



Australian Government
Department of the Environment

Issues Paper for the Grey Nurse Shark (*Carcharias taurus*)



2014

The recovery plan linked to this issues paper is obtainable from:

<http://www.environment.gov.au/resource/recovery-plan-grey-nurse-shark-carcharias-taurus>

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Abbreviations

AFMA	Australian Fisheries Management Authority, Commonwealth
ASFP	Australian Society for Fish Biology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoE	Department of the Environment
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
QDPI&F	Queensland Department of Primary Industries and Fisheries
SEACAMS	Sustainable Expansion of the Applied Coastal and Marine Sectors

1 Summary

The grey nurse shark (*Carcharias taurus*) is listed as two separate populations under the *Environment Protection and Biodiversity Conservation Act 1999*. The east coast population is listed as critically endangered and the west coast population is listed as vulnerable. A recovery plan for the species was finalised in 2002.

A review of the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia was completed in 2009. The review concluded that while progress had been made on most of the recovery plan actions, there was not sufficient evidence to indicate that the population had recovered sufficiently to be removed from the list of protected species. The review further concluded that a new recovery plan was required to remove completed actions and include new conservation priorities. The Department of the Environment, with the support of key stakeholders, has developed a new recovery plan for the grey nurse shark.

This issues paper has been developed to support the development of the new recovery plan and includes information on the biology and ecology of grey nurse sharks, 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:

- Recent research has obtained a relatively robust population estimate for the east coast grey nurse shark population. Recent studies suggest estimates of population size are above 1131 individuals, with the highest estimate being 2142 individuals. While this number is still very low and does not warrant changing the protected status of the east coast population from critically endangered, it is higher than previous estimates.

- Since the introduction of the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia, all but one of the 19 key aggregation sites identified as habitat critical to the survival of the species in the 2002 recovery plan have been given some level of protection. The remaining site—China Wall off Moreton Island in Queensland—was ultimately not considered a key aggregation site as the sharks were not consistently seen there.
- Fishing pressure from the recreational and commercial sectors represents the greatest ongoing threat to the grey nurse shark in Australian waters, followed by mortalities as a result of the New South Wales and Queensland bather protection programs (beach meshing/ drumlining¹).
- Despite significant advances over the last decade in the knowledge base concerning the grey nurse shark in Australian waters, 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 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) 2014 can be found at: <http://www.environment.gov.au/resource/recovery-plan-grey-nurse-shark-carcharias-taurus>

¹ The drumlines used in Queensland comprise a series of baited shark hooks suspended from an inflatable buoy.

2 Introduction

2.1 Purpose

The purpose of this paper is to provide a summary of the biology, population ecology and current threats to the grey nurse shark in Australian waters and to make recommendations on the future research necessary to protect this species. This paper has been written to inform the development of a revised recovery plan for the grey nurse shark and is designed to be read in conjunction with the Review of the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (DEWHA, 2009) and the Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) 2014 (DoE, 2014).

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 grey nurse 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.



Photo by Justin Gilligan

2.3 Scope

This document provides a contemporary picture of the biology and ecology of the grey nurse 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 declines.

2.4 Sources of information

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

2.5 Recovery planning process

2.5.1 Purpose of recovery plans

The Australian Government minister responsible 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 Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (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 Grey Nurse Shark Recovery Plan

The overarching objective of the Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) 2014 is to assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to:

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

The east coast population of grey nurse shark is considered to be critically endangered and this population will be the primary focus of the actions outlined in the recovery plan, with an emphasis placed on monitoring and compliance. Although the proposed actions are still relevant to the west coast population, further information is required to better understand the status of the population in the west and the importance of critical habitat sites for that population.

3 Biology and ecology

3.1 Species description

The grey nurse shark (*Carcharias taurus*) (Rafinesque, 1810) is one of three species belonging to the family Odontaspidae (Last & Stevens, 2009). It is also known as the sand tiger shark in the north-west and south-west Atlantic and the spotted ragged-tooth shark in South Africa (Pollard, et al., 1996; Last & Stevens, 2009). The species has a large stout body and is coloured grey to grey-brown dorsally, with a paler off-white underbelly.

Key morphological characteristics include a conical snout, long awl-like teeth in both jaws, similarly-sized first and second dorsal fins and an asymmetrical caudal (tail) fin (Pollard, et al., 1996; Last & Stevens, 2009). The species is a slow but strong swimmer and is thought to be more active at night (Pollard, et al., 1996). The caudal fin and posterior half of the body often have reddish or brownish spots (Pollard, et al., 1996; Bansemer & Bennett, 2008; Last & Stevens, 2009). Grey nurse sharks can grow to a maximum total length of 318 cm and a maximum weight of approximately 190 kilograms (kg) (Pepperell, 1992; Cavanagh, et al., 2003; Last & Stevens, 2009).

3.2 Life history

3.2.1 Reproduction

The grey nurse shark has a relatively slow development and low reproductive rate with a long gestation period (Bass, et al., 1975; Gilmore, et al., 1983). It has an unusual reproductive mode (NSW DPI, 2002; Gilmore, et al., 2005) which includes intra-uterine cannibalism (adelphophagy), whereby embryos (about 100 mm long and with well developed teeth) hunt and consume other embryos until only one remains in each of the two uteri, resulting in only two pups in a litter (Gilmore, et al., 2005; Last & Stevens, 2009). After the cannibalistic stage (approximately 100 days after first insemination and at approximately 335 mm in length) the single remaining embryo in each uterus then feeds on unfertilised ova (oophagy) resulting in its body wall extending to produce a “yolk-gut” (Bass, et al., 1975; Compagno, 1984; Gilmore, et al., 2005). During the last 100 days no feeding on ova occurs. Instead the yolk in the gut is absorbed and the baby shark gradually resumes its normal shape in readiness for birth. Gestation is thought to take between nine and 12 months and at birth, pups are about one metre long (Last & Stevens, 2009).



Photo by Justin Gilligan

Grey nurse shark reproduction has been found to be biennial—that is, these sharks pup every second year (Bass, et al., 1975; Lucifora, et al., 2002; Dicken, et al., 2006, 2007). Although grey nurse sharks are thought to have a biennial reproductive pattern in Australia, a recent study along the east coast suggests that some individuals may take an extra year between mating and/or pregnancy events potentially resulting in a three year interval (Bansemer & Bennett, 2009). However, this study was based on photo-identification and observational data alone and further work is required to verify this finding.

3.2.2 Age and growth

Studies of the grey nurse shark in South Africa and Australia indicate that individuals may live for up to 35 years in captivity (Smith, et al., 1998). There is less certainty about maximum ages reached in the wild but it is thought that wild male sharks may live for up to 30 years and female sharks for 40 years (Goldman, et al., 2006).

Research in the north-western Atlantic Ocean by Goldman, et al., (2006) indicates that growth rates of the sexes are similar up to the age of five years, at which time females outgrow males at a significant rate. The total length at maturity for females was estimated at 2.2–2.6 m (9–10 years) and for males at 1.9–2.2 m (6–7 years) (Bass, et al., 1975; Gilmore, et al., 1983; Branstetter & Musick, 1994; Lucifora, et al., 2002; Goldman, et al., 2006). Based on analysis of the Australian population, 50 per cent of males are reproductively mature at a total length of 2.1 m and 50 per cent of females are reproductively mature at a total length of 2.6 m (Otway, et al., 2009; Otway & Ellis, 2011).

3.3 Diet

The diet of adult grey nurse sharks consists of a wide range of fish, other sharks and rays, squid, crabs and lobsters (Compagno, 1984). In the north-west Atlantic the grey nurse shark diet has been shown to consist primarily of fish and elasmobranchs (dominated by rajid skates). In South Africa, grey nurse sharks have been shown to feed on herring

(family Clupeidae), mackerel (family Scombridae), butterfish (family Sciaenidae), snapper (family Lutjanidae), wrasse (family Labridae), mullet (family Mugilidae), sole (family Solidae), small sharks and rays (including eagle rays and juvenile *Carcharhinus* spp.), squid, and occasionally crustaceans (Bass, et al., 1975; Compagno, 1984).

Over the past decade, necropsies of accidentally caught and killed grey nurse sharks from eastern Australian waters have confirmed a wide-ranging fish based diet, similar to that of grey nurse sharks in other parts of the world. The gut contents of these animals have included pilchards (family Clupeidae), mulloway (family Sciaenidae), tailor (family Pomatomidae), Australian bonito (family Scombridae), blue groper (family Labridae), snapper (family Sparidae), sea mullet (family Mugilidae), flathead (family Platycephalidae), silver trevally (family Carangidae), eastern Australian salmon (family Arripidae), small and juvenile sharks (*Carcharhinus* spp.) and squid (Otway, et al., 2003).

Stomach contents of 22 grey nurse sharks caught off the west coast of Australia included whiting (family Sillaginidae), buffalo bream (family Kyphosidae), breaksea cod (family Serranidae), dusky morwong (family Cheilodactylidae), mackerel (family Scombridae), pilchards (family Clupeidae), goatfish (family Mullidae), scorpionfish (family Scorpaenidae), pink snapper (family Sparidae), trevally (family Carangidae) and numerous unidentified teleosts and octopi. As all sharks examined were captured in demersal gillnets, it cannot be determined whether these dietary items represent natural prey species, or were opportunistically consumed from the same nets (McAuley, 2009). However, given the similarities with the diet of the east coast population, it appears likely these data reflect the natural diet of the Australian west coast population.

3.4 Distribution

Grey nurse sharks have been recorded from tropical and temperate parts of the north and south Atlantic, Indian and western Pacific Oceans. They are known to occur on the continental shelf from the surf zone down to at least 190 m (Last & Stevens, 2009) and

occasionally off the continental shelf to depths of approximately 230 m (Otway, et al., 2009).

The Australian east coast population covers a range of approximately 2700 km and extends from the Capricornia Coast (central Queensland) to Narooma in southern New South Wales (Otway, et al., 2003; Bansemer, 2009; Otway, et al., 2009). Grey nurse sharks have been recorded at 153 locations along the east Australian coast as far south as the NSW/Victorian border (NSW DPI, 2002).

Figure 1 includes grey nurse shark sightings collected by the New South Wales Department of Primary Industries (NSW DPI) and includes recognised aggregation sites (five or more sharks), sites where small aggregations have been observed (fewer than five sharks) and also sites where single sharks have been recorded.

