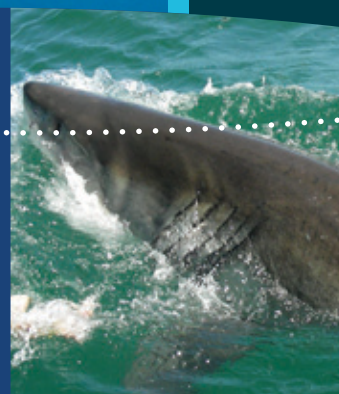




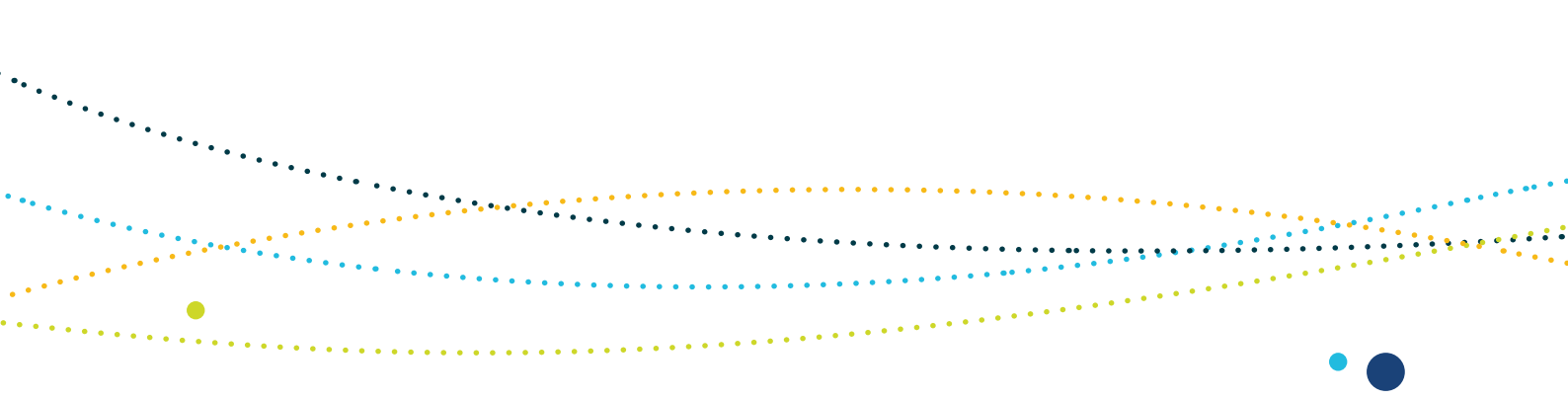
Australian Government

Department of Sustainability, Environment,
Water, Population and Communities



Issues Paper for the White Shark (*Carcharodon carcharias*)

2013



The recovery plan linked to this issues paper is obtainable from:
www.environment.gov.au/coasts/species/seals/index.html

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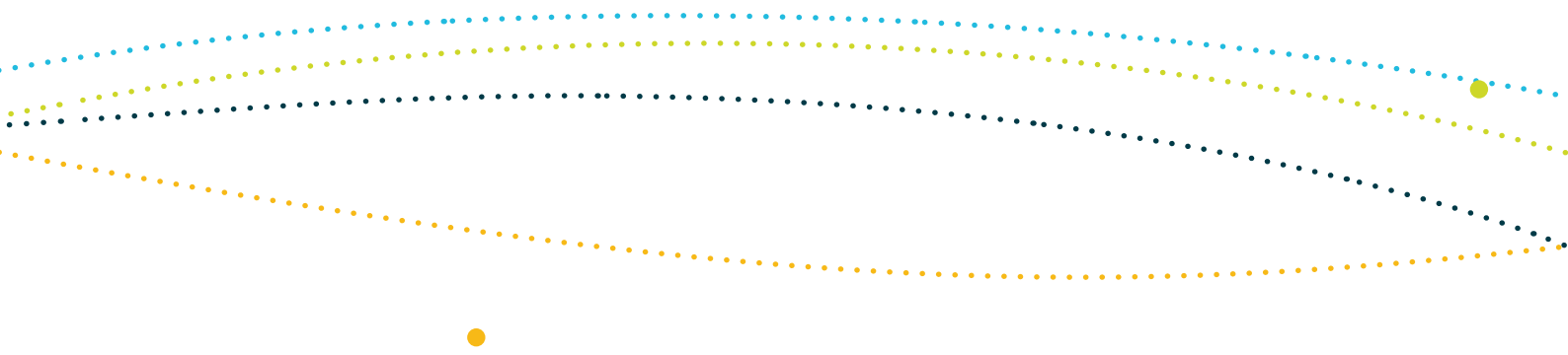
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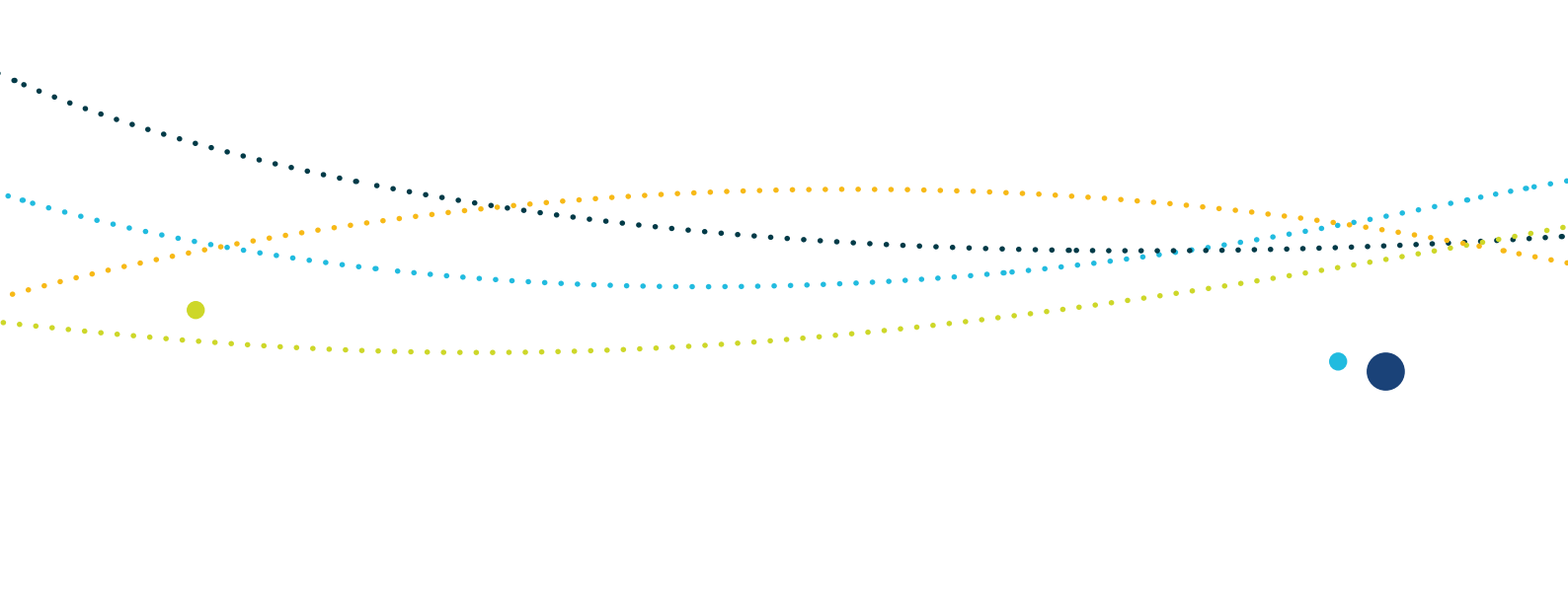
Images credits

Front and back cover left to right: white shark over seabed — Rachel Robbins, white shark in open water — Barry Bruce, close up image of white shark — Les Parsons, white shark on the water's surface — Mark Allen



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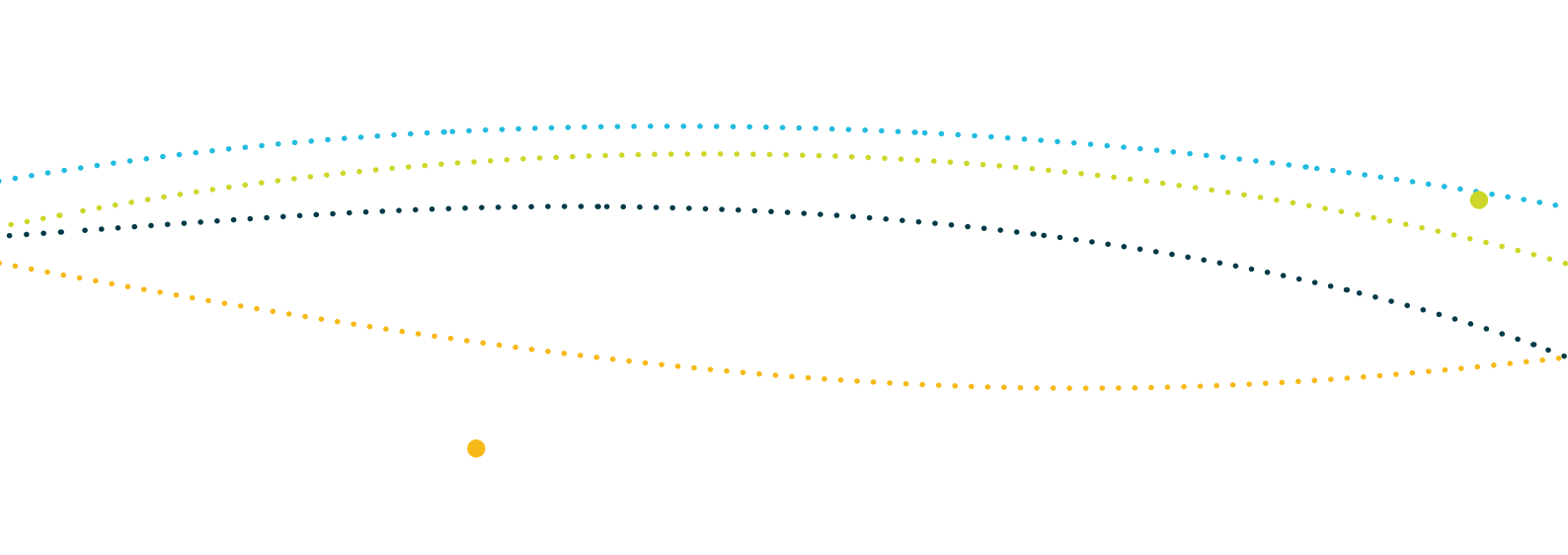
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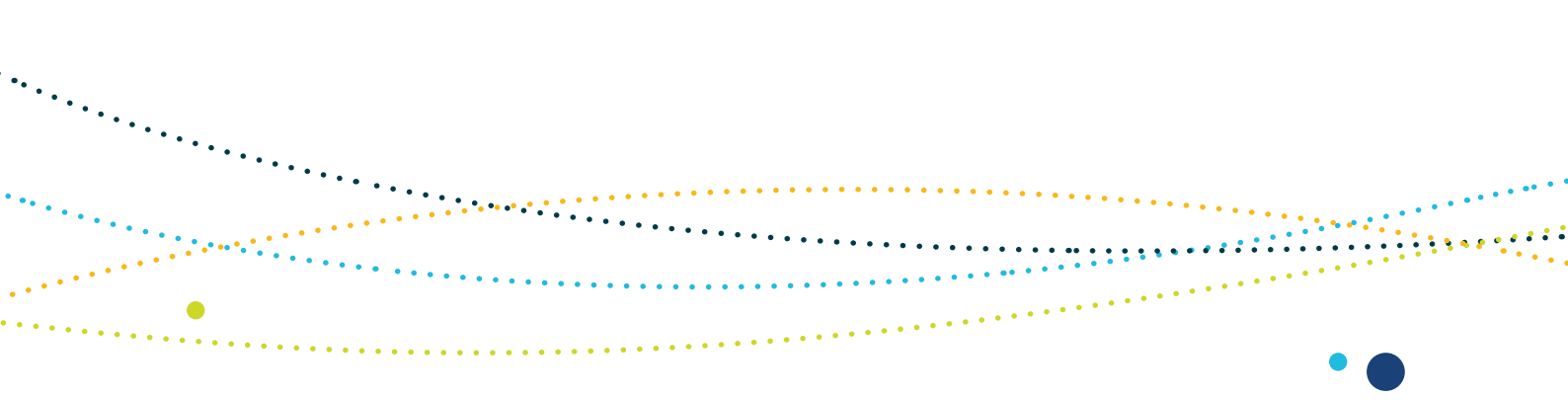
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Abbreviations

AFMA	Australian Fisheries Management Authority, Commonwealth
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEWNR SA	Department of Environment, Water and Natural Resources, South Australia
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities, Commonwealth
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
IUCN	International Union for Conservation of Nature
NSW DPI	New South Wales Department of Primary Industries
PIRSA	Department of Primary Industries and Regions of South Australia
QDAFF	Queensland Department of Agriculture, Fisheries and Forestry
SMP	Shark Meshing (Bather Protection) Program



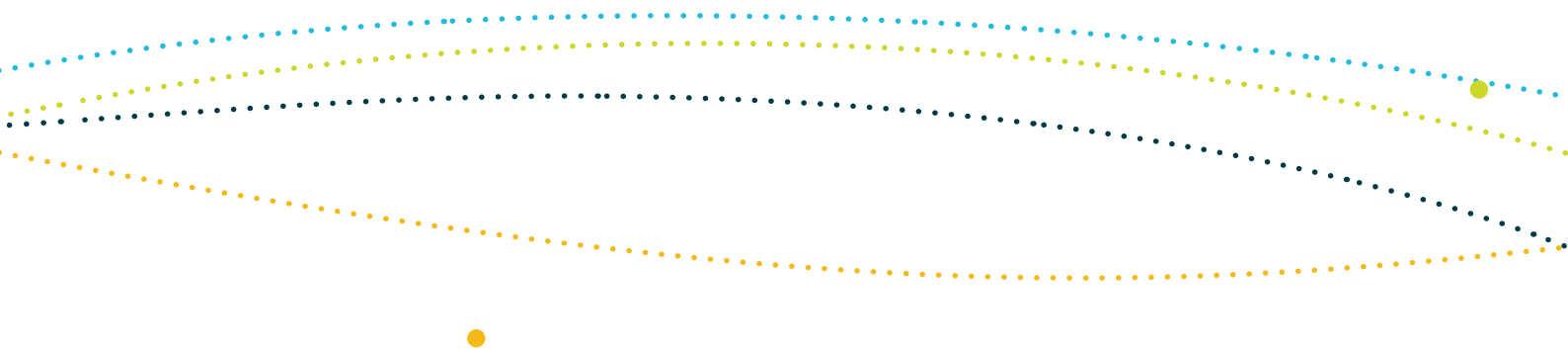
1 SUMMARY

The white shark (*Carcharodon carcharias*) is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). A recovery plan for the species was finalised in 2002.

A review of the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan, finalised in November 2008, concluded that it was not possible to determine if the white shark population in Australian waters has shown any sign of recovery (DEWHA, 2008). Considering the lack of evidence supporting a recovery of white shark numbers — together with historical evidence of a greater decline in white shark numbers over the last 60 years as compared to other shark species — the review supports the white shark's current status as vulnerable under the EPBC Act. The review concluded that a new recovery plan should be developed to remove the completed actions and include new conservation priorities. The Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), with support of key stakeholders, has developed a revised recovery plan for the white shark.

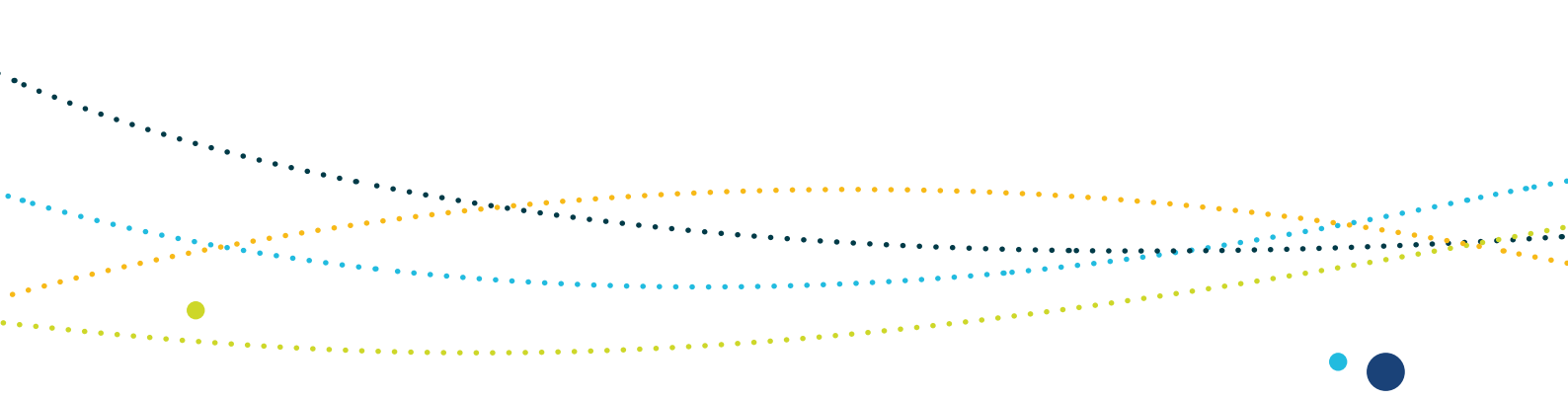
This issues paper has been developed to support the new recovery plan and includes information on the biology and ecology of the white shark, the species' current conservation status, a description of the key threats endangering the species' survival in Australian waters and recommendations for future research. Some of the key findings of this paper are:

- There is currently no reliable estimate of the total size of the Australian white shark population and therefore no robust measure of population trends or status. This lack of information makes it difficult to assess the effectiveness of any actions undertaken to conserve the species.
- Fishing pressure from the recreational and commercial sectors represents an ongoing, but largely unquantified, threat to the white shark in Australian waters. Mortalities as a result of the state government administered bather protection programs are also a potential threat.
- The need remains to identify habitats, migratory paths and specific locations that are used to meet essential life cycle requirements of white sharks, such as mating, pupping, temporary residence sites during migration and feeding, and to minimise threats at these localities.



Despite significant advances in the knowledge base concerning the white shark in Australian waters over the past decade, continuation of research into their ecology and biology, as well as into causes of anthropogenic mortality, will assist in developing programs to aid the long-term recovery of this species.

The accompanying 2013 Recovery Plan for the White Shark (*Carcharodon carcharias*) can be downloaded from the department's website at: www.environment.gov.au/biodiversity/threatened/recovery-list-common.html



2 INTRODUCTION

2.1 Purpose

The purpose of this issues paper is to provide a summary of the biology, population ecology and current threats to the white shark in Australian waters, and to make recommendations on the future research necessary to protect the species. This paper has been written to inform the development of a revised recovery plan for the white shark and is designed to be read in conjunction with the review of the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan (DEWHA, 2008) and the 2013 Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC, 2013).

2.2 Objectives

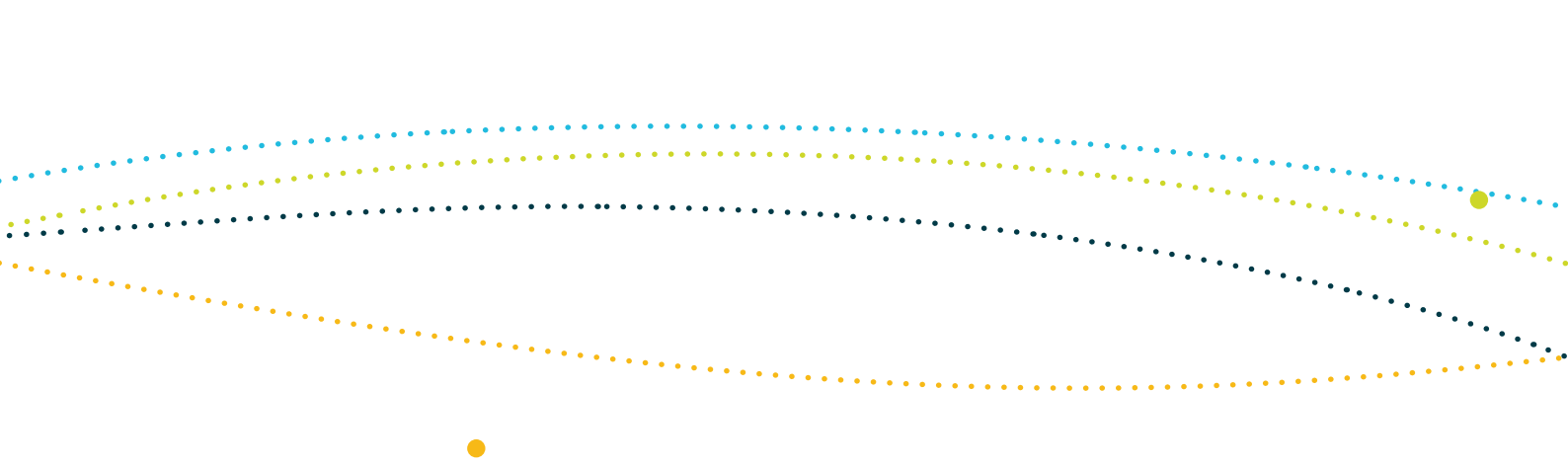
The specific objectives of this paper are to:

- collate the most recent scientific information (published and, where appropriate, unpublished) on distribution, abundance and population trends for the white shark
- identify gaps in our knowledge of the biology and threats to the species and make recommendations on future research
- discuss any natural and anthropogenic factors that are currently limiting the recovery of the species in Australian waters.

2.3 Scope

This document provides a contemporary picture of the biology and ecology of the white shark, and identifies threats to its long-term persistence in the wild. This document is not a recovery plan and does not prescribe management actions necessary to address population decreases.





2.4 Sources of information

This document has been prepared following a review of the literature and consultation with key stakeholders including relevant agencies, researchers and interested organisations.

2.5 Recovery planning process

2.5.1 Purpose of recovery plans

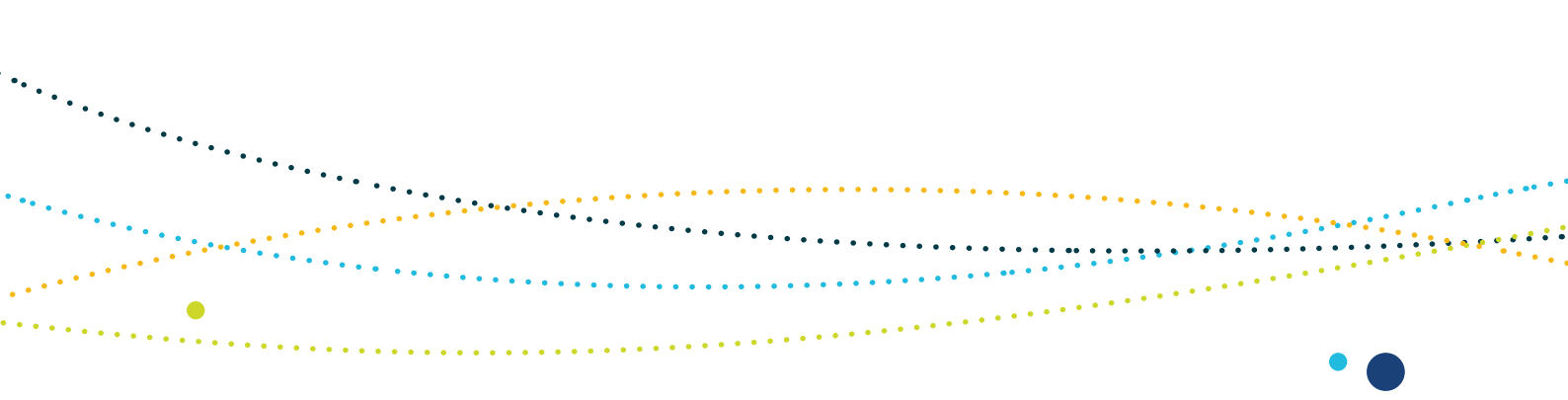
The Australian Government minister for the environment may make or adopt recovery plans for threatened fauna, threatened flora (other than conservation dependent species) and threatened ecological communities listed under the EPBC Act.

