NSW DPI

Report into the NSW Shark Meshing (Bather Protection) Program

Incorporating a review of the existing program and environmental assessment

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Public Consultation Document

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PRIMARY INDUSTRIES

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Background

The NSW Department of Primary Industries manages the Shark Meshing (Bather Protection) Program in NSW, hereinafter referred to as the SMP. A total of 51 ocean beaches from Wollongong to Newcastle are currently netted between 1 September and 30 April each year using bottom-set mesh nets. Since it was introduced in Sydney in 1937, the SMP has been effective in reducing incidences of fatal shark attack at major metropolitan beaches, with only one fatal shark attack on a netted beach since the SMP began.

Although the SMP has been effective in reducing the risk of shark attack, it is also listed as a Key Threatening Process under both the *Fisheries Management Act 1994* and *Threatened Species Conservation Act 1995* in recognition of its impacts on threatened species. The nets also impact on protected species and other non-target animals. Since the SMP began, a range of measures have been introduced to reduce the impacts on non-target species, such as fitting acoustic devices to reduce interactions with whales and dolphins, and setting nets on the sea bed to reduce interactions with marine mammals, reptiles and birds. The nets are also removed during the majority of the whale migration season between May and August, further reducing the risk of harm to whales. The SMP aims to find a balance between providing an important public safety measure while reducing environmental impacts.

The NSW Government recently passed legislative amendments to allow the future management of the SMP to be undertaken through joint management agreements under the State's threatened species legislation; the *Threatened Species Conservation Act 1995* and the *Fisheries Management Act 1994*. Joint management agreements are a simplified adaptive management arrangement, and include independent third-party annual review by the NSW Scientific Committee (established under the *Threatened Species Conservation Act 1995*) and the Fisheries Scientific Committee (established under the *Fisheries Management Act 1994*). The draft agreements are subject to public exhibition before they are finalised. As part of this process, NSW Department of Primary Industries has committed to review the SMP to assess its potential environmental impacts, and to thus its inform future management.

This report represents the first such systematic and publicly available report into the SMP. The aim of this report is to review the existing operational aspects of the SMP, to assess its potential environmental impacts, and to identify and make recommendations about ways to improve the operation of the SMP. This report is considered to be an important reference source to enhance public understanding of the operation of the SMP, and to assist the public make informed comment on the draft joint management agreements and draft management plan during the public exhibition period.

Major outcomes of this report

The last major review of the SMP was in 1972, and although there have been some amendments to the program since then, most of existing operational aspects of the SMP were set at that time. The risk analysis of the SMP used in the environmental assessment indicated that it poses a moderate risk to grey nurse and great white sharks, negligible risk to other sharks, rays and finfish, and a low risk to marine mammals, reptiles and birds.

The draft management plan provides an opportunity to further reduce the potential impact on threatened species and other non-target species, and to maximise the potential scientific benefits of the SMP. Recommendations are made throughout the body of the report.

A summary of the key recommendations are:

i. Prepare publicly available annual reports for the program.
ii. Undertake a major review of the program every 5 years.
iii. Ensure the objectives of the program are clearly stated.
iv. Ensure transparency and public understanding of the operation of the program.
v. Maintain the temporal extent of the program.
vi. Increase the frequency of net checking.
vii. Investigate standardising mesh sizes.

viii. Remove double meshing provisions.
ix. Consider the use of smaller administrative regions.
x. Establish a strategic research and monitoring plan.
xi. Monitor changes in catch and establish trigger points for review.
xii. Prepare a shark attack risk assessment.
xiii. Consider alternatives to meshing in areas where numbers of grey nurse shark are caught.
xiv. Investigate the feasibility and merit of identification guides for stingrays and cetaceans.
xv. Maximise the retention of biological samples of sharks, stingrays and cetaceans.
xvi. Undertake ongoing assessment of the impact and risk of the program on marine species.
xvii. Continue to monitor, assess and report on catch and release rates of marine mammals, reptiles and birds.
xviii. Develop formal disentanglement, release and revival procedures, especially for large cetaceans and sea turtles.

Consulting the Community

You are invited to make written submissions on this Report, the draft Joint Management Agreements and draft Management Plan for the NSW Shark Meshing (Bather Protection) Program, which are on public exhibition until **Friday 1st May 2009**.

The documents can be viewed during normal business hours at the following locations:

- Department of Primary Industries Head Office, 161 Kite Street, Orange
- Department of Primary Industries, Level 6, 201 Elizabeth St, Sydney
- Department of Primary Industries coastal fisheries offices
- Department of Environment and Climate Change Head Office, Level 14, 59-61 Goulburn Street, Sydney
- Department of Environment and Climate Change Newcastle Office, 117 Bull Street, Newcastle West
- Botany Bay National Park, Cape Solander Drive, Kurnell
- Ku-Ring-Gai Chase National Park, Ku-Ring-Gai Chase Road, Bobbin Head
- Department of Environment and Climate Change Illawarra Area Office, 84 Crown Street, Wollongong

The documents are also available by contacting DPI on 1300 550 474, and online at www.dpi.nsw.gov.au; and www.environment.nsw.gov.au. You can also lodge an online submission at those websites.

Would you like to comment?

Write to: Shark Meshing Submissions
Locked Bag 1
Nelson Bay NSW 2315

Fax: (02) 4982 1107 (marked attention "Shark Meshing Submissions")

Email: sharkmesh.submissions@dpi.nsw.gov.au

If you wish your name and address to remain confidential your submission should be so marked.

Submissions must be received by close of business FRIDAY 1st MAY 2009

1 INTRODUCTION

1.1 BACKGROUND AND AIMS

The NSW Department of Primary Industries (DPI) manages the Shark Meshing (Bather Protection) Program in NSW, hereinafter referred to as the SMP. Since it was introduced in Sydney in 1937, the SMP has been effective in reducing incidences of shark attack at major metropolitan beaches, with only one fatal shark attack on a netted beach since the SMP began. A total of 51 beaches from Wollongong to Newcastle are currently netted between 1 September and 30 April each year.

Although the SMP has proved an effective prevention against shark attacks, it is also listed as a Key Threatening Process (KTP) under both the NSW *Fisheries Management Act 1994* (FM Act) and the NSW *Threatened Species Conservation Act 1995* (TSC Act) as it adversely affects two or more threatened species listed under those acts. It was also nominated as a KTP under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), but was deemed ineligible for inclusion as it was found to adversely affect only one species, grey nurse shark (TSSC 2005). The National Plan of Action for the Conservation and Management of Sharks (SAG and Lack 2004) also lists the SMP as an activity requiring some form of assessment to gauge it its potential impacts on threatened species of sharks, as the nets do not discriminate between target species and non-target species, including threatened or protected species such as grey nurse sharks, turtles, dolphins and whales.

Measures to minimise harm to non-target species and to improve bather protection have been introduced as a result of previous reviews of the SMP, not least of which was the Scientific Shark Protection Summit hosted by DPI in 2006. Some of those measures include fitting acoustic devices to all nets to reduce interactions with marine mammals, and setting nets on the sea bed to reduce interactions with marine mammals, reptiles and birds. Removing the nets during the majority of the whale migration season between May and August further decreases the risk of harm to whales.

For these and other reasons that will be discussed below, the DPI considered it timely to review the SMP, and this report represents the first such systematic and publicly available report into the SMP. The aim of this report is to review the existing operational aspects of the SMP, to assess its potential environmental impacts, and to identify those aspects of the SMP that require some modifications and/or risk mitigation strategies. Those modifications and strategies will be outlined in subsequent documents, namely joint management agreements and a management plan for the SMP.

1.2 LEGISLATIVE CONTEXT

Until recently, the SMP was listed along with the State's commercial fisheries as a designated fishing activity under the FM Act and the *Environmental Planning and Assessment Act 1979* (EP&A Act). Designated fishing activities require the preparation of an Environmental Impact Statement (EIS) under Part 5 of the EP&A Act, incorporating a fishery management strategy and associated environmental assessment (the term 'environmental' in that instance encompasses ecological, social and economic components). The aim of the environmental assessment is to determine the actual or likely impact of the activity on the environment, consider feasible alternatives, and propose measures to mitigate harm.

Recent legislative amendments mean that the SMP is not an activity for the purposes of the FM Act or EP&A Act, and as such is not subject to a fishery management strategy and environmental assessment. The DPI has however, identified similar environmental management provisions in both the TSC Act and the FM Act, namely Joint Management Agreements (JMA), and considers JMAs a more appropriate tool by which to manage the SMP with respect to its potential to jeopardise the survival of threatened species, populations or ecological communities.

Joint Management Agreements are a simplified adaptive management arrangement, and they include independent third-party annual review by the NSW Scientific Committee (established under the TSC Act) and the Fisheries Scientific Committee (established under the FM Act), and the draft JMAs are also subject to public comment before they are finalised. The nature of the legislation requires that two JMAs will be required: one under section 121 of the TSC Act between the Directors-General of the NSW Department of Environment and Climate Change and the NSW Department of Primary Industries; and a second under section 221V of the FM Act between the NSW Minister for Primary Industries and the Director-General of the NSW Department of Primary Industries.

The content and form of JMAs are spelt out in their respective legislature, but as 'agreements' they are not designed to contain detailed information about the management, processes and reporting functions of a complex program like the SMP. Instead, that information will be contained in an intrinsically and explicitly linked draft management plan, which like the draft JMAs, will be subject to comment by the public and scientific committees before it is finalised.

1.3 STRUCTURE AND SCOPE OF THIS REPORT

This chapter provided some background and context to this report, and to the subsequent draft JMAs and management plan.

Chapters 2 and 3 will identify and make recommendations about those aspects of the SMP that require some modification and/or monitoring through the draft JMA and management plan.

Chapter 2 will review the broader management and day to day aspects of the existing operation of the SMP, examine other bather protection strategies, and review the nature of shark attacks in NSW. By critically analysing the operational aspects of the SMP relative to other programs and incidences of shark attack, the review will identify those operational aspects that should continue unchanged and those that require modification.

Chapter 3 will use a risk analysis framework based on the Australian Standard (AS/NZS 4360) to identify the potential environmental impacts of the existing SMP.

Whilst this report will also be placed on public exhibition, it will not be modified following public exhibition unless there are significant errors or misrepresentations in this report, as is standard practice for a document of this nature (i.e. analogous to an EIS). The primary role and scope of this report is to inform the development of the draft JMAs and management plan, and to enhance public understanding of the operation and potential environmental impacts of the existing SMP.

The NSW Government is committed to the existing spatial coverage of the SMP, and whilst some technical and operational aspects may change as a result of this report, the number and location of meshed beaches will remain unchanged.

2 REVIEW OF THE EXISTING SHARK MESHING PROGRAM

2.1 OBJECTIVES

The SMP began in Sydney in 1937 and since then has had varying objectives, including but not limited to: reducing the risk of shark attack for surfers and swimmers; culling populations of large aggressive sharks; and deterring large sharks from establishing territories adjacent to metropolitan swimming beaches.

The most recent and widely accepted objective of the SMP is to reduce the risk of shark attack at major metropolitan beaches. To meet that objective, nets are deployed in nearshore waters on a seasonal basis to restrict the ability of large, potentially dangerous sharks to access those swimming beaches.

With large sharks the focus of the SMP, it is not unexpected that to date the objective has not included or referred to any other components of the marine ecosystem. However, given its potential for impacts on other marine fauna, including some threatened species, the management plan for the SMP should include an overarching aim or objective related to reducing the risk of shark attack, but should also contain some secondary objectives related to minimising the impacts of the SMP on other marine fauna.

2.2 AREA OF OPERATION

2.2.1 Scope and number of contractors

The SMP began on most of Sydney's beaches in October 1937 and has operated continuously except for a three year break during World War 2. In December of 1949 it was expanded to include beaches at Wollongong and Newcastle, and in January 1987 the Central Coast was included (Reid and Krogh 1992). The decision to use meshing was made after evaluation of several different options, including total enclosure of some beaches to prevent any access by sharks (SMAC 1935). It was acknowledged that complete enclosure of swimming areas on coastal beaches, such as the enclosure at Coogee in the early 1900s, was not feasible due to the rough seas frequently experienced along the coast.

The SMP uses specially designed nets along 51 beaches from Newcastle to Wollongong (Table 1), where the majority of people in NSW swim and surf. The SMP is currently divided into five geographical regions, namely Newcastle (10 beaches), Central Coast (11 beaches), Sydney North (15 beaches), Sydney South (10 beaches) and Illawarra (5 beaches), with one contractor employed per region.

Table 1 The 5 regions and 51 beaches of the SMP

Newcastle	Central Coast	Sydney North	Sydney South	Illawarra
Stockton	Lakes	Palm	Bondi	Coledale*
Nobbys	Soldiers	Whale	Bronte	Austinmer
Newcastle	The Entrance	Avalon	Coogee	Thirroul
Bar	Shelly	Bilgola	Maroubra	North Wollongong
Dixon Park*	Terrigal	Newport	Wanda*	South Wollongong
Merewether	North Avoca	Mona Vale	Elouera*	
Redhead	Avoca	Warriewood	North Cronulla*	
Swansea-Blacksmiths	Copacabana	North Narrabeen*	Cronulla	
Caves	MacMasters	Narrabeen	Wattamolla*	
Catherine Hill Bay	Killcare	Dee Why	Garie*	
	Umina	Curl Curl		
		Harbord		
		Queenscliff		
		North Steyne*		
		Manly		

* denotes beaches that were not meshed until 1972

2.2.2 Marine protected areas within the area of operation

The NSW Government is committed under international, national and state agreements to conserve marine biodiversity and manage the ecologically sustainable use of fish and marine vegetation. A key component of these strategies is to establish a system of marine protected areas that adequately represent the biodiversity found in the oceans and estuaries of Australia. Sixty-five marine bioregions and provinces have been identified by scientists and conservation managers to assist in planning a National Representative System of Marine Protected Areas in Australian waters (IMCRA 1998), five of which are located in NSW waters.

The five marine bioregions in NSW waters include: Tweed-Moreton, which extends from the Tweed River south to Nambucca Heads; Manning Shelf Bioregion, which extends from Nambucca River south to Stockton; Hawkesbury Shelf Bioregion, which extends from Stockton south to Shellharbour; Batemans

Shelf Bioregion, which extends from Shellharbour to Tathra; and Twofold Shelf Bioregion, which extends from Tathra to beyond the NSW-Victoria border. The SMP extends across the Hawkesbury Shelf Bioregion, and also includes a couple of beaches from the northern and southern end of Batemans Shelf and Manning Shelf Bioregions, respectively.

Marine parks are the primary and largest marine protected area, and other areas for marine biodiversity conservation in NSW waters include aquatic reserves, marine extensions of national parks, and critical habitats. There are also fishery-specific closures, closed waters, intertidal protected areas and habitat protection plans but those protective provisions have no bearing on and are unaffected by the SMP.

Marine parks

Marine parks are the largest type of marine reserve in NSW. Marine parks are areas of coastal, estuarine or oceanic waters and adjoining lands permanently set aside to protect the organisms including plant life, fish, birds and other animals that live in that environment. Marine parks are managed to effectively conserve biodiversity and associated natural and cultural resources, while still allowing for the sustainable use and enjoyment of these areas by the community.

Marine parks aim to conserve biodiversity by protecting representative samples of the habitats in the five defined marine bioregions occurring in NSW waters. Of the six existing marine parks in NSW, none are within the area of the SMP as there are currently no marine parks in the Hawkesbury Shelf Bioregion. The southern edge of Port Stephens/Great Lakes Marine Park is located at the northern end of Stockton Beach, which is the northern most meshed beach.

Stockton Bight is approximately 35 km in length and is thought to be an important area for juvenile great white sharks and whalers (specifically spinner shark, *Carcharhinus brevipinna*), and possibly other *Carcharhinus* species. Between 1990/91 and 2007/08, a total of 190 sharks were caught in the nets off Stockton Beach (Table 2), almost 50% more than at Wattamolla with 129 over the same period. Species and numbers of sharks caught at Stockton over that period included 124 hammerheads, 38 whalers, 19 great whites (~22% of all great whites caught over the period), 7 Port Jacksons, 1 sevengill and 1 tiger shark.

Aquatic reserves

Aquatic reserves play an important role in conserving biodiversity and protecting significant marine areas. Currently 12 aquatic reserves have been declared in NSW. Each aquatic reserve is unique, with the type of protection varying throughout the reserves. In some areas, diving and observing are the only activities permitted whilst in others, activities such as recreational angling are allowed.

Of the 12 aquatic reserves, 10 are within the Hawkesbury Shelf Bioregion and thus overlap with the SMP (Table 2). Only Cook Island Aquatic Reserve and Bushrangers Bay Aquatic Reserve are outside the area of operation and all forms of fishing are prohibited in those reserves. Of the 10 aquatic reserves within the area of operation, three are within estuaries and the other seven are located on and extend 100 m beyond rocky headlands.

Marine or estuarine extensions of National Parks or Nature Reserves

The only existing marine extension reserved as a national park occurs adjacent to Bouddi National Park on the Central Coast. The marine extension covers an area of almost 300 hectares between Gerrin Point and Third Point, a distance of approximately 3.8 km and encompassing Maitland Bay, Maitland Bombora, Bouddi Point and Caves Bay. With the exception of Maitland Bay, the foreshore is comprised of steep rocky headlands. The marine extension includes both the seabed and the waters beneath which it is submerged. A section 8 closure under the FM Act applies to the marine extension, which prohibits the taking of fish by all methods. Nets are not set in the waters off Bouddi National Park, with the closest meshed beaches being Killcare (Table 2) to the south and MacMasters to the north.

Critical habitats

Under the FM Act, the whole or any part of the habitat of an endangered species, population or ecological community that is critical to the survival of the species, population or ecological community is eligible to be declared as critical habitat. Grey nurse shark is the only species for which critical habitat has been declared, and there are currently 10 such locations (www.dpi.nsw.gov.au). Grey nurse sharks roam over most of the NSW coast, but are known to gather, feed, mate and pup at a limited number of locations. Studies of the distribution and abundance of grey nurse shark suggest that there are numerous such sites in

NSW waters (Otway and Parker 2000; Otway et al. 2003), and to date most of those have been declared as critical habitats or protected as sanctuary zones in NSW and Commonwealth marine protected areas.

Magic Point at Maroubra is the only critical habitat within the SMP’s area of operation, with the northern end of the critical habitat abutting the southern end of Maroubra Beach (Table 2). Magic Point consists of large cave overhangs and nearby gutter formations that are part of the reef system extending from the headland, and the nets at Maroubra are generally set some 200 m to the north on bare sand. Aggregations were observed at Magic Point during 56% of surveys conducted between 1998 and 2001, and account for approximately 3.5% of the total sampled population, and 4.1% of the female sampled population (Otway and Parker 2000; Otway et al. 2003). Despite Magic Point being adjacent to Maroubra Beach, the last grey nurse shark entangled in the nets off Maroubra was in 1958. Between 1990/91 and 2007/08: two grey nurse were caught at nearby Coogee Beach (4 km away), one of which was released alive; one caught and released alive from Bronte Beach (6.5 km); and four were caught at Bondi Beach (8 km), one of which was released alive.

Table 2 Marine protected areas within or adjacent to beaches of the SMP

Marine Protected Area	Name	Closest meshed beach	Distance	Sharks caught at closest beach from 1990/91 - 2007/08
Marine Parks	Port Stephens/Great Lakes	Stockton	20 km	124 hammerheads, 38 whalers, 19 great whites, 7 Port Jacksons, 1 tiger, 1 sevengill
Aquatic Reserves	Barrenjoey Head	Palm Beach	400 m	49 hammerheads, 3 whalers, 2 whites, 1 tiger, 1 angel shark, 1 thresher, 1 mako
	Narrabeen Head	Narrabeen	400 m	13 hammerheads, 7 whalers, 2 angel sharks, 1 tiger, 1 sevengill, 1 grey nurse
	Long Reef	Dee Why	1 km	7 hammerheads, 2 whites, 2 sevengills, 1 whaler
	Cabbage Tree Bay	Manly	400 m	15 hammerheads, 3 whalers, 3 angel sharks
	North Harbour (estuarine)	Manly	6.5 km	15 hammerheads, 3 whalers, 3 angel sharks
	Bronte-Coogee	Coogee	400 m	27 Port Jacksons, 13 angel sharks, 4 whalers, 2 grey nurse
	Cape Banks	Maroubra	6 km	22 whalers, 18 angel sharks, 17 hammerheads, 4 tigers, 4 makos, 2 Port Jacksons, 1 thresher
	Boat Harbour	Wanda	3 km	8 hammerheads, 6 angel sharks, 5 whalers, 2 tigers, 2 threshers, 1 white, 1 Port Jackson
	Towra Point (estuarine)	Maroubra	10 km	22 whalers, 18 angel sharks, 17 hammerheads, 4 tigers, 4 makos, 2 Port Jacksons, 1 thresher
	Shiprock (estuarine)	Cronulla	5 km	21 hammerheads, 7 whalers, 6 Port Jacksons, 5 angel sharks, 2 tigers, 1 sevengill, 1 mako
	Bushrangers Bay	South Wollongong	15 km	88 hammerheads, 25 angel sharks, 10 whalers, 4 sevengills
Marine Extensions of National Parks	Bouddi National Park	Killcare	1 km	63 hammerheads, 14 whalers, 2 sevengills, 2 threshers, 1 white, 1 grey nurse, 1 angel shark
Critical Habitat	Magic Point	Maroubra	200* m	22 whalers, 18 angel sharks, 17 hammerheads, 4 tigers, 4 mako, 2 Port Jacksons, 1 thresher

* denotes the estimated distance between the critical habitat and general location of the shark meshing net off Maroubra Beach

2.2.3 Other factors that potentially influence the operation of the SMP

Weather

Storms and rough seas have significant effects on the operation of the equipment, and increase the likelihood of mortalities of any entangled animals. In particular, rough seas and storms reduce the effectiveness of the electronic pinging devices that are installed to deter dolphins. Contractors endeavour to remove the nets from the water prior to major storms to reduce the chance of net loss and prolonged entanglement of animals, but occasionally forecasts do not allow enough lead-time even though the nets are generally less than 500 m from shore. When nets are damaged in heavy seas, they sink and then generally roll up on themselves and are usually washed up onto beaches soon after. The close proximity to sandy ocean beaches restricts the potential for ghost-fishing from lost nets. Over the past five seasons, each of the contractors has lost an average of 1 net per season, although very few nets were lost because of storms or sea conditions, rather the contractors attributed most net losses to damage by other boats, e.g. trawlers.

Spoil grounds

Spoil grounds for major excavations and dredging are generally in waters greater than 20 m depth and so generally beyond the 10 m depth at which most nets are set. Major spoil grounds within the area of operation are located off the ports of Wollongong and Newcastle in waters ranging from 30 - 120 m deep. There are also periodic beach nourishment exercises at Cronulla and Narrabeen beaches. Every 3 to 5 years sand is dredged from Port Hacking and deposited on Cronulla Beach. The last occasion was for a six-week period in November - December 2007. Similarly, sand is dredged from Narrabeen Lagoon and deposited onto the Collaroy-Narrabeen stretch of beach. There has been no apparent impact on the SMP at either beach during those beach nourishment exercises.

Cable protection zones

In early July 2007, the Commonwealth's Australian Communications and Media Authority (ACMA) made two declarations for submarine cable protection zones off the Sydney coast which have now been in effect since 1 October 2007. The protection zones were developed around two cables that are regarded as nationally significant: the Southern Cross Cable, which links Australia's communications network with New Zealand, Fiji and the United States; and the Australia Japan Cable, which links Australia with Guam, Japan and Asia. The Northern Sydney Protection Zone extends from Narrabeen Beach to around 40 nautical miles offshore, to the 2,000 metre water depth, and covers the northern branches of the Australia Japan Cable and the Southern Cross Cable. This zone extends one nautical mile either side of each cable and includes the area in between the two cables. The Southern Sydney Protection Zone extends from Tamarama and Clovelly beaches and extends 30 nautical miles offshore, to the 2000 metre water depth, and covers the southern branches of the Australia Japan Cable and the Southern Cross Cable. This zone extends one nautical mile either side of each cable and includes the area in between the two cables (ACMA 2007).

The SMP is unaffected by the protection zones because they pose a low risk of damage to a cable. Nets are generally set within 500 m from shore, and in those areas the cables are buried several metres below the seabed and housed in metal conduit. Anchoring is unrestricted in that area, although anchoring restrictions apply beyond 500 m from shore.

2.3 OPERATIONAL CHARACTERISTICS

2.3.1 Contractual arrangements and implementation

Numerous NSW government departments, private contractors and their employees, and scientific observers are involved in the SMP. The NSW Treasury department funds the SMP and in 2007/08 cost in excess of $800,000, and the projected cost for 2009/10 is estimated to be approximately $990,000. This includes provision for increase in contract price, salary for shark meshing observers and shark technician, shark meshing equipment (dolphin pingers and whale alarms etc.), and an allocation for undertaking compliance audit activities. The Government Contracts Board within the NSW Department of Commerce administers the tendering process for contracts, and developed the metric for selection of contractors in collaboration with the DPI Fisheries Compliance Branch (see Appendix 1 for the 2008/09 contract specifications). The DPI is responsible for the day-to-day administration and management of the SMP.

Operations in each of the five regions involve the contractor (i.e. skipper of the vessel), a deckhand and a scientific observer employed by DPI. The scientific observers are employed in a casual capacity for 40 -72 hours per month, depending on region, during the months of September to April inclusive.

2.3.2 Gear and deployment

The configuration of nets currently used in the SMP was standardised in 1972, including a change from surface-set to bottom-set nets. The nets are multifilament flat braid polyethylene with a corkline and leadline, with 160 kg breaking strength, 150 m long, 6 m high, 50 - 60 cm mesh size when measured between knots when stretched taut, 12 - 14 meshes deep, 0.67 hanging coefficient for the net on the corkline and leadline (i.e. 33% slack hung in) and 0.74 coefficient for the sidelines at the end of each net. The hanging coefficient determines the looseness of the net, and a coefficient of 29.3% would mean that the nets hang squarely. The 33% slack results in a vertically elongated mesh (Dudley 1997).

The nets are bottom-set on bare sand and held in position using sand anchors weighing between 27 and 30 kg. Nets are required to be set parallel to the beach in waters 10 to 12 m deep (i.e. about 4 - 6 m below the surface), which generally corresponds to a distance of within 500 m of the beach. This configuration for a net is referred to as a ‘set’ (Figure 1), although two nets can be set simultaneously to constitute two sets for that beach. The location of a set is determined by the prevailing and forecast wind, seas and currents, but is usually adjacent to the surf clubs and patrolled swimming areas.

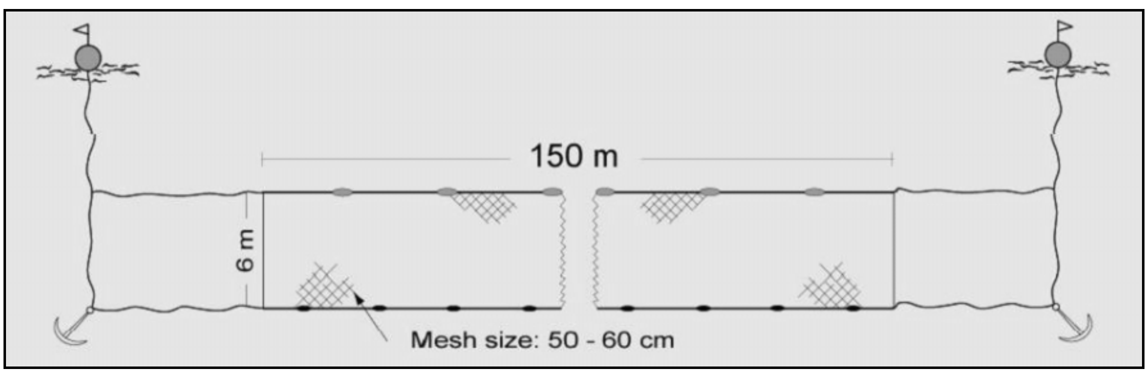

Figure 1 Indicative configuration of a ‘set’ net (not to scale)

(Source: Reid 2006)

Contractors are currently required to set and check nets at each beach for each weekend day and nine weekdays per month over the period of the SMP, which is between 1 September to 30 April each year. At its commencement in Sydney in 1937 and Newcastle and Illawarra in 1949, the SMP ran year round, however June and July were dropped from the SMP following a review in 1983. In 1989, May and August were also dropped, reducing the overall effort for the Newcastle, Sydney and Illawarra regions by a third from the pre-1983 level. This effort was effectively shifted along the coast following the inclusion of Central Coast beaches into the SMP in January 1987. This effort shift enables the SMP to maintain a high

degree of protection during the peak summer months for bathers while simultaneously reducing the potential impact on migrating cetaceans.

The checking of nets (referred to as ‘running the nets’) is completed by working hand-over-hand along the floatline, pulling the floatline up to the boat, and observing any entangled animals in each section of the net (Figure 2). A meshing is complete when a net is run and cleared after it has been set continuously in the water for a minimum of 12 hours between 4 pm on one day and sunrise the following day. Set nets are to be run and cleared after a period not exceeding 96 hours.

Figure 2 ‘Running the nets’

2.3.3 Boats used in the SMP

There are no contractual specifications for the sizes of boats or dinghies to be used in the SMP other than that they be registered commercial boats. The most commonly used boats in the SMP are about 15 m long, with winch capacities of between 2 and 4 tonnes (Figures 3 - 6).

Figure 3 Wooden hull boat, 14 m long, lifting gear 2 tonne capacity used in the Newcastle region

Figure 4 Metal hull boat, 15 m long, lifting gear 2 tonne capacity used in the Sydney North region

Figure 5 Wooden hull boat, 15 m long, lifting gear 4 tonne capacity used in the Sydney South region

Figure 6 Wooden hull boat, 15 m long, lifting gear 2 tonne capacity used in the Illawarra region

2.3.4 Mitigative measures to reduce capture of non-target animals

A range of technical and logistical mitigative measures are used to minimise capture of non-target animals. A trial of acoustic ‘pingers’ commenced in the 1999/00 season, with full coverage from 2001/02. Pingers and ‘whale alarms’ are deployed on every net to reduce captures of dolphins and whales, respectively. Pingers and whale alarms emit a sound wave that deters the mammals from the area and thus reduces the chances of entanglement.

Prior to the installation of pingers, an average of 3.3 dolphins were caught per year from 1990 - 2000, but since pingers were introduced the average has been reduced to 2 dolphins per year. As with any acoustic device in water, the signal/sound wave is muted and distorted by the noise of heavy seas during storms and rough seas, increasing the potential for entanglement and mortality of dolphins.

Only one humpback whale has been found dead in the nets since the SMP began. The whale was believed to have died at sea and washed into the net en-route to washing ashore, as the net was reportedly in good condition and still in position following police removal of the carcass before the contractor was able to launch. Although the historical whale catch has been extremely low, it is possible that with increasing numbers of humpback whales there could be an increase in the number of entanglements in future. Following the success of whale alarms in reducing whale entanglements in fishing gear, both internationally and in the Queensland shark control program, whale alarms were deployed on the SMP nets in the 2004/05 season. No whale entanglements have been reported since then. In addition to whale alarms, the SMP does not include the winter months from 1 May until 30 August, as this is the major part of the humpback whale migration season.

Nets are also bottom-set on open sandy beaches, lessening the probability of turtle entanglement.

In addition to measures that have already been implemented in the SMP, the DPI is a signatory to some national bycatch and shark catch reduction policies, namely the National Plan Of Action for the Conservation and Management of Sharks (NPOA-Sharks) (SAG and Lack 2004) and the National Bycatch Policy (MCFFA 1999). The NPOA-Sharks identifies 43 actions that are designed to reduce the impact of Australian fishing practices on populations of sharks in Australian waters. Action 7 of NPOA-Sharks is directly relevant to this report in that it states: “Initiate an assessment of the ecological impacts of shark

control programs for bather protection (including drumlines and nets) or if this assessment has recently been undertaken, continue to monitor the ecological impacts”. Further, the National Bycatch Policy provides a policy mandate to all Australian fishing agencies to manage the impact of fishing on non-target species and in particular to address the level of bycatch. The existing measures, this review of the SMP and the draft JMA and associated draft management plan represent significant steps towards meeting national and international obligations with respect to both the conservation and management of sharks and to reducing bycatch.

2.3.5 Procedures for handling captured animals

Until recently, large and/or dangerous sharks caught in the nets were euthanased and disposed of at sea, but now all sharks found alive in the nets, or with a reasonable chance of recovery from injuries, are released alive. If the contractor assesses that the shark is unlikely to recover from injuries, the shark is euthanased. The observers monitor these operations, under the general instructions of the Shark Biologist. Acknowledging the potential risk for harm to both contractors and animals from such a practice, a Workplace Safety Plan has been developed by DPI in collaboration with the contractors and their deckhands, and overseen by consultants in workplace safety. The Workplace Safety Plan is a contractual requirement, and contractors are also required to prepare Safe Work Methods Statements, incorporating the principles and practices contained in the Commonwealth’s information booklet, ‘Protecting Whales and Dolphins’. Examples of some procedures for safe handling include using a sea-hose to spray water over the gills of live dangerous sharks during transport away from shore (non-dangerous sharks are released *in situ*), and the use of air-tubes to revive recently caught turtles.

2.3.6 Scientific studies

Flesh samples are taken for DNA/genetic analysis from live sharks and rays and provided to a large number of scientists in Australia and overseas. Morphometric data (i.e. up to 57 measures of length and weight) and biological data (including reproductive status and stomach contents) are collected from as many specimens as is logistically possible and vertebral samples are also taken for age and growth studies. Jaws are retained for research and education purposes at Cronulla Fisheries Centre, Taronga Zoo and the Australian Museum. After sampling by the observer or scientific staff at Cronulla Fisheries Centre or Port Stephens Fisheries Institute, dead sharks are disposed of several kilometres out to sea or in municipal waste disposal facilities.

2.3.7 Data gathering, management and reporting

Catch and effort

Contractors use monthly catch returns to report all animals entangled in the nets, whether or not they were released alive, approximate lengths, the setting and checking/hauling of each net, extent to which dead animals were sampled/processed and whether dead animals were disposed of at sea or returned to DPI for further scientific processing (Appendix 2). Reports from observers, including photo images of each animal caught are provided monthly to the DPI Shark Biologist. The data is entered into a Microsoft Access™ database, which has records dating back to 1950. The database is updated by an observer/technician under the direction of the Shark Biologist. The database is currently being rewritten in SQL language. Retrieval of data and reports is by Access queries and/or by tables in Microsoft Excel™.