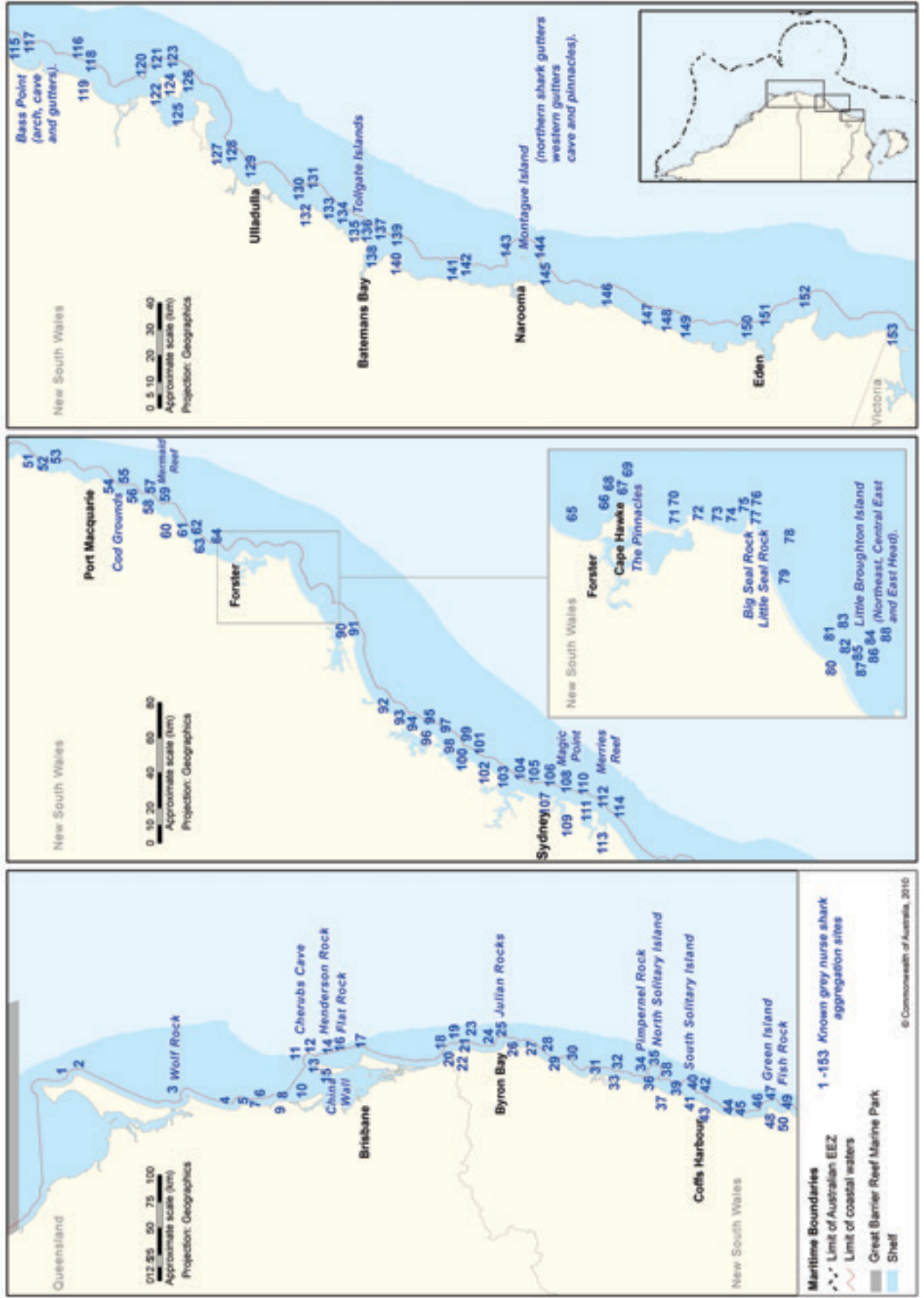
The range of the west coast population is less well known. However, commercial fishery shark bycatch data, fishery and research records, as well as detailed interviews with commercial fishers, professional dive operators and members of dive clubs, indicate that the species occupies sites from the North West Shelf (including coastal waters in Exmouth Gulf), south to coastal waters near Cocklebidy in the Great Australian Bight (McAuley, et al., 2002; Cavanagh, et al., 2003; Chidlow, et al., 2005), covering a range of approximately 2900 km.

The only Northern Territory record is from around Lynedoch Bank in the Arafura Sea (Northern Territory Department of Natural Resources, Environment and the Arts, 2006). However, as this is a single sighting it has been assumed that these sharks were either misidentified or were vagrants.



Photo by Justin Gilligan

Figure 1: Grey nurse shark sightings



3.5 Aggregation sites

Grey nurse sharks in the east coast population tend to be found together in groups at specific locations.

These locations are commonly known as aggregation sites. Otway, et al., (2003) defined aggregation sites as being locations where five or more grey nurse sharks were regularly found throughout the year. For the purposes of this paper, the Otway, et al., (2003) definition of aggregation sites will be used.

Grey nurse sharks are often observed aggregating around inshore rocky reefs or islands. At these locations they are typically found near the bottom (at depths of 10–40 m) in deep sandy or gravel filled gutters, or in rocky caves (Otway & Burke, 2004; Dicken, 2006; Last & Stevens, 2009). Grey nurse sharks have also been observed congregating in the mid-water column adjacent to, or above pinnacles or wrecks, at depths of five to 15 m.

Research has identified differences in the way males, females and juveniles use the aggregation sites.

Research by the NSW DPI has identified behaviours, such as segregation according to size and sex (Otway, et al., 2003). Studies in New South Wales have shown that while a sex ratio of 1:1 exists over the coastline as a whole (Otway, et al., 2004), proportionally more juvenile and adult male sharks have been found at aggregation sites off Forster and sites to the north, whereas proportionally more juvenile and adult female sharks have been found off Seal Rocks and sites to the south. The differences in sex ratios between these sections of coastline were attributed to a combination of sexual segregation, reproductive activities (pupping and mating) and sex-related differences in migratory movements (Otway, et al., 2003).

It has also been suggested that the distribution of pregnant grey nurse sharks at aggregation sites throughout most of their gestation is seasonally and temporally distinct from other grey nurse sharks, and that pregnant females may prefer particular aggregation sites over others (Bansemer, 2009).

Further research is required to better understand the use of particular aggregation sites by pregnant females. Juvenile sharks, in addition to being found at regular aggregation sites, have also been observed in small gutters and crevices in shallow, wave-exposed waters

close to known aggregation sites but segregated from other adult sharks (Bansemer, 2009; Cardno Ecology Lab, 2010).

Surveys by the NSW DPI (Otway & Parker, 2000; Otway, et al., 2003) showed that grey nurse sharks were consistently found in aggregations of five or more individuals at 14 sites along the New South Wales coast, of which two were in Commonwealth waters. These sites were deemed 'key sites' in Otway, et al., (2003) and, along with five sites identified in Queensland waters, labelled as 'key aggregation sites' or 'habitat sites critical to the survival of grey nurse sharks' in the 2002 recovery plan (EA, 2002).

Additional sites along the New South Wales coast, which had five or more sharks, were recently identified as part of a survey undertaken by Cardno Ecology Lab (2010). These additional sites were mostly at already identified locations but were at separate reefs to those listed in Otway, et al., (2003) and the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002). In particular, significant additional sites were found near Brunswick Heads, the Solitary Islands, Laurieton, Forster, Seal Rocks, Broughton Island and the Central Coast. Mermaid Reef near Laurieton has also been recognised in NSW as a key aggregation site and afforded protection. However, as the Cardno Ecology Lab study was confined to only two surveys, more research is needed to confirm the long term importance of the other additional sites before they can be considered as known 'key aggregation sites'.

The China Wall aggregation site in the Moreton Bay Marine Park, Queensland, was identified in the 2002 recovery plan (EA, 2002) but is not considered a 'key aggregation site' by current definitions. This is because the number of individual grey nurse sharks observed at any one time is consistently less than five, and sightings of grey nurse shark at the site are generally infrequent compared to those at other sites (Bennett & Bansemer, 2004).

Currently there are no aggregation sites officially recorded for the west coast grey nurse shark population. Targeted research has been undertaken to identify sites (Chidlow, et al., 2005); however, this project failed to confirm any aggregations or individual grey nurse sharks. The study concluded that

this failure to find any grey nurse sharks was unlikely to be due to the absence of grey nurse shark across the study region. An examination by the study team of fishery and research records, in combination with detailed interviews with commercial fishers, professional dive operators and members of dive clubs, provided anecdotal evidence that grey nurse sharks were widely distributed along the western Australian coast. The study authors suggested that the apparent absence of known grey nurse shark aggregations on the west coast may have been due to the aggregations being located in deeper water beyond normal scuba diving limits and therefore undetectable by diver

surveys. Alternatively, it may be possible that the west coast population of the grey nurse shark behaves differently from the east coast population and aggregations are not as common (Chidlow, et al., 2005). While game fishing records from 1960 to 1977 suggest that suitable grey nurse shark habitat may also be located further offshore in deeper water (Pepperell, 1992), no offshore deep water aggregation sites have been confirmed to date.

Currently confirmed key aggregation sites critical to the survival of the grey nurse shark are summarised in Table 1.

Table 1: Known key aggregation sites critical to the survival of the grey nurse shark in Australian waters

Queensland Waters
Wolf Rock off Rainbow Beach
Cherubs Cave off Moreton Island
Henderson's Rock off Moreton Island
Flat Rock off North Stradbroke Island
New South Wales Waters
Julian Rocks near Byron Bay
North Solitary Island (Anemone Bay)
South Solitary Island (Manta Arch)
Green Island near South West Rocks
Fish Rock near South West Rocks
Mermaid Reef near Laurieton
The Pinnacle near Forster
Big Seal, Seal Rocks
Little Seal, Seal Rocks
Little Broughton Island near Port Stephens
Magic Point at Maroubra, Sydney
Tollgate Islands near Batemans Bay
Montague Island near Narooma
Commonwealth Waters (off New South Wales Coast)
Pimpernel Rock off Brooms Head (northern section of Solitary Islands Marine Park)
Cod Grounds off Laurieton

3.6 Localised movements at aggregation sites

Several tracking studies on the east coast of Australia have been undertaken using transmitters attached to grey nurse sharks, in order to determine localised movements of sharks at aggregation sites (Bruce, et al., 2005; Bansemer & Bennett, 2009; Otway, et al., 2009). These studies have all concluded that when in residence at an aggregation site, the sharks tend to stay close to the site for the majority of the time, but do undertake small excursions of up to 1500 m away from the site. These excursions were seen to occur during day or night but were more common at night (Bruce, et al., 2005; Otway, et al., 2009). When in residence the sharks tend to patrol back and forth in the gutters. Otway, et al., (2009) estimated that individual grey nurse sharks tend to remain at an aggregation site for between one day and in excess of six months, with an average of about 11 days.

3.7 Migratory movements

The most detailed assessment of grey nurse shark migratory movements has been undertaken in South African waters. In South Africa, adult grey nurse sharks—particularly females—have been shown to be highly migratory. Female sharks undergo a well-defined biennial migration through distinct phases of mating, gestation and giving birth. Mating is believed to occur in the central part of their distribution, along the south-coast of KwaZulu-Natal in mid to late spring. After mating, females are thought to migrate northwards to gestate in warmer waters. Towards the latter part of gestation—from late winter to spring—the sharks migrate south to colder waters, where they pup and remain for a year before they return north again to mate (Smale, 2002; Dicken, et al., 2006, 2007). There is less information on mature male migration patterns (Dicken, et al., 2007). Grey nurse shark nursery areas have been identified in the Eastern Cape region in shallow inshore waters, where juvenile grey nurse sharks may remain for the first four to five years of life before joining the adult populations (Smale, 2002). The juveniles are considered to be much less migratory than adults, rarely venturing further than 50 km from the nursery areas (Dicken, et

al., 2006, 2007), although this finding may be an artefact of the tagging technique and frequency of sampling. The average distance moved between sites for mature sharks has been measured at 342 km compared to 18.7 km for juvenile sharks. The greatest distance a juvenile grey nurse shark was recorded to have moved between sites was 268 km compared to a maximum of 1897 km for a mature shark (Dicken, et al., 2006, 2007).

Research on the movements of grey nurse sharks along the east coast of Australia has also shown a strong migratory pattern, with a northerly migration of grey nurse sharks over autumn and winter followed by a southerly migration in spring and summer (Otway & Burke, 2004; Bansemer, 2009; Otway, et al., 2009; Otway & Ellis, 2011). These studies show that grey nurse sharks typically move in relatively shallow waters (less than 80 m) but also exhibit movements offshore and into deeper waters, albeit for limited durations (Otway, et al., 2009). Otway & Ellis (2011) showed evidence of mature males swimming in shallower waters (less than 50 m) during the northward migration, while travelling in deeper waters (60–80 m) during the southward migration. Otway & Ellis (2011) further showed that migration was often punctuated by occupation of sites en-route for periods of up to 14 days.

On the east coast of Australia, migratory movements have also been shown to be sex-biased and linked to level of maturity. There is evidence that the distribution and movement patterns of larger individuals varies with reproductive activities while immature sharks of both sexes tend to be found mostly in the mid to southern parts of the species east coast range (Otway & Burke, 2004; Bansemer, 2009, Otway & Ellis, 2011). Mature grey nurse sharks have been recorded moving distances of up to 1260 km for a female (Bansemer, 2009) and up to 1550 km for a male (Otway & Ellis, 2011), while immature grey nurse sharks have been shown to travel distances exceeding 500 km (Otway & Burke, 2004; Bansemer, 2009; Otway, et al., 2009).

A project that examined the movements of three juvenile grey nurse sharks on the west coast of Australia found that the juvenile sharks moved hundreds of kilometres along the mid-west coast

between Perth and Kalbarri (McAuley, 2004). This study suggested that individual grey nurse sharks were not restricted to particular localities or habitats, although one of these sharks returned to within 10 km of its release location within three months of its release. Additionally, tagged sharks moved between depths of 20 and 160 m, indicating broad use of the continental shelf in Western Australia (McAuley, 2004).