Recovery plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities. The aim of a recovery plan is to maximise the long-term survival in the wild of a threatened species or ecological community.

2.5.2 Objectives of the white shark recovery plan

The overarching objective of the 2013 white shark recovery plan is to assist the recovery of the white shark in the wild throughout its range in Australian waters with a view to:

- improving the population status, leading to future removal of the white shark from the threatened species list of the EPBC Act
- ensuring that anthropogenic activities do not hinder recovery in the near future, or impact on the conservation status of the species in the future.



3 BIOLOGY AND ECOLOGY

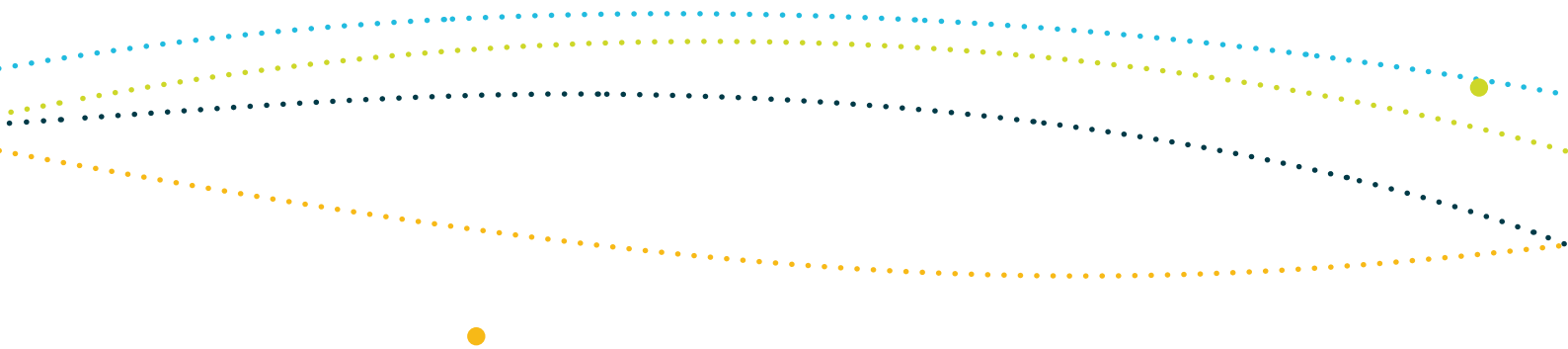
3.1 Species description

The white shark, also known as the great white shark or white pointer, is a close relative of the mako shark (*Isurus oxyrinchus*, *Isurus paucus*) and porbeagle shark (*Lamna nasus*), in the mackerel shark family Lamnidae (Last & Stevens, 2009). The white shark has a moderately stout and torpedo-shaped body, is coloured blue-grey to grey-brown on the upper surface and white below, has large serrated triangular teeth, and a distinctive lateral keel along the body midline immediately before a crescent-shaped tail. The white shark is a large apex predator that grows to at least 6 m in length — unverified reports exist of white sharks up to 7m in length — and can weigh up to about 3000 kg (Last & Stevens, 2009; Mollet et al., 1996). A heat-exchanging circulatory system allows the shark to maintain a body temperature up to 14° C above that of the surrounding seawater, enabling individuals to tolerate a wide range of temperatures (Goldman, 1997).

3.2 Life history

The white shark is a long-lived species, with longevity estimates ranging up to 60 years, although this is unverified and estimates of 40–50 years may be more reasonable (Bruce, 2008). The species has a relatively slow development and low reproductive rate with a long gestation period, estimated at up to 18 months (Mollet et al., 2000). These characteristics imply a low reproductive potential which has implications for the vulnerability of the white shark to non-natural mortality and the rate at which populations, once depleted, can recover. These factors have considerable implications for the conservation of the white shark.

Female white sharks nourish embryos via oophagy whereby, during gestation, embryos eat unfertilised eggs that the female continues to ovulate during the first periods of pregnancy (Compagno, 2001). Reported litter sizes range from two to 17, although the maximum number of near term pups confirmed by dissection of pregnant females is 10 (Francis, 1996). The white shark measures around 120–150 cm at birth and up to 32 kg in weight. The white shark initially grows at a rate of approximately 30 cm per year, although this rate is likely to slow considerably as the sharks reach maturity (Wintner & Cliff, 1999; Malcolm et al., 2001). Males mature at 3.6–3.8 m (7–9 years) and females at 4.5–5.0 m (12–17 years) (Francis, 1996; Pratt, 1996; Bruce, 2008).

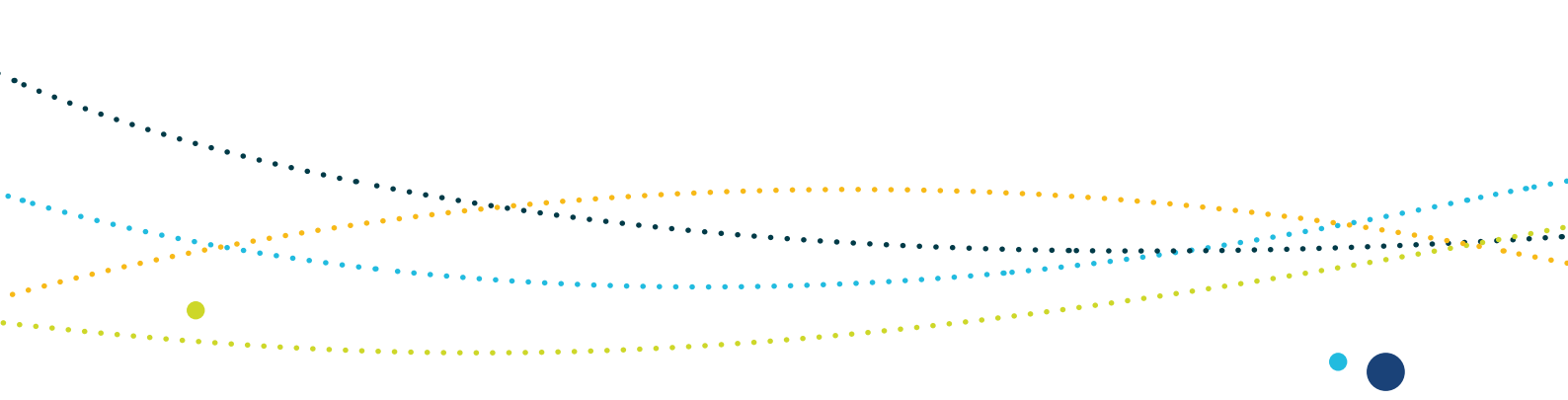


3.3 Diet

The white shark is a versatile predator. As juveniles (< 3 m), they feed primarily on finfish, rays and shark species prior to adding larger prey items to their diet. The smallest white shark known from Australian waters to contain seal remains was a 2.7 m individual reported by Malcolm et al. (2001). The white shark first commonly appears at fur seal (*Arctocephalus pusillus doriferus* and *Arctocephalus forsteri*) and Australian sea lion (*Neophoca cinerea*) colonies in Australian waters by about 3 m in length and this probably indicates the size at which such marine mammals become more common in their diet (Bruce & Bradford, 2012). These observations are consistent with vertebral isotope analyses, which indicate a dietary shift to include marine mammals by approximately 3.4 m (Estrada et al., 2006). White sharks of all sizes will, at least in Australia, continue to target elasmobranchs and finfish throughout their life (Malcolm et al., 2001). The white shark does not feed continually and a large meal such as a seal may last a medium-sized shark as long as a week (Bruce, 1995), although the overall frequency at which they feed is likely dependent on the type of prey being targeted (Semmens et al., 2013). In some areas (e.g. South Australia), large white sharks will feed on fur seals and Australian sea lions at colonies for brief periods and then move into other habitats where they switch to targeting elasmobranchs and finfish species such as snapper (*Pagrus auratus*) (Bruce et al., 2006; Semmens et al., 2013).

Adult, sub-adult and juvenile white sharks (including young-of-the-year sized individuals) have been observed to scavenge on floating whale carcasses, (Carey et al., 1982; Curtis et al., 2006; Dicken, 2008) and they may be particularly active around the site of whale strandings (Bruce & Stevens, 2004). Other prey reportedly taken at times include seabirds, ocean sunfish, sea otters and turtles (Ames et al., 1996; Fergusson et al., 2000).

Predatory strategies in the white shark have been the subject of a series of studies primarily based in California at the Farallon Islands (Ainley et al., 1985; Klimley et al., 1996; Pyle, 1996; Klimley et al., 2001) and in South Africa (Martin et al., 2005). These studies deal specifically with predatory behaviour on pinnipeds and provide useful insights into behaviour in such habitats. Klimley et al. (1996) described how sharks usually kill their prey quickly; however, there are instances where seals struggled underwater, were chased or carried in the mouth of the shark until dead. White sharks at Seal Island offshore of South Africa appear to selectively target lone cape fur seal pups (*Arctocephalus pusillus pusillus*) at or near the surface. White shark predatory success at Seal Island is greatest (55 per cent) within one hour of sunrise and



decreases rapidly with increasing ambient light. Sharks cease active predation on seals when success rate drops to equal or less than 40 per cent (Martin et al., 2005).

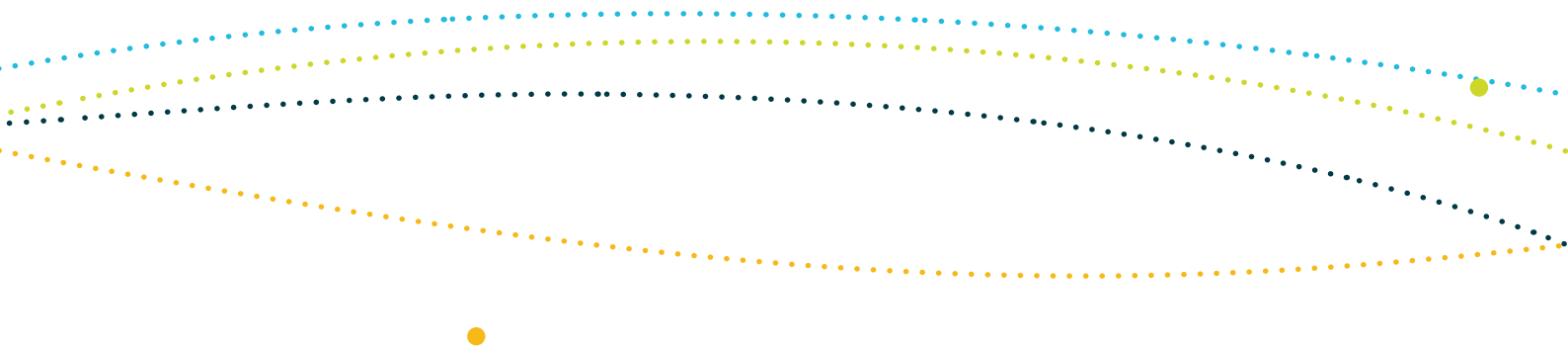
Recent satellite tracking studies indicate that the white shark may spend considerable periods of each year in waters remote from pinniped colonies and will undertake very different predatory behaviours while doing so (Boustany et al., 2002; Bruce et al., 2006; Weng et al., 2007a; Domeier & Nasby-Lucas, 2008). Observations on how sharks behave at pinniped colonies cannot necessarily be used to infer behaviour in other habitats and around other prey species. This may also apply to inferences about shark behaviour with respect to attacks on humans.

3.4 Distribution

3.4.1 Worldwide

The white shark occurs worldwide in coastal temperate and subtropical regions but it can also occur in tropical areas and, in some regions, may spend considerable periods in the open ocean (Compagno, 2001; Weng et al., 2007a; Bruce, 2008; Domeier & Nasby-Lucas, 2008). White sharks are most frequently encountered off South Africa (Bonfil et al., 2005), southern Australia (Bruce et al., 2006), northern California (Boustany et al., 2002) and the north eastern United States (Last & Stevens, 2009). Some tagged white sharks have been tracked moving well offshore and observations of trans-ocean movements suggest that interactions occur between individuals from populations that are otherwise geographically widely separated (Boustany et al., 2002; Bonfil et al., 2005; Bruce et al., 2006; Bruce & Bradford, 2008). The tracking data also suggests that while white sharks may travel long distances to offshore areas they also return to their areas of departure, suggesting a level of philopatry (Weng et al., 2007a; Domeier & Nasby-Lucas, 2008).

Recent genetic analyses confirm that white sharks are capable of long distance movements, but also suggest populations remain genetically distinct. Pardini et al. (2001) analysed samples from Australia, New Zealand and South Africa and concluded that there was little genetic difference between the New Zealand and Australian white shark populations but that both were distinct from the South African population. More recent work by Blower et al. (2012) suggests that the north-east Pacific Ocean population (as sampled by Jorgensen et al., 2010) also represents a discrete population. Blower et al. (2012) also found that while the South African population was genetically distinct from the Australian population, the South African haplotype was represented in the Australian samples, suggesting that migration between the two populations does occur.



Evidence from Blower et al. (2012) supports the theory that white sharks exhibit philopatry — that is, they return to their natal area for biological purposes such as breeding. Previously it was thought that only females exhibited philopatry (Pardini et al., 2001) but evidence in Blower et al. (2012) suggests that males may also display similar behaviour.

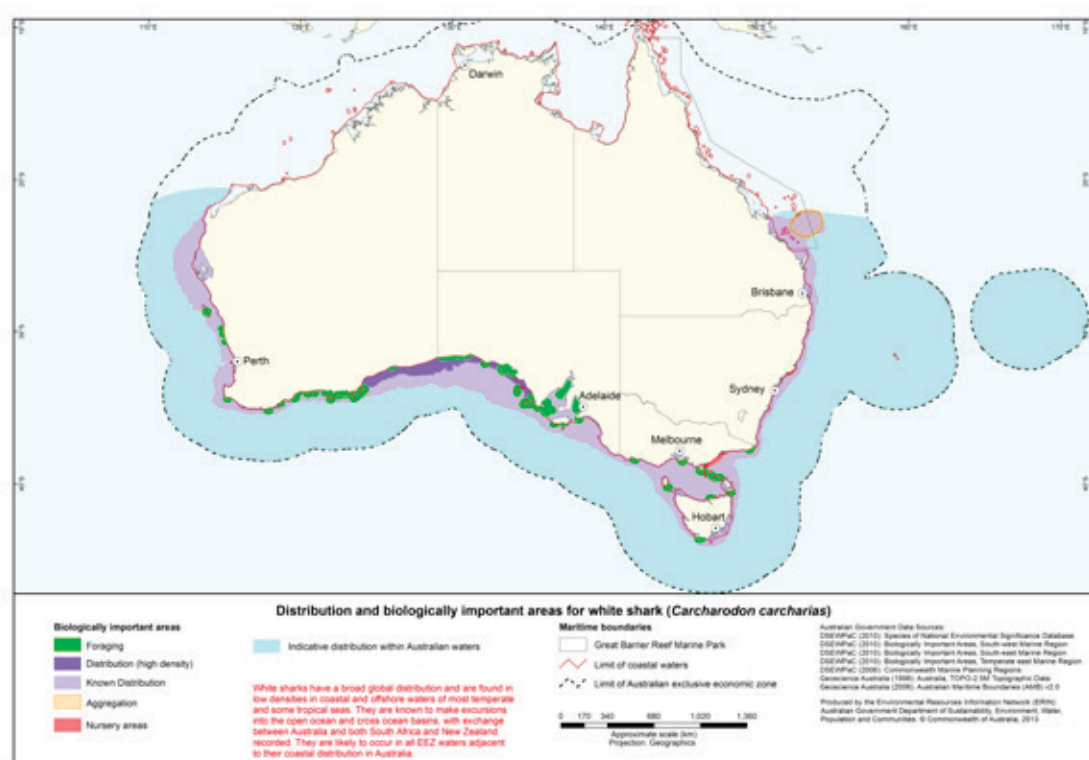
3.4.2 Australia

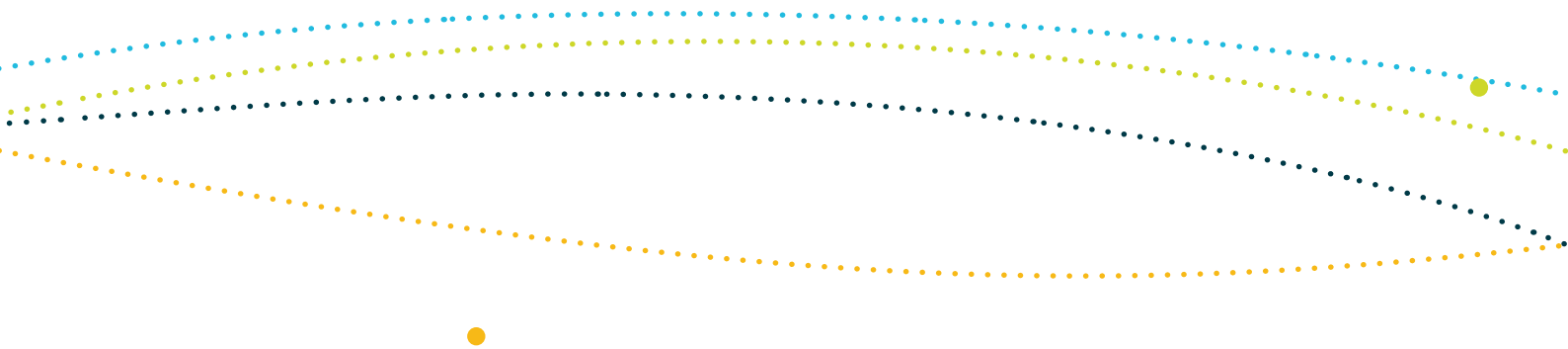
In Australia, the white shark has been recorded from central Queensland around the south coast to northwest Western Australia, but may occur further north on both coasts (Patterson, 1990; Bonfil et al., 2005; Bruce et al., 2006; Last & Stevens, 2009). The white shark is widely, but not evenly, distributed in Australian waters, with observations more frequent in some areas (Figure 1). These areas include waters in and around some fur seal and Australian sea lion colonies such as: the Neptune Islands (South Australia); areas off the Great Australian Bight as well as the Recherche Archipelago and the islands off the lower west coast of Western Australia (Malcolm et al., 2001; EA, 2002: see Figure 1). Juveniles appear to aggregate seasonally in certain key areas including the Corner Inlet–Ninety Mile Beach area of eastern Victoria (Wilson’s Promontory to Lakes Entrance) and the coastal region between Newcastle and Forster in New South Wales (Bruce & Bradford, 2008, 2012; see Figure 1).

There is some evidence for genetic structuring within the Australian population. Recent genetic evidence provides support for maternal structuring between the eastern and south-western coastal regions (Blower et al., 2012). It is suggested that this structuring is a result of female philopatry. Blower et al. (2012) also found evidence of male philopatry using biparentally inherited nDNA microsatellite loci. These results are in accordance with tracking data, which show individual white sharks moving up and down the east and west coasts but not moving between the regions (Bruce et al., 2006, Bruce & Bradford, 2012). Blower et al. (2012) also found some evidence of maternal genetic structuring between the New South Wales and Queensland white shark populations, which may be a result of as yet unidentified pupping grounds existing in Queensland.

Figure 1: Biologically important areas for the white shark, as identified in the Commonwealth Marine Bioregional Planning process.

Biologically important area maps and descriptions are available in the South-west Marine Region and Temperate East Marine Region Conservation Values Atlas at: <http://www.environment.gov.au/coasts/marineplans/cva/index.html>





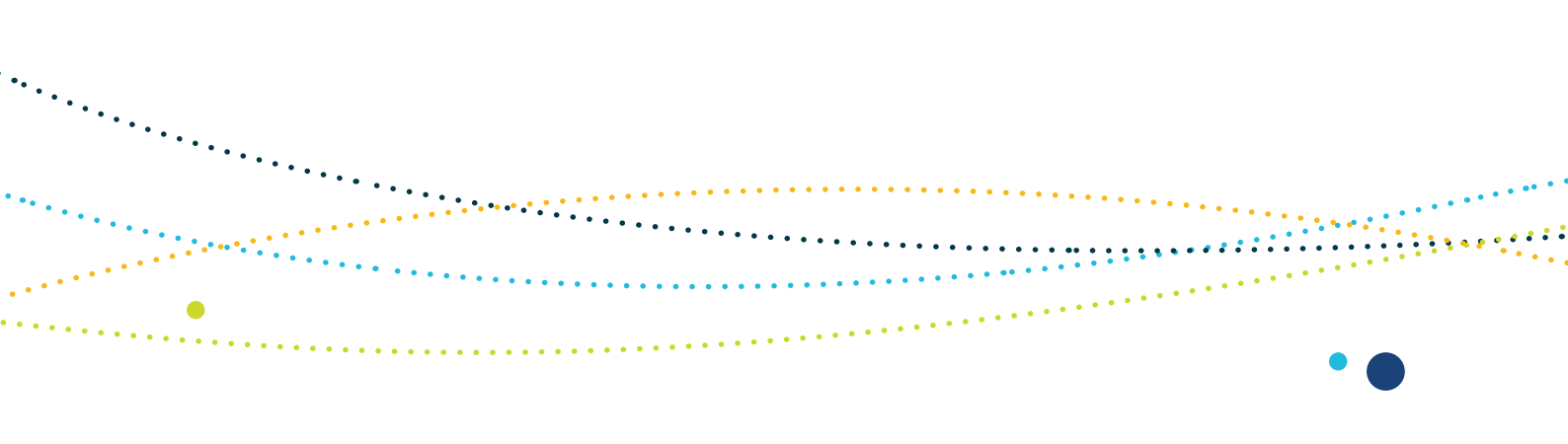
3.5 Movement patterns

The white shark is known to travel widely over distances of thousands of kilometres, which can include travel associated with shelf waters and offshore excursions. Cross-ocean basin travel has been documented between South Africa and northwest Australia (Bonfil et al., 2005). Open ocean excursions have also been recorded for sharks from the Farallon Islands (California) and those tagged at Guadalupe Island (Mexico). In both cases, sharks have been recorded moving to the same offshore region of the central eastern Pacific, with some individuals moving as far west as Hawaii (Boustany et al., 2002; Weng et al., 2007a; Domeier & Nasby-Lucas, 2008). Return of sharks to their site of tagging on a seasonal, or in some cases more frequent basis, has been a feature of most of these studies. The reasons for these broad scale offshore movements are unclear, but it is presumably related to feeding opportunities and/or reproductive activities; however, not all sharks undertaking such movements are adults (Bonfil et al., 2005; Bruce et al., 2006; Bruce & Bradford, 2008, 2012).

Within Australian waters, the white shark is known to travel extensively along the east and southwest coasts, as well as travelling across the Tasman Sea to New Zealand (Bruce et al., 2006; Bruce & Bradford, 2012). Tagging in New Zealand waters has also demonstrated movements from the Chatham Islands and Stewart Island to New Caledonia and Tonga, as well as to the southern Great Barrier Reef (Duffy et al., 2012). Thus it is possible that the Australasian population may also extend to regions in the tropical western Pacific. The recent record of a 2.1 m juvenile white shark crossing the Tasman Sea from New South Wales to New Zealand indicates that large scale movements are not restricted to adults (Bruce & Bradford, 2012).

