Australia but which are more aligned with isolated Western Pacific oceanic reefs, such as those of Tonga and American Samoa, than with those of the Great Barrier Reef, which are more closely aligned with Papua New Guinea, the Solomon Islands and Vanuatu (see figure 3.9). A defining similarity of Coral Sea reefs and remote Pacific Island reefs is that the shallow-water biota must arrive by long-distance dispersal and inhabit a reduced set of habitat types, with relatively few options for shelter (Edgar *et al.* 2015).

Edgar *et al.* (*op. cit.*) also show that the Coral Sea supported reef shark densities similar to remote locations with little or no human exploitation and suggest that, despite a history of fishing on most of the reefs, food web structure appeared largely intact. Reefs within marine national parks zoned as no-take since 1982, including the Coringa–Herald and Lihou reef systems, supported higher fish biomass (approximately 70 per cent[19]) than comparable reefs where some fishing is allowed. Shark biomass was approximately 90 per cent higher and large predator biomass was 50 per cent higher in these zones than at comparable fished areas nearby (Edgar *et al.* 2015).

These results emphasise the importance of recognising a latitudinal difference in the Coral Sea coral reefs and distinguishing the Queensland and Marion plateau reefs in the CMR. The assumption that the Coral Sea provides connectivity between the Great Barrier Reef and South Pacific for two key ecological features of the Coral Sea—the reefs, cays and herbivorous fish of the Queensland Plateau; and the reefs, cays and herbivorous fish of the Marion Plateau—may need to be revised for macroinvertebrates and herbivorous fish.

Research shows that the Coral Sea offers an environment that is closer to a baseline condition than most other tropical regions and thus provides a reference for assessing changes at locations elsewhere with similar wave-exposed coral reef environments

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[19] Edgar *et al.* 2015 reported this figure as 70 per cent but have subsequently revised this figure to 58 per cent (Rick-Stuart Smith IMAS *pers. comm*.).

but greater human-related stresses, including across the wider oceanic Pacific region (Ceccarelli *et al.* 2013; Edgar *et al.* 2015).

Figure 3.8 Reef Life Survey Coral Sea survey sites (Edgar *et al.* 2015) © Copyright, Reef Life Survey

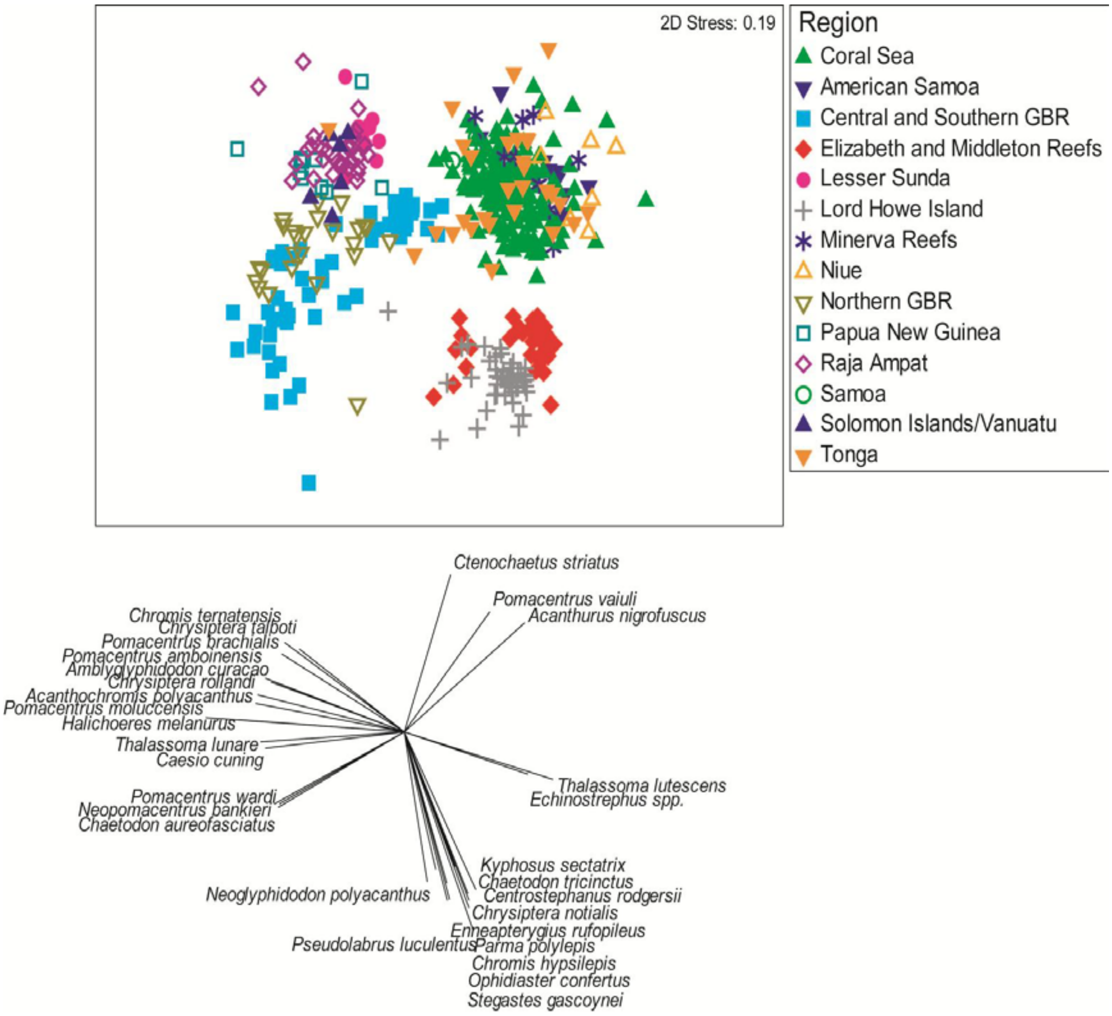

Figure 3.9 Similarity analysis for key Coral Sea species (Edgar *et al.* 2015) © Copyright, Reef Life Survey

A recent study found a previously undescribed clade of giant clam *Tridacna sp*. in the Western Pacific, including in the Coral Sea and Great Barrier Reef (Huelsken *et al.* 2013). Through DNA sequence analysis, the study also found that there was greater geographical distinction between *Tridacna crocea* populations than had previously been thought, with some populations likely to be regionally endemic; while *Tridacna maxima* generally also had geographically restricted populations, with only one population having much broader extension than previously thought (Huelsken *et al.* 2013).

Both the discovery of a new species and substantial geographic differentiation may have implications for monitoring and recovery of giant clams and inform management actions in the Coral Sea: presence of cryptic sympatric species would result in overestimates of species abundance; depleted populations are unlikely to receive recruits from geographically distant locations; and physical relocation of clams could move species outside their natural range and effect genetic population distributions (Huelsken *et al.* 2013). The 2012 Reef Life Survey recorded high densities of tridacnid clams on Mellish and Abington Reefs but only the Herald Cays had significant densities of the giant clam *Tridacna gigas*, which is listed as ‘Vulnerable’ by the IUCN (Edgar *et al.* 2015).

Sea turtles

A recent analysis of mark and recapture data of green turtles (*Chelonia mydas*) demonstrated that the Coral Sea is an important migration route between multiple nesting and foraging grounds within the Great Barrier Reef and New Caledonia (Read *et al.* 2014). Green turtles are listed as ‘Vulnerable’ and are a conservation value of the reserve. This research indicates that nearly all the waters of the Coral Sea reserve are traversed by turtles from the northern and southern Great Barrier Reef and New Caledonia. Multiple migrations between these areas show heterogeneous patterns in connectivity (Read *et al.* 2014).

No sites from Coral Sea breeding areas (identified as biologically important areas) were included in the study, although it was noted that no individuals from Australian Coral Sea populations were found in New Caledonia. While there has previously been some tagging work done in the Coral Sea, there is comparatively little known about Coral Sea turtle populations compared to the Great Barrier Reef stocks.

The study found turtles do not necessarily choose feeding areas based solely on abundance and proximity of food sources (for instance, turtles from New Caledonia were feeding at Heron Reef in the Great Barrier Reef and vice versa). Other cues are likely to be used by turtles and it is suggested that significant factors yet to be identified during the ‘lost year’ of their life cycle may drive migration patterns (Read *et al.* 2014).

Sea snakes

Southern reefs were shown to have high densities of sea snakes, although none were observed on northern reefs in the Coral Sea (Edgar *et al.* 2015). Figure 3.10 shows the clear latitudinal delineation between presence and absence of sea snakes during the Reef Life Surveys. These differences are unexplained; however, sea snakes are a vulnerable group on coral reefs elsewhere, especially those with human impact. Although the role of reserves in safeguarding sea snake populations is unclear (Lukoschek *et al.* 2013), the opportunity to use the Coral Sea as a reference site to understand sea snake ecology was noted.