Species identification

Contractors are reasonably proficient in the identification of most shark groups, and updates or advancements in identification techniques are ongoing at DPI. A shark identification guide for use in the field was recently prepared by DPI for commercial fishery observers, and will be provided to contractors and observers in the SMP.

Until recently, sharks identified to genus level were the whalers, which could include up to 10 species of the genus *Carcharhinus* (Paxton et al. 1989), hammerheads (*Sphyrna*, three species), wobbegongs (*Orectolobus*, three species (Huveneers 2006)), Port Jackson sharks (*Heterodontus*, two species), and threshers (*Alopias*, two species). Similarly, rays are not routinely identified to species and are recorded as rays, but the group is likely to comprise skates (family Rajidae), stingrays (family Dasyatididae), stingarees (family Urolophidae) and other rays which belong to the families Mobulidae, Mylibatididae, Rhinobatidae, Rhinopteridae and Rhynchobatidae.

Sharks identified to species include great white (*Carcharodon carcharias*), shortfin mako (*Isurus oxyrinchus*), tiger (*Galeocerdo cuvier*), sevengill (*Notorhynchus cepedianus*), grey nurse (*Carcharias taurus*), and angel sharks (*Squatina australis* - could actually be two species) (Reid and Krogh 1992).

Most species, apart from those generically referred to as 'whalers', can be identified with a high degree of accuracy by the contractors and observers. The whaler species are very difficult to distinguish, even for trained observers, and have only been identified to species since the 1997/98 season. Since 1997/98, five species of whalers have been caught in the SMP: bronze whaler (*Carcharhinus brachyurus*); spinner shark (*C. brevipinna*); bull shark (*C. leucas*); common blacktip shark (*C. limbatus*); and dusky shark (*C. obscurus*).

Flesh samples are routinely collected for DNA analysis, as this is the best method to obtain irrefutable identifications for whalers, and for other species which occur infrequently in the nets.

Reporting

Formal and scheduled reporting of the SMP's outcomes is currently via weekly and monthly reports of catches to the Minister for Primary Industries. The Compliance branch of DPI also prepares periodical compliance reports for internal reporting procedures. Scientists occasionally present summaries of the SMP and catches to scientific conferences on sharks and rays, in 'grey literature' (e.g. DPI 2006a; Reid and Broadhurst 2004; Hamer 1992; Collins 1972), and in peer-reviewed scientific journals. Reid and Krogh (1992) examined the catch data for the SMP between 1950 and 1990; Krogh (1994) analysed spatial, seasonal and biological changes in the catch between 1972 and 1990; and Krogh and Reid (1996) examined the bycatch in the SMP between 1950 and 1993.

Information available to the broader public is primarily on an ad hoc basis through the Factsheets / Primefacts section of the DPI website (see http://www.dpi.nsw.gov.au) and/or in response to Freedom of Information requests.

In contrast to DPI's limited reporting and reviewing schedule, the websites of Queensland's Office of Economic and Statistical Research (http://www.oesr.qld.gov.au/queensland-by-theme/industry/index.shtml) and the Department of Primary Industries and Fisheries (http://www2.dpi.qld.gov.au/fishweb/2920.html) contain detailed, regularly updated information about Queensland's Shark Control Program. In addition, Queensland's Shark Control Program was reviewed by the Department of Primary Industries and Fisheries in 1992, 1998, 2001 and most recently in 2006 following a fatal shark attack at Amity Beach (QDPIF 2006).

2.4 OTHER MEASURES TO MINIMISE SHARK ATTACKS

2.4.1 Complementary measures to the shark meshing program

In 2006, DPI and the Sydney Aquarium hosted the Scientific Shark Protection Summit at Darling Harbour (hereinafter referred to as the shark summit). Scientific experts in the field of shark research and/or shark attack, and representatives from surf lifesaving organisations (Appendix 3) were invited to the shark summit with the aim of facilitating discussion on the shark meshing program and to enable more cooperation between the various agencies. The shark summit focused on the latest scientific information available and empirical information provided by attendees to develop a series a recommendations and advice on ways to reduce the risk of shark attack in NSW (see Appendix 4 for the reported recommendations and actions arising from the shark summit).

Complementary measures previously considered and/or reviewed at the shark summit to minimise shark attacks include enhancing the capacity/capability of lifeguards to detect sharks in the immediate vicinity of beaches, aerial observation using fixed-wing aircraft and helicopters, and electronic deterrents.

Lifesavers/lifeguards

From November to March, most beaches in the area of the SMP have weekend patrols by volunteer lifesavers (members of Surf Life Saving New South Wales (SLSNSW)), and weekday patrols by professional, council-employed lifeguards (Surf Life Saving Services Pty Ltd). In addition, council-employed lifeguards patrol normally un-patrolled beaches on weekdays during the December/January school holidays.

Lifesavers establish safe swimming areas through the use of flags and use signs and flags to mark other dangerous or hazardous areas. This enables lifesavers on the beach to focus their attention on swimmers, and for lifesavers in observation towers to monitor areas outside of the flags for sharks and other hazards. Surf Life Saving New South Wales has developed a range of policies and procedures for use by its lifesavers during the normal course of their activities, including recognising and overcoming risks associated with sharks, standardised responses for shark sightings, shark attacks, beach closures, and a shark recording protocol for use at all beaches (Appendix 5).

Sirens are also used at all beaches to notify beachgoers of the presence of sharks and to aid lifesavers in the evacuation of swimmers from the water. Of the 151 times a shark alarm was activated by surf lifesavers in 2006/07, approximately two-thirds (110) were in the Hunter to Illawarra branches (SLSNSW 2007a). In most cases, lifesavers deploy some form of watercraft, often a jet ski, and/or call the Westpac Helicopter Rescue Service to chase sharks out to sea. One of the advantages of jet skis, owing to their speed and size, is that they do not need to be positioned on every beach. Rather, they can be shared between multiple adjacent beaches, e.g. Wyong Council has two jet skis that service a 33 km stretch of beach.

Recognising the benefits and potential of lifesavers with respect to minimising the risk of shark attack, the shark summit recommended increased funding for lifesavers, particularly for the purchase of rescue water craft (jet skis) (DPI 2006a). In late 2006, DPI provided a $115,000 grant to SLSNSW to assist it carrying out activities that complement the Government’s shark meshing program. The grant was used to buy four new jet skis (one each for the Hunter, Central Coast, Sydney and Illawarra branches of SLSNSW) and to undertake a trial of shark surveillance flights by helicopter (SLSNSW 2007a). Between 9 December 2006 and 4 March 2007, the jet skis had logged 812 hours of on-water patrol, and the helicopter had flown 30.2 hours on dedicated shark patrols, 40 minutes on dedicated shark callouts, 90.4 hours over coastal areas on other calls but undertaking shark patrols, and logged 5 shark incidents and preventative actions (SLSNSW 2007b).

Aerial observations

Aerial observations, from either small fixed-wing aeroplanes or from helicopters, may be a useful supplement to the SMP on a limited spatial and temporal scale, but the main disadvantage is that aerial patrols spend a very small amount of time over each beach (about two minutes), and meteorological and sea conditions can severely restrict visibility. The shark summit concluded that the benefits of aerial patrols were minimal and did not recommend using aerial patrols as a means of reducing the risk of shark attack in NSW, and the government-funded aerial patrols using fixed-wing aircraft were ceased in 2007.

In response to the shark summit, DPI funded a small-scale trial of the effectiveness of shark surveillance by helicopter flights off Wollongong. Although more functional than fixed-wing aircraft, helicopters are also very expensive and can still only spend a limited amount of time at any one beach, restricting the usefulness of this technique and the trial was not repeated. It was however, also acknowledged that helicopter flights may assist in the identification of problems with sharks on weekends and checking that the nets remain in position. A similar trial using fixed-wing aircraft off Newcastle beaches between 1963 and 1973 reported an average of approximately 500 shark sightings per year (D. Reid, DPI, unpub. data).

In Western Australia, which does not use protective nets, large-scale trials using volunteer pilots and observers in fixed-wing aircraft were conducted between 2001 and 2005. Sharks accounted for only 3% (62) of sightings, with dolphins and seals accounting for more than 90% of sightings, and on average there were 19 sharks sighted per year (McAuley 2006). Only three large sharks (>2.5 m) were seen in the five years of the trial (McAuley 2006). Reasonably large whaler sharks are common of the WA coast (based on the catches of the commercial gillnet fishery), but those sharks were not seen from the air during the trials, and several largish sharks sighted by beachgoers and boaters close to shore were also not seen by the trial flights, further highlighting the limited effectiveness of aerial patrols.

Electronic deterrents

Electrical barriers for the purpose of deterring sharks were considered as far back as 1929 (reported in the Shark Menace Advisory Committee Report (1935) and Whitley (1940)). The 1929 experiments in the pool of the now DPI Cronulla laboratories were conducted by Swedish inventor, Dr O. P Möller, but were rejected in the report of the 1929 Shark Menace Advisory Committee, who noted that “the electrical device for the stunning of sharks might be satisfactory in still water, but there are many drawbacks to its use on the beaches, with no guarantee of effectiveness” (SMAC 1935).

The idea of using electrical fields to deter sharks was not looked at seriously again until 1963, when an engineer, John Hicks, showed than an electrical field would repel lemon and tiger sharks at distances of up to 15 m. In 1974, a South African physicist, E. D. Smith demonstrated the use of an electrical current to deter juvenile dusky sharks. In the early 1990s, the Natal Sharks Board (NSB) in South Africa demonstrated the agitated response of dusky and bull sharks to an electrical current generated by a wire loop, energised by a 12V direct current. Subsequently the NSB carried out extensive development and testing on a waveform which was successful in deterring sharks (Smit and Peddemors 2003), later to be used in a device marketed as SharkPOD™ (Protective Oceanic Device), which was for use by SCUBA and skindivers.

Attempts to scale-up the SharkPOD design to complement and/or replace shark nets was unsuccessful, and included the use of a cable that was mounted in the sand and emitted an electric pulse to deter sharks. The cables tended to snap, it was very costly and required significant electronic infrastructure and technology to get enough power from the cable to the housing. There are still technological barriers to developing these alarm systems at a larger scale, although the QDPIF is currently funding work on electronic devices. The full development and effectiveness of electrical devices for use in NSW waters was reviewed by Peddemors (2007), who concluded that it was not feasible to replace NSW shark nets with the currently available technology for electrical repulsion of sharks. The engineering problems of maintaining the technology in the high energy environment of NSW beaches and prohibitive ongoing costs were cited as the basis of this conclusion.

Chemical deterrents, air bubbles, sound, sonar tracking

There has been a long history of attempts to develop chemical approaches to deterring sharks, particularly by researchers in the United States of America. Eugenie Clark established in 1974 that a substance secreted by the Moses sole repelled at least four species of sharks for 10 hours or longer. Further research showed that this chemical was stable only in a freeze-dried form, but in that form was only 30% as effective as it was in the fresh state. Later work by Eliahu Zlotkin, Samuel Gruber and Donald Nelson showed that two components of common soap effectively deterred blue sharks and white sharks when squirted in the mouth. While these results proved a significant deterrent effect, there has been no practical solution to the rapid dilution of such deterrent substances in an open-water situation similar to that of the NSW coast.

Extensive experiments with air bubbles and sound over a number of decades have not resulted in any practical measures for deterring sharks. There have also been recent proposals put forward to DPI for the

use of sonar approaches to track the movements of sharks near surf beaches in Sydney, but at this stage these are not feasible on logistic or economic grounds.

2.4.2 Alternative meshing protocols

Alternative meshing gear

A review of the specification and deployment of the nets was conducted in 1972 by a fisheries gear technologist employed by the then NSW Department of Fisheries (now DPI). The review lead to: an increase in the number of meshed beaches; tighter specifications for the nets and their deployment; the requirement for bottom-set nets; and a standardising of the effort for beaches (each beach to be meshed 13 times per month). Those changes were equivalent to an increase of about 20% in nominal fishing effort (Reid and Krogh 1992). Most of the existing specifications were set at that time and to this point there has not been a similar review that could have identified the need or otherwise to alter those specifications.

In South Africa, the NSB has experimented with different mesh sizes in an attempt to reduce dolphin bycatch. A 70 cm mesh size was constructed following measurement of the size required to allow juvenile dolphins to pass through the net. It was found that a reduction in the selectivity from 81% to 25% for a shark of 1.6 m precaudal length (i.e. a size considered potentially dangerous, especially in the case of a bull shark) would result from an increase in mesh size from 50.8 cm to 70 cm (Dudley, 1998). This was considered an unacceptable risk and corroborates the retention of 50 - 60 cm mesh in the SMP.

Similarly, four of the five boats used in the existing program are 15 m, wooden hull, diesel-powered boats, and with the rising costs of business and community expectations of greenhouse gas emissions, it may be timely to examine the need for a fleet of smaller, more energy efficient vessels.

Alternative setting times and locations

The SMP has undergone limited changes since its inception in 1937, despite some sectors calling for an expansion of the SMP to other beaches, and yet other sectors seeking a reduction of both the area and timing of the SMP. The spatial coverage of the SMP has not changed since the Central Coast was added in 1987, however the temporal coverage has been modified on two occasions. Up until 1983, the nets were in place all year round, but in 1983 June and July were dropped from the SMP. May and August were also removed from the SMP in 1989 to further mitigate potential impacts on migrating whales.

Recently, some conservationists and scientists have argued that the nets should not be deployed in September and October to further mitigate potential impacts on grey nurse shark and migrating whales. Furthermore, there were five shark attacks in the month of September and 12 in October since 1791, none of which were fatal.

Potentially supporting such a reduction in the SMP is the fact that whilst only 15 grey nurse were caught between 1990/91 - 2007/08, five of which were released alive, more than a third were caught in September. Catches of Port Jackson, great white, sevengill, and thresher sharks and dolphins are also highest in September (Table 3). Conversely, another third of all grey nurse caught between 1990/91 - 2007/08 were caught in December, in the midst of the netting season (Table 3).

September is also the third highest month for total captures, driven largely by the high catch of sevengill sharks and Port Jackson sharks. Two of the ‘target’ or potentially dangerous sharks, namely tiger and bull sharks, are recorded in their lowest numbers during September and October, and only five tiger sharks were caught in those months between 1990/91 - 2007/08. ‘Whalers’ have been identified to species since 1997/98, and seven bull sharks have been recorded in those 10 years, none of which were caught in September or October.

Potentially opposing and complicating such a reduction in the SMP however, is the fact that September and October have traditionally accounted for the highest months of great white captures, representing 57% of all great whites caught between 1990/91 - 2007/08. Great whites are a threatened species, so there are potential benefits by omitting those months, however they are also one of the target species that the SMP aims to deter from metropolitan beaches. Removing the nets to potentially reduce the number of grey nurse sharks or whales affected by the SMP could potentially increase the likelihood of interactions between bathers and great white sharks.

Of the 57 great whites caught in the months of September and October from 1990 - 2008 (Table 3), 15 were caught at Stockton Beach, 18 at other beaches in the Newcastle region, and 16 on the Central Coast,

indicating that those areas are likely to notice any potential increase in great white shark abundance. Nine of those 16 great whites from the Central Coast were caught in September in each of the three seasons from 2005/06 - 2007/08. Mortality is relatively high in great whites caught in the nets, and only 17 of the 100 great white sharks caught between 1990/91 - 2007/08 survived entanglement and were subsequently released alive. Rather than removing the nets during September and October, it is possible that running the nets more regularly, perhaps daily, could further mitigate impacts on grey nurse and great white sharks, particularly in the Newcastle and Central Coast regions. The draft management plan should include provisions for such a change in subsequent contract reviews.

Furthermore, of the three baleen whales recorded between 1990/91 - 2007/08, a 4 m female minke whale is the only record for September and none were recorded for October (Table 3), limiting the benefits to whales of any such changes to the SMP.

Examination of the existing contracts indicates that the soak times and specific locations of nets are not standardised, rather are largely dictated by logistics and the aim of meeting contract specifications for the number of days per month. In Queensland, mesh nets are surface set and are positioned in the same places using GPS marks, the latter of which has not been considered in NSW. Minimum set-times were recently reviewed prior to the tender process for the existing contracts (Appendix 1), however it would seem prudent and timely that any changes to the overall management of the SMP (i.e. through the draft JMA and associated draft management plan) should incorporate an initial and ongoing review of the meshing protocols by an expert gear technologist.

Table 3 Catch data for the eight months of the SMP from 1990/91 to 2007/08

	January	February	March	April	September	October	November	December	Total
Elasmobranchs									
Hammerheads	231	183	143	137	157	138	137	166	**1292**
Stingrays	154	104	189	170	110	120	176	246	**1269**
Whalers	69	116	98	87	34	38	39	55	**536**
Angel sharks	54	47	42	29	22	16	23	26	**259**
Port Jacksons	3	1	0	4	52	39	4	4	**107**
Great whites	9	6	3	6	36	21	9	10	**100**
Sevengills	3	1	0	0	50	18	19	1	**92**
Tigers	10	7	7	9	4	1	4	7	**49**
Thresher	1	1	0	0	16	5	13	4	**40**
Shortfin mako	3	2	0	4	5	4	7	6	**31**
Grey nurse	1	0	1	0	6	1	1	5	**15**
Other fauna									
Dolphins	8	4	5	5	12	7	9	2	**52**
Turtles	6	9	11	9	2	4	3	3	**47**
Finfish	2	8	4	16	1	3	3	6	**43**
Whales*	2*	0	0	1	1	0	1	1*	**6**
Seal	0	1	1	0	2	0	0	0	**4**
Penguin	0	0	0	0	0	0	0	1	**1**
Dugong	0	0	0	0	0	0	0	1	**1**
Total	**556**	**490**	**504**	**477**	**510**	**415**	**448**	**544**	**3944**

* denotes that this includes 3 false killer whales, which are members of the dolphin family but are reported as ‘whales’ in the DPI database (Source: DPI unpub. data)

Alternative contractual and management arrangements

Any review of the meshing protocols should also consider the spatial structure of the SMP and demographics of its contractors. The Sydney North region, for example, includes 15 beaches compared to 5 in the Illawarra region. Whilst the limited distance between beaches in Sydney North may make this a

fairly routine exercise for a contractor, it may increase competition for future contracts and benefit existing contractors if the region and contract was divided into two smaller ones comprising eight and seven beaches, respectively. Some of the existing contractors have extensive experience in the SMP and it will be important to ensure that such experience is conveyed to potential future contractors through either work experience (e.g. as deckhands), some form of mentoring program or specific training provided by DPI. Any future reviews should also consider the costs and benefits of out-sourcing the SMP as opposed to establishing a dedicated team within DPI, as is done in both Queensland (for research and supervision of contractors) and South Africa.

2.5 BATHER PROTECTION STRATEGIES IN OTHER JURISDICTIONS

Shark control programs in various forms have been used on ocean beaches in Queensland, Australia, and overseas in South Africa, New Zealand, Hong Kong and Hawaii. Those in New Zealand, Hong Kong and Hawaii are on a much smaller scale than that of NSW and the limited available information for those areas will be provided in section 2.5.1. Queensland and the Province of KwaZulu-Natal in South Africa are the only other places in the world that implement bather protection programs in coastal waters on a scale similar to that of NSW. The programs in those areas will be compared and contrasted to the NSW program in sections 2.5.2 and 2.5.3, respectively, and the main features of those three programs will be summarised in Table 5.

It is important to note that whilst understanding experiences from other programs assists this assessment and review of the SMP, there are significant differences between the three areas, particularly in terms of the physical, oceanographic, climatic, species composition and patterns of beach usage (Dudley 1997; DPI 2006a; QDPIF 2006). Those differences preclude direct comparisons and it would be inappropriate to assume that strategies successful in those other regions would necessarily be suitable in NSW.

Of the other Australian states within the distribution of large aggressive sharks (e.g. great whites and tiger sharks), South Australia and Western Australia do not have direct and active anti-shark measures, although both States have used aerial patrols of beaches and maintain databases of shark sightings and attacks. Victoria does not have a shark control program, even though the waters adjacent to its coastline are central within the Australian distribution of great white sharks.

With the exception of Hong Kong harbour where barrier nets are installed on 32 beaches, barrier nets used in harbours and estuaries are not examined in further detail in this assessment as they are impractical for use on the NSW coast. Barrier nets are generally limited to calm, estuarine waters and embayments such as Sydney Harbour, where nets are installed at Manly and Nielsen Park (Figure 7) and until 2008 were also installed at Edwards Beach, Balmoral. Those nets use small mesh and are designed to protect swimmers at harbour beaches from sharks of all sizes. They are permanent and are generally only removed for a limited time for cleaning and/or replacing.

Figure 7 Barrier nets used within Sydney Harbour (Nielsen Park and Manly)

(Photos: Nielsen Park, Dept of Environment and Climate Change; Manly, Manly Council)

2.5.1 Small-scale bather protection strategies used overseas

New Zealand

Beaches at Dunedin, New Zealand, have been meshed since 1969 following four shark attacks between 1964 and 1968, three of which were fatal (Cox and Francis 1997; Francis 1998; Dudley and Gribble 1999). In late 1969, two shark nets were laid off St Clair and St Kilda Beaches to protect swimmers and surfers. The number of nets was increased to 16 by 1976 (though not all were used at one time), and the SMP was extended to include Brighton Beach. By 1992, the number of nets had dropped to eight, six of which were in use at any one time. The netting program covers St Kilda, St Clair and Brighton Beaches, with two nets set permanently at each beach between December and February. Each net is about 100 m long, 5.5 m high, and has a mesh size of 30 cm. The nets are inspected three times a week (Francis 1998).

Accurate catch details were first kept in 1986, and 72 sharks were reportedly caught between 1986 and 1991, comprising 36 sevengill sharks, 24 school sharks, six threshers and three mako and blue sharks. No

great white sharks were caught, although they were reportedly caught in the 1970s. In the 1995 - 96 season, 29 sharks were caught, including 10 sevengill, eight thresher, five blue, four school, and one rig shark and one unidentified shark (Francis 1998). Since deployment of the nets, there was one attack at St Clair Beach in late summer 1971, after netting had finished for the year, and another at Moeraki (in the region, but never netted) in 1973. There have been no attacks since 1973 (Francis 1998).

Hong Kong

In Hong Kong fatal shark attacks on three swimmers in 10 days in 1993 prompted authorities to install barrier nets (Figure 8) on a trial basis at Clear Water Bay. Following the reported success of the trial, barrier nets were installed at another 17 beaches in 1995 and 1996. These nets are designed on the basic principles of those used in aquaculture, and are 500 m in average length, with meshes of between 35 mm and 100 mm square. These nets remain in the water for an average of nine months a year. They are suspended from polyethylene pipe or marine float lines, with heavy anchorage to resist typhoons and waves to 10 m, and are inspected by divers a minimum of twice per week. Although these nets have been used for 13 years, the costs are thought to be significant and there are numerous technical problems maintaining barrier nets in a high-energy wave environment.

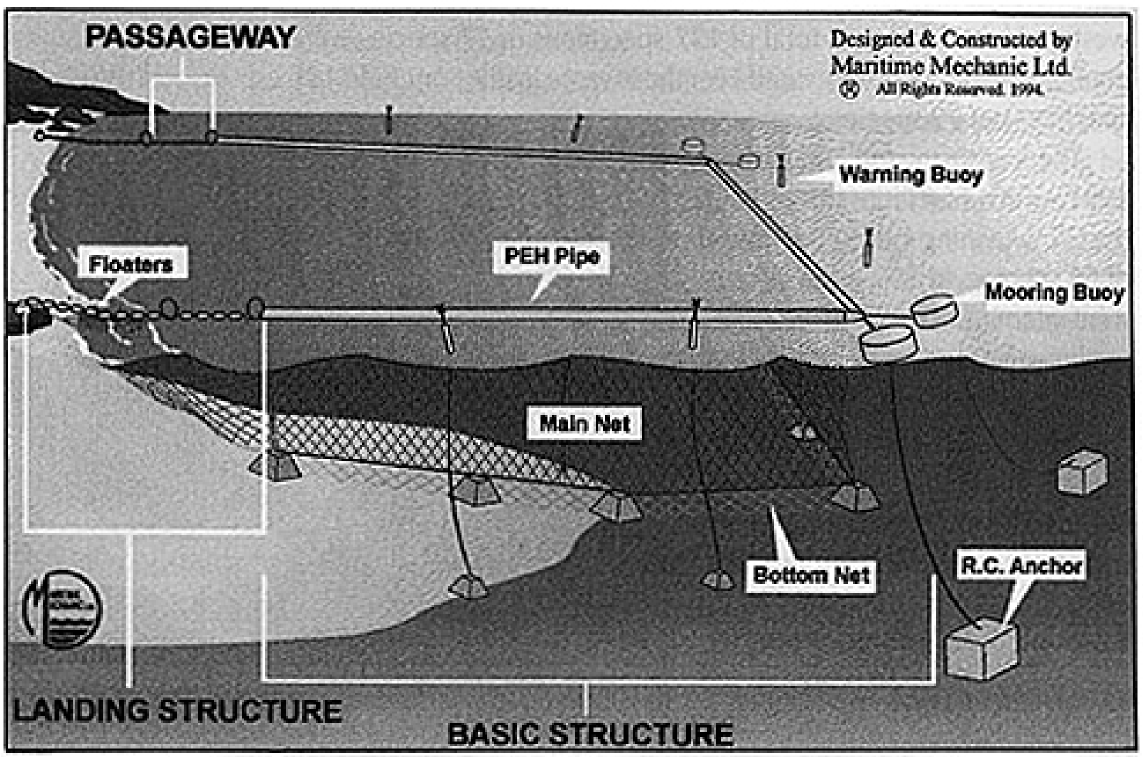

Figure 8 Schematic of the barrier nets used at 18 beaches in Hong Kong
(Source: Maritime Mechanic Ltd).

Hawaii

There were at least seven shark control programs in Hawaii between 1959 and 1995, however they do not appear to have had measurable effects on the rate of shark attacks in Hawaiian waters and are not currently operational. The prevalent feeling in the Hawaiian community is quite strong against such proactive programs and currently seems to be supported by government use of reactive measures. Beaches are sometimes closed to swimmers for a brief period after an attack, such as the closure of two miles of beach for a day following a non-fatal attack (first of the year) in July 2008 (Kim Holland, Hawai‘i Institute of Marine Biology, pers. comm., August 2008).

Between 1959 and 1976, six control programs of various intensity were used in an attempt to allay public fears and to reduce the risk of shark attack (Wetherbee et al. 1994). During these programs, 4,668 sharks were caught using standard bottom long-line gear, consisting of 3 sections of 800 m each with 24 hooks per

section, baited primarily with skipjack tuna (*Katsuwonus pelamis*). In general, lines were set in the late afternoon, parallel with the shore at an average depth of approximately 45 m, but ranging to depths of 300 m, and retrieved the next morning. Sharks (primarily smaller individuals) were also captured on light tackle long-lines (12 hooks, set between 18 and 118 m) and hand-lines (Papastamatiou et al. 2006). The programs provided information on diet, reproduction, and distribution of sharks in Hawaii, but were not directed toward the tiger shark, which is responsible for most attacks in Hawaii. The limited success changed the focus to shark research and public education rather than shark control (Wetherbee et al. 1994).

Following two fatal attacks in 1991 - 1992, there was a program of directed shark fishing in areas where there had been an attack or where sharks were sighted. Over the next few years an estimated 100 tiger sharks were killed by state-sponsored and private fishing in the waters around Oahu. This small-scale fishing lasted until 1994 or 1995, by which time the number of attacks, and consequently public demand for action, had dwindled. Research has shown that tiger sharks move long distances around the Hawaiian Islands (Holland et al. 1999) and hence that localised fishing following an attack is of limited use if the objective is to catch the shark in question.

2.5.2 The Queensland Shark Control Program

Spatial and temporal extent

Queensland's Shark Control Program (QSCP) began in 1962 and is implemented by the Queensland Department of Primary Industries and Fisheries (QDPIF). The QSCP currently uses a 'mixed gear strategy' comprised of 6.5 km of mesh nets and 344 drumlines to protect 84 beaches stretching from the Gold Coast to Cairns, a distance of approximately 1,720 km (Appendix 6). Unlike NSW, the nets and drumlines are in place all year round. The mixed gear strategy is used in Queensland as it adapts the type of gear to the characteristics of a site (e.g. extreme tidal range, turtle breeding areas) and has reduced the incidental capture of non-target species compared to deploying nets alone (Gribble et al. 1998).

Gear

The nets used by QDPIF are similar to those in NSW in that they are made of 2.7 mm Venetian blind cord, are 6 m deep, with 50 cm mesh and are 186 m long comprised of 3 x 62 m sections (QDPIF 2006). Drumlines are large baited shark hooks suspended from a large plastic float (originally a drum, hence the name), which in turn is anchored to the sea bed (Figure 9). Drumlines are designed to catch actively feeding sharks and are baited with fresh, natural baits. At each beach there are normally one to three nets and up to six drumlines (Gribble et al. 1998). The QSCP equipment is serviced every second day, weather permitting, by independent contractors who are supervised by staff of Queensland Boating and Fisheries Patrol. All fishing equipment is removed from the water for maintenance and replaced with fresh equipment at least once every 21 days.

Minimisation of non-target catch

Mitigative measures to reduce the catch of non-target species has been the subject of two reviews by QDPIF and subsequent modifications of the QSCP (QDPIF 2006). Key initiatives in this regard have included the use of acoustic and sonic warning devices for dolphins and whales, replacement of nets with drumlines in some locations, formation of mammal release teams, testing turtle-friendly hooks, and different drumline baits. The QDPIF continues to support research into minimising inadvertent impacts of the QSCP.

Gribble et al. (1998), reported that for most threatened species the average annual number of mortalities in the QSCP relative to the total population was too small to have significant demographic effects, and that the effect of that incidental mortality on their populations was probably minor. In the QSCP between 1962 - 95, the average annual mortality of humpback and small, unidentified whales was 0.1 and 2, respectively. By comparison, in the NSW program between 1990 - 2008 the average annual mortality for humpback, minke and false killer whales was 0.05, 0.05 and 0.16, respectively.

In the QSCP between 1962 - 95, the average annual capture (fate unknown) of dugong, dolphins and turtles was 20, 19, and 78, respectively (Gribble et al. 1998). By comparison, in the NSW program between 1990 - 2008, the average annual capture of dugong, dolphins and turtles was 0.05, 2.7, and 2.5, respectively.

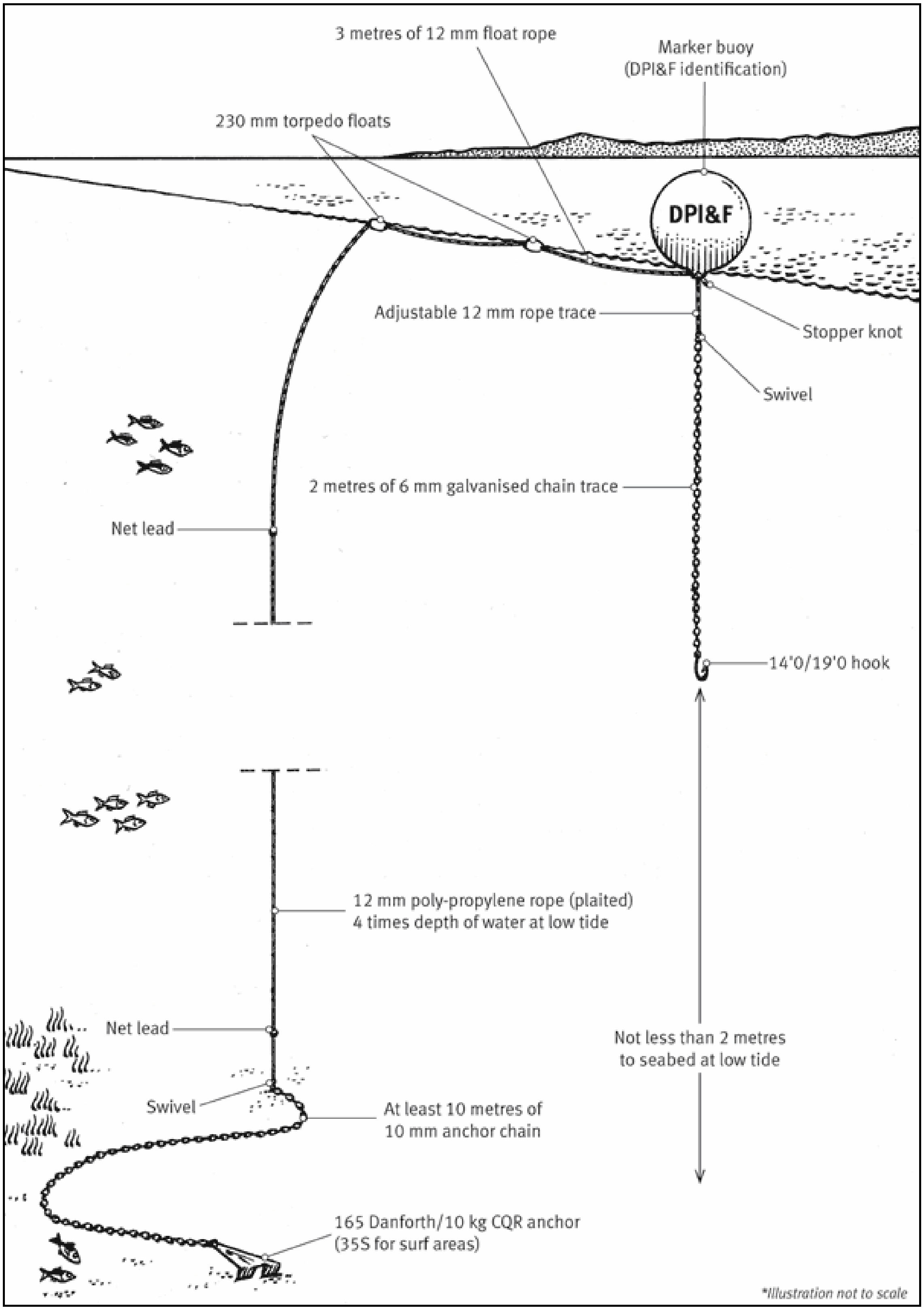

Figure 9 Drumline configuration used by Queensland's Department of Primary Industries & Fisheries
(Source: QDPIF 2006)

Science and research

Research experiments by QDPIF into the differences between nets and drumlines indicate that even though the total number of sharks does not differ significantly between drumlines and mesh nets, there are differences in the species distribution and, overall, there are more dangerous sharks (primarily tiger sharks) caught on drumlines compared to mesh nets (DPI 2006a). In contrast, however, there is evidence to suggest that during the wet season (summer, warm waters), drumlines are not as effective as nets at catching bullsharks (a species of major concern in NSW).