In Australia, coastal movements have been documented from the Neptune Islands, South Australia to Exmouth in Western Australia and from the Neptune Islands to Rockhampton (Queensland) and return (Bruce et al., 2006). No individuals, however, have been observed to travel up both west and east coasts of Australia. This may reflect the difficulty in obtaining long-term tracking data, rather than actual lack of movement. The finding is consistent with evidence of genetic population subdivision between the eastern and south-western coastal regions of Australia (Blower et al. 2012).

Not all white shark movements are long distance, as individuals have also been recorded moving regularly between the Neptune Islands and the central and western regions of the Great Australian Bight (Malcolm et al., 2001; Bruce et al., 2005a). Some sharks have also been recorded returning to the Neptune Islands on a highly seasonal basis — sometimes to within



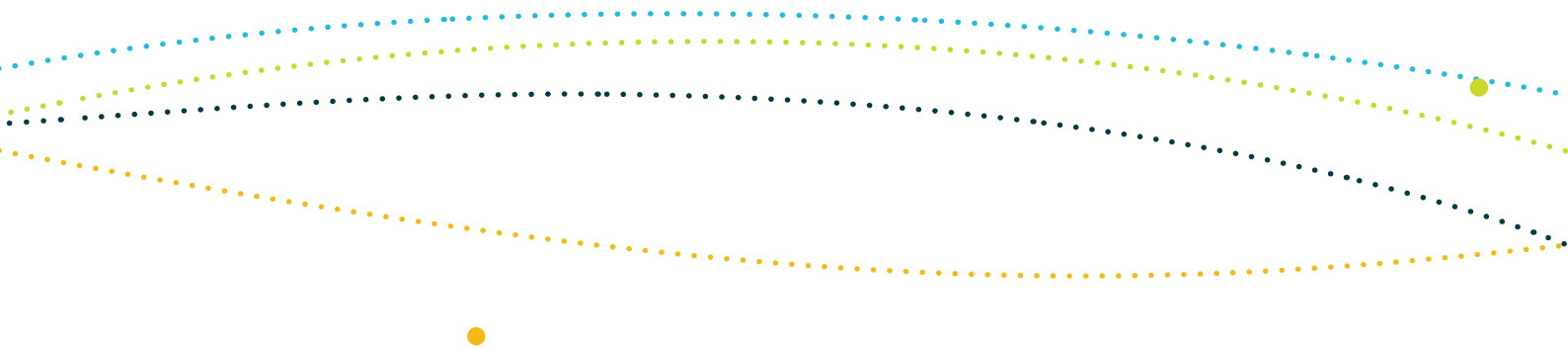
a few days of their date of arrival the previous year—while others were more frequent in their visits (Bruce et al., 2005a). These patterns of site fidelity are similar to those reported for white sharks in Californian and South African waters (Klimley, 1985; Cliff et al., 1996; Long & Jones, 1996; Bonfil et al., 2005).

Acoustic and satellite telemetry studies indicate that temporary residency of the white shark at particular sites can vary from days to weeks. Bruce et al. (2005b) used acoustic tags and listening stations to investigate the number of days that tagged white sharks were detected within the vicinity of the Neptune Islands and at Dangerous Reef in South Australia between 2001 and 2004. Most visits at the three locations were between one and three days duration, although some individual sharks remained active in these areas for up to 90 days. Bruce & Bradford (2008, 2012) used satellite telemetry to identify periods of residency of juvenile white sharks at possible aggregation sites in central New South Wales and eastern Victoria. Some juveniles remained resident to these areas for periods up to 122 days and showed evidence of fidelity to particular regions or individual beaches. Juveniles travelled extensively after departing the central New South Wales region, moving as far north as Fraser Island, south to eastern Bass Strait and northern Tasmania and across the Tasman Sea to New Zealand (Bruce & Bradford, 2012). Consistent occupancy by juvenile white sharks of two residency sites over multiple years — the Corner Inlet-Ninety Mile Beach region of eastern Victoria and the Port Stephens region of New South Wales — has these sites being defined as seasonal ‘shark nursery areas’ after the definition applied by Heupel et al. (2007).

3.5.1 Seasonal movements

Satellite tracking studies have helped explain seasonal movements in white sharks. As already mentioned, tracking studies have shown regular movements along the east and the southwest coasts of Australia, with evidence that individuals may mix in the waters around the Neptune Islands in South Australia (Bruce, et al. 2006, Bruce & Bradford, 2008, 2012).

These studies also suggest a degree of seasonality in the movement of the white shark in Australian waters. In general, the white shark appears to move north along the east coast from autumn to spring. This pattern is supported by the capture of white sharks by shark control programs in New South Wales and Queensland. Historical catches (1950–1993) show highest catch rates occur in New South Wales from May to November, with a peak from September to November (Reid & Krogh, 1992). Of the 100 white sharks caught since 1990/91, 57 were caught in September and October (NSW DPI unpublished data). Catches similarly peak in the Queensland program during September and October (Patterson, 1986). In addition, Bruce &

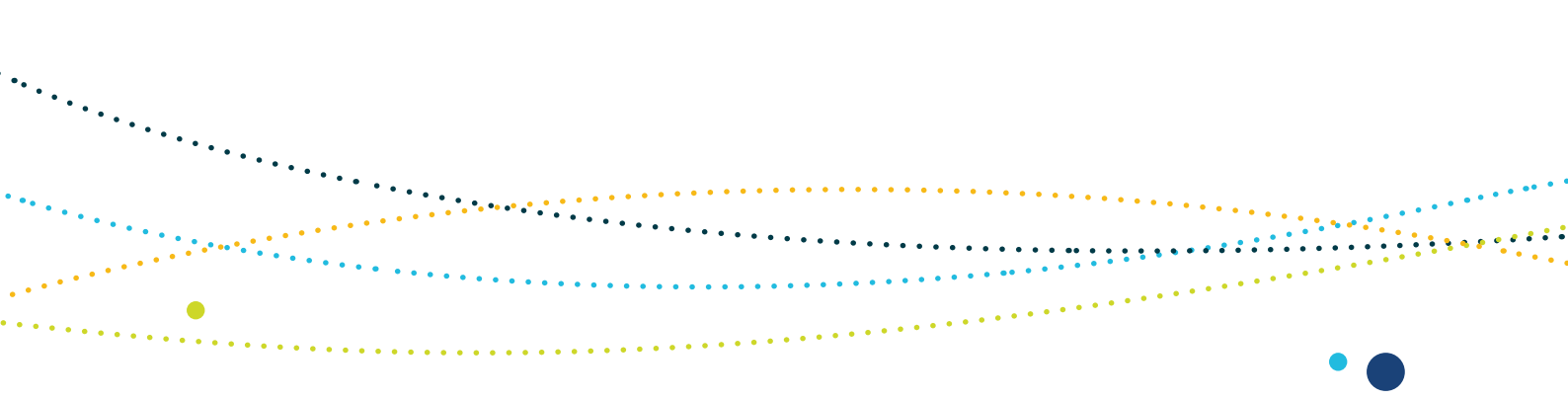


Bradford (2012) used satellite telemetry of juvenile white sharks to indicate that the eastern Australian residency sites were not randomly distributed but seasonally focused at two sites. Sharks were resident in the Corner Inlet region of eastern Victoria from mid-summer through to autumn, and sharks were resident in the Port Stephens region of central New South Wales from spring to early to mid-summer.

In Western Australia, white sharks have been tracked moving up the coast as far as North West Cape during spring and appear to return south during summer (Bruce et al., 2006), although data for this region are still sparse. Coastal movements are more complex than simple seasonal migrations north and south along these coasts. The movements of individuals are not coordinated with each other, with some sharks moving north while others move south during the same period (Bruce & Bradford, 2008). White sharks can be recorded in northern localities at any time of the year. Despite the recorded movements of some individuals across the Tasman Sea to New Zealand (Bruce et al., 2006; Bruce & Bradford, 2008, 2012), most white sharks tracked in Australian waters have made extensive coastal movements where they have remained in Australian waters (Bruce & Bradford, 2012). This is in contrast to the regularity of movements by tagged white sharks into open ocean and international waters from California, Mexico, New Zealand and, to some extent, South Africa (Boustany et al., 2002; Bonfil et al., 2005; Weng et al., 2007a; Domeier & Nasby-Lucas, 2008; Duffy et al. 2012).

3.5.2 Depth-swimming behaviour

The white shark shows complex patterns in their swimming behaviour that are dependant, in part, on what habitat they are in and presumably what prey species they are targeting. There have been various separate reports of different swimming behaviours and this is likely to be a result of the short-term nature of many such studies, which do not obtain data for individuals over all occupied habitats. The deployment of relatively long-life satellite and acoustic tag technology has provided more multi-habitat data series that more adequately illustrate the complexities in behaviour. Bruce et al. (2006) noted that white sharks around pinniped colonies in South Australia showed a diel signature in behaviour, with sharks occupying shallow water during the day close to the colony and deeper swimming, away from the colony at night. One shark rapidly switched behaviour within days of departing the Neptune Islands and entering the adjacent Spencer Gulf, where it changed to bottom oriented swimming with no diel difference and where it was believed to be feeding on finfish and bottom dwelling rays. The same shark then showed highly repetitive dive-surfacing behaviour after leaving Spencer Gulf and rapidly heading west into the Great Australian Bight, a behaviour noted by other authors, possibly to



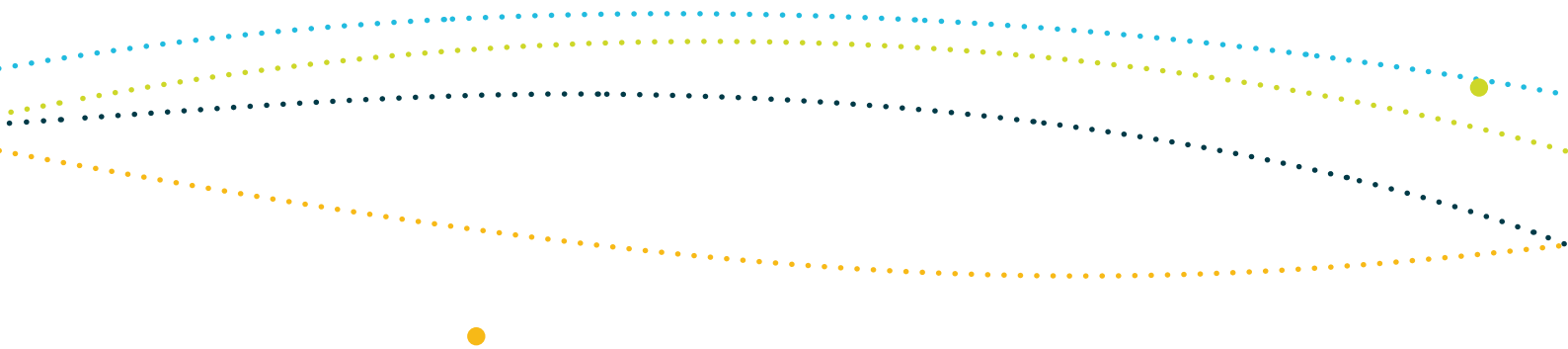
assist in navigation (e.g. Klimley et al., 2002). Off-shelf and open ocean movements generally describe adult and sub-adult white sharks diving to common depth zones of 400–600 m (Boustany et al., 2002; Weng et al., 2007a; Domeier & Nasby-Lucas, 2008; Bruce & Bradford, 2012) and to 800–1000 m (Bonfil et al., 2005; Bradford et al., 2012; Bruce & Bradford 2012). These depths are also similar to those commonly reached by juvenile white sharks off eastern Australia and when crossing the Tasman Sea (Bruce & Bradford, 2008, 2012). Overall, these studies have documented a wide range of behaviours in white sharks, including: prolonged periods at the surface or at depth; oscillatory or “yo-yo” ascents and descents; short regular intervals at the surface and depth; diel periodicity; deep dives at dawn and dusk; and periods of highly erratic swimming behaviour (Bruce et al., 2006).

3.5.3 Sexual segregation behaviour

Sexual segregation has been recorded in a wide variety of sharks (Bres, 1993). The seasonal, sex-specific occurrence of individually identified white sharks was studied at the South Farallon Islands, California, between 1987 and 2000 by Anderson & Pyle (2003). Individual males were sighted every year, whereas individual females showed a biennial occurrence pattern, being recorded every other year at most. The authors suggest that female sharks may travel significant distances to give birth, whereas copulation may occur closer to the South Fallon Islands, allowing males to return annually. These results imply a two year reproductive cycle and are consistent with estimates of gestation periods (Mollet et al., 2000).

The seasonal visitation of white sharks to the Neptune Islands, South Australia was studied by Robbins (2007) and compared between sexes. This study reported that male sharks were more common in the Neptune Islands in all months except for April and May and that males generally preferred cooler water temperatures than females during the period from 2001–2004. In 2003, the observed water temperature was lower throughout the year and this corresponded with an absence of females, prompting the suggestion that females preferred warmer water that may be beneficial for the development of young (Robbins, 2007). However, relatively few mature females are recorded from the Neptune Islands and their movements after departure from the area are still poorly known.

Sex ratios appear to vary at the Neptune Islands and other island groups in South Australia over time. Malcolm et al. (2001) reported a female dominated sex-ratio (58:20) between August 1999 and August 2000 at the Neptune Islands and Bruce (1992) noted that the female biased sex ratio observed at Dangerous Reef during 1990 and 1991 was contrary to the high incidence of males historically reported from that area. These observations suggest a more complex pattern of spatial dynamics between the sexes than water temperature cues alone.



3.5.4 Ongoing issues

- Sub-structuring within the Australasian population is likely, and will have implications for the impact of regional and site specific threats on the overall population (Blower et al., 2012). More data on the extent of the sub-structuring, in particular, the extent and nature of male mixing between the two populations, are required to ensure the efficacy of protective measures and spatial management initiatives.

3.6 Abundance

There are currently no reliable estimates of the size of the white shark population in Australian waters. Blower et al. (2012), using genetic techniques, suggest a genetically effective population size of 1500 for the Australian population. However, this should be considered a minimum estimate.

The lack of reliable population size estimates is due partly to the scarcity of white sharks and also to the difficulty in distinguishing population changes from the high rates of inter-annual variability in the numbers observed within any one site or region (Cliff et al., 1996). This high level of inter-annual variability means that what may be seen as a decline or increase in numbers over a stretch of a few years may actually be the result of changes in the distribution of white sharks from one place to another (Bruce, 2008). In addition to this variability caused by movements of white sharks, any rate of increase in the population size of white sharks will be inherently low because of their life history characteristics, and will thereby be difficult to detect.

However, there is clear evidence from a range of sources of a decline in the relative abundance of the white shark population in Australian waters over the last 60 years, including:

- **Game fishing records:** Evidence from the Game Fishing Club of South Australia indicates that the annual take of white sharks was greater than 10 sharks per year in the 1950s, while data from 1980–1990 suggests that only 1.4 white sharks per year were being caught (Malcolm et al., 2001), which represents a decline of approximately 94 per cent (Presser & Allen, 1995). Similarly, New South Wales game fishing records show a marked decline in the proportion of white sharks caught relative to the number of other sharks, with white sharks accounting for approximately one shark in 22 in the 1960s and only one shark in 651 in the 1980s. However, caution is needed when interpreting these results, as fishing effort and strategies changed markedly over these time periods. This may mean these differences reflect factors other than changes in abundance. For example, there has been a trend for game-fishers to fish further offshore, away from areas where they were likely to encounter

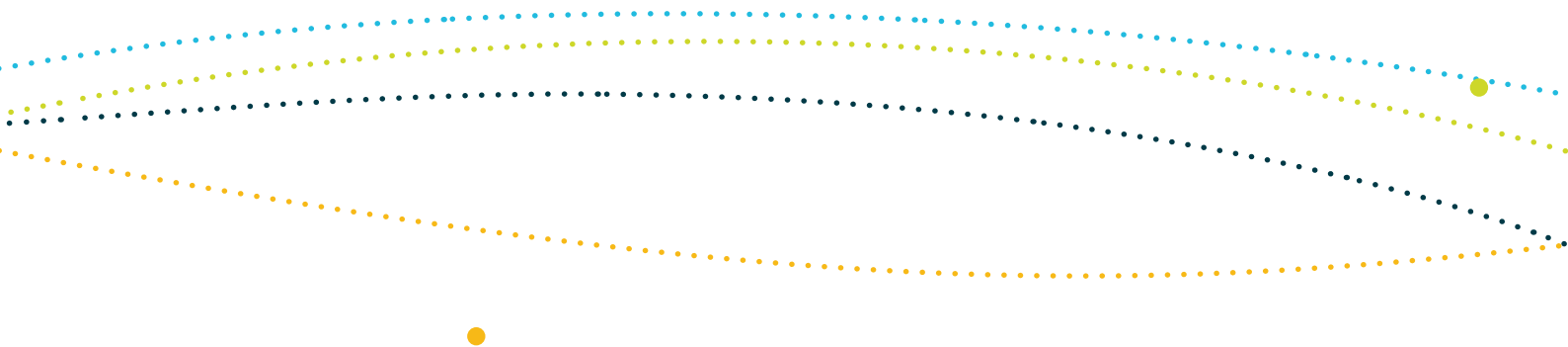
white sharks in New South Wales. Similarly, South Australian game-fishers changed practices that favoured tag-release rather than landing some time prior to the species' protection (Pepperell, 1992; see Section 4.1).

- **Shark Control Program (Bather Protection) data:** Evidence from both the Queensland and New South Wales shark control programs indicates a long-term decline in the capture of white sharks, at least during the period since the identification of shark species was recorded. In the New South Wales Shark Meshing (Bather Protection) Program (SMP), there is an indication of an increase in catch numbers from 2000–2008 from the previous decade (1990–2000) but it is uncertain whether this reflects an actual increase in white shark numbers or is a result of natural variability. Recent catches (1980s, 1990s, and 2000s) in the SMP are only a third of those from the 1950s and 1970s (Table 1). In addition, catch-per-unit-effort fell from about 3.5 to < 1 shark(s) per 1000 nets (>70 per cent) in the same period (Malcolm et al., 2001). The New South Wales numbers may also mask a greater decline, considering that the first 13 years of data (1937–1950) are not included as the species of sharks killed were not specified (Table 1).

Effort in the SMP was reduced in the 1980s from year-round to eight months of the year and this may have reduced the take of white sharks by the program. The program is currently restricted to the months between 1 September and 30 April each year. This period of operation includes the months of September and October when historical (and current) catches of white sharks are highest.

Table 1: Reported catches of white sharks in the NSW SMP, 1950/51–2010/11 (NSW DPI, 2009, 2011, 2012).

Year	1950/ 51–59/60	1960/ 61–69/70	1970/ 71–79/80	1980/ 81–89/90	1990/ 91–99/00	2000/ 01–09/10	2010/2011
Number of white sharks	151	106	161	59	44	69	6



The Queensland Shark Control Program has been in existence since 1962 and had caught 631 sharks in nets and on drumlines by 1998 (Malcolm et al., 2001). Catch-per-unit-effort is highly variable but has substantially decreased over time by about 60–75 per cent. Data on white sharks caught per year are available from 1985. There were 63 white sharks caught from 1985–1990, 101 caught from 1990–2000, and 62 caught from 2000–2010. In 2011, six white sharks were caught (QOESR, 2012).

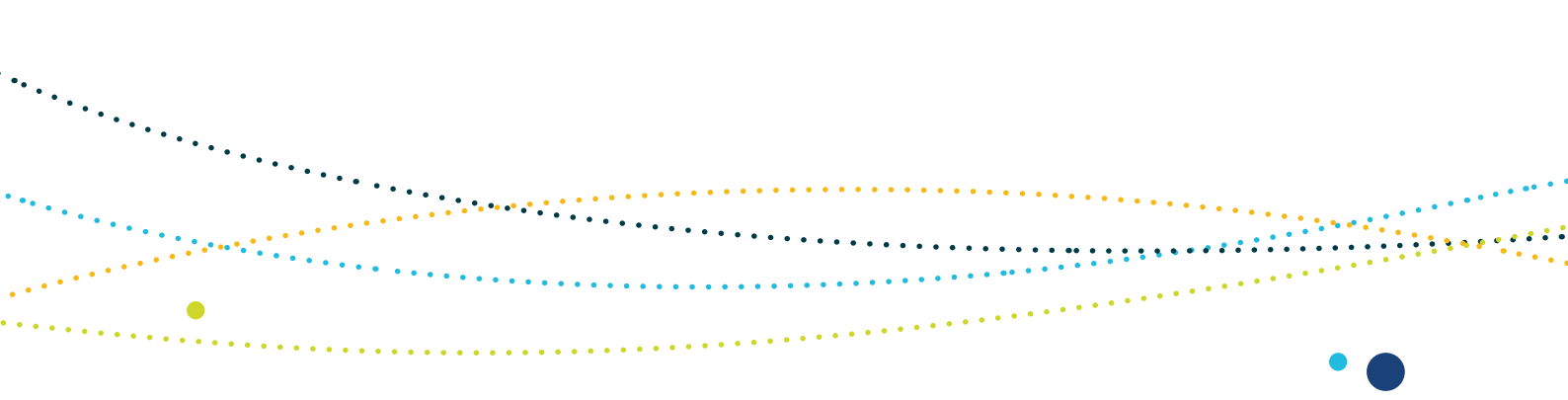
The New South Wales SMP data also provides evidence that the average size of white sharks caught is declining. In the period between 1950–1970, 31 per cent of white sharks taken were smaller than 2.25 m; from 1970–1990, 50 per cent were smaller than 2.25 m and over 90 per cent were smaller than this length in the 1990s (Pogonoski et al., 2002). From the 1990s individuals caught were usually in the 1.5–2.0 m range (Reid et al., 2011).

- **Data from monitoring at the Neptune Islands:** Logbook data from shark cage dive operators at the Neptune Islands has been collected since 1999. These data suggest high levels of seasonal and inter-annual variability in shark activity at the North Neptune Island site where most shark cage diving occurs, but no consistent long-term trend (Bruce & Bradford, 2011). This is consistent with site specific variability being driven by changes in distribution, rather than changes in population size. Nevertheless, there has been a noticeable increase in the number of white sharks sighted by shark cage dive operators since 2007, when the number of days of burleying increased substantially.
- **Global records:** Evidence of a decline in other regions of the world is suggested by game fishing records from North America, which show the proportion of white sharks caught dropped from one in 67 in 1965 to one in 210 in 1983 (Casey & Pratt, 1985). It is also suggested by the noted decline in the catch of white sharks in the South African beach meshing program over time (Cliff et al., 1996).

Given the limited long-term information available for the white shark, it is difficult at this stage to assess how its status compares to that at the time of its protection and listing in Australian jurisdictions, which occurred from 1996–1999.