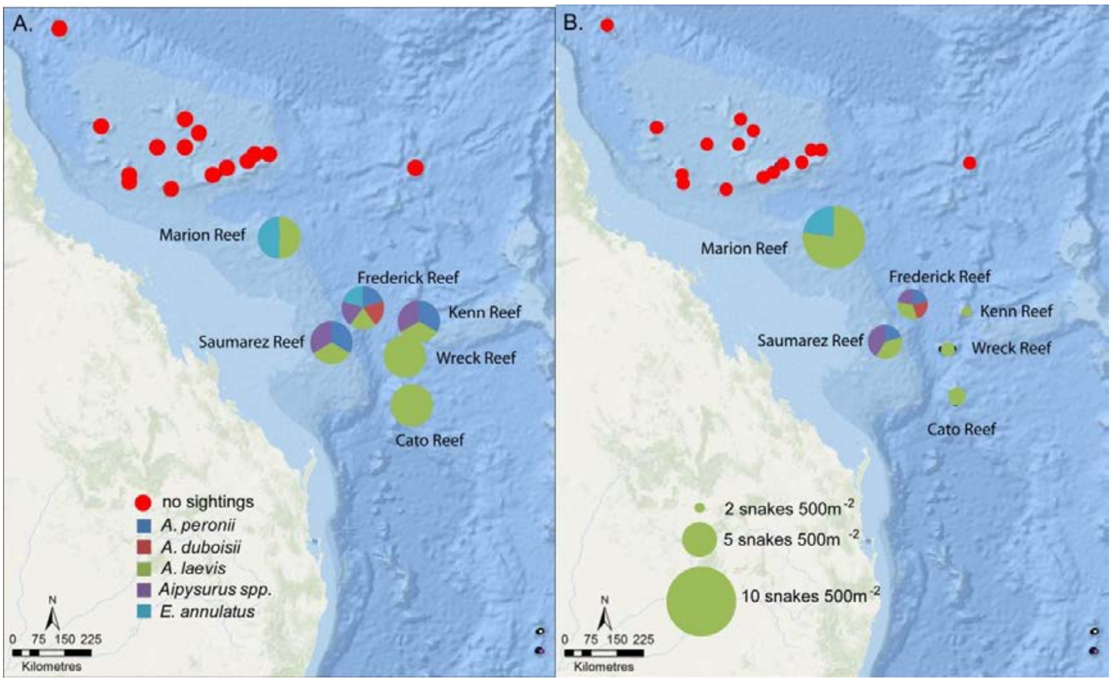

Figure 3.10 Distribution of sea snake species across Coral Sea reefs

A. All reefs with sea snake sightings using several different methods, with unscaled species composition

B. Sea snakes recorded on underwater transects with bubbles scaled according to mean snake density (per 500 m^2) on each reef (circle diameter = density x 2) (from Edgar *et al.* 2015)

Sharks

Coral Sea reefs comprise a globally significant hotspot for reef sharks, with higher numbers sighted by divers than are present at most locations worldwide. Reef shark density for the Coral Sea reefs was ranked fifth highest in comparison to all Indo-Pacific regions surveyed by Reef Life Survey, following the Kermadecs, Elizabeth and Middleton Reefs, French Polynesia and the Marshall Islands (Edgar *et al.* 2015).

The Reef Life Survey analysis shows that the Coral Sea supports reef shark densities similar to remote locations with little or no human exploitation, suggesting that, despite a history of fishing on most Coral Sea reefs (reviewed in Ceccarelli *et al.* 2013), food web structure appears largely intact (Edgar *et al.* 2015).

Acoustic telemetry was used to study site fidelity and residency in sharks at Osprey Reef (Barnett *et al.* 2012). Of the three dominant species that were found—whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynos*) and silvertip reef sharks (*Carcharhinus albimarginatus*)—all had relatively high numbers of individuals with year-round residency at Osprey Reef. Five of the 49 tagged individuals moved to Shark Reef, while one travelled to the Great Barrier Reef.

Spatial use by these species was generally confined to the north-west corner of Osprey Reef. Whitetip reef sharks had very low overlap or mixing between sharks residing in areas separated by approximately 10 km, which agrees with previous estimates that their movement is limited to three km to five km. Grey reef sharks also displayed low spatial overlap, contrary to populations on the Great Barrier Reef, which displayed little site fidelity (Barnett *et al.* 2012).

Acoustic telemetry was also used to compare movement, reef fidelity and ocean migration for tiger sharks (*Galeocerdo cuvier*) across the Coral Sea region, with an emphasis on New Caledonia. Although not listed in Australia, the tiger shark is listed as 'Near-Threatened' by the IUCN. Thirty-three tiger sharks (1.54 m to 3.9 m total length) were tagged with passive acoustic transmitters and monitored on receiver arrays in New Caledonia, the Chesterfield and Lord Howe Islands in the Coral Sea, and the east coast of Queensland (Werry *et al.* 2014). Satellite tags were also used to determine habitat use and movements among habitats across the Coral Sea and found that, between 2009 and 2013, 14 sharks undertook wide-ranging movements up to 1114 km across the Coral Sea (Werry *et al.* 2014). This suggests oceanic Coral Sea reefs may be particularly important for this species, both as potential mating grounds and feeding grounds for large individuals.

Seabirds

Seabird monitoring in the Coringa-Herald National Nature Reserve and Coral Sea CMR has been conducted since 1992. Surveys are timed to coincide with periods of peak breeding activity for three species with important breeding populations in the region—red-footed booby, lesser frigatebird and great frigatebird (Baker and Holdsworth 2013).

The data, including from a special patrol in August 2012 after Cyclone Yasi, show strong inter-annual fluctuations, but trends are now apparent for the breeding populations of most species examined on North East Herald Cay:

- The breeding population of red-footed booby in the Herald Cays has increased by 38 per cent since 1992 at an annual rate of increase of +3.3 per cent.
- The breeding population in the Herald Cays of great and lesser frigatebirds has declined by 89 per cent since 1992 at an average growth rate of –7.7 per cent. In 2012, there were a total of 419 nesting pairs on North East Herald Cay.
- The breeding population of black noddy in the Herald Cays has declined by 67 per cent since 1992 at an average growth rate of –3.81 per cent. The count in 2012 was the lowest recorded since monitoring commenced.
- From the surveys and banding data of the masked booby, mean annual adult survival is estimated to be in excess of 90 per cent—a value that would be expected for a long-lived species with a stable population. One bird had

originated as a chick on Phillip Island (near Norfolk Island) in 2000—a distance of 2341 km away.

The results show that, from a regional perspective, the Herald Cays of the Coral Sea contain a significant proportion of the region's breeding populations, particularly for red-footed booby, great frigatebird, lesser frigatebird and red-tailed tropicbird (Baker and Holdsworth 2013).

This research supports and informs a number of biologically important areas for seabirds that have been identified within the Coral Sea. All these seabirds are listed marine species under the EPBC Act.

Species richness and endemism of deep-sea fish of the Western Coral Sea[20]

An unusually high level of local endemicity characterises the deepwater ichthyofauna of the Coral Sea between 162 m and 1200 m depth. Catch data and specimens, obtained from two exploratory voyages in 1985 and 1986 in the Coral Sea, were recently investigated, taxonomically classified and analysed for any patterns according to depth or geographic distribution. The study found very high levels of endemicity (more than 36 per cent) of deepwater fishes in the western Coral Sea, with about 50 per cent of well-studied groups, such as sharks and rays, confined to this relatively small geographic region.

Biogeographically informative fishes such as skates appear to be cryptically partitioned within the region, differing in composition to other Australian regions and those of French territories to the east. Strong depth-related partitioning of the fauna is also evident, and its structure follows zonation patterns observed across the wider Australian region.

The number of fish species known from the Northeast Slope Province increased to 272—more than 36 per cent endemic species. The levels of endemicity in this region appear to be the highest for any Australian continental slope province, and more than 15 per cent higher than the two more comprehensively surveyed tropical deepwater provinces off Western Australia (20.4 per cent and 20.0 per cent). The Cape Province in the north of the Coral Sea (12 per cent endemicity) is largely unexplored and any future surveys are likely to result in major discoveries in biodiversity.

Given the high level of micro-endemicity, regional uniqueness of the fauna and the restricted distributions of members of otherwise widespread pelagic genera (for example, *Polyipnus*), there is a compelling argument for the existence of a faunal gyre in the Coral Sea.

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[20] Unless otherwise referenced, this section attributable to Last *et al*. 2014.