3.8 Natural predators

Research in South Africa has shown that juvenile grey nurse sharks are prey to the white shark (*Carcharodon carcharias*), short-finned mako (*Isurus oxyrinchus*), tiger shark (*Galeocerdo cuvier*) and bull shark (*Carcharhinus leucas*). These four shark species also occur within the ranges of the Australian grey nurse shark populations. It is therefore likely that these four species are natural predators of grey nurse sharks in Australian waters, but confirmation would require examination of the gut contents of these four species.

3.9 Abundance

Prior to 1998, only sparse data describing the spatial and temporal patterns of grey nurse shark abundance along the east coast of Australia existed (Pepperell, 1992; Reid & Krogh, 1992; Krogh, 1994; Dudley, 1997). In the 1960s, grey nurse sharks were anecdotally known to aggregate at approximately 60 sites along the east coast of Australia, with at least 30 individuals observed at each site (Cropp, 1964). However, later surveys (1999, 2000 and 2003) conducted by the NSW DPI found that grey nurse sharks were absent from many of the sites occupied during the 1960s. At the time of these surveys, there were only a few sites where the species could be reliably observed. This suggested a dramatic decline in numbers—along with evidence of similar declines from the bather protection program and game fishing records (Pepperell, 1992)—led to the listing of the grey nurse shark as a threatened species, firstly in New South Wales and later in other states and nationally (refer to Section 4 for more details on conservation status).

Estimates of abundance of the grey nurse shark along the east coast of Australia have now been derived from research conducted by the NSW DPI (Otway & Burke, 2004), the University of Queensland (Bansemer, 2009) and the Cardno Ecology Lab (2010). The first such study, conducted by the NSW DPI, was a physical mark-recapture (re-sighting) survey in 2003. A total of 24 sharks were physically tagged at five sites (four in New South Wales and one in Queensland) with the first sharks being tagged in March 2002. Of those, 16 were re-observed over a two week recapture period in June 2003. This study estimated that the total population of grey nurse sharks in the coastal waters of south east Australia was between 410 and 461 individuals, with upper 95 per cent confidence values ranging between 541 and 766 individuals. The total number of sexually mature (adult) grey nurse sharks was estimated to be between 161 and 194 individuals, with a maximum upper 95 per cent confidence limit of 321 individuals (Otway & Burke, 2004). Similarities in the abundances and population size-structure of grey nurse sharks between the mark-recapture/re-sighting survey in winter 2003 and previous visual surveys in 1999 and 2000 indicated that the total population estimates developed in 2003 provided a realistic indication of the total number of grey nurse sharks in eastern Australian waters at that time (Otway & Burke, 2004).

Due to the limited size of the 2003 survey, which relied on estimates from only 24 captures, the Department of the Environment commissioned the Cardno Ecology Lab to undertake a more extensive study (Cardno Ecology Lab, 2010). The aims of the new project were to:

1. develop a standardised protocol, including a review and assessment of the current population abundance estimation techniques, to estimate the size of the east coast population of grey nurse sharks
2. apply the agreed, proposed method, to provide a robust estimate of the number of grey nurse sharks comprising the east coast population.

Stage one was undertaken in 2008 and was based on a pilot investigation, literature review and consultation, including a stakeholder workshop. The protocol

agreed upon at the workshop was based on mark-recapture procedures using non-invasive photo-identification, whereby sharks are individually identified from the unique spot-patterns on their flanks, and photographic ‘recaptures’ of individuals are determined by matching spot-patterns in the initial images with subsequent images. The geographical extent of the surveys spanned the range of previous surveys of grey nurse sharks and also included 22 additional sites identified by local divers and fishers that were not previously surveyed.

The mark-recapture study commenced in winter/spring 2008 and the recapture phase was undertaken in autumn/winter 2009. During the first phase of the study, 188 individual sharks were photographed and in the second stage 402 individual sharks were photographed. In total, there were 66 re-sightings between the two survey periods. Using the statistical package ‘MARK’, it was estimated that the east coast population was 1315 individual grey nurse sharks, with a 95 per cent confidence interval for the population estimate of between 1104 and 1601 individual grey nurse sharks. The adjusted population estimate—to include the ‘unmarkable’ portion of the population (those with fewer than 12 spots that could not be identified using the software program)—was 1365 individual grey nurse sharks with a 95 per cent confidence interval for this population estimate of between 1146 and 1662 individual grey nurse sharks. Potential site fidelity—indicated by the same sharks occurring at the same locations at the same time of year from survey one to survey two in this study—may lead to an underestimate of the shark population when incorporated into mark-recapture analyses. Therefore, an additional adjustment for potential temporal site fidelity was made and resulted in a population estimate of 2142 individual grey nurse sharks with a 95 per cent confidence interval for this population estimate of between 1465 and 3249 individual grey nurse sharks. This confidence interval is very broad and hence less precise than those obtained without the adjustment for site fidelity.

The use of a different statistical method, Bailey’s Binomial Modification, to enable a more direct comparison with the previous population estimate by Otway & Burke (2004), yielded slightly different

results. The population estimate calculated using Bailey’s Binomial Modification was 1131 individual grey nurse sharks, with a 95 per cent confidence interval for this population estimate of between 885 and 1376 individual grey nurse sharks. The adjusted population estimate to include the unmarkable portion of the population was 1174 individual grey nurse sharks, with a 95 per cent confidence interval for this population estimate of between 919 and 1429 individual grey nurse sharks. An additional adjustment to account for potential temporal site fidelity resulted in a population estimate of 2049 grey nurse sharks, with a 95 per cent confidence interval for this population estimate of between 1216 and 2883 individual grey nurse sharks.

All estimates provided by the Cardno Ecology Lab (2010) study put the total east coast grey nurse shark population above 1131 individuals, with the highest estimate being 2142 individuals. However, the estimate of 1365 individual grey nurse sharks, with 95 per cent confidence intervals for this population estimate of between 1146 and 1662 individuals, was considered the most robust estimate.

The Cardno Ecology Lab report (2010) concluded that the increase in numbers between the Otway & Burke (2004) estimate and the 2010 estimates could not have occurred naturally, as the rate of population increase needed would have been beyond the reproductive limits of a population of only 450 individuals. Therefore, they reasoned, the Otway & Burke (2004) estimate was probably an underestimation of the true population size at the time and cited three possible reasons why this may have occurred. The reasons given were:

1. the sample of tagged sharks in the Otway & Burke (2004) study was very small
2. some of the tagged sharks were likely to have been recorded at the same location of tagging, suggesting site fidelity and hence an underestimation of the population
3. recent work has identified a winter migration of mature male sharks extending well to the north of the original study sites (Otway, et al., 2009), which may have led Otway & Burke (2004) to underestimate the population size if these sharks were absent during the resighting survey.

The Cardno Ecology Lab report also did not rule out that a natural increase in the size of the grey nurse shark population on the east coast over the six years between the studies may have occurred. It cited the high incidence of small sharks seen during their surveys as providing some support for that conclusion.

A separate photo-identification study, using a Jolly-Seber (open model design) mark-recapture analysis on data obtained during four scheduled photo-identification surveys—conducted between July 2006 and February 2008 at 25 sites along the east coast of Australia—was also used to estimate the size of the east coast population (Bansemer, 2009). This study estimated a total population of 756 males (95 per cent confidence interval of 590–922) and 1185 females (95 per cent confidence interval of 901–1469). Although the estimate found in this study was higher than in the Cardno Ecology Lab study, the confidence intervals overlap, suggesting a broad agreement in total numbers.

In addition to the physical surveys, Ahonen & Stow (2009) assessed the genetic diversity of the east coast and west coast populations using microsatellite markers in order to provide an estimate of effective population size. The study used 87 DNA samples, of which 63 were from the east coast population and 24 from the west coast population. The study concluded that a contemporary effective population size for the east coast was approximately 126 individuals (95 per cent confidence interval of 67.73–474.11), which may indicate a total population of between 1000 and 1500 sharks. This result is broadly consistent with the lower end of the Cardno Ecology Lab (2010) and Bansemer (2009) studies but

greater than the Otway, et al. (2003) estimate. The study did not provide an estimate of the west coast population, as the sample size was too small for any meaningful conclusions to be drawn.

It is possible that these mark-recapture methods have missed sampling a portion of the population because they were limited to sites where grey nurse sharks are known to occur and to depths that divers can access. Interactions of grey nurse sharks with fisheries suggest that grey nurse sharks may use deeper water and areas other than known aggregation sites. Different population estimate techniques, coupled with further tracking, could be used to gain a better estimation of the extent that grey nurse sharks use these other areas.

There is currently no reliable population estimate of the west coast grey nurse shark population. This is in part due to the lack of known aggregation sites along the west coast, where grey nurse sharks can be reliably found and mark-recapture studies undertaken. However, annual catches of between 70 and 105 sharks (mean of 77) and a stable trend in standardised catch rates from the Western Australian temperate shark fisheries over the period from 1989 to 1997 suggest that the west coast population was larger than the east coast at the time and that their numbers were relatively stable during that period. Although the current status of the grey nurse shark on the west coast is unclear, it has been suggested that the population is at least stable, as commercial shark fishing effort—the main known source of mortality—has decreased to below the 1989 level. Unfortunately, no reliable estimates of grey nurse shark catch rates exist post 1998 for the Western Australian shark fisheries.

4 Conservation

4.1 Conservation status worldwide and in Australia

Declines in grey nurse shark numbers are evident throughout their range, which led to the global listing of the grey nurse shark as endangered in 1996. This listing was reassessed and changed to vulnerable on the IUCN Red List of Threatened Animals in 2000. More recently, the eastern Australian and south west Atlantic populations were upgraded to critically endangered (in 2003 and 2007 respectively) and the western Australian population was listed as near threatened in 2003 (Cavanagh, et al. 2003; Pollard, et al., 2003; Pollard & Smith, 2009). The grey nurse shark has also been afforded some protection through protected species legislation in the United States of America, South Africa and Namibia, although the level of protection varies between countries.

Despite being currently listed as vulnerable on the IUCN Red List, the grey nurse shark can still be caught in Brazil, Uruguay and Argentina as part of multi-species fisheries (Chiaramonte, 1998) and can be taken by recreational fishers in South Africa. The grey nurse shark is sometimes captured in Japan but extensive harvesting in Japanese waters has caused the population to decline to a level where they are now rarely caught by commercial fishers (Compagno, 1984; EA, 2002).

The grey nurse shark east coast population is one of Australia's most endangered marine species. Historically (1950s through 1970s), this species was fished in eastern Australia for its oil, flesh, skin and fins. Due to its fierce appearance and being mistaken for other sharks that posed a danger to humans, large numbers were also killed by recreational spear fishers and line fishers who targeted the sharks at their aggregation sites (EA, 2002).

The grey nurse shark was first listed as protected in New South Wales under the then *Fisheries and Oyster Farms Act 1935* in November 1984, following concerns over declining populations. This was the first time a shark species had been listed as protected anywhere in the world. The Queensland Government also listed the grey nurse shark as endangered in 1997 under its *Nature Conservation Act 1992*.

In October 1999, the New South Wales Government added the grey nurse shark to the list of vulnerable species under the *Fisheries Management Act 1994* (Schedule 5) and in January 2008 this status was upgraded to critically endangered (Schedule 4A, part 2). The grey nurse shark was listed as vulnerable under the Western Australian *Wildlife Conservation Act 1950* in December 1999.

The species was given national protection in 1997, when it was listed as vulnerable under the *Endangered Species Protection Act 1992* and the subsequent EPBC Act in August 2000. In October 2001, this was revised and the species was listed as two separate populations—the east coast population as critically endangered and the west coast population as vulnerable. This listing protects the grey nurse shark from intentional harm in Commonwealth waters and requires all development projects that may impact on the grey nurse shark in Commonwealth and state waters to be assessed through the referrals process, as part of the Matters of National Environmental Significance legislation in the EPBC Act. The EPBC Act threatened species listing also requires state fisheries to report any interactions to the federal environment department. State, territory and Commonwealth fisheries that export product are required to have management arrangements in place that ensure all reasonable steps are taken to ensure individuals of protected species are not killed or injured as a result of fishing in the fishery. The current conservation status of the grey nurse shark in Australia is detailed in Table 2.