In 2002, $500,000 was committed over five years to support research initiatives related to the QSCP, mainly related to reducing the catch of non-target species (QDPIF 2006; http://www2.dpi.qld.gov.au/fishweb/2920.html), including:

- Advances in acoustic alarm/pinger technology for reducing entanglement of marine mammals. In 2006 the QSCP purchased acoustic deterrent devices, the “SaveWave” dolphin pingers. Developed and manufactured in Holland, they are a multi-frequency pinger used world wide in commercial fisheries. Monitoring of acoustic alarm/pinger technology will continue in an attempt to find effective methods to reduce marine animal entanglements.
- The introduction of plastic “hook guards”, which have been effective at reducing turtle interactions with drumlines in southern Queensland while not affecting shark catches.
- The introduction of sea temperature data loggers on Gold Coast nets to correlate shark and bycatch activity, which is providing insights into the seasonal activity of sharks and bycatch species.
- In 2004, a tag and release program for harmless shark species was established to help understand their behaviour upon release.
- A recently concluded trial comparing two hook drumline rigs and single hook rigs indicated no difference in the shark catching ability of either rig although the single hook rig resulted in reduced turtle interactions.
- Alternative baits, drumline rigs and net modifications continue to be assessed.

Cost

In the 2004/05 financial year, the QSCP cost approximately $1.7M (Table 4).

Table 4 Expenditure in Queensland’s Shark Control Program from 2002/03 to 2004/05

	2002/03	2003/04	2004/05
Contract Payments	$975,000	$1,147,000	$1,193,000
Bait	$73,000	$88,000	$70,000
Management	$139,000	$225,000	$239,000
Equipment	$60,000	$244,000	$110,000
Research	$102,000	$90,000	$91,000
TOTAL	$1,349,000	$1,794,000	$1,703,000

(Source: QDPIF 2006)

2.5.3 KwaZulu-Natal, South Africa

The primary source of the following information was the website of the Natal Sharks Board (http://www.shark.co.za/index.htm) and reflects the information available during August 2008.

South Africa’s bather protection program began in 1907, when Durban City Council erected a large semi-circular enclosure, approximately 180 m in diameter, to protect swimmers from the surf and strong currents and against shark attack (Cliff and Dudley 1992). The enclosure was constructed of steel piles with vertical steel grids placed between them, but was demolished in 1928 as a result of the damage it had suffered from the often rough surf, extensive corrosion and the high cost of maintenance. In 1952, Durban City Council decided to emulate the shark net program introduced to waters off Sydney. Seven gill nets, each 130 m long, were laid along the Durban beachfront. In the first year of operation 552 sharks were caught in the

nets. Nets were originally maintained either by commercial fishermen or municipal employees and overseen by field staff of the Natal Anti-Shark Measures Board, now known as the Natal Sharks Board (NSB), which was formed in 1962. By 1982, the NSB was solely responsible for all shark netting in the province of Natal (Davis et al. 1989).

Spatial and temporal extent

The NSB currently uses surface-set mesh nets and drumlines all year round in a manner similar to that of Queensland, although during the annual June-July sardine run, almost all nets at beaches south of Durban are out of the water to avoid heavy mortalities of sharks and dolphins. The NSB program covers 320 kilometres of coastline comprised of 38 locations, using 23.4 km of nets and approximately 80 drumlines, all of which are in the southern third of the province.

Gear and coverage

Most of the nets are 214 m long (305 m long off Durban), 6 m deep with 51 cm mesh and are anchored at each end by two 35 kg anchors. The nets are generally laid in two parallel rows (staggered, not continuous) approximately 400 m offshore and in water 10 - 14 m deep. Most beaches are protected either by two nets or one net and four drumlines, but the quantity of gear varies from beach to beach. Nets are serviced 20 times per month by employees of the NSB (http://www.shark. co.za/NSB.htm).

Science and research

The NSB employs three biologists whose primary aim is to analyse information taken from catches in the shark nets. This information is used to: improve understanding of the biology of animals caught in the nets; assess the impact of shark net-induced mortalities on the stocks; and to reduce mortalities in the shark nets without jeopardising the safety of beach users. Every animal caught is identified, sexed, measured and recorded. Dead sharks that are not badly decomposed are brought into the laboratory, where they are weighed and measured. They are then frozen until they are dissected for the collection of biological data and a section of the vertebral column is removed for ageing studies. Some jaws are kept for the NSB reference collection and others sold as curios (http://www.shark.co.za/overview.htm).

In September 1999, following a comparative study of the shark control programs in NSW, Queensland and KwaZulu-Natal (see Dudley 1997), the NSB began reducing both the number of nets at each beach and their configuration. Typically, a beach that was protected by three overlapping nets had one net removed and the overlap was eliminated. By the end of 2004, netting effort had been reduced by 30%, although this figure included the complete removal of the installation at Mzamba (http://www.shark.co.za/mort.htm).

The NSB also has examined differences in catches between drumlines (like those used in Queensland) and mesh nets for more than 10 years since an initial experiment using baited drumlines suggested that an optimal solution may be to deploy a combination of nets and drumlines (Dudley et al. 1998). The reported results were greater species selectivity for sharks and also a reduced bycatch of non-shark animals. The shark catch included the three species responsible for most shark attacks on the KwaZulu-Natal coast, namely bull sharks, tiger sharks, and great whites. As a result of the research, the NSB has been introducing drumlines since February 2007. It is worth noting that between 2003 and 2007, the nets off KwaZulu-Natal caught an average of 666 sharks and 433 non-sharks per year, in contrast to the current meshing program in NSW that has averaged approximately 143 sharks and 67 non-sharks (88% of which were stingrays) per year over the last 20 years. The relatively low number of sharks caught and limited amount of bycatch is likely to provide a significant statistical constraint to any such experiment to assess the efficacy of drumlines throughout the NSW program.

The NSB began tagging in 1976 and by 1986 some 2,030 animals were tagged. Sharks were tagged in the nets (480), but most were tagged during dedicated fishing outings and those were mainly small dusky sharks. Between 1987 and the end of 2007, the NSB tagged and released a further 2,062 sharks, comprising 14 species. The majority (919) of these sharks were raggedtooth sharks (known as grey nurse sharks in Australia), followed by tiger sharks (327) and dusky sharks (225) and also included 66 great white sharks.

In 1993, the NSB started injecting live sharks with the antibiotic, oxytetracyline, to enable growth ring deposition verification when ageing these sharks. Injected sharks are marked with a different coloured tag to the standard tags and a reward is offered for the return of tagged sharks or a section of vertebrae. Between 1993 and 2007, 856 sharks were injected, both in the nets and through opportunistic tagging (137). The majority were raggedtooth sharks (324), followed by tiger (158) and dusky sharks (79). In

addition, 33 great white sharks and nine mako sharks have also been injected (http://www.shark.co.za/overview.htm). The overall recapture rate of sharks tagged and released from the nets is about 4%. The recapture rate of free-swimming raggedtooth sharks tagged by divers, where there is no capture stress, is higher (9.5%) than that of those tagged in the nets (5.4%). Recapture rates for other net-tagged species vary, e.g. 5.2% for blacktip and 4.6% for tiger shark. The overall recapture rate for injected sharks is 4.9%.

The NSW program does not currently tag sharks on a consistent or strategic basis, and although recapture rates are low in South Africa, as a minimum tagging of live sharks within the SMP should be included for further investigation in the research and monitoring section of the draft management plan.

Table 5 Summary of the main features of shark control (bather protection) programs in NSW and Queensland, Australia, and KwaZulu-Natal, South Africa

	NSW	Queensland	KwaZulu-Natal
Spatial extent			
Number of beaches	51	84	38
Distance of coastline in program	250 km	1,720 km	320 km
Coverage by nets	Varies - max. 7.65 km	6.5 km	23.4 km
Temporal extent	1 September - 30 April: every weekend; & 9 weekday sets per month per beach	All year	All year, but removed from beaches south of Durban for June-July during the annual sardine run
Methods			
Mesh nets - specifications			
Total number	Varies, maximum 51	35	101
Length	150 m	186 m	most 214 m; 305 m at Durban
Depth	6 m	6 m	6 m
Mesh size	50 - 60 cm	50 cm	51 cm
Hanging coefficient	0.67	unknown	unknown
Distance from shore	~ 500 m	Varies	400 m
Position in water column	Bottom-set	Surface-set	Surface-set
Drumlines - specifications			
Total number	0	344	80
Hook size	n/a	14/0	14/0
Bait type	n/a	Sea mullet & shark	Sea mullet
Bait checking frequency	n/a	daily	unknown
Catch[A] summary			
Annual average number of sharks[B]	143 (1987 - 2007 data)	787 (1987 - 2007 data)	666 (2003 - 2007 data)
Maximum number of sharks & year	234 in 1993/94 (1987-07)	1,063 in 1989/90 (1987-07)	2,272 in 1985 (1964-2003)
Minimum number of sharks & year	76 in 2001/02 (1987-07)	521 in 2003/04 (1987-07)	513 in 2002 (1964-2003)
Annual average number of non-sharks[C]	67 (1995-07)	unknown	433 (2003-07)
Number of reported non-shark groups	7	5	6
Cost	> $800,000	$1.7M in 2004/05	unknown

A - denotes total number of animals caught and is not indicative of mortality or of number of released animals

B - denotes that ‘sharks’ includes target/dangerous sharks and harmless sharks (e.g. angel sharks), but excludes stingrays

C - stingrays comprise 88% and 59% of non-shark catch in NSW and KwaZulu-Natal, respectively.

(Source: http://www.shark.co.za/statistics.htm; QDPIF 2006; NSW DPI unpub. data; Dudley and Simpfendorfer 2006)

2.6 UNPROVOKED SHARK ATTACKS IN NSW

2.6.1 Data sources and limitations

The Australian Shark Attack File (ASAF) is maintained by the Life Sciences Operations unit at Taronga Zoo, and records details of all reportedly provoked and unprovoked shark attacks in Australian waters. Provoked attacks are generally incidents involving: divers feeding sharks in aquaria; accidents or bites after sharks have been landed by fishermen; and incidents where spearfishers have dead fish on their spears and/or in catch bags, or where they have provoked sharks in some manner and subsequently been bitten. Provoked attacks will not be examined in this report as the SMP cannot mitigate those attacks and they have no bearing on operational reviews.

The ASAF is an 'active' database, in that it is continuously updated as attacks happen and as new information becomes available about the nature and/or authenticity of historical attacks. The following analyses of unprovoked shark attacks in NSW waters are based on the ASAF provided to DPI in January 2009 and updated to include attacks up to the 13th March 2009 (hereinafter referred to as March 2009).

In the following descriptions of shark attack trends by regions and locations, this report uses the coastal regions broadly defined by the NSW Department of State and Regional Development as:

- Northern Rivers - Tweed Heads to Woolgoolga
- Mid-North Coast - Woolgoolga to Taree
- Hunter - Taree to Lake Macquarie
- Central Coast - Lake Macquarie to the Hawkesbury River
- Sydney - Hawkesbury River to Coledale
- Illawarra - Coledale to Shoalhaven River
- Capital - Shoalhaven River to Eden

Tables 6 and 7 contain information from the ASAF for reportedly unprovoked shark attacks in NSW coastal waters (i.e. does not include Lord Howe Island) between the first recorded attack in 1791, and March 2009. The tables include fatalities, injuries, and non-injuries, the latter of which includes attacks where sharks have bitten watercraft, bumped surfers from their boards, or circled swimmers or surfers but not actually bitten anybody.

Table 6 summarises the information using four time periods: 1791 - 1899; 1900 - 1936; 1937 - 1973; and 1974 - March 2009, and Table 7 provides some details of the attacks using the regions described above. The time periods in Table 6 were chosen as they provide some insight into the number of attacks before and after meshing, which started on most of Sydney's ocean beaches in 1937, and divides the years post-1900 into similar sized units (and described in more detail in 2.6.3). The years prior to 1900 were amalgamated as there were relatively few attacks, and prior to 1902 it was illegal to bathe at beaches during daylight hours. The popularity of ocean bathing gave rise to the surf life saving movement in response to the number of drownings, and to the SMP in response to the number of shark attacks and ineffectiveness of other shark prevention measures (SMAC 1935). The actual numbers of those beach users and the associated proportion of shark attack victims is unknown, which precludes the ability to draw any valid, quantitative conclusions about the risk of shark attacks based on changes in the number of shark attacks.

2.6.2 Trends in unprovoked shark attacks in NSW, 1791 to March 2009

Since 1791, there have been 222 unprovoked shark attacks in NSW, of which 126 have occurred at ocean beaches, 74 in estuarine waters, 13 in other nearshore coastal waters, and 9 in unknown waterways (Tables 6 and 7). The overall number of attacks was the same (61) in the 37 years before and after the SMP, but the number of attacks at meshed beaches was reduced by 62%. In the last 35 years, there has been a 28% increase in the number of attacks relative to the previous 37 years: most of that increase is attributable to attacks at ocean beaches outside of the SMP, which have more than doubled in that time, whereas attacks at meshed beaches were similar and attacks in estuaries were down more than 40% (Table 6).

Approximately one-third of unprovoked attacks were fatal, and there have been three fatal attacks since 1974. Estuarine waters account for approximately one-third of attacks since 1791, but account for more than half (59%) of the fatalities, although there has not been a fatality in an estuary in the last 35 years. Similarly, the proportion of attacks in estuaries has dropped from nearly 80% in the 1800s, to currently about 14%, and probably reflects the shift to predominantly bathing at ocean beaches over that time. Fatalities are 9% of the rate in the early 1900s and is due to various factors, including but not limited to advances in on-site trauma treatment, beach surveillance by lifesavers, emergency response times, and patient transfer times.

Only 25 of the 126 (20%) shark attacks on ocean beaches have resulted in fatalities, and all but two of those occurred before 1974. Before the SMP began, there were 37 attacks at beaches that are now part of the SMP ('pre-SMP beach' in Table 6), and 18 of those attacks were fatal. Since the SMP began, there have been 23 attacks at meshed beaches, and the only fatality at a meshed beach occurred at Merewether in 1951 (Table 7). Since 1974, two of the three fatalities have occurred at ocean beaches outside of the SMP, and the other fatality occurred at a nearshore island (Julian Rocks, Byron Bay).

Table 6 A summary of unprovoked shark attacks in all NSW waters, 1791 to March 2009

Period		Waterway	Result of attack			TOTAL
			Fatal	Injured	Uninjured	
Pre-Shark Meshing Program	1791 - 1899	Pre-SMP beach	0	1	0	1
		Estuary	13	4	0	17
		Unknown	2	2	0	4
		Sub-total	**15**	**7**	**0**	**22**
	1900 - 1936	Pre-SMP beach	13	14	1	28
		Other beach	2	2	0	4
		Estuary	18	8	1	27
		Unknown	0	2	0	2
		Sub-total	**33**	**26**	**2**	**61**
Post- Shark Meshing Program	1937 - 1973	Meshed beach	1	7	3	11
		Pre-SMP beach	5	2	1	8
		Other beach	2	13	2	17
		Other ocean waters	1	2	0	3
		Estuary	10	8	1	19
		Unknown	0	3	0	3
		Sub-total	**19**	**35**	**7**	**61**
	1974 - March 2009	Meshed beach	0	7	5	12
		Other beach	2	26	17	45
		Other ocean waters	1	7	2	10
		Estuary	0	6	5	11
		Sub-total	**3**	**46**	**29**	**78**
		TOTAL	**70**	**114**	**38**	**222**

Pre-SMP beach refers to attacks at ocean beaches prior to their inclusion in the SMP.

(Source: Australian Shark Attack File, data up to 13 March 2009)

In the absence of reliable estimates of the number of beach visitors, the available data for the number of shark attacks suggests that the annual rate of attack was the same both before and after meshing commenced, and that in the last 35 years there has been an increase in that rate of some 28%. In addition, the 52 attacks in the last 9.25 years (January 2000 to March 2009), is almost twice the rate of the next highest period, 1930 to 1939 when there were 28 attacks. This increase is consistent with overseas statistics, where it is also reported that the number of shark attacks are increasing each decade because of increasing numbers of bathers in the water: there is no indication that there is any change in the per capita rate of attack (International Shark Attack File, 2009). Recent increases may also reflect increased reporting due to a better reporting regime, broader awareness, and the influence of the media, especially the internet.

At face value, those increases could incorrectly be construed as an increase in the number of sharks, and/or the rate of attacks. However, such conclusions are not supported by either: international statistics on attacks; the declining catch numbers and rates of the SMP (Figure 10, Tables 12 and 13); decreasing commercial catches in NSW up to 2005 (DPI 2006b); decreasing numbers of sharks and rays in trawl grounds off the NSW coast (Graham et al. 2001); or the increasing resident and visitor population of NSW, which for the sake of this analysis will be used as a surrogate for beach visitors. The inherent assumptions in the following analysis are that: the SMP has continued to catch the same proportion of the population of sharks; and that beach users also represent a consistent proportion of the population over time.

Accepting those limitations, the relatively small increase in the number of shark attacks since 1900 is somewhat in contrast to the increasing population of NSW, the Sydney region in particular, and the increased amount and variety of recreation focussed in coastal waters. The estimated resident population of NSW has risen from 1.4 million in 1901, to in excess of 6.9 million at June 2008 (preliminary estimate - ABS 2008). Add to that approximately 2.8 million international overnight visitors and 24 million domestic overnight visitors to NSW each year, more than 10 million of which stay in Sydney (TRA 2008). On the basis of resident population alone, and all other things being equal, one would expect there to be a corresponding five-fold increase in the number of attacks over that time period. On the contrary, there has been a relatively small increase (<30%) in attacks relative to those population increases over the longer term, which coupled with decreasing catches in the SMP, suggests that there are relatively fewer sharks in coastal waters of NSW than there were in the early to mid 1900s.

The relatively small increase in the number of attacks could be due to a variety of interacting factors, including but not limited to: a decrease in shark numbers; an improvement in waste and effluent treatment and disposal, the poor state of which is thought to have contributed to abnormally high numbers of sharks in the 1920 and 1930s (Paxton 2006); changes in bathing patterns; and/or increased awareness. Although as previously stated there are no data about beach usage, the relatively high annual rate of more than five attacks per year since 2000 suggests that this period is more reflective of the anecdotally high numbers of people that use coastal waters. This limited qualitative analysis suggests that the risk of shark attack, particularly a fatal one, on ocean beaches is extremely low.

Table 7 Details of unprovoked shark attacks by region in NSW, 1791 to March 2009

Date	Location	Outcome	Activity	Suspected species	Part of program at the time?
Northern Rivers					
24/01/1936	Angourie, Yamba	Injured	Swimming	Unknown	No
23/10/1937	Byron Bay	Injured	Swimming	Unknown	No
13/01/1939	Clarence River	Uninjured		Whaler	No
13/01/1939	Clarence River	Injured		Unknown	No
1/01/1957	Sharkeys Beach, Byron Bay	Uninjured	Body boarding	White shark	No
19/01/1959	Brunswick Heads	Injured		Unknown	No
15/01/1961	Cook Island, Tweed Heads	Injured		Unknown	No
14/01/1962	Lennox Head	Injured	Surfing	Unknown	No
18/11/1964	Fingal Beach	Injured	Swimming	Unknown	No
2/02/1968	Brunswick Heads	Injured		Unknown	No
22/04/1969	Kingscliff Beach	Injured		Unknown	No
12/10/1975	Ballina	Injured		Unknown	No
17/09/1979	The Pass, Byron Bay	Injured	Swimming	Unknown	No
1/01/1981	Byron Bay	Injured	Surf ski	Tiger shark	No
7/03/1982	Tallow Beach, Byron Bay	Fatal	Surfing	Whaler	No
1/10/1984	Suffolk Park	Uninjured	Surfing	Whaler	No
3/01/1989	Half Tide Beach, Ballina South	Injured	Surfing	Tiger shark	No
13/08/1989	Lennox Head	Uninjured	Surfing	Bronze whaler	No
6/04/1990	Fingal	Uninjured	Surfing	White shark	No
9/06/1993	Julian Rocks, Byron Bay	Fatal	Scuba diving	White shark	No
1/12/1997	Shark Bay, Evans Head	Injured	Swimming	Unknown	No

Table 7 cont.

Date	Location	Outcome	Activity	Suspected species	Part of program at the time?
Northern Rivers cont.					
4/02/2001	Brooms Head	Injured	Surfing	Tiger shark	No
23/11/2001	Flat Rock, Ballina	Uninjured	Surfing	Whaler	No
3/12/2001	Main Beach, Yamba	Injured	Swimming	Wobbegong	No
23/03/2003	Turners Beach	Injured	Surfing	Whaler	No
3/02/2007	Angels Beach	Injured	Body boarding	Whaler	No
20/03/2007	South Golden Beach, Brunswick Head	Injured	Surfing	Unknown	No
13/10/2007	The Pass, Byron Bay	Injured	Surf ski	White shark	No
8/11/2007	Wategos Beach, Byron Bay	Uninjured	Surfing	Bronze whaler	No
28/01/2008	Turtle Sanctuary, Cook Island	Injured	Scuba diving	Wobbegong	No
8/04/2008	Lighthouse Beach, Ballina	Fatal	Body boarding	Bull shark	No
30/08/2008	Tallow Beach, Byron Bay	Uninjured	Surfing	Bull Shark	No
8/09/2008	Byron Bay	Uninjured	Surfing	Whaler	No
11/01/2009	Dreamtime Beach, Fingal Head	Injured	Surfing	Bull Shark	No
Mid-North Coast					
7/01/1837	Macleay River, Trial Bay	Fatal		Unknown	No
8/12/1919	Pelican Island, Macleay River	Fatal		Unknown	No
11/01/1937	Smokey Cape Lighthouse	Injured	Swimming	Unknown	No
28/12/1938	North Beach, Bellinger River	Fatal		Unknown	No
8/11/1947	Maria River, Port Macquarie	Fatal	Swimming	Whaler	No
8/11/1947	Maria River, Port Macquarie	Injured	Swimming	Whaler	No
13/04/1960	Horseshoe Bay	Injured		Unknown	No
25/04/1961	Kempsey	Injured		Unknown	No
21/12/1963	Coffs Harbour	Injured		Unknown	No
20/05/1966	Bundagen, Sawtell	Injured	Swimming	Unknown	No
23/12/1971	Smokey Cape	Injured		Unknown	No
14/12/1985	North Solitary Island	Injured		Wobbegong	No
24/02/1999	Scotts Head	Injured	Surfing	Bronze whaler	No
21/01/2001	South West Rocks	Uninjured	Kayaking	White shark	No
2/04/2001	Nambucca River Entrance	Injured	Surfing	Bronze whaler	No
1/10/2003	Charlesworth Beach, Coffs Harbour	Injured	Surfing	Wobbegong	No
3/01/2004	Scotts Head Beach	Injured	Swimming	Wobbegong	No
15/01/2004	Nambucca Heads	Injured	Swimming	Wobbegong	No
7/09/2005	Park Beach, Coffs Harbour	Injured	Surfing	Wobbegong	No
24/09/2005	Little Bay, South West Rocks	Uninjured	Surfing	Tiger shark	No
5/06/2007	Shelly Beach, Crescent Head	Injured	Surfing	Bull shark	No
9/02/2009	Sandon Beach	Uninjured	Surfing	Unknown	No
18/02/2009	Shelly Beach, Port Macquarie	Uninjured	Surfing	Unknown	No
Hunter (program began in December 1949)					
10/01/1863	Manning River	Fatal		Whaler	No
06/05/1871	Manning River	Fatal		Unknown	No
28/11/1894	Newcastle Beach	Injured	Swimming	Whaler	No
1/10/1907	Merewether Beach	Injured	Swimming	Unknown	No
26/01/1910	Newcastle Harbour	Fatal	Swimming	Unknown	No
22/03/1918	Newcastle Beach	Injured	Swimming	Unknown	No
17/01/1919	Newcastle Beach	Injured	Swimming	Unknown	No
16/01/1920	Throsby Creek	Fatal	Swimming	Whaler	No
8/01/1922	Stockton Beach	Fatal	Swimming	Unknown	No

Table 7 cont.

Date	Location	Outcome	Activity	Suspected species	Part of program at the time?
Hunter cont.					
13/01/1922	Stockton Beach	Injured	Swimming	Unknown	No
12/03/1925	Newcastle Beach	Fatal	Swimming	White shark	No
1/03/1927	Merewether Beach	Injured	Swimming	Tiger shark	No
4/04/1928	Bar Beach	Fatal	Swimming	Unknown	No
31/10/1932	Shark Tower Rock, Redhead Beach	Injured	Swimming	White shark	No
12/12/1936	Throsby Creek	Fatal	Swimming	Whaler	No
13/02/1937	Bar Beach	Fatal	Swimming	White shark	No
26/12/1940	Stockton Beach	Fatal	Swimming	Unknown	No
14/01/1944	Forster	Injured	Surfing	Unknown	No
14/10/1946	Swan Bay, Lake Macquarie	Injured	Entering water	Unknown	No
12/02/1948	Stockton Beach	Fatal	Swimming	Unknown	No
23/01/1949	Bar Beach	Fatal	Swimming	Bronze whaler	No
6/12/1951	Merewether Beach	Fatal	Swimming	Whaler	Yes
23/04/1957	Merewether Beach	Injured	Surfing	Wobbegong	Yes
3/04/1960	Broughton Island, Port Stephens	Injured		Unknown	No
7/04/1968	Stockton Bight	Injured		Unknown	Yes
27/12/1999	The Pinnacle, Forster	Uninjured	Scuba diving	Bronze whaler	No
30/01/2002	Fingal Spit, Port Stephens	Uninjured	Swimming	Tiger shark	No
12/04/2002	Bar Beach	Injured	Swimming	Unknown	Yes
31/10/2003	Lighthouse Beach, Seal Rocks	Injured	Surfing	Bronze whaler	No
26/04/2004	Latitude Reef, Forster	Injured	Scuba diving	Wobbegong	No
21/10/2004	Stockton Beach	Injured	Surfing	White shark [1]	Yes
6/11/2004	Saltwater Beach, Taree	Injured	Surfing	Wobbegong	No
11/04/2006	Cowrie Hole, Newcastle	Injured	Surfing	Wobbegong	No
9/01/2007	Sandbar Beach	Uninjured	Surfing	White shark	No
18/12/2007	Port Stephens (inside headland)	Injured	Surfing	White shark	No
28/12/2008	Seal Rocks	Uninjured	Body boarding	Whaler	No
7/02/2009	Cellito Beach	Uninjured	Surfing	Unknown	No
Central Coast (program began in January 1987)					
01/02/1888	Hawkesbury River	Fatal		Unknown	No
1/01/1909	Woy Woy	Injured		Unknown	No
24/12/1934	Brisbane Water, Woy Woy	Fatal	Diving into water	White shark	No
24/12/1934	Brisbane Water, Woy Woy	Injured	Swimming	White shark	No
1/01/1937	Terrigal Beach	Uninjured	Surf ski	White shark	No
27/02/1954	The Entrance	Fatal	Swimming	White shark	No
9/03/1955	Wamberal	Fatal	Swimming	White shark	No
12/01/1973	Umina Beach	Injured	Surfing	Unknown	No
4/07/1988	Norah Head	Injured	Swimming	Unknown	No
5/01/1991	Putty Beach	Uninjured	Snorkelling	Whaler	No
31/12/1995	Little Patonga Beach, Hawkesbury River	Injured	Diving into water	Unknown	No
15/03/2000	MacMasters Beach	Uninjured	Surfing	Unknown	Yes
4/05/2001	Lakes Beach, Budgewoi	Injured	Surfing	White shark	Yes
25/03/2005	Crackneck Point, Bateau Bay	Uninjured	Surfing	White shark	No
Sydney (program began in October 1937)					
01/01/1791	Near Sydney	Fatal		Unknown	No
12/01/1807	Cockle Bay	Injured		Unknown	No
17/11/1839	Sydney Harbour, near Shark Island	Fatal		Unknown	No

Table 7 cont.

Date	Location	Outcome	Activity	Suspected species	Part of program at the time?
Sydney cont.					
01/01/1840	Sydney Harbour, off Domain	Fatal	Swimming	Unknown	No
05/04/1842	Sydney Harbour	Fatal		Unknown	No
03/12/1849	Woolloomooloo Bay	Fatal	Swimming	Whaler	No
09/01/1874	Darling Harbour	Injured		Unknown	No
01/01/1876	Sydney	Fatal		Unknown	No
15/12/1877	Balmain	Injured	Swimming	Bull Shark	No
01/01/1878	Balmain	Fatal		Unknown	No
01/01/1887	Parramatta River	Fatal		Whaler	No
01/01/1887	Ryde	Fatal		Unknown	No
01/03/1887	Dobroyd Head	Fatal		Unknown	No
10/12/1888	Iron Cove Bridge	Fatal		Unknown	No
01/01/1896	Leichhardt	Injured		Unknown	No
28/12/1900	Folly Point, Middle Harbour	Fatal	Swimming	Bull shark	No
10/01/1903	Lane Cove River	Fatal	Swimming	Bull shark	No
28/01/1906	Georges River	Fatal	Swimming	Whaler	No
21/12/1907	Sugarloaf Bay, Middle Harbour	Fatal	Swimming	Bull shark	No
6/01/1912	Sydney	Injured	Swimming	Bronze whaler	No
26/01/1912	Lane Cove River, Figtree	Fatal	Swimming	Bull shark	No
19/02/1912	Coogee Beach	Injured		Unknown	No
1/01/1913	Sirius Cove	Fatal		Unknown	No
9/11/1914	Manly	Injured	Swimming	Unknown	No
1/01/1915	Sirius Cove	Fatal		Unknown	No
21/03/1916	Curl Curl Beach	Injured	Swimming	Unknown	No
8/12/1916	Seven Shillings Beach	Fatal		Unknown	No
8/12/1916	Seven Shillings Beach	Injured	Swimming	Unknown	No
9/04/1918	Parramatta River	Uninjured	Swimming	Bull shark	No
9/01/1919	Sirius Cove	Fatal	Swimming	Unknown	No
4/02/1922	Coogee Beach	Fatal	Swimming	White shark	No
3/03/1922	Coogee Beach	Fatal	Swimming	Whaler	No
19/01/1924	Parramatta River, Camellia	Fatal	Swimming	Whaler	No
13/02/1924	Bronte Beach	Injured	Swimming	Unknown	No
27/03/1925	Coogee Beach	Injured	Swimming	Unknown	No
4/01/1927	Greys Point, Port Hacking	Fatal		Unknown	No
14/04/1928	Bondi Beach	Injured	Swimming	Unknown	No
1/01/1929	Garden Island	Injured		Unknown	No
12/01/1929	Bondi Beach	Fatal	Swimming	Unknown	No
8/02/1929	Bondi Beach	Fatal	Swimming	Unknown	No
18/02/1929	Maroubra Beach	Fatal	Swimming	White shark	No
16/12/1929	Collaroy Beach	Injured	Swimming	Unknown	No
26/12/1929	White Bay, Balmain	Fatal	Swimming	Bull shark	No
25/12/1930	Homebush Bay	Injured	Swimming	Whaler	No
10/01/1931	Sydney	Injured		Unknown	No
7/01/1934	Queenscliff	Injured	Swimming	Tiger shark	No
28/01/1934	Georges River	Injured		Whaler	No
12/03/1934	Dee Why	Fatal	Swimming	White shark	No
1/04/1934	North Steyne	Fatal	Swimming	Whaler	No

Table 7 cont.

Date	Location	Outcome	Activity	Suspected species	Part of program at the time?
Sydney cont.					
31/12/1934	Milperra Bridge, Georges River	Fatal	Swimming	Bull shark	No
31/12/1934	Georges River	Injured	Swimming	Bull shark	No
2/03/1935	North Narrabeen	Fatal	Swimming	White shark	No
9/03/1935	Maroubra Beach	Fatal	Swimming	White shark	No
1/01/1936	Bondi Beach North	Uninjured	Surf ski	White shark	No
4/02/1936	South Steyne, Manly	Fatal	Swimming	White shark	No
3/01/1938	Cronulla Beach	Uninjured	Surf ski	Tiger shark	Yes
14/01/1938	Lady Martins Beach	Injured		Unknown	No
28/12/1939	Georges River	Injured		Unknown	No
23/01/1940	Brighton-Le-Sands, Botany Bay	Fatal	Swimming	Whaler	No
4/02/1940	Brighton-Le-Sands, Botany Bay	Fatal	Swimming	Unknown	No
4/01/1942	Bantry Bay	Fatal	Swimming	Unknown	No
4/03/1942	Georges River	Fatal		Unknown	No
26/12/1942	Bantry Bay	Fatal	Swimming	Bull shark	No
7/01/1946	Oatley Bay, Georges River	Fatal	Swimming	Unknown	No
13/01/1949	Mona Vale Beach	Uninjured	Surf ski	Unknown	Yes
20/11/1949	Kurnell	Injured	Skindiving	Wobbegong	No
1/02/1951	Bondi Beach	Injured	Swimming	Unknown	Yes
1/02/1953	Sydney	Injured		Unknown	Yes
1/12/1953	Maroubra Beach	Uninjured	Surf ski	Unknown	Yes
5/02/1955	Sugarloaf Bay, Middle Harbour	Fatal	Swimming	Bronze whaler	No
26/04/1959	Maroubra Beach	Injured		Unknown	Yes
16/01/1960	Roseville Bridge, Middle Harbour	Fatal	Skindiving	Whaler	No
27/11/1960	Bondi Beach	Injured		Unknown	Yes
27/11/1960	Harbord Beach	Injured	Swimming	Unknown	Yes
7/01/1962	Long Reef	Uninjured	Surfing	Unknown	No
28/01/1963	Middle Harbour	Fatal	Standing	Bull shark	No
20/11/1975	Queenscliff	Injured		Unknown	Yes
18/05/1986	North Head	Injured	Scuba diving	Wobbegong	No
3/08/1986	North Head	Injured	Scuba diving	Wobbegong	No
21/03/1995	Clark Island	Uninjured	Surf ski	Unknown	No
26/02/1996	Parramatta River	Injured	Swimming	Bronze whaler	No
26/04/1996	Mona Vale Beach	Injured	Swimming	Wobbegong	Yes
26/04/1996	Mona Vale Beach	Injured	Swimming	Wobbegong	Yes
3/02/1997	Parramatta River	Uninjured	Rowing	Whaler	No
7/02/2000	Wanda Beach	Uninjured	Surf ski	Unknown	Yes
2/03/2000	Athol Bay, Sydney Harbour	Injured	Swimming	Whaler	No
9/03/2000	Parramatta River	Uninjured	Rowing	Whaler	No
10/03/2000	Parramatta River	Uninjured	Rowing	Whaler	No
3/04/2000	Maroubra Beach	Uninjured	Surf ski	Unknown	Yes
7/02/2002	Parramatta River, Cabarita	Uninjured	Kayaking	Bull shark	No
22/12/2002	Shelly Beach, Manly	Uninjured	Scuba diving	Wobbegong	No
16/04/2005	Bronte Beach	Uninjured	Surfing	Whaler	Yes
15/03/2006	Bondi Beach	Uninjured	Surfing	Bronze whaler	Yes
14/07/2007	Shelly Beach, Manly	Injured	Scuba diving	Wobbegong	No
11/02/2009	Garden Island, Sydney Harbour	Injured	Scuba Diving	Bull shark	No

Table 7 cont.