Pelagic fish

Analysis of mid-water trawl sampling and fisheries data has found highly seasonal spawning aggregations of the lanternfish *Diaphus danae* associated with aggregations of bigeye (*Thunnus obesus*) and yellowfin (*T. albaceres*) tuna in the north-western Coral Sea (Flynn and Paxton 2012). The bigeye tuna individuals collected from aggregations were estimated to have 81 to 319 *D. danae* specimens in their stomachs. An earlier study (McPherson 1988; McPherson 1991) had shown a synchronous spawning of yellowfin and bigeye tuna associated with the annual lanternfish spawning aggregation but also demonstrated spawning of tuna over a much wider area and longer period.

The minimum depth of the lanternfish aggregation recorded was 200 m, and spawning is likely to occur at night (Flynn and Paxton 2012).

Although biomass was not able to be robustly calculated due to small sample size and lack of acoustic data, the authors indicate that the estimates they were able to make suggest that the spawning biomass of *Diaphus danae* in Australian mainland waters was second only to *Lampanyctodes hectoris* off Tasmania.

On the basis of the location of tuna longline vessels and catches of tuna between 1994 and 2010, but with no historic evidence of lanternfish aggregations, Flynn and Paxton (*op. cit*.) suggested that lanternfish tuna aggregations often occurred in the vicinity of Cairns Seamount, and elsewhere throughout the Queensland trough, with isolated instances in the Townsville trough.

D. danae may be a keystone species because of its importance to the life cycle of two of the most important species of tuna on the east coast of Australia, and unknown other species, in the Coral Sea (AIMS 2011).

In August 2015 the Walker Seafoods MSC public certification (with the corresponding certification report also available) for pelagic longlining was granted (ME Certification Ltd. (2015) and Gascoigne *et al*. 2015). The most relevant material to this review is Griffiths *et al.* (2010c) and AFMA (2014c).

Griffiths *et al*. (2010c) developed an ecosystem model to investigate the potential effects of longline fishing and climate change on the eastern Australia pelagic ecosystem. The model incorporated a large expanse of ocean extending well into the Pacific off eastern Australia, which included part of the Coral Sea but did not specifically analyse that region. Using biomass data and fishery catch data from 1952 to 2006, the model simulated changes in fishing effort and mortality rates on individual target and non-target species for 2008–2018. While simulated increases or decreases in fishing mortality caused biomass decreases or increases of some predators, the reduction in biomass of individual apex predator species, such as billfish, tunas and sharks, had only modest effects on the structure of the ecosystem. Griffiths *et al.* (*op. cit.*) suggested that this was because the removal of the relatively small biomass of a single species from the large group of predators could be compensated by increased consumption of available prey by the various other species that share the same prey base. However, where a large proportion of the biomass from a trophic level is removed, as was simulated by the removal of all shark groups, more dramatic trophic cascades can result. Griffiths *et al.* (*op. cit.*) point out that the models used in this study relied on a vast number of input parameters, many of which were completely unknown. Nevertheless, the authors suggest that the results of the simulations do inform the direction and relative magnitude of biomass change for specific groups and for tracing complex trophic interactions throughout the system.

More recently, on the basis of a Scale Intensity Consequence Analysis (SICA) performed during the ERA process, AFMA concluded that no habitats or communities were at risk from the effects of pelagic longlinine fishing in the Eastern Tuna and Billfish Fishery, which incorporates the Coral Sea (AFMA 2014c).

The black marlin (*Istiompax indica*) spawns annually at the edge of the northern Great Barrier Reef during October and November and afterwards disperses throughout the Coral Sea and beyond (Domeier and Speare 2012). On the basis of the extent of movements of pop-up satellite-tagged fish, Domeier and Speare (*op. cit.*) suggested an extensive area offshore from Lizard Island to Brisbane, and incorporating the Queensland and Marion Plateaux and the Townsville Trough, as 'the Great Barrier Reef Environment'—a region of importance for black marlin spawning. However, they demonstrated spawning of the species only in a region adjacent to the Great Barrier Reef itself between Lizard Island and Cairns.

Domeier and Speare (*op. cit.*) also incorporated the use of popup satellite tags to study movements of black marlin tagged during the spawning aggregation. Of 67 pop-up tags, fewer than 10 remained on fish for more than 100 days—the longest for 180 days. Within these time periods, the majority of fish had travelled 1000 km to 2000 km away from the edge of the Great Barrier Reef, with several travelling more than 4000 km to areas near Fiji, Kiribati and southern Micronesia. On this basis, Domeier and Speare (*op. cit.*) defined a wider 'catchment area' of the south western Pacific extending as far as Kiribati where they suggested the majority of the black marlin stock probably resides during the non spawning season, although conventional tags had demonstrated more extensive movement over longer time periods, some moving well north of the equator or crossing the breadth of the Pacific. Since this study, adult female black marlin, also tagged with pop-up satellite tags at the edge of the northern Great Barrier Reef, have been shown to move rapidly to the central Pacific, even as far as 10 000 km east, within six months of release (www.igfa.org/Conserve/IGMR.aspx (IGFA 2013)).

Mesophotic zone corals

Higher than expected diversity of staghorn corals (*Acropora* and *Isopora* spp.) were found in the mesophotic zone of the Great Barrier Reef and western Coral Sea (Bougainville, Osprey, West and East Holmes, Flora and Flinders Reefs) (Muir *et al.* 2015). The recent discovery of the significant contribution of these genera to the upper mesophotic (30–60 m) communities indicates that it is generally a poorly understood and researched area. This zone may play a significant role in providing refugia for lineages of these genera against shallow water disturbances and temperature changes, particularly for depth generalist and marginal generalist species (Muir *et al.* 2015).

Surveys in 2012–13 used a remote operated vehicle (ROV) to video coral communities in the mesophotic zone to establish the deepest limits of zooxanthellate scleractinian corals at Bougainville Reef in the Coral Sea and selected reefs in the GBRMP. Although zooxanthellate corals were scarce below 80 m, communities of small (less than 10 cm in diameter), *Leptoseris* spp. were found down to 125 m at all locations (Englebert *et al.* 2014). These are the deepest records for zooxanthellate coral in the Coral Sea CMR and GBRMP (Englebert *et al.* 2014). Zooxanthellate scleractinian corals were also found between 40 and 100 m depth at West and East Homes Reefs and Flora Reef, with the deepest recorded at 102 m (Bongaerts *et al.* 2011). Azooxanthellate octocorals on these reefs were observed down to 150 m—the maximum depth of the ROV for that study (Bongaerts *et al.* 2011).

Mesophotic communities are less well described and mapped compared to shallow water corals and communities. With further study, these communities may help to better articulate and inform two of the KEFs of the Coral Sea: the reefs, cays and herbivorous fish of the Queensland Plateau (which includes Bougainville, Osprey, East and West Holmes, Flora and Flinders reefs) and the reef and reefs, cays and herbivorous fish of the Marion Plateau.

Bathymetry

A national remapping exercise recently completed by Geoscience Australia better identified submarine canyons in the Coral Sea (see figure 3.11). Some shelf-incising canyons in Australia have been shown to harbour high biodiversity and several shelf-incising canyons are located in the Coral Sea (Bax and Hedge 2015).

Satellite derived bathymetry (SDB) is being used as a substitute for modern digital bathymetry data as a means of obtaining accurate three-dimensional shapes of the reefs. This novel method has been used over the Flinders and Abington reefs, Coringa Islets and Herald Cays. (Beaman, *pers. comm.*).