Table 2: Current conservation listings for the grey nurse shark in Australia

Listing	Conservation Status
<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Commonwealth)	West coast population: Vulnerable East coast population: Critically Endangered
<i>Fisheries Management Act 1994</i> (New South Wales)	Critically Endangered
<i>Fisheries Act 1994; Fisheries Regulation 2008</i> (Queensland)	Protected
<i>Nature Conservation Act 1992 and Nature Conservation (Wildlife) Regulation 1994</i> (Queensland)	Endangered
<i>Wildlife Conservation Act 1950</i> (Western Australia)	Vulnerable
<i>Living Marine Resources Management Act 1995 and Fisheries Regulations 1996 (General and Fees)</i> (Tasmania)	Protected
<i>Fisheries Act 1995</i> (Victoria)	Protected
<i>Flora and Fauna Guarantee Act 1988</i> (Victoria)	Threatened
Australian Society for Fish Biology (ASFB)	Vulnerable
World Conservation Union (IUCN)	East coast of Australia: Critically Endangered West coast of Australia: Near Threatened (Worldwide: Vulnerable)

4.2 Protection at key aggregation sites in Australian waters

The Australian Government released a national recovery plan for the grey nurse shark in June 2002 (EA, 2002). This plan identified incidental capture by commercial and recreational fisheries, shark control activities, shark finning and ecotourism as the major threats to the recovery of the grey nurse shark. It also listed the establishment of protected areas around the known aggregation sites as one of the key mechanisms to protect the species.

The 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002) identified 19 key aggregation sites, 17 of which are in state waters and two of which are in Commonwealth waters. Since 2002, all but one of these 19 aggregation sites—China Wall, in Moreton Bay National Park, Queensland—have been given some level of protection (DEWHA, 2009). This was achieved through the declaration of critical habitats, marine parks and fishing closures in New South Wales; grey nurse shark protection areas and marine national park

zones in Queensland; and marine reserves in Commonwealth waters. At a minimum, this includes restrictions on fishing methods and fishing gear. However, it should be noted that the conditions and size of sanctuary zones varies between sites, with some sites afforded greater protection than others (DEWHA, 2009).

4.2.1 New South Wales

All 12 grey nurse shark key aggregation sites in New South Wales waters listed in the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002) have been given some level of protection—ranging from allowing low-risk fishing methods (as considered by the NSW DPI) through to prohibiting all forms of fishing. Many of the key aggregation sites have been afforded further protection through their inclusion within a marine park. These parks include the Cape Byron Marine Park, the Port Stephens-Lakes Marine Park, the Solitary Islands Marine Park and the Batemans Marine Park. An extra aggregation site at Mermaid reef has also been recognised and afforded protection.

The full range of protection measures varies at each of the sites and up to date information on the restrictions is available on the New South Wales Government's website at: www.mpa.nsw.gov.au

4.2.2 Queensland

The 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002) identified five key aggregation sites in Queensland. On 19 December 2003, four of these sites—Wolf Rock, Cherubs Cave, Henderson Rock and Flat Rock—were declared through Queensland Fisheries legislation as grey nurse shark protection areas, prohibiting line fishing within a 1.2 km radius of each of these sites. However, at Flat Rock, a few existing commercial mackerel fishers have been allowed to continue to operate on the western side of the site, but not directly over the 'shark gutter', between 6 am and 6 pm on any day of the year. In December 2003, the *Marine Parks (Moreton Bay) Zoning Plan 1997* was amended to include three designated grey nurse shark areas—restricting diving activities—that extend for 1.2 km from a central coordinate around Flat Rock, Cherubs Cave and Henderson Rock. In 2006, a marine national park zone (no-take zone) and designated grey nurse shark area—restricting diving activities within 1.2 km of a central coordinate at the site—was established at Wolf Rock in the Great Sandy Marine Park. A further 300 m buffer zone that provides for trolling for pelagic fishes only was also established at this time.

In March 2009, a new zoning plan for Moreton Bay Marine Park (*Marine Parks (Moreton Bay) Zoning Plan 2008*) commenced. Changes included a marine national park zone (no-take zone) for 1.2 km from a central coordinate around Flat Rock and a 31.56 km² marine national park area, which incorporates Henderson Rock and Cherubs Cave.

The only aggregation site identified in Queensland in the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002) that has not received some level of protection is the China Wall aggregation site located in the Moreton Bay Marine Park. This site was not considered a key aggregation site by current definitions, as the number of individual grey nurse sharks observed at any one time was

consistently less than five and sightings of grey nurse shark were generally infrequent compared to those at other sites (Bennett & Bansemer, 2004).

The full range of protective measures for these sites is available on the Queensland Government's website at: www.nprsr.qld.gov.au

4.2.3 Western Australia

There is currently no specific protection afforded to grey nurse shark aggregation sites in Western Australia.

4.2.4 Commonwealth

The two aggregation sites identified in the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002) located in Commonwealth waters are Pimpnel Rock (Solitary Islands) and the Cod Grounds (Laurieton). Both of these sites are now protected by marine reserves declared under the EPBC Act, which means all forms of fishing are prohibited within the sanctuary zone, extending in a 500 m radius around the site.

4.2.5 Ongoing issues

- The majority of the sites identified in the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002) as requiring habitat protection have some level of legal protection. However, concerns regarding the effectiveness of these protection mechanisms in reducing impacts from fishing on grey nurse shark populations remain (Otway & Burke, 2004).
- The size of the habitat protection zones and the level of protection provided for grey nurse sharks along the east coast of Australia currently vary within and between jurisdictions. A review of the level and spatial extent of protection at key aggregation sites is required to ensure appropriate levels of protection are applied.
- Ongoing protection at key aggregations sites is critical to the long-term survival of the east coast population of grey nurse sharks. Best practice protection at these sites should continue to be a focus.

5 Threats to the grey nurse shark

The primary threats to the grey nurse shark are:

- incidental capture (accidentally or illegally) by commercial and recreational fisheries
- mortality related to shark control activities.

Secondary threats to the species include impacts from ecotourism, collection for public aquaria, pollution and disease and ecosystem effects as a result of habitat modification and climate change—including changes in sea temperature, oceanography and ocean acidification.

5.1 Primary threats

5.1.1 Incidental capture by commercial and recreational fisheries

Incidental capture of grey nurse sharks by commercial and recreational fishers is a major threat to the eastern Australian grey nurse shark population and to a lesser extent the western Australian grey nurse shark population. Incidental capture (bycatch) may include grey nurse sharks that are caught—either accidentally or illegally targeted—and killed at the time of capture, or those that are incidentally hooked and released, only to die some time later (cryptic mortality).

Incidental capture also occurs in nets set by the commercial fishing sector targeting other fish and/or shark species. The Commonwealth marine bioregional plans characterise bycatch of grey nurse sharks in commercial and recreational fishing as a pressure ‘of concern’ in the Temperate East Marine Region and as a pressure ‘of potential concern’ in the South-west Marine Region. More information on Commonwealth marine bioregional plans is available at: www.environment.gov.au/coasts/marineplans/index.html

It is difficult to estimate the total level of grey nurse shark mortality as a result of the commercial and recreational fishing sectors, as there have been very few

official reports of interactions since the introduction of the 2002 recovery plan. This is despite reporting of interactions with protected species being compulsory (DEWHA, 2009). However, monitoring evidence from New South Wales suggests that 45 cases of grey nurse shark deaths occurred as a result of interactions with these sectors between 2002 and 2007—23 from the commercial sector and 22 from the recreational sector. Details such as the location of the incidents were not reported (AAT, 2007). The mortality data, collected by the New South Wales Government for an Administrative Appeals Tribunal investigation (AAT, 2007), was obtained through a range of methods—including reports from the general public and observations made directly by fisheries officers. The low level of reporting by commercial and recreational fishers, despite education programs by the Queensland and New South Wales governments, is of concern and suggests that the total level of mortality is probably higher than currently estimated. Only a small number of interactions with grey nurse sharks have been reported from Commonwealth-managed fisheries. From 2007 to March 2012, five interactions with grey nurse sharks were reported (AFMA, 2012).

In addition to direct mortality events, it is likely that many grey nurse sharks die as a result of hook wounds from encounters with fishing tackle. Hook wounds to grey nurse sharks can puncture the stomach, pericardial cavity and oesophagus, leading to infections and eventual death. The stress of capture may also cause changes in the physiology of a shark, including bradycardia (abnormally slow heartrate), blood acidosis, hyperglycaemia and muscle rigidity. A hooked shark, upon release, may swim away seemingly unharmed, only to die several days later from internal bleeding or peritonitis (EA, 2002).

Several studies have estimated the proportion of grey nurse sharks which showed evidence of retained fishing gear. Otway, et al., (2003) summarised a number of studies and concluded the incidence of hooking rose between 1991 and 2000.

Earlier data, taken from Pollard et al., (1996), suggested a hooking rate of around 2 per cent of all individual sharks recorded in the study. Later data from studies conducted in 1999 and 2000 by NSW DPI showed a hooking incidence of approximately 12 per cent and 6 per cent respectively (Otway, et al., 2003).

In more recent work, Otway & Burke (2004) found that seven of 24 tagged sharks (29 per cent) were hooked within one year of tagging. Bansemer & Bennett (2010) reported that of 52 sharks recorded during their photographic survey (29 males and 23 females), 52 per cent of males and 29 per cent of females had retained fishing gear or showed gear related injuries. Evidence from necropsies on eight accidentally killed sharks suggests the rates of internal hooking may be even higher than those reported through visual census. Of eight sharks investigated through necropsy, six were internally hooked (Otway & Burke, 2004).

Bansemer & Bennett (2010) also categorised observed fishing gear into five broad categories. Of the 95 instances where the gear could be categorised: 48 were of relatively light gear, consistent with that used by recreational fishers; 11 were of gear commonly used by commercial long-liners; three were of gear used when trolling or drifting; and 33 were of heavier gear that may have been used for targeting sharks. These findings suggest that both the recreational and the commercial sectors are responsible for incidental capture and that the grey nurse shark is susceptible to a wide range of fishing gear and related activities.

Ongoing issues

There are a number of ongoing issues related to the threat posed to grey nurse sharks:

- Evidence presented to the Administrative Appeals Tribunal (AAT, 2007) suggests the number of grey nurse shark mortalities as a result of interactions with the commercial and recreational fishing sectors is much higher than official reports would suggest. This level of under reporting is of significant concern and it is recommended that arrangements for reporting interactions be reviewed.

- The high rate of retained fishing gear reported in recent studies suggests that the level of protection afforded by sanctuary zones around grey nurse shark aggregation sites needs to be re-assessed and, in some cases, the zones expanded. In addition, the types of fishing allowed should be re-evaluated, as the Bansemer & Bennett (2010) study clearly shows that the grey nurse shark is susceptible to a wide range of fishing gear and associated activities, including trawl fishing.
- A greater understanding of the level of cryptic mortality caused by incidental hooking from the commercial and recreational fishing sector is required. Details of capture and release events (e.g. fishing gear and bait used, hook and line removed, line cut, hook swallowed, condition of shark upon release) and the ability to identify individual sharks post-release could provide information on survival rates from different fishing and release methods.
- Since the release of the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002), there have been several initiatives by the Australian and state governments to increase the awareness of the protected status of grey nurse sharks among commercial and recreational fishers (DEWHA, 2009). These programs are important and should be continued; however, there is also a need to assess their effectiveness to identify areas in need of further work and to identify better methods for the delivery of educational material.

5.1.2 Shark control programs

Shark control programs are fishing activities that aim to reduce shark numbers near major swimming beaches and thereby reduce the risk of shark attack. These programs involve the placement of mesh nets or drumlines off beaches. New South Wales uses shark meshing only, while Queensland uses a combination of meshing and drumlines (Reid, et al., 2011). Western Australia is currently trialling a shark control program that uses drumlines only.