Date	Location	Outcome	Activity	Suspected species	Part of program at the time?
Sydney cont.					
12/02/2009	Bondi Beach	Injured	Surfing	White shark	Yes
1/03/2009	Avalon Beach	Injured	Surfing	White shark	Yes
Illawarra (program began in December 1949)					
6/01/1835	Tasman Sea off Wollongong	Injured		Unknown	No
16/06/1923	Bellambi	Fatal	Swimming	Unknown	No
25/04/1924	Kiama	Fatal	Swimming	Unknown	No
14/02/1935	Austinmer Beach	Injured	Surfing	Unknown	No
20/03/1940	Gerringong	Injured	Collecting bait	Wobbegong	No
5/04/1959	Thirroul	Injured		Unknown	Yes
24/02/1963	Austinmer Beach	Injured		Unknown	Yes
27/02/1966	Coledale Beach (meshed in 1972)	Injured	Swimming	White shark	No
12/01/2009	Windang, Lake Illawarra	Injured	Snorkelling	Bull shark	No
Capital					
1/01/1871	Jervis Bay	Injured		Wobbegong	No
1/10/1927	Kiah River, Eden	Injured		Unknown	No
20/05/1966	Jervis Bay	Fatal	Shipwreck survivor	Unknown	No
27/01/1969	Currarong Beach	Injured	Snorkelling	Bronze whaler	No
21/10/1972	Tabourie Beach, Ulladulla	Injured	Surfing	Unknown	No
9/04/1995	Eden	Injured	Scuba diving	Wobbegong	No
1/09/1998	Jervis Bay	Injured	Scuba diving	Wobbegong	No
24/01/2009	Surf Beach, Batemans Bay	Injured	Swimming	Unknown	No

(Source: Australian Shark Attack File, data up to 13 March 2009)

1: the ASAF lists bull shark, but subsequent analysis by DPI indicates that a white shark was probably responsible

2.6.3 Shark attacks by region in NSW, 1900 to March 2009

Shark attacks in all regions

Between 1900 and March 2009, of the 200 unprovoked shark attacks in NSW, 82 were in the Sydney region, 34 in the Hunter, 34 in the Northern Rivers, 22 in the Mid-North Coast, 13 in the Central Coast, eight in the Illawarra and seven in the Capital region (Table 7). The highest number of fatalities (32 of 55) and injuries (34 of 107) have occurred in the Sydney region, although there has not been a fatality in the Sydney region since 1963, and like most (69%) fatalities in the Sydney region it occurred in an estuary (Table 7).

In the last 35 years (1974 - 2009), there were 78 unprovoked shark attacks in NSW waters, with 23 and 21 of those in the Northern Rivers and Sydney regions, respectively. The three fatalities over that period have all occurred in the Northern Rivers region, the most recent of which occurred at Lighthouse Beach, Ballina in April 2008 (Tables 7 and 8). In contrast, prior to the attack in January 2009, there had not been a shark attack in the Illawarra since 1969, and the last fatality in that region was in 1924.

Shark attacks in regions outside of the SMP

The Northern Rivers, Mid-North Coast and Capital regions have collectively accounted for ~32% (63) of attacks and 13% (seven) of fatalities in NSW waters between 1900 and March 2009 (Tables 7 and 8). In the last 35 years (1974 - March 2009), those figures have increased to 49% and 100% (three), respectively. All three fatalities occurred in the Northern Rivers region: two at Byron Bay and one at Ballina. Twenty-three of the 34 attacks in the Northern Rivers region have occurred since 1974 and represents the highest proportion of attacks (29%) across all regions for that period (Tables 7 and 8).

Across all three regions, there has been a gradual increase in the number of attacks per decade, rising from zero in 1900 - 09, to an annual average of 1.1/yr in the 1960s, and to 2.6/yr in the nine years from 2000 - March 09 (Tables 7 and 8). The ratio of attacks at ocean beaches compared to other waterways across these

regions is approximately 2.5:1 (Table 8). There were seven fatalities across all three regions in the last 109 years, three of which were at ocean beaches.

Table 8 Summary of unprovoked shark attacks in regions outside of the SMP, 1900 to March 2009

	Northern Rivers				Mid-North Coast				Capital			
	Ocean beaches		Other waters		Ocean beaches		Other waters		Ocean beaches		Other waters	
Years	Attacks	Fatal	Attacks	Fatal	Attacks	Fatal	Attacks	Fatal	Attacks	Fatal	Attacks	Fatal
1900 - 1936	1	0	0	0	0	0	1	1	0	0	1	0
1937 - 1973	7	0	3	0	3	1	6	1	2	0	1	1
1974 - 2009	21	2	2	1	10	0	2	0	1	0	2	0

(Source: Australian Shark Attack File, data up to 13 March 2009)

Shark attacks in regions of the SMP

Prior to the SMP commencing in Sydney in October 1937, 40 of the 64 attacks in NSW waters since 1900 occurred in that region and 23 were fatal (approximately 0.6 fatalities/year - Tables 7 and 9). In that period there were 19 attacks at ocean beaches and 10 were fatal (approximately 0.26 fatalities/year).

Since the SMP began there have been 42 attacks in the Sydney region, 19 at ocean beaches and 23 in other waterways (Table 9). Nine attacks were fatal and none of those occurred at ocean beaches: five were from Middle Harbour (which flows into Sydney Harbour); and two each from the Georges River and Brighton-Le-Sands (flows into and part of Botany Bay, respectively). Since 1937, there have been 16 attacks at meshed beaches in Sydney, with the other three attacks at ocean beaches involving wobbegong sharks biting scuba divers at Shelly Beach, Manly, and an attack on a surfer at Long Reef in 1962 (Tables 7 and 9). With eight attacks, including one in February 2009, Bondi Beach has had the highest number of shark attacks at NSW beaches since 1900, and other Sydney ocean beaches of note include Maroubra with five and Coogee with four (see Appendix 7 for summaries of the information collected by NSW DPI from the three most recent attacks within the regions of the SMP). These figures suggest that the rate of fatal shark attacks at Sydney's ocean beaches has been reduced from approximately 1 every 4 years before the SMP began, to effectively zero since the SMP began. The rate of all attacks at ocean beaches has reduced from 1 every 2 years to 1 every 3.7 years since the SMP began.

Prior to the SMP commencing in the Hunter region in December 1949, 18 of the 86 attacks in NSW waters between 1900 and December 1949 occurred in that region and 10 were fatal. In that period there were 14 attacks on ocean beaches, seven of which were fatal. There were four attacks in that period at Stockton, three of which were fatal, and all three attacks at Bar Beach were fatal. Three of the four attacks in parts of the Hunter estuary were fatal, including two at Throsby Creek.

In the nearly 60 years since meshing was introduced, there have been 16 shark attacks in the Hunter region and only one was fatal, which occurred at Merewether Beach in 1951 (Tables 7 and 9). Of those 16 attacks, 12 were at ocean beaches, four of which were meshed beaches, including the fatality at Merewether. In the last 35 years (1974 - 2009) there have been 12 attacks in the Hunter region, two of which were at meshed beaches, namely Bar Beach in 2002 and Stockton Beach in 2004. Six of the 34 attacks in the Hunter region since 1900 have occurred at Stockton, second only to Bondi Beach in the Sydney region in the number of attacks. These figures suggest that the rate of fatal shark attacks at the Hunter's ocean beaches has been reduced from approximately 1 every 7 years before the SMP began, to 1 every 60 years since the SMP began. The rate of all attacks at the Hunter's ocean beaches has reduced from 1 every 3.6 years to 1 every 5 years since the SMP began.

Prior to the SMP commencing in the Illawarra region in December 1949, four of the 86 attacks in NSW waters between 1900 and December 1949 occurred in that region and two were fatal (Tables 7 and 9). There was a fifth attack at Coledale in 1966 before that beach was included in the SMP in 1972, a total of five pre-meshing attacks. In the nearly 60 years since meshing was introduced, there have been three shark attacks in the Illawarra region (excluding the one at Coledale), two of which were at meshed beaches, and none were fatal. Before the recent attack in Lake Illawarra in January 2009, the last shark attack in the Illawarra was nearly 40 years ago in June 1969. The SMP appears to have further reduced the already relatively low figure of 1 fatality every 25 years at Illawarra's ocean beaches prior to the SMP, to effectively zero since its inception.

Prior to the SMP commencing in the Central Coast region in January 1987, seven of the 131 attacks in NSW waters between 1900 and 1987 occurred in that region (Tables 7 and 9). Four were on ocean beaches and three were at Woy Woy, in Brisbane Water. Three of the seven attacks were fatal: all took place prior to the 1960s, and great white sharks were thought responsible for each of those fatalities. In the 22 years since meshing was introduced, there have been six shark attacks in the Central Coast region, none of which were fatal. Similar to other areas of the SMP, the incidence of fatal attacks at the Central Coast's ocean beaches has been reduced to effectively zero since its inception. However, in contrast to other areas of the SMP, the Central Coast's ocean beaches have experienced an increase in the rate of attacks since the SMP began, up from 1 attack every 22 years to 1 attack every 4.4 years.

Table 9 Summary of unprovoked shark attacks in regions of the SMP, 1900 to March 2009

			Number of attacks and fatalities by waterway type			
			Ocean beaches		Other waters	
Region	**Status**	**Period**	Attacks	Fatalities	Attacks	Fatalities
Sydney	**Pre - program**	**1900 - Oct 1937**	19 (18)	10 (10)	21	13
	Post - program	**Oct 1937 - 2009**	19 (16)	0	23	9
Hunter	**Pre - program**	**1900 - Dec 1949**	14 (13)	7 (7)	4	3
	Post - program	**Dec 1949 - 2009**	12 (4)	1 (1)	4	0
Illawarra	**Pre - program**	**1900 - Dec 1949**	5* (2)	2 (0)	0	0
	Post - program	**Dec 1949 - 2009**	2 (2)	0	1	0
Central Coast	**Pre - program**	**1900 - Jan 1987**	4 (3)	2 (1)	3	1
	Post - program	**Jan 1987 - 2009**	5 (2)	0	1	0
		TOTAL	80 (60)	22 (19)	57	26

Note: the number in brackets denotes the number of attacks that were at beaches that are now part of the SMP

* denotes that the attack at Coledale in 1966 was before that beach became part of the SMP in 1972

(Source: Australian Shark Attack File, data up to 13 March 2009)

2.6.4 Species implicated in shark attacks

The reliable identification of the species of shark responsible for an attack is often not possible, especially from attacks in the early 1900s. Of the 200 unprovoked attacks in NSW since 1900, the identity of the shark is unknown in 39% (77) of attacks (Table 7). More recently, scientists have used the unique bite mark patterns for each species to identify bull sharks, tiger sharks and great white sharks as probably responsible for some of the most recent cases of fatalities or serious injuries.

Whalers as a group (comprised of 'bronze', 'whalers - general' and 'bull' sharks) are thought responsible for approximately 30% (60) of attacks and 42% (23) of fatalities since 1900. Approximately 55% (33) of the attacks by whalers were in estuaries or embayments, predominantly Sydney Harbour and its tributaries, which accounts for 20 of those 33 attacks. There were also 25 reported attacks by whalers at ocean beaches, five of which were fatal, including one at a meshed beach, Merewether in 1951 (whaler - general). The most recent fatality at Ballina, in April 2008, and the attack in February 2009 at Garden Island that resulted in the loss of a diver's hand and leg, were also attributed to bull sharks.

Other species implicated in shark attacks in NSW include great white sharks (28 ~14%), wobbegongs (25 ~13%) and tiger sharks (10 ~5%). Of the 28 attacks attributed to great whites, 12 were fatal and 11 of those were on swimmers prior to 1956. The other fatal attack attributed to a great white was on a scuba diver at Julian Rocks, Byron Bay in 1993. The most recent attacks in February and March 2009 on surfers at Bondi and Avalon Beach were also attributed to great whites, based on an examination of the bite marks by DPI scientists (Appendix 7).

There is a potential risk of attack from other species of sharks generally greater than 2 m in length, and the other whaler species, makos and sevengill sharks are the most likely species to cause injury to swimmers or surfers. Despite accounting for a third of the catch reported for the SMP since 1990 (Table 3), hammerhead sharks have not been implicated in a single attack in NSW since 1900. In fact, hammerheads have only been suspected of one attack in Australia since 1900, a bite on a victim's arm while snorkelling in Upolo

Bay, Cairns in 2002. With their distinctly shaped head, hammerheads are readily identified when observed and are unlikely to be responsible for attacks where the identity of a shark is unknown.

2.6.5 Seasonality of shark attack

Not unexpectedly, the warmer summer and Easter holiday months from December to April account for 80% (160) of all shark attacks and for 93% of fatalities in NSW waters from 1900 - March 2009 (Table 10). Ninety-six of those attacks were at ocean beaches, and 19 were at meshed beaches. The two most recent attacks at meshed beaches also occurred in those warmer months: at Bondi in February 2009; and at Avalon in March 2009 (Table 7; Appendix 7).

Winter and spring account for only eight and 28 attacks, respectively, since 1900 (Table 10) and only four of those 36 attacks were at meshed beaches. Three of those attacks at meshed beaches occurred in November and the other attack at a meshed beach occurred in October (Table 7).

These peaks and lows in attacks correspond to the periods of highest and lowest annual average sea surface temperatures, which for summer and autumn is 21^{o}C and for winter and spring is 17^{o}C as measured off Sydney from 1961 - 90 (Australian Bureau of Meteorology web-based mapping). These findings are similar to those of Paxton (2006) and Coppleson (1962), in that shark attacks seem not unexpectedly to be correlated with water temperature. However in the absence of better information about beach usage and a formal statistical appraisal of all factors, it is not possible to be more specific than to say that there are more attacks in the peak bathing seasons of summer and autumn, than there are in winter and spring.

The relatively low number of attacks in November over 109 years (Table 10) and the relatively low number of tiger sharks and whalers caught in the SMP since 1990 (Table 3) offers measured support to Coppleson's view that few or any dangerous sharks occur in NSW waters in November. The fatality in November occurred in 1947 in the Maria River, Port Macquarie, and was reportedly a 'whaler - general', further supporting that view. Countering that argument, however, is the fact that since 1990 an average of one great white has been caught in the nets during November every two years (Table 3), and that of the 28 attacks attributed to great whites, three have occurred in both October and December (Table 7).

Table 10 Number of unprovoked shark attacks by month for NSW from 1900 to March 2009

	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Attacks	55	29	23	24	4	3	2	3	5	12	11	29	**200**
Fatalities	18	9	8	4	1	2	0	0	0	0	1	12	**55**

(Source: Australian Shark Attack File, data up to 13 March 2009)

2.6.6 Time of shark attacks

The time of attack has been recorded in 95 of the 200 attacks in NSW waters between 1900 - March 2009 (ASAF, unpub. data). Of those 95 attacks: one was between 12 am and 6 am; 36 between 6 am and 12 pm; 50 between 12 pm and 6 pm; and eight between 6 pm and 12 am.

Of the 52 attacks that have occurred since 2000, the time of attack is unknown in 21 instances. Of the remaining 31 attacks: 16 occurred between 6 am and 12 pm; 10 between 12 pm and 6 pm; and five between 6 pm and 12 am.

It is likely that these figures are more indicative of the preferred swimming periods of humans, surfers and body boarders in particular, than they are of the feeding or active periods of sharks.

2.6.7 Biological and habitat factors

It is often the case that schools of migrating baitfish, Australian salmon or mullet are accompanied by the presence of sharks. Since 2000, at least 10 of the 52 attacks have occurred when schools of baitfish and/or larger fish were present in the area (ASAF, unpub. data). These and schools of other prey such as snapper,

rays or mulloway may also create temporary hotspots of great white activity (Bruce 2006) and are likely to increase the probability of sharks being present in a particular area. As sharks grow they change diet from small fish to larger fish and mammals (Estrada et al. 2006), thus increasing the likelihood of an interaction between mature sharks and humans. Recent studies on great white sharks have also revealed diverse and extensive patterns of movement of juvenile great white sharks from the Great Australian Bight into NSW waters during autumn and moving southward again in spring (Bruce 2006, Bruce et al. 2006).

Krogh (1994) reported significantly higher catches of whalers, great whites and tiger sharks in the nets of the SMP when deeper water was closer to the beach. Nearshore troughs and channels, either parallel or perpendicular to the beach, are thought to provide suitable habitat to allow the movement of large sharks into and out of beaches from adjacent areas of deep water and that as such they may be an important factor affecting the frequency of shark attack (Simpfendorfer 1992; Coppleson and Goadby 1988).

2.6.8 Comparisons with other Australian states and overseas statistics

West (2006) reported that in the 32 years from 1974 to 2005, there were 164 sharks attacks in Australia which resulted in injuries to the victim. The number of attacks in descending order by State was: Queensland 60; NSW 46; Western Australia 30; South Australia 16; Victoria 7; Northern Territory 5; and Tasmania 0. Over the same period there were 41 fatal shark attacks. Fifteen of these were in Queensland, 14 in South Australia, six in Western Australia, three in Tasmania, two in NSW, one in Victoria, and none in the Northern Territory. Because of the extreme rarity of shark attacks, it is not possible to identify statistically valid trends in attacks by State.

The International Shark Attack File (at www.flmnh.ufl.edu/fish/sharks/statistics/2008attacksummary.htm) reported that of 59 attacks worldwide in 2008, the majority (71%: 42 attacks) of world-wide unprovoked attacks occurred in North American waters, compared to 43 in 2007. Elsewhere in 2008, attacks occurred in Australia (12), Mexico (three), and Brazil (two), with a single incident reported from the Republic of Seychelles.

Of the 71 unprovoked attacks recorded in 2007, 50 occurred in North American waters, as well as Australia (13 [14 recorded in the ASAF]), South Africa (two), and New Caledonia (two), with single incidents reported from Fiji, Ecuador, Mexico, and New Zealand.

While the US has traditionally reported the largest number of shark attacks, the proportion of attacks which are fatal is much less than in Australia. A large proportion of attacks in the US waters have resulted in relatively minor injuries.

2.6.9 Conclusions

It is not yet possible to draw valid, quantitative conclusions about the likelihood of attacks based on these trends in shark attacks. This is primarily due to the lack of data about the numbers of bathers, but also reliable estimates of the numbers of sharks, and various environmental and biological factors existing at the time of the attacks. Whilst some of the latter issues are now better understood, the issue of bather numbers is as valid now as it was for historical attacks, and was an issue discussed at the shark summit in 2006. Until such time as the data exists, it will not be possible to make rigorous and widely-accepted quantitative estimates of the likelihood of a shark attack at any particular beach or location.

At best, qualitative estimates could be made of the likelihood of a fatal shark attack relative to other sources of human mortality (e.g. motor vehicle accidents, bee stings or drownings). Similarly, it should be acknowledged that the increasing population of NSW, especially on the coast, will increase the number of interactions with sharks. That is not to say that the rate of shark attacks is increasing, rather that the number of attacks is increasing commensurate with or slower than the bathing population.

The draft management plan for the SMP should include provisions to collect and analyse the data to inform a risk assessment, based on the Australian standard, in the short to medium term. In addition, the Government should enhance its existing community education campaign in the immediate to short term. The advisory material should contain information about sharks and some of the common traits of shark attacks, e.g. the presence of schools of baitfish, seasonal movements of prey items of sharks, migratory movements of sharks, and the increased activity of sharks around dawn and dusk.

2.7 RECOMMENDATIONS ARISING FROM THE REVIEW OF THE EXISTING PROGRAM

This section will provide a synopsis of the major issues arising from the review of the existing program. It will also provide some recommendations to mitigate those issues and that should be used to inform the development of the draft management plan.

2.7.1 Administrative and reporting procedures

This report represents the first systematic and publicly available review of the SMP in its entirety since it began in Sydney in 1937. Historically there has been limited reporting, either internally or externally, of the operation or outcomes of the SMP and the management plan needs to incorporate standardised and scheduled reporting. Articles have appeared in peer-reviewed scientific journals and in various 'grey literature', but usually of only one or two components, and invariably of the reported catch and/or bycatch (e.g. Krogh and Reid 1996; Krogh 1994; Reid and Krogh 1992; DPI 2006a; Reid and Broadhurst 2004, Hamer 1992). As the legislation requires an annual review by the FSC and SC of the performance of all parties to a draft JMA, then it would follow that the schedule of reporting would be annual, and that the report would be a performance report upon which the FSC and SC could base their annual review. As a minimum, it would need to contain a suite of performance criteria/indicators and associated trigger points, but should also provide details of the catch and effort for that financial year. Any such performance report, or a separate but intrinsically-linked report, should also identify how and why trigger points were tripped, and propose measures (where necessary) to remedy any such triggered performance indicators. The 'performance report' should be publicly available.

Recommendation 1
That DPI prepare an Annual Performance Report at the end of each meshing season commencing 2008/09 and prior to commencement of the subsequent season. The report will form the basis of the annual review by the FSC and SC, and should also be publicly available.

There have been numerous ad hoc internal reviews that have implemented some important changes, not least of which was adjusting the SMP from a year-round program off Sydney beaches to one that included adjacent regions and standardised the number of sets per month. Two of the reviews also resulted in a reduction of the length of the netting season by omitting the winter months from May to August to mitigate the impacts of the SMP on migrating whales. In addition to the annual performance reporting discussed above, the management plan should incorporate a process for ongoing review, refinement and subsequent reporting of the SMP, based loosely on this initial review report. Five years is the sort of timeframe commonly used for legislative purposes and would allow a reasonable analysis of a series of annual reports and associated data upon which to determine the need or otherwise for any further modifications of the program.

Recommendation 2
That DPI make provision in the draft management plan for a review of the SMP every five years to determine the need or otherwise for further changes to the program.

In its 71 years, the SMP has operated under various aims and objectives, none of which have provided much focus on threatened and other non-target species. The draft management plan provides an opportunity to consolidate and document the objectives of the SMP, and perhaps more importantly, to establish a suite of performance criteria by which the success or otherwise of the SMP can be measured.

Recommendation 3
That DPI provide a clear statement of the objectives of the program, including an objective to minimise impacts on threatened and other non-target species.

In the absence of systematic reporting mechanisms and publicly available reports, the SMP has been viewed with considerable uncertainty and scepticism from some sectors, largely attributable to a perceived lack of transparency and availability of information. The management plan and Joint Management Agreement provides the first opportunity for public comment on the SMP, as well as an annual reporting

mechanism and annual review by external and independent bodies (i.e. the Fisheries Scientific Committee and the Scientific Committee). To remove a lot of the uncertainty and subjectivity associated with the SMP, the annual reports should be publicly available documents, a research plan should be developed as part of the management plan, and all monitoring and reporting should be undertaken transparently.

Recommendation 4
That DPI improve public understanding of the SMP by ensuring that reports and research results are written in lay terms ("plain English") and are readily available to the public.

2.7.2 Temporal extent

This review does not support a reduction in the temporal extent of the SMP, despite recent opposition from some environmental and shark conservation sectors of the community. September and October and often cited as months that could be dropped from the SMP to further mitigate impacts on grey nurse sharks and migrating whales.

Between 1990/91 and 2007/08, six grey nurse and one minke whale were caught in the month of September, i.e. one grey nurse in September every three years. Only one grey nurse has been caught in that period in the month of October. Conversely, September and October account for 57 of the 100 great whites caught in the SMP over that period. Removing the nets to potentially reduce the number of grey nurse sharks or whales affected by the SMP could potentially increase the likelihood of interactions between bathers and great white sharks, and the available data suggests that any potential increase would be more noticeable in the Newcastle and Central Coast regions. Additionally, recent modelling of the Australian east coast grey nurse shark population suggests that catches in shark nets make a minimal contribution to the continued demise of this population (Bradshaw et al. 2008).

Rather than remove the nets in September and October, the management plan should include trigger points to monitor catches of grey nurse sharks and other threatened species. Additionally, monitoring and research into the distribution and movements of great white sharks, and contract reviews that examine the feasibility of running the nets on a daily basis in the Newcastle and Central Coast regions in September and October should be considered. As a minimum there should be some consideration given to shortening the existing 96 hours within which contractors have to run the nets after initially setting them. Reducing the maximum time to 72 hours for a weekend set and 48 hours for weekday sets could provide a schedule of net checking on Monday, Wednesday and Fridays, weather permitting. For example, for a weekend set, the net could be set and/or checked on Friday and would then be checked on the following Monday.

These measures, and the annual performance report and five year reviews discussed above, should enable future reviews to identify the need or otherwise to modify the coverage and/or operating protocols of the program.

Recommendation 5
That in the immediate term there be no change to the temporal extent of the SMP.

Recommendation 6
That at the expiration of existing meshing contracts, subsequent contracts be modified to reduce the net checking requirement from 96 hours to 72 hours and three times per week, and that the feasibility of even more frequent checking be investigated for the Newcastle and Central Coast regions.

2.7.3 Operational characteristics

The meshing protocols of the SMP have not been examined in detail since 1972, and whilst the length of nets has not changed in that time, the size and number of meshes in the nets has been optional on the basis that the depth of 6 m of net can be met. Further, two nets can be set simultaneously to constitute two of the nine meshing days of effort per month. Such variability in the contract unnecessarily complicates calculation of CPUE and reduces the comparability of data both within and between regions. As a minimum, the management plan should incorporate an initial review of the meshing protocols by an expert gear technologist, and for similar reviews to be part of the five year reviews discussed above.

Recommendation 7
That at the expiration of the existing contracts, subsequent contracts be modified to a single type of mesh net with a standardised mesh size and number based on a review of the existing mesh nets by an expert gear technologist.

Recommendation 8
That at the expiration of the existing contracts, subsequent contracts be modified to remove the existing provision for setting two nets simultaneously to constitute two meshing days.

The management plan should also re-examine the spatial structure of the SMP and demographics of its contractors. The Sydney North region, for example, includes 15 beaches compared to 5 in the Illawarra region, and it may be more practical to divide Sydney North into two smaller regions. Some of the existing contractors have extensive experience in the SMP and the management plan needs to provide a mechanism by which that experience is conveyed to potential future contractors through either work experience (e.g. as deckhands), some form of mentoring program or specific training provided by DPI. In considering the structural and contractual arrangements of the SMP, the review should also consider the costs and benefits of out-sourcing the SMP as opposed to establishing a dedicated team within DPI, as is done in both Queensland (for research and supervision of contractors) and South Africa.

Recommendation 9
That the management plan and any future contracts contain provisions that enable the establishment of a 6th region, i.e. to enable Sydney North to be divided into two smaller regions.

Some scientific analyses are conducted on some captured sharks, but mostly when there is a scientific observer aboard the contractor's vessel, and even then shark identification can still be problematic. The SMP does not currently tag sharks on a consistent or strategic basis, and although recapture rates are low in South Africa, the SMP provides an opportunity to obtain better scientific data about the distribution and movements of sharks. Such research would contribute to meeting the aims and actions of the National Plan of Action for the Conservation and Management of Sharks, and the Commonwealth's recovery plans for grey nurse and great white sharks. The management plan needs to formalise a research and monitoring plan and as a minimum should investigate the broader use of tag and release and its potential risk to threatened and protected species.

Recommendation 10
That the management plan contain a strategic research and monitoring plan for the SMP, including timeframes and priorities for each component, one of which should be to investigate the feasibility and associated risks of tagging threatened or protected species.

As a passive, non-specific form of fishing, the nets of the SMP have resulted in some bycatch, which has been dominated by elasmobranchs such as hammerhead sharks and stingrays. Historically, the SMP has also caught a substantial number of grey nurse and great white sharks. In addition, since 1990/91 the SMP has caught 52 dolphins (100% mortality), 47 turtles (60% mortality), 4 seals (50% mortality), 3 false killer whales (100% mortality), 2 humpback whales (50% mortality), 1 penguin (100% mortality) and 1 minke whale (100% mortality). The potential impact on these groups will be examined in detail in Chapter 3, and whilst they appear to represent low numbers of animals per year, it is recommended that the management plan not only continue to record bycatch but also to both improve identifications and to establish trigger levels for each species that as a minimum would result in a performance report outlining the trends and the need for any mitigative measures.

Recommendation 11
That the management plan contain trigger points and an associated review to more rigorously monitor changes in catch and thus potential abundance of threatened and protected species.

2.7.4 Trends in unprovoked shark attacks

Lack of data about the numbers of bathers, in addition to reliable estimates of the numbers of sharks and various environmental and biological factors existing at the time of the attacks, precluded any valid, quantitative conclusions about the likelihood of attacks. Whilst it has been acknowledged that the annual number of attacks has increased recently, the available data suggests that this is a reflection of an increasing bather population and not an increase in the number of sharks off the NSW coast. Quantitative data is required on the bather population and ecological requirements of sharks to better understand the potential for these interactions.

Recommendation 12
That the management plan include provisions to collect and analyse the data to inform a shark attack risk assessment.

NSW DPI provides information on ways to minimise the risk of shark attack, including avoiding swimming during twilight hours and avoiding murky water or waters with signs of baitfish or fish feeding behaviour. The circumstances associated with the more recent attacks along the coast suggest an ongoing emphasis on community education and awareness is warranted. Rather than make a recommendation specific to the management plan and regions of the SMP, it is recommended that DPI enhance its existing State-wide community education campaign in the immediate to short term.

3 ENVIRONMENTAL ASSESSMENT OF THE EXISTING SHARK MESHING PROGRAM

The SMP has operated in Sydney since 1937, however catch records up to 1949 are incomplete and inconsistent, so the descriptions throughout this chapter represent data from January 1950 to July 2008. The data are presented in financial years wherever possible as this includes a complete meshing season (i.e. September - April), and is consistent with other publications (e.g. Collins 1972; Reid and Krogh 1992).

It is important to note that most of these figures for reported catch are likely to be an underestimate due to the often inconsistent and inaccurate reporting within the SMP prior to the mid-90s. In the 1995/96 season, NSW Fisheries (now DPI) began a scientific monitoring program, which included the mandatory use of trained, scientific observers aboard contractors' boats and this period is likely to represent a more accurate account of the catch composition of the SMP.

3.1 GENERAL CATCH STATISTICS, 1950 TO 2008

Overall, in the period between January 1950 and 2007/08, at least 16,064 animals were caught in the SMP, comprised mostly of hammerhead sharks (29%), rays (18.9%), whalers (18.4%) and angel sharks (14.4%) (Table 11). Nine other groups of sharks collectively comprised a further 15.2%, and finfish accounted for 2.5%. Due to identification problems with sharks it is not possible to know exactly how many species were caught in the SMP, but based on species' distributions it appears that at least 23 species of shark were caught in nets of the SMP between January 1950 and July 2008 (Table 11).

Marine mammals, reptiles and birds collectively accounted for the remaining 1.6% of the catch, and were dominated by dolphins and turtles (Table 11). The following sections will describe each of these groups and use a risk analysis to determine the level of risk posed to each group/species by the SMP.

Table 11 Summary of major animal groups caught in the SMP from January 1950 to 2007/08

Fish	Likely composition	Number	Marine mammals, reptiles, birds	Likely composition	Number
Elasmobranchs			Dolphins	3 species	143
Hammerheads	3 species	4666	Turtles	3 species	98
Stingrays	Up to 8 families	3040	Whales[2]	4 species	7
Whalers	5 species	2949	Dugong	*Dugong dugon*	6
Angel shark	2 species	2313	Seals	2 species	4
Port Jackson	2 species	651	Penguins	*Eudyptula minor*	1
Great whites	*Carcharodon carcharias*	577	**Sub-total**		**259**
Grey nurse	*Carcharias taurus*	377			
Tigers	*Galeocerdo cuvier*	352			
Sevengills[1]	*Notorhynchus cepedianus*	158			
Shortfin mako	*Isurus oxyrinchus*	144			
Threshers	3 species	125			
Wobbegongs	3 species	42			
Unknown		5			
Osteichthyes					
Finfish	At least 14 species	406			
Sub-total		**15,805**			
Total		**16,064**			

[1] denotes that sevengill is the common name historically used to describe this species, but CSIRO's Codes for Australian Aquatic Biota now uses the common name of broadnose shark. For consistency and data comparisons, the term sevengill will be used in this document.

[2] denotes that 'whales' includes killer and false killer whales which are members of the dolphin family

(Source: DPI unpublished data)

3.2 SHARKS

3.2.1 Groups/species

The purpose of these descriptions is not to present all the available information for each group or species, but to gather enough information about a species' biology, ecology, distribution, other anthropogenic sources of mortality, and catch in the SMP to inform the risk analysis.

Last and Stevens (1994) provide detailed descriptions of all Australian sharks and rays, and is the primary reference for the following synopses. Other references used in these descriptions include: Compagno 1984, Stevens 1984, Krogh 1994, Pogonoski et al. 2002, and Scandol et al. 2008 for all sharks; Otway and Parker 1999 and 2000, Otway et al. 2003, and Bradshaw et al. 2008 for grey nurse sharks; Huveneers 2006 for wobbegongs; Simpfendorfer et al. 2002 and McAuley et al. 2005 and 2007 for whalers; Bishop et al. 2006, Dulvy et al. 2008 and Stevens 2008 for shortfin makos; and Compagno et al. 1997, Malcolm et al. 2001, Environment Australia 2002, Bruce 2006, Bruce et al. 2006, and Estrada et al. 2006 for great whites.

Unless otherwise stated, sharks have low resilience to fishing pressure with a minimum population doubling time of 4.5 - 14 years (www.fishbase.org).

Angel sharks (Squatina species)

The eastern angel shark (*Squatina albipunctata*) and the Australian angel shark (*Squatina australis*) are demersal species caught off New South Wales and both are thought to have been caught in the SMP.

The eastern angel shark occurs on the mid to outer continental shelf and upper slope waters off eastern Australia in depths of 130 - 315 m, between Lakes Entrance in Victoria and Cairns in Queensland. The size range for angel sharks caught south of Jervis Bay by the Fisheries Research Vessel *Kapala* in 1993-94 for females was 27 - 132 cm and for males 30 - 106 cm, with the maximum weight of females close to 20 kg.