3.6.1 Ongoing issues

- There is still no reliable estimate of the total size of the Australian white shark population and no adequate measure of population trends or status. This lack of information makes it difficult to assess the effectiveness of any actions undertaken to conserve the species. Understanding the relationship between the numbers of sharks sighted at any one site and overall population size or trend is a critical issue. At least some changes (both increases



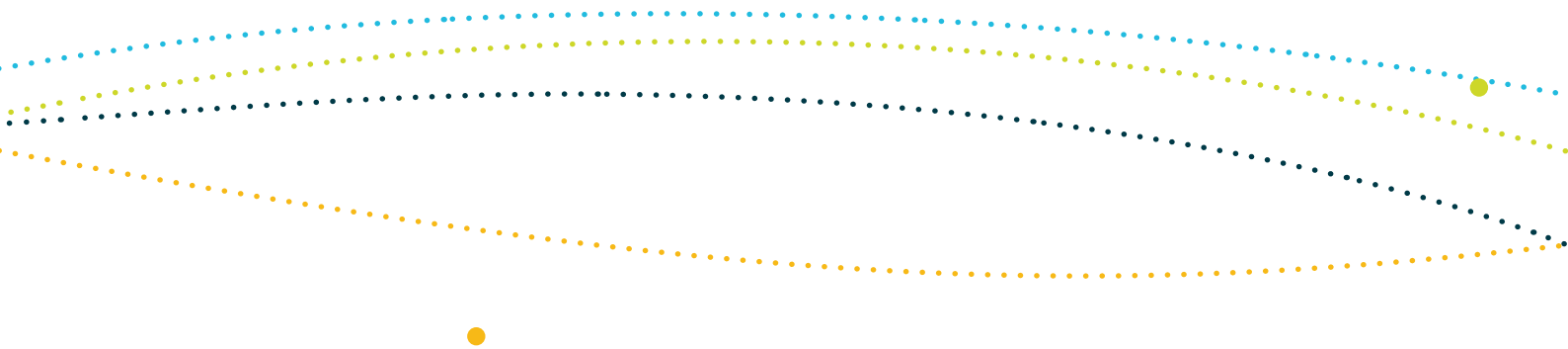
and decreases in observed numbers) are likely to be a function of temporal changes in distribution, rather than population size. If purely distribution driven, increases in numbers of white sharks in areas where human activity is also high may indicate periods where shark populations are also most at risk from interactions, rather than indicating a recovery of the population.

3.7 Habitat

The white shark can be found from close inshore, around rocky reefs, surf beaches and shallow coastal bays, to outer continental shelf and slope areas (Pogonoski et al., 2002; Bruce et al., 2006; Last & Stevens, 2009). They also make open ocean excursions, can cross ocean basins and both adults and juveniles have been recorded diving to depths of 1000 m (Bonfil et al., 2005; Weng et al., 2007b; Bruce & Bradford, 2008; Bradford, et al. 2012). Most white shark movements and activity in Australian waters occur between the coast and the 120 m depth contour (Bruce et al., 2006; Bruce & Bradford, 2008, 2012). However, the importance of offshore and high seas habitat cannot be dismissed, although unlike white sharks tracked off the western coast of North America (Weng et al., 2007a; Domeier & Nasby-Lucas, 2008), there is no evidence that the white shark in Australia utilises oceanic habitats other than for transit between temporary sites of continental residency.

The white shark is widely, but not evenly, distributed in Australian waters, with some areas having higher concentrations of sharks than others (Malcolm et al., 2001; Bruce & Bradford, 2008). These regions of higher concentration have been mapped as part of the Australian Government's marine bioregional planning process. Figure 1 shows the biologically important areas (BIA) for white sharks in Australia's Commonwealth Marine Regions. This map shows not only the broad distribution of white sharks within Australian waters but also identifies high density foraging sites, mostly around seal and sea lion colonies, and juvenile aggregation sites, where known. Important regions in the east/southeast of Australia include juvenile aggregation sites at Port Stephens in New South Wales and Corner Inlet-Ninety Mile Beach off eastern Victoria (Bruce & Bradford, 2012). The data collected by Bruce & Bradford (2012) demonstrate that these areas were utilised repeatedly on a seasonal basis across different years and are consistent with the definition of 'shark nursery areas' applied by Heupel et al. (2007).

It should be noted that Figure 1 represents current knowledge and that there are likely other areas that are biologically important to white sharks that have not yet been identified. In particular, there have been no juvenile nursery sites identified in the South-west region and pupping locations for white sharks remain unknown.

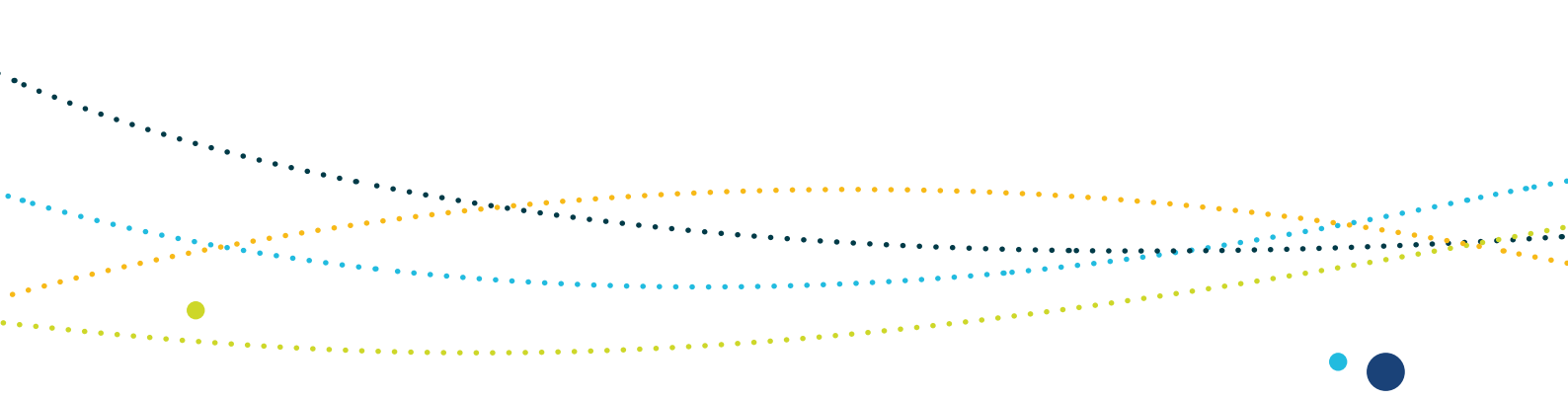


Although biologically important areas have been identified, white sharks do not live in one specific area or territory but travel great distances between sites of temporary residency (Bruce, 2008). There is also mounting evidence for common movement pathways between some areas of temporary residency in Australian waters (Bruce et al., 2006; Bruce & Bradford, 2008, 2012). Identified foraging areas, aggregation areas and sites to which white sharks return on a regular basis may represent habitat critical to the survival of the species. However, further research is needed to identify such habitat.

There are few observations or data on the location of mating, pregnant sharks or the sites for pupping in Australian waters, despite the abundance of juveniles in certain localities (Bruce, 2008; Bruce & Bradford, 2008, 2012).

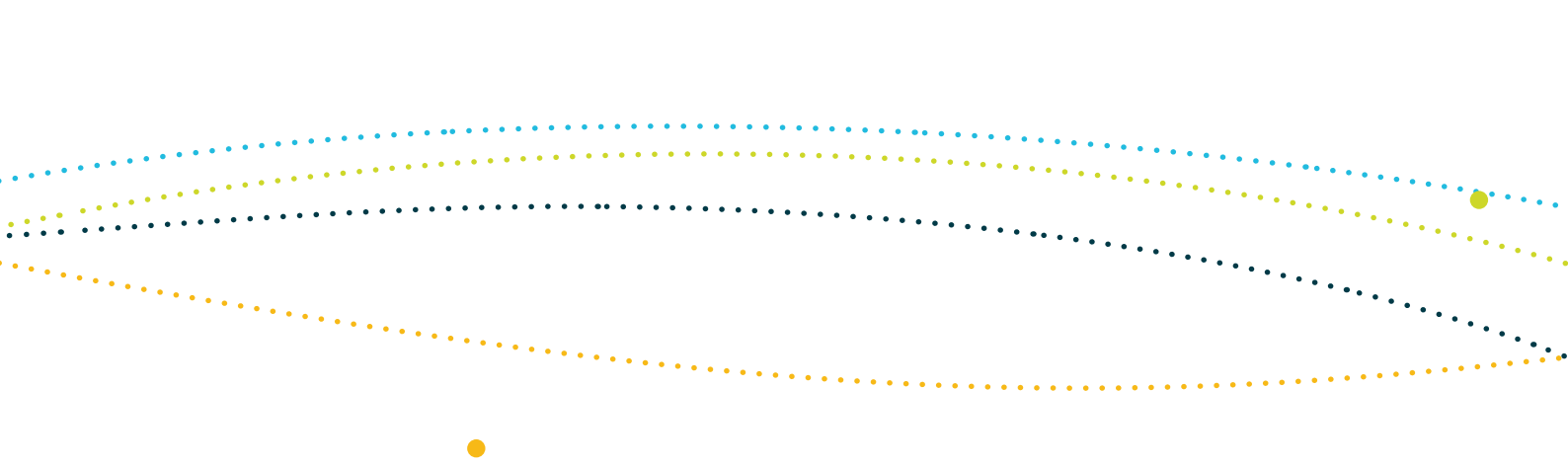
The locations of Australian pupping grounds are unknown (EA, 2002; Bruce, 2008), although neonate white sharks have been taken as bycatch by commercial and recreational fishers in the western Great Australian Bight and Bass Strait (Malcolm et al., 2001). A neonate white shark was also caught in coastal waters near Port Phillip Bay (Bruce & Bradford, 2008). Pupping is believed to occur during spring or early summer which coincides with the period when Robbins (2007) reported the absence of female white sharks from the Neptune Islands in South Australia. However, the species' reproduction in Australian waters remains poorly known and, despite a considerable number of records of young-of-the-year and juveniles (Malcolm et al., 2001; Bruce & Bradford, 2008), no pregnant white sharks have yet been reliably examined in Australian waters.

While some inshore regions have been identified as being important foraging grounds for juvenile white sharks, it remains unclear why other areas that also seemingly have a similar concentration of prey species are not frequented as commonly (Bruce & Bradford, 2008, 2012). Identifying areas that are important for reproduction, including sites for mating, development of young during pregnancy, pupping grounds and the relationship between these and juvenile nursery habitat, remains a priority so that these areas can be adequately protected. It may also be possible to use estimates of abundance in key juvenile habitats as an index of population status (Bruce & Bradford, 2008, 2012).



3.7.1 Ongoing issues

- Despite a body of knowledge being accumulated on habitat preferences of juvenile, sub-adult and adult white sharks, there remain significant gaps in knowledge — particularly as to why certain areas seem favoured by different life history stages, the geographic extent of such areas and the timing of ontogenetic changes in the species' habitat requirements.
- There is still no conclusive information about the location of key pupping grounds for the white shark. It is important to locate these regions in order to provide them with adequate levels of protection.
- Continued integrated project work is required to identify habitats critical to the survival of the white shark, the pattern of use of these habitats and movements between them — including the influence of physical and biological habitat cues driving distribution patterns.



4 CONSERVATION

4.1 Conservation status — worldwide and in Australia

The white shark is protected under Commonwealth and state legislation. It is also listed on the International Union for the Conservation of Nature (IUCN) Red List and listed under the Convention on International Trade in Endangered Species (CITES), Appendix II (CITES, 2004b, 2004c & 2004d) and the Convention on Migratory Species (CMS), Appendix I and II. Details of the legislation under which the white shark is protected in Australian waters are provided in Table 2.

On 1 April 2007, the white shark was protected under Schedule 7A of *New Zealand's Wildlife Act 1953* and the taking of white sharks by New Zealand fishing vessels on the high seas was also prohibited under the *New Zealand Fisheries Act 1996*. As white sharks are known to move between Australia and New Zealand on occasion (Bruce et al., 2006), complementary protective arrangements in New Zealand will enhance those previously implemented in Australia. However, the white shark is not protected in areas of international waters between these jurisdictions, apart from the 'high-seas fishing' provision under the New Zealand Fisheries Act 1996. The waters in the south-west Pacific also have no protection. While it is not known if members of the Australian population move into the south-west Pacific the possibility remains, considering individuals tagged in New Zealand have been known to move there after being tagged in New Zealand waters (e.g. New Caledonia and Tonga; Duffy et al., 2012). White sharks have also been tracked moving between Australia and South Africa (Bonfil et al., 2005) and genetic evidence exists for limited mixing between the eastern Australian and the South African populations (Blower et al., 2012). White sharks are protected in South African waters but there is only limited protection of the species in the international waters between Australia and South Africa.

4.1.1 Ongoing issues

- The geographic footprint of the Australasian white shark population is, at present, ill-defined and thus the extent to which current protective measures adequately cover the population across its range cannot be determined. Given the movements of the white shark from both Australia and New Zealand into international waters and into other international jurisdictions where protective measures are not in place, this issue may require further international negotiations to achieve full legislative protection of the population.

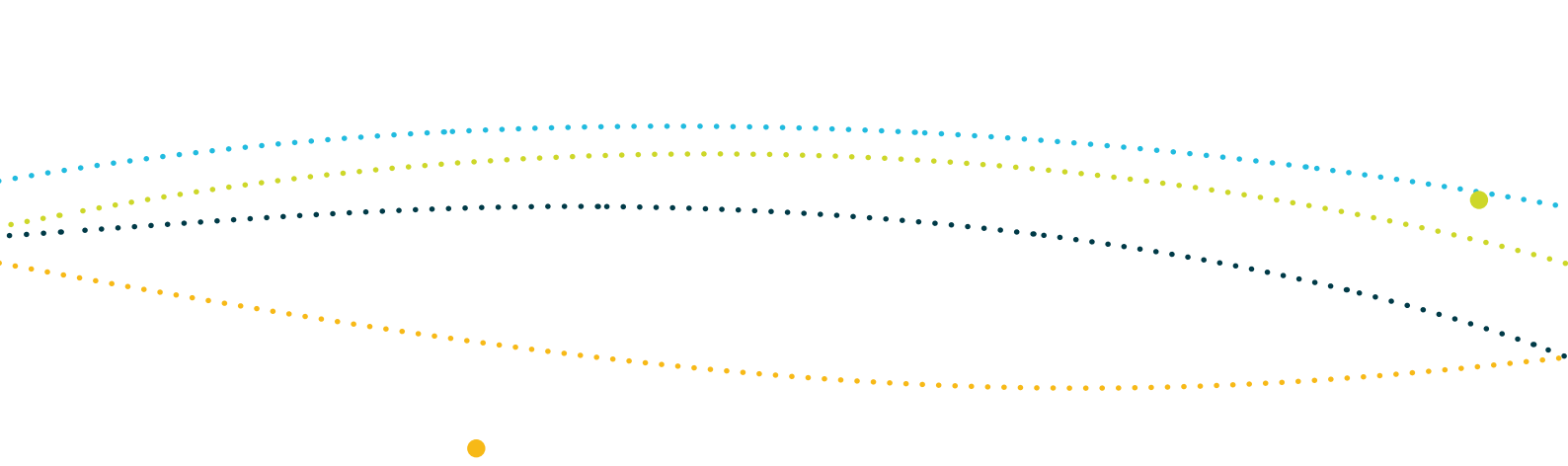
Table 2: Current conservation status of the white shark in various jurisdictions
(adapted from a compilation by (Malcolm et al., 2001))

Jurisdiction	Legislation	Section Summary	Date of Declaration
International			
CITES ¹		Appendix II	2004
CMS ²		Appendix I and II	September 2002
IUCN ³		Red List — Vulnerable	1996
Domestic			
Australian Government	<i>Environment Protection and Biodiversity Conservation Act 1999</i>	Part 13 Div 1 Listed as a Vulnerable species with prohibition on taking and trade. Part 13 A Prohibition of certain exports and imports.	16 July 1999 (Amended Sept 2001) (Initially declared under the <i>Endangered Species Protection Act 1992</i> on 17 October 1997).
	<i>Great Barrier Reef Marine Park Act 1983</i>	White shark listed as a Protected Species under Regulation 29.	
Victoria	<i>Fisheries Act 1995</i>	Species listed as Vulnerable. S.69 Aquatic Biota can be declared protected by the Governor in Council.	4 August 1998.
	<i>Flora and Fauna Guarantee Act 1988</i>	S.71 A person must not take, injure, damage, destroy, possess, keep, display for reward, release or sell any protected biota.	6 October 1997.

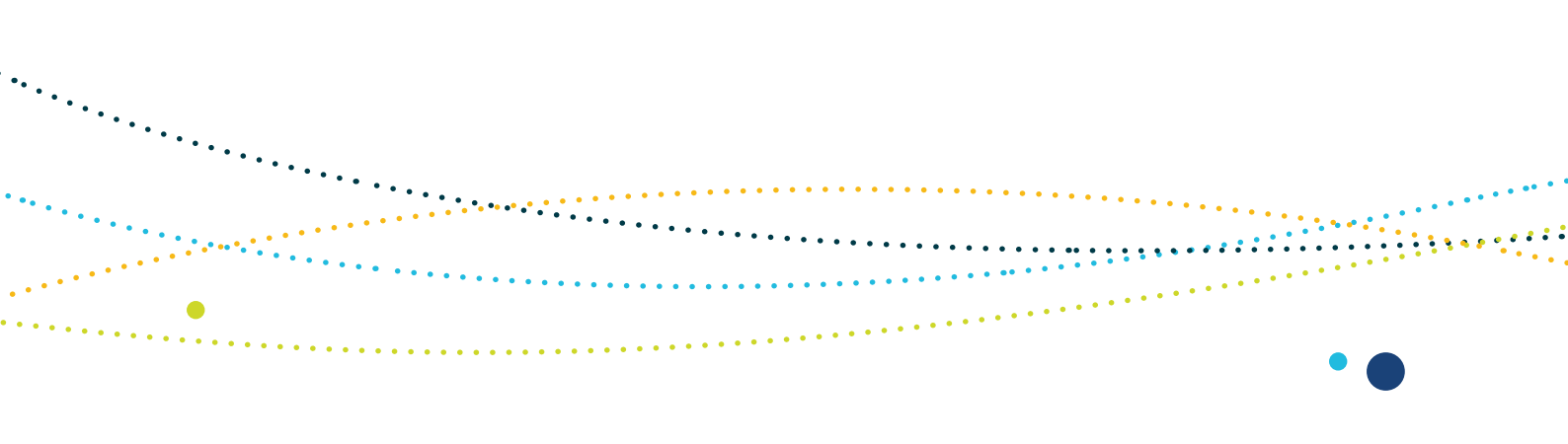
1 Convention on International Trade in Endangered Species of Wild Fauna and Flora

2 Convention on the Conservation of Migratory Species

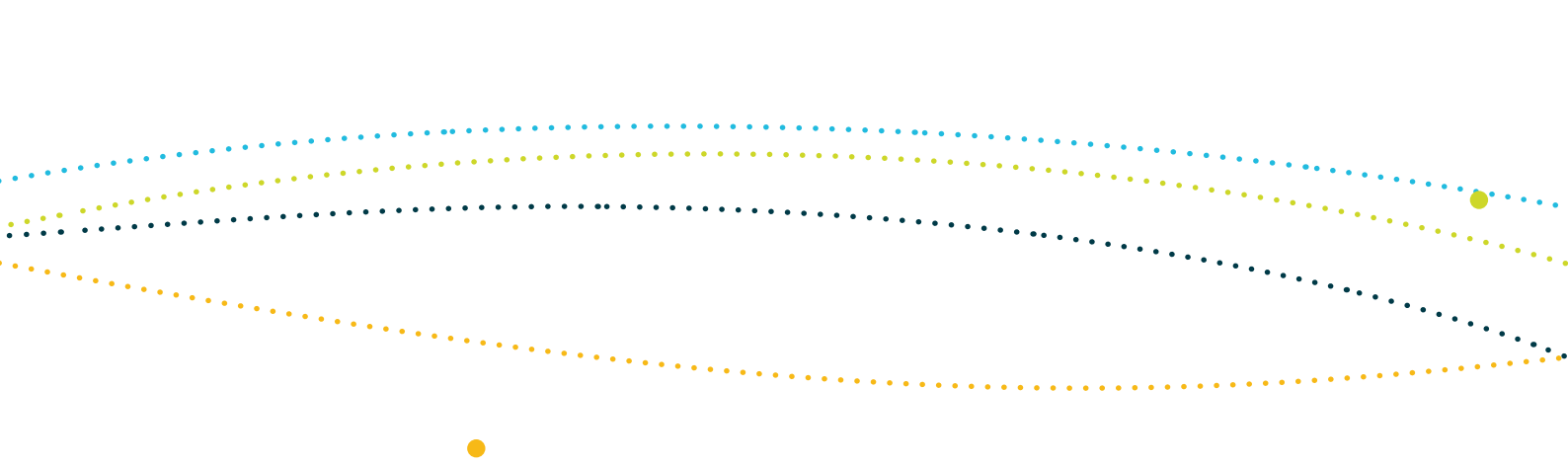
3 International Union for the Conservation of Nature



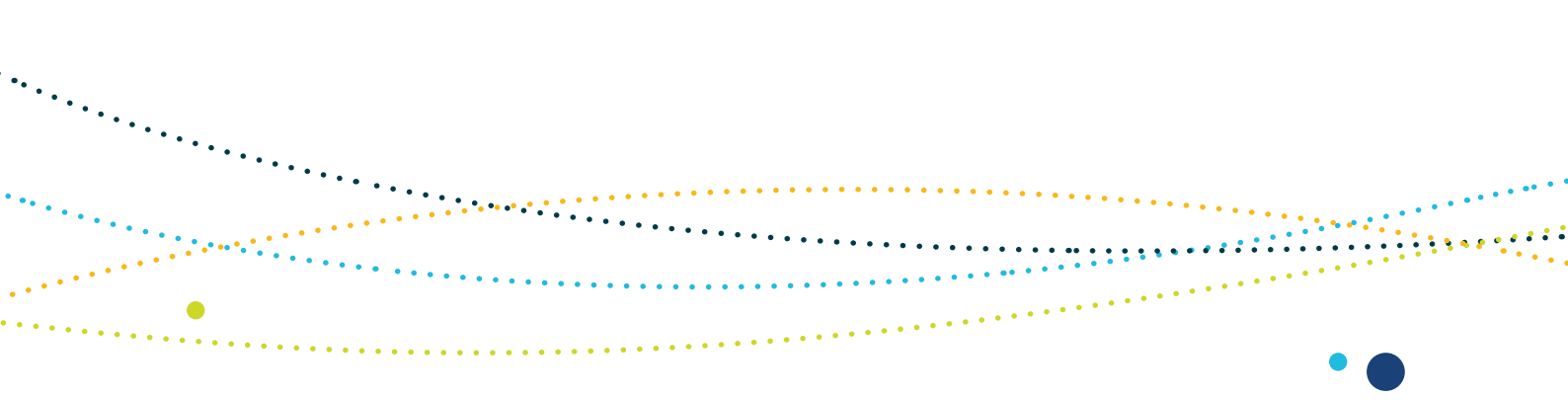
Jurisdiction	Legislation	Section Summary	Date of Declaration
Tasmania	<i>Threatened Species Protection Act 1995</i>	S.135(2) A person must not take any protected fish.	Declared 1 March 2000 (Initially declared under previous Act in 1995).
	<i>Living Marine Resources Management Act 1995</i>	Rule 18(a)3, A person must not take, or be in possession of the white shark.	Applied 9 December 1998.
	Fisheries (General and Fees) Regulations 1996	Species declared Vulnerable.	2005.
New South Wales	<i>Fisheries Management Act 1994</i>	Part 7a Listed under Schedule 5, Part 1, Vulnerable Species.	Listed as a Vulnerable species under Part 7a on 14 May 1999. Previously listed as a Protected species under Part 2 Division 1 of the Fisheries Management (General) Regulation in January 1997.
Western Australia	<i>Fish Resources Management Act 1994</i>	S.46 A person must not take, possess, sell or purchase, consign, bring in to the state: any totally protected fish. As of September 2012, in some circumstances, the destruction of individual sharks is authorised under the <i>Fish Resources Management Act 1994</i> in Western Australia.	November 1997.



