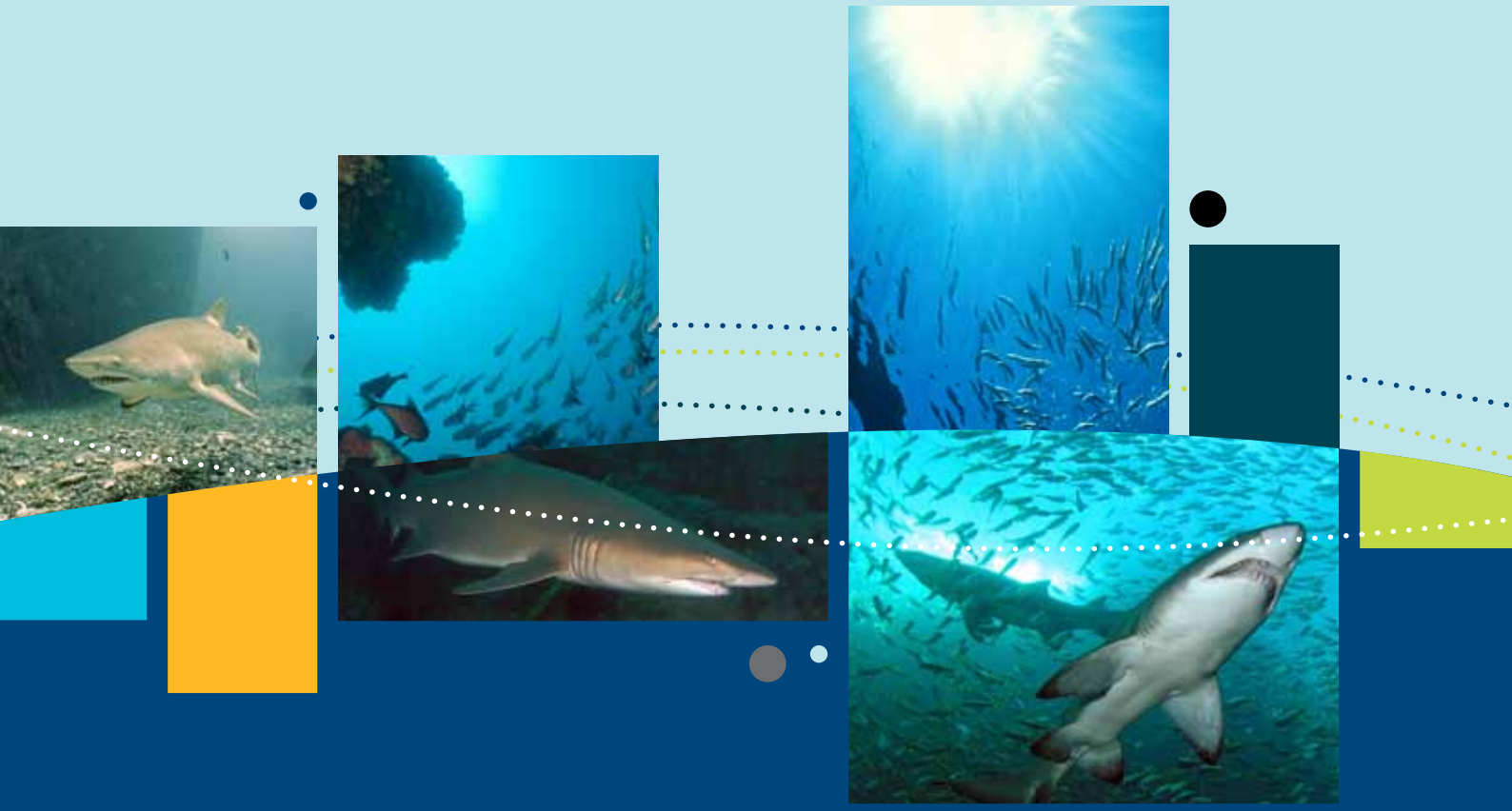
Australian Government

Department of Sustainability, Environment,
Water, Population and Communities



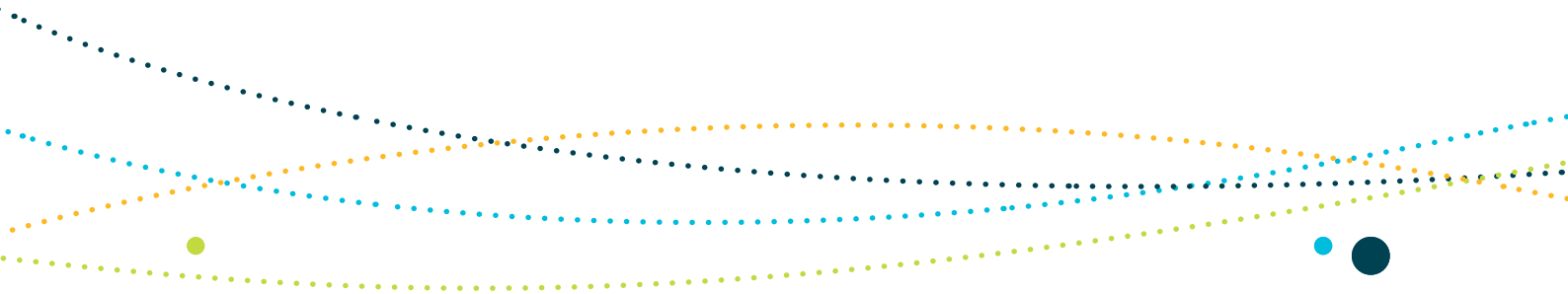
Species group report card —sharks

Supporting the draft marine bioregional plan for the South-west Marine Region

prepared under the *Environment Protection and Biodiversity Conservation Act 1999*

Disclaimer

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for Sustainability, Environment, Water, Population and Communities. The contents of this document have been compiled using a range of source materials and while reasonable care has been taken in its compilation, the Australian Government does not accept responsibility for the accuracy or completeness of the contents of this document and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of or reliance on the contents of the document.