Shark mesh nets do not act as a complete barrier to sharks reaching beaches, as they 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.

Meshing of beaches as a protective measure for swimmers and surfers was introduced to New South Wales beaches in 1937 and to Queensland beaches in 1962 (Paterson, 1990; Krogh & Reid, 1996).

In New South Wales, there are currently 51 meshed beaches covering approximately 200 km of coastline between Newcastle and Wollongong. New South Wales has a policy of releasing grey nurse sharks where possible. In the early 1950s between 24 and 36 grey nurse sharks were caught in the nets per year (Krogh & Reid, 1996; Pollard, et al., 1996). By the 1980s this rate had decreased to between zero and three per year (Pollard, et al., 1996).

In Queensland, the shark control program relies on mesh nets, drumlines or a combination of both to remove high risk sharks from particular locations. The program was initially restricted to the Gold and Sunshine coasts; however, extensions continued into other beaches throughout the state up until 1996. The shark control program is presently set on 84 beaches in Queensland (Lane, 2006). All sharks captured through the Queensland shark control program are euthanased.

The drumlines used in Queensland comprise a series of shark hooks suspended from inflatable buoys. 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.

As in New South Wales, a downward trend in grey nurse shark interactions with shark control devices has

been detected in Queensland waters, with a decrease from 90 grey nurse sharks captured between 1962 and 1972 to 20 between 1981 and 1991 (Queensland DPI, 1992).

More recently, data from the New South Wales program shows that nine grey nurse sharks were caught and killed through the program between July 2002 and July 2008, and a further two were released alive following entanglement. In 2009/10, there were two grey nurse sharks killed and in 2010/11, there were two grey nurse sharks released alive and one killed in the New South Wales program (NSW DPI, 2012). Data from 2011/12 (three killed, one released alive) and 2012/13 (six killed, three released alive) shows a slight increase in interaction of grey nurse sharks with the program, though whether this is a demonstration of increased populations, an increased impact, or a statistical anomaly, is unclear. In Queensland, 12 grey nurse sharks were caught through the program between 2002 and 2009. Three were caught in 2010, two in 2011, two in 2012 and four in 2013.

Biochemical analyses of stress responses (Otway, in prep.) suggest that survival of grey nurse sharks after release from shark nets is unlikely. This finding is supported by research from South Africa that has shown that the recapture rate of grey nurse sharks tagged prior to release from shark nets is substantially lower than when tagged by other means.

Currently, beach meshing and drumlines are considered by state governments to be an effective means of reducing the risk of shark attacks at popular beaches. Without an effective alternative measure, the risk to human life of removing meshing and drumlining programs is believed to be too high. However, alternative measures to protect bathers continue to be developed and these should be explored where possible. Best practice techniques should also be implemented, which may reduce the capture of grey nurse sharks or which may reduce post-release mortality. In addition, beach meshing programs can and do provide valuable information in terms of genetic material and specimens that can be examined and these aspects of the programs should be continued and strengthened.

Review of shark control programs

The then Queensland Department of Primary Industries and Fisheries (QDPI&F) reviewed the Queensland 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 the program, including the minimisation of bycatch.

The 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 cooperation between the relevant agencies nationally. 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 and handling of sharks that are caught in the net).

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 QDPI&F and South Africa).

To address those matters, NSW DPI undertook an assessment of the New South Wales 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). A number of recommendations from this assessment have been implemented, including annual reporting on the performance of the program.

Ongoing issues

There are a number of ongoing issues related to the shark control programs:

- Shark control programs generally rely on lethal methods to control ‘dangerous sharks’ near popular beaches. More work needs to be undertaken to promote non-lethal methods of shark control in all Australian 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.
- Genetic material should be collected from sharks through shark control programs and made available to researchers.
- 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.
- Further research focusing on the suitability of each net type (top or bottom set) and the use of drumlines in place of nets to reduce bycatch of grey nurse sharks (and other threatened species) is required.
- More work is needed to develop non-lethal methods of shark control in all Australian shark control programs.
- Areas where grey nurse sharks are regularly caught in the shark control programs should be investigated to identify any seasonal trends and options that may facilitate a reduction in grey nurse shark captures at these locations.
- More research needs to be undertaken on the survival rates of grey nurse sharks when released from shark nets, with the intention of developing systems and techniques that maximise survival.

5.2 Secondary threats

5.2.1 Ecotourism

Scuba diving is a popular recreational activity at key grey nurse shark aggregation sites in New South Wales, as well as at the Moreton Bay Marine Park and Wolf Rock in the Great Sandy Marine Park, in Queensland. During the development of the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia, it was considered that these shark dives may have an impact on the grey nurse shark and its behaviour, and hence ecotourism (diving) was listed as a threat in the 2002 recovery plan (EA, 2002).

The 2002 recovery plan (EA, 2002) prescribed a grey nurse shark diver's code of conduct that has been adopted in Commonwealth waters and all New South Wales aggregation sites. The Queensland Government also has diving restrictions in grey nurse shark areas at the three most important aggregations sites in Queensland. Voluntary compliance with these diving restrictions is encouraged at other sites in Queensland waters where grey nurse sharks are observed.

With support from the NSW DPI, a research project was completed in the Julian Rocks critical habitat area. This found that scuba divers had negligible effects on the numbers and overall behaviour of grey nurse sharks (Hayward, 2003). The study quantified the proportion of hovering, directional change, cruising, accelerated swimming and tail cracking behaviour of grey nurse sharks in the presence of scuba divers. Of the 279 observations of grey nurse sharks during the study, only on four occasions (1.4 per cent) were sharks seen to display tail cracking behaviour, a fight-flight response. The study concluded that the overall effects of scuba divers on grey nurse sharks were negligible.

More recently, NSW DPI conducted a series of experiments across 15 sites from Julian Rocks, near the New South Wales/Queensland border, to the Tollgate Islands, off Batemans Bay in southern New South Wales, to assess the effects of scuba diving on grey nurse sharks. The experiments involved monitoring the behaviour of acoustically-tagged sharks via acoustic listening stations, the day before, the day of and the day after scuba diving. Comparisons among these situations enabled assessment of whether changes in

behaviour of grey nurse sharks could be attributed directly to scuba diving, as distinct from those behavioural changes associated with the noise and vibrations of the divers and dive boat (Otway, et al., 2009). The study found there were no discernible impacts on grey nurse shark behaviour from scuba diving on the east coast population.

However, a small study undertaken in Queensland concluded that grey nurse sharks did show some level of avoidance behaviour if groups of divers approached but no response if divers approached individually (Bennett & Bansemer, 2004). This study also concluded that there were no lasting negative impacts from scuba diving.

At Magic Point, a recent study identified that recreational divers can impact the short-term behaviour of grey nurse sharks and that the intensity of impacts could be closely related to the distance at which divers view these sharks. The study found that when groups of eight divers or more were placed three metres (or less) from the Magic Point cave, the shark respiration and aggregation behaviour changed significantly (Barker, 2009).

Research by Smith (2009) at Fish Rock—off South West Rocks on the mid-north coast of New South Wales—examined the compliance of recreational scuba divers with the scuba diving code of conduct when diving with grey nurse sharks at critical habitat sites. The compliance with the code of conduct was considered satisfactory—that is, at least 80 per cent compliance—with 100 per cent compliance in seven of nine criteria examined. The remaining two criteria were met in 92 per cent and 88 per cent of cases respectively.

In Western Australia, grey nurse sharks are observed during some ecotourism diving activities but there are no tours that specifically target grey nurse shark aggregations.

Ongoing issues

While scuba diving within the code of conduct is generally thought to pose little threat to grey nurse sharks at aggregation sites, there is some concern about the impacts of increased diver activity at the more popular sites. This situation needs to be

continually monitored and, if necessary, the code of conduct revised to ensure disturbance to the sharks is minimised.

5.2.2 Aquarium trade

Historically, grey nurse sharks were collected from the wild to be kept in aquaria as their fierce appearance, relatively docile nature, slow movements and slow metabolic rate make them a good species for display. Since 2002, there has been no take allowed from either the east or west coast populations for aquarium display purposes and thus, aquaria have not posed a threat to the grey nurse shark populations in recent years.

The moratorium on collection of grey nurse sharks from Commonwealth waters for use in aquaria is enforced by DoE through the EPBC Act. In New South Wales, a moratorium was also established on the collection of grey nurse sharks for aquarium use in 2002. A moratorium is also in place in Western Australia that limits capture of grey nurse sharks to injured individuals only.

In Queensland, the take, by anyone, of grey nurse sharks is prohibited. Although aquarium operators could apply for a permit to collect grey nurse sharks from the wild, it would be unlikely that a permit would be granted while the east coast population is listed as critically endangered under the EPBC Act.

There are currently 18 individual grey nurse sharks in captivity in Australia. Under the auspices of the Australian Zoo and Aquarium Association, a population management program is currently being developed for captive grey nurse sharks, including ongoing cooperative research into captive breeding of the species. The aim of this program is to ensure a sustainable captive population.

5.2.3 Pollution and disease

The introduction of pollutants, pathogens, disease, introduced species and contaminants into the coastal marine environment can be derived from land-based impacts (e.g. coastal development, sediment and nutrient run-off), but can also result from spills and ship groundings. Although these potential threats may

impact upon ecosystems relied upon by the grey nurse shark, potentially affecting the recovery capability of the species (McLoughlin, 2007), they are largely poorly understood.

5.2.4 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 grey nurse 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. More information on Commonwealth marine bioregional plans is available at: www.environment.gov.au/coasts/marineplans/index.html

Climate change is a global threat and much uncertainty remains around the management of potential impacts associated with changes in sea temperature, ocean currents and ocean acidification (Beeton, et al., 2012). Increasing sea temperatures may result in changes in shark metabolism, behaviour and movement patterns (Chin & Kyne, 2007). A climate change vulnerability assessment in the Great Barrier Reef region assessed the grey nurse shark as having high exposure levels to the effects of rising temperatures and ranked the species as moderately vulnerable to this pressure (Chin, et al., 2010). Changes in ocean current systems also have the potential to alter marine productivity, which in turn could significantly affect community structure and function (Hobday, et al., 2009) that grey nurse shark populations rely upon.

The rate of increase in ocean acidity is estimated to be 100 times faster than any change in acidity experienced by marine organisms for at least the past

20 million years (Orr, et al., 2009). There is a high level of uncertainty about the effects of ocean acidification on marine life. While some organisms might be able to adapt (Orr, et al., 2009), anticipated changes to phytoplankton and zooplankton have the potential to detrimentally affect ecosystem processes and the structure of ecological communities. The potential effects of increased ocean acidity on shark and fish species are not well understood.

The Commonwealth marine bioregional plans characterise climate change effects—including change in sea temperature, ocean currents and ocean acidification—as a pressure ‘of potential concern’ in the South-west Marine Region and the Temperate East Marine Region.



Photo by Justin Gilligan

6 Research and management priorities

A number of research projects have been funded by the Australian Government, state governments, regional natural resource management (NRM) bodies, universities and foundations, with the explicit aim of carrying out actions identified in the 2002 Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) in Australia (EA, 2002).

These have included a variety of studies on migratory and localised movements, population estimates, mortality estimates, identification of maternity sites, estimation of bycatch levels and advancing biological knowledge, education and awareness initiatives. The results of these studies have greatly enhanced our knowledge of the grey nurse shark. However, a number of research priorities remain, including:

- a continuation of monitoring on the east coast to ensure a robust assessment of population dynamics. This program will help assess the effectiveness of recovery actions implemented for the grey nurse shark
- evaluation and investigation of further monitoring methods to provide robust population estimates, such as photo-tagging, conventional tagging (non-biofouling tags), acoustic tagging, satellite tracking and close-kin genetics
- further investigation into the injury and mortality associated with capture and release of the grey nurse shark by the recreational and commercial fishing sectors and by the shark control programs
- a continuation of programs to collect, analyse and disseminate age, growth, reproduction, survival and diet information to help improve understanding of the population dynamics, habitat requirements and the ecological role of grey nurse sharks
- a continuation of programs to collect and analyse genetic material to determine the stock structure, inbreeding depression (with particular emphasis on sampling diseased individuals), population boundaries and abundance of grey nurse shark populations within Australian waters
- a continuation of programs to examine habitat use, ontogeny and regional connectivity across life history stages through the use of tagging technologies including acoustic listening station networks and photo identification
- investigation and development of potential bycatch mitigation measures for the grey nurse shark in both recreational and commercial fisheries.