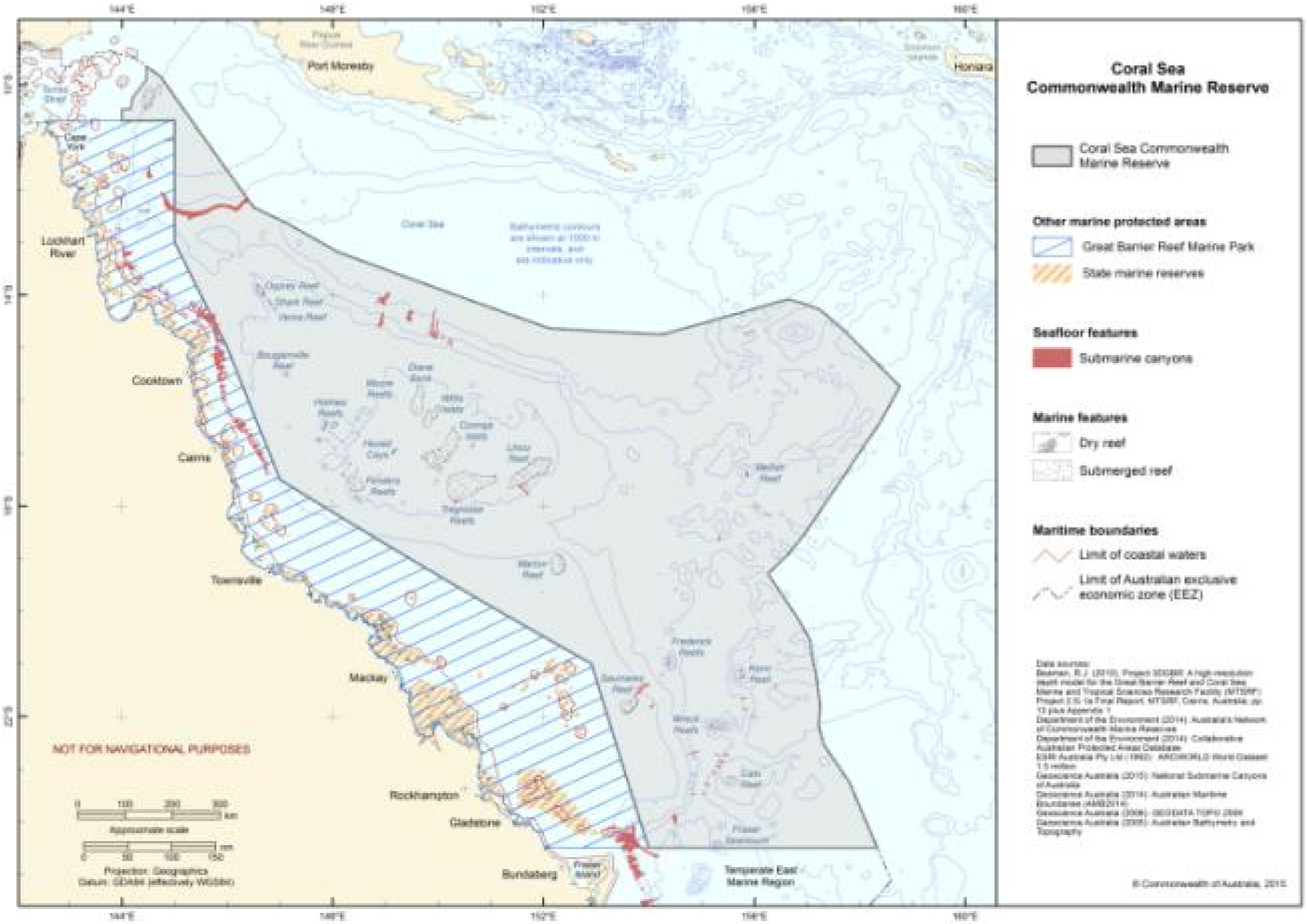

Figure 3.11 Submarine canyons of the Coral Sea CMR identified by recent Geoscience Australia mapping

ESP finding

The coral reefs in the Coral Sea Commonwealth Marine Reserve have been shown to be distinctive at the species and functional group level in southern, central and northern parts of the reserve. The Coral Sea is shown to be a significant biodiversity hotspot for reef-associated sharks and is an important area for pelagic resources such as tuna and marlin. All six species of turtle are found in the Coral Sea and it is also a significant area for breeding seabirds. The Coral Sea Commonwealth Marine Reserve is also significant in that it is one of few remaining areas globally that has not been significantly impacted by human activities.

The diversity of the Coral Sea reefs warrants a higher level of protection, especially in the southern region. Because they are relatively un-impacted by human activity, the reefs, pelagic and demersal biodiversity of the Coral Sea form an important baseline reference area and an adequate representation should be contained in highly protected, no-take reserves.

3.5.2 Geographe Commonwealth Marine Reserve

Benthic habitat

The Commonwealth marine environment within and adjacent to Geographe Bay is a KEF due to high benthic productivity; high biodiversity; and high feeding, resting, breeding and nursery aggregations of several species. The preliminary findings from recent Marine Biodiversity Hub surveys provide additional information to support this. Geographe Bay contains one of the largest continuous seagrass beds recorded in Australia and is shown to contain a much larger extent of continuous seagrass beds and to greater depth that previously reported (see figure 3.12)[21] (Bax and Hedge 2015; Lawrence 2015). Rocky reefs occur throughout the bay and contributes to habitat heterogeneity (see figure 3.13).

The Marine Biodiversity Hub has used BRUV drops in deeper water across the CMR, which confirm that fish assemblages differ by depth and between seagrass, reef and sand habitats (Bax and Hedge 2015).

A recent report investigating the interaction between herbivory by fish, nutrients and water depth in Geographe Bay concluded that, despite the bay's diverse and extensive seagrass beds and high nutrient loads (largely from agricultural sources), the level of grazing by fish was low and not correlated with nitrogen content of seagrass in

[21] During the Geographe CMR project the BRUV sites were selected using two methods: (1) a spatially balanced random approach, and (2) a targeted approach (hand-selected in the field to target specific notable features such as seagrass and reefs).

contrast to studies from other locations and countries. While eight species that were potential seagrass grazers were among the 36 species of fish from 24 families recorded in the study, the abundance of herbivorous fish was low and appeared to be related most closely with the distribution of preferentially grazed seagrass species and habitat heterogeneity (White *et al*. 2011).

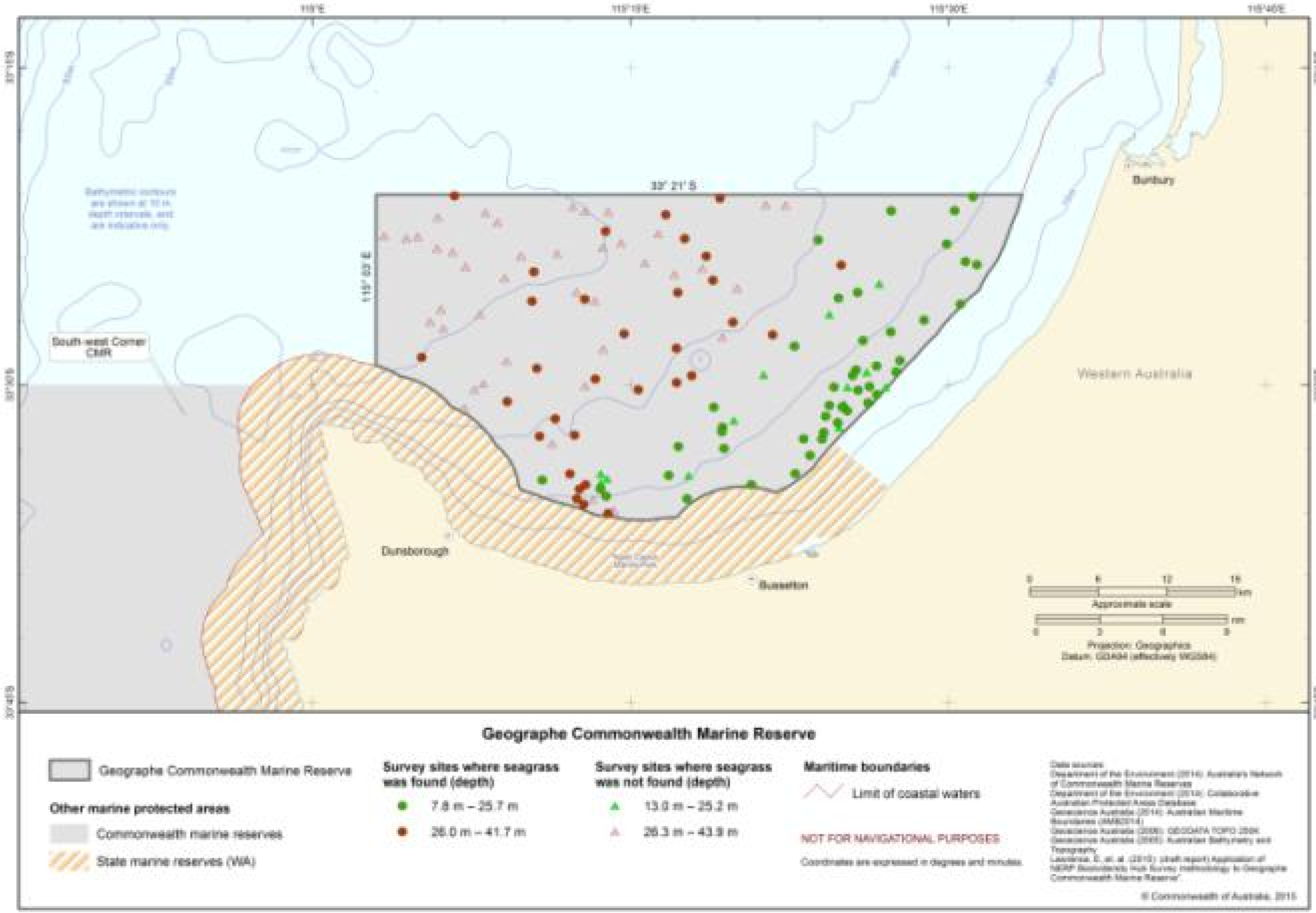

Figure 3.12 Seagrass coverage from 2015 Marine Biodiversity Hub BRUV surveys showing distribution of seagrass across the reserve