Species group report card—sharks

Supporting the draft marine bioregional plan for the South-west Marine Region
prepared under the *Environment Protection and Biodiversity Conservation Act 1999*

Report cards

The primary objective of the report cards is to provide accessible and up-to-date information on the conservation values found in Commonwealth marine regions. This information is maintained by the Department of Sustainability, Environment, Water, Population and Communities and is available online through the department's website (www.environment.gov.au).

Reflecting the categories of conservation values, there are three types of report cards:

- species group report cards
- marine environment report cards
- heritage places report cards.

Species group report cards

Species group report cards are prepared for large taxonomic groups that include species identified as conservation values in a region; that is, species that are listed under Part 13 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and live in the Commonwealth marine area for all or part of their lifecycle. All listed threatened, migratory and marine species and all cetaceans occurring in Commonwealth waters are protected under the EPBC Act and are identified in the relevant marine bioregional plans as conservation values.

Species group report cards focus on species for which the region is important from a conservation perspective; for example, species of which a significant proportion of the population or an important life stage occurs in the region's waters.

For these species, the report cards:

- outline the conservation status of the species and the current state of knowledge about its ecology in the region
- define biologically important areas; that is, areas where aggregations of individuals of a species display biologically important behaviours
- assess the level of concern in relation to different pressures.

1. Sharks of the South-west Marine Region

Seven species of shark listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) are known to occur in the South-west Marine Region: white shark, grey nurse shark, whale shark, shortfin mako, longfin mako, porbeagle shark and school shark (Attachment 1). Sharks in the region predominantly feed on bony fish and cephalopods, although some species feed on other sharks, rays, crustaceans, birds and marine mammals. Some of the pelagic species are diverse in their ecological function; whale sharks are plankton feeders, while other sharks are predominantly fish and cephalopod predators.

White shark

White sharks (*Carcharodon carcharias*) are listed as vulnerable under the EPBC Act. They are widely distributed throughout temperate and subtropical regions, and are most frequently observed and captured in inshore cool to warm temperate continental waters. Data from recent tracking studies show that white sharks can travel thousands of kilometres. There are currently no estimates of the size of the white shark population in Australian waters and no reliable measures with which to compare changes in population status over time. This is due partly to the scarcity of white sharks and also to the difficulty in distinguishing population changes from the high rates of variability in numbers observed within any one site or region between years (Bruce 2008).

White sharks eat a variety of prey including finfish, other sharks and rays, marine mammals such as seals, sea lions, dolphins and whales, as well as squid, crustaceans and seabirds (DEWHA 2009a). Their diet is known to change with size—juveniles less than 2.7 m long feed primarily on fish and other sharks and rays while larger sharks (reaching up to 6 m in length) are known to feed on marine mammals (Malcolm, Bruce & Stevens 2001). Although catch estimates for white sharks are based on incomplete information, the region appears to be an important area for the species as available records of incidental catches in fisheries are highest in this region and are not well correlated with fishing effort (Malcolm, Bruce & Stevens 2001). White sharks thus appear to be more abundant in the South-west Marine Region, particularly in the waters from Shark Bay to Bunbury and in waters of the Great Australian Bight, than in other Australian waters (Malcolm, Bruce & Stevens 2001). Due to the internationally threatened status of this species, the region may not only be significant for the conservation and management of white sharks in Australia, but possibly also in a global context.

Habitat requirements for white sharks

White sharks are widely but not evenly distributed in Australian waters. Areas where white shark observations are more frequent include waters in and around some fur seal and sea lion colonies such as the Neptune Islands (South Australia), areas of the Great Australian Bight, the Recherche Archipelago and the islands off the lower west coast of Western Australia (DEWHA 2009a). The coast off the Goolwa region of South Australia is reportedly frequented by juvenile white sharks at times. The locations of Australian pupping grounds are unknown, although neonate white sharks have been taken as bycatch by commercial and recreational fishers in the western Great Australian Bight and Bass Strait (CSIRO unpublished data, in DEWHA 2009a). Pupping is believed to occur during spring or early summer (DEWHA 2009a), which coincides with the period when Robbins (2007) reported the absence of female white sharks from the Neptune Islands.

In Western Australia, white sharks move up the coast as far as North West Cape during spring and appear to return south during summer (Bruce, Stevens & Malcolm 2006; CMAR 2007), although data for this region are still sparse. Coastal movements are more complex than simple seasonal migrations north and south along these coasts. The waters of the Great Australian Bight appear to be the common link for at least sub-adult and adult white sharks, with individuals moving from there

across their Australian range and then returning to this region (Bruce, Stevens & Malcolm 2006; CMAR 2007).