Jurisdiction	Legislation	Section Summary	Date of Declaration
	<i>Wildlife Conservation Act 1950</i>	S. 14(2)(ba) (i) such fauna is wholly protected throughout the whole of the state at all times; and (ii) a person who commits an offence under section 16 or section 16A with respect to or in relation to such fauna is liable, notwithstanding any other provision of this Act, to a penalty of \$10,000.	17 December 1999.
Queensland	<i>Fisheries Act 1994</i>	S.78 (1) A person must not unlawfully take, possess or sell a regulated fish.	18 July 1997.



Jurisdiction	Legislation	Section Summary	Date of Declaration
South Australia	<i>Fisheries Act 1982</i>	S.42 A person must not take a fish declared by regulation to be protected. Regulations restrict the tackle recreational fishers can use and the use of berleying and mammal baits is prohibited. S.59 Berleying was prohibited in coastal and island waters. Island waters extend to 2 nm from the low tide mark. Regulation 35C prevented berleying for the purposes of attracting white sharks to a boat, and keeping them in the vicinity of the boat for viewing purposes.	January 1998.
	<i>National Parks And Wildlife Act 1972</i>	Under the provisions of the Act it is an offence to kill, hunt, catch, restrain, injure, molest or harass a protected animal. Schedules 7, 8 and 9 of the Act list Rare, Vulnerable and Endangered species.	



5 THREATS TO THE WHITE SHARK

5.1 Primary threats

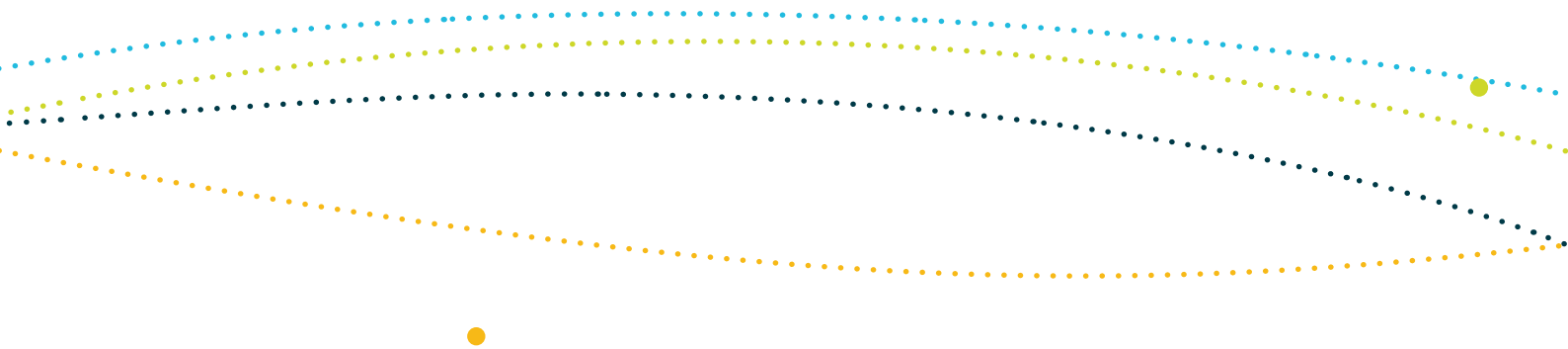
5.1.1 Commercial fishing

Jurisdiction for Australian shark resources rests with the six states, the Northern Territory and the Australian Government. In general, the states and Northern Territory have jurisdiction over waters from their shoreline out to three nautical miles and the Australian Government has jurisdiction outside these limits to the 200-nautical-mile Exclusive Economic Zone. The Commonwealth and all state and Northern Territory fisheries agencies have reporting measures for interactions with protected species. The white shark is not commercially targeted in Australian waters but is caught as bycatch (AFMA, 2010).

Commercial fisheries that are known to interact with white sharks include (see AFMA, 2012):

- Small Pelagic Fishery
- Southern and Eastern Scalefish and Shark Fishery (including the Commonwealth Trawl and Scalefish Hook Sectors and the Shark Gillnet and Shark Hook Sectors)
- Southern Bluefin Tuna Fishery
- Eastern and Western Tuna and Billfish Fisheries
- various finfish (scalefish) fisheries in Tasmania, Victoria and South Australia
- the tuna industry in South Australia
- the temperate demersal gillnet and longline fisheries in Western Australia (southern and western coast)
- New South Wales Ocean Trap and Line Fishery.

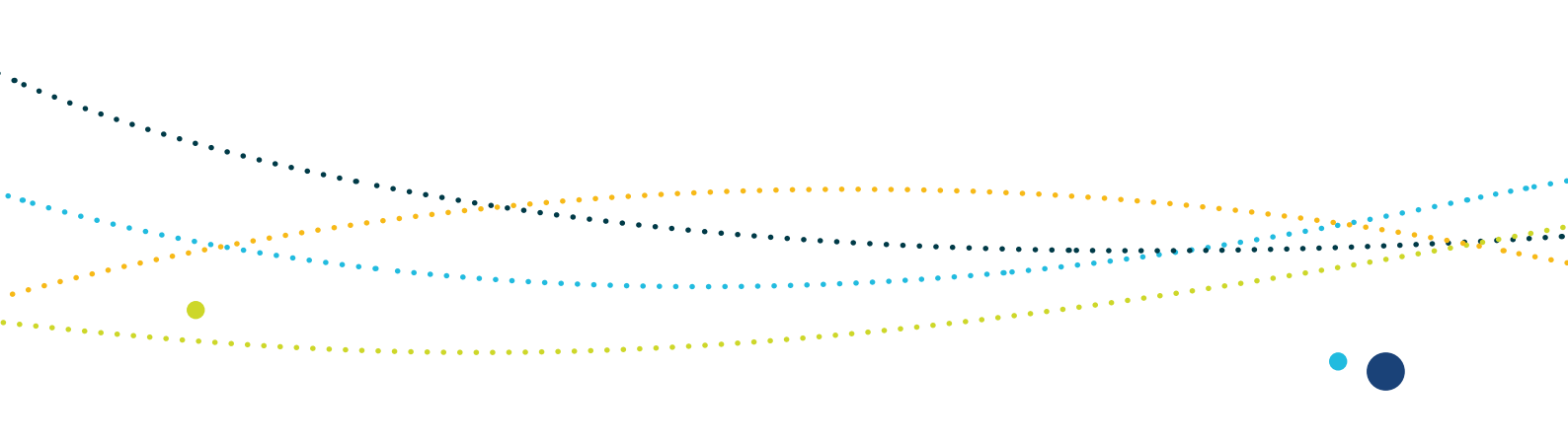
White sharks interact with commercial fishing operations, sometimes swimming along a net or long-line and biting off sharks and other fish that are caught. Signals given by struggling fish in the net or on hooks — such as vibrations or smell — may attract white sharks to the gear and subsequent interaction with fishing equipment can lead to entanglement (net) or hooking (Malcolm et al., 2001). Incidental mortality may occur if a shark dies during capture



or entanglement, is killed during retrieval of the fishing gear, or if those that are incidentally hooked and released die sometime later (cryptic mortality). Successful release and subsequent survival depends on factors, such as the degree of entanglement, the fisher's attitude towards sharks and motivation to achieve a successful release, fisher's experience with release techniques, the weather and sea conditions at the time, the size of the shark, the period that the shark has been restrained by the fishing gear, the degree of personal risk (real or perceived) involved in the release attempt, and the type of gear used (Malcolm et al., 2001).

The numbers of white sharks landed by commercial fishers have been difficult to assess because interactions with the species were not required to be recorded until the species was protected. The most comprehensive study of white shark mortality as a result of interactions with the commercial fishing sector estimated that up to 165 sharks were caught per year (between 1973 and 1999) by the sector and, of those, approximately 92 died before they could be released (Malcolm et al., 2001). This study acknowledged that the average annual variability was high, and that the mortality estimate of 92 was probably an underestimate due to post release mortality. This study was based on fisher logbooks and through phone interviews with fishers in multiple fisheries over a period from 1973 to 1999. Malcolm et al. (2001) reported that the southern and western shark fisheries, and the South Australian Marine Scalefish Fishery operating in southwest Western Australia, the Great Australian Bight and Victoria, were responsible for the highest capture of white sharks and that this was indicative of the higher numbers of white sharks in these regions than other areas of Australia. Similarly, the Commonwealth Marine Bioregional Plans characterise bycatch in commercial fisheries as a pressure 'of concern' in the South-west Marine Region and as a pressure 'of potential concern' in the Temperate East Marine Region for white sharks. These plans are available for download from the department's website at: www.environment.gov.au/coasts/marineplans/index.html

A review of the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan (DEWHA, 2008) found that information from Commonwealth-managed fisheries logbooks indicated that approximately 37 white sharks were caught between 2002 and 2008, of which 27 were reported as being released alive. Additional information provided by state governments suggested that a further five interactions occurred in South Australian managed fisheries between July 2007 and June 2008, and that 10 interactions occurred in Western Australian-managed fisheries between June 2006 and April 2007. According to more recent Australian



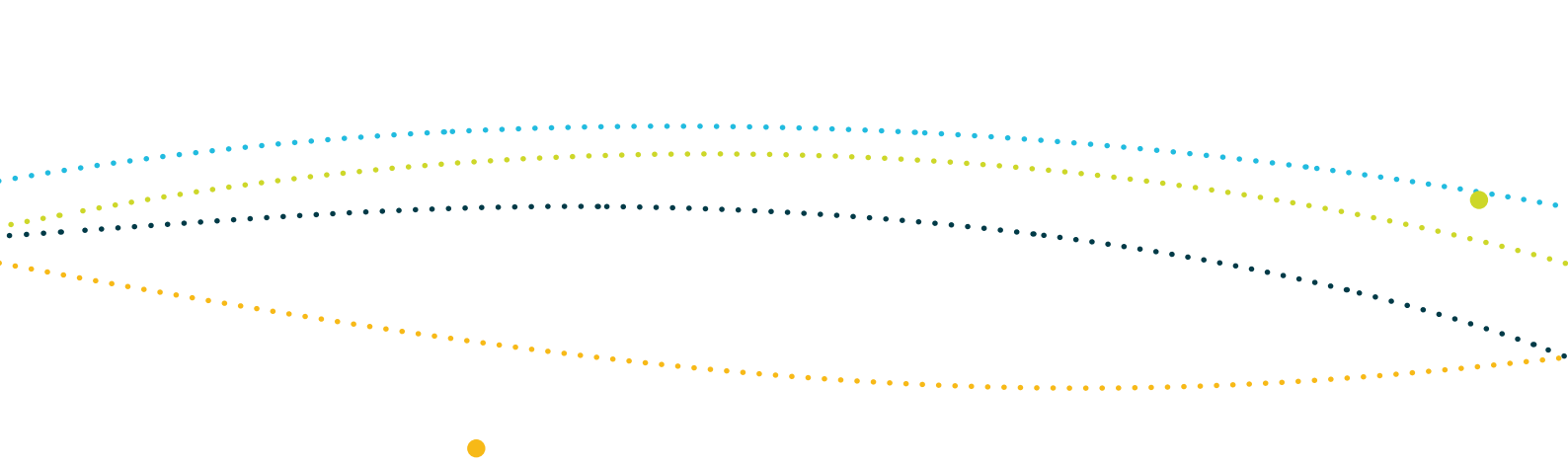
Fisheries Management Authority (AFMA) interaction reports, between 2008 and March 2011, 22 white sharks were caught in the Southern and Eastern Scalefish and Shark Fishery, 20 of which were released alive.

Regardless of the incomplete nature of the commercial fishing data (i.e. numbers not reported by each state or for extended periods of time), the combined figures still suggest that significantly fewer white sharks are now caught as compared to the previous estimate of 165 per annum (Malcolm et al., 2001). However, these estimates are difficult to compare, as the Malcolm et al. (2001) study used a variety of techniques (including questionnaire and phone survey) to obtain their data while the above estimate is from limited logbook reporting. Overall, these data suggest that either a significant drop in catch rates (and concomitant mortality) of the white shark has occurred since their protection or that there remain major reporting issues with the logbook systems set up by the states and the Australian Government. A third explanation may be that the white shark has experienced a substantial decline in numbers since the protection of the species, thus reducing the level of interactions. In the absence of consistent reporting and comprehensive fisheries-independent data, it is difficult to interpret what otherwise appears to be significant decline in white shark interactions with the commercial fishing sector. Resolving this issue should be a priority for future research efforts.

Interactions between the white shark and aquaculture cages in South Australia have also been identified as a threat to the species (EA, 2002). The white shark is known to become entangled in nets or to enter aquaculture cages in search of food, posing a risk to stock and cage operators. Most of the sharks are destroyed in the cage. The aquaculture industry was estimated to be responsible for up to 20 white shark deaths per year prior to the review by Malcolm, et al. (2001).

In 2004, a meeting titled 'Workshop on Shark Interactions with Aquaculture' was held in South Australia to bring together industry representatives, state representatives and shark researchers. The meeting addressed the need for best practice guidelines for removing white sharks from cages and to identify effective methods, techniques and technologies to prevent entry of large predators to cages (Murray-Jones, 2004).

Since the 2004 workshop, South Australia has introduced new regulations (Aquaculture Regulations 2005) to help monitor and reduce the impacts of the South Australian aquaculture industry on seabirds and large marine vertebrates. These regulations require aquaculture operations to have a management plan, which needs to be approved by the state environment minister, detailing strategies to minimise interactions with large marine vertebrates and also requires reporting of any interactions that do occur.



The Commonwealth's Marine Bioregional Plans assessed the collision or entanglement with infrastructure as of 'potential concern' for the white shark in the South-west Marine Region, particularly with respect to interactions with aquaculture ropes and nets, which may result in entanglement and drowning.

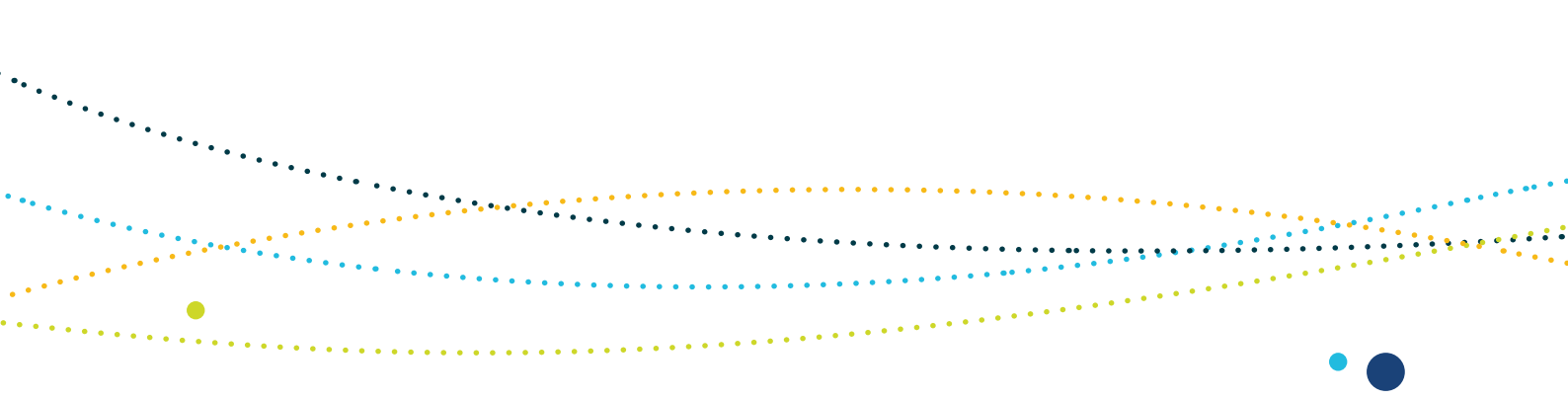
5.1.1.1 Ongoing issues

- The current frequency of interactions between commercial fishing operations and white sharks is unclear. This requires resolution in order to better understand the actual level of interactions with this sector and to enable such data to be reliably used as an index of population status and degree of threat to the species. Furthermore, estimates of interaction frequency with the commercial fishing sector — including sightings by aquaculture industry at specific locales such as Port Lincoln — may be useful as an index of population trends.
- There is a need to identify habitats, migratory paths and/or specific locations that are used to meet essential life cycle requirements such as mating, pupping, temporary residence sites during migration and feeding, and to minimise the impacts of commercial fishing activities at such localities.
- There is a need to investigate post release survival of white sharks in commercial fisheries (e.g. cryptic mortality).

5.1.2 Recreational fishing

Since the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan was put in place, there have been no interactions reported to the Australian Government between white sharks and the recreational fishing sector (DEWHA, 2008). This is despite various reports of captures to other jurisdictions and agencies. These captures include both tag-release and mortalities, which in some cases have been widely reported in the media and have resulted in the introduction of legislated area-specific fishing/gear restrictions (e.g. Stockton Beach, NSW).

Prior to protection, white sharks were captured and either killed or tagged and released as part of game-fishing activities. The full extent of the take of white sharks by the game fishing sector is not recorded, apart from club records which indicate that in South Australia approximately 25 white sharks per year were taken in the 1950s and that this declined to 1.4 sharks per year in the 10 years prior to 1990 (Presser & Allen, 1995). Records collected by the Game Fishing Association of Australia for New South Wales indicate that approximately 183 white sharks were caught between 1960 and 1995, at an average of approximately 5.2 a year. However, catch rates in New South Wales declined in the years prior to protection, with an average catch rate of 4 per year between 1981 and 1990.



These changes cannot, however, be completely attributed to a decline in white shark numbers over this period and a combination of factors is likely involved. Such factors may include a reduction in effort by recreational fishers and changes in fisher habits, such as a shift in angling away from white shark habitat; a reluctance to report interactions; changes in fishing equipment or techniques or changes in the abundance of other sharks (Bruce, 1992; Pepperell, 1992).

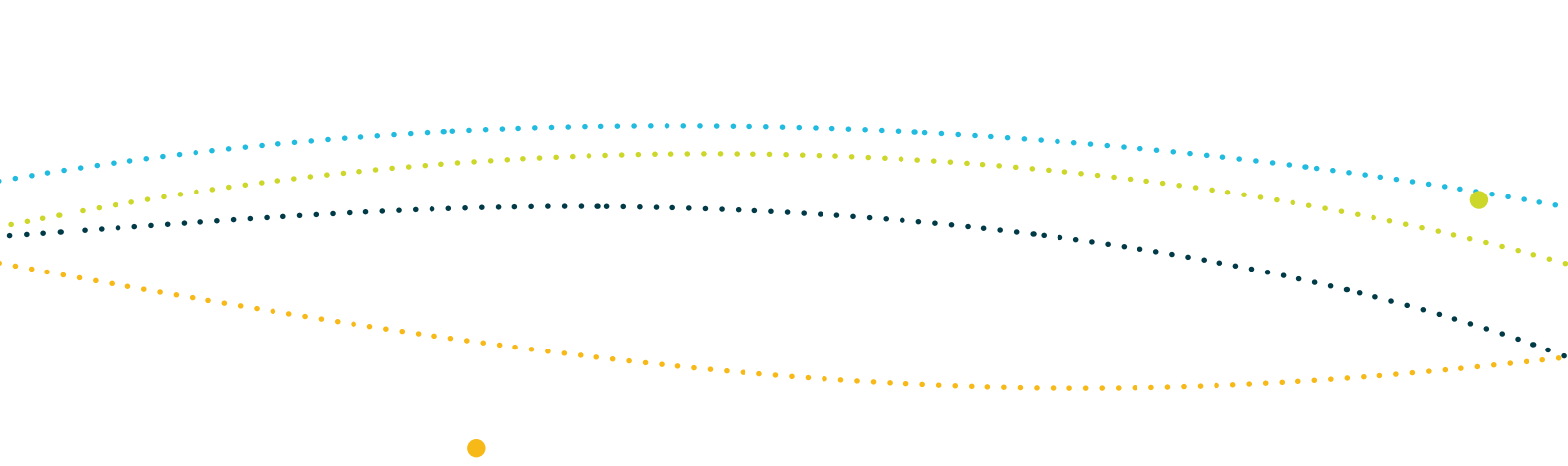
Tagging currently requires a permit and game fishing groups continue to express interest in accessing white sharks for tag-release purposes. However, concerns over the impact of this activity remain as there is little understanding of capture induced mortality or sub-lethal stress as a result of hooking, playing, capture and then release of white sharks by recreational fishers. Given that the white shark is protected, such work would only be promoted when the species has recovered sufficiently to be considered for down listing from the threatened species schedules. Re-instating tag release programs is only possible under current legislation if the regulatory authorities grant an exemption permit (EA, 2002).

Evidence suggests that there has been a failure to report captures by and interactions with recreational fishing operations. This is either a function of deliberately evading the law, fishers misidentifying the species or, more likely, fishers not knowing the reporting requirements, despite a number of education campaigns undertaken by Australian and state government agencies in recent years about the protected status of the species (DEWHA, 2008). Future work should focus on gaining a better understanding about the level of interactions between this sector and white sharks, and promoting a greater understanding of reporting requirements.

The Commonwealth's Marine Bioregional Plans categorise bycatch in recreational and charter fishing as pressures 'of concern' in both the South-west Marine Region and the Temperate East Marine Region. These plans are available for download from the department's website at: www.environment.gov.au/coasts/marineplans/index.html

5.1.2.1 Ongoing issues

- Reporting mechanisms for white shark sightings or captures do not exist in all states. This makes it difficult to estimate the level of interaction by the recreational sector.
- It is desirable that recreational fishing associations continue to provide information on the protection of white sharks to their members, including links to further information on websites, and the implementation of appropriate reporting mechanisms. This should include information on obligations and penalties under the EPBC Act.

- 
- A streamlined system for reporting interactions with white sharks, similar to the one developed for all Commonwealth commercial fisheries may provide a useful reporting mechanism for recreational fishers.
 - Education campaigns targeted at informing the recreational sector about the protected status of the white shark and the importance of reporting interactions have had little or limited effect to date and other means of promoting these messages are required for such programs to be effective.

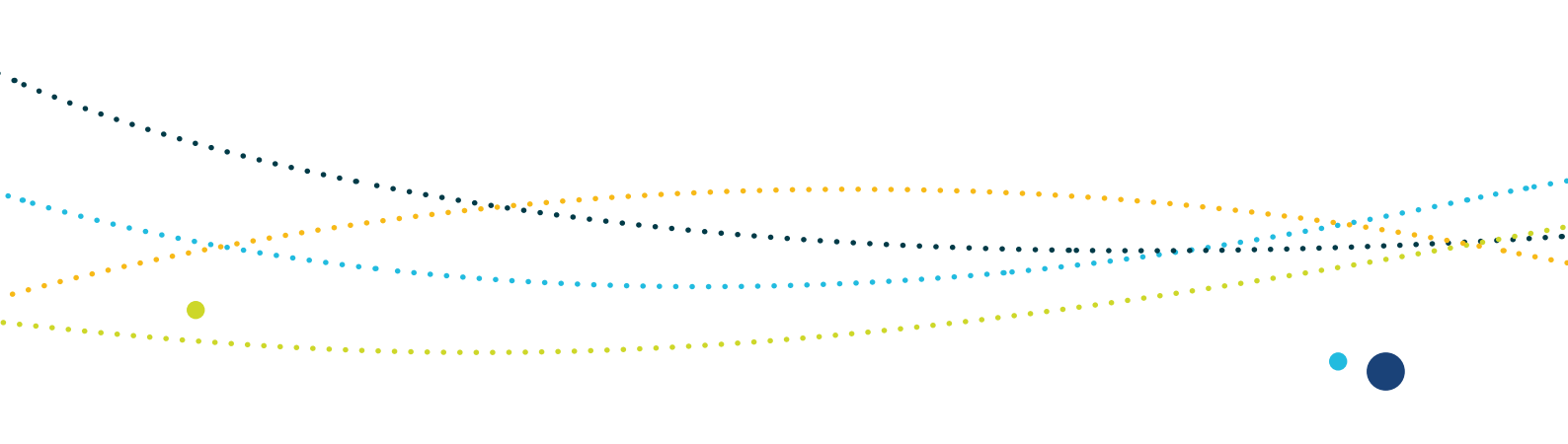
5.1.3 Shark control activities

Shark control programs are activities that aim to reduce shark numbers near major swimming beaches and thereby reduce the risk of shark attack. They involve the placement of mesh nets or drumlines off beaches and, in Australian waters, are currently only practised in New South Wales and Queensland. New South Wales only uses beach meshing, whereas Queensland uses a combination of meshing and drumlines (Reid et al., 2011).