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8 References

- AAT (2007) *Administrative Appeals Tribunal Decision and Reasons for Decision AATA 1876*. Administrative Appeals Tribunal General Administrative Division, No: N2006/1443.
- AFMA (2012). *Protected species interaction reports from AFMA logbooks*. Australian Fisheries Management Agency, Canberra. Available on the internet at: <http://www.afma.gov.au/managing-our-fisheries/environment-and-sustainability/protected-species/>
- Ahonen, H., & Stow, A. (2009). *Population size and structure of grey nurse shark in east and west Australia*. Final report to the Department of Environment, Water, Heritage and the Arts. 19 pp.
- Bansemer, C. (2009). *Population biology, distribution, movement patterns and conservation requirements of the grey nurse shark (Carcharias taurus; Rafinesque 1810) along the east coast of Australia*. University of Queensland. St Lucia, Queensland, Australia. 143 pp.
- Bansemer, C., & Bennett, M. (2008). Multi-year validation of photographic identification of grey nurse sharks, *Carcharias taurus*, and applications for non-invasive conservation research. *Marine and Freshwater Research* 59, 322–331.
- Bansemer, C., & Bennett, M. (2009). Reproductive periodicity, localised movements and behavioural segregation of pregnant *Carcharias taurus* at Wolf Rock, southeast Queensland, Australia. *Marine Ecological Progress Series* 374, 215–227.
- Bansemer, C., & Bennett, M. (2010). Retained fishing gear and associated injuries in the east Australian grey nurse sharks (*Carcharias taurus*): Implications for population recovery. *Marine and Freshwater Research* 61(1), 97–103.
- Barker, S. (2009). *Monitoring diver impacts and movement patterns of the grey nurse shark, Carcharias taurus, through non-invasive techniques*. Honours thesis. Macquarie University, Australia: 77 pp.
- Bass, A. J., D'Aubrey, J. D., & Kistnasamy, N. (1975). *Sharks of the east coast of southern Africa. IV. The families, Odontaspidae, Scapanorhynchidae, Isuridae, Cetorhinidae, Alopiidae, Orectolobidae and Rhiniodontidae*. Oceanographic Research Institute Investigational Report 39, pp. 7–17.
- Beeton, R. J. S., Buxton, C. D., Cutbush, G. C., Fairweather, P. G., Johnston, E. L., & Ryan, R. (2012). *Report of the Independent Scientific Audit of Marine Parks in New South Wales*. New South Wales Government, Sydney. 142pp.
- Bennett, M., & Bansemer, C. (2004). *Investigations of grey nurse shark in Queensland to fulfil actions under the Recovery Plan for grey nurse shark (Carcharias taurus) in Australia regarding the impact of divers, and establishment of a photographic database to improve knowledge of migratory movements, localised site movements, and estimation of bycatch*. National Heritage Trust, Canberra.
- Branstetter, S., & Musick, J. A. (1994). Age and growth estimates for the Sand Tiger in the northwestern Atlantic Ocean. *Transactions of the American Fisheries Society* 123, 242254.
- Bruce, B. D., Stevens, J. D., & Bradford, R. W. (2005). *Designing protected areas for grey nurse sharks off Eastern Australia*. CSIRO Marine and Atmospheric Research, Hobart. pp. 156.
- Cardno Ecology Lab (2010). *Development and implementation of a population protocol to provide an estimate of the size of the east coast population of grey nurse sharks (Carcharias taurus)*. Department of Environment, Water, Heritage and the Arts, Canberra. 162pp.

- Cavanagh, R. D., Kyne, P. M., Fowler, S. L., Musick, J. A., & Bennett, M. B. (2003). *Conservation Status of Australian Chondrichthyans. Report of the IUCN Shark Specialist Group Australia and Oceania Regional Red List Workshop*. University of Queensland - School of Biomedical Sciences. 170 pp.
- Chiaromonte, G. E. (1998). Shark fisheries in Argentina. *Marine and Freshwater Research* 49, pp. 601–609.
- Chidlow, J., Gaughan, D., & McAuley, R. (2005). *Identification of Western Australian Grey Nurse Shark aggregation sites*. Department of the Environment and Heritage, Canberra. 54 pp.
- Chin, A., & Kyne, P. M. (2007). Vulnerability of chondrichthyan fish of the Great Barrier Reef to climate change. In J. E. Johnson, & P.A. Marshall (eds), *Climate change and the Great Barrier Reef: a vulnerability assessment*. Great Barrier Reef Marine Park Authority, Townsville, & Australian Greenhouse Office, Canberra. pp. 393–425.
- Chin, A., Kyne, P. M., Walker, T. I., & McAuley, R. B. (2010). An integrated risk assessment for climate change: analysing the vulnerability of sharks and rays on Australia's Great Barrier Reef. *Global Change Biology* 16, pp. 1936–1953.
- Compagno, L. J. V. (1984). FAO species catalogue Vol. 4. Sharks of the world. An annotated and illustrated catalogue of sharks species known to date: Part 1 Hexanchiformes to Lamniformes. *FAO Fisheries Synopsis* 125 (Vol. 4, Pt. 1). 249 pp.
- Cropp, B. (1964). *Shark Hunters*. Rigby, Adelaide.
- DEWHA (2009). *Review of the Grey Nurse Shark Recovery Plan*. Department of Environment, Water, Heritage and the Arts, Canberra. 43 pp.
- Dicken, M. L. (2006). *Population dynamics of the raggedtooth shark (Carcharias taurus) along the east coast of South Africa*. PhD thesis, Rhodes University, Grahamstown, South Africa. Available on the internet at: http://eprints.ru.ac.za/247/1/Dicken_-_PhD_thesis.pdf
- Dicken, M. L., Smale, M. J., & Booth, A. J. (2006). Spatial and seasonal distribution patterns of the ragged-tooth shark *Carcharias taurus* along the coast of South Africa. *African Journal of Marine Science* 28 (3), pp. 603–616.
- Dicken, M. L., Smale, M. J., Booth, A. J., & Cliff, G. (2007). Spatial and seasonal distribution patterns of juvenile and adult raggedtooth sharks (*Carcharias taurus*) tagged off the east coast of Africa. *Marine and Freshwater Research* 58, pp. 127–134.
- DoE (2014). *Recovery Plan for the Grey Nurse Shark (Carcharias taurus) 2014*. Department of the Environment, Canberra. 48 pp.
- DSEWPaC (2013). *Draft Recovery Plan for the Grey Nurse Shark (Carcharias taurus)*. Department of Sustainability, Environment, Water, Population and Communities, Canberra. pp. 43
- Dudley, S. F. J. (1997). A comparison of the shark control programs of New South Wales and Queensland (Australia) and KwaZulu-Natal (South Africa). *Ocean and Coastal Management* 34, pp. 1–27.
- EA (2002) *Recovery Plan for the Grey Nurse Shark (Carcharias taurus) in Australia*. Environment Australia, Canberra. 53 pp.
- Gilmore, R. G., Dodrill, J. W., & Linley, P. A. (1983). Reproduction and embryonic development of the sand tiger shark, *Odontaspis taurus* (Rafinesque). *Fisheries Bulletin* 81(2), pp. 201– 225.
- Gilmore, R. G., Putz, O., Dodrill, J. W. (2005). Oophagy, intrauterine cannibalism and reproductive strategy in lamnoid sharks. In W.C. Hamlett (ed), *Reproductive Biology and Phylogeny of Chondrichthyes: Sharks, Batoids and Chimaeras*. Science Publishers Inc, New Hampshire, USA. pp. 435–462.

- Goldman, K. J., Branstetter, S., & Musick, J. A. (2006). A re-examination of the age and growth of sand tiger sharks, *Carcharias taurus*, in the western North Atlantic: the importance of ageing protocols and use of multiple back-calculation techniques. *Developments in Environmental Biology of Fishes* 25, pp. 241–252.
- Green, M., Ganassin, C., & Reid, D. D. (2009). *Report into the New South Wales shark meshing (bather protection) program*. NSW Department of Primary Industries, Orange, NSW. 134 pp.
- Hayward, A. (2003). *Observations of grey nurse shark (Carcharias taurus) and scuba diver behaviour*. Honours thesis. Southern Cross University, Australia. 112 pp.
- Hobday, A. J., Griffiths, S., & Ward, T. (2009). Pelagic Fishes and Sharks. In E. S. Poloczanska, A. J. Hobday, & A. J. Richardson (eds), *A Marine Climate Change Impacts and Adaptation Report Card for Australia 2009*. NCCARF Publication 05/09. Available on the internet at: http://www.oceanclimatechange.org.au/content/images/uploads/Pelagic_fishes.pdf
- Krogh, M. (1994). Spatial, seasonal and biological analysis of sharks caught in the New South Wales protective beach meshing programme. *Australian Journal of Marine and Freshwater Research* 45, pp. 1087–1106.
- Krogh, M., & Reid, D. (1996). Bycatch in the protective shark meshing programme off South-Eastern New South Wales, Australia. *Conservation Biology* 77, pp. 219–226.
- Lane, B. (2006). The shark control program in Queensland. In *Proceedings of the Scientific Shark Protection Summit, 10 April 2006, Darling Harbour*. NSW Department of Primary Industries. Available on the internet at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/137294/Report-from-the-Scientific-Shark-Protection-Summit.pdf.
- Last, P. R., & Stevens, J. D. (2009). *Sharks and Rays of Australia. Second Edition*. CSIRO Division of Fisheries, Hobart. 644 pp.
- Lotze, H. K., Lenihan, B. J., Bourque, B. J., Bradbury, R. H., Cooke, R. C., Kay, M.C., Kidwell, S. M., Kirby, M. X., Peterson, C. H., & Jackson, J. B. C. (2006) Depletion, degradation and recovery potential of estuaries and coastal seas. *Science* 312, pp. 1806–1809.
- Lucifora L., Menni, R. & Escalante, A. H. (2002). Reproductive ecology and abundance of the sand tiger shark, *Carcharias taurus*, from the Southwestern Atlantic. *ICES Journal of Marine Science* 59, pp. 553–561.
- McAuley, R. (2004). *Western Australian Grey Nurse Shark Pop Up Archival Tag Project. Final Report to Department of Environment and Heritage*. Department of Fisheries, Western Australia. 49 pp.
- McAuley, R. B. (2009). Demersal Gillnet and Longline Fisheries Status Report. In W. J. Fletcher, & K. Santoro (eds) *State of the Fisheries Report 2008/09*. Department of Fisheries, Western Australia. pp. 225–229.
- McAuley, R., Newbound, D., & Ashworth, R. (2002). *Field Identification Guide to Western Australian Sharks and Shark-like Rays. Fisheries Occasional Publications No. 1, July 2002*. Department of Fisheries, Western Australia. 25 pp.
- McLoughlin, K. (2007). Shark Gillnet and Hook Sectors. In J. Larcombe, & K. McLoughlin (eds) *Fishery status reports 2006: status of fish stocks managed by the Australian Government*. Bureau of Rural Sciences, Canberra. pp. 174–186.
- Northern Territory Department of Natural Resources, Environment and the Arts (2006). *Threatened Species of the Northern Territory, Grey Nurse Shark (Carcharias taurus)*. Northern Territory Department of Natural Resources, Environment and the Arts. Available on the internet at: http://www.nretas.nt.gov.au/__data/assets/pdf_file/0009/10899/Grey_Nurse_Shark_DD.pdf
- NSW DPI (2002). *Grey Nurse Shark (Carcharias taurus) Draft Recovery Plan*. New South Wales Department of Primary Industries, Sydney. 102 pp.