White sharks can be found from close inshore around rocky reefs, surf beaches and shallow coastal bays to outer continental shelf and slope areas. However, they also make open ocean excursions and can cross ocean basins, and both adults and juveniles have been recorded diving to depths of 1000 m. Most white shark movements and activities in Australian waters occur between the coast and the 100 m depth contour (Bruce & Bradford 2008; Bruce, Stevens & Malcolm 2006). White sharks are often found in regions with high prey density, which results in higher numbers near seal colonies and in sites where other prey species aggregate. They are not known to form and defend territories, and do not live in one specific area or territory but travel great distances between sites of temporary residency. There is also mounting evidence for common movement pathways between some areas of temporary residency in Australian waters (Bruce & Bradford 2008; Bruce, Stevens & Malcolm 2006). However, their ability to return on a highly seasonal or more regular basis implies a degree of site fidelity that has implications for repeat interactions with site-specific threats (DEWHA 2009a). Research on site fidelity and residence patterns of white shark in Australian waters has contributed to the identification of habitat critical for its recovery (Bruce & Bradford 2008; Bruce, Stevens & Bradford 2005).

Grey nurse shark

Grey nurse sharks (*Carcharias taurus*) are listed as two separate populations under the EPBC Act. The west coast population is listed as vulnerable, while the east coast population is listed as critically endangered. The extent to which the west coast population extends into South Australian waters has not been well established. The species is found primarily in warm–temperate (from subtropical to cool–temperate) inshore waters around rocky reefs and islands and is occasionally found in the surf zone and in shallow bays. Grey nurse sharks have been recorded at varying depths. They are commonly found between 15 m and 40 m (Otway & Parker 2000), but have occasionally been recorded at depths of approximately 200 m (Pollard, Lincoln-Smith & Smith 1996). The diet of grey nurse sharks in Australia has not been well studied, but is likely to consist of species such as pilchards, jewfish, tailor, bonito, moray eels, wrasses, sea mullet, flathead, yellowtail kingfish, small sharks, squid and crustaceans (EA 2002a).

Aggregation behaviour for the west coast population is not well understood. An aggregation area on the west coast was identified at Roebuck Bay off Broome, in the North-west Marine Region. A comprehensive study investigating the presence of grey nurse shark aggregations in the area between North West Cape and Cape Leeuwin has resulted in a list of sites where, based on catch and sightings records, there is greater likelihood of the species aggregating (Chidlow, Gaughan & McAuley 2006). A tracking study found that juveniles can move hundreds of kilometres north along the Western Australia coast, from Perth to Kalbarri, before returning south (McAuley 2004). The length of the migration indicates that grey nurse sharks do not need to stay close to what is considered their typical habitat, such as rocky ledges, gutters and caves (McAuley 2004).

Whale shark

Whale sharks (*Rhincodon typus*) are listed as vulnerable to extinction under the EPBC Act. It is a wide-ranging species with a broad distribution, usually observed between latitudes 30° N and 35° S in tropical and warm–temperate seas, both oceanic and coastal (Compagno 1984). The species is generally encountered close to or at the surface, as single individuals or occasionally in schools or aggregations of hundreds of sharks. No whale shark aggregation areas have been identified in the region and no interactions with the species, such as capture in fisheries, are known to occur in the region. As a result, whale sharks are not discussed further in this report card. Further information on

whale sharks and threats to the species is available at
www.environment.gov.au/biodiversity/threatened/publications/recovery/r-typus

Shortfin mako shark
Shortfin mako sharks (*Isurus oxyrinchus*) are listed as migratory under the EPBC Act and are being considered for listing as a threatened species. It is an oceanic and pelagic species, although it is occasionally seen inshore. Shortfin mako sharks are found throughout temperate seas but are rarely found in waters colder than 16 °C. Their diet consists mainly of bony fish and cephalopods (Last & Stevens 2009).

Longfin mako shark
Longfin mako sharks (*Isurus paucus*) are listed as migratory under the EPBC Act. They are widely distributed but rarely encountered oceanic tropical sharks. In Australia, longfin mako sharks range from Geraldton (Western Australia) to at least Port Stephens (New South Wales) (Last & Stevens 2009). The species is often confused with its slightly more slender-bodied relative, shortfin mako. They can grow to just over 4 m in length and are thought to feed on pelagic fish and cephalopods. Their relatively large eyes suggest it may feed at depth.

Porbeagle shark
Porbeagle sharks (*Lamna nasus*) are listed as migratory under the EPBC Act. They are wide-ranging coastal and oceanic sharks. In Australian waters, porbeagle sharks are found off southern Australia from southern Queensland to southern Western Australia (Last & Stevens 2009). Porbeagle sharks can be confused with shortfin makos. Their diet consists mainly of bony fish and squid (Last & Stevens 2009).

School shark
School sharks (*Galeorhinus galeus*) are listed as conservation dependent under the EPBC Act. As suggested by their common name, school sharks are found in small schools composed predominately of one sex and size group (Last & Stevens 2009). School sharks occur throughout the temperate coastal waters of southern Australia, from Moreton Bay in southern Queensland to Perth (Pogonoski, Pollard & Paxton 2002). However, recent records suggest that their distribution is confined to the area south of Bermagui (New South Wales) to east of Cape Leeuwin (Western Australia) (Last & Stevens 2009). School sharks move extensively throughout the waters of southern Australia and are known to make long migrations (up to 1400 km) that appear to be associated with reproduction (Last & Stevens 2009). The species also makes movements on a diurnal basis, which are probably related to feeding. School sharks are found mainly in demersal waters, over the continental and insular shelves, but also over the upper slopes, in depths from near shore to 600 m (Last & Stevens 2009). Inshore areas are particularly important as birthing and nursery sites (TSSC 2009a). Their diet consists of bony fish and cephalopods.