Shark mesh nets do not act as a complete barrier to sharks reaching beaches as they are not permanently set in the water, do not cover the whole length of the beach, and do not extend from the water surface to the seabed. The primary purpose of shark mesh nets is not to eliminate all risk of shark attack but to reduce local shark abundance and to make it more difficult for sharks to set up home ranges in the vicinity of popular beaches. Shark mesh nets are generally set parallel to the beach in about 10–12 m of water, and out of the range of swimmers (NSW DPI, 2010).

The Queensland shark control program relies on mesh nets, drumlines, or a combination of the two. The drumlines used in Queensland comprise a series of shark hooks suspended from an inflatable buoy. The hook is baited every other day, usually with fresh sea mullet, which is a naturally occurring food source for sharks. Each drumline is anchored to the seabed using rope and a holding anchor. The bait attracts sharks and the float provides high impact resistance to set the hook if the bait is taken. Equipment is serviced every second day (weather permitting) by independent contractors who work under the supervision of fishery officers and whose performance is regularly reviewed. All fishing equipment is changed for maintenance and replaced with fresh equipment at least once every 21 days. The shark control program is presently set on 85 beaches in Queensland (QDAFF, 2012).

Meshing of New South Wales beaches (the placing of mesh nets along beaches or other waters for the purpose of protecting swimmers) commenced in 1937 and has continued to the present, with a break of three years during World War II. The program was extended to cover



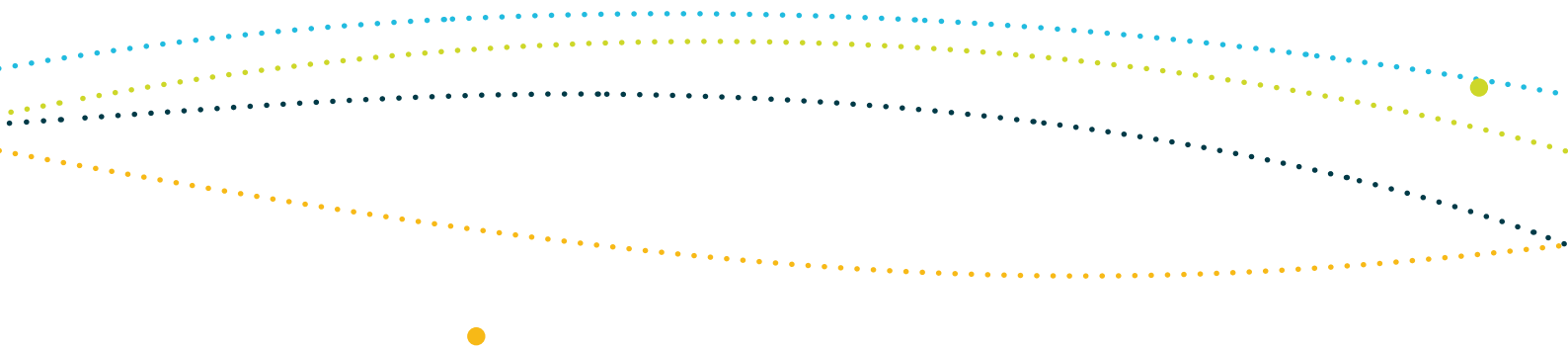
Newcastle and Wollongong beaches in 1949 and Central Coast beaches in 1987. The program presently covers 51 beaches between the Hunter region in the north to the Illawarra region in the south and there has not been a fatal attack on a meshed beach since 1951 (Reid et al., 2011). All non-dangerous and/or threatened or protected animals, including white sharks, are released from the nets if alive and where safe to do so. Where logistically possible, dead animals caught in the New South Wales beach meshing program are retained for examination.

The sizes of the mesh used in the nets have been varied over time, as has the duration the nets are set. Since 1973, the nets have had a stretched mesh size of 50 to 60 cm, have been 150 m long, six metres deep, set on the bottom in approximately 10 m of water, and usually located 400 to 500 m offshore. The program currently extends from 1 September to 30 April each season. The nets are not in place during May to August, which covers part of the peak whale migration season. Nets may not be in place on every beach every day. They are, however, currently required to be in place at each of the 51 beaches on the weekends to help minimise the risk of a shark encounter during peak beach-use period. Contractors carry out beach meshing and the nets are checked regularly for maintenance purposes and to remove any marine life caught (NSW DPI, 2010).

The Queensland shark control program commenced in 1962 and was initially restricted to the Gold and Sunshine coasts. Requests from local governments led to inclusion in the program of other beaches throughout the state, and extensions to the program occurred up to 1996. In 2012, there were 85 beaches with shark protection between Cairns and the Gold Coast (QDAFF, 2012). It should be noted that bottom set nets were phased out in 2006 and all shark control nets are now surface set. The total effort in the Shark Control Program in 2012 consisted of 35 nets and 354 drumlines (QDAFF, 2012).

5.1.3.1 Shark mortality in shark control programs

The New South Wales shark meshing program has caught and killed many thousands of sharks in the 76 years since its introduction. In the first 12 months of meshing in 1937, approximately 1000 sharks were taken off Sydney beaches alone. In the 58 years from 1950 to June 2008, more than 12 300 sharks were caught in the nets across the program, with annual shark catches during this period ranging from 76 to 650 sharks. The majority of sharks caught have been of sizes or species considered not to be dangerous. Due to changes in the numbers, sizes and mesh specifications of nets, as well as setting times, direct comparisons across years are not possible. Nevertheless, catch rates for the 18 years from 1990/91 to 2007/08 of 26 sharks per 1000 nets set are almost half the rate of the preceding 18 years

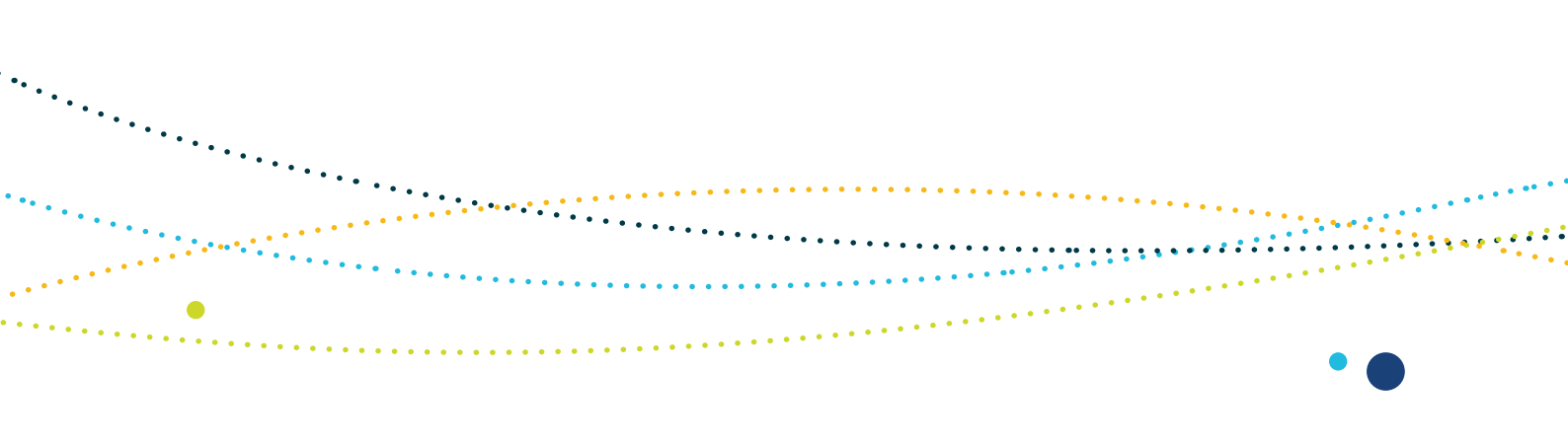


(1972/73–1989/90) of 45 sharks per 1000 nets set (Green et al., 2009). Similarly, the annual capture of all sharks from all 51 beaches of the program has generally been less than 150 sharks since 1987. The variety of sharks caught in New South Wales includes hammerheads (scalloped, smooth and great), a variety of whalers (dusky, blacktip, spinner, bronze, bull and tiger), mackerel (white, mako and thresher sharks), wobbegong, Port Jackson, grey nurse, angel and seven-gill sharks, some of which are non-dangerous and therefore are not the target of the program. Other non-shark species that are captured in the shark nets include a relatively high number of rays and a limited number of whales, dugongs, turtles and dolphins (Green et al., 2009).

Data on the numbers of white sharks caught in the New South Wales and Queensland shark control programs was provided in section 3.6 and are available at the New South Wales Department of Primary Industries (NSW DPI, 2009, 2011, 2012) and Queensland Office of Economic and Statistical Research (QOESR, 2012) websites.

White shark captures have decreased over time, while the catch effort in the New South Wales and Queensland shark control programs has increased (the catch effort is a measure of the amount of shark control equipment installed and the time it spends in the ocean). In New South Wales, species-level reporting was incomplete for the first 12 years of the program (Reid & Krogh, 1992) and thus the initial take of white sharks is unknown. Reid & Krogh (1992) reported a consistent decline in captures of white sharks subsequent to this period. These authors suggested that further catches in the program resulted from sharks (in reference to all species, including white sharks) moving into meshed areas for opportunistic feeding and breeding, or colonisation of vacant territories (Reid & Krogh, 1992; EA, 2002). However, more recent research has revealed that the white shark does not establish local territories per-se, does not breed in these areas and moves extensively along the east coast of Australia and throughout Australasian waters (Bruce et al., 2006; Bruce & Bradford, 2008). The decline in white shark captures per unit effort may reflect a reduction in the overall abundance of white sharks in eastern Australian waters, rather than localised population depletion around areas where shark control equipment is installed as proposed by previous reviews (e.g. EA, 2002). It is unclear whether changing from bottom set nets to surface set nets has assisted in reducing white shark captures in Queensland, as white sharks are known to use the entire water column when swimming in coastal waters (Bruce & Bradford, 2008).

From 1962/3 to 1971/2 (representing the first 10 years of the Queensland Shark Control Program), 247 white sharks were caught and killed in the Queensland Program and 108 were caught and killed in New South Wales—a combined average of 36 white shark mortalities each



year. Fewer white sharks have been caught in shark control programs in recent years. Over the 10 year period from 1993/4 to 2002/3, 143 white sharks were captured in the two programs — a combined average of 14 individuals each year. The catch was comprised of 52 in the mesh nets in New South Wales and 91 in Queensland, of which 60 were caught on drumlines and 31 in mesh nets. Of the 143 individuals, 138 died or were euthanised, with an average of 13.8 mortalities each year.

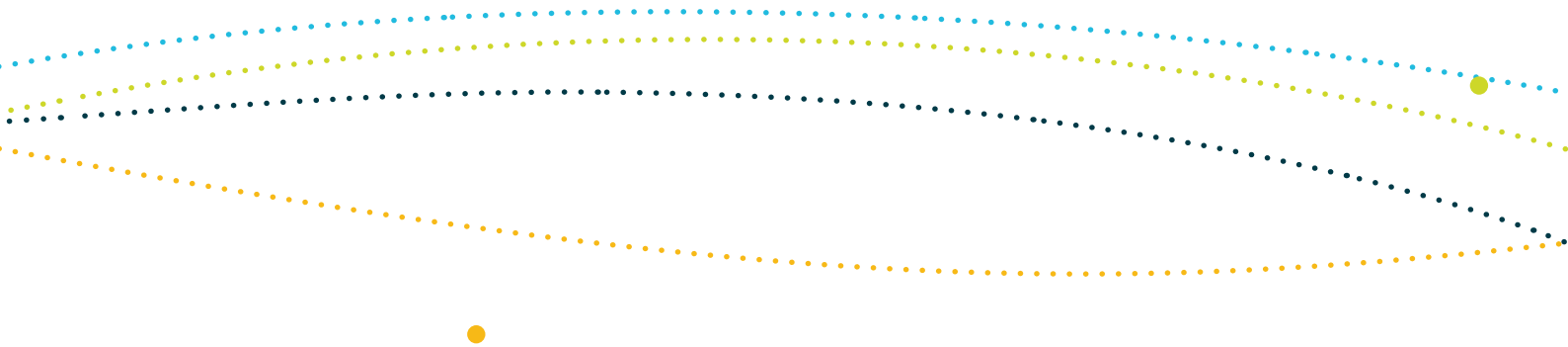
In the five years from 2003/04 to 2007/08, 41 white sharks were caught in the New South Wales program, four of which were released alive. In Queensland, a total of 16 white sharks have been caught within the same time period, of which all were euthanised. For comparison with previous years, this provides a combined average of 11 individuals per year. Data in recent years (2008/09 to 2010/11) indicate a combined average of 16 individuals per year (averaged across Queensland and New South Wales).

All white sharks captured in the Queensland Shark Control Program are currently euthanised. Since 1995/96 in New South Wales, white sharks have been released alive whenever possible (Green et al., 2009). Of the 79 white sharks caught in New South Wales between 1995/96 and 2007/08, 12 were released alive, comprising of 10 females and two males (Green et al., 2009).

5.1.3.2 Review of shark control programs

Queensland Department of Agriculture Fisheries and Forestry (QDAFF) reviewed the shark control program in 1992, 1998, 2001 and 2006 (QDPI&F, 2006). The 2006 review of the program concluded that there were no compelling reasons for change in relation to the gear being used. The Queensland Government has continued to monitor the program. The 2006 report makes some suggestions regarding a number of issues, including the minimisation of bycatch.

The New South Wales Department of Primary Industries (NSW DPI) hosted a Scientific Shark Protection Summit in April 2006 (NSW DPI, 2006). This meeting was formed in response to a directive from the New South Wales Minister for Primary Industries as a way to facilitate discussion on the issue of shark control on the east coast of Australia and to enable co-operation between the various agencies nationally. The participants were restricted to the scientific experts in the field, as well as representatives from surf lifesaver organisations. The summit identified a need to review the terms of the current beach-meshing program in New South Wales, including its objectives, observer program (e.g. using coastal lifeguards to assist in performance monitoring of shark meshing contractors) and general operation (e.g. daily checking regimes, type of boat, management of entangled individuals).



The summit recommended that a working group be formed to do an independent review of the New South Wales shark-meshing contracts. The working group was to be comprised of people with expertise in shark meshing programs (e.g. from QDAFF and South Africa).

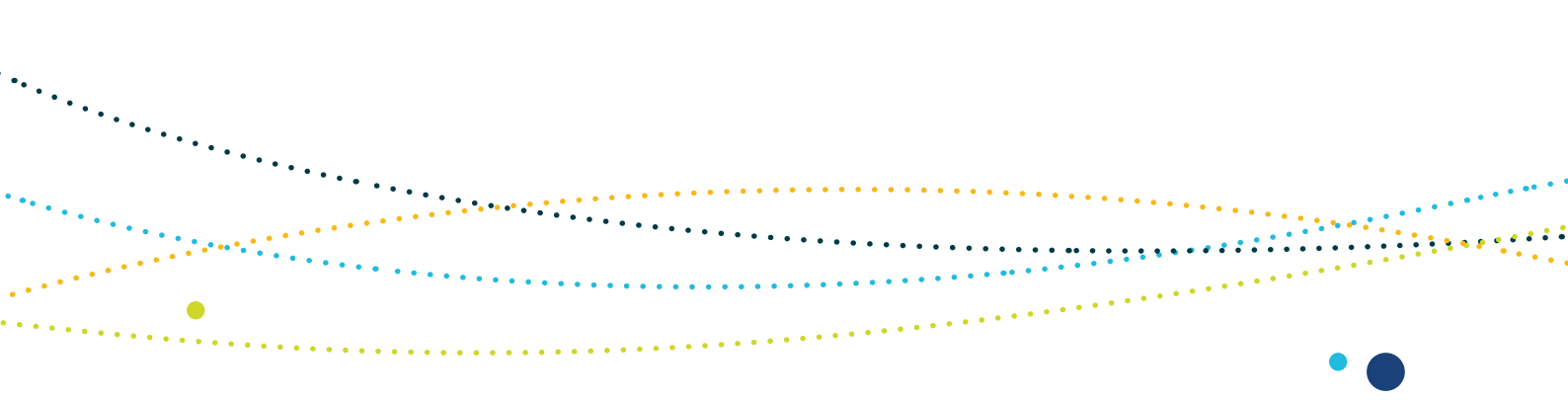
To address those matters, NSW DPI began a report into its shark meshing program in 2008, which included a risk assessment of the existing activity to inform the development of a management plan for the program. This report was released for public comment in late March 2009 (Green et al., 2009). Annual Performance Reports have been released by the New South Wales Government in 2009–2010 (NSW DPI, 2011) and 2010–2011 (NSW DPI, 2012). Both reports found that there were no shark attacks on meshed beaches in 2009–10 or 2010–11 that resulted in a fatality or posed a serious threat to life or limb. Catch statistics showed the number of white sharks reported entangled in the nets during the reportable period from 1 September 2009 to 30 April 2010 was five for 2009–10 and six for 2010–11.

5.1.3.3 Western Australia

In response to a series of shark attacks in 2011–2012, the Western Australian Government commissioned a desktop study into the effectiveness of beach meshing as a shark hazard mitigation strategy. The study, by McPhee et al. (2012), concluded that due to the environmental impacts of shark control activities, it is not recommended that either beach mesh nets or drumlines be introduced into Western Australia. The Western Australian Government is continuing to consider bather protection options.

5.1.3.4 Ongoing issues

- Shark control programs generally rely on lethal methods to control ‘dangerous sharks’ near popular beaches. Although one of the stated aims of the New South Wales program is to deter ‘dangerous’ sharks from establishing territories through their beach meshing program, evidence suggests that white sharks do not maintain ‘territories’ and more likely pass through meshed areas of the east Australian coast on route to favoured aggregation areas. New South Wales has a policy of releasing white sharks where possible; however, this is not always successful. More work needs to be undertaken to promote non-lethal methods of shark control in both the New South Wales and Queensland shark control programs.
- The collection of data from sharks taken in Australian shark control programs has been historically inconsistent and further data should be collected for research purposes. The collection and processing of samples needs to be better coordinated both within and between states.

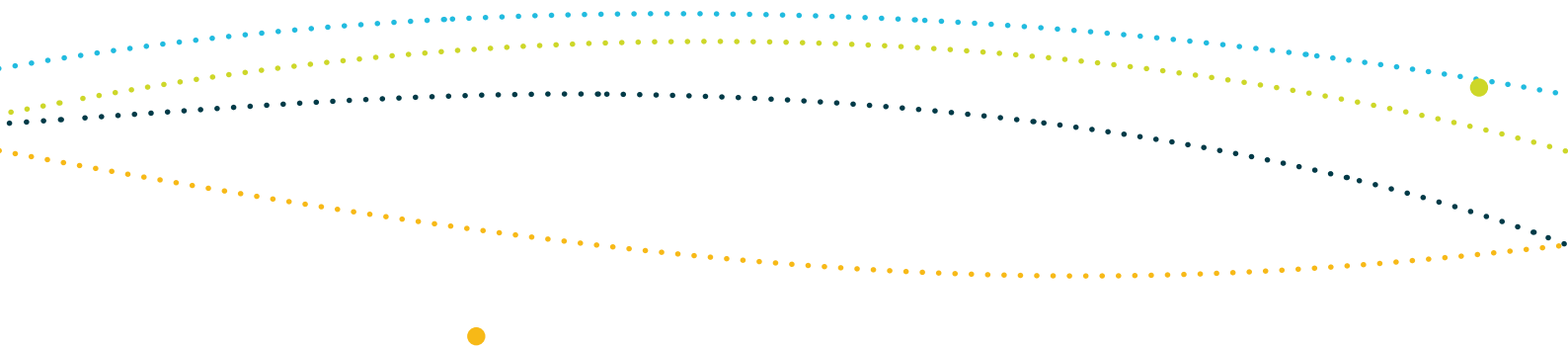
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- During the Scientific Shark Protection Summit in 2006, it was recommended that a scientifically-based risk analysis of shark attack in state waters be undertaken to provide comparative quantitative risk levels. This would assist in providing a baseline to evaluate changes to any beach meshing program to mitigate the risk of shark attack.
 - White sharks are neither evenly nor randomly distributed in eastern Australian waters and some near-shore areas are known seasonal nursery areas. The risk of interaction between white sharks, shark control program activities and beach users is thus uneven along the coast. Further research is required on the movement patterns, temporary residency areas and details of habitat use in these areas to balance the impact of shark control activities and maintaining public safety.
 - There is a need for more effective public education on the movements and behaviour of white sharks in coastal waters and specifically in surf-zone habitats.
 - Balancing perceptions of public safety (and subsequent pressure on governments to 'act' after incidents of shark attack) with conservation remains a significant issue with respect to possible actions taken that can increase threats to the species. Public education and demystifying white sharks in the public domain remains a priority.

5.2 Secondary threats

5.2.1 Trade in white shark products

The white shark is listed on Appendix II of CITES and Appendix I and II of CMS. Despite these listings, illegal trade still poses a threat to the global and Australian populations of the white shark. Traded products derived from white sharks include fins, jaws, teeth and meat (fresh, frozen or salted for human consumption), cartilage (used as a health food product), oil and hide (for leather products). White shark body parts are of considerable value. There are reports of up to \$5000 paid for jaws in Australia, about \$500 for single teeth and sets of jaws selling internationally for up to US\$50 000 (Malcolm et al., 2001; CITES, 2004a). White shark parts can now be bought and sold via the internet, without requiring access to an intermediate dealer. Despite stricter regulations on a national and international scale, the high prices obtained for white shark products provide continued incentive for illegal trade (Shivji et al., 2005).

Illegal fishers generally target larger sharks for their teeth and jaws and this could have a significant, long-term impact on population numbers. As female white sharks reach sexual maturity at approximately 4.5 to 5 m long, compared to males that reach sexual maturity at smaller sizes, it is the reproductively active females and larger males that are being targeted.