The Australian angel shark occurs on coastal and shelf waters to about 130 m depth off southern and central New South Wales, and around southern Australia to Rottenest Island, Western Australia. The size range for Australian angel sharks caught south of Jervis Bay in 1993-94 was 30 - 117 cm for females and 34 - 104 cm for males, with the large females weighing up to 15 kg.

Males of both species mature at between 80 and 90 cm in length. For females, eastern angel sharks matured between 100 and 110 cm and Australian angel sharks between 90 and 100 cm. Both species are aplacental livebearers and have around 10 - 13 pups over summer and early autumn in New South Wales waters and gestation probably takes about one year. Interstate and overseas studies on other angel sharks have found one or two year breeding cycles.

Hammerhead sharks (Sphyrna species)

The smooth (*Sphyrna zygaena*), scalloped (*Sphyrna lewini*) and great hammerheads (*Sphyrna mokarran*) are all caught off the New South Wales coast and have been caught in the SMP.

The smooth hammerhead (*Sphyrna zygaena*) occurs in temperate, and some tropical waters in both hemispheres. In Australia, it occurs south from Coffs Harbour to about Jurien Bay in Western Australia and is thought to be the main hammerhead species caught in the SMP. It prefers coastal and shelf waters from the surface to 20 m deep, although it has been reported at depths greater than 100 m (V. Peddemors, NSW DPI, unpub. data). It attains a maximum length of 350 cm, males mature at about 250 cm and females at about 265 cm. Hammerheads are placental livebearers, and smooth hammerhead litters vary in size from 20 to 50 pups. Parturition off the New South Wales coast is thought to occur between January and March after a gestation of 10 - 11 months. The presence of pregnant females in the nets of the SMP suggests that at least some of these hammerheads may be moving into shallow water to give birth.

The scalloped hammerhead (*Sphyrna lewini*) occurs in tropical and warm temperate seas. In Australia, it is recorded throughout the north from Sydney in New South Wales to Geographe Bay in Western Australia. It occurs over the continental shelf and adjacent deep water, from the surface to at least 275 m depth, with juveniles often found close inshore, often in large migratory schools. Adult females are rarely caught inshore and may live in deeper water, only moving onto the continental shelf to mate and give birth. Males mature at between 140 - 160 cm, females at about 200 cm and they attain a maximum length of about 350 cm. In Australian waters, scalloped hammerheads produce litters of 13 to 23 pups between October and

January after a gestation of 9 - 10 months. Stevens (1984) suggested that this species is unlikely to account for more than 10% of the catch of hammerheads in offshore New South Wales waters.

The great hammerhead (*Sphyrna mokarran*) is circumglobal in tropical and warm temperate seas. In Australia, it occurs north from Sydney in New South Wales to the Abrolhos Islands in Western Australia. It is found on the continental and insular shelves, from inshore to at least 120 m depth (V. Peddemors, NSW DPI, unpub. data). It attains 600 cm, though rarely more than 450 cm. In Australia, males mature at about 225 cm and females at about 210 cm. Litters of 6 - 33 pups are produced in December and January (in northern Australia) after a gestation of 11 months.

Great white shark (Carcharodon carcharias)

The great white shark is listed as Vulnerable under the FM Act and Vulnerable under the EPBC Act, and protected in all State waters under a variety of Acts (from 1998).

It occurs in all seas in both hemispheres and is most commonly found in inshore cool to warm temperate waters of the Western North Atlantic, Mediterranean Sea, southern Africa, southern Australia, New Zealand and the Eastern North Pacific. In Australia, the great white shark generally occurs in inshore temperate waters, often around rocky reefs and islands, and often in the vicinity of seal colonies. It has been recorded from central Queensland, around the southern coast to North West Cape, Western Australia, but is more common in the south. Genetic data suggests that white sharks comprise a single population in Australian and New Zealand waters that is distinct from the South African population.

Smaller great whites feed on a variety of finfish, sharks and rays, and marine mammals form a significant part of the diet of adult great white sharks at about 3.4 m in length. Large numbers of juvenile white sharks occur in Stockton Bight, between Newcastle and Port Stephens during the winter and spring. A CSIRO program for tagging of white sharks on the New South Wales coast has been underway for the past two years, and is continuing to provide information on the movements of juvenile white sharks.

The great white shark is a member of the Lamnidae family (mackerel sharks), which also includes the mako and porbeagle sharks. Mackerel sharks have a heat-exchanging circulatory system that enables them to maintain body temperatures above that of the surrounding water. White sharks are long lived, with a maximum age estimated to be approximately 30 years. White sharks are aplacental livebearers, and in utero the developing embryos feed on unfertilised eggs continually ovulated during gestation. Litter sizes are relatively small, with a range of 2 to 10 pups, and the gestation period is estimated to be more than 12 months. Great whites are born at 1.2 - 1.5 m in length and grow to approximately 6 m. The great white shark is a livebearer, producing litters of 2 - 11 pups every 2 - 3 years. Females reach maturity at 4 - 5 m in length and 12 - 14 years of age, while males mature between 3.5 and 4.1 m long and 9 - 10 years of age.

Neither a stock assessment nor an estimate of population size is yet possible for Australian waters. With a minimum population doubling time of more than 14 years (K = 0.06; tm = 8 - 12; t max = 36; Fec = 7) (www.fishbase.org), the great white shark is considered to have very low resilience to fishing pressure.

Grey nurse shark (Carcharias taurus)

The grey nurse shark is listed as a Critically Endangered species under the FM Act and as a Critically Endangered Population (East Coast) under the EPBC Act, with the population considered by some scientists to comprise fewer than 800 sharks. The eastern population of the grey nurse shark is genetically distinct (Stow et al. 2006), and is protected throughout its range, including both Queensland and Victoria.

In Australia, the grey nurse shark occurs from about Yeppoon, Queensland to Shark Bay, Western Australia, but is less common on the south coast of the continent. In New South Wales, it has recently been predominantly found confined to coastal waters along the entire coast. There are several sites in New South Wales waters where significant numbers of grey nurse sharks are reported to consistently occur, most of which are protected as critical habitats and/or sanctuary zones within marine parks. There are also two sites off the New South Wales coast in Commonwealth waters: Pimpernel Rock and the Cod Grounds, both of which are sanctuary zones.

Grey nurse sharks occur in warm temperate and subtropical waters from rocky inshore reefs down to 200 m on the continental shelf. In New South Wales, the species is commonly seen in or near sandy-bottomed gutters or rocky caves around inshore islands or reefs between 15 and 40 m.

At certain times of the year these sharks aggregate along the coast according to sex - from July to October males occur together in southern Queensland and females in central New South Wales. Grey nurse sharks are reported from other sites along the coast (e.g. Long Reef and South Marley), but these sites do not appear to be used as aggregation sites. Grey nurse sharks are reported to move extensive distances at certain times of the year, and unidirectional distances ranged from 25 to 681 km over a two month period. Furthermore, males and females tended to move north during autumn and winter and females then moved south during spring and summer.

The grey nurse shark is an aplacental livebearer, with cannibalism inside the egg case and uterus, resulting in one or two pups (rarely four) per litter. They reproduce every two years, with an estimated population doubling time of more than 14 years. Gestation lasts 9 - 12 months. An age and growth study of grey nurse in waters of the western North Atlantic indicates that males reach sexual maturity at 190 - 195 cm and 6 - 7 years of age, while females mature at 220 - 230 cm and 9 - 10 years of age (Goldman et al. 2006). A study of sharks caught in the protective nets off South Africa report size at maturity for males and females at 163 cm and 175 cm, respectively (Dudley and Simpfendorfer 2006). Male and female grey nurse sharks from New South Wales waters reportedly mature at 200 cm and 6 - 7 years, and 260 cm and 10 - 12 years, respectively (M. Ellis, NSW DPI, unpub. data). With a minimum population doubling time of more than 14 years (Fec = 2; K = 0.14 - 0.17; tmax = 17), the grey nurse shark is considered to have very low resilience to fishing pressure (www.fishbase.org).

This has recently been highlighted when, using a series of stochastic, density-dependent population viability models, Bradshaw et al. (2008) predicted that under currently reported fishing related-mortality (particularly from hook and line fisheries) the east coast population has a >40% chance of becoming quasi-extinct (<50 females) within 3 generations (~50 years). If fishing mortality is under-reported, the probability of extinction rises to nearly 100% over the same interval.

Port Jackson shark (Heterodontus portusjacksoni) *and crested horn shark* (Heterodontus galeatus)

Heterodontids are medium-sized sharks (up to 1.6 m) with restricted distributions in tropical and warm temperate seas. They are egg layers and live on or near the bottom, usually in fairly shallow water. Of the eight recognised species, two occur in New South Wales waters.

The Port Jackson shark is distributed around southern Australia, from Byron Bay in New South Wales to the Houtman Abrolhos Islands, Western Australia, including Tasmania. It attains a maximum length of about 165 cm, with males maturing at about 8 - 10 years and 75 cm, and females at about 11 - 14 years and 80 - 95 cm. They segregate by sex and maturity, with sharks found on New South Wales sublittoral reefs consisting mainly of adult females, which migrate south in summer and return north in winter. On the central New South Wales coast, breeding occurs in late winter and spring. Females lay 10 - 16 eggs in rock fissures on inshore reefs usually less than 5m deep. The egg-cases are spirally flanged but lack tendrils, and hatch after about 12 months. It is a demersal species occurring on coastal and shelf waters of New South Wales to 275 m depth, but is most common in shallower coastal waters.

The crested horn shark is generally similar in appearance to the Port Jackson shark, and has not been separately distinguished in contractors' records of catches from the SMP. It is distributed from Cape Moreton, Queensland to Batemans Bay on the New South Wales south coast. It occurs on the continental shelf from close inshore to about 90 m depth. It attains a maximum length of 130 cm, and males mature at about 60 cm and females at about 70 cm. The egg-cases are spirally flanged, have long tendrils at their bases and are laid amongst seaweed or sponges during July or August and hatch after a gestation of about 8 months.

Sevengill shark (Notorhynchus cepedianus)

Sevengill sharks are found in temperate waters of the south Atlantic, Pacific and Indian Oceans. In Australia, they occur from Sydney, New South Wales to Esperance, Western Australia, including Tasmania. They are found from close inshore in bays and estuaries to depths of at least 136 m on the continental shelves. They attain a maximum size of 300 cm, and males mature at approximately 150 cm and females at 220 cm. They are aplacental livebearers, with litters of up to 82 pups. It occurs in the beach protection nets in the Illawarra region much more frequently than in the other regions of the SMP, which is consistent with its reported distribution. With a minimum population doubling time of more than 14 years (rm = 0.026; K = 0.25; tm = 16; tmax = 32; Fec = 82 - 95), the sevengill shark is considered to have very low resilience to fishing pressure (www.fishbase.org).

Shortfin mako shark (Isurus oxyrinchus)

The shortfin mako is a highly migratory species and is circumglobal in tropical and warm temperate oceanic waters. It is widespread in Australian coastal, shelf and oceanic waters with the exception of the Arafura Sea, Gulf of Carpentaria and Torres Strait, and is caught along the entire New South Wales coast. It is oceanic and pelagic, and occurs from the surface to at least 600 m. Mako sharks are seldom found in waters below 13^{o}C, although captures have been made in 10°C surface temperatures in the South Pacific. Like other lamnid sharks it has a heat-exchanging circulatory system. The shortfin mako attains 395 cm and there is a large sexual difference in the size at maturity, with males maturing at about 195 cm total length, and females at about 265 - 280 cm. Published information on growth rates and age estimates are conflicting, and further studies are required to resolve age and growth in this species.

Shortfin makos are aplacental livebearers, and in utero the developing embryos feed on unfertilised eggs continually ovulated during gestation, which is about 15 - 18 months. Breeding frequency appears to be every three years, and litters of 4 to 16 pups (12 on average) are born in late winter to spring. Little is known about stock structure or population status, although most populations do not (yet) appear to have been severely impacted by fishing pressure. With a minimum population doubling time of more than 14 years (rm = 0.051; K = 0.2; tmax = 28; Fec = 4) the shortfin mako shark is considered to have very low resilience to fishing pressure (www.fishbase.org).

Thresher sharks (Alopias vulpinus, A. supercilious, and A. pelagicus)

Three thresher sharks are recorded in New South Wales waters, namely the thresher shark (*Alopias vulpinus*), bigeye thresher (*A. supercilious*) and pelagic thresher (*A. pelagicus*). Those species are all aplacental livebearers, and in utero the developing embryos feed on unfertilised eggs that are continually ovulated during gestation. Litter sizes are usually 2 - 4 pups.

The thresher shark is found in temperate and tropical seas of both hemispheres. In Australia, it is recorded from Brisbane, Queensland, around southern Australia (including Tasmania) to central Western Australia. The thresher shark is a coastal, shelf and oceanic species and is generally found in waters from the surface to 370 m. It attains a maximum length of 550 cm, with the long tail accounting for about half of the total length. In Australia, males mature at about 340 cm although they may mature as small as 260 cm in other areas, and females mature between 350 - 400 cm. Like the lamnid sharks, the thresher has a heat-exchanging circulatory system that enables it to maintain body temperatures above that of the surrounding water. The thresher shark is thought to account for the majority of the catch in the SMP. With a minimum population doubling time of more than 14 years (K = 0.1; tm = 5 - 7; tmax = 19; Fec = 2 - 4) thresher sharks are considered to have very low resilience to fishing pressure (www.fishbase.org).

Bigeye threshers are also found in coastal, shelf and oceanic waters of all tropical and warm temperate seas. In Australia, it is recorded from the North West Shelf in Western Australia, Middleton Reef in Queensland, and throughout New South Wales and South Australia. It occurs in oceanic and coastal waters from the surface to at least 500 m deep. It attains a maximum size of about 460 cm. Males mature at about 270 cm and females at about 300 cm. It has a pronounced groove from above its eyes and down each side of the head, suggesting that this species would be readily distinguishable from the other threshers if it were caught in the SMP. With a minimum population doubling time of more than 14 years (Fec = 2 - 4), bigeye thresher sharks are considered to have very low resilience to fishing pressure (www.fishbase.org).

Pelagic threshers are generally found in the tropical and sub-tropical Indo-Pacific, and have been recorded from the North West Shelf off Western Australia. They are also thought to occur off northern New South Wales, limiting the potential for interaction with the SMP. Pelagic threshers are the smallest of the three threshers found in Australia, growing to about 330 cm. With a minimum population doubling time of more than 14 years (Fec = 2; tm = 7 - 9; tmax = 29) pelagic thresher sharks are considered to have very low resilience to fishing pressure (www.fishbase.org).

Tiger shark (Galeocerdo cuvier)

Tiger sharks are found in tropical seas of both hemispheres, with seasonal excursions into warm temperate areas. In Australia, they occur across northern Australia, and south to southern New South Wales and Perth in Western Australia. It occurs from close inshore to well off the continental shelf, from the surface to a depth of over 150 m and reportedly in excess of 600 m off the South African coast (V. Peddemors, NSW DPI, unpub. data). It attains a maximum length of 600 cm, males mature at about 300 cm and females at between 287 - 330 cm. Unlike the other members of the Carcharhinidae family (i.e. whaler sharks), tiger

sharks are aplacental livebearers and produce between 10 and 80 pups after a gestation period of about 12 months. Breeding and pupping both occur every two years, usually in summer.

Whaler sharks (Carcharhinus species)

Whalers have been identified to species by observers and contractors since 1997/98. In that time five species of whaler sharks have been caught in the SMP, including bronze whaler (*Carcharhinus brachyurus*), spinner shark (*C. brevipinna*), bull shark (*C. leucas*), common blacktip shark (*C. limbatus*), and dusky shark (*C. obscurus*). These five species are all placental livebearers and produce between 2 and 20 pups per litter.

Most whalers have very low resilience to fishing pressure, yet prior to 2005 an annual average of 60 tonnes of large whalers was captured by New South Wales commercial fisheries. Since 2005, that catch increased rapidly to over 300 tonnes in 2007/08 following initiation of large shark fishing in northern New South Wales waters, particularly targeting sandbar sharks (*C. plumbeus*). Two carcharhinid sharks that are caught in New South Wales commercial fisheries, namely the silky shark (*C. falciformis*) and sandbar shark (*C. plumbeus*), have not been recorded in the SMP as they are more commonly found in waters of the north and mid-north coast.

The bronze whaler (*C. brachyurus*) occurs in warm temperate and some tropical areas of both hemispheres. It occurs throughout southern Australia, from Jurien Bay in Western Australia, to Coffs Harbour in New South Wales. In New South Wales it is mainly caught south of Newcastle. It is found in coastal waters from the surf zone to at least 100 m depth.. It attains a maximum size of 295 cm, males mature at 235 cm, females at 245 cm, and produce litter sizes of 7 to 20 pups.

The spinner shark (*C. brevipinna*) is usually demersal, found in depths to 75 m and commonly occurs in coastal and shelf waters of warm temperate and tropical areas of the Atlantic, Indian and Western Pacific Oceans. In Australia, it occurs from Geographe Bay in Western Australia, through tropical northern Australia and south to at least Jervis Bay on the New South Wales south coast. It attains a maximum size of 280 cm, and both sexes mature at 190 - 200 cm. There is a seasonal migration of spinner sharks into New South Wales waters, which may be associated with reproduction, as near-term pregnant females and new born young have been caught around March and April in those waters. There is a late summer commercial fishery on juvenile spinner sharks in Stockton Bight.

The common blacktip shark (*C. limbatus*) is pelagic and demersal, found in depths to 75 m and commonly occurs in coastal and shelf waters in tropical and warm temperate areas. In Australia, it occurs from Western Australia, through tropical northern Australia and south to at least Sydney, New South Wales. Common blacktips are also occasionally caught further offshore than spinner sharks and grow to about 250 cm. Maturity in the common blacktip varies geographically, males maturing at 135 - 180 cm and females between 120 and 190 cm. Litter sizes vary from 3 to 15.

The bull shark (*C. leucas*) is a coastal, estuarine and riverine shark, and in the marine environment occurs near the bottom, from the surf zone to depths of at least 150 m. Bull sharks are the only widely distributed shark that penetrates far into freshwater for extended periods and is often found in turbid waters. It occurs in tropical and warm temperate seas of both hemispheres. In Australia, it occurs from Sydney in New South Wales, across the northern coast and south to Perth in Western Australia. It attains a maximum size of 340 cm. There is no Australian data on size at maturity, and in other parts of the world different populations show considerable variation in maturation size, with males maturing between 160 - 225 cm and females between 180 - 230 cm. Females normally give birth in estuaries and river mouths, and produce litters of 1 - 13 pups after gestation of 10 - 11 months.

The dusky whaler (*C. obscurus*) is widespread in tropical and warm temperate seas of both hemispheres. It occurs on continental and insular shelves from the surf zone to adjacent oceanic waters, and from the surface to a depth of at least 400 m. They feed throughout the water column but are more frequently found on the bottom than on the surface. It occurs throughout Australian waters, although it is rare off southern Tasmania. Dusky whalers make distinct seasonal migrations over their range, and in Western Australia adolescent and adults move inshore during summer and autumn. It attains a maximum size of about 365 cm, with both sexes maturing at between 220 - 280 cm. Stock assessments for dusky sharks in Western Australia report that 50% of females are sexually mature at about 251 cm (fork length) and about 30 years of age. Litter sizes range from 3 to 14 pups.

Wobbegong sharks (Orectolobus species)

Three species of wobbegongs are known to occur in New South Wales waters: the ornate wobbegong (*Orectolobus ornatus*), the spotted wobbegong (*O. maculatus*) and the banded wobbegong (*O. halei*). The three species occur in shallow inshore waters on coral and rocky reefs, in lagoons on reef-flats and in reef channels. They are usually found on the seabed in depths less than 50 m, but have been recorded at 220 m. They are all aplacental livebearers, whereby the young develop in the uterus from eggs before being born at about 20 cm in length, and the number of young varies with the size of the sharks. Gestation for all species is 10 - 11 months and they breed only once every three years, making their apparently high fecundity (for sharks) much lower in practice.

The ornate wobbegong occurs from Port Douglas in northern Queensland, south to at least Sydney, New South Wales. They grow to about 100 cm, mature at about 80 cm, and have up to 18 pups in a litter, but usually 7 - 10.

The spotted wobbegong is also found along Australia's east coast from about Gladstone in central Queensland, around southern Australia to Fremantle, Western Australia. The spotted wobbegong has a maximum length of 300 cm, but seldom exceeds 160 cm in New South Wales. It matures at 120 - 130 cm and may have up to about 30 pups in a litter.

The banded wobbegong is found around the southern half of Australia from southern Queensland to southern Western Australia. The banded wobbegong is the largest of the three species found in New South Wales, reaching at least 210 cm and reportedly growing to 300 cm. It matures at 170 - 180 cm, and may have as many as 53 pups in a litter.

3.2.2 Regional catch trends

Across all regions of the SMP there has been a large reduction in the total number of sharks caught per year and the catch per unit of effort (CPUE, calculated as the number of entanglements per 1,000 net sets) from 1950 to 2008 (Figure 10; Table 12). This is particularly the case for Newcastle, where average catches between 1990/91 - 2007/08 are approximately a quarter of the catches for a similar period from 1950 to 1970. The average CPUE has also constantly declined, unlike the other regions where there was an increase in catch and CPUE in the 1970s following a review of netting protocols. Catches from the Sydney area also show a decline from the 1950s and is most noticeable in the 18 years from 1990/91 - 2007/08.

According to Coppleson (1962), in the first 17 months of the shark meshing program in Sydney approximately 1,500 sharks were caught, or an average of 88 sharks per month. Within a decade, catches from the SMP averaged less than 8 sharks per month in the Sydney region (Reid and Krogh 1992). Between 1950 and 1972 it had reduced further to approximately 6 sharks per month, but there was an increase to approximately 10 sharks per month in the 1972 - 1990 period following an increase in effort in 1972. However, the catch has continued to declined between 1990/91 - 2007/08 and has averaged approximately 6 sharks per month in the Sydney region (Table 12), 68% of which were caught in the Sydney South region.

The peaks observed in the 1970s in Figure 10 and Table 12 relate to a review and subsequent modification of the netting protocols in 1972, which effectively increased effort by approximately 20% (Reid and Krogh 1992), and was reflected by an increase in shark catch of almost 300%, up from 223 sharks in 1971/72 to 650 sharks in 1972/73 (Figure 10; Appendix 8). The modifications resulted in a substantial increase in catches of hammerheads, up from 20% to 50% of the catch in the 22 years before and after the modifications, respectively (Appendix 8). There were also large, initial increases in the captures of whalers, angel sharks and great white sharks.

By 1983, annual catch levels were similar to pre-1972 levels, but catches have continued to decline ever since, even though the Central Coast was added to the SMP in 1987. The declining catches and CPUE in the Central Coast are similar to the changes recorded in Sydney and Newcastle shortly after meshing commenced in those regions. The average number of sharks and CPUE in the nine years 1999/00 - 2007/08 are almost a third of those reported for the first nine years of the SMP in the Central Coast (Table 12). Those changes were driven by the decline in hammerheads, which account for 72% of the catch on the Central Coast.

A similar decline in hammerheads was recorded in the other regions following the modifications to the SMP in 1972/73, indicating that those changes were more selective to hammerheads and shifted the

dominance away from whalers and angel sharks. These changes from periods of very high initial catches, to one of continual decline suggests that the SMP has probably had a significant effect on local shark populations in the regions of the SMP, and most of the effects are noticeable immediately after meshing commences. That is not to say that the SMP is the sole or causal factor in any decline in shark abundances off the NSW coast, rather that the nets are effective at reducing the numbers of sharks (most notably hammerheads) in localised areas.

Table 12 Annual average number of sharks and catch per unit of effort (CPUE) by region from 1950/51 to 1971/72, 1972/73 to 1989/90 and 1990/91 to 2007/08

Region	Mean number / year			Mean CPUE		
	1950/51 - 71/72	1972/73 - 89/90	1990/91 - 2007/08*	1950/51 - 71/72	1972/73 - 89/90	1990/91 - 2007/08*
Newcastle	132.09	101.78	35.06	86.2	62.2	33.71
Sydney	77.14	128.28	51.22	27.4	37.1	19.70
Illawarra	20.91	31.89	23.83	25.8	45.3	45.83
Central Coast	n/a	n/a	29.89[a]	n/a	n/a	26.13[b]
Mean total	230.14	261.94	140.00	44.62	45.18	26.4

[*] denotes that since 1990/91 the SMP has operated for eight months per season and the averages are calculated against whole years, i.e. 18

[a] denotes that the average catch for 90/91 - 98/99 was 43.33 and for 99/00 - 07/08 was 16.67

[b] denotes that the average CPUE for 90/91 - 98/99 was 37.88 and for 99/00 - 07/08 was 14.57

(Source: DPI database extraction, July 2008; Reid and Krogh 1992)

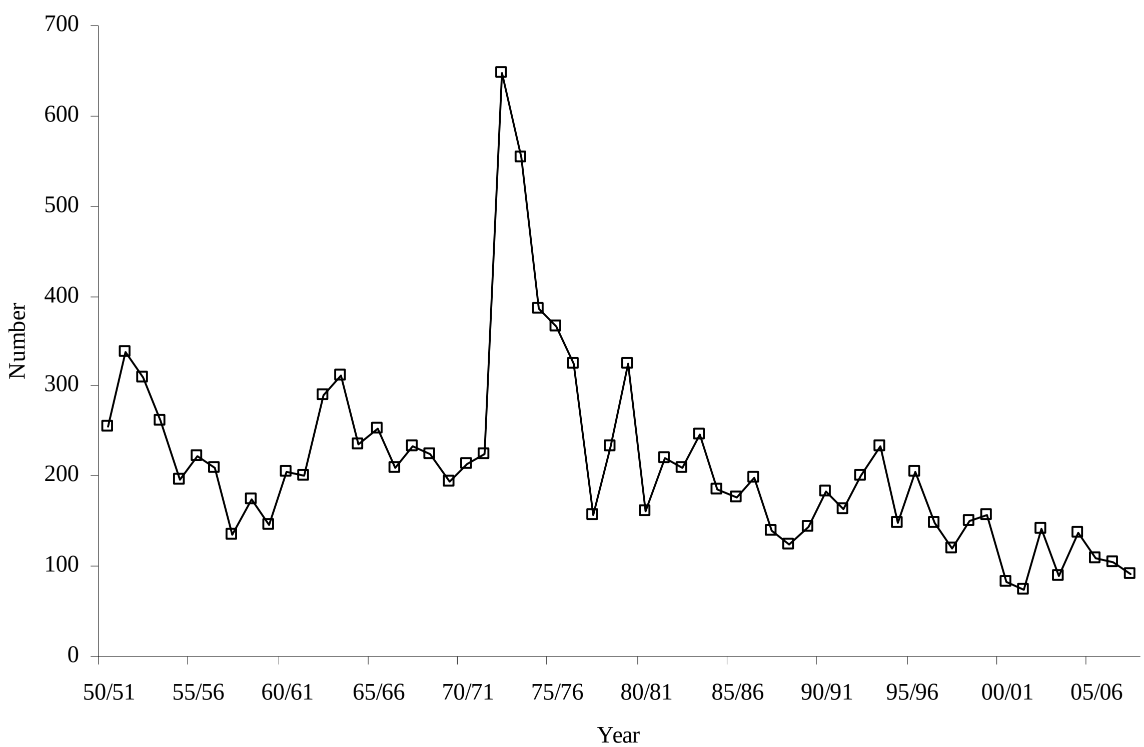

Figure 10 Total annual catch of sharks in the SMP from 1950/51 to 2007/08

(Source: DPI database extraction, July 2008)

3.2.3 Annual catch trends

Excluding the period of the early 1970s when the netting protocols were modified, there has been a generally consistent decline in the total numbers of sharks and CPUE in the SMP from 1950 to 2008 (Table 12; Figure 10). Almost all species have declined over that period except for sevengill and thresher sharks, which appear to be increasing in abundance (assuming that catches in the SMP are representative of catches

throughout NSW waters). Nearly six times more sevengill sharks were caught in the SMP between 1990/91 - 2007/08 than in the 20 years prior to 1972, and nearly double the amount caught between 1972/73 and 1989/90 (Table 13).

Table 13 Shark catch for the periods 1950/51 to 1971/72, 1972/73 to 1989/90 and 1990/91 to 2007/08

Year	Hammerheads	Whalers	Angel sharks	Port Jackson	Great white	Grey nurse	Tiger	Sevengill	Shortfin mako	Threshers	Wobbegong	Other	Total
1950/51 - 1971/72	998	1507	1314	335	279	297	109	16	95	62	27	2	5041
1972/73 - 1989/90	2376	906	740	209	198	65	194	50	18	23	15	0	4794
1990/91 - 2007/08	1292	536	259	107	100	15	49	92	31	40	0	3	2524
Total	4666	2949	2313	651	577	377	352	158	144	125	42	5	12359

(Source: DPI database extraction, July 2008)

Hammerheads, whalers and angel sharks

Since 1950, hammerheads, whalers and angel sharks have collectively comprised approximately 80% of the catch, although grey nurse sharks were also a substantial component of the catch up to 1960 (Table 13; Figures 11 and 12; Appendix 8). Following the modifications to the netting protocols in 1972, there appears to have been a shift in species dominating the proportion of catch.

Prior to 1972, whalers and angel sharks were the dominant species, with more than 50% of the total catch of whalers between 1950 - 2008 taken before 1972 (Table 13). Since then, hammerheads have averaged approximately 50% (ranged from 34 - 67%) of the annual catch, although in the five years 2002/03 - 2007/08 they have averaged only 35% (range 20 - 42%) of the annual catch (Appendix 8). Whalers and angel sharks have also shown a similar, long-term decline since the 1970s, although whalers have recently been increasing since their lowest catch in the SMP of 14 sharks in 2001/02.

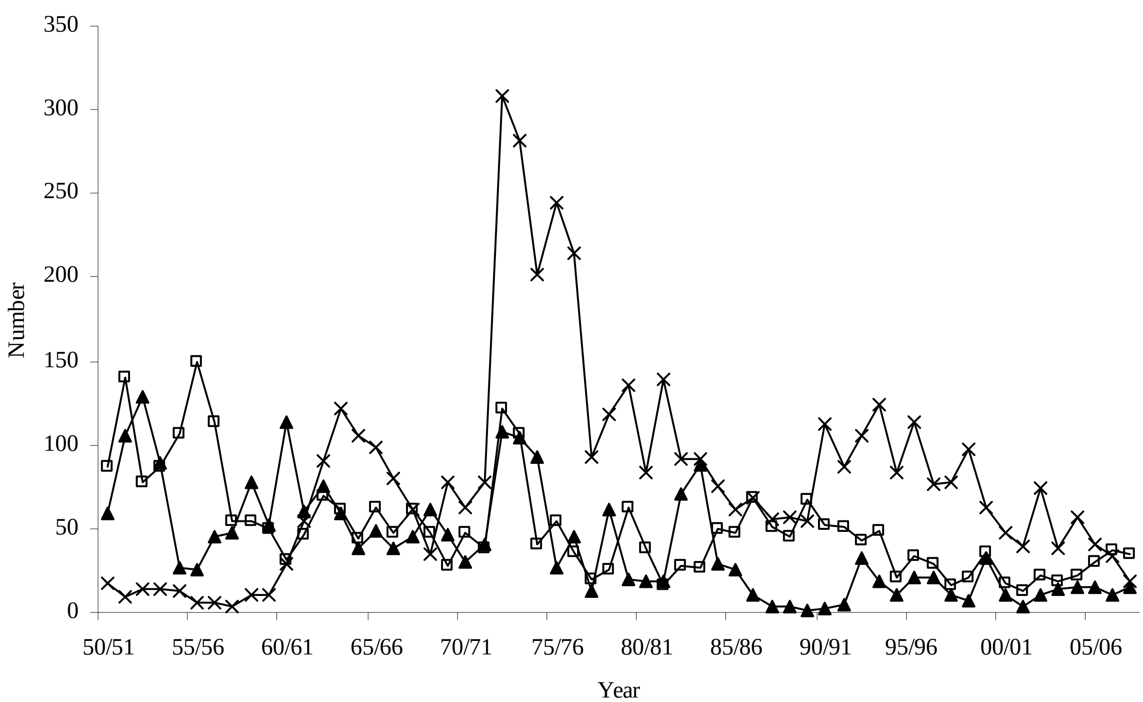

Figure 11 Annual catches of hammerheads (x), whalers (□) and angel sharks (▲) in the SMP from 1950/51 to 2007/08

(Source: DPI database extraction, July 2008)

Grey nurse, tiger, great white and Port Jackson sharks

Catches of grey nurse, tiger, great white and Port Jackson sharks have been highly variable since 1950 (Figure 12; Appendix 8). Like hammerheads, catches of grey nurse have shown a constant decline in the SMP, although their decline started in 1950 and in the Sydney region was probably even more pronounced in the years 1937 - 1950. Twenty-eight grey nurse were caught between 1980/81 - 2007/08, ranging from zero to three sharks per year and most of those were caught in the Sydney South region. Since 1972, almost 60% of captured grey nurse sharks were released alive, resulting in an average mortality (at time of release) of approximately 1.3 grey nurse sharks per annum due to the SMP.

Catches of tiger, great white and Port Jackson sharks over that time were generally less than 30 per species per year. Unlike hammerheads and grey nurse, catches of great whites increased between 2002/03 - 2007/08, averaging eight per year (range 5 - 11) compared to approximately five per year (range 0 - 14) in the preceding 25 years (Figure 12; Appendix 8). Assuming that catches from this limited time series in the SMP are broadly representative of the abundance of sharks in NSW waters, it would appear that unlike hammerheads and grey nurse sharks, great white sharks may be increasing in abundance.