Biologically important areas

Biologically important areas (BIAs) are areas where aggregations of individuals of a species display biologically important behaviours. Behaviours that have been used to define BIAs for sharks in the South-west Marine Region include distribution (high density), foraging (abundant food source) and foraging (likely). BIAs have been identified for one species of shark in the region: white shark, and are included in the South-west Marine Conservation Values Atlas, which can be accessed at: **www.environment.gov.au/coasts/mbp/south-west/index.html**.

2. Vulnerabilities and pressures

Vulnerabilities

The life history strategies of sharks make them vulnerable to a range of pressures in the marine environment. In general, sharks show slow growth, late attainment of sexual maturity, low fecundity and a close stock-recruitment relationship. White sharks are long lived, with estimates ranging up to 40–60 years (Bruce 2008). They have relatively slow development, a low reproductive rate and a long gestation period, estimated at up to 18 months (Mollet et al. 2000). The grey nurse shark displays a rare reproductive strategy called intrauterine cannibalism, whereby embryos feed on other embryos, thus reducing the overall reproductive output. These characteristics suggest a low reproductive potential, which has implications for the vulnerability of white sharks to non-natural mortality and the rate at which populations, once they experience declines, can recover.

Assessment of pressures

The assessment of pressures focused on species listed as threatened or migratory under the EPBC Act that have a substantial proportion of their range in the South-west Marine Region. As the range of whale sharks does not extend substantially into the region, pressures on this species were not considered.

A description of the pressure assessment process, including the definition of substantial impact used in this assessment is provided in the *Overview of marine bioregional plans* available at **www.environment.gov.au/coasts/mbp/index.html**. A summary of the pressure assessment for sharks is provided in Figure 1. Pressures that have been ranked as *of concern* or *of potential concern* are discussed in further detail below.

Protected species	Pressures																			
	Sea level rise	Changes in sea temperature	Change in oceanography	Ocean acidification	Chemical pollution / contaminants	Nutrient pollution	Changes in turbidity	Marine debris	Noise pollution	Light pollution	Physical habitat modification	Human presence at sensitive sites	Nuisance species	Extraction of living resources	Bycatch	Oil pollution	Collisions with vessels	Collision/entanglement with infrastructure	Disease	Invasive species
Grey nurse shark																				
Longfin mako shark																				
Shortfin mako shark																				
Porbeagle shark																				
School shark																				
White shark																				

Figure 1 Assessment of the level of concern associated with the effects of pressures on selected shark species of the South-west Marine Region

Legend		*of concern*		*of potential concern*		*of less* or *no concern*

Climate change (sea level rise)
This pressure is of *potential concern* to school sharks. The impacts of sea level rise are unlikely to be significant for deepwater species. However, those with important life history stages in inshore habitats, such as estuaries, may be affected. These include commercially important species such as school shark, which has nursery areas in inshore habitats (Hobday, Poloczanska & Matear 2007). School sharks are thought to occur in high concentrations on the inner shelf in Commonwealth waters adjacent to the Head of Bight. School sharks appear to use this relatively sheltered area of mixed seagrass, sand and limestone reef as nursery and feeding grounds.

Climate change (changes in sea temperature)
Changes in sea temperature are of *potential concern* to white sharks, grey nurse sharks, porbeagle sharks and school sharks. The CSIRO Marine Climate Change report card (Poloczanska, Hobday & Richardson 2009) reports a high level of agreement from different datasets that warming is occurring: it is likely that this warming is affecting the ranges and growth of temperate marine fishes (Booth et al. 2009). Waters around Australia are projected to warm by 1–2 °C by the 2030s and 2–3 °C by the 2070s (Hobday et al. 2006). With these temperature increases, preferred habitat for a range of species, including sharks, is predicted to move southwards by an average of 3.5 degrees (about 390 km) along the west coast of Australia (Hobday, Griffiths & Ward 2009).

Climate change (change in oceanography)
Changes in the strength of the Leeuwin Current are *of potential concern* to white sharks, grey nurse sharks, porbeagle sharks and school sharks through changes in productivity, influencing the distribution and abundance of sharks. A number of productivity hotspots in the region may be affected by this; for example, the Western Eyre and Kangaroo Island upwelling. This upwelling of productivity supports Australia's largest population of sardines, which in turn supports large aggregations of predators. Changes to this productivity could significantly affect community structure and function (Hobday, Griffiths & Ward 2009).

Ocean acidification
Ocean acidification is considered *of potential concern* for all species assessed. Ocean acidity has increased by 30 per cent across all oceans since the late 18th century (pH of open ocean waters has decreased from 8.2 to 8.1) and the rate of this increase is estimated to be 100 times faster than any change in acidity experienced by marine organisms for at least the past 20 million years (Orr et al. 2009). Projected changes in Australia's marine environment by 2070 include a decline in pH of 0.2 units (Lawrence, Ridley & Lunty 2007). There is a high level of uncertainty about the effects of ocean acidification on marine life. While some organisms might be able to adapt (Orr et al. 2009), anticipated changes to phytoplankton and zooplankton have the potential to detrimentally affect ecosystem processes and the structure of ecological communities. The potential effects of increased ocean acidity on shark and fish species are not well understood. It is believed that for some invertebrates and fish, accumulation of CO2 in the body may result in morphological changes, and impact metabolic state, physical activity and reproduction (Orr et al. 2009). Effects on phytoplankton and zooplankton are also likely to disrupt trophic dynamics and affect fish species and communities.