- NSW DPI (2006). *Proceedings of the Scientific Shark Protection Summit, 10 April 2006, Darling Harbour*. Available on the internet at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/137294/Report-from-the-Scientific-Shark-Protection-Summit.pdf
- NSW DPI (2009). *Report into the NSW Shark Meshing (Bather Protection) Program*. Available on the internet at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/276029/Report-into-the-NSW-Shark-Meshing-Program.pdf.
- NSW DPI (2010). *NSW beach meshing program: Primefact 147*. Available on the internet at: <http://www.dpi.nsw.gov.au/fisheries/info/sharksmart/meshing/nsw-shark-meshing-program-primefact-147>
- NSW DPI (2011). *Shark Meshing (Bather Protection Program) 2009-10 Annual Performance Report*. Available on the internet at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/377615/2009-10-Annual-Performance-Report.pdf.
- NSW DPI (2012). *Shark Meshing (Bather Protection) Program 2010-2011*. Available on the internet at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/429537/Final-Report-Apr-2012.pdf.
- Orr, J. C., Caldeira, K., Fabry, V., Gattuso, J. P., Haugan, P., Lehodey, P., Pantoja, S., Pörtner, H. O., Riebesell, U., Trull, T., Hood, M., Urban, E., & Broadgate, W. (2009). *Research priorities for ocean acidification*. Report from the Second Symposium on The Ocean in a High CO₂ World. SCOR, UNESCO-IOC, IAEA and IGBP. Available on the internet at: [http://scor-int.org/High-CO₂_World/2008-Research_Priorities.pdf](http://scor-int.org/High-CO2_World/2008-Research_Priorities.pdf).
- Otway, N.M. Personal communication. Senior Research Scientist, Fisheries Research Aquatic Ecosystems, Department of Primary Industries, New South Wales.
- Otway, N. M., Bradshaw, C., & Harcourt, R. (2004). Estimating the quasi-extinction of the Australian grey nurse shark (*Carcharias taurus*) population using deterministic age- and stage-classified models. *Biological Conservation* 119, pp. 341–350.
- Otway, N. M. & Burke, A. L. (2004). *Mark-recapture population estimate and movements of grey nurse sharks*. *New South Wales Fisheries Final Report Series No.63*. NSW Fisheries Office of Conservation, Nelson Bay, NSW. 63 pp.
- Otway, N. M., Burke, A. L., Morrison, N. S., Parker, P. C. (2003). *Monitoring and identification of New South Wales critical habitat sites for conservation of grey nurse sharks*. *New South Wales Fisheries Final Report Series No. 47*. New South Wales Fisheries Office of Conservation, Nelson Bay, New South Wales, 62 pp.
- Otway, N. M., & Ellis, M. T. (2011). Pop-up archival satellite tagging of *Carcharias taurus*: movements and depth/temperature-related use of SE Australian waters. *Marine and Freshwater Research* 62(6), pp. 607–620.
- Otway, N. M., & Parker, P. C. (2000). *The biology, ecology, distribution and abundance, and identification of marine protected areas for the conservation of threatened grey nurse sharks in south east Australian waters*. *New South Wales Fisheries Final Report Series No. 19*. New South Wales Fisheries Office of Conservation, Sydney, New South Wales. 132 pp.
- Otway, N. M., Storrie, M. T., Loudon, B. M., & Gilligan, J. J. (2009). *Documentation of depth-related migratory movements, localised movements at critical habitat sites and the effects of scuba diving for the east coast grey nurse shark population*. Department of Environment, Water, Heritage and the Arts, Canberra. 88 pp.
- Paterson, R. A. (1990). Effects of long-term anti-shark measures on target and non-target species in Queensland, Australia. *Biological Conservation* 52, pp. 147–159.

- Pepperell, J. G. (1992). Trends in the distribution, species composition and size of sharks caught by gamefish anglers off south-eastern Australia, 1961–90. *Australian Journal of Marine and Freshwater Research* 43, pp. 213–225.
- Pollard, D., Gordon, I., Williams, S., Flaherty, A., & McAuley, R. (2003). *Carcharias taurus* (East coast of Australia subpopulation). In IUCN (2012). *IUCN Red List of Threatened Species. Version 2012.1*. Available on the internet at: <http://www.iucnredlist.org/details/44070/0>
- Pollard, D. A., Lincoln-Smith, M. P., & Smith, A. (1996). The biology and conservation status of the grey nurse shark (*Carcharias taurus*, Rafinesque 1810) in New South Wales, Australia. *Aquatic Conservation* 6, 1–20.
- Pollard, D., & Smith, A. (2009). *Carcharias taurus*. In: IUCN (2012). *IUCN Red List of Threatened Species. Version 2012.1*. Available in the internet at: <http://www.iucnredlist.org/details/3854/0>
- Queensland DPI (1992). *Review of the Operation and Maintenance of Shark Meshing Equipment in Queensland Waters*. DPI, Brisbane. 114 pp.
- QDPI&F (2006). *Shark Safety Program Review 2006*. Available on the internet at: <http://www2.dpi.qld.gov.au/extra/pdf/fishweb/sharksafetyreport.pdf>.
- Raudino, H. (2012). Personal communication by email, 21 March 2012, Western Australian Department of Environment and Conservation.
- Reid, D. D., & Krogh, M. (1992). Assessment of catches from protective shark meshing off New South Wales beaches between 1950 and 1990. *Australian Journal of Marine and Freshwater Research* 43, pp. 283–296.
- Reid, D. D., Robbins, W. D., & Peddemors, V. M. (2011). Decadal trends in shark catches and effort from the New South Wales, Australia, Shark Meshing Program 1950-2010. *Australian Journal of Marine and Freshwater Research* 62, pp. 676–693.
- Smale, M. J. (2002). Occurrence of *Carcharias taurus* in nursery areas of the Eastern and Western Cape, South Africa. *Marine and Freshwater Research* 53, pp. 551–556.
- Smith, K. (2009). *Grey nurse shark (Carcharias taurus) diving tourism: tourist compliance with a code of conduct, shark behaviour and tourist's biocentrism at Fish Rock, Australia*. Honours Thesis, Victoria University, Australia. 102 pp.
- Smith, S. E., Au, D. W., & Show, C. (1998). Intrinsic rebound potentials of 26 species of Pacific sharks. *Marine and Freshwater Research* 49, pp. 663–678.
- Western Australia Department of Fisheries (2011). *State of the Fisheries and Aquatic Resources Report 2010/11*. Department of Fisheries, Western Australia. 359 pp. Available on the internet at: http://www.fish.wa.gov.au/Documents/sofar/state_of_the_fisheries_2010-11.pdf

9 Appendices

Appendix 1: Grey nurse shark sighting locations

Table 3: List of known sightings of grey nurse sharks along the east coast of Australia, including aggregation sites that are regularly and consistently used (five or more sharks), sites where small aggregations have been observed (less than five sharks) and also sites where single sharks have been recorded on single occasions. Source: NSW DPI, unpublished data, (2002).

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
1	Waddy Point (Fraser Island)	24° 58' 00 S	153° 21' 45 E	AUS 365
2	Indian Head (Fraser Island)	25° 00' 35 S	153° 21' 45 E	AUS 365
3	Wolf Rock (Double Island Point)	25° 54' 40 S	153° 12' 20 E	AUS 365
4	Jew Shoal (Noosa Head)	26° 21' 30 S	153° 06' 50 E	AUS 365
5	Hancock Shoal	26° 30' 45 S	153° 06' 30 E	AUS 365
6	Arkwright Shoal (Arkwright Point)	26° 33' 10 S	153° 06' 50 E	AUS 365
7	Mudjunba Island	26° 37' 00 S	153° 06' 50 E	AUS 365
8	Gneering Shoal (Point Cartwright)	26° 38' 40 S	153° 09' 35 E	AUS 365, AUS 235
9	Raper Shoal	26° 45' 30 S	153° 09' 20 E	AUS 365, AUS 235
10	Bray Rock (Caloundra)	26° 48' 30 S	153° 09' 40 E	AUS 814, AUS 365, AUS 235
11	Hutchison Shoal (Moreton Island)	26° 57' 30 S	153° 29' 05 E	AUS 814, AUS 365, AUS 235
12	Flinders Reef (Moreton Island)	26° 59' 00 S	153° 29' 05 E	AUS 814, AUS 365, AUS 235
13	Cherubs Cave (Moreton Island)	27° 07' 00 S	153° 28' 30 E	AUS 814, AUS 364
14	Henderson Rock (Moreton Island)	27° 08' 00 S	153° 28' 40 E	AUS 814, AUS 364
15	China Wall	27° 05' 15 S	153° 28' 50 E	AUS 814, AUS 364
16	Flat Rock (North Stradbroke Island)	27° 08' 00 S	153° 33' 30 E	AUS 814, AUS 364

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
17	Shag Rock (North Stradbroke Island)	27° 24' 50 S	153° 31' 33 E	AUS 814, AUS 364
18	Cook Island	28° 11' 55 S	153° 34' 30 E	AUS 813, AUS 364
19	5-mile Reef	28° 12' 45 S	153° 36' 15 E	AUS 813, AUS 364
20	9-mile Reef	28° 11' 55 S	153° 37' 30 E	AUS 813, AUS 64
21	Fido Reef	28° 11' 55 S	153° 35' 05 E	AUS 813, AUS 364
22	Alberta Wreck	28° 15' 00 S	153° 35' 05 E	AUS 813, AUS 364
23	Windarra Bank	28° 27' 35 S	153° 41' 40 E	AUS 813, AUS 364
24	Mackerel Boulders	28° 36' 20 S	153° 37' 35 E	AUS 813, AUS 364
25	Julian Rocks (off Byron Bay)	28° 36' 50 S	153° 37' 35 E	AUS 813, AUS 364
26	Lennox Head	28° 48' 50 S	153° 37' 00 E	AUS 813, AUS 364
27	North Riordan Shoal	28° 58' 20 S	153° 31' 30 E	AUS 813, AUS 364
28	South Riordan Shoal	29° 00' 35 S	153° 30' 00 E	AUS 813, AUS 364
29	North Evans Reef	29° 10' 15 S	153° 27' 40 E	AUS 813, AUS 364
30	South Evans Reef	29° 13' 15 S	153° 25' 30 E	AUS 813, AUS 364
31	Freeburn Rock	29° 31' 05 S	153° 22' 15 E	AUS 812, AUS 363
32	Buchanan's Rock	29° 36' 15 S	153° 21' 00 E	AUS 812, AUS 363
33	Sandon Bluffs	29° 40' 45 S	153° 20' 00 E	AUS 812, AUS 363
34	Pimpernel Rock	29° 42' 10 S	153° 23' 30 E	AUS 812, AUS 363
35	North Solitary Island	29° 55' 05 S	153° 23' 00 E	AUS 812, AUS 363
36	North Rock	29° 58' 30 S	153° 15' 30 E	AUS 812, AUS 363
37	Chopper Rock	30° 00' 45 S	153° 15' 00 E	AUS 812, AUS 363

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
38	Northwest Solitary Island	30° 01' 30 S	153° 17' 00 E	AUS 812, AUS 363
39	South Solitary Island	30° 12' 30 S	153° 17' 00 E	AUS 812, AUS 363
40	Split Solitary Island	30° 14' 50 S	153° 10' 30 E	AUS 812, AUS 363
41	Changtes Shoal	30° 19' 20 S	153° 11' 20 E	AUS 812, AUS 363
42	Whitmore Shoal	30° 21' 15 S	153° 09' 00 E	AUS 812, AUS 363
43	Sawtell Shoal	30° 22' 45 S	153° 08' 55 E	AUS 812, AUS 363
44	North Nambucca Head	30° 39' 10 S	153° 01' 30 E	AUS 812, AUS 811, AUS 363
45	Scotts Head	30° 45' 25 S	153° 00 40 E	AUS 812, AUS 811, AUS 363
46	Grassy Head	30° 48' 00 S	153° 01' 00 E	AUS 812, AUS 811, AUS 363
47	Green Island	30° 54' 45 S	153° 05' 10 E	AUS 812, AUS 811, AUS 363
48	Fish Rock	30° 56' 25 S	153° 05' 45 E	AUS 812, AUS 811, AUS 363
49	Black Rock	30° 57' 00 S	153° 04' 00 E	AUS 811, AUS 363
50	Hat Head (Korogoro Point)	31° 03' 05 S	153° 04' 05 E	AUS 811, AUS 363
51	Crescent Head	31° 11' 30 S	152° 59' 15 E	AUS 811, AUS 363
52	Green Islet	31° 16' 05 S	152° 58' 25 E	AUS 811, AUS 363
53	Point Plomer	31° 19' 15 S	152° 58' 25 E	AUS 811, AUS 363
54	Grants Head	31° 36' 15 S	152° 51' 25 E	AUS 811, AUS 363
55	Cod Grounds	31° 40' 55 S	152° 54' 35 E	AUS 811, AUS 363
56	Diamond Head	31° 43' 30 S	152° 48' 25 E	AUS 811, AUS 363