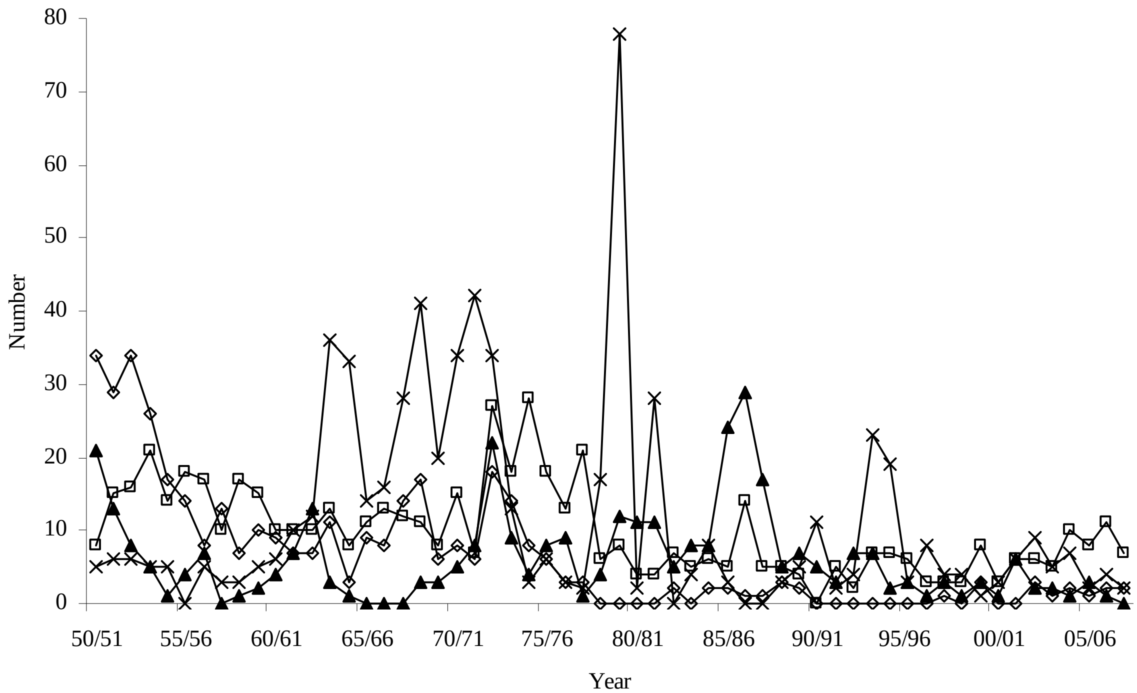

Figure 12 Annual catches of grey nurse (◊), tiger (▲), great white (□) and Port Jackson sharks (x) in the SMP from 1950/51 to 2007/08

(Source: DPI database extraction, July 2008)

Sevengill, mako and thresher sharks

Catches of sevengill, mako and thresher sharks have also been highly variable since 1950, and for the most part have been fewer than 10 sharks per species per year (Figure 13; Appendix 8). In particular, catches of sevengill sharks since 1990/91 have ranged between zero and 15 sharks, but the catch of sevengill sharks in that 18-year period (92) is nearly one and half times greater than the catch in the preceding 40 years (66). This could either indicate that abundances of sevengill sharks are increasing, and/or that identifications have improved over time. However given that sevengill sharks are fairly unique in having seven gills, one dorsal fin close to the caudal fin, and an elongated caudal fin, the latter seems unlikely.

Krogh (1994) reported that catches of sevengill sharks between October 1972 and December 1990 were confined mainly to a small number of beaches in the Illawarra region, and that lower numbers were caught from Curl Curl to Whale Beach in the Sydney North region. The data from 1991 - 2007/08 continues that trend: of the 92 sevengills caught, 59 were caught in the Illawarra and 14 in Sydney North.

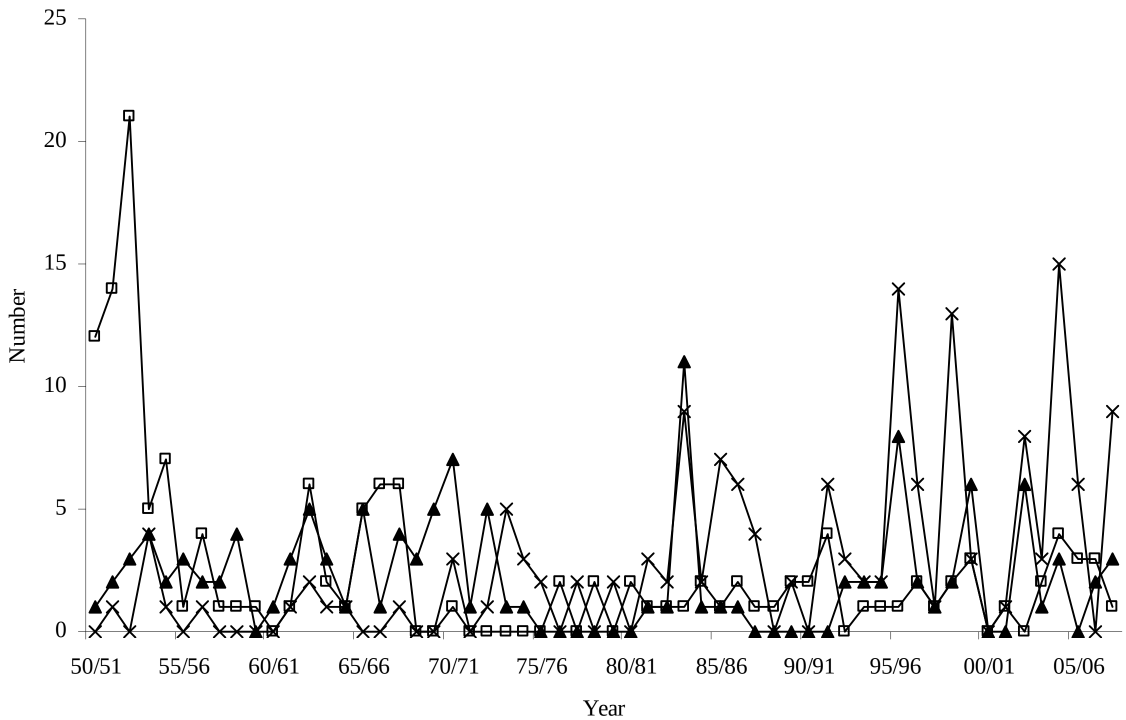

Figure 13 Annual catches of sevengill (x), mako (□) and thresher sharks (▲) in the SMP from 1950/51 to 2007/08

(Source: DPI database extraction, July 2008)

3.2.4 Seasonal catch trends

The following descriptions of seasonal trends are divided into two periods. The first is from 1950/51 to 1981/82 and represents the period when nets were set all year round (and based on descriptions in Reid and Krogh 1992). The second period is 1990/91 to 2007/08 and represents the period in which all four winter months of May - August were omitted from the SMP. June and July were dropped from the SMP in 1983, and then in 1989/90 the season was reduced to the existing eight months after omitting May and August.

Since 1990/91, there has been wide variation within and among the species by months of capture (Table 3). Hammerheads, whalers and angel sharks accounted for approximately 83% of the catch and were mostly caught in the summer months. Hammerheads dominated the catch, accounting for approximately 51% of sharks caught since 1990/91, a third (32%) of which were caught in January and February. Whalers were also commonly caught in January, but the highest catches were from February to April. A large proportion (40%) of angel sharks were also caught in January and February. These recent patterns for whalers and angel sharks were similar to those reported from 1950/51 - 81/82 (Reid and Krogh 1992). Hammerheads, however, were caught in relatively high proportions from December to April in the 1950/51 - 81/82 period, which is consistent with the timing of parturition for smooth hammerheads in NSW waters (Stevens 1984). Monthly catches since the 1980s were more evenly distributed, with a peak in January.

Port Jackson, great whites and sevengill sharks have accounted for approximately 12% of sharks caught since 1990/91. These three species were caught in greatest numbers during Spring, with September and October accounting for 85% and 57% of Port Jacksons and great whites caught, respectively, since 1990/91 (Table 3). Between 1950/51 - 81/82, great whites were most commonly caught in October and November, and almost all Port Jackson sharks were caught between July and October (Reid and Krogh 1992). More than half (54%) of all sevengill sharks caught since 1990/91 were caught in September, with October (20%) and November (21%) also comprising a significant proportion of the catch (Table 3). Sevengill sharks have not been caught in the SMP in the months of February, March, April or May (Table 3; Reid and Krogh 1992). Between 1950/51 - 81/82, October and November collectively accounted for approximately 65% of the annual catch of sevengill sharks.

Tiger, thresher, shortfin mako and grey nurse sharks have collectively accounted for approximately 5% of sharks caught since 1990/91 (Table 3). In that time, catches of those species have been relatively low and infrequent. Both recently and historically (1950/51 - 1981/82), December through to April has accounted for approximately 80% of the catch of tiger sharks, in contrast to thresher sharks that are more commonly caught from September to November, and like sevengill sharks, threshers have not been caught in March or April (Table 3). Shortfin makos have not been caught in March either, with approximately 71% of the catch taken from September to December (Table 3). As previously mentioned, grey nurse sharks were historically caught in much greater numbers, averaging 19 per year from 1950/51 to 1959/60 (Appendix 8), in contrast to the 15 caught in total in the SMP between 1990/91 and 2007/08 (Table 3; Appendix 8). Of those 15, six were caught in the month of September and five in December. Historically (1950/51 - 1981/82), the months from January to April and from September to December have accounted for approximately 45% and 35%, respectively, of the catches of grey nurse shark (Reid and Krogh 1992).

3.2.5 Sharks released alive from 1995/96 to 2007/08

Since 1995/96, records have been kept of the number of sharks released alive after entanglement in the mesh nets. Of the 1,617 sharks caught since 1995/96, approximately 10% (163) were released alive (Table 14). Port Jackson sharks (88%), angel sharks (36%) and grey nurse sharks (33%) have the highest rates of release, although there has been no research into the survival of the released animals. Port Jackson and angel sharks are bottom-dwelling, relatively slow-moving species, so it is likely that these sharks settle back on the bottom soon after entanglement and can remain alive longer than most other sharks. Grey nurse are also relatively sedentary and observers have reported less entanglement for this species, suggesting that they too are able to settle soon after capture. Makos are the fastest moving sharks, and tigers are reportedly extremely aggressive sharks. No makos or tigers have been released alive. Hammerheads and whalers are also relatively fast moving species, and these faster, pelagic and mid-water sharks reportedly roll themselves in the nets when they become entangled (D. Reid, DPI, pers. comm.). It is unlikely that those species survive very long after initial entanglement in the nets.

Table 14 Number and species of sharks released alive, 1995/96 to 2007/08

	Angel shark		Port Jackson		Whalers		Great white		Grey nurse		Hammerheads		Threshers		Sevengill		Total released	Total caught
Year	**R**	**C**	**R**	**C**	**R**	**C**	**R**	**C**	**R**	**C**	**R**	**C**	**R**	**C**	**R**	**C**	**R**	**C**
1995/96	11	21	3	3	3	34	2	6	0	0	0	114	2	8	0	14	21	204
1996/97	9	21	8	8	2	29	1	3	0	0	0	77	0	2	0	6	20	149
1997/98	5	10	1	4	2	16	1	3	1	1	0	78	0	1	0	1	10	119
1998/99	5	7	4	4	0	21	0	3	0	0	1	97	0	2	0	13	10	151
1999/00	4	32	1	1	1	36	2	8	2	3	0	63	0	6	0	3	10	158
2000/01	0	12	3	3	1	17	0	3	0	0	0	47	0	0	0	0	4	83
2001/02	0	3	6	6	1	14	1	6	0	0	3	40	0	0	0	1	11	76
2002/03	2	12	9	9	0	22	1	6	1	3	0	74	1	6	0	8	14	142
2003/04	5	14	3	5	0	20	0	5	0	1	0	39	0	1	0	3	8	93
2004/05	5	15	7	7	0	22	1	10	0	2	0	57	0	3	0	15	13	137
2005/06	9	15	2	2	2	31	2	8	0	1	0	40	0	0	0	6	15	109
2006/07	4	10	4	4	1	37	1	11	1	2	0	34	0	2	0	0	11	104
2007/08	8	15	0	2	5	35	0	7	0	2	0	18	1	3	2	9	16	92
Total	67	187	51	58	18	334	12	79	5	15	4	778	4	34	2	79	163	1617

Where R = released, and C = caught

(Source: DPI database extraction, July 2008)

3.2.6 Risk analysis for sharks

Methodology

The detailed methodology for this risk analysis is provided in Appendix 9 and is based on the Australian/New Zealand Standard 4360 and similar risk analysis frameworks applied to each of the NSW commercial fisheries. Briefly, the analysis involves the steps of risk assessment, risk management and risk communication. Risk assessment includes the steps of risk context, identification and characterisation and will be outlined below, and some recommendations will be made as to how to mitigate some of that risk from environmental perspective.

The risk context defines the risk to be analysed and sets some spatial and temporal boundaries. The risk for most species is the likelihood of the SMP resulting in overfishing, similar to any other harvesting activity. For the two threatened species, grey nurse shark and great white shark, risk is defined as the likelihood of the SMP increasing the threatened status such that grey nurse became a critically endangered population (under the FM Act), or that great whites changed from vulnerable to endangered. Consistent with previous fishery assessments the timeframe is 20 years, and the spatial extent includes the waters of the SMP from Wollongong to Newcastle.

The aim of risk identification is to list the sources of risk, which for the SMP is limited to the mesh nets and their timing and configuration of deployment.

Risk characterisation estimates the likelihood (or probability) that the various sources of risk will indirectly or directly cause overfishing for commercially harvested species, or that it will increase the status of a threatened species. Briefly, the degree of extent and magnitude of risk posed by the SMP is based on a suite of eight criteria, including:

- status (is the threat a recognised Key Threatening Process (KTP) for the species);
- extent (what range of the species is affected, are there refuges from the threat, does it occur in critical habitat);
- severity (does it affect individuals or the entire population);
- effect (does it prevent range extension, recruitment, individual survival);
- response (is the species resistant and/or resilient to the threat, how and to what degree is the species and/or its habitat recovery rate or potential affected by the threat);
- frequency (how regularly does it occur and what is the proportional effect relative to other threats);
- form (what is the nature of the disturbance – pulse [acute/short term], press [sustained/chronic], or catastrophic [major/widespread]); and
- historical context (period of significance: more than 100 years ago; 50 - 100 years; last 50 years).

A Delphic ranking assessment (0 = not applicable; 1 = low; 2 = moderate; 3 = high) will be applied to each of these criterion based on the available information, and then summed to determine the overall level of risk to each species by the existing activity of shark meshing. The use of eight criteria provides an overall risk scale of 0 (negligible risk) to 24 (highest risk), and on that basis risk levels can be categorised as:

- LOW RISK – score of 0 to 12;
- MODERATE RISK – score of 13 to 18; and
- HIGH RISK – score of 19 to 24.

Species scoring less than eight are actually at negligible risk, but for the purposes of this analysis have been grouped with the low risk species to account for the considerable uncertainty associated with distribution, abundance and population estimates for most threatened species.

Risk management that considers the longer term social, economic and environmental implications of changes to the existing program will be addressed through the draft management plan for the SMP.

The risk communication phase of the framework is addressed through the public exhibition of this document, the draft JMAs and draft management plan for the SMP, as well as through the annual performance reports and reviews by the FSC and SC.

Threatened species

Grey nurse sharks and great white sharks are the only threatened species of shark that have been recorded in the SMP. The threat to those species will be detailed below and summarised in Table 15.

Green sawfish (*Pristis zijsron*) is the only other shark listed as threatened (presumed extinct) under the FM Act that could potentially be affected by the SMP based on its historical distribution. The FSC (1999) report that it has been recorded in the tropical Indo-West Pacific from eastern Australia and Papua New Guinea through western India with a disjunct population off Mozambique and eastern South Africa. In Australia the species occurs mainly in the tropics from Broome to southern Queensland, with individuals reported from as far south as Sydney and a single record from Glenelg, South Australia. In NSW, specimens have been collected from Byron Bay in the north to the Parramatta River in the south, plus a Jervis Bay record without a museum voucher specimen. The last recorded museum specimen from NSW was in 1972. Prior to this, the species was regularly found in the shallow waters at the mouth of the Tweed, Clarence and Richmond Rivers and on outside beaches such as at Yamba. The last specimen from the Sydney region was taken in 1926, which was 11 years before meshing began in Sydney. Based on the very limited potential and zero actual interactions between the SMP and this species, it is considered to be at negligible risk and will not be subject to a more detailed analysis.

Table 15 Summary of the risk posed to grey nurse and great white sharks by the SMP

	Criteria								Score	Risk
Shark	Status	Extent	Severity	Effect	Response	Frequency	Form	History		
Grey nurse	3	1	3	2	3	1	2	2	17	Moderate
Great white	3	1	1	1	2	1	2	2	13	Moderate

Grey nurse shark (*Carcharias taurus*)

Status: The SMP is a KTP for this critically endangered species (FM Act); high risk = 3

Extent: The SMP currently affects only a small proportion (less than 1%) of its range, and there are 10 critical habitats, sanctuary zones and other aggregation sites in NSW waters where there is no meshing; low risk = 1.

Severity: The size range of grey nurse sharks has not changed much since 1950, but the relative proportion of larger sharks, the average size, the number of sharks and number of apparent cohorts has declined significantly over the period (Figure 14). This is due to a combination of factors including but not limited to spearfishing and gamefishing during the 1960s and 1970s, catches in the SMP following its inception, and catches by recreational and commercial fishers. Even though the SMP now catches a relatively low number of grey nurse (1 or 2 a year from 1998/99 - 2007/08 - Table 16; Appendix 8), 12 of the 14 caught in those 10 years were female and with the population thought to be between 500 - 1500 individuals, every fatality affects the long-term viability of the population. The SMP's impact, whilst relatively low (~9%) is contributing to a significant cumulative impact on grey nurse; high risk = 3.

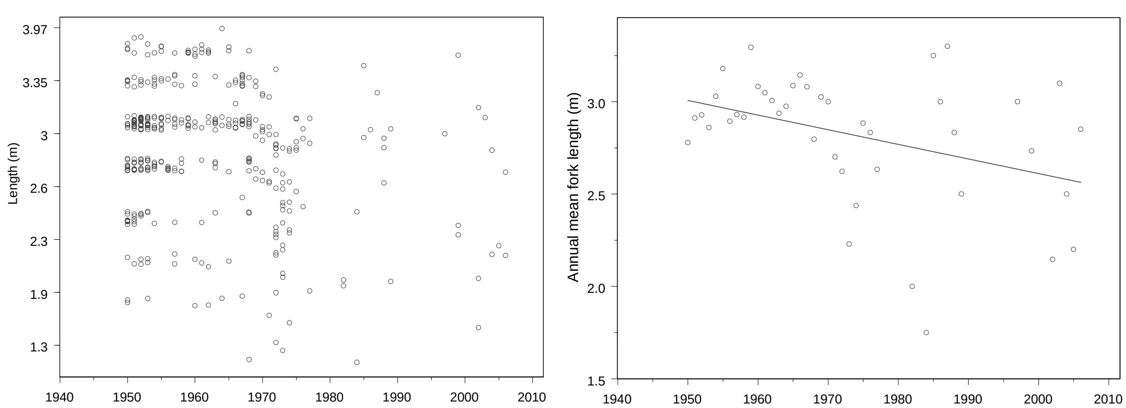

Figure 14 Fork lengths and average annual fork lengths for grey nurse sharks caught in the SMP, 1950/51 to 2006/07

Effect: As the SMP is located almost centrally within the east coast distribution of grey nurse shark, it is unlikely to affect its overall range in terms of north-south extent, however it and other sources of fishing mortality may have contributed to its apparent local extirpation from various sites, particularly in the Newcastle region (Table 16). So whilst not necessarily directly affecting or operating in the fringes of its range, by removing part of the breeding population it restricts the ability of the population to repopulate historical aggregation sites. Moderate = 2.

Response: Catches may be relatively low, however the SMP predominantly catches female sharks, severely limiting the ability to recover and the rate of that recovery - this is likely to pose a significant risk to a critically endangered species. High = 3.

Frequency: In the 10 years from 1998/99 - 2007/08, the SMP has caught 14 grey nurse, 4 of which were released alive, but for the purposes of this assessment, in the absence of data about their survival it will be assumed that they died. That equates to a worst case average of 1.4 fatalities per year in the SMP in those 10 years. By comparison, in a four and a half year period between 2002 and 2007 in NSW there were reportedly 45 grey nurse shark fatalities from all other reported sources of fishing mortality, an average of 10 per year. The NSW recreational fishery (including spearfishing) was responsible for 17 female and five male fatalities (~5/year), and the commercial Ocean Trap and Line Fishery was responsible for 18 female and one male fatality (~4/year) in that time. The other four deaths were in commercial fisheries other than the Ocean Trap and Line Fishery (AAT 2007). Whilst these figures are bound to be understated, it shows that catches in recent times in the SMP are relatively low and infrequent. Low = 1.

Form: The available catch data for grey nurse suggests that in its early days, particularly in the Newcastle region, the SMP may have been contributing to a catastrophic disturbance for grey nurse shark from which they are still struggling to recover. In its current format of eight months per year, the SMP represents a press disturbance. Moderate = 2.

Historical context: Thirty-seven of the 51 beaches of the SMP have recorded grey nurse sharks since 1950/51, and over that period there has been a significant decline from 192 in the first decade down to 11 in the eight years from 2000/01 - 2007/08 (Table 16; Appendix 8). Approximately 93% of grey nurse caught in the program were caught in the first 30 years of the SMP, and 71% of those were caught in the Newcastle region. Between 1980/81 - 2007/08, the Newcastle region has accounted for only 7% of grey nurse shark entanglements, with two of the 10 beaches in the region each recording one grey nurse over that period. The SMP continues to catch small numbers of grey nurse shark, however the data suggests that its impact was most significant in its first 10 - 20 years. Moderate = 2.

RISK TO GREY NURSE SHARKS = MODERATE (score of 17)

Table 16 Grey nurse shark entanglements in the SMP by beach, region and decade, 1950/51 to 2007/08

BEACH	50/51 to 59/60	60/61 to 69/70	70/71 to 79/80	first 30 years	80/81 to 89/90	90/91 to 99/00	00/01 to 07/08	last 28 years	Total
Nobbys	33	12	10	**55**	0	0	0	**0**	**55**
Newcastle	25	13	4	**42**	1	0	0	**1**	**43**
Bar	22	14	7	**43**	0	0	0	**0**	**43**
Redhead	10	12	2	**24**	1	0	0	**1**	**25**
Caves	7	8	7	**22**	0	0	0	**0**	**22**
Merewether	12	5	4	**21**	0	0	0	**0**	**21**
Catherine Hill Bay	8	4	5	**17**	0	0	0	**0**	**17**
Austinmer	11	3	0	**14**	0	0	0	**0**	**14**
Stockton	7	7	0	**14**	0	0	0	**0**	**14**
Thirroul	12	0	0	**12**	0	0	0	**0**	**12**
Narrabeen	5	3	2	**10**	0	1	0	**1**	**11**
Cronulla	6	1	2	**9**	0	0	0	**0**	**9**
Whale	4	1	1	**6**	0	1	0	**1**	**7**
Avalon	2	0	2	**4**	2	0	0	**2**	**6**
Palm	2	2	2	**6**	0	0	0	**0**	**6**
Swansea / Blacksmiths	2	2	2	**6**	0	0	0	**0**	**6**

Table 16 cont.

BEACH	50/51 to 59/60	60/61 to 69/70	70/71 to 79/80	first 30 years	80/81 to 89/90	90/91 to 99/00	00/01 to 07/08	last 28 years	Total
Bondi	2	0	0	**2**	0	0	4	**4**	**6**
Dixon Park	na	na	5	**5**	0	0	0	**0**	**5**
Garie	na	na	4	**4**	0	1	0	**1**	**5**
Manly	2	2	0	**4**	1	0	0	**1**	**5**
Newport	1	1	0	**2**	3	0	0	**3**	**5**
Wattamolla	na	na	2	**2**	1	0	2	**3**	**5**
Dee Why	3	0	0	**3**	1	0	0	**1**	**4**
Mona Vale	4	0	0	**4**	0	0	0	**0**	**4**
North Wollongong	4	0	0	**4**	0	0	0	**0**	**4**
Bilgola	1	0	2	**3**	0	0	0	**0**	**3**
Coogee	1	0	0	**1**	0	1	1	**2**	**3**
South Wollongong	2	1	0	**3**	0	0	0	**0**	**3**
Warriewood	0	0	1	**1**	1	0	1	**2**	**3**
Bronte	1	0	0	**1**	0	0	1	**1**	**2**
Maroubra	2	0	0	**2**	0	0	0	**0**	**2**
North Cronulla	na	na	1	**1**	0	0	1	**1**	**2**
Harbord	1	0	0	**1**	0	0	0	**0**	**1**
Killcare	na	na	na	**na**	0	0	1	**1**	**1**
MacMasters	na	na	na	**na**	1	0	0	**1**	**1**
North Narrabeen	na	na	1	**1**	0	0	0	**0**	**1**
Soldiers	na	na	na	**na**	1	0	0	**1**	**1**
TOTAL	192	91	66	**349**	13	4	11	**28**	**377**

REGION	50/51 to 59/60	60/61 to 69/70	70/71 to 79/80	first 30 years	80/81 to 89/90	90/91 to 99/00	00/01 to 07/08	last 28 years	Total
NEWCASTLE	126	77	46	**249**	2	0	0	**2**	**251**
CENTRAL COAST	na	na	na	**na**	2	0	1	**3**	**3**
SYDNEY NORTH	25	9	11	**45**	8	2	1	**11**	**56**
SYDNEY SOUTH	12	1	9	**22**	1	2	9	**12**	**34**
ILLAWARRA	29	4	0	**33**	0	0	0	**0**	**33**
TOTAL	192	91	66	**349**	13	4	11	**28**	**377**

na = not applicable as the beach or region was not meshed in those years.

Great white sharks (*Carcharodon carcharias*)

Status: the SMP is a KTP for this vulnerable species (FM Act); high risk = 3

Extent: The SMP currently affects a very small proportion of its range. It is not near the suspected breeding grounds for the species (thought to be in Great Australian Bight - Bruce 2006), although Stockton Beach and to a lesser extent Wattamolla, Redhead and Catherine Hill Bay beaches appear to be areas frequented by juvenile great white sharks during their northward, autumn-winter movements not long after birth. Of the 19 sharks caught at Stockton since 1990/91 (Table 17), 15 were under 2 m in length, the smallest of which was 1.3 m long, which is in the bandwidth of estimated birth sizes for great whites of 1.2 - 1.5 m. The smallest great white caught since 1990/91 was 1.1 m at Catherine Hill Bay.

Whilst undoubtedly affecting some juveniles, the widespread occurrence of similar sized/aged sharks in other waters of NSW and Australia where the SMP does not operate suggests that the SMP represents a limited proportion of those areas. The limited spatial extent of the SMP compared to the range and breadth of habitats used by both adult and juvenile great whites suggests that any potential impact is limited in its extent. Low = 1.

Severity: The SMP appears to predominantly affect a limited number of juvenile great whites, and since 1990/91 the sex ratio of the catch has been effectively 1:1 (47 females and 50 males - 3 unknown), and not biased towards females which would have a greater effect on the potential population. Large, mature females have been identified as likely to be the most important portion of the population for the survival of great white sharks, and few if any are caught in the SMP. The annual mean lengths of great white sharks in the SMP has declined from 2.5 m to 1.75 m between 1950 - 2007 (Figure 15). Given that the mesh size of the nets has not changed in that time, it indicates that all sources of fishing mortality on this species have contributed to both a reduction in the size of the population and of its individuals.

The CPUE data (Figure 15) suggest that there has been a slight increase in the abundance of juvenile great whites since 1990, although for various reasons CPUE is not necessarily a reliable indicator of population trends. Further supporting the notion of increased abundance is that the reported catch of great whites in the four years 2004/05 - 2007/08 (36) is similar to that caught in the preceding eight years (37 - Appendix 8), although such a short time series should be used cautiously. Overall, it would appear that the SMP is currently affecting individuals and not the population. Low = 1.

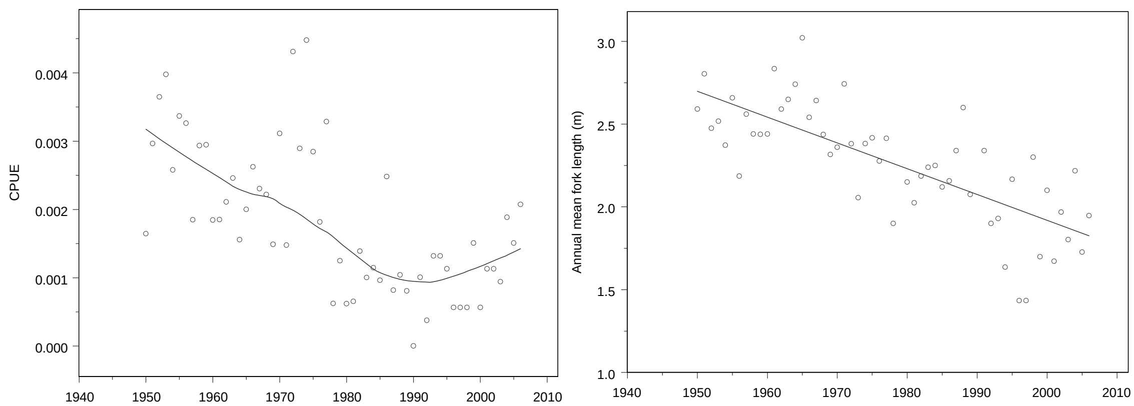

Figure 15 CPUE and average annual fork lengths for great white sharks caught in the SMP, 1950/51 to 2006/07

Effect: Even though the SMP is within the east coast movement pathways of juvenile great whites, it occupies a very small component of the range of great whites and neither prevents its extension nor the breeding part of the population, and the loss of a relatively small number of juveniles each year would have a limited effect on the population. Low = 1.

Response: Great whites generally have very low resilience to fishing pressure, however given the limited spatial and temporal extent of the SMP, and that it generally does not affect the breeding component of the population, the SMP represents limited fishing pressure. Moderate = 2.

Frequency: Between 1990/91 - 2007/08 there was an average of approximately six great white sharks caught in the SMP per year. This compares to an estimated annual average of just under 200 captures in other fisheries in Australian waters. Fisheries that account for more than half of those captures include an estimated 72 in the South East Shark and Scalefish Fishery, 30 in the South Australian Marine Scale-fish Fishery, and 28 in the Western Australian Shark Fishery.

Those levels of catch, which are 4.6 - 12 times greater than that of the SMP, are not considered a major threat to the survival of the species, nor did the evidence warrant upgrading its status from vulnerable to endangered (Malcolm et al. 2001 and DEH 2003). Although catches occur annually in the SMP, relatively low numbers of animals are affected. Low = 1.

Form: The current spatial and temporal nature of the SMP relative to the range and recent relatively consistent catches suggests that the SMP represents a press disturbance. Moderate = 2.

Historical context: Since 1950/51, great whites were caught at 46 of the 51 beaches of the SMP. From 1950 to 2008, approximately 64% of great white sharks entangled in the nets were from the Newcastle region, and 78% of those were caught in the first 30 years of the SMP (Table 17; Appendix 8). Significantly reduced catches were recorded at all Newcastle beaches except Stockton Beach, which maintained fairly stable catches over the 58 years. The total number of white sharks caught at Newcastle,

Bar, Nobbys and Merewether beaches between 1950/51 - 1979/80 was 167 great whites sharks compared to only 20 sharks in the 28 years from 1980/81 - 2007/08.

Whilst historical catches were numerically greater than in recent times, there are no reliable estimates of the proportion of population that those catches represent, and as a precaution recent catches are considered to pose a relatively moderate threat. Moderate = 2.

RISK TO GREAT WHITE SHARKS = MODERATE (score of 13)

Table 17 Great white shark entanglements in the SMP by beach, region and decade, 1950/51 to 2007/08

BEACH	50/51 to 59/60	60/61 to 69/70	70/71 to 79/80	first 30 years	80/81 to 89/90	90/91 to 99/00	00/01 to 07/08	last 28 years	TOTAL
Stockton	8	16	12	**36**	8	10	9	**27**	**63**
Newcastle	15	20	13	**48**	1	3	3	**7**	**55**
Bar	12	22	15	**49**	2	0	2	**4**	**53**
Merewether	16	14	8	**38**	2	0	0	**2**	**40**
Nobbys	13	11	8	**32**	2	2	3	**7**	**39**
Redhead	5	7	12	**24**	6	3	1	**10**	**34**
Catherine Hill Bay	9	7	5	**21**	4	2	4	**10**	**31**
Wattamolla	0	0	15	**15**	4	1	8	**13**	**28**
Narrabeen	17	1	1	**19**	1	0	0	**1**	**20**
Caves	5	2	7	**14**	2	1	2	**5**	**19**
Avalon	6	0	3	**9**	5	0	1	**6**	**15**
Swansea / Blacksmiths	4	4	2	**10**	1	3	0	**4**	**14**
Garie	na	na	8	**8**	1	2	3	**6**	**14**
Dixon Park	na	na	10	**10**	2	0	1	**3**	**13**
Palm	4	0	1	**5**	0	2	1	**3**	**8**
Mona Vale	6	0	0	**6**	1	0	0	**1**	**7**
Whale	4	0	2	**6**	1	0	0	**1**	**7**
Cronulla	4	0	2	**6**	1	0	0	**1**	**7**
Bronte	4	1	0	**5**	0	2	0	**2**	**7**
Bondi	3	0	2	**5**	1	0	1	**2**	**7**
Bilgola	1	0	3	**4**	3	0	0	**3**	**7**
Shelly	na	na	na	**na**	2	3	2	**7**	**7**
Wanda	na	na	2	**2**	2	0	2	**4**	**6**
Maroubra	1	0	4	**5**	0	0	0	**0**	**5**
Dee Why	1	1	1	**3**	0	1	1	**2**	**5**
Warriewood	2	0	1	**3**	0	1	1	**2**	**5**
Manly	3	0	1	**4**	0	0	0	**0**	**4**
Queenscliff	3	0	0	**3**	0	0	1	**1**	**4**
Newport	1	0	1	**2**	2	0	0	**2**	**4**
The Entrance	na	na	na	**na**	1	2	1	**4**	**4**
Avoca	na	na	na	**na**	0	2	2	**4**	**4**
North Narrabeen	na	na	3	**3**	0	0	0	**0**	**3**
South Wollongong	0	0	2	**2**	0	0	1	**1**	**3**
Lakes	na	na	na	**na**	0	0	3	**3**	**3**
Coledale	na	na	0	**0**	1	1	0	**2**	**2**
Coogee	1	0	1	**2**	0	0	0	**0**	**2**
Curl Curl	2	0	0	**2**	0	0	0	**0**	**2**
Elouera	na	na	2	**2**	0	0	0	**0**	**2**
North Cronulla	na	na	1	**1**	0	0	1	**1**	**2**

Table 17 cont.