Marine debris
Marine debris is recognised nationally as a key threatening process, and is considered here *of potential concern* to white sharks and school sharks through either ingestion or entanglement in debris. Entanglement of Australian sharks in derelict fishing gear has been observed on numerous occasions (Alderman et al. 1999 cited in DEWHA 2009b; Sloan, Wallner & Mounsey 1998), although few published records exist. Within the region, many shark species, including white sharks and school sharks, are exposed to areas where marine debris is located. However, it is unknown to what extent sharks interact with marine debris in the region. Marine debris is expected to increase as both marine- and land-based sources of debris intensify in the region.

Physical habitat modification

Habitat modification is of *potential concern* to grey nurse sharks and school sharks, due to possible effects on juvenile sharks, prey availability and quality of nursery and other biologically important habitat. Coastal marine habitats can be altered through activities such as dredging, installation of pipelines and outfalls, construction of piers, sewerage and industrial outlets, and land run-off. Habitat use by the west coast population of grey nurse shark and the species' dependency on quality of habitat are little understood (Chidlow, Gaughan & McAuley 2006). Habitat degradation as a result of coastal development or climate-related increases in coastal and inshore erosion may affect this vulnerable species. Research surveys of school shark nursery areas in Tasmania and Victoria have indicated a decline in abundance of pups between the 1950s and 1990s (McLoughlin 2007). School sharks depend on inshore nursery areas as habitat for females giving birth and for juveniles. Coastal development and human activity in adjacent waters are likely to have increased pollution and environmental degradation around these areas, and may be affecting the recovery capability of the species (McLoughlin 2007).

Bycatch

Bycatch is considered *of concern* for the school shark and the great white shark and *of potential concern* for shortfin mako sharks, porbeagle sharks and grey nurse shark.

In Australia, the principal cause of shark mortality is the commercial and recreational fishing industry, where protected sharks are caught incidentally. School shark was listed in 2009 as conservation dependent under the EPBC Act. A rebuilding strategy is in place and while the species is currently not targeted (AFMA 2009), some incidental catch is unavoidable by those fisheries in the region that target gummy shark. Effectiveness of reduction in by-catch allowable catch is as yet unknown as it is likely to take several years before increases in the stock can be detected. Consequently, evidence of management effectiveness is at present inconclusive.

Incidental bycatch of white sharks has been reported in a number of shark fisheries and occasionally in crab trap and rock lobster pot ropes and in demersal trawls (DEWHA 2008). White sharks are also accidentally taken on recreational lines, droplines and longlines. Studies indicate that there are more interactions between white sharks and fishing activities along the west coast of Western Australia (from Shark Bay to Bunbury) and in the Great Australian Bight than in other areas of Australia (Malcolm, Bruce & Stevens 2001). Whether the species is recovering is unknown given the lack of data on the population size and structure; consequently, the effectiveness of management measures is not fully understood and bycatch mortality continues to be *of concern* for this species until evidence of management effectiveness is conclusive.

The Australian Fisheries Management Authority's ecological risk assessment identifies shortfin mako as a high-risk species in the gillnet fishery (AFMA 2010a). Porbeagle sharks are caught as byproduct in pelagic longline fisheries and gillnets in the region. The significance of bycatch mortality from the region for these species is unknown but it is not likely to be significant relative to the pressure experienced by the species elsewhere in the world. Targeted commercial fishing of these species is prohibited. They may be retained as bycatch if caught in accordance with approved management arrangements, but if landed alive they must be returned to the water. Recreational targeting of shortfin mako, longfin mako and porbeagle sharks is permitted under amendments to the EPBC Act in July 2010. The amendment allows recreational fishers, including charter boat operators and game fishers, to legally catch the sharks as they did before the listing in January 2010.

Grey nurse sharks are incidentally caught in commercial demersal nets, droplines and other line fishing gear. A significant cause of death of grey nurse sharks has been incidental capture in demersal gillnet fisheries operating in the region (Chidlow, Gaughan & McAuley 2006; Pollard et al. 2003). Records from the mid-1990s indicated that grey nurse shark was commonly distributed across the area and the population was stable (the west coast population was not subjected to the severe fishery-related declines experienced by the east coast population and populations elsewhere in the world). Reporting of incidental catches, however, ceased in 1997 following listing of the species as vulnerable under the EPBC Act, and thus there is some uncertainty about the ongoing status of the west coast population (Chidlow, Gaughan & McAuley

2006). While the population is likely to be stable, the pressure is of potential concern, given the intrinsic vulnerability of this species and the limited understanding of the west coast population levels and structure.

Collision or entanglement with infrastructure

Collision or entanglement with infrastructure is *of potential concern* for the white shark, particularly with respect to interactions with aquaculture ropes and nets, which may result in entanglement and drowning (Trinder 2006). White sharks are the only protected species of shark recorded in and around tuna pens in South Australia. White sharks are known to become entangled in nets or to enter aquaculture cages in search of food, posing a risk to stock and cage operators. Malcolm, Bruce & Stevens (2001) estimated that interaction with aquaculture infrastructure resulted in up to 20 white shark deaths per year, the significance of which is not understood given the uncertainty about white shark population levels and structure. Releasing sharks after they have entered aquaculture cages has had some success (Galaz & De Maddalena 2004). Evidence of effectiveness of management is not conclusive.

3. Current protection measures

While there are some differences in the protective management measures in place for species listed under different categories, under the EPBC Act in general it is an offence to kill, injure, take, trade, keep, or move listed marine, migratory or threatened species[1] on Australian Government land or in Commonwealth waters without a permit.