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
57	Mermaid Reef	31° 46' 05 S	152° 48' 25 E	AUS 811, AUS 363
58	Curphey Shoal	31° 48' 30 S	152° 47' 30 E	AUS 811, AUS 363
59	Giles Shoal	31° 49' 05 S	152° 45' 55 E	AUS 811, AUS 363
60	Crowdy Head	31° 50' 30 S	152° 45' 30 E	AUS 811, AUS 363
61	Dennis Shoal	31° 59' 00 S	152° 38' 10 E	AUS 810, AUS 362
62	Schnapper Rock	32° 02' 30 S	152° 36' 45 E	AUS 810, AUS 362
63	Red Head	32° 04' 15 S	152° 33' 10 E	AUS 810, AUS 362
64	Hallidays Point	32° 04' 55 S	152° 33' 05 E	AUS 810, AUS 362
65	The Barge (off Wallis Lake entrance)	32° 09' 10 S	152° 32' 20 E	AUS 810, AUS 362
66	Latitude Rock	32° 12' 34 S	152° 34' 00 E	AUS 810, AUS 362
67	Latitude Reef	32° 12' 32 S	152° 34' 05 E	AUS 810, AUS 362
68	Cape Hawke	32° 13' 00 S	152° 35' 10 E	AUS 810, AUS 362
69	The Pinnacles (off Cape Hawke)	32° 14' 25 S	152° 36' 05 E	AUS 811, AUS 362
70	Charlotte Head	32° 19' 55 S	152° 34' 00 E	AUS 11, AUS 362
71	Boomerang Point	32° 20' 00 S	152° 32' 55 E	AUS 811, AUS 362
72	Danger Point	32° 22' 30 S	152° 32' 25 E	AUS 811, AUS 362
73	Skeleton (Black) Rock	32° 24' 30 S	152° 32' 20 E	AUS 811, AUS 362
74	White-topped Rock	32° 26' 00 S	152° 32' 15 E	AUS 811, AUS 362
75	Sawtooth Rocks	32° 26' 41 S	152° 32' 20 E	AUS 811, AUS 362
76	Big Seal Rock	32° 28' 00 S	152° 33' 00 E	AUS 811, AUS 362
77	Little Seal Rock	32° 28' 35 S	152° 32' 50 E	AUS 811, AUS 362

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
78	Edith Breaker	32° 29' 00 S	152° 30' 00 E	AUS 811, AUS 362
79	The Big Gibber	32° 30' 00 S	152° 24' 40 E	AUS 811, AUS 362
80	The Little Gibber	32° 36' 30 S	152° 16' 05 E	AUS 811, AUS 362
81	North Rock	32° 36' 20 S	152° 19' 45 E	AUS 811, AUS 362
82	The Sisters	32° 36' 50 S	152° 17' 20 E	AUS 811, AUS 362
83	Northeast Little Broughton Island	32° 37' 30 S	152° 20' 20 E	AUS 811, AUS 362
84	Central East, Little Broughton Island	32° 37' 30 S	152° 20' 21 E	AUS 811, AUS 362
85	East Head, Little Broughton Island	32° 37' 33 S	152° 20' 21 E	AUS 811, AUS 362
86	Broughton Pinnacle (due east of Looking Glass Island)	32° 38' 30 S	152° 20' 00 E	AUS 811, AUS 362
87	Looking Glass (Looking Glass Island)	32° 38' 30 S	152° 18' 40 E	AUS 811, AUS 362
88	Cabbage Tree Island	32° 41' 40 S	152° 18' 40 E	AUS 809, AUS 811, AUS 362
89	Boondelbah Island	32° 42' 55 S	152° 13' 50 E	AUS 809, AUS 811, AUS 362
90	Morna Point	32° 47' 50 S	152° 07' 00 E	AUS 809, AUS 810, AUS 362
91	Birubi Point	32° 48' 40 S	152° 04' 45 E	AUS 809, AUS 810, AUS 362
92	Redhead Point	33° 00' 50 S	151° 44' 00 E	AUS 809, AUS 362
93	Moon Island	33° 05' 45 S	151° 40' 25 E	AUS 809, AUS 362
94	Catherine Hill Bay	33° 09' 40 S	151° 38' 30 E	AUS 809, AUS 362
95	Wybung Head	33° 12' 00 S	151° 37' 30 E	AUS 809, AUS 362
96	Bird Island	33° 14' 00 S	151° 36' 26 E	AUS 809, AUS 362

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
97	Norah Head	33° 16' 55 S	151° 34' 55 E	AUS 809, AUS 362
98	2-mile Reef	33° 21' 05 S	151° 31' 35 E	AUS 809, AUS 361
99	Tuggerah (3-mile) Reef	33° 21' 45 S	151° 32' 15 E	AUS 809, AUS 361
100	Wamberal Point	33° 25' 00 S	151° 27' 55 E	AUS 361, AUS 204, AUS 197
101	Cave off Skillion	33° 29' 30 S	151° 29' 00 E	AUS 361, AUS 204, AUS 197
102	Boudi-Broken Bay Reef	33° 31' 50 S	151° 22' 00 E	AUS 809, AUS 361, AUS 204, AUS 197
103	Bangalley Head	33° 37' 40 S	151° 20' 45 E	AUS 809, AUS 361, AUS 204, AUS 197
104	Bungan Head	33° 39' 50 S	151° 20' 15 E	AUS 809, AUS 361, AUS 204, AUS 197
105	Long Reef Wall	33° 44' 10 S	151° 19' 30 E	AUS 809, AUS 361, AUS 197
106	North Head Bombora	33° 49' 05 S	151° 18' 15 E	AUS 809, AUS 361, AUS 197
107	South Head	33° 50' 30 S	151° 16' 20 E	AUS 809, AUS 361, AUS 197
108	Bondi Caves	33° 54' 05 S	151° 16' 20 E	AUS 809, AUS 361, AUS 197
109	Bronte Head	33° 53' 55 S	151° 16' 00 E	AUS 809, AUS 361, AUS 197
110	Magic Point	33° 57' 45 S	151° 15' 50 E	AUS 808, AUS 361, AUS 197
111	Merries Reef	34° 03' 15 S	151° 10' 35 E	AUS 808, AUS 361, AUS 198, AUS 197

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
112	Osborn Shoal	34° 03' 50 S	151° 11' 40 E	AUS 808, AUS 361, AUS 198, AUS 197
113	Jibbon Bombora	34° 04' 50 S	151° 10' 30 E	AUS 808, AUS 361, AUS 198, AUS 197
114	Wattamolla Reef	34° 08' 55 S	151° 08' 35 E	AUS 808, AUS 361
115	Windang Island	34° 32' 55 S	150° 52' 40 E	AUS 808, AUS 361
116	Bass Point - Gutters	34° 46' 30 S	150° 54' 25 E	AUS 808, AUS 361
117	Bass Point - Arch and Cave	34° 35' 55 S	150° 54' 05 E	AUS 808, AUS 361
118	Black Rock (off Gerroa)	34° 47' 10 S	150° 49' 35 E	AUS 808, AUS 361
119	The Big Bommy (off Gerroa)	34° 47' 40 S	150° 49' 00 E	AUS 808, AUS 361
120	Sir John Young Banks (off "The Banks", Crookhaven Bight)	34° 59' 30 S	150° 50' 50 E	AUS 807, AUS 360, AUS 193
121	Bombora to the west of Sir John Young Banks ("The Banks", Crookhaven Bight)	34° 59' 40 S	150° 50' 00 E	AUS 808, AUS 807, AUS 360, AUS 193
122	Lobster Bay (near Little Beecroft Head)	35° 00' 15 S	150° 51' 30 E	AUS 808, AUS 807, AUS 360, AUS 193
123	Drum and Drumsticks (Lamond Head, Beecroft Peninsula)	35° 02' 55 S	150° 50' 25 E	AUS 808, AUS 807, AUS 360, AUS 193
124	The Docks (Jervis Bay)	35° 05' 25 S	150° 47' 55 E	AUS 808, AUS 807, AUS 360, AUS 193
125	Black Boat Cove (Jervis Bay)	35° 04' 45 S	150° 47' 25 E	AUS 808, AUS 807, AUS 360, AUS 193

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
126	Bowen Island (Jervis Bay)	35° 07' 10 S	150° 45' 25 E	AUS 808, AUS 807, AUS 360, AUS 193
127	Red Point (Bendalong)	35° 15' 05 S	150° 32' 25 E	AUS 807, AUS 360
128	Green Island (off Cunjurong Point)	35° 16' 05 S	150° 31' 00 E	AUS 807, AUS 360
129	South Warden Head (off Ulladulla)	35° 22' 00 S	150° 29' 55 E	AUS 807, AUS 360
130	Brush Island - Gutter	35° 31' 55 S	150° 25' 20 E	AUS 807, AUS 360
131	Brush Island - Pinnacle	35° 31' 45 S	150° 25' 30 E	AUS 807, AUS 360
132	Belowla Island (to the north of O'Hara Head)	35° 33' 20 S	150° 23' 30 E	AUS 807, AUS 360
133	Grasshopper Island (off Durras North)	35° 38' 05 S	150° 21' 15 E	AUS 807, AUS 360
134	Wasp Island (off Durras)	35° 40' 20 S	150° 18' 55 E	AUS 807, AUS 360
135	North Head (Batemans Bay)	35° 43' 20 S	150° 16' 30 E	AUS 807, AUS 360
136	Tollgate Islands (Batemans Bay)	35° 45' 20 S	150° 15' 15 E	AUS 807, AUS 360
137	Trennant Rock (Batemans Bay)	35° 45' 40 S	150° 15' 00 E	AUS 807, AUS 360
138	Black Rock (Batemans Bay)	35° 46' 55 S	150° 15' 00 E	AUS 807, AUS 360
139	Burrewarra Point	35° 50' 05 S	150° 13' 45 E	AUS 807, AUS 360
140	Broulee Island	35° 51' 55 S	150° 11' 05 E	AUS 807, AUS 360
141	Tuross Head	36° 03' 30 S	150 08' 35 E	AUS 807, AUS 360
142	Potato Point	36° 05' 40 S	150° 08' 15 E	AUS 807, AUS 360
143	Montague Island - northern shark gutters	36° 14' 30 S	150° 13' 35 E	AUS 807, AUS 360
144	Montague Island - western gutters, cave and pinnacles	36° 15' 25 S	150° 13' 20 E	AUS 807, AUS 806, AUS 360

Number	Location	Approximate Coordinates (WGS84)		Nautical Chart Reference Number
		South	East	
145	Aughinish Rock (south of Montague Island)	36° 16' 30 S	150° 12' 35 E	AUS 807, AUS 806, AUS 360
146	Mimosa Rock (south of Bunga Head)	36° 35' 15 S	150° 03' 35 E	AUS 806, AUS 360
147	Tathra Head	36° 43' 30 S	149° 59' 30 E	AUS 806, AUS 360
148	Turingal Rock (off Turingal Head)	36° 47' 30 S	149° 58' 15 E	AUS 806, AUS 360
149	Tura Head (north of Merimbula)	36° 51' 25 S	149° 57' 00 E	AUS 359
150	Mewstone Rock (off Worang Point, Twofold Bay)	37° 04' 00 S	149° 57' 00 E	AUS 359
151	Seahorse Shoals (off Red Point, Twofold Bay)	37° 05' 40 S	149° 57' 25 E	AUS 359
152	Green Cape	37° 15' 55 S	150° 03' 10 E	AUS 359
153	Gabo Island	37° 33' 55 S	149° 55' 20 E	AUS 359