BEACH	50/51 to 59/60	60/61 to 69/70	70/71 to 79/80	first 30 years	80/81 to 89/90	90/91 to 99/00	00/01 to 07/08	last 28 years	TOTAL
Soldiers	na	na	na	**na**	1	0	1	**2**	**2**
Umina	na	na	na	**na**	0	2	0	**2**	**2**
North Wollongong	1	0	0	**1**	0	0	0	**0**	**1**
Austinmer	0	0	0	**0**	1	0	0	**1**	**1**
Killcare	na	na	na	**na**	0	1	0	**1**	**1**
MacMasters	na	na	na	**na**	0	0	1	**1**	**1**
Thirroul	0	0	0	**0**	1	0	0	**1**	**1**
Beach unspecified			13	**13**					**13**
TOTAL	151	106	161	**418**	59	44	56	**159**	**577**

REGION	50/51 to 59/60	60/61 to 69/70	70/71 to 79/80	first 30 years	80/81 to 89/90	90/91 to 99/00	00/01 to 07/08	last 28 years	TOTAL
NEWCASTLE	87	103	92	**282**	30	24	25	**79**	**361**
CENTRAL COAST	na	na	na	**na**	4	10	10	**24**	**24**
SYDNEY NORTH	50	2	17	**69**	13	4	5	**22**	**91**
SYDNEY SOUTH	13	1	37	**51**	9	5	15	**29**	**80**
ILLAWARRA	1	0	2	**3**	3	1	1	**5**	**8**
Unspecified	0	0	13	**13**	0	0	0	**0**	**13**
TOTAL	151	106	161	**418**	59	44	56	**159**	**577**

na = not applicable as the beach or region was not meshed in those years.

Other sharks

Other than the threatened species, most of the other sharks caught in the SMP are commercially harvested, and some are also taken by recreational fishers. To put catches in the SMP into some perspective, Table 18 summarises the reported commercial catch in NSW from 2001/02 to 2007/08; and Table 19 summarises the reported recreational gamefish catch at selected tournaments from 1993/94 - 2004/05.

Traditionally, sharks were commercially harvested as byproduct in several NSW commercial fisheries. In recent years, however there has been a significant increase in targeted fishing for sharks in certain areas, mostly on the north and mid-north coasts targeting sandbar whalers. Prior to the recent increases, landings of most shark species by NSW commercial fishers had remained fairly consistent (Table 18), although 'mixed sharks' (which comprises various species, including most of those in Table 18) and wobbegongs were assessed as at high risk due to the operation of the Ocean Trap and Line Fishery and the Ocean Trawl Fishery (DPI 2006b and 2004). Most of the risk was associated with poor species identifications, lack of stock assessments, declining catches and CPUE in some cases, and high fishing pressure.

Table 18 Reported commercial landings (tonnes) for some shark groups, 2001/02 to 2007/08

SHARK GROUPING	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08
Hammerheads	7.73	4.18	2.83	2.16	2.61	4.11	2.41
Whalers	184.82	172.35	134.75	148.14	226.82	429.23	224.3
Angel sharks	44.45	32.9	45.32	40.11	50.17	53.39	28.57
Port Jacksons	0.08	0.89	0.48	0.84	0.01	0.39	
Tigers	3.44	0.8	1.98	1.44	6.55	4.92	2.03
Makos	4.66	2.23	1.52	2.28	2.95	6.42	1.73
Wobbegongs	99.05	91.83	87.44	71.33	73.85	53.27	41.1
Total	**341.68**	**305.18**	**274.32**	**266.30**	**362.96**	**551.73**	**300.14**

Values represent estimated whole weights in tonnes

(Source: DPI Comm. Catch data extract Sept 2008)

Whilst even less species-specific than the data from the SMP, there are estimates available of the recreational catch of 'sharks/rays' in the National Recreational and Indigenous Fishing Survey (NRIFS - Henry and Lyle 2003). Some sharks are targeted by the game fishing sector, and there is likely to be some targeted and incidental capture of sharks by other recreational fishers. Henry and Lyle (2003) estimated that the annual number of sharks/rays recreationally harvested in NSW in 2000/01 to be 30,093 fish (+/- 6,617), and that up to four times as many could have been caught and released with unknown levels of mortality, indicating that the fishing mortality by the recreational sector could be higher than estimated. By comparison, the catch of sharks and rays in the SMP in the 2000/01 survey year was 94 fish, and the total catch of sharks and rays between 1990/91 - 2007/08 was 3,793 fish.

Estimates for species groups based on the NRIFS and on game fishing tournament data suggest that the annual landings of whalers from the recreational fishery are between 40 t and 160 t; catches of hammerheads up to 50 t; and shortfin mako between 30 t and 140 t. More specifically, data from the NSW Gamefish Tournament Monitoring Program (GTMP) alone indicates that the annual catch from monitored tournaments between 1993/94 - 2004/05 was significantly greater than in the SMP for tigers and makos, often similar for whalers, and usually less for hammerheads, although the majority of sharks in tournaments are tagged and released (Table 19). This represents only a fraction of the recreational sector and tournaments for that matter, but does provide some indication of the relative catches in the various sectors.

On the whole, it would appear that the potential individual and cumulative impacts of commercial and recreational fishing on shark stocks of NSW waters is significantly greater than that of the SMP. Such relatively low numbers and limited spatial extent (analogous to fishing pressure and susceptibility commonly used in risk assessments of commercial fisheries) makes a more detailed risk analysis of little use for these other sharks.

Table 19 Reported catches in the NSW Gamefish Tournament Monitoring Program and in the SMP for some shark groups, 1993/94 to 2004/05

Year	Program	Shark groups				Totals
		Hammerheads	Whalers	Tigers	Makos	
1993/94	GTMP	59 (49)	48	67 (13)	53 (33)	227 (95)
	SMP	124	49	7	1	181
1994/95	GTMP	18 (14)	14	55 (8)	43 (23)	130 (45)
	SMP	83	21	2	1	107
1995/96	GTMP	29 (26)	42	68 (12)	99 (69)	238 (107)
	SMP	114	34 (3)	3	1	152 (3)
1996/97	GTMP	39 (35)	46 (37)	54 (11)	11 (8)	150 (91)
	SMP	77	29 (2)	1	2	109 (2)
1997/98	GTMP	23 (23)	75 (67)	30 (5)	29 (23)	157 (118)
	SMP	78	16 (2)	3	1	98 (2)
1998/99	GTMP	36 (33)	31 (21)	76 (23)	308 (265)	451 (342)
	SMP	97 (1)	21	1	2	121 (1)
1999/00	GTMP	65 (60)	54 (39)	55 (25)	148 (110)	322 (234)
	SMP	63	36 (1)	3	3	105 (1)
2000/01	GTMP	61 (54)	20	39 (15)	119 (68)	239 (137)
	SMP	47	17 (1)	1	0	65 (1)
2001/02	GTMP	42 (30)	13	50 (21)	114 (73)	219 (124)
	SMP	39 (3)	13 (1)	6	1	59 (4)
2002/03	GTMP	37 (32)	35	29 (21)	62 (39)	163 (92)
	SMP	74	22	2	0	98
2003/04	GTMP	21 (20)	15	32 (5)	55 (34)	123 (59)
	SMP	38	19	2	2	61
2004/05	GTMP	15 (13)	28	34 (6)	116 (81)	193 (100)
	SMP	57	22	1	4	84

Numbers in brackets indicate the number of sharks that were tagged and released from the GTMP and released alive from the SMP.

(Source: Murphy et al. 2002 and Park 2007; Appendix 8)

3.3 RAYS

3.3.1 Species

It has not been possible to identify most rays to species, however members of the ray group which are likely to have been caught in the SMP comprise members of the following families: Rajidae - skates; Rhinobatidae - guitarfishes; Dasyatididae - stingrays; Urolophidae - stingarees; Mylibatididae - eagle rays; Rhinopteridae - cownose rays; Mobulidae - manta rays; Rhinidae - wedgefishes /shark rays.

3.3.2 Catch trends

There is a strong seasonal component to entanglements of rays, with the majority of rays caught between 1990/91 and 2007/08 caught between November and April (Table 3), which is consistent with the catch profile from 1950 - 1993 (Krogh and Reid 1996). This probably reflects the inshore movements of more than one species (Krogh and Reid 1996), and is probably related to reproduction as has been reported in the northern hemisphere (Babel 1967; Vaudo and Lowe 2006).

Between 1950 and 1993, approximately 75% of the rays recorded were caught in the Newcastle region (Krogh and Reid 1996), however since 1995/96 Sydney South has caught 50% more rays than the Newcastle region and a large proportion (69%) of Newcastle's catch in that time occurred in one year, 1998/99 (Table 20). Of the 157 rays caught that year in Newcastle, 109 were caught on Stockton Beach and 86 of those were caught in March 1999, supporting the theory that there are aggregations on central NSW waters at that time of year. Since 1990, Stockton Beach has accounted for approximately 18% (227) of all rays caught, and other beaches with relatively high catches of rays include Wattamolla and Bondi (72 each) in Sydney South, and Lakes (49) and Terrigal (46) on the Central Coast.

Since 1995/96, catches have been highly variable in the Sydney North region, and appear to be declining in the Central Coast and Newcastle regions. There have only been three rays recorded in that time in the Illawarra region, and only 16 since 1990/91. This is unlikely to be a function of under-reporting as observers have operated since the 1995/96 season.

3.3.3 Rays released alive from 1995/96 to 2007/08

Since 1995/96, records were kept of the number of rays released alive after entanglement in the mesh nets. Of the 797 rays caught since 1995/96, approximately 61% were released alive, and almost 50% of those came from the Sydney South region (Table 20).

Table 20 Number of rays released alive by region, 1995/96 to 2007/08

Year		Central Coast	Illawarra	Newcastle	Sydney North	Sydney South	Total
1995/1996	Released	32	2	17	5	11	67
	Caught	35	2	24	5	16	82
1996/1997	Released	7				24	31
	Caught	12				35	47
1997/1998	Released	7				24	31
	Caught	10				29	39
1998/1999	Released	21		59	16	22	118
	Caught	39		157	25	31	252
1999/2000	Released			1	2	5	8
	Caught			2	7	7	16
2000/2001	Released				8	9	17
	Caught				11	14	25
2001/2002	Released	3		25	4	8	40
	Caught	4		30	5	29	68
2002/2003	Released	1		2		14	17
	Caught	3		4		19	26

Table 20 cont.

Year		Central Coast	Illawarra	Newcastle	Sydney North	Sydney South	Total
2003/2004	Released		1			22	23
	Caught		1	2	1	23	27
2004/2005	Released			3		42	45
	Caught			3	2	53	58
2005/2006	Released			3	6	24	33
	Caught			3	22	35	60
2006/2007	Released				9	20	29
	Caught			2	24	25	51
2007/2008	Released				12	16	28
	Caught				17	29	46
Total	**Released**	**71**	**3**	**110**	**62**	**241**	**487**
	Caught	**103**	**3**	**227**	**119**	**345**	**797**

(Source: DPI database extraction, July 2008)

3.3.4 Risk analysis for rays

Most of the rays likely to be caught in the SMP are commercially harvested, and a limited number are also taken by recreational fishers, primarily shovelnose rays. Table 21 summarises the reported commercial catch in NSW from 2001/02 to 2007/08 for three groups of rays. Annually, there are greater tonnages taken in the commercial fisheries than there are individuals taken in the SMP (Tables 20 and 21).

The NRIFS grouped sharks and rays, complicating estimates of the recreational catch. The NRIFS reported ~30,000 (+/- 6,600) sharks/rays, and assuming that rays only accounted for 0.5% of the catch, that would represent approximately 150 rays, or two and a half times the annual average number of rays caught in the SMP in the 10 years from 1997/98 - 2007/08.

Table 21 Reported commercial landings (tonnes) for some ray groups, 2001/02 to 2007/08

Ray grouping	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08
Fiddler/banjo rays	113.18	120.59	122.26	115.18	86.83	100.39	80.32
Shovelnose rays	35.93	36.25	18.05	14.30	34.03	28.22	21.16
Stingray	39.81	24.57	29.77	24.25	38.60	28.41	25.58

Values represent estimated whole weights in tonnes

(Source: DPI CommCatch data extraction 030908)

The SMP represents relatively negligible fishing pressure and susceptibility to rays. The potential individual and cumulative impacts of commercial and recreational fishing on ray populations of NSW waters is significantly greater than that of the SMP, and on that basis a more detailed risk analysis is considered unnecessary.

3.4 FINFISH

3.4.1 Species

While the large mesh-size of the nets is not expected to catch significant numbers of finfish, the reporting of the number of teleost fishes in the NSW shark meshing program is known to be very patchy, and probably underestimates the true catch. Krogh and Reid (1996) reported that between 1950 to December 1993, there were 282 mulloway (*Argyrosomus hololepidotus*), 22 kingfish (*Seriola lalandi*), and 53 unidentified tunas. Other species occasionally caught were eastern blue groper (*Achoerodus viridis*), frigate mackerel (*Auxis thazard*), snapper (*Pagrus auratus*), mackerel tuna (*Euthynnus affinis*), black marlin (*Makaira indica*), cobia (*Rachycentron canadus*), bonito (*Sarda australis*), and horse mackerel (*Trachurus declivis*) (Krogh and Reid 1996).

Forty-three finfish have been reported since 1994 and was similarly dominated by mulloway (33%). Other reported species include striped tuna, frigate mackerel, longtail tuna, black marlin, blue groper, kingfish, snapper and bonito. More than half of the reported finfish were caught in the Sydney South region, including the three finfish released alive since 1994.

3.4.2 Risk analysis for finfish

As the SMP reportedly catches an almost negligible number of finfish, it follows that there is negligible risk to any of the reported species.

Further, threatened species such as black cod (vulnerable) and southern bluefin tuna have never been recorded in the nets, although a small number of unidentified tunas have been recorded since 1950. Assuming worst case that they were all southern bluefin tunas, that represents an average of less than one per year.

Southern bluefin tuna (*Thunnus maccoyii*) are highly migratory pelagic fish occurring in oceanic waters normally on the seaward side of the continental shelf. In Australian waters they range from northern NSW around southern Australia to north-western Australia. They tend to form large surface schools in offshore waters off southern Australia at certain times of the year, and their only spawning ground is between the Western Australian coast and Java. The species is historically considered to be rare within NSW State waters boundary of three nautical miles (FSC 2003), making it highly unlikely that the 53 unidentified tunas were southern bluefin. Southern bluefin tuna are commercially harvested by Commonwealth fisheries throughout its range and are also taken by recreational anglers in offshore waters of NSW. Given that it has not been caught in the SMP and that there is limited potential for interactions with southern bluefin tuna, then at worst the SMP represents negligible fishing pressure and potential proportion of the catch.

For both reported species of fish and those that could potentially be affected by the SMP, the level of risk posed by the SMP is considered to be negligible and it is not considered necessary to conduct a more detailed risk analysis.

3.5 MARINE MAMMALS, REPTILES AND BIRDS

3.5.1 Species

There are 15 marine mammals, three reptiles and one bird species that commonly occur in the pelagic inshore marine waters of central NSW that could potentially or have become entangled in nets of the SMP (Table 22). Other species of seabirds, such as petrels, albatross, gannets, gulls, terns, sea eagles etc. are unlikely to be attracted to and/or become entangled in the nets as captured animals (primarily sharks and a very limited number of large fish) are too large for those birds to feed on, and are captured at a depth (4 - 10 m) that is generally beyond the preferred diving range of most seabirds. Coupled with their limited potential and as yet unreported interaction with the SMP, the majority of seabirds and other birds that infrequently occur on or near the coast are considered at negligible risk from the SMP and will not be considered any further. Broad descriptions of the species listed in Table 22 will be provided below (see Appendix 10 for detailed descriptions), as well as an indication of their actual and potential interactions with the SMP to inform the risk analysis for those species/groups.

The SMP could contribute to the range contraction and decline of the marine mammals, reptiles and birds listed in Table 22 through their capture or entanglement in the nets. These animals tend to die from this interaction unless they are released by humans shortly after capture. The animals most likely to be released alive after capture are sea turtles, which are known to survive for up to 90 minutes after capture in trawl nets (Henwood and Stuntz 1987, Poiner et al. 1990), and large whales which may swim away with entangled gear. Further, the chance of turtle recovery after capture is increased if recovery procedures are used on comatose individuals (Robins et al. 2002).

Table 22 The conservation status of marine mammal, reptile and bird species that have been or could potentially be affected by the SMP

Species	Conservation status in NSW[1]	Recorded interactions
Mammals – Odontocete cetaceans		
Sperm whale (*Physeter macrocephalus*)	Vulnerable	No
Risso's dolphin (*Grampus griseus*)	Protected	Yes
Bottlenose dolphin – inshore (*Tursiops aduncus*)	Protected	Yes
Pantropical spotted dolphin (*Stenella attenuata*)	Protected	No
Common dolphin (*Delphinus delphis*)	Protected	Yes
False killer whale (*Pseudorca crassidens*)	Protected	Yes
Killer whale (*Orcinus orca*)	Protected	Yes
Shortfinned pilot whale (*Globicephala macrorhyncus*)	Protected	No
Mammals – Baleen whales		
Southern right whale (*Eubalaena australis*)	Vulnerable	No
Minke whale (*Balaenoptera acutorostrata*)	Protected	Yes
Blue whale (*Balaenoptera musculus*)	Endangered	No
Humpback whale (*Megaptera novaeangliae*)	Vulnerable	Yes
Mammals - Pinnipeds[2]		
New Zealand fur-seal (*Arctocephalus forsteri*)	Vulnerable	Yes
Australian fur-seal (*Arctocephalus pusillus*)	Vulnerable	Yes
Mammals - Sirenians		
Dugong (*Dugong dugon*)	Endangered	Yes
Reptiles – Sea turtles		
Green turtle (*Chelonia mydas*)	Vulnerable	Yes
Loggerhead turtle (*Caretta caretta*)	Endangered	Yes
Leathery turtle (*Dermochelys coriacea*)	Vulnerable	Yes
Birds		
Little penguin (*Eudyptula minor*)	Protected; Endangered population (Manly)	Yes

1 – out to 3 nm under the *Threatened Species Conservation Act 1995* and the *National Parks and Wildlife Act 1974*.

2 - the two seals caught in the SMP were not identified to species, so this table has recorded both as having been caught

Odontocete cetaceans

Odontocete cetaceans (toothed whales and dolphins) use echolocation to detect objects in their environment, tend to live in groups and feed on fish, squid, octopus, cuttlefish, shrimp, crabs, and for killer whales only, marine mammals and seabirds. They are long-lived, mature at a late age and produce one calf after a variable breeding interval ranging from a little over one year for some species to nine years for others (Bannister et al. 1996).

The bottlenose dolphin, common dolphin, and killer whale are regularly sighted in NSW, while the Risso's dolphin, pantropical spotted dolphin and shortfinned pilot whale are primarily known in NSW from stranding records (Ganassin and Gibbs 2005a). The survival of any of these species is not considered to be under threat. Sperm whales rarely occur within 5 km of the NSW coast and prefer continental shelf waters (i.e. >200 m deep) (Table 23). Small groups of sperm whales have been sighted inside 5 km of the coast, off Eden and Broken Bay. Human activities that can immediately injure or kill cetaceans include illegal direct killing, entanglement or incidental capture in fishing gear and boat-strike. These species can also be impacted by reduced prey availability from fishing activities, habitat degradation, plastic debris and disturbance from seismic operations and whale watching activities (Bannister et al. 1996; Threatened Species Scientific Committee 2003). A recent investigation of fishing-related impacts on odontocete whales and dolphins within 3 nm of the NSW coast found the incidental capture of dolphins (most probably common and bottlenose dolphins) on this fishing gear, the entanglement of whales in traps, the effect of fishing-related noise in these waters and the illegal killing of these animals by fishers to have an uncertain impact on odontocete whale and dolphin populations (Ganassin and Gibbs 2005b).

Table 23 The distribution, seasonal occurrence and habitat preference of the odontocete cetaceans that could be affected by the SMP

Species	Habitat	Distribution in NSW	Seasonal occurrence in NSW
Blue whale	Shelf, polar and oceanic waters	Bermagui to Green Cape	October and November
Risso's dolphin	Oceanic and coastal waters	Brooms Head to Eurobodalla National Park	Mostly December to June
Bottlenose dolphin - inshore form	Mostly coastal waters	Entire coast	Throughout the year
Pantropical spotted dolphin	Oceanic and coastal waters	Coffs Harbour to Sydney	January to March, June, September
Common dolphin	Oceanic and coastal waters	Entire coast	Throughout the year
False killer whale	Oceanic and coastal waters	Tweed Heads to Jervis Bay	May to January
Killer whale	Oceanic and coastal waters	Mostly Broken Bay to Green Cape, furthest north Byron Bay	Throughout most of the year, mostly between May and November
Shortfinned pilot whale	Oceanic and coastal waters	Brunswick Heads to Culburra	January, February, April, June, July, October

(Source: adapted from Ganassin and Gibbs 2005a)

Baleen whales

Baleen whales feed on krill, small fish and, to a lesser extent, squid and they migrate between cold water feeding grounds and warm water breeding grounds. These long-lived species mature at a late age and most species produce one calf every two to three years, except the minke whale that produces one calf annually (Bannister et al. 1996).

Southern right and humpback whales migrate each year from their summer feeding grounds in Antarctic waters to warmer waters to breed during winter. They commonly occur in NSW coastal and estuarine waters on a seasonal basis. Humpback whales occur along the length of the NSW coast during winter and spring staying close to the coast, with numbers peaking in June and July on their northwards migration and during September to November on their southward migration. Southern right whales occur along most of the NSW coast, except the far north, mostly between May to November (Smith 2001).

Minke whales, both the dark-shoulder and dwarf forms, have been reported to occur in NSW from June to November, between Twofold Bay and Minnie Water (Smith 2001). Minke whales are oceanic, but are not restricted to deep water and do occur close to coasts. The dark-shoulder form of the minke whale undertakes a seasonal migration between approximately 21°S and Antarctica. The dwarf form of the minke whale generally does not travel to Antarctic waters (Bannister et al. 1996).

Humpback and southern right whales are listed as threatened at a NSW, Australian and International level. The current population size of these species is small when compared to the likely size before historical whaling activities. The east coast population of humpback whales has been estimated at between 3,000 - 4,000 animals, and Australian populations of both species are reportedly increasing at a rate of about 10% per year (Bannister et al. 1996). Minke whales are not considered to be threatened. The Southern Hemisphere population of the dark-shoulder form of the minke whale has been estimated to be 700,000 animals and around 210,000 of these animals occur off the east coast of Australia (Bannister et al. 1996). When close to the coast threats to these species include disturbance from whale watching activities, recreational and research related boating activities, collision with large vessels, swimmers, divers, low-flying aircraft, coastal industrial activity, defence operations, entanglement in fishing gear or shark nets, plastic debris, and pollution leading to the accumulation of toxic substances in body tissues. Ingestion of harmful marine debris also affects this species (Bannister et al. 1996; Threatened Species Scientific Committee 2003). The minke whale is a commercially harvested species. A recent investigation of fishing-related impacts on whales within 3 nm of the NSW coast found the entanglement of whales in traps and the effect of fishing-related noise in these waters to have an uncertain impact on whale populations (Ganassin and Gibbs 2005b).

Seals

Seals spend most of their time feeding at sea and come ashore (haul-out) to breed at preferred localities, moult and rest. Seals are agile fast swimmers and usually feed on fish, squid and seabirds. Australian and New Zealand fur-seals are probably long-lived, as they become sexually mature after six years. They produce one pup annually during spring - summer. Currently seals do not regularly breed in NSW, although Seal Rocks on the central coast of NSW was once a regular breeding site for the Australian fur-seal (Shaughnessy 1999).

Australian and New Zealand fur-seals occur within continental shelf waters and haul-out on islands and coastlines in inshore regions. Their range includes the waters off NSW where they regularly haul-out on Montague Island mostly during winter (July to October) (Shaughnessy 1999). Elsewhere in NSW, there are scattered records of New Zealand fur-seals along the NSW coast north to Yamba. Australian fur-seals also regularly haul-out at Steamers Beach and Green Cape in southern NSW, and come ashore at irregular sites along the whole NSW coast (Smith 2001).

Populations of Australian and New Zealand fur-seals are increasing, although they are still lower than they were before historical commercial sealing operations (Shaughnessy 1999). In the early 1990s, the total population size in Australian waters was estimated between 47,000 and 60,000 for the Australian fur-seal and 34,700 for the New Zealand fur-seal (Shaughnessy 1999; Arnould et al. 2000). Listed as Vulnerable under the TSC Act, these species are considered to be under threat from commercial and recreational fishing operations (mostly through bycatch and reduced prey availability), entanglement or ingestion of plastic debris, stochastic events such as oil spills and perhaps also illegal shooting activity (NSW Scientific Committee 2002a, b; Shaughnessy 1999). Other threats to seals in Australian waters include disturbance to breeding and haul-out sites, disease, seismic survey activity, chemical contamination and climate change (Shaughnessy 1999). A recent investigation of fishing-related impacts on seals within 3 nm of the NSW coast found that the entanglement of seals in debris from fishing activities and the illegal killing of seals by fishers to have an uncertain impact on seal populations (Ganassin and Gibbs 2005b).

Dugong

The dugong lives entirely at sea and usually occurs over seagrass beds, where this slow moving species spends a large part of its day feeding, generally in the shallow coastal waters and sometimes over deeper habitats. Dugongs feed on seagrass (mostly from the Halophila and Halodule families), marine algae when seagrasses are rare or incidentally on some invertebrates. They do not undertake large-scale migrations, though some individuals can wander widely. This long-lived species matures at 9 - 17 years of age and produces one calf every 3 - 7 years. Breeding activity appears to be seasonal, occurring in the second half of the year in Queensland (Queensland Environmental Protection Agency 1999).

The dugong is found in tropical Australian waters from Shark Bay (WA) to Moreton Bay (Qld). Dugongs usually only occur in NSW as occasional stragglers from the more northern populations, usually in waters north of Jervis Bay, although they have also been reported as far south as Twofold Bay (Smith 2001). Vagrant dugongs tend to be sighted in areas where seagrasses occur, and in NSW this includes estuarine waters (Allen et al. 2004).

A recent population decline of this species in southern Queensland has been experienced. Although listed as Endangered in NSW under the TSC Act, nationally the species is not considered to be threatened and is listed as protected under the EPBC Act. Threats include large-scale destruction of seagrass resulting from many processes and activities including trawling, incidental mortality in commercial gill and mesh nets and shark meshing nets, indigenous hunting, boat strike and disturbance (Allen et al. 2004). A recent investigation into fishing-related impacts on dugongs within 3 nm of the NSW coast found that dugongs were not significantly impacted by these activities (Ganassin and Gibbs 2005b).

Turtles

Sea turtles are long-lived, grow slowly and reach sexual maturity at 30 - 50 years of age. They almost always live in the marine environment, only coming ashore to nest on sandy beaches. After hatching, young sea turtles drift in the open ocean currents until they are large enough to settle into inshore feeding grounds. The exception is the leathery turtle, which remains in oceanic waters throughout its life. In general, every two to seven years, adult turtles migrate over large distances from their feeding grounds to nesting grounds where they nest a number of times before the return journey. Clutch sizes range from 115 - 130 eggs. Sea turtles do not form obvious social groups and feed as individuals on algae, seaweed, seagrasses, sponges and other invertebrates (Environment Australia 1998).

Green and loggerhead turtles feed and breed in Australian waters. On the east coast these animals generally nest in Queensland (Environment Australia 1998). However, each year there is a scattering of nesting events of these species on the north coast of NSW, with hatching turtles emerging in April – May (L. Tarvey, NSW DECC, pers. comm., 2005). Leathery turtles mostly nest in the Asia-Pacific region and generally only feed in and migrate through Australian waters, although some rare nesting events also occur on Australian shores (Environment Australia 1998). Rare nestings of leathery turtles have been recoded on the NSW coast on two occasions, near Ballina in 1993 and Forster in 1995, the latter of which was unsuccessful due to cold conditions (Tarvey 1993).

The abundance of sea turtles off NSW is much lower than Queensland. Sea turtles occur in the waters off NSW throughout the year, mostly in inshore waters in the northern half of the state. The green turtle is a relatively common resident of inshore waters off NSW, with small numbers occurring from central NSW north (Cogger 2000). Individuals of this species also visit the more southern estuaries in NSW (Environment Australia 2003). Loggerhead turtles are also relatively common residents of inshore waters off NSW, occurring in moderate numbers in the far north and occasionally reaching the southern waters of the state (Cogger 2000). Leathery turtles are rare in Australian waters where they are found in oceanic temperate waters as far south as Tasmania (Environment Australia 1998). Small numbers occur in deep offshore waters along the whole NSW coast (Cogger 2000).

Although the green, loggerhead and leathery turtles are listed as threatened at a NSW, Australian and International level, populations of these species are still in decline (Environment Australia 1998; C. Limpus, Qld EPA, pers. comm. 2003). Threats to these species include fishing activities, shark control activities, boat strike, disease, tourism, indigenous harvesting, synthetic debris, coastal development, defence activities and predation of eggs by feral animals (Environment Australia 1998). A recent investigation into fishing-related impacts on sea turtles within 3 nm of the NSW coast found that the incidental capture of sea turtles, mostly green and loggerhead turtles, in fishing gear, especially trawling gear, could potentially negatively impact the population of these species (Ganassin and Gibbs 2005b).

Little penguin

Penguins are flightless birds that forage within the water column and nest and rest on land. Little penguins are often found in bays, harbours and estuaries and feed mainly in inshore waters around the coast of breeding localities and also out to the continental shelf and slopes. Little penguins appear to be opportunistic feeders, foraging in relatively shallow waters. When feeding their young they generally do not disperse far from their colonies and their daily foraging range is 10 - 30 km. They usually feed by pursuit-diving up to depths of 30 m on small shoaling fish, cephalopods, less often crustaceans. They

usually feed singly, occur in pairs within breeding colonies and at sea are either solitary or occur in small groups. There are approximately 19 little penguin breeding locations in NSW, south of Port Stephens. Breeding in Australia and New Zealand mainly occurs from August to February. A clutch size of two eggs is laid, although usually only one chick fledges successfully (Marchant and Higgins 1990).

Little penguins are relatively common in temperate southern Australian waters. In NSW, they are increasingly reported southwards along the coast and there are few reports of the species north of Port Stephens (Marchant and Higgins 1990). The species is not considered to be threatened, but the only mainland breeding population at Manly is listed as Endangered under the TSC Act. Threats to this species include the alteration of breeding habitat, residential development, disturbance, trampling of burrows by cattle, predation of birds by introduced foxes, dogs and cats, oil pollution, capture in fishing nets, the killing of birds for use as crayfish bait and commercial fishing activities that harvest penguin food resources (NSW NPWS 2000). A recent investigation into fishing-related impacts on little penguins within 3 nm of the NSW coast found that little penguins were not significantly impacted by these activities (Ganassin and Gibbs 2005b).

3.5.2 Catch trends

Information on the catch of marine mammals, reptiles and birds in NSW shark meshing nets from January 1950 – December 1993 has been described as inconsistent, through under-reporting and non-quantified reporting of the number of individuals caught, although more accurate information has been collected from meshing contractors since 1989/90 (Krogh and Reid 1996). The catch statistics from this time period probably represent an underestimate of the total bycatch of these animals (Krogh and Reid 1996). These inconsistencies were not systematic and the information collected on the species or species group caught and their relative proportions are assumed to be representative of what occurred naturally over this time period (Krogh and Reid 1996).

To improve the reporting and identification of bycatch in the SMP, NSW Fisheries (now DPI) began a coordinated monitoring program in 1995/96, which included the use of trained scientific observers to accompany shark meshing contractors.

Owing to the inconsistent and under-reported nature of the catches, it is not possible to accurately describe any trends in catch rates and distributions prior to 1990, and even those up to 1995/96 before the introduction of scientific observers may also contain some degree of under-reporting and/or inaccuracies. For example, in the 44 years between 1950 and 1993, there were an estimated 94 dolphins (~2/year) and 56 turtles (~1/year) caught in the nets, compared to 49 dolphins (~3/year) and 42 turtles (~3/year) in the 15 years since 1994.

Since 1990, with the exception of dolphins and turtles, there have been less than 10 individuals caught of each major group (Tables 3 and 24), precluding the identification of any trends on either an annual or monthly basis. Such rare captures are irregular, infrequent occurrences.

Of the 52 dolphins caught between 1990/91 and 2007/08, dolphins were caught in every month of the SMP season, ranging from 2 in the month of December to 12 in the month of September (Table 3), with most caught in 1994/95 (10 dolphins). The two Sydney regions account for approximately 60% of the catch in that time, 17 and 13 at Sydney North and Sydney South, respectively. To date, dolphins have suffered 100% mortality in the nets, although the rate of capture has dropped from ~3.3/year from 1990 - 2000 to ~2/year since pingers were introduced in 2001/02. Krogh and Reid (1996) reported an average of one or two dolphins per year in the late 1980s, from a peak of about 14 in 1973. This compares to approximately 10 dolphins per year in the Queensland SCP (Gribble et al. 1998).

Of the 47 turtles caught between 1990/91 and 2007/08, approximately 74% were caught in the months of January - April, and although turtles are found off the NSW coast all year round, it may indicate that the southward movement of the warm waters of the East Australian Current is facilitating their movements down the coast. Catches have ranged between 1 and 6 turtles every year except for 1990/91 and 2001/02 when no turtles were caught, and is similar to the figures reported by Krogh and Reid (1996) of between zero and five turtles per year in the late 1980s, from a peak of nine in 1981. Between 1990/91 and 2007/08, just over a third (38%) of the turtles captured were released alive. At an average mortality rate of approximately 1.6 turtles per year, mortality in the SMP is significantly less than the 11 per year reported for the Queensland SCP (Gribble et al. 1998). Eighteen of the 47 were caught in the Newcastle region, five

at each of Stockton and Redhead beaches, with Sydney North (14) and Sydney South (11) also accounting for significant proportions of the catch.

As populations of the species listed in Table 22 increase or recover, the capture rate of these animals in nets of the SMP may also increase. If sufficient numbers are impacted this could result in broader impacts at the population level. As stated in the humpback and southern right whale recovery plans, such broader population impacts are more likely when the threat occurs intensively and/or cumulatively, or over a large portion of the species range (DEH 2005a, b). This is unlikely as the SMP only occurs for part of the year over a small part of the range of the potentially affected species (Table 22).