Alongside the EPBC Act, a broad range of sector-specific management measures to address environmental issues and mitigate impacts apply to activities that take place in Commonwealth marine areas. These measures give effect to regulatory and administrative requirements under Commonwealth and state legislation for activities such as commercial and recreational fishing, oil and gas exploration and production, ports activities and maritime transport. In some instances, as in the case of shipping, these measures also fulfil Australia's obligations under a number of international conventions for the protection of the marine environment from pollution and environmental harm.

Protection and conservation measures administered under the EPBC Act that are relevant to the conservation values described in this Report Card are listed below.

EPBC Act conservation plans and action plans

- White Shark (*Carcharodon carcharias*) Recovery Plan (EA 2002b)
- Draft White Shark Recovery Plan (DEWHA 2009c)
- Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA 2002a)
- Whale Shark (*Rhincodon typus*) Recovery Plan 2005–2010 (DEH 2005)
- Addendum to the School Shark Rebuilding Strategy 2008 (TSSC 2009b)
- Conservation Overview and Action Plan for Australian Threatened and Potentially Threatened Marine and Estuarine Fishes (Pogonoski, Pollard & Paxton 2002)
- Threat Abatement Plan for the Impacts of Marine Debris on Vertebrate Marine Life (DEWHA 2009b).

Other management plans and strategies of particularly relevant for these species that are not administered under the EPBC Act include:

- National Plan of Action for the Conservation and Management of Sharks (DAFF 2004)
- Australian Shark Assessment Report for the Australian National Plan of Action for the Conservation and Management of Sharks (Rose & Shark Advisory Group 2010)
- School Shark Stock Rebuilding Strategy 2008 (AFMA 2009a)
- Australian Tuna and Billfish Longline Fisheries Bycatch and Discarding Workplan November 1, 2008 to October 31, 2010 (AFMA 2009b)
- Shark Gillnet Fishery Bycatch and Discarding Workplan 1 July, 2009 to 30 June, 2011 (AFMA 2009c)

[1] This does not apply to conservation dependent species (see Section 196 of the EPBC Act).

International agreements

Australia is also a signatory to three international agreements for the conservation of sharks:

- Convention on International Trade in Endangered Species of Wild Fauna and Flora 1975 (CITES)—www.cites.org
- Convention on the Conservation of Migratory Species of Wild Animals 1979 (CMS)—www.cms.int
- Memorandum of Understanding on the Conservation of Migratory Sharks—www.cms.int/species/sharks/MoU/Migratory_Shark__MoU_Eng.pdf
- International Plan of Action for the Conservation and Management of Sharks 1999 (IPOA-Sharks)—ftp://ftp.fao.org/docrep/fao/006/x3170e/X3170E00.pdf.

For more information on conservation listings under the EPBC Act, and related management objectives and protection measures, visit the following sites:

- www.environment.gov.au/epbc/protect/species-communities.html (listed threatened species)
- www.environment.gov.au/epbc/protect/migratory.html (listed migratory species).

4. References

AFMA (Australian Fisheries Management Authority) 2009a, *School shark stock rebuilding strategy 2008*, AFMA, Canberra, viewed 3 March 2011, <www.afma.gov.au/wp-content/uploads/2010/07/school_shark_rebuild.pdf>.

AFMA (Australian Fisheries Management Authority) 2009b, *Australian Tuna and Billfish Longline fisheries bycatch and discarding workplan November 1, 2008 to October 31, 2010*, AFMA, Canberra, viewed 3 March 2011, <www.afma.gov.au/wp-content/uploads/2010/06/ATBLF_bycatchdiscard_08-10.pdf>.

AFMA (Australian Fisheries Management Authority) 2009c, *Shark Gillnet Fishery bycatch and discarding workplan 1 July, 2009 to 30 June, 2011*, AFMA, Canberra, viewed 3 March 2011, <www.afma.gov.au/wp-content/uploads/2010/06/shark_gillnet_bdwp.pdf>.

AFMA (Australian Fisheries Management Authority) 2010a, *Residual risk assessment of the level 2 ecological risk assessment species results report for the Gillnet Sector of the Gillnet, Hook and Trap Fishery*, AFMA, Canberra, viewed 3 March 2011, <www.afma.gov.au/wp-content/uploads/2010/06/rra_lvl2_psa.pdf>.

AFMA (Australian Fisheries Management Authority) 2010b, *Annual domestic compliance and enforcement program 2010/11*, AFMA, Canberra, viewed 3 March 2011, <www.afma.gov.au/wp-content/uploads/2010/09/AFMA-Domestic-Compliance-and-Enforcement-Program-2010-11Final.pdf>.

Alderman, R, Pauza, M, Bell, J, Taylor, R, Carter, T & Fordham, D 1999, 'Marine debris in northeast Arnhem Land Northern Territory Australia', in K Leitch (ed.), *Entanglement of marine turtles in netting: northeast Arnhem Land, Northern Territory*, *Australia*, Dhimurru Land Management Aboriginal Corporation, Nhulunbuy.

Booth, D, Edgar, G, Figueira, W, Jenkins, G, Kingsford, M, Lenanton, R & Thresher, R 2009, 'Temperate coastal and demersal fish and climate change', in ES Poloczanska, AJ Hobday & AJ Richardson (eds), *A marine climate change impacts and adaptation report card for Australia 2009*, National Climate Change Adaptation Research Facility, viewed 9 March 2011, <www.oceanclimatechange.org.au>.

Bruce, BD 2008, 'The biology and ecology of the white shark (*Carcharodon carcharias*)', in M Camhi & EK Pikitch (eds), *Sharks of the open ocean*, Blackwell Scientific, Oxford, pp. 69–81.

Bruce, BD & Bradford, RW 2008, *Spatial dynamics and habitat preferences of juvenile white sharks: identifying critical habitat and options for monitoring recruitment*, final report to the Department of Environment, Water, Heritage and the Arts, Marine Species Recovery Program, CSIRO, Hobart.

Bruce, BD, Stevens, JD & Bradford, RW 2005, *Site fidelity, residence times and home range patterns of white sharks around pinniped colonies*, final report to the Australian Government Department of the Environment and Heritage, Canberra.

Bruce, BD, Stevens, JD & Malcolm, H 2006, 'Movements and swimming behaviour of white sharks (*Carcharodon carcharias*) in Australian waters', *Marine Biology*, vol. 150, pp. 161–72.

Chidlow, J, Gaughan, D & McAuley, R 2006, *Identification of Western Australian grey nurse shark aggregation sites*, final report to the Australian Government Department of the Environment and Heritage, Canberra, Fisheries Research Report no. 155, Department of Fisheries, Western Australia.

CMAR (CSIRO Marine and Atmospheric Research) 2007, *New insights into white shark movements in Australia*, information page, viewed 16 August 2010, <www.cmar.csiro.au/whitesharks/ozmovements.html>.

Compagno, LJV 1984, *FAO species catalogue,* vol. 4, *Sharks of the world: an annotated and illustrated catalogue of sharks known to date,* part 1, *Hexanchiformes to lamniformes*, FAO Fisheries Synopsis, no. 125, Food and Agriculture Organization of the United Nations, Rome.

DAFF (Australian Government Department of Agriculture, Fisheries and Forestry) 2004, *National plan of action for the conservation and management of sharks*, DAFF, Canberra, viewed 3 March 2011, <www.daff.gov.au/__data/assets/pdf_file/0017/5840/web-shark-plan-full.pdf>.

DEH (Australian Government Department of the Environment and Heritage) 2005, *Whale shark (*Rhincodon typus*) recovery plan 2005–2010*, DEH, Canberra, viewed 21 March 2011, <www.environment.gov.au/biodiversity/threatened/publications/recovery/r-typus>.

DEWHA (Australian Government Department of the Environment, Water, Heritage and the Arts) 2008, *South-west marine bioregional plan: bioregional profile: a description of the ecosystems, conservation values and uses of the South-west Marine Region*, DEWHA, Canberra, viewed 3 March 2011, <www.environment.gov.au/coasts/mbp/publications/south-west/pubs/sw-profile-full.pdf>.

DEWHA (Australian Government Department of the Environment, Water, Heritage and the Arts) 2009a, *White shark issues paper*, DEWHA, Canberra, viewed 3 March 2011, <www.environment.gov.au/biodiversity/threatened/publications/recovery/pubs/white-shark-issues-paper.pdf>.

DEWHA (Australian Government Department of the Environment, Water, Heritage and the Arts) 2009b, *Threat abatement plan for the impacts of marine debris on vertebrate marine life*, DEWHA, Canberra, viewed 3 March 2011, <www.environment.gov.au/biodiversity/threatened/publications/tap/marine-debris.html>.

DEWHA (Australian Government Department of the Environment, Water, Heritage and the Arts) 2009c, *Draft* w*hite shark recovery plan*, DEWHA, Canberra.

EA (Environment Australia) 2002a, *Recovery plan for the grey nurse shark (*Carcharias taurus*) in Australia,* EA, Canberra, viewed 3 March 2011, <www.environment.gov.au/coasts/publications/grey-nurse-plan/index.html>.

EA (Environment Australia) 2002b, *White shark (*Carcharodon carcharias*) recovery plan*, EA, Canberra, viewed 21 March 2011, <www.environment.gov.au/coasts/publications/gwshark-plan/index.html>.

Galaz, T & De Maddalena, A 2004, 'On a great white shark, *Carcharodon carcharias* (Linnaeus 1758), trapped in a tuna cage off Lybia, Mediterranean Sea', *Annales Series Historia Naturalis*, vol. 14, no. 2, pp. 159–64.

Hobday, AJ, Griffiths, S & Ward, T 2009, 'Pelagic fishes and sharks', in ES Poloczanska, AJ Hobday & AJ Richardson (eds), *A marine climate change impacts and adaptation report card for Australia 2009*, National Climate Change Adaptation Research Facility, viewed 7 March 2011, <www.oceanclimatechange.org.au>.

Hobday, AJ, Okey, TA, Poloczanska, ES, Kunz, TJ & Richardson, AJ (eds) 2006, *Impacts of climate change on Australian marine life*, report to the Australian Greenhouse Office, Canberra.

Hobday, AJ, Poloczanska, ES & Matear, RJ 2007, *Climate impacts on Australian fisheries and aquaculture: implications for the effects of climate change*, report to the Department of Climate Change, Canberra.

Last, PR & Stevens, JD 2009, *Sharks and rays of Australia*, 2nd edn, CSIRO Publishing, Melbourne.

Lawrence, M, Ridley, J & Lunty, K 2007, 'The impacts and management implications of climate change for the Australian Government's protected areas', Australian Government Department of Environment and Water Resources, discussion paper, Canberra.

Malcolm, H, Bruce, BD & Stevens, J 2001, *A review of the biology and status of white sharks in Australian waters,* final report to Environment Australia, Canberra.

McAuley, R 2004, *Western Australian grey nurse shark pop up archival tag project*, final report to the Department of Environment and Heritage, Canberra.

McLoughlin, K 2007, 'Shark Gillnet and Hook sectors', in J Larcombe & K McLoughlin (eds), *Fishery status reports 2006: status of fish stocks managed by the Australian Government*, Bureau of Rural Sciences, Canberra, pp. 174–86.

Mollet, HF, Cliff, G, Pratt Jr, HL & Stevens, JD 2000, 'Reproductive biology of the female shortfin mako *Isurus oxyrinchus* with comments on the embryonic development of lamnoids', *Fishery Bulletin*, vol. 98, pp. 299–318.

Orr, JC, Caldeira, K, Fabry, V, Gattuso, J-P, Haugan, P, Lehodey, P, Pantoja, S, Pörtner, H-O, Riebesell, U, Trull, T, Hood, M, Urban E & Broadgate, W 2009, *Research priorities for ocean acidification*, report from the Second Symposium on The Ocean in a High-CO_2 World, Monaco, 6–9 October 2008, convened by SCOR, UNESCO-IOC, IAEA and IGBP, viewed 3 March 2011, <ioc3.unesco.org/oanet/Symposium2008/ResearchPrioritiesReport_OceanHighCO2WorldII.pdf>.

Otway, NM & Parker, PC 2000, *The biology, ecology, distribution, abundance and identification of marine protected areas for the conservation of threatened grey nurse sharks in south-east Australian waters*, New South Wales Fisheries Final Report Series no. 19, New South Wales Fisheries, Sydney.

Pogonoski, JJ, Pollard, DA & Paxton, JR 2002, *Conservation overview and action plan for Australian threatened and potentially threatened marine and estuarine fishes,* Environment Australia, Canberra, viewed 21 March 2011, <www.environment.gov.au/coasts/publications/marine-fish-action/index.html>.

Pollard, DA, Gordon, I, Williams, S, Flaherty, AA & McAuley, RB 2003, 'Grey nurse shark (sand tiger shark or spotted ragged tooth shark) *Carcharias taurus*', in RD Cavanagh, PM Kyne, SL Fowler, JA Musick & MB Bennett (eds), *The conservation status of Australasian chondrichthyans: report of the IUCN shark specialist group Australia and Oceania Regional Red List Workshop Queensland, Australia, 7–9 March 2003,* University of Queensland, Brisbane, pp. 62–4.

Pollard, DA, Lincoln-Smith, MP & Smith, AK 1996, 'The biology and conservation of the grey nurse shark (*Carcharias taurus* Rafinesque 1810) in New South Wales, Australia', *Aquatic Conservation*, vol. 6, pp. 1–20.

Poloczanska, ES, Hobday AJ & Richardson, AJ (eds) 2009, *A marine climate change impacts and adaptation report card for Australia 2009*, National Climate Change Adaptation Research Facility, viewed 7 March 2011, <www.oceanclimatechange.org.au>.

Robbins, RL 2007, 'Environmental variables affecting the sexual segregation of great white sharks *Carcharodon carcharias* at the Neptune Islands, South Australia', *Journal of Fish Biology*, vol. 70, pp. 1350–64.

Rose, C & the Shark Advisory Group 2010, *Australian shark assessment report for the Australian national plan of action for the conservation and management of sharks*, report to the Department of Agriculture, Forestry and Fisheries, Canberra, viewed 3 March 2011, <www.daff.gov.au/__data/assets/pdf_file/0019/681013/shark-assess-report.pdf>.

Sloan, S, Wallner, B & Mounsey, R 1998, *Fishing debris around Groote Eylandt in the Western Gulf of Carpentaria. A report on the Groote Eylandt Fishing Gear Debris Project*, Australian Fisheries Management Authority, Canberra.

Trinder, D 2006, 'Elasmobranchs', in S McClatchie, J Middleton, C Pattiaratchi, D Currie & G Hendrick (eds), *The South-west Marine Region: ecosystems and key species groups*, Department of the Environment and Heritage, Canberra.

TSSC (Threatened Species Scientific Committee) 2009a, *Commonwealth listing advice on* Galeorhinus galeus, Department of the Environment, Water, Heritage and the Arts, Canberra, viewed 3 March 2011, <www.environment.gov.au/biodiversity/threatened/species/pubs/68453-listing-advice.pdf>.

TSSC (Threatened Species Scientific Committee) 2009b, *Addendum to the school shark rebuilding strategy 2008*, Department of the Environment, Water, Heritage and the Arts, Canberra, viewed 3 March 2011, <www.environment.gov.au/biodiversity/threatened/species/pubs/68453-addenum-rebuilding-strategy.pdf>.

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

Attachment 1. Listed sharks known to occur in the South-west Marine Region

Species (common name/scientific name)	Conservation status
White shark (*Carcharodon carcharias*)	Vulnerable, migratory—listed under CITES (Appendix II) and CMS (Appendix I)
Whale shark (*Rhincodon typus*)	Vulnerable, migratory—listed under CITES (Appendix II) and CMS (Appendix II)
Shortfin mako (*Isurus oxyrinchus*)	Migratory—listed under CMS (Appendix II)
Longfin mako (*Isurus paucus*)	Migratory—listed under CMS (Appendix II)
Porbeagle shark (*Lamna nasus*)	Migratory—listed under CMS (Appendix II)
School shark (*Galeorhinus galeus*)	Conservation dependent
Grey nurse shark (*Carcharias taurus*) west coast population	Vulnerable

CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora; CMS = Convention on the Conservation of Migratory Species of Wild Animals