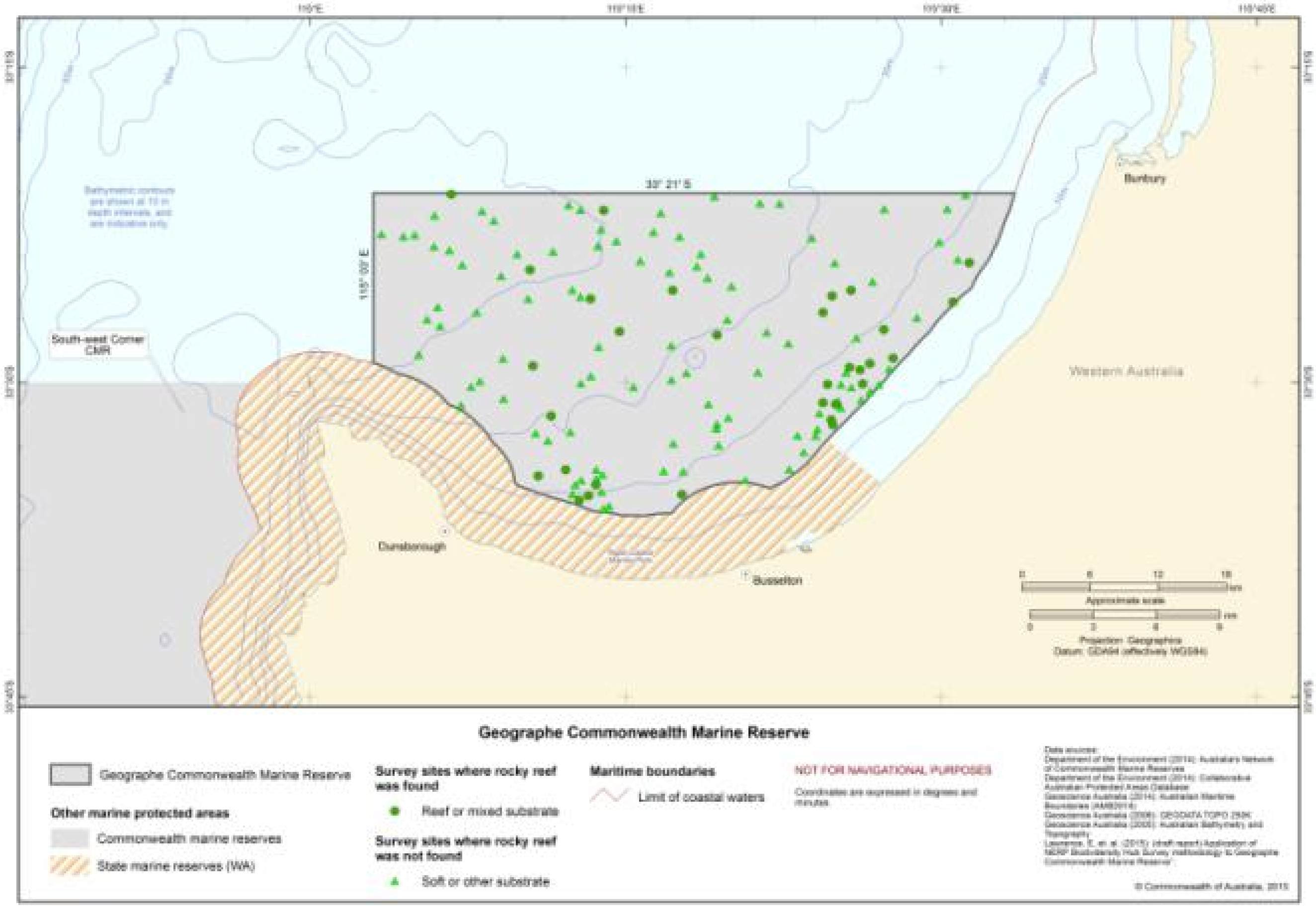

Figure 3.13 Rocky reef coverage from 2015 Marine Biodiversity Hub BRUV surveys showing distribution of rocky reef across the reserve

Cetaceans

Geographe Bay is identified as a biologically important area as migratory habitat for pygmy blue and humpback whales (DNP 2013e). This is supported by recent research on pygmy blue whale non-song vocalisations (Recalde-Salas *et al.* 2014) Five previously undescribed non-song vocalisations were produced by pygmy blue whales travelling in one direction within Geographe Bay, indicative of migratory behaviour (Ricalde-Salas *et al.* 2014).

North Pacific populations of blue whales have been known to vocalise when exhibiting feeding dive behaviours in a foraging area; however, Geographe Bay is not considered a feeding ground (Ricalde-Salas *et al.* 2014).

ESP finding

New information about Geographe Commonwealth Marine Reserve confirms that it contains important habitat and reveals that its seagrass beds extend further and deeper than previously thought. Protection of these extensive and potentially important seagrass beds extents should be maintained or improved.

The Marine Biodiversity Hub surveys provide valuable baseline information to underpin future monitoring of the CMR.

3.5.3 Bremer Commonwealth Marine Reserve

Recent findings

The Bremer Canyon (figure 3.14) is described as one of nine shelf-incising canyons in the South-west bioregion and one of the larger and most topographically complex of the Albany Canyons group (figure 3.15) mapped in a recent Geoscience Australia mapping study (Huang *et al*. 2014).

There is evidence that Bremer CMR is an important location for feeding aggregations of megafauna such as orcas and sharks (De Barros *et al.* 2013). Marine fauna observers on the Ennovation seismic survey, which extended west and east over the Bremer CMR area, sighted 555 marine mammal individuals in nearly 600 hours of observation. They recorded orcas apparently attacking sperm whales and predatory herding behaviour (in both locations within the Bremer CMR) and a nursery aggregation of 40 sperm whales was sighted three times immediately to the west of the CMR (McCarthy and Woodcock 2010). Stakeholder consultation in Esperance reported by Arcadia confirmed that pods of killer whales are seen in certain areas near the Bremer Canyon herding and attacking large fish such as tuna (Arcadia 2012).

The current hypothesis is that hydrocarbon seepage in the vicinity of the Bremer Canyon supports a productive phytoplankton feedstock for bait species, higher-order predators and marine mammals (Hovland and Riggs 2014).

The documentary titled 'The search for the ocean's super predator', which aired on the ABC network in November 2013, reports a significant megafaunal aggregation in the Bremer region (De Barros *et al.* 2013).

Modelling to simulate marine larval dispersal undertaken by Geoscience Australia through the Marine Biodiversity Hub suggests that canyons with 'high source capacity' (typically topographically complex) have a high potential to contribute to resilience of the protected area network by exporting larvae to other connected locations (Bax and Hedge 2015).

The Bremer Canyon was predicted to have a medium–high source capacity due to its size and topographic complexity. The connectivity between and across the Albany Canyons (which include the Bremer Canyon) is driven by the Leeuwin Current flowing eastwards, the deeper Flinders Current flowing westwards, and augmented secondary flows that recirculate modelled dispersal clouds westward (Bax and Hedge 2015).

ESP finding

The Bremer Canyon is a biodiversity hotspot, especially in terms of aggregations of megafauna, and is worthy of protection that enhances eco-tourism in the area.

Further research that measures larval transport from the area may be warranted.

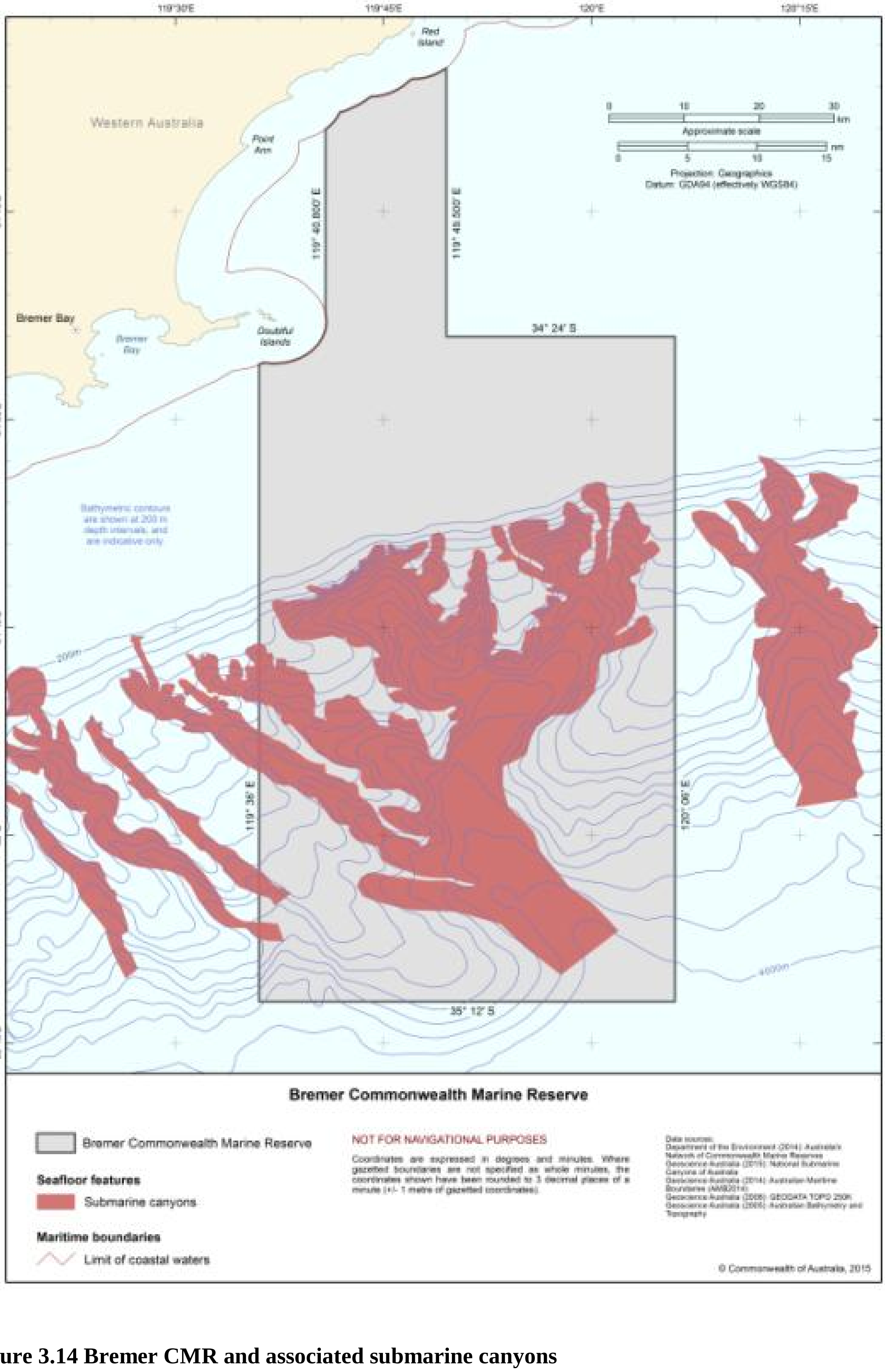

Figure 3.14 Bremer CMR and associated submarine canyons

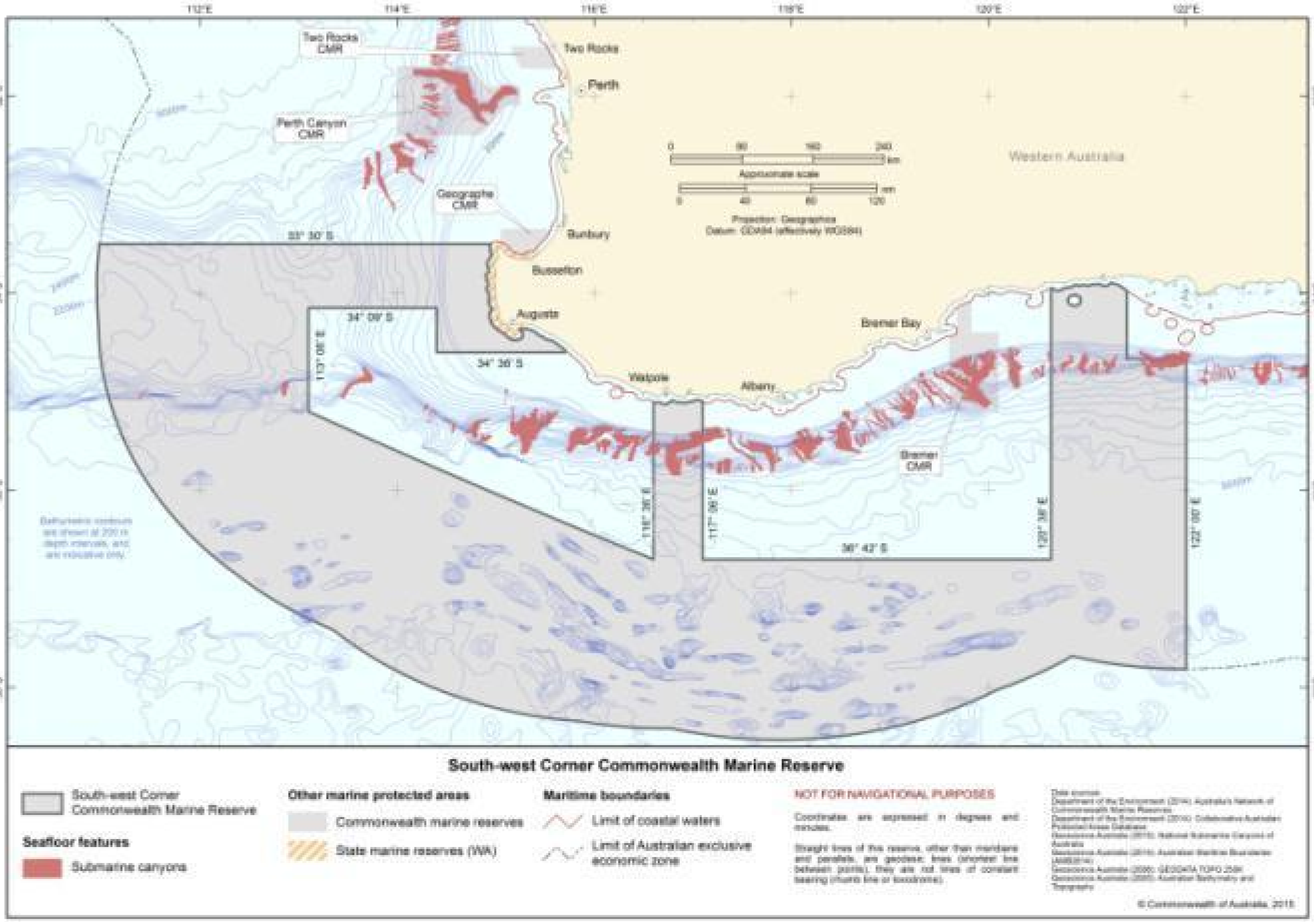

Figure 3.15 South-west Corner, Bremer CMRs and the associated Albany submarine canyons group

3.5.4 Perth Canyon Commonwealth Marine Reserve

The Perth Canyon / Naturaliste Plateau and surrounding region provides habitat for a number of cetacean species and deep-sea communities.

Whales[22]

Recent satellite tagging studies have shown that the greater Perth Canyon / Naturaliste Plateau region is a seasonal feeding area for pygmy blue whales.

The Double *et al.* (2014) study described the migratory distribution and behaviour of pygmy blue whales that feed in the Perth Canyon region, tracking several individuals for over 20 000 km (801 locations).

If the movements of the tracked whales are representative of the broader population that feeds off Western Australian, it can be inferred that pygmy blue whales migrate:

- north from the feeding grounds of the Perth Canyon / Naturaliste Plateau region in March/April, reaching Indonesia by June
- south from Indonesia from September, arriving in the subtropical frontal zone in December
- slowly north again from the subtropical frontal zone to arrive in the Perth Canyon / Naturalist Plateau region by March/April. This temporal pattern of migration as revealed by satellite telemetry is supported by acoustic recordings of Australian type pygmy blue whale calls off south Western Australia.

Genetic evidence indicates mixing between the animals in the feeding areas of the Perth Canyon (off Western Australia) and Bonney Upwelling (off southern Australia), and animals photographed in the Bonney Upwelling have also been resighted in the Perth Canyon. This indicates the potential for individuals from the Bonney Upwelling to follow a similar migration route to those animals feeding in the Perth Canyon.

Drawing on current and historical records, a recent study suggested that the submarine canyons off Albany and Perth provide important habitat for sperm whales (Johnson *et al.* 2013).

Deep-sea communities

Deep-sea communities have recently been surveyed for the first time within the Perth Canyon. Invertebrate and coral species (Pattiaratchi and McCulloch 2015), including live specimens of aragonitic coral (for example, *Desmophyllum*), were recorded

[22] This section refers to information found in Double *et al*. 2014 unless otherwise referenced.

below 1000 m in water temperatures of 3°C to 4°C and bamboo coral recorded at depths between 1000 m and 1700 m (Schoepf and Falter 2015).

Recent surveys of the expedition of *RV Falkor* have described communities that live in total darkness on the hard rock of the canyon walls 1600 m below the surface (Pattiaratchi and McCulloch 2015). They include Venus flytrap anemones, brisingid seastars, golden coral (*Metallogorgia*), basket star (*Gorgonocephalidae*) and mushroom soft coral (*Anthomastus*) (Hosie 2015).

The data from the expedition has also revealed undersea terrain of varied topography and substrate, including vertical cliff faces of up to 600 m and evidence of landslides. In combination with the nutrient-rich waters of the canyon, these different landforms provide a wide array of habitats (Pattiaratchi and McCulloch 2015).

Fromont *et al.* (2012) completed an assessment of sponges on Australia's deep western continental margin (100 m to 1100 m), which found that highly species-rich sponge assemblages dominate the mega-benthic invertebrate biomass in both south-western (86 per cent) and north-western (35 per cent) areas. The Perth Canyon sits on the boundary of the central western and south-western regions, where many of these assemblages were found to be present. It was noted that lithistid demosponges were only collected within three areas (the north-western and central western provinces and transition zones) and not found south of Perth Canyon (Fromont *et al.* 2012). The data suggests that depth-related factors, substrate type, and current regimes (such as those found within the Perth Canyon) are the most influential when considering sponge distribution patterns.

<u>Upwelling and downwelling</u>

The Perth Canyon (figure 3.16) facilitates nutrient-rich deep water upwelling onto the continental shelf, but at certain times of the year it may also be a conduit for transporting water masses from the shallow continental shelf down into the deep sea. These processes significantly influence the water chemistry and nutrient flows and therefore also impact the marine life within the canyon (Pattiaratchi and McCulloch 2015).

Surveys reported by Pattiaratchi and McCulloch (*op. cit*.) found that, at the Perth Canyon's western, deeper end, the northern wall is much more rugged than the southern wall, with several semicircular features showing evidence of landslides. The dog-leg section of the canyon also features a very narrow gorge. The maximum water depth recorded in the canyon is 4376 m.

Modelling and observation studies have shown that the Perth Canyon interacts strongly with the Leeuwin Current and the Leeuwin Undercurrent, leading to eddy generation and upwelling at all depths in the canyon (Rennie *et al.* 2009). Complex patterns of circulation and upwelling in the canyon that bring nutrients into shallower waters at the head of the canyon and the surrounding shelf support high seasonal phytoplankton biomass accumulations which are likely to be responsible for aggregations of krill near the canyon head, attracting pygmy blue whales (Rennie *et al.* 2009), other megafauna, fish and birds.

These observations confirm that the Perth Canyon oceanography is an important source of localised upwelling and nutrient enrichment and productivity and is an important feeding ground for associated megafauna, including seabirds, cetaceans and pelagic fish. This aggregation is also the basis for an important recreational game fishery.

ESP finding

New information supports the understanding that the Perth Canyon is an area of biological significance, driven by localised upwelling around canyon heads that drives productivity and the associated feeding aggregations of an array of species, from whales and seabirds to pelagic predators such as tuna and marlin.

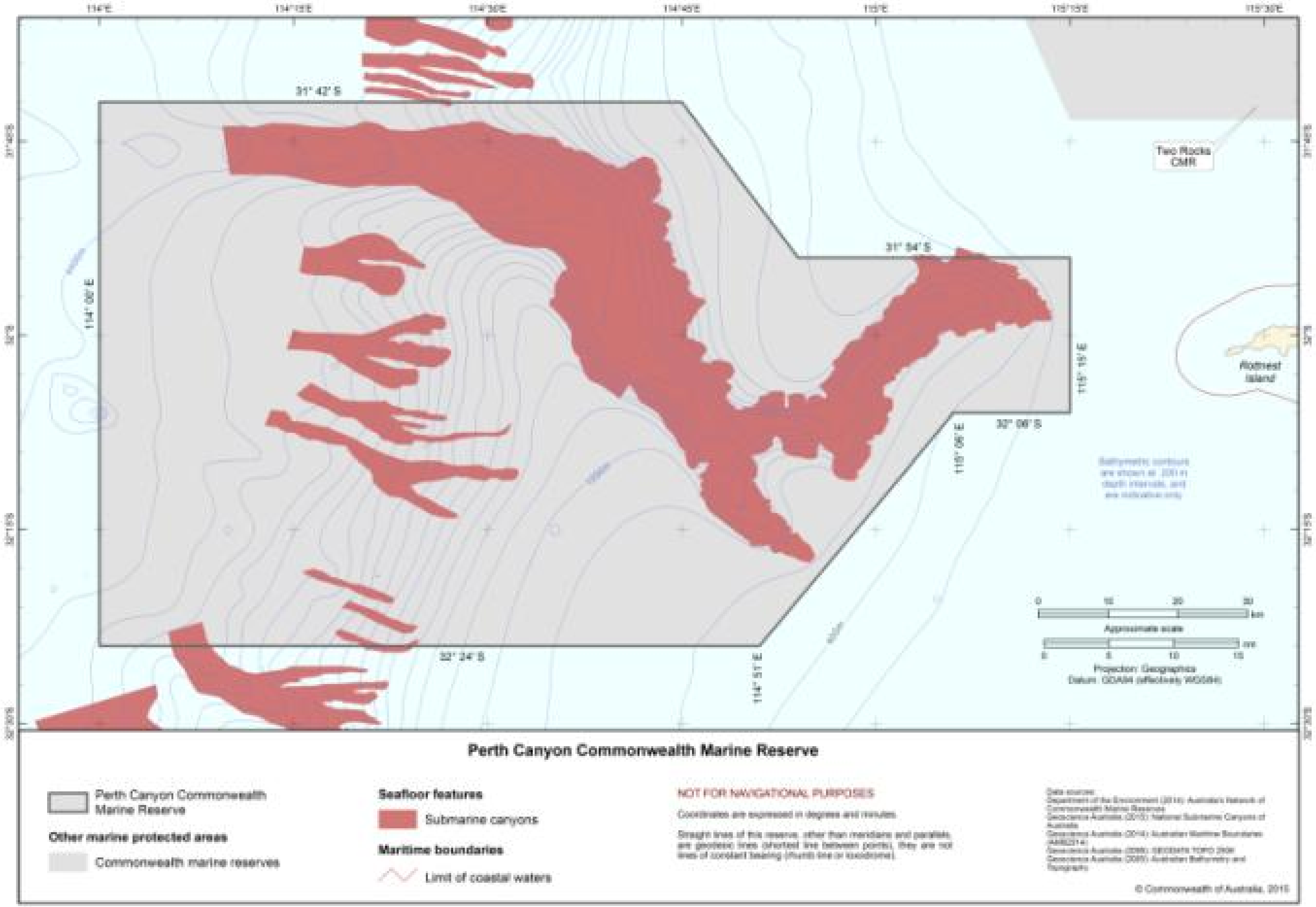

Figure 3.16 Perth Canyon Commonwealth Marine Reserve and associated submarine canyons

3.5.5 Oceanic Shoals Commonwealth Marine Reserve

Marine Biodiversity Hub survey results[23]

In 2012, a voyage of discovery to the western part of the Oceanic Shoals CMR was undertaken by the Marine Biodiversity Hub (Nichol *et al.* 2013). The voyage was designed to complement the findings and discoveries of the two previous surveys completed by Geoscience Australia and the Australian Institute of Marine Science in 2009 (Heap *et al.* 2010) and 2010 (Anderson *et al.* 2011b), and provide better understanding of east–west gradients in the physical environments of the CMR and their relationships to patterns of biodiversity in the region. Key findings from the voyage include:

- A higher variety than previously thought of seabed geomorphic features across water depths from 30 m to 180 m, including carbonate banks, terraces and pinnacles as well as soft sediment plains and valleys, was discovered.
- The high resolution mapping revealed 41 additional banks and pinnacles covering an area of 152 km^2—an increase from 105 km^2. This indicates that hard substrate, which is important to benthic biodiversity, is more extensive than previously thought.
- Benthic biodiversity of invertebrates on banks and pinnacles decreases with water depth and across the transition from the hard substrate of banks to soft sediment plains.
- Banks that rise to at least 45 m water depth support more invertebrate biodiversity, including isolated hard corals, most likely because of greater light penetration at these shallower depths.
- Tidal currents play an important role in shaping the seabed by scouring holes into soft sediments around the base of banks and pinnacles and by extending the length of these pockmarks. Typically, a more complex physical environment will host more species, but such a relationship has not been confirmed in this case.
- Levels of suspended sediment (turbidity) appear higher in the western part of the Oceanic Shoals CMR than the eastern part, with some smaller pinnacles partly buried by sediment. This indicates both ongoing dynamic sedimentary processes and environmental gradients which are likely to be responsible for some of the differences between the structure of invertebrate communities observed at these locations. This high turbidity precluded the analysis of video

[23] This section refers to information found in Caley *et al* (2015) unless otherwise referenced.

collected using demersal baited cameras. Understanding of the local fish communities in the survey area remains an information gap.

- The surveyed area supports a wide range of pelagic vertebrates—32 species were observed, including 11 shark species, black marlin, barracuda, olive ridley turtle, sea snakes and orca.

- Four species of hard corals listed by IUCN as Vulnerable, Near Threatened or Endangered were collected.

- Sediment dwelling invertebrates were highly diverse—266 species were collected, including newly discovered species of sea spider, squat lobster and worm.

- Significant differences were found in polychaete family composition between surveys one year apart, suggesting strong temporal patterns may be operating.

- At least 350 species of marine sponge occur within the Oceanic Shoals CMR, with modelling indicating there may be as many as 900—almost twice the number estimated for the Ningaloo CMR.

- Twenty-nine sponge species are new to science, with as many as 100 potential new species yet to be confirmed.

- Among all observed and/or sampled biota, 57 species are first-time observations for the Sahul Shelf and Northern Territory, seven are first-time records for Australia, and 13 are new for the Indo-Pacific region.

- The survey confirmed that this area supports large numbers of marine species and that many of these species rely on the KEFs that are present.

The data collected during the 2012 survey provided sufficient information to build a qualitative model of the KEFs in the Oceanic Shoals CMR. Qualitative modelling of the carbonate banks, terraces and pinnacles of the Sahul Shelf and Van Diemen Rise within the Oceanic Shoals CMR found five plausible threats for these KEFs over the next 50 years: oil and gas spills, illegal fishing, ocean acidification, increased storm intensity and increased agricultural run-off. The areas surveyed are shown in figure 3.17.

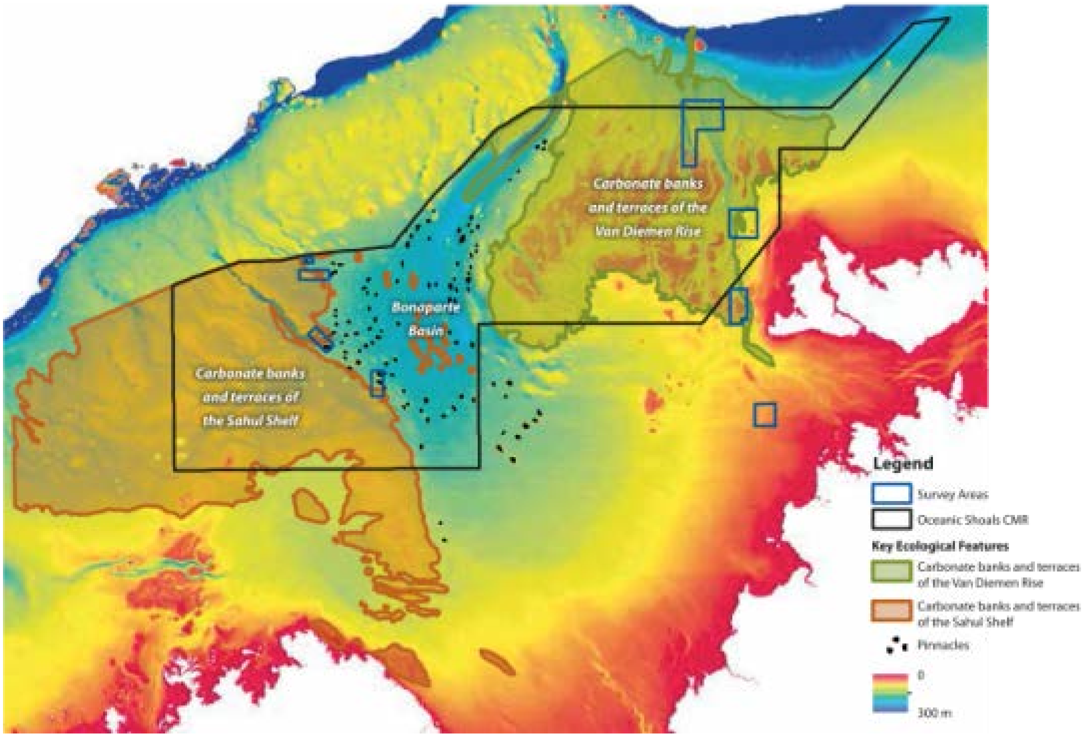

Figure 3.17 Carbonate banks, terraces and pinnacles in the Timor Sea region, showing the intersection with the Oceanic Shoals Commonwealth Marine Reserve. Areas surveyed during voyages in 2009, 2010 (Eastern CMR) and 2012 (Western CMR) voyages are also shown © Copyright, Marine Biodiversity Hub

Other findings indicate that demersal fish communities appear to correlate with the spatial patterns observed for the benthic biodiversity, occurring in larger and more diverse communities on the shallower, less turbid banks (Bax and Hedge 2015).

Sponges[24]

Research by the Marine Biodiversity Hub found a total of 283 species of sponges from the Oceanic Shoals CMR, representing four classes, 53 families and at least 117 genera. Sponge diversity was generally highest further offshore and on raised geomorphic features, particularly banks. Distinct sponge assemblages may occur on each bank in the eastern Oceanic Shoals CMR, suggesting that fine-scale monitoring programs and/or management at the level of individual banks may be appropriate.

Sponge richness, biomass and morphology may be proxies for other taxa and represent one of the key surrogate taxa for biodiversity assessments in the northern region.

Diverse sponge assemblages were confirmed for banks and other raised geomorphic features, supporting the use of the carbonate banks and terrace systems as KEFs due to associated high biodiversity and feeding aggregations. The terraces and banks of

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[24] This section refers to information found in Przeslawski *et al.* 2014 unless otherwise referenced.

both the Sahul Shelf and the Van Diemen Rise, each a KEF, are associated with high biodiversity and feeding aggregations and are biodiversity hotspots for sponges, with at least 350 species of marine sponge occurring, including 29 species new to science. It is estimated that up to 900 sponge species may exist in the reserve.

Connectivity[25]

The data collected during the 2012 survey (Nichol *et al.* 2013) enabled the development of a new dispersal model that predicts connectivity patterns among Australia's north-western CMRs (including the Oceanic Shoals). The model is provides quantitative information on regional connectivity, how and to what extent the marine reserves may contribute larvae to areas outside of the reserves, and where this may occur.

The dispersal modelling suggests areas of relative stability connecting several CMRs: Arafura, Oceanic Shoals, Kimberly, Argo Rowley Terrace, Gascoyne and southwards. This modelling warrants testing by physical sampling to confirm the interconnections among the group of reserves of the Yambi Shelf and Joseph Bonaparte Gulf (Oceanic Shoals, Argo Rowley Terrace, Mermaid Reef, Kimberley, Ashmore Reef, Cartier and Josef Bonaparte Gulf) with the Oceanic Shoals CMR identified (along with Joseph Bonaparte Gulf, Arafura and Arnhem CMRs) as a dominant area due to its central location in the northern network.

Linkages among the Argo Rowley Terrace, Kimberley and Oceanic Shoals reserves emerge as key connections.

Seabed geomorphology and benthic habitats[26]

Geoscience Australia has integrated their new data from high-resolution seabed mapping with existing information on seabed geomorphology and associated benthic habitats and has used this to develop a framework that maps geomorphic features and habitats and characterises their spatial and temporal processes, enabling the development of conceptual models of seabed–basin connectivity and benthic ecosystems.

[25] This section refers to information found in Kool and Nichol 2015 unless otherwise referenced.

[26] This section refers to information found in Heap *et al.* 2014 unless otherwise referenced.

ESP finding

The carbonate banks and terraces of both the Sahul Shelf and Van Diemen Rise are associated with high biodiversity and feeding aggregations. A higher level of protection could be provided for a representative sample of these key ecological features.

The survey sites established by the Marine Biodiversity Hub study of the Oceanic Shoals Commonwealth Marine Reserve warrant protection as scientific reference sites that provide valuable baseline information for the reserve.