Table 24 The recorded capture and fate of marine mammals, reptiles and birds from 1950 to 1993 and 1994 to 2007/08

Group	January 1950 – December 1993[a]	January 1994 - 2007/08	Total (January 1950 - July 2008)
Mammals			
Odontocete cetaceans	1 killer whale* (dead) 94 dolphins (dead)	3 false killer whales* (dead) 49 dolphins[b] (dead)	4 toothed 'whales'* (dead) 143 dolphins (dead)
Baleen whales		1 humpback whale (released) 1 humpback whale (dead) 1 minke whale (dead)	2 baleen whales (dead) 1 baleen whale (released)
Pinnipeds		2 seals (dead) 2 seals (released)	2 seals (dead) 2 seals (released)
Sirenians	5 dugong (dead)	1 dugong (dead)	6 dugongs (dead)
Reptiles	56 turtles entangled (5 released alive and 51 unreported status)	29 turtles[c] (dead) 13 turtles[d] (released)	29 turtles (dead) 18 turtles (released) 51 turtles (unreported status)
Birds		1 little penguin (dead)	1 little penguin (dead)

a - data from Krogh and Reid 1996

b - Catch consisted of at least 6 bottlenose dolphin; 8 common dolphin; 1 Risso's dolphin

c - Catch consisted of at least 13 green turtles; 5 loggerhead turtle; and 1 leathery turtle

d - Animals released alive consisted of at least 4 green turtles; 3 loggerhead turtles and 1 leathery turtle

* denotes that killer and false killer 'whales' are in fact members of the dolphin family, i.e. Family Delphinidae

(Source: DPI, unpub. data)

3.5.3 Risk analysis for marine mammals, reptiles and birds

Methodology

The methodology for the risk analysis for marine mammals, reptiles and birds was outlined in 3.2.6, and the detailed methodology is in Appendix 9. This section will be limited to describing the context for the analysis and the risk character for each of the eight criteria, i.e. the outcomes of the analysis and levels of risk to each species (Table 25).

For the purpose of this assessment, the risk to the species listed in Table 22 is that the SMP will significantly contract the range or reduce the populations of these species such that protected species will be listed as threatened or that populations of threatened species will further decline or not recover.

Consistent with the risk analysis of threatened sharks affected by the SMP, the temporal setting for this risk analysis is 20 years. This allows adequate time to detect population trends of the long-lived species assessed in this section. The spatial extent includes the coastal waters (within 3 nm) of the existing SMP from Newcastle to Wollongong.

Risk summary

The risk analyses for the various groups are outlined below, and the detailed species descriptions for each species are contained in Appendix 10. Overall, the SMP was found to pose a low level of risk to the range and population of the marine mammals, reptiles and birds that have been or could potentially be affected by the SMP (Table 25).

Table 25 A summary of the risk posed by the SMP on the population and range of marine mammals, reptiles and bird species that have been or could potentially be affected by the SMP

Species	Criteria								Total score	Overall risk
	Status	Extent	Severity	Effect	Response	Frequency	Form	Historical context		
Odontocete cetaceans										
bottlenose dolphins	2	1	1	1	1	2	1	1	10	LOW
common dolphins	2	1	1	1	1	2	1	1	10	LOW
Risso's dolphins	2	1	1	1	1	1	1	1	9	LOW
false killer whales	2	1	1	1	1	1	1	1	9	LOW
killer whales	2	1	1	1	1	1	1	1	9	LOW
pantropical spotted dolphins	1	1	1	1	1	1	1	1	8	LOW
shortfinned pilot whales	1	1	1	1	1	1	1	1	8	LOW
sperm whales	1	1	0	0	1	0	0	0	3	LOW
Baleen whales										
humpback whale^	3	1	1	1	2	1	1	1	11	LOW
minke whale	2	1	1	1	1	1	1	1	9	LOW
southern right whale^	1	1	0	0	1	1	1	1	6	LOW
blue whale^	1	1	0	0	1	0	0	0	3	LOW
Seals										
Australian^ fur-seals	3	1	1	1	1	1	1	1	10	LOW
New Zealand^ fur-seals	2	1	1	1	1	1	1	1	9	LOW
Dugong^	3	1	1	1	0	1	1	1	9	LOW
Turtles										
green^	3	1	1	1	1	1	1	1	10	LOW
loggerhead^	3	1	1	1	1	1	1	1	10	LOW
leathery^	3	1	1	1	1	1	1	1	10	LOW
Little penguins										
endangered population (Manly^)	1	1	1	1	2	1	1	1	9	LOW
others	2	1	1	1	1	1	1	1	9	LOW

^ denotes species and populations listed as threatened under the TSC Act.

Odontocete cetaceans

Status: Not a listed KTP for sperm whales, which is the only threatened odontocete that could be affected by the SMP, but has not been recorded to date. Risso's, bottlenose and common dolphins and killer and false killer whales have been recorded; Pantropical spotted dolphin and shortfinned pilot whale captures are possible but none to date. Moderate risk to Risso's, bottlenose and common dolphins and killer and false killer whales = 2; Low risk to the other species that have not been recorded in the SMP = 1.

Extent: Only a very small part of the geographic range of any of these species is affected and each has spatial and temporal refuges from the SMP. The nets do not fragment or isolate areas of pelagic waters and do not totally restrict the movement or migration of these species for any period of time at any location. As shark meshing is currently a seasonal activity, these animals are only exposed to this activity for up to eight months of the year, from September 1 - April 30. This period of exposure is shorter for those animals whose seasonal occurrence in NSW only partly overlaps with the shark meshing season, i.e. Risso's dolphin (five months; December - April); killer whale (mostly over three months, September - November); and perhaps also the pantropical spotted dolphin, shortfinned pilot whale, false killer whale and sperm whale. Low risk = 1.

Severity: Since 1950, there were no recorded captures of most of these species and relatively low catches of the others, thus limiting the effects to individuals, not the population. Low for most species = 1, Negligible for sperm whales = 0.

Effect: Restricted to individuals, mostly adult dolphins, with little to no effect on range extension or recruitment. Low for most species = 1, Negligible for sperm whales = 0.

Response: Although marine mammals have a generally slow recovery potential, the SMP does not appear responsible for many, if any deaths of most of these species, and so the population would be able to withstand the limited losses (for those that have been affected) to the SMP. Low =1.

Frequency: For bottlenose and common dolphins common occurrence of low numbers; for most other species rare event to date, and zero occurrences for sperm whales. Moderate for bottlenose and common dolphins = 2, Low for most others = 1, Negligible for sperm whales.

Form: The SMP is considered a pulse disturbance as it is an acute, short term episode of disturbance, limited in its spatial extent and is unlikely to have any bearing on the populations of these animals. Low for most species = 1, Negligible for sperm whales = 0.

Historical context: The SMP has operated in Sydney since 1937, Newcastle and Wollongong since 1949 and the Central Coast since 1989, and in that time very few individuals were caught and there has not been a particular period of significance. Low for most species = 1, Negligible for sperm whales = 0.

RISK TO ODONTOCETES = LOW (score of 10 for bottlenose and common dolphins; score of 9 for Risso's dolphin, killer and false killer whales; score of 8 for pantropical spotted dolphin and shortfinned pilot whale, and score of 3 for sperm whale).

Baleen whales

Status: Listed KTP for humpback whales; not a listed KTP for other species, but captures of minke whales have been reported and captures of southern right and blue whales are possible. High for humpbacks = 3, Moderate for minke whales as they have been captured in the SMP = 2, and Low for southern right and blue whales = 1.

Extent: Only a very small part of the geographic range of any of these species is affected and each has spatial and temporal refuges from the SMP. The nets do not fragment or isolate areas of pelagic waters and do not totally restrict the movement or migration of these species for any period of time at any location. As shark meshing is currently a seasonal activity, these animals are only exposed to this activity for up to eight months of the year, from September 1 - April 30, but the actual period of exposure is shorter for those animals whose seasonal occurrence in NSW only partly overlaps with the shark meshing season, i.e. humpback and southern right whales (three months; September - November); Low = 1.

Severity: Since 1950, relatively low numbers of humpback and minke whales have been caught, thus limiting the effects to individuals, not the population; Low = 1, and Negligible for southern rights and blue whales as none have been recorded to date = 0.

Effect: Restricted to very few individual humpbacks and minke whales with little to no effect on range extension or recruitment. Low = 1, and Negligible for southern rights and blue whales as none have been recorded to date = 0.

Response: Slow recovery potential for these species and populations and they are thought to be currently recovering at or close to their biologically optimum level. Moderate for humpback as they are Vulnerable and have been recorded = 2; and Low for minke, southern right (Vulnerable), and blue whales (Endangered) = 1.

Frequency: For southern right, minke and humpbacks capture is a rare event; Low = 1, and to date blue whales have not been recorded in the SMP; Negligible = 0.

Form: For southern right, minke and humpbacks it is a pulse disturbance; Low = 1, and to date blue whales have not been recorded in the SMP; Negligible = 0.

Historical context: Very few individuals have been caught and there has not been any particular period of significance. Low for southern right, minke and humpbacks = 1; and to date blue whales have not been recorded in the SMP; Negligible = 0.

RISK TO BALEEN WHALES = LOW (score of 11 for humpback whale; score of 9 for minke whale; score of 6 for southern right whale and score of 3 for blue whales).

Seals

Status: Listed KTP for Australian fur-seals, High = 3; not a listed KTP for New Zealand fur-seals but they have been recorded, Moderate = 2.

Extent: Only a very small part of the geographic range for these species is affected and each has spatial and temporal refuges from the SMP. The nets do not fragment or isolate areas of pelagic waters and do not totally restrict the movement or migration of these seals for any period of time at any location. Low = 1.

Severity: Since 1950, only four seals have been recorded in the SMP, thus limiting the effects to individuals, not the population; Low = 1.

Effect: Restricted to very few individuals with little to no effect on range extension or recruitment, Low = 1.

Response: Although seals generally have a low potential for recovery following a disturbance, populations are currently recovering, and the SMP affects so few animals that it would not be affecting the rate or ability of that recovery; Low = 1.

Frequency: Rare event to date, Low = 1.

Form: The SMP is considered a pulse disturbance as it is an acute, short term episode of disturbance, limited in its spatial extent and is unlikely to have any bearing on the populations of these animals. Low = 1.

Historical context: Only four individuals have been recorded in the SMP and there has not been any particular period of significance. Low = 1.

RISK TO SEALS = LOW (score of 10 for Australian fur-seals; score of 9 for New Zealand fur-seals).

Dugongs

Status: Listed KTP for this species, High = 3.

Extent: Only a very small part of the geographic range for these species is affected and each has spatial and temporal refuges from the SMP. The nets do not fragment or isolate areas of pelagic waters and do not totally restrict the movement or migration of dugongs for any period of time at any location. Low = 1.

Severity: Since 1950, only six dugongs have been recorded in the SMP, thus limiting the effects to individuals, not the population; Low = 1.

Effect: Restricted to very few individuals with little to no effect on range extension or recruitment, Low = 1.

Response: Although dugongs generally have a low potential for recovery following a disturbance, they occur as a vagrant in NSW and are unlikely to return to or contribute to the main breeding population; Negligible = 0.

Frequency: Rare event to date, Low = 1.

Form: The SMP is considered a pulse disturbance as it is an acute, short term episode of disturbance, limited in its spatial extent and is unlikely to have any bearing on the populations of these animals. Low = 1.

Historical context: Only six individuals have been recorded in the SMP and there has not been any particular period of significance. Low = 1.

RISK TO DUGONGS = LOW (score of 9).

Turtles

Status: Listed KTP for the three species of turtles, High = 3.

Extent: Only a very small part of the geographic range for these species is affected and each has spatial and temporal refuges from the SMP. The nets do not fragment or isolate areas of pelagic waters and do not totally restrict the movement or migration of these turtles for any period of time at any location. Low = 1.

Severity: Since 1990/91, the annual average catch rate recorded in the SMP has been less than two turtles per year, and about a third of the turtles entangled are released alive, thus limiting the effects to individuals, not populations; Low = 1.

Effect: Restricted to very few individuals with little to no effect on range extension or recruitment, Low = 1.

Response: Although turtles have a slow recovery potential in general and populations are currently in decline, the low average catch and the high rate of release in the SMP suggest that it is having little effect on the ability and/or rate of recovery for these turtles. Low = 1.

Frequency: Irregular occurrence of low numbers for green and loggerhead turtles; rare event to date for leathery turtles, Low = 1.

Form: The SMP is considered a pulse disturbance as it is an acute, short term episode of disturbance, limited in its spatial extent and is unlikely to have any bearing on the these populations. Low = 1.

Historical context: Less than 100 turtles have been recorded in the SMP since 1950, and because of issues with under-reporting and identifications, it is not readily possible to identify any particular period of significance. Low = 1.

RISK TO TURTLES = LOW (score of 10).

Little penguins

Status: Not a listed KTP for the Endangered Population at Manly, and the single record of a penguin in the nets from 1994 was at Garie Beach, making it unlikely that the animal was from the Endangered Population; Low = 1. The majority of little penguins in waters of the SMP nest on offshore islands and are protected under the NPW Act; Moderate = 2.

Extent: Only a very small part of the geographic range for the protected species and Endangered Population is affected and each has spatial and temporal refuges from the SMP. It does not occur in the Endangered Population’s critical habitat inside North Head of Sydney Harbour. The nets do not fragment or isolate areas of pelagic waters and do not totally restrict the movement or migration of these penguins for any period of time at any location. Low = 1.

Severity: Since 1950, only one penguin has been recorded in the SMP, thus limiting the effects to individuals, not the population; Low = 1.

Effect: To date restricted to one individual with little to no effect on range extension or recruitment, Low = 1.

Response: The SMP has little effect on the ability and rate of recovery of the Endangered Population, and whilst protected, little penguins in general are not thought to be declining in distribution or abundance. Assuming worst case that the captured penguin was from the Endangered Population, then the potential threat to the recovery of that population would be Moderate = 2, and low for little penguins in general = 1.

Frequency: Rare event to date; Low = 1.

Form: The SMP is considered a pulse disturbance as it is an acute, short term episode of disturbance, limited in its spatial extent and is unlikely to have any bearing on the these populations. Low = 1.

Historical context: Limited historical impact, Low = 1.

RISK TO LITTLE PENGUINS = LOW (score of 9 for both the protected species and the Endangered Population at Manly).

3.6 RECOMMENDATIONS ARISING FROM THE ENVIRONMENTAL ASSESSMENT

3.6.1 Sharks

The majority of species of shark that are caught in the SMP are also retained by both commercial and recreational fishers, and the SMP was considered to pose a relatively low risk to those species. If it is correct that catches in the SMP reflect broader changes in distribution and abundance of sharks in NSW waters, then the data suggests that most species have been declining over the last 50 years. Whilst this is not necessarily an issue for or created by the SMP, it provides scope for future reviews of the effort and netting protocols for the SMP.

In particular, previous changes to the SMP in the early 1970s saw a pronounced shift in the catch away from whalers and angel sharks and onto hammerhead sharks. Whilst there may be some argument as to whether or not hammerheads are a target species of the SMP, as they are in Queensland, they have not been implicated in a shark attack in NSW waters in the review period from 1900 - 2008, and on that basis alone it would be appear they should be considered a non-target species.

Consistent with Recommendation 3 in section 2.7, the management plan should include provisions for a review of the objectives and netting protocols of the SMP to establish means by which impacts on hammerheads and other non-target species can be mitigated.

The risk analysis indicated that two threatened species of sharks, namely grey nurse and great white sharks, have historically been significantly affected by the SMP, although it is important to note that the analysis only examined the threat posed by the SMP and was not a broader risk analysis of all threats to those species. The analysis indicated that the SMP continues to pose a moderate risk to grey nurse and great white sharks, although proportionally the SMP only accounts for an estimated 9% and 5%, respectively, of the known anthropogenic sources of mortality on those species.

In comparison with other threats to grey nurse shark, the SMP reportedly poses a relatively low risk to grey nurse shark (Bradshaw et al. 2008), suggesting that if the other threats were analysed using the risk analysis in this review that they would probably be found to pose a high to very high risk to the species. Bradshaw et al. (2008) also modelled a change from mesh nets to drumlines for a third of the program. Although they found that it would only marginally reduce the risk of extinction to grey nurse sharks, they did imply that alternative avenues should be considered in areas where grey nurse shark are relatively common. Similarly, this review has indicated that a more location-specific change may be warranted or that its potential effectiveness should at least be investigated.

The analyses also indicate that September is one of the months in which grey nurse sharks are caught more often, but it is also the month in which the greatest numbers of great whites are caught. Although they are also a threatened species, great whites are a ‘target’ species of the fishery and modifying the seasons to mitigate impacts on grey nurse could simultaneously increase the risk of attack by reducing the number of great whites that are prevented from accessing swimming beaches.

Consistent with Recommendations 10 and 11, the management plan needs to include both catch monitoring and trigger points to identify any changes in the catch frequency and abundance of these and other threatened or protected species,

Recommendation 13
That the research and monitoring plan considers the efficacy of the use of drumlines in those areas where proportionately high numbers of grey nurse sharks are caught.

3.6.2 Rays

The relatively low number of rays caught in the SMP compared to commercial and recreational fisheries negated the need for a detailed risk assessment, as it was readily apparent that the SMP poses a relatively low risk. There is however, only limited species level reporting and with less than 100 rays caught per year, it should not be an overly onerous task to identify rays to species, or at least genus.

The SMP also disposes of most rays, and the management plan should seek to minimise disposal at sea as it both a waste issue and lost opportunity in terms of biological/educational material. The management plan should instead be trying maximise the retention of biological samples.

Recommendation 14
That DPI investigate the feasibility and merit of developing and distributing identification guides of rays for use by contractors and observers.

Recommendation 15
That the management plan include provisions to maximise the retention of biological samples of sharks and rays.

3.6.3 Finfish

To date, the SMP has not recorded the capture and/or death of any threatened species of finfish, although the occasional blue groper (a species protected from commercial fishing under s.20 of the FM Act) has been caught, but blue groper are also harvested by recreational fishers. The SMP catches less than 10 finfish per year and poses no threat to the stocks or populations of any species, threatened or otherwise.

3.6.4 Marine mammals, reptiles and birds

Shark meshing in NSW is a KTP that can have a negative impact on some marine mammals and reptiles. The current impact of this activity was found to be low for all marine mammals, reptiles and birds that are likely to occur in the inshore waters between Newcastle and Wollongong. Any changes to the SMP need to consider subsequent impacts on these animals and given the KTP status of this activity should also seek to reduce the current level of impact.

Management mechanisms are required so that any detected increase in capture rates is investigated and mitigated when necessary. An increase in the population of marine mammals and reptiles, as is the management goal for threatened species recovery, could result in an increased rate of interaction. Any ongoing or new monitoring of interactions between shark meshing and marine mammals and reptiles will need to be cognisant of such changes as they relate to estimates of population size and distribution.

Recommendation 16
The annual performance report and five year review (Recommendations 1 and 2) should include a revised assessment of the potential impacts/risk levels on these species based on the best available information, particularly with respect to population estimates and trends.

Acknowledging the low impact of the SMP on the survival of marine mammals, reptiles and birds that frequent the NSW coast, the following recommendations are made to ensure that the management of this activity is aligned with the current recovery plans for those species (Environment Australia 2003; DEH 2005a, b):

Recommendation 17
Monitoring of marine mammal, reptile and bird catch and release rates in these nets at a species level needs to continue, be regularly assessed and reported to the Department of Environment and Climate Change. Improvements to the current reporting at a species and spatial level may be useful in determining future alternative management arrangements if required.

Recommendation 18
The mortality of entangled animals is to be minimised through the use of formal disentanglement, release and revival procedures, especially for large cetaceans and sea turtles.

There is currently limited species level reporting and with less than 10 cetaceans caught per year, it should not be an overly onerous task to identify cetaceans to species, or at least genus. The SMP also disposes of most dolphins, and the management plan should seek to minimise disposal at sea as it both a waste issue

and lost opportunity in terms of biological/educational material. This is of particular relevance as bycaught animals tend to represent healthy members of the population, allowing feeding studies and investigations into their role in the ecosystem, while the usual source of cetacean material is strandings, which usually represent unhealthy animals. The management plan should therefore be trying maximise the retention of biological samples.

Recommendation 19
That DPI investigate the feasibility and merit of developing and distributing identification guides of cetaceans for use by contractors and observers.

Recommendation 20
That the management plan include provisions to maximise the retention of cetacean biological samples.

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APPENDICES

A1 Generic contract specifications for the 2008/09 season at July 2008

Schedule 2

Specification

The shark meshing services are to be in accordance with the Specification detailed herein.

1. WORK TO BE PERFORMED

1.1 The Contractor will be required to carry out a specified number of meshings, off the beaches detailed in the attached Table between 1 September and 30 April for the Term of the Agreement. (NSW DPI will reserve the right, by giving reasonable notice in writing to the Contractor, to extend the Term by three (3) further periods of one (1) year each.)

1.2 The number of meshings in respect of the beaches specified in the attached Table shall be calculated on the basis of the number of nets, 150 metres in length, used. Such nets may be joined to a maximum of two nets, each net 150 metres in length (e.g. where two nets, each 150 metres in length and joined together are used, it shall constitute two meshings for the purpose of the Table(s), provided that the Contractor complies with all other conditions.)

1.3 A meshing shall be completed when a net is hauled, or run and cleared, after it has been set continuously in the water for a minimum of twelve (12) hours between 4 pm on one day and sunrise the following day. Set nets are to be hauled or run and cleared after a period not exceeding 96 hours.

1.3.1 Set nets are to be inspected by the Contractor within 96 hours of the previous inspection, to ensure they are operating efficiently. At each inspection the operator is to remove all catch and debris from the nets.

1.4 A minimum of 10% of the total number of meshings of each beach as per the Tables must constitute multiple meshing using two nets, up to a maximum of 30% of the total number of meshings of each beach.

1.5 Not more than 70% of the number of meshings specified opposite each beach in the Table(s) are to be completed in either half of the calendar month.

1.6 At the completion of sets/hauls for the month, all shark nets are to be completely removed from the water until the commencement of the next month’s operations.

1.7 In addition to the number of weekday meshings specified in the Tables, every weekend in the calendar month shall have nets set as a minimum between sunrise on Saturday to sunset on Sunday, with nets hauled or run and cleared on Monday, to be completed off each of the beaches as specified in the Tables. Calculation of the number of meshings during this period shall be the same as that referred to in clause 1.2 above.

1.8 Nets shall be set not more than 500 metres offshore (measured to the nearest land drying point) or in depth of water not greater than 12 metres or at a position determined by the authorised Observer.

1.9 The meshing net must be used as a sunk net only. No part of the net (other than that used for the purposes of tagging, prescribed in Clause 1.14 of this Specification) shall be on the surface.

1.10 The work involved in hauling or running of nets shall be supervised by an accredited Observer who has delegated authority from the Director General, NSW DPI to certify that the number of meshings meet with the Table(s) as per the Agreement and that all terms and conditions of the Agreement are met including materials supplied, method of meshing, vessels, crew, gear, maintenance of records of operations, disposal of catch or other duties as directed by the Director General NSW DPI or his authorised representative.

1.11 NETS

Nets used shall comply with the following specifications:-

Floatline: 150 metres of not less than 8mm diameter, synthetic rope with a breaking strain of not less than 900kg.

Leadline: 150 metres of not less than 8mm diameter, synthetic rope with a breaking strain of not less than 900kg.

Floats: Gill net floats used shall be of not less than 10cms in diameter and 5cms thickness, or a float of equivalent buoyancy approved by the Principal's Delegate at not more than 5 metre centres.

Netting Twine: The twine used shall be continuous synthetic filament with a breaking strain of not less than 60 kgs.

Mesh Size: The mesh size shall not be less than 50cms and not more than 60cms measured in accordance with the manner prescribed in Clause 115 of the (General) Regulation 1995 made under the Fisheries Management Act 1994. A rule may be used in lieu of the prescribed net measuring device.

Meshes Deep: The number of meshes for each mesh size shall be as follows:

60cms mesh - not less than 12 meshes deep)

55cms mesh - not less than 13 meshes deep)

50cms mesh - not less than 14 meshes deep)

so that the net height is approximately 6 metres when set.

Hanging Coefficient: The hanging coefficient on the corkline and leadline shall be 0.67 (33% slack hung in) i.e. each 60 metres of net will be hung into 40 metres of corkline or leadline.

1.12 The hanging coefficient on the sidelines at the end of each net, joining the corkline and leadline, shall be 0.74 of the mesh size used in the net:

Mesh Size	Distance Between Knots	No. of Meshes	Length of Side Rope
i.e. 60cms	44cms	12	5.28m
55cms	41cms	13	5.33m
50cms	37cms	14	5.18m

1.13 The bridle from each net to the anchors shall have sufficient slack to fish to its maximum depth.

1.14 Nets shall be kept in repair to the satisfaction of the shark meshing Supervisor and/or Observer.

1.15 Nets shall be tagged at the surface with a minimum of 25cms bubbles and clearly marked "Shark Net" in accordance with Set Fishing Gear Regulations.

1.16 The Contractor shall lay out nets for inspection and measurement in a manner and at a place and time specified by the shark meshing Supervisor. These inspections will be required on a minimum of three (3) separate occasions between 1 September to 30 April during the Term.

2. METHODS OF MESHING

2.1 A meshing shall consist of:-

(a) a net set and completely hauled into the Vessel. Such net shall remain in the water for a minimum period as specified in Clause 1.3; or

(b) a net set which has been set and run and cleared from end to end after remaining in the water for a minimum period as specified in Clause 1.3.

2.2 Running the net shall consist of:-

(i) lifting the floatline progressively from the water sufficiently to ascertain if any sharks or by-catch are meshed and then clearing them from the net; and

(ii) returning the net to the water.

2.3 The position and method of setting nets, and the procedure in all matters affecting the efficiency of the meshing operations, shall be subject to the direction of the shark meshing Supervisor, who may also decide whether a meshing shall be counted as a meshing for the purpose of Clause 1.3.

2.4 Not more than two nets shall be set on any one beach on any one day unless authorised by the Principal's Delegate.

2.5 The Observer must be on board the Vessel used to haul or run the nets.

3. VESSELS, CREW, GEAR AND OBSERVER

3.1 The Vessel(s) shall be under survey in accordance with the requirements of NSW Maritime and shall be maintained in a seaworthy condition at all times and be manned by a sufficient crew to properly perform the Agreement.

3.2 The Vessel must be capable of safely securing and transporting sharks or bycatch up to three and a half (3.5) metres in length.

3.3 All equipment as specified by NSW Maritime to cover all crew, the Observer and one other person authorised by the Principal's Delegate under Clause 7.1 shall be provided on board the Vessel at all times.

3.4 At least 24 hours notice of proposed departures of the Vessel shall be given to the Observer. This time of departure shall be determined by agreement between the Contractor and the Observer.

3.5 The following accommodation shall be provided for the Observer on each Vessel used in the provision of the services:

(a) a fully enclosed marine type flushing toilet.

(b) a hand basin with connected running fresh water.

(c) adequate individual cabin seating with provision for writing.

(d) a suitably enclosed changing area.

3.6 Whilst the Contractor is engaged in shark meshing operations, no persons, apart from normal Crew members and approved DPI personnel, are permitted to be on board the Vessel without the express written authority of NSW DPI.

3.7 The Contractor shall at all times use the nominated Vessel in the performance of works under the Agreement unless the Contractor has obtained prior written notification, from the Principal's Delegate to use a vessel other than the nominated Vessel.

4. CONTRACTOR'S WORK REPRESENTATIVE

4.1 The Contractor shall be required to, at all times during the progress of the work under the Agreement, have in charge of the work a responsible Representative authorised to receive instructions on behalf of the Contractor and to represent the Contractor for all purposes of the Agreement.

5. MAINTENANCE OF EQUIPMENT AND SAFETY OF EMPLOYEES

5.1 The Contractor shall be required to:

(a) maintain equipment in good condition and repair;

(b) secure the safety, health and welfare of persons engaged in the performance of the Agreement.

6. RECORDS AND REPORTING OF OPERATION

6.1 The Contractor shall keep a complete log on each Vessel in which shall be recorded daily the operations of the Vessel, the number and position of nets set, and any further information which may be required from time to time by the Principal's Delegate.

6.2 The Contractor shall measure the length of each shark taken in a net and, as far as possible, identify the shark species and provide this to the Observer.

6.3 The Contractor will supply a photographic image of each shark, threatened or protected fish, or aquatic mammal captured or entrapped in the nets. The image should be of adequate quality to allow reasonable identification and assessment of decomposition (where this applies).

6.4 The Contractor shall at all times permit the shark meshing Supervisor and/or Observer to have access to such records and shall on the last day of each calendar month when meshing is required, forward to the Principal's Delegate a copy of such record.

6.5 The Contractor is required to notify the Supervisor by 4 pm each Friday of the proposed shark meshing activities for the next 7 days.

6.6 The Contractor is required to notify the Supervisor if any nets have not been set on any beach on weekends, as specified in the Tables.

6.7 The Contractor is required to notify the Supervisor if set nets are to be removed from the water during a weekend (i.e. before sunrise on Monday), and advise the reason for such action.

7. ACCESS FOR OBSERVER

7.1 The Contractor shall at all times allow the Observer or any other person authorised by the Principal's Delegate access to and conveyance on any Vessel used in connection with the Agreement.

7.2 Notwithstanding the provisions of clause 9 hereof, the Contractor shall at all times allow any person so authorised in writing by the Principal's Delegate to collect any shark or any portion of a shark.

8. BAIT AND LURES NOT TO BE USED

8.1 The Contractor shall not, within three (3) miles of any point on the coastline of New South Wales, use any bait or lure for the purpose of attracting sharks.

9. DISPOSAL OF CATCH

9.1 No sharks, fish or other animal caught under the Agreement or skins, carcass or any other portion thereof shall be landed anywhere in New South Wales or dumped within three (3) miles of the New South Wales coastline except as provided by clause 10.1 and 7.2. Any breach of this clause, except as provided by 10.1 and clause 7.2, shall be a ground for termination in accordance with the provisions of the Agreement.

9.2 In the case where aquatic mammals (whales, porpoises or dugong etc) are accidentally taken in a net, the Contractor is to immediately advise both NSW DPI and Department of Environment and Conservation (NSW DEC).

9.3 The Contractor shall notify the shark biologist or the shark meshing Supervisor in the event of capture or entrapment of any shark or marine mammal, within 24 hours. The Contractor is to advise the species and approximate length and provide a photographic image, as outlined in clause 6.3.

9.4 In the case where threatened or protected fish are accidentally taken in a net, the Contractor is to immediately advise the Threatened Species Unit of NSW DPI and provide a photographic image, as outlined in clause 6.3.

9.5 Any carcass requiring disposal outside three (3) miles should have sufficient weight attached to cause the carcass to the sink to the bottom.

10. ADDITIONAL REQUIREMENTS CONCERNING ENTRAPPED MARINE LIFE

10.1 All reasonable effort shall be made by the Contractor to safely release entrapped marine life, including protected species of fish and mammals, to minimise harm to the entrapped marine life.

10.2 The Contractor shall remove head, vertebrae, tissue or any other samples specified by NSW DPI from captured sharks and deliver them to a local NSW DPI office or other local place nominated by the shark meshing Supervisor or shark biologist.

10.3 The Contractor shall retain all carcasses of white sharks (Carcharodon carcharias) and grey nurse sharks (Carcharias taurus), and deliver them to a local place nominated by the shark meshing Supervisor or shark biologist.

10.4 The Contractor shall retain all carcasses of threatened and protected fish and deliver them to a local place nominated by the shark meshing Supervisor or shark biologist.

10.5 The Contractor shall collect tissue samples as specified by NSW DPI from dead or entrapped marine mammals and reptiles, and tag live entrapped marine turtles prior to release, after appropriate training has been provided by approved DPI personnel.

10.6 The Contractor shall deploy acoustic warning devices on shark meshing nets as specified by the shark meshing Supervisor. The Contractor shall not be responsible for supply or maintenance of the devices, or the supply of batteries for their operation.

10.7 The Contractor shall co-operate with any research or monitoring program authorised by NSW DPI, where such authority is evidenced in writing and produced to the Contractor.

11. MEDIA COMMUNICATIONS

11.2 Neither the Contractor nor Crew shall communicate in any way with any media organisation or media representative concerning any aspect of shark meshing operations without the express written authority of NSW DPI, and must refer all such inquiries to the NSW DPI Media Unit.

ATTACHMENT 1 TO SCHEDULE 2

Generic table of beaches and number of meshing days - modify for each contract

REGION

NAME OF BEACH	NUMBER OF WEEKDAY MESHINGS PER MONTH	WEEKEND MESHINGS
		*
		*
		*
		*

* A weekend meshing must be completed for each weekend which falls in full or in part during the period 1 September to 30 April, as identified in clause 1.7 of the Specification.

A2 Contractor's catch return

NSW DEPARTMENT OF OF PRIMARY INDUSTRIES **SHARK MESHING PROGRAM** **CATCH DATA**

Area **Month** Year:

Date	Beach	Species	Sex	Fork Length	Dead or Alive	Ultrasonic	Stomach Contents		Sample Taken	Number of Pups	Photo Taken	Wind Direction & Speed	Water Temp

Marine Mammal Catch Notification

Date	Beach	Species	Dead/ Alive	Length	Sex	Sonic device	NSW DPI	NPWS	Persons Name	Disposal Action Taken

Comments

Indicate if zero catch

Signature of Contractor **Logbooks checked and certified by Observer:** **Page ___of___**

Appendix 2 cont.

NSW DEPARTMENT OF PRIMARY INDUSTRIES **SHARK MESHING PROGRAM** **SET DATA**

W/E Hauls to be circled
Observer initial days present

Contractor: **Vessel:** **Area:** **Month:** **Year:**

Beach	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Compl.	Total set / hauls	Short Falls
	Day																																		
	Obs. Present																																		
	Set																																	13	
	Hauls																																	13	
	Set																																	13	
	Hauls																																	13	
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	Set																																	13	
	Hauls																																	13	

*** No more than 70% of meshings to be completed in either half of month**

Signature of Contractor: **Logbooks Checked and certified by Observer:**

A3 List of attendees at the Scientific Shark Protection Summit

Scientific	
NSW DPI	
Dr Doug Ferrell	NSW Department of Primary Industries
Dr Steve Kennelly	NSW Department of Primary Industries
Dr Nick Otway	NSW Department of Primary Industries
Mr Dennis Reid	NSW Department of Primary Industries
Other Agencies	
Mr Barry Bruce	CSIRO Marine Research
Mr Baden Lane	Queensland Department of Primary Industries & Fisheries
Mr Rory McAuley	Western Australia Fisheries
Dr John Paxton	Australian Museum
Dr Vic Peddemors	Macquarie University (and former Natal Sharks Board)
Mr Craig Sowden	Sydney Aquarium
Dr Adam Stow	Macquarie University
Dr Iain Suthers	University of NSW
Mr Terry Walker	Victoria Department of Primary Industries
Mr John West	Taronga Zoo
Surf Lifesaving Organisations	
Mr John Andrews	Australian Professional Ocean Lifeguard Association (APOLA)
Mr Craig Roberts	Surf Life Saving Australia (SLSA)
Mr Ian Vaughan	Australian Professional Ocean Lifeguard Association (APOLA)
Mr Geoff Withycombe	Surfrider Foundation (alternate for Mr Stuart Ball)
Ministerial staff	
Amanda Delaforce	Fisheries