Pelagic Habitats
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Pelagic habitats and the physical processes that ultimately define them are represented in South Australian gulf and inshore continental shelf ecosystems. Many species of the migratory megafauna traverse and use these spatially and temporally dynamic habitats on their way to and from our State, so it is important to have a clear understanding of the oceanography and pelagic ecology of this region.

This overview pays special attention to the megafauna that inhabit the pelagic habitat because they are high-profile species, they are generally near the top of the food web, and are often more susceptible to the major anthropogenic threat (e.g., fishing) than most teleost species. Other potential threats to species that use the pelagics include chemical and industrial pollutants, noise pollution, mining, oil and gas exploration (Game \textit{et al.} 2009).

Marine megafauna are here defined as Chondrichthyes (sharks, rays, skates and chimaeras), pinnipeds (seals and sea lions), cetaceans (whales and dolphins), seabirds (e.g., albatrosses and petrels), and turtles. These groups are not only important in an ecological sense but are high profile and therefore valued by the human community. Hoyt (2005) listed three reasons why it is important to consider whales and dolphins when designing marine protected areas: 1) their habitat needs have hitherto been neglected, 2) there is now more information than ever before on cetaceans and 3) cetaceans need large conservation areas so this may be the key to protecting ocean habitats and large new areas. The above reasons can also be connected to other marine megafauna such as pinnipeds and elasmobranchs.

\begin{center}
\textbf{Bottlenose dolphin}
\footnotesize{(Photograph: MLSSA)}
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\textbf{Description/Definition}

The marine pelagic environment is the largest realm on Earth, constituting 99\% of the biosphere volume (Angel 1993). In addition to supplying $>$80\% of the fish consumed by humans (Pauly \textit{et al.} 2002), pelagic ecosystems account for nearly half of the photosynthesis on Earth (Field \textit{et al.} 1998), thus directly or indirectly support almost all marine life.

It is helpful to define some of the common terms used when describing the ‘Pelagia’ since these are often confused. For example:
Neritic: Inhabiting the sea over the continental shelf, i.e. coastal waters to about 200 m depth
Oceanic: Pertaining to the open sea, beyond the continental shelf
Pelagic: Pertaining to the open sea, including neritic and oceanic waters
Continental slope: The steep seaward face of a continental shelf, averaging about 4° from the vertical

By the above definitions, the waters of the South Australian gulfs are therefore pelagic but they are also protected by Eyre, Yorke and Fleurieu Peninsulas and Kangaroo Island. This makes them quite unique in the Australian context, and for this reason they warrant special conservation status.

Some terms used to describe where organisms live in the pelagic environment are:
Epipelagic: Living in the upper, sunlit level or epipelagic zone of the oceans (from the surface to about 200 m deep).
Mesopelagic: Living in the twilight zone below the epipelagic zone where little light penetrates (from 200 to 1,000 m).
Bathypelagic: Living in the sunless zone below 1,000 m extending to the deep slopes rises, ocean floor and trenches (down to 6,000 m or more).
Semipelagic: Penetrate oceanic waters but concentrate close to continental landmasses over continental slopes and rises.
Demersal: Living near the sea floor.
Benthic: Living on the sea floor.

Marine megafauna may use several zones of the water column.

Oceanic waters are generally less productive and contain less biomass and less diversity than coastal waters. Nevertheless, there are also ‘hotspots’ of relatively high productivity and biodiversity in the open ocean, generally associated with nearby bathymetric structures, such as seamounts and mid-ocean ridges, and oceanographic features including, eddies and sea-surface temperature defined frontal zones (Worm et al. 2003), whereas pelagic waters can also be influenced by the interaction between landmasses, wind regimes and currents, which can result in upwelling. Areas of high productivity can vary seasonally, or shift with oceanographic conditions, so it can be necessary for pelagic organisms to migrate long distances (Block et al. 2001).

South Australian (SA) marine waters fall within the temperate to warm temperate zone where sea surface temperatures (SST) are about 10–20°C. For the most part, water temperatures range 14–23°C, with 10°C being rare at the surface (Figure 5). Oceanographic features, such as currents and upwelling affect coastal and southern gulf conditions. The Leeuwin Current is a warm water mass that flows southward along the Western Australian coast and into the Great Australian Bight during early winter. It is variable in strength and the eastward extent to which it flows varies from year to year (Feng et al. 2003) and this may influence how far east it
penetrates the SA region. In some years, the Leeuwin Current can reach as far east as Tasmania. It is likely that some vagrant tropical and subtropical marine fauna (e.g. turtles, Bryde’s whale, pygmy killer whale) make their way to SA waters in this current (Maxwell and Cresswell, 1981, Segawa 2009). During the summer, the Flinders Current flows along the continental slope at around 600m depth from the west coast of Tasmania. This deep-water current drives cold water onto the shelf where it can be brought to the surface via wind driven upwelling. One of the major drivers of the ocean systems to the south of Australia is the Westwind Drift (Tomczak and Godfrey, 1994). However, during winter, an easterly flowing counter-current appears over the flow of the Flinders current and pushes it deeper.

Figure 5).
The upwelling systems that are found on the continental shelf off SA may be the most important in Australia (Kampf et al. 2004). As discussed in the chapter on upwellings, the Bonney Upwelling occurs off the Limestone Coast in Southeast SA from about November to April and may have a major influence on the vertebrate fauna of the region (Middleton and Bye 2007). This upwelling represents the most biologically significant seasonal oceanographic feature in the SA marine region and occurs over a narrower part of the shelf than those that occur in the GAB. The upwelling region is used by a suite of large migratory species both during the peaks of the upwelling and in the periods directly following the events. For example, pygmy blue whales are present and feed on krill in the upwelling system (Gill 2002) and there is evidence that some other baleen whales (pygmy right whales, Gill et al. 2008) may also take advantage of the zooplankton blooms. Other highly migratory species that use this pelagic foraging area include small pelagic (e.g., sardine, anchovy) and large pelagic fish species (e.g., southern bluefin tuna, albacore), sharks (white sharks, shortfin mako), pinnipeds (e.g., New Zealand fur seals, Australian sea lions), and birds (e.g., wandering albatross, Australasian gannets, little penguins) (Goldsworthy et al. 2011).

Flow-on effects of increased productivity as a result of upwelling are likely to be advantageous for other marine vertebrates. For example, 86% of the Australian sea-lion population is found in SA waters (Goldsworthy et al. 2009). Two smaller regions of upwelling are found west of Kangaroo Island and west of southern Eyre Peninsula (McClatchie et al. 2006; van Ruth 2009). Productivity there is inter-annually variable (van Ruth et al. 2009) and may influence the presence/abundance of marine vertebrates using this region as a pelagic foraging area. (Kemper and Ling 1991, Shaughnessy et al. 1994).

The Subtropical Front (Convergence) lies between 39 and 49°S (Belkin and Gordon 1996) and is also an important nutrient-rich zone. Some species of whales are known to feed in this region (Kawamura 1974) and there is evidence that New Zealand fur seals forage across this broad area (Baylis et al. 2008, Page et al. 2006). The position of the Front is variable in its latitudinal position and in some years may be responsible for the irregular appearance of subantarctic species along the SA coast.

The continental slope, Murray Canyons and Ceduna Canyons are features of steep gradients in water depth. Deep sea fish and squid that inhabit these areas are the prey of sperm whales and beaked whales that are sometimes recorded (alive or dead) in coastal waters (Kemper and Link 1991).

There are far fewer species of elasmobranchs (sharks and rays) in the open ocean than in coastal waters, these species are wide-ranging and play an important role in the food webs of the high seas. Of the roughly 1,160 extant species of elasmobranchs fishes, 26–31 species (about 2.5%) are oceanic, spending much of their life in open ocean waters away from continental landmasses, while an additional 2.8% are semipelagic (Compagno 2008).

**Threats**

Pelagic ecosystems face a multitude of threats including overfishing, pollution, climate change, eutrophication, mining and species introductions (
Figure 6). These threats can act synergistically and can fundamentally alter pelagic ecosystems (Game et al. 2009).

![Intensity of activity graph](image)

Figure 6. Schematic of the intensity of the eight largest threats in the pelagic ocean as a function of depth. Blue shading indicates the penetration of light (euphotic zone) into the water column. The solid line is the current intensity of these threats, while the dashed line indicates the potential change in intensity over the next 50 years (generally increasing and moving deeper). This figure is reproduced from Game et al. (2009).

Mechanisms that threaten the conservation of the pelagic habitat and associated organisms are poorly understood because of the often-remote nature of this environment. Many of the examples listed below apply to sharks and marine mammals but can equally be relevant for other fauna, including other vertebrate megafauna. An in-depth discussion of the threats to Australian cetaceans is found in Bannister et al. (1996), to pinnipeds in Shaughnessy (1999) and Goldsworthy et al. (2009), and to chondrichthyans in Camhi et al. (2007, 2008). Immediate threats involve processes that result in mortality and serious injury, intermediate and long-term threats are those that are more subtle and may take more time to show an effect on marine mammals.

Pelagic shark species exhibit a wide range of life-history characteristics, but many have relatively low productivity and consequently relatively high intrinsic vulnerability to threats such as over-exploitation (Dulvy et al. 2008). Overall, 32% of the world’s pelagic sharks and rays are threatened. As a group, pelagic elasmobranchs suffer significantly greater threats than do elasmobranchs as a whole (Camhi et al. 2009).
Immediate Threats

Commercial fishing including longline, purse seines and gillnets has been identified as the single most important threat to pelagic chondrichthyans wherever they occur. Oceanic shark and ray species taken regularly in high-seas fisheries (e.g., shortfin mako) are more likely to be threatened (52%) than are pelagic elasmobranchs in general (Camhi et al. 2009). Pelagic sharks occur in international waters and most migrate across national borders. Because they move regularly between the EEZ’s of different countries and into the high seas, they do not fully benefit from regulations that apply only to the waters or fleets of a single country.

Immediate threats to marine mammals include illegal killing (all marine mammals are protected in Australian waters under the Environmental Protection and Biodiversity Conservation Act 1999), incidental catch, vessel collisions, pollution in the form of plastic and other debris, and entanglement. Illegal killing of dolphins (Kemper et al. 2005) and pinnipeds has been recorded in several regions in the state (SA Museum, unpublished data), including Gulf St Vincent, lower Spencer Gulf and south of Kangaroo Island. Incidental catch (bycatch) is a documented and serious concern for Australian sea-lions in the demersal shark fishery in four areas: off Ceduna, off Port Lincoln, south of Kangaroo Island and south of the Flinders Peninsula (Goldsworthy et al. 2009; Goldsworthy et al. 2010) and for short-beaked common dolphins in the SA Sardine Fishery in lower Spencer Gulf and Investigator Strait (Hamer et al. 2008). Bycatch of bottlenose dolphins has also been recorded in the sardine fishery but the degree of threat is not known. If offshore finfish aquaculture is established in SA, there is potential for entanglement of cetaceans and pinnipeds since this has been documented in coastal areas (Kemper and Gibbs 2001). Entanglement of large cetaceans in SA is documented for southern right whales (Kemper et al. 2008) and sperm whales (Shaughnessy et al. 2003) and there is one case of a humpback whale trapped in a tuna cage near Port Lincoln (Kemper 2005). In the pelagic environment, longlines are probably the most common form of recorded entanglement of large whales. Monitoring fatal entanglements in SA (both in the coastal and pelagic environment) is difficult because, although there is a requirement to report incidents, there is no co-ordinated approach by government agencies. Mortality of Australian sea-lions has been reported in rock lobster pots and there is potential for considerable interaction in three areas of the State: off Streaky Bay, south of Eyre Peninsula and south of Kangaroo Island (Goldsworthy et al. 2009).

Fatal vessel collisions are documented in SA for the southern right whale (Kemper et al. 2008), dolphins (Kemper et al. 2005), sperm whale, fin whale, Antarctic minke whale and pygmy right whale (SA Museum, unpublished data). Collisions involving large vessels are more likely to occur in the ship corridors between Melbourne and Adelaide and Adelaide/Melbourne to Perth. At present these routes are not as heavily used as along the eastern seaboard of Australia and therefore not considered a serious threat to large cetaceans but many collisions are likely to go unreported.

Intermediate Threats

Intermediate threats to vertebrate megafauna include competition from commercial fisheries, the less immediate effects of oil spills, disturbance and harassment, degradation of habitat, and exposure to human and domestic animal diseases. There is now a reasonable knowledge of the
diet, feeding locations and population size of the Australian sea lion and a concern for overlap with the demersal gillnet fishery for sharks (Goldsworthy et al. 2009). For all species of cetacean living in SA, there is inadequate data on diet, feeding areas and population size to comment on these threats except to say there is some overlap in species harvested by humans and consumed by toothed whales and dolphins (Kemper and Gibbs 2001). There is potential that harvesting sardines may impact short-beaked common dolphins through resource competition.

Exploration for petroleum and gas are being undertaken in the SE of SA, the Great Australian Bight and to the west of Kangaroo Island. Oil exploration usually involves seismic surveys which may affect some marine mammal species (Richardson et al. 1995). If adequate reserves are found and mining commences, the benthic zone and other layers of the water column will be affected in localised areas. Oil spills are a substantial risk in the pelagic environment and marine mammals (Geraci and St Aubin 1990), even with tight controls on mining processes. There are no documented cases of oil spills in pelagic waters of SA but there is potential for serious consequences to the Australian sea-lion and New Zealand fur-seal if oil washes up in the vicinity of many breeding colonies around Kangaroo Island and the south and west coast of Eyre Peninsula (Shaughnessy 1999). In the event of a substantial oil spill, the effects on calving grounds of southern right whales (e.g. Head of Bight, Sleaford Bay, and Encounter Bay) are likely to be serious.

Bottom trawling impacts benthic fauna and flora through alterations, sometimes recurrent, to the ocean floor. There are commonwealth deep water bottom trawlers that operate in the Great Australian Bight, while three South Australian prawn trawlers operate in inshore waters (~10-50m) between Ceduna and Coffin Bay. State prawn trawl fisheries also operate within Spencer Gulf and Gulf St Vincent. South Australian prawn fisheries operate within a management framework that restricts fishing both spatially and temporally to maximise economic returns and reduce impacts. For example in Spencer Gulf, fishing generally occurs for ~50 nights of the year, with >90% of the catch trawled from ~20% of the available fishing area (generally waters >10m).

Exposure to infectious human and domestic animal diseases is likely to be more concern in the coastal habitats and associated fauna. However, pathogens could spread to pelagic habitats. No outbreaks of morbillivirus have been reported in Australian waters and there have been no mass mortalities as a result of disease. The potential exists for a variety of diseases to be spread by ‘rescued’ and released pinnipeds, a practise that is currently being carried out in the State. Although the South Australian Museum performs necropsies on marine mammals opportunistically collected during grant-funded research, there is no recognition by the South Australian Government that routine sampling should be carried out in order to monitor disease outbreaks.
Long-term Threats

Except in cases of acute toxicity, chemical pollution and marine debris are long-term threats for marine megafauna. For example, heavy metal pollution from the Port Pirie smelter is a known threat to Spencer Gulf and possibly beyond (through water circulation and movement of organisms) and there are documented cases of high levels of zinc, lead and cadmium in sediments, fauna and flora, particularly from upper Spencer Gulf (Lavery et al. 2008). Heavy metals accumulate in the tissues of long-lived vertebrates and can cause a range of deleterious effects, including bone disease in dolphins from Spencer Gulf (Lavery et al. 2009). Much of the pelagic environment of SA is remote from industrial pollution (e.g. Great Australian Bight) and this threat is not generally considered a concern. However, there may be far-ranging effects from pollutants due to water movement in currents, both surface and deeper layers. For example, it is known that the heavy, salt-laden (and presumably contaminated with heavy metals) water takes about 1 year to travel from the head of Spencer Gulf to Investigator Strait (Nunes and Lennon 1986).

There is little information on the extent of floating debris in South Australia. A project is currently underway to document marine debris in Gulf St Vincent bioregion and Kangaroo Island (through a ‘Caring for our Country’ grant to the Adelaide and Mount Lofty NRM Board) and there are published data on the west coast of Eyre Peninsula. Entanglement rates for Australian sea lions and New Zealand fur seals in South Australia are reported as amongst the highest in the world for pinniped species (Page et al. 2004).

Other long-term threats include the reduced genetic variation in depleted populations. Such a scenario may apply to Australian sea lions, New Zealand fur seals, southern right whales and other ‘great whales’ because these species were substantially reduced by hunting in the 19th and 20th centuries.

The effects of climate change on the marine megafauna are not known. The likely scenarios include altered distributions of species as a result of higher sea levels, warmer water and changes in upwelling patterns. There may be deleterious effects on species already vulnerable or endangered, e.g. Australian sea lion, blue whale.

For some species, long-term threats may include resource competition from other marine megafauna. For example, the New Zealand fur seal is increasing at rates of about 11.2 % per annum (Shaughnessy et al. 2009). The overall trend for the Australian sea lion is not known: numbers are increasing at Dangerous Reef, stable at The Pages and decreasing at Seal Bay (Goldsworthy et al. 2009).

Vulnerability

South Australian waters include pelagic environments primarily in Spencer Gulf, Gulf St Vincent, Investigator Strait and around offshore islands. These will be the focus of the discussion below although it should be recognised that areas along the open ocean coast are considerably influenced by the nearby pelagic habitat. Emphasis is placed on species either listed as threatened (EPBC Act) or for which there is concern for their long-term future.
The pelagic and semipelagic shark species which occurred in South Australian waters include the thresher shark, bigeye thresher, white shark, shortfin mako, blue shark, porbeagle shark, school shark, bronze whaler, dusky whaler, scalloped hammerhead, and smooth hammerhead. The whale shark, basking shark, oceanic whitetip shark, and goblin shark are also pelagic species known to occur in South Australia but have only been observed on rare occasions. The IUCN listing of the regular species of pelagic sharks highlights the vulnerability of these species with 82% listed as globally Threatened and the remaining listed as Near Threatened. According to a report determining the vulnerability of over-exploitation of pelagic sharks, the South Australian species at the highest risk are the bigeye thresher and shortfin mako. The porbeagle and common thresher were grouped and identified as having the next greatest risk.

The pelagic habitats found in Gulf St Vincent, Investigator Strait, Backstairs Passage and Spencer Gulf are unique in Australia and likely to be more affected than other parts of the State simply because there are so many human activities in the gulfs. In addition, they are shallow, protected bodies of water which have limited exchange with the oceanic environment and therefore there is potential to accumulate pollutants. The waters of Investigator Strait are important because they represent an ecotone between the gulfs and the pelagic habitat of the Southern Ocean. As such it contains a diverse mix of inshore and offshore species. A dolphin survey in 2005 detected many more dolphins south and east of the tip of Eyre Peninsula compared to within Spencer Gulf (Kemper et al. 2006).

Megafauna species that are most affected by human activities are those that are resident in the gulfs (e.g. Indo-Pacific bottlenose dolphins, possibly short-beaked common dolphins and whaler sharks) as opposed to those that are seasonal visitors (e.g. southern right whale, humpback whale, shortfin mako). The Australian sea lion can be found throughout the gulfs but breeding colonies are at the southern end of the gulfs, near the open ocean environment.

The coastal waters from Kangaroo Island to the Victorian border are rich in marine life because of the nearby Bonney Upwelling. Pelagic species of whales, dolphins and sharks frequent the region and may come closer to shore than elsewhere in the State, in part because the shelf is relatively narrow. Upwelling is also important in the area south of Eyre Peninsula and west of Kangaroo Island (McClatchie et al. 2006). This factor may explain the numerous cetacean strandings (Kemper and Ling 1991), and the abundance of Australian sea lion and New Zealand fur seals (Shaughnessy et al. 1994, Goldsworthy et al. 2009) in that region. In addition to the enhanced nutrients as a result of upwelling, the region is close to the edge of the continental shelf where pelagic species are frequently encountered.
Considerations for MPAs in South Australia

Because pelagic systems are not static on the same scale as most benthic marine habitats, the use of protected areas to help mitigate threats to pelagic biodiversity represents a departure from conventional thinking regarding their utility. Whereas there is no question that protected areas will be neither the best nor only required response to some threat, well-selected pelagic MPAs can directly or indirectly help address the threats addressed in the previous section of this document. For entirely anthropogenic threats such as harvesting, mining or non-extractive use, MPAs can result in direct localised abatement. Through a reduction in cumulative impact, MPAs can also help mitigate the severity of threats where direct abatement is not possible (Hooker et al. 2004).

The below pelagic areas have been identified and listed in order of perceived importance based on relative ecological importance and predictability of oceanographic features, abundance and diversity of threatened species of pelagic predators in these areas, and habitat/bathymetric complexity.

1. Southeast SA (Bonney upwelling system) during summer and autumn.
2. Great Australian Bight (during spring–autumn and early winter in some years)
3. Central Gulf St Vincent and Spencer Gulf
4. Lower Eyre Peninsula (this upwelling is relatively small and sporadic and really only stretches from to Pt Sir Issacs to Liguanea Is) (spring–autumn)
5. Investigator Strait
6. West Coast (most of the pelagic productivity is out on the slope so not really relevant to this planning process)
7. South coast of Kangaroo Island (spring–autumn)
8. South Australian shelf edge

Southeast South Australia (Bonney upwelling): The continental shelf in this region is particularly narrow. This characteristic in association with strong Southeast trade winds in summer and autumn months creates strong upwelling events (Bonney Upwelling). As a result, many truly pelagic small pelagics (e.g., jack mackerel, redbaft blue mackerel, arrow squids), large pelagics (e.g., Southern bluefin tuna), sharks (e.g., shortfin mako, blue, thresher), and cetaceans (e.g., blue whale) have been recorded in the area. The influence of the Bonney Upwelling on the surrounding ecosystem, and the abundance and diversity of marine megafauna is considerable.

Great Australian Bight: The seasonal upwelling boosts primary, secondary and fish production, making the Eastern GAB Australia’s richest pelagic ecosystem, and an ecological ‘hot-spot’ of international significance. The region supports the highest densities of small pelagic fishes in Australian waters. These rich pelagic resources also underpin arguably the greatest density and biomass of apex predators to be found in Australian coastal waters. These include marine mammals such as pygmy blue whales, and >80% of Australia’s populations of New Zealand fur seals and Australian sea lions. Other key apex predators include seabirds, such as short-tailed shearwaters (~1.3 million pairs breed in the eastern GAB), little penguins and crested terns; pelagic sharks including bronze and dusky whalers, white sharks, and shortfin mako; and predatory fishes such as southern bluefin tuna.

Central Gulf St Vincent and Spencer Gulf: The gulfs are oceanographically and geographically unique in Australia, in part because they are inverse estuaries. It is important that not just the coastal parts of the gulfs be conserved.

Lower Eyre Peninsula (including Coffin Bay): One of the important upwelling systems for South Australia occurs in this region. Stranding records show that it is a hotspot for diverse range of cetacean species (Kemper and Ling 1991). It includes major breeding colonies of the
Australian sea lion and New Zealand fur seal, which are also areas where white sharks often occur. It is an area frequented by many species of pelagic sharks (e.g., white sharks, whaler sharks, blue shark and shortfin mako) which interact with the aquaculture industry (Murray-Jones 2004). This region also encompasses the Neptune Islands, which is considered the largest aggregation of adult white sharks in Australia, and is a breeding area for New Zealand fur seals, Australian sea lions and short-tailed shearwaters.

**Investigator Strait:** This area is important for both inshore and pelagic marine megafauna (Kemper et al. 2008) and is the ecotone between the gulfs and the Southern Ocean. It is likely to be an important corridor for many forms of marine life. A strong frontal system is found near the entrance to Spencer Gulf and this enhances nutrient exchange.

**West Coast:** This area is adjacent to the pelagic environment of the wide shelf of the Great Australian Bight, a unique feature on the southern coast of Australia. It includes one of the likely migration routes for white sharks, shortfin makos, and southern right whales and a potential hotspot for the pygmy sperm whale in Australia. The influence of the Leeuwin Current may result in subtropical and tropical fauna appearing from time to time in the region.

**South Coast of Kangaroo Island:** Like the Lower Southeast of SA, this region is important because it has a narrow continental shelf and abuts the true force of the Southern Ocean. In addition, the Cape De Couedic and Murray Canyons are nearby and believed to support a diverse faunal community, including sharks and cetaceans. Furthermore, recent tagging studies suggest that shortfin makos are often associated with the shelf canyons and the seamounts located south and southeast of Kangaroo Island, respectively.

**South Australian shelf edge:** Several tagging studies (Bruce et al. 2006; Rogers, unpublished data) have found that the shelf edge is commonly used as migratory routes for pelagic species such as white sharks and shortfin makos. Although it is outside State waters but in Commonwealth waters, the shelf edge is likely to be an important pelagic habitat for many species such as tunas, sharks, and cetaceans.

**References**