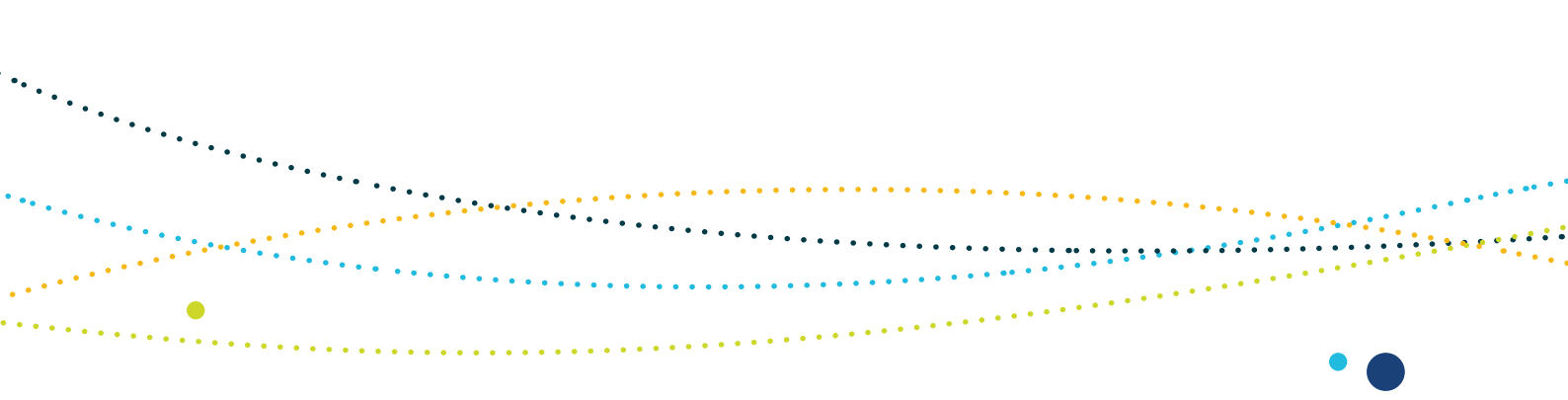
This has obvious implications for effective population size, which for this species is heavily dependent on the number of mature females (Murray-Jones, 2004).

Compounding the problem, the identification of the species-of-origin of shark products (flesh, fins etc.) is difficult, owing to morphological similarity among many species and the frequent removal of body parts (e.g. head and tail) for storage at sea (McAuley et al., 2005; Shivji et al., 2005). Historically, this has presented a major impediment to assessment of catch rates, detection of potential illicit trade and formulation of conservation strategies for individual species. However, the development of molecular techniques have resulted in a variety of genetic analysis methods that can determine the species-specific DNA sequences, which allow accurate species identification from very small samples of animal or plant material (Briscoe et al., 2005; McAuley et al., 2005; Shivji et al., 2005). In addition, morphological methods have recently been developed to identify sharks from fins (Marshall, 2011).

The impact of shark finning on global shark numbers has driven international concern over recent times (Rose & McLoughlin, 2001). While finning bans are in place in Australian waters, it is likely that white sharks are caught in international waters as part of the fin trade. Considering that recent research has identified that white sharks move in the open ocean (Boustany et al., 2002; Bonfil et al., 2005; Bruce et al., 2006), it is likely that the Australian population will be negatively impacted by finning operations that occur beyond our waters. The Commonwealth's Marine Bioregional Plans assessed the extraction of living resources related to non-domestic commercial fishing as a pressure of 'potential concern' for the white shark in the Temperate East Marine Region.

5.2.1.1 Ongoing issues

- The extent of the illegal trade in body parts and of illegal finning of white sharks in Australian waters is unknown. Genetic techniques have been developed to identify white shark products being traded, but could be applied more strategically in a program that routinely and randomly tests shark products. Such a program could identify the level of any illegal trade within Australia and provide a deterrent to such trade.
- There is currently no information on the legal and illegal take of white sharks in the broader Australasian region. Future work should establish the relative importance of this threat and how it might be impacting on white shark numbers in Australian waters.



5.2.2 Ecosystem effects — habitat modification and climate change

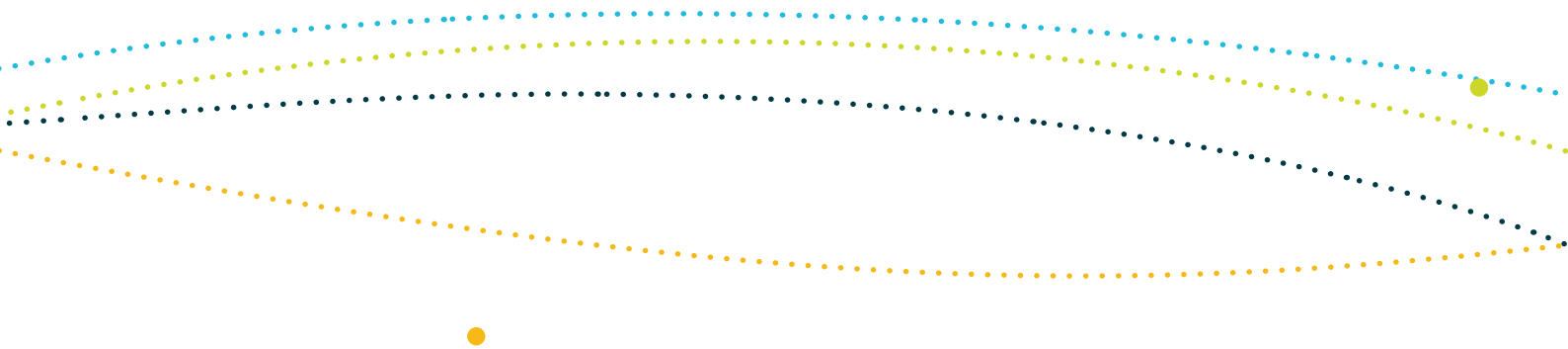
Habitat loss and/or modification resulting from coastal development has been extensive along the New South Wales coastline (Beeton et al., 2012) and is considered one of the greatest threats to biodiversity and ecosystem function as resident assemblages can be removed entirely, in turn affecting the ecosystem services provided by the assemblage (Lotze et al., 2006). The modification or loss of important habitat to the white shark therefore has the potential to impact upon the ecosystems upon which this species relies for survival. The Commonwealth Marine Bioregional Plans characterise physical habitat modification as a pressure ‘of potential concern’ in the South-west Marine Region.

Juvenile white sharks are known to occur in near-shore environments where they are vulnerable to interactions with, and impacts generated by human activities. Recent research in New South Wales and Victoria has highlighted that preferred juvenile white shark habitat can be highly localised, sometimes coinciding with areas of high human use (Bruce & Bradford, 2008). Activities such as commercial and recreational fishing, urban induced impacts and other sectoral impacts on the near-shore zone, all have the potential to either directly impact juvenile white sharks, prey species in these areas, or influence the attractiveness of these habitats to white sharks.

Climate change is a global threat to the Australian coastline, with much uncertainty around the management of potential impacts associated with changes in sea temperature, ocean currents and acidification. For sharks, increasing sea temperatures may result in changes in metabolism, behaviour and movement patterns (Chin & Kyne, 2007).

The links between white shark movements and the movements, distribution and abundance of various prey species are poorly understood. Physical changes in the marine environment via the impacts of climate change have the potential to modify the distribution of prey species (particularly finfish) in Australian waters, and thus influence the distribution and behaviour of white sharks. The nature and impact of such changes are unknown.

The Commonwealth’s Marine Bioregional Plans assessed a change in sea temperature and oceanography associated with climate changes as ‘of potential concern’ for the white shark in the South-west Marine Region and the Temperate East Marine Region. A change in ocean acidification associated with climate change was assessed as ‘of potential concern’ for the white shark in the South-west Marine Region.



White sharks feed on a wide variety of prey species at all life history stages although certain prey appear to be more important at particular life history stages (e.g. snapper, Australian salmon and various species of rays in juveniles and pinnipeds in adults). The impact of changing the distribution and abundance of the white sharks' prey species via commercial and recreational fishing or other anthropogenic activities is unknown. Establishing the likelihood and nature of such impacts remains important.

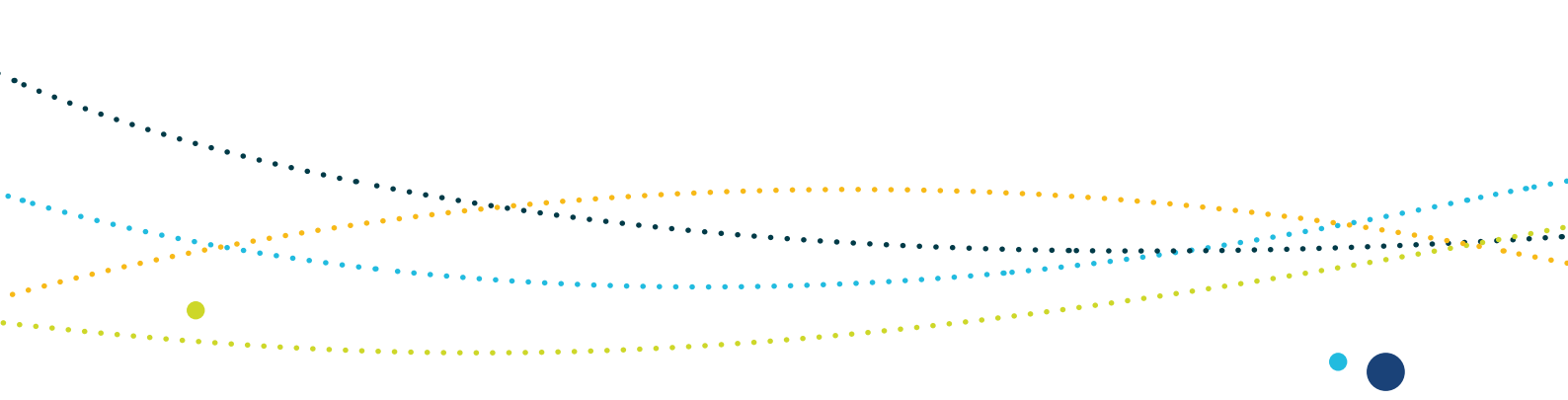
5.2.3 Ecotourism (including cage diving)

By the late 1970s, commercial tourist operations had been established for the viewing of white sharks in Spencer Gulf waters (South Australia) after the activity was trialed during the late 1960s. By the mid-1990s there were five charter companies operating out of Port Lincoln, Kangaroo Island and Adelaide. Charters predominantly targeted New Zealand fur seal and Australian sea lion colonies at the Pages Islands, Dangerous Reef, North and South Neptune Islands and the Sir Joseph Banks Group (DEH, 2005).

Since the introduction of the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan, a number of restrictions on the cage diving industry have been put in place. These include regulations on the type of berley that can be used for the purposes of attracting white sharks (fish products only), the way it is stored on vessels and restrictions on where operators can view sharks. Cage diving operators require permits from the Department of Environment, Water and Natural Resources, South Australia (DEWNR, SA) and if berleying is undertaken, a second permit from Department of Primary Industries and Regions of South Australia (PIRSA) is required. The activity is currently only permitted in the waters of the Neptune Islands Conservation Park.

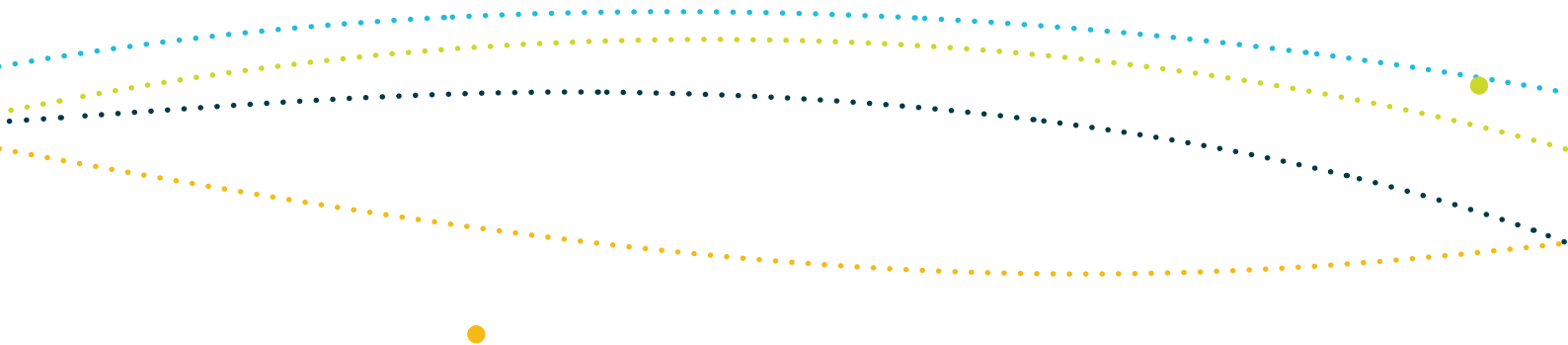
In 2013, there are only three operators undertaking shark cage diving activities, and these base their operations around North Neptune Island. Two operators have permits from the DEWNR, SA to operate as a commercial entity at the Neptune Islands and hold a berley exemption permit from PIRSA. The third operator started cage diving in 2011, this operator has a permit from DEWNR, SA to operate as a commercial entity at the Neptune Islands but does not hold a berley exemption permit from PIRSA (DEWNR SA, 2012).

As a result of the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan, a series of research projects were undertaken to examine the residency times and behaviour of white sharks at various pinniped colonies in South Australia. Bruce et al. (2005b) conducted a research project that used listening station-based monitoring of white shark residency at



the Neptune Islands and included the site of most cage dive operator activity in the main bay at North Neptune Island. Overall this study found little difference in detection patterns when operators were on site and berleying, compared to when they were not. The effects of berleying appeared to be highly localised with some evidence that individual sharks tended to spend more time in the immediate vicinity of the main bay at North Neptune Island, where operator activities were concentrated during periods of berleying. However, the mean number of sharks visiting the area was similar between berley days and non-berley days both inside and outside the bay. The report concluded that 'berleying appears to have a localised effect, increasing the detection rate of tagged sharks for a relatively short period at sites close to the berleying operation' (Bruce et al., 2005b).

The impact of berleying on shark behaviour was re-investigated by Bruce & Bradford (2011) in response to a change in industry practices, which saw the number of days where berleying occurred at the Neptune Islands rise significantly from approximately 120 days per annum prior to 2007 to 270 days per annum by 2009–2010. This study compared shark behaviour post-2008 to the data available from the earlier study. The study concluded that various aspects of shark behaviour had changed between the two study periods. These changes were restricted to North Neptune Island, where most of the berley operations occur. Observed changes in behaviour included an increase in the period of residency of sharks within the Neptune Islands system; an increase in the duration of visits to the sites where berleying occurs and changes to the daily pattern of use of these sites to more closely approximate their arrivals and departures to the daily schedule of cage diving operations. It is unclear what the broader implications of these changes are on the white shark, particularly in regards to their long-term survival and breeding success, as the white shark is only a temporary resident at these islands. Regardless, the study concluded that the observed changes in white shark behaviour are significant enough to warrant a precautionary approach to managing cage diving operations at the Neptune Islands. The study recommended reducing the exposure of sharks to berleying and bait; ongoing monitoring of shark behaviour at the islands to establish the effectiveness of any management response and an education program aimed at clients and operators of shark cage diving ventures informing them of how the industry is managed, why the management is important and how the impacts on sharks and the environment from industry activities is minimised and regulated.

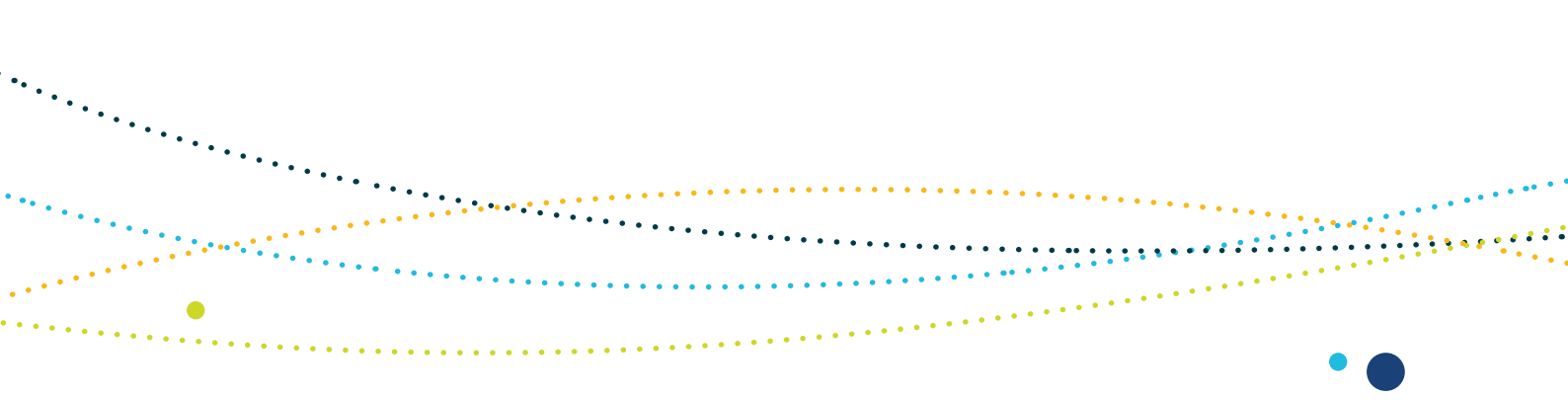


The Commonwealth's Marine Bioregional Plans assessed human presence at sensitive sites as 'of potential concern' for the white shark in the South-west Marine Region.

Shark cage dive operators continue to offer significant opportunities for white shark research and provide useful data on shark numbers through their logbooks. Cage dive tours also offer significant opportunities for public education.

5.2.3.1 Ongoing issues

- Shark cage diving has been shown to impact on the behaviour and residency times of white sharks at North Neptune Island. While the implications of these changes in behaviour are not fully understood, the findings suggest that a precautionary approach needs to be used when considering new applications for berleying permits or allowing any new cage diving operations to be established.
- Shark cage diving and shark-based tourism activities offer significant opportunities for on-going access to and research on white sharks and opportunities for public education.



6 RESEARCH AND MANAGEMENT PRIORITIES

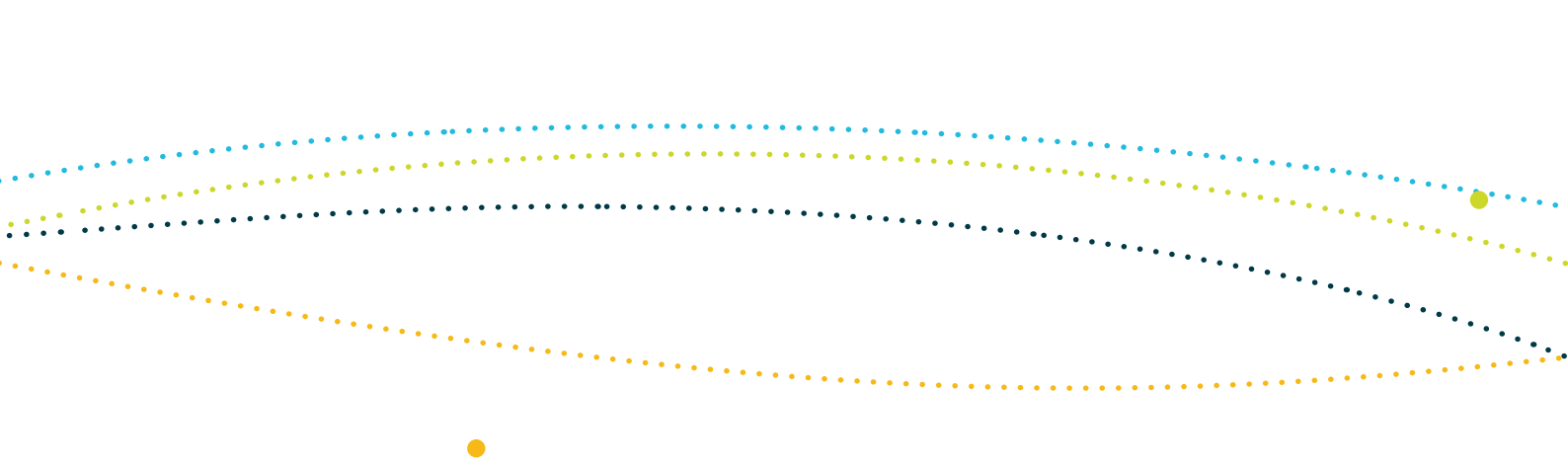
6.1 Development of a research agenda

Research on the white shark is ongoing and carried out by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), state governments and universities. Over recent years, a number of projects have been funded by the Australian Government with the explicit aim of addressing identified actions from the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan.

In October 2012, DSEWPac convened a workshop of key Australian researchers on the white shark to assess the current population data and discuss ways to improve our understanding of the Australian white shark population. This workshop outcome was agreement on the options available to address the requirements of a population assessment for this species and the process required to develop a robust assessment of the Australian white shark population.

The current research priorities include:

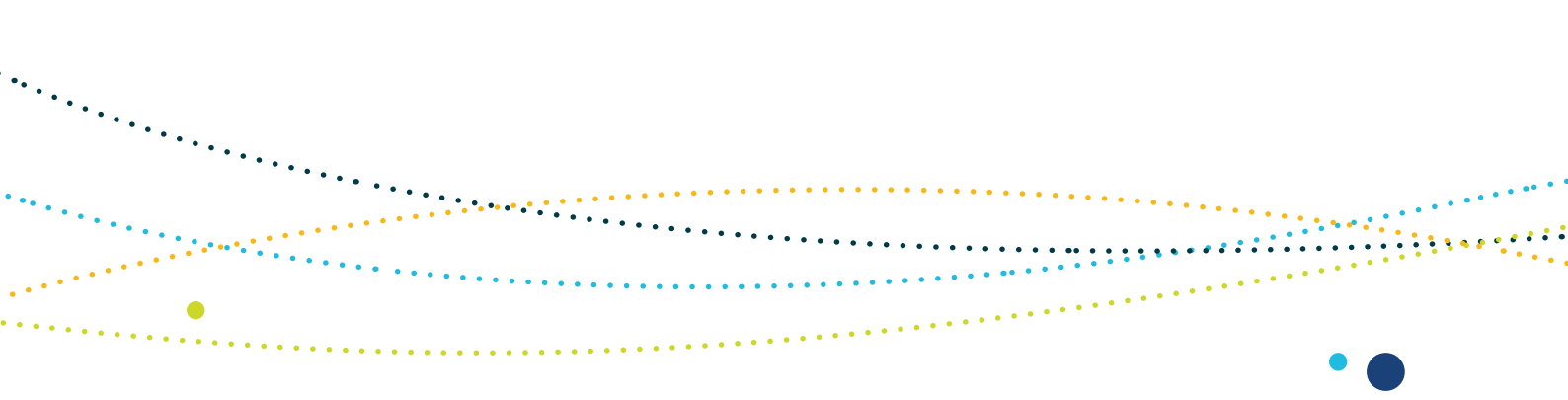
- Developing and implementing a systematic methodology for monitoring the Australian population of the white shark over time. This technique could then be used to assess the effectiveness of future white shark recovery actions.
- Estimating juvenile survival using acoustic tagging and adult survival using genetics.
- Ongoing work to identify key habitat regions, including those areas important for pupping and juvenile white shark survival.
- Further research on the inter-connectedness of the Australian white shark population within our Exclusive Economic Zone and internationally. Increasing our understanding of this relationship will help focus conservation efforts.

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- Additional coordination in the use of and collection of genetic samples to enhance understanding of the biology, distribution, population sub-structuring and, potentially, population estimates of white sharks.
 - A focus on expanding the underwater acoustic listening station network around Australia and increasing the number of white sharks tagged with acoustic transmitters. A general expansion of the tagging program using other sorts of tags, such as pop-off archival tags and satellite tags, is an area of future research. This research possibly could include the commercial fishing sector and the shark control programs run by the New South Wales and Queensland governments.
 - Undertaking a comprehensive assessment of the estimated interactions of white sharks with the commercial and recreational fishing sectors. Currently estimates rely solely on logbook reporting and notification by fishers in the recreational sector. Current estimates of capture and interactions by these sectors are clearly an underestimate. Considering the steep decline reported in white shark interactions from the commercial sector, an independent project should be undertaken examining the scope and veracity of these reports.
 - Examination of post-release mortality by commercial fishers and in shark control programs through the use of tagging studies.

6.2 Community education strategy

The volume of information on white sharks that is available has increased dramatically since the 2002 White Shark (*Carcharodon carcharias*) Recovery Plan was released. Commonwealth departments involved in the implementation of the recovery plan have provided detailed information regarding the protection status of the white shark, changes to legislation, and reporting requirements for both recreational and commercial fishers. State agencies responsible for management of coastal and marine environments have implemented initiatives to raise awareness of white shark-related issues. These include: identification guides, websites that contain comprehensive information on white shark biology and research, guidelines for the public (such as safe swimming guidelines) and telephone reporting services for white shark interactions and sightings. For an example see NSW Governments' shark smart website at: www.dpi.nsw.gov.au/fisheries/info/sharksmart

Information on reporting requirements regarding incidental interactions with white sharks is also available on state and Australian Government websites (NSW: www.dpi.nsw.gov.au/fisheries/species-protection/report-it; Queensland: www.daff.qld.gov.au/28_12726.htm; Australian Government: www.environment.gov.au/epbc/permits/notifications.html for interactions in Commonwealth waters). However, it is unclear how well understood these requirements are amongst the general public, particularly recreational fishers who are not involved with any of



the recreational fishing organisations. In addition, there is a large amount of information on white sharks available on the internet — although much of this information has not been peer reviewed and therefore may not be as reliable as factual educational material.

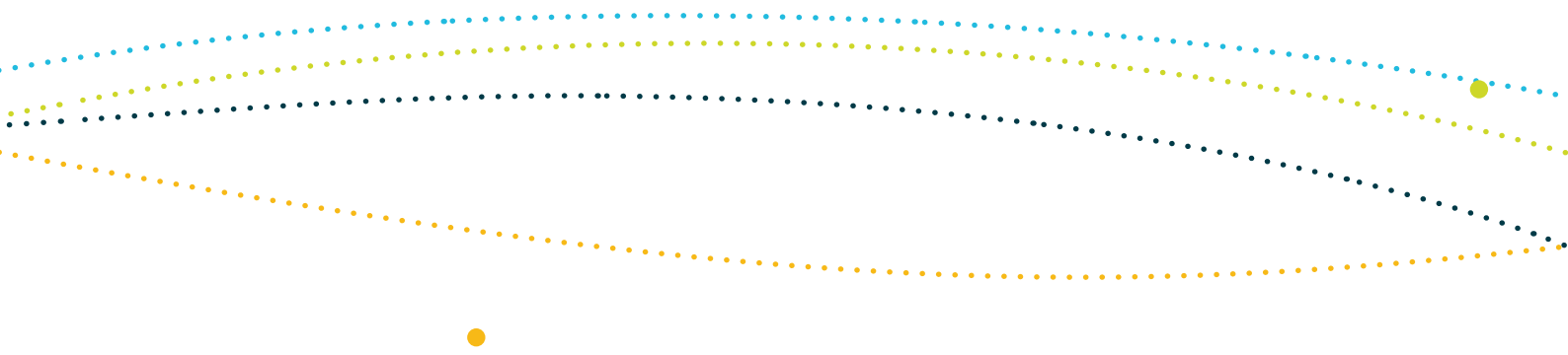
6.2.1 Ongoing issues

- An assessment needs to be made of the effectiveness of white shark education programs, in order to better target new programs towards recreational and commercial fishers, as well as the public and media in general to promote awareness of white shark biology, juvenile identification, and regulations and legislation protecting white sharks in Australia.
- Effective programs of education need to be implemented taking consideration of the above.

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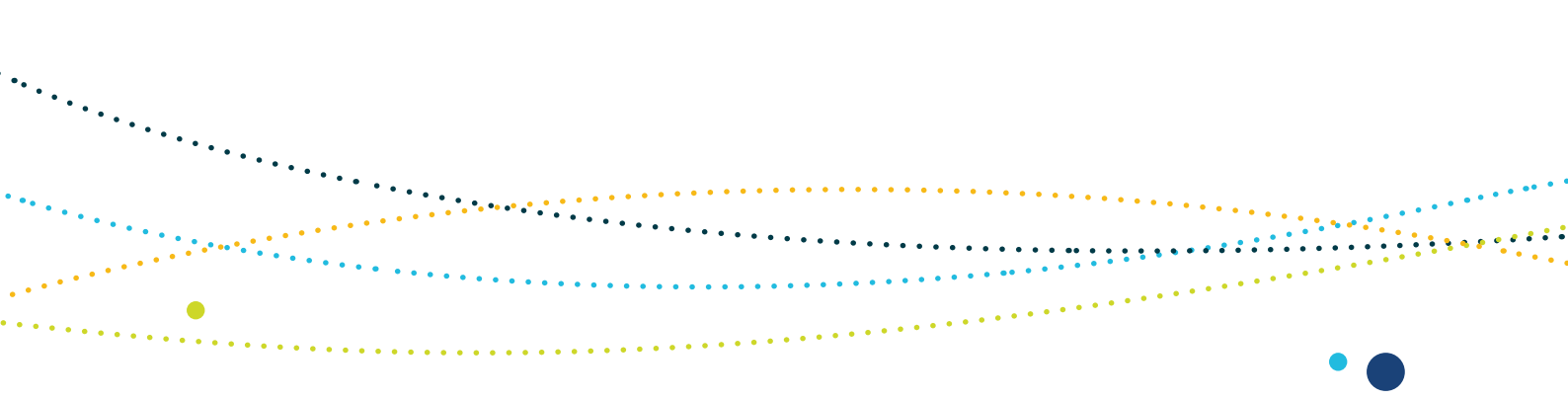
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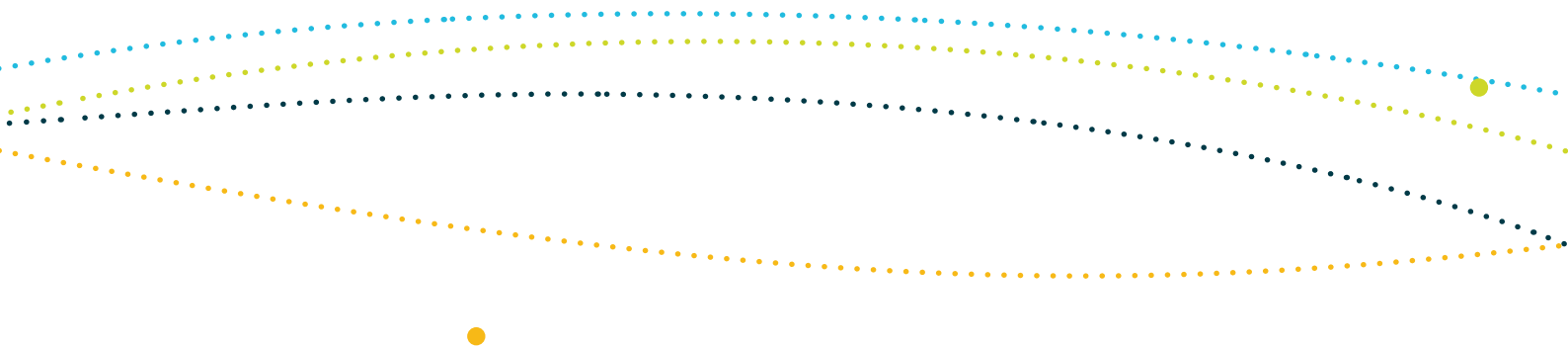
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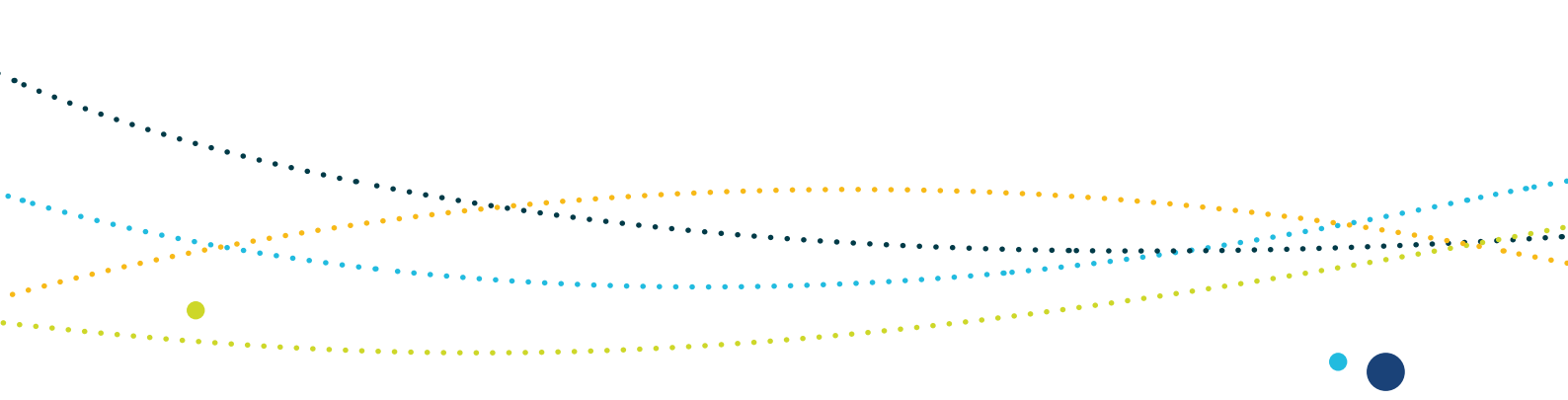
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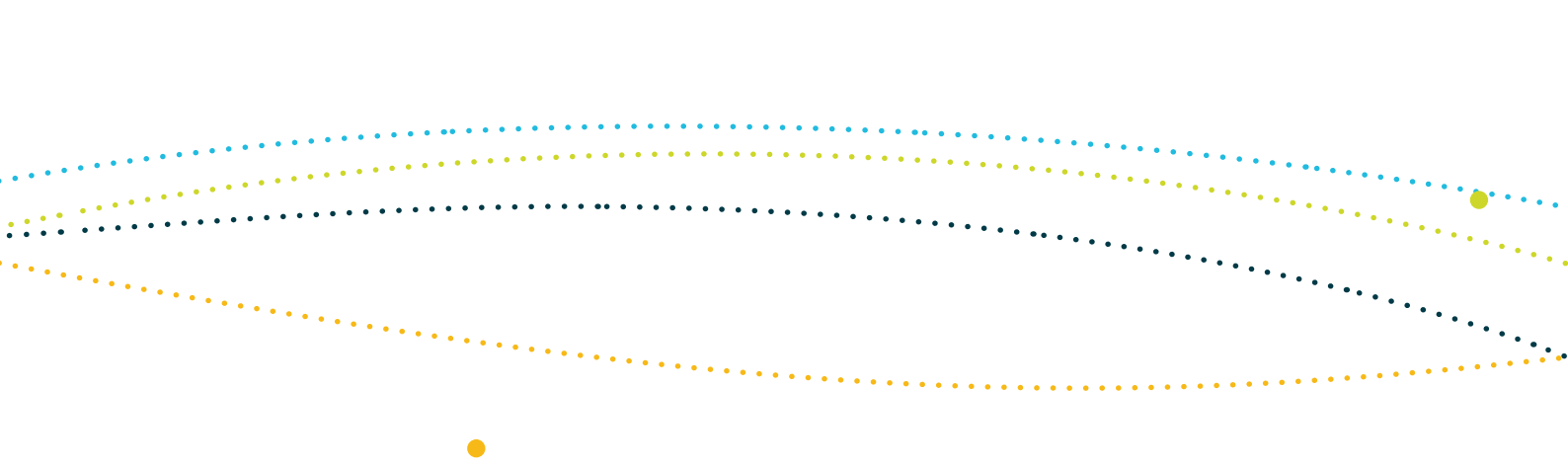
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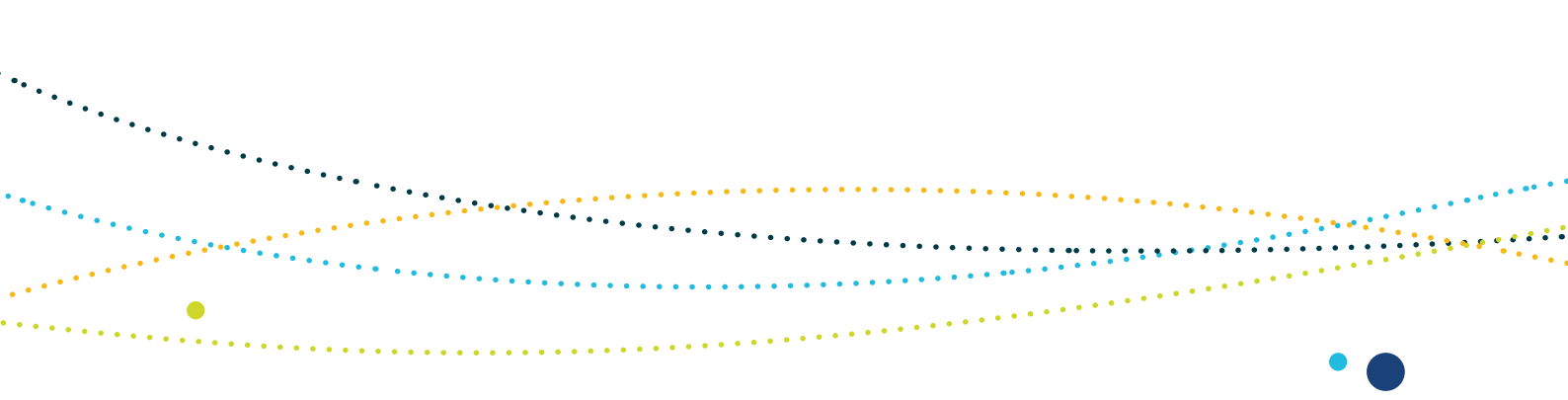
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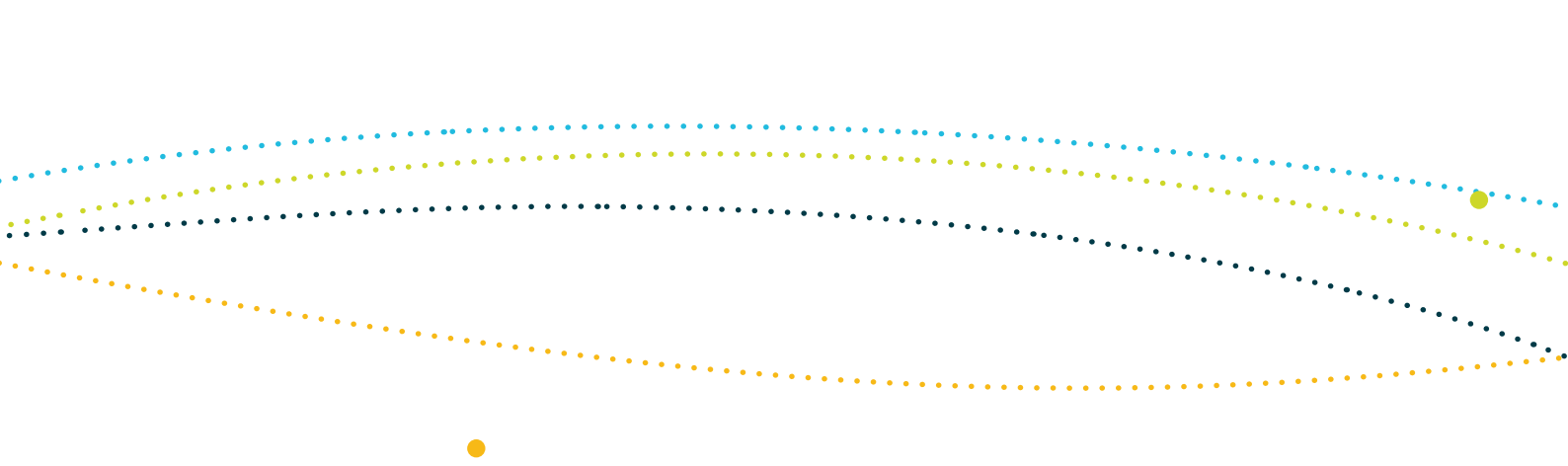
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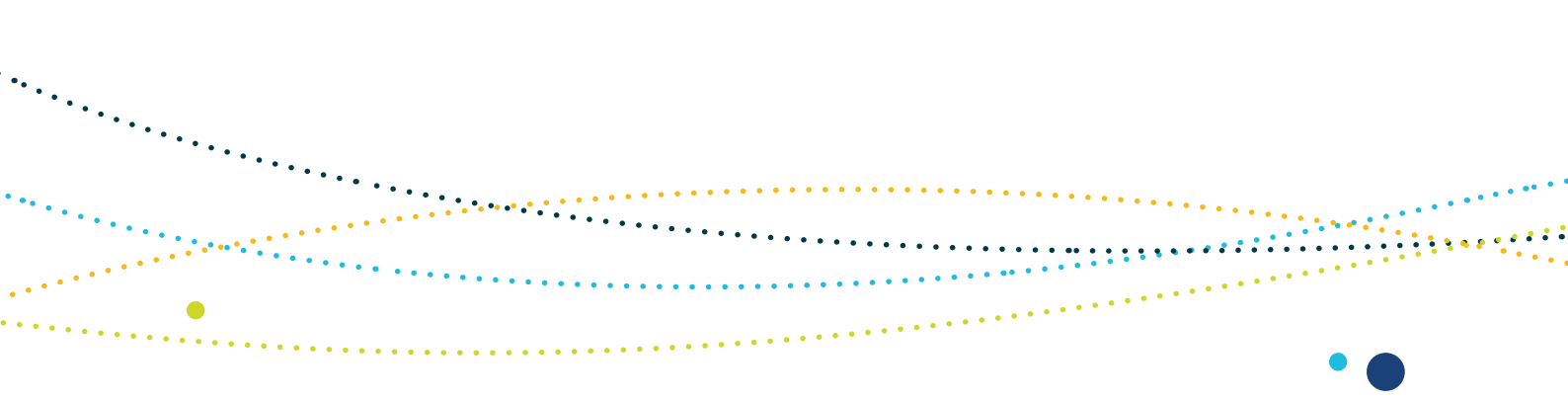
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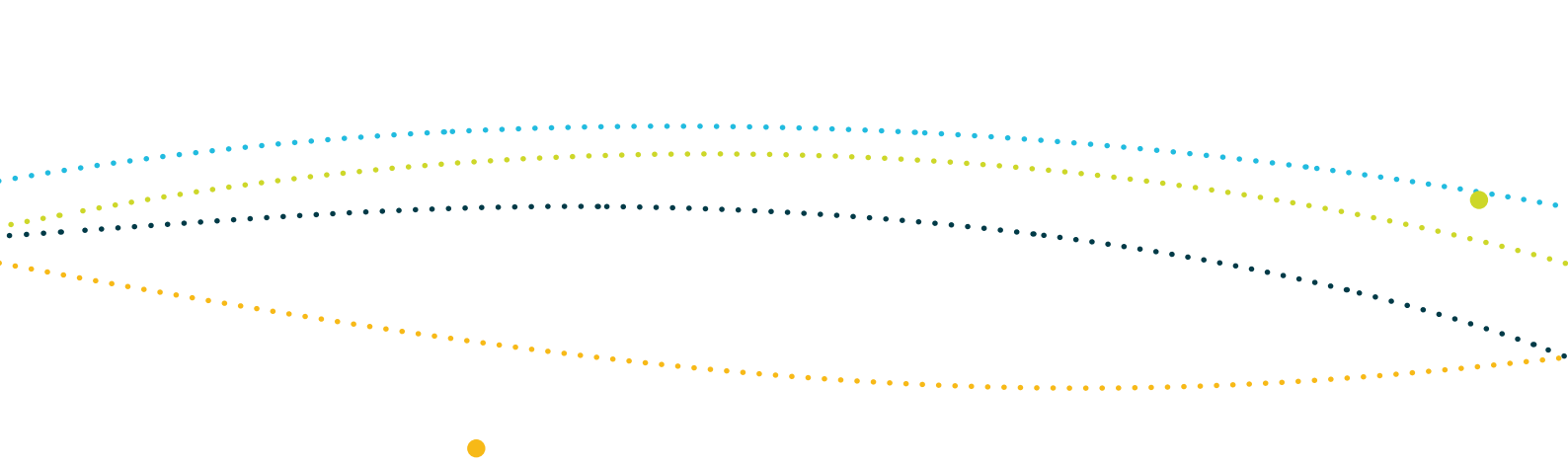
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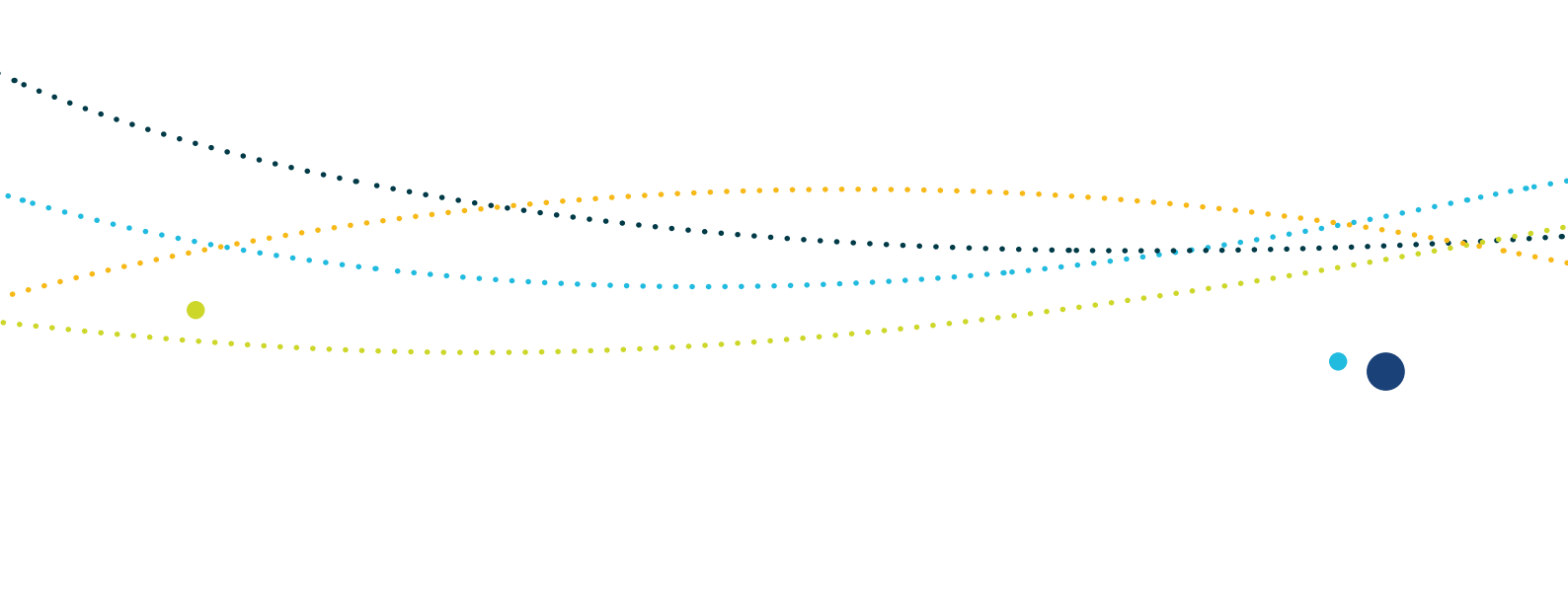
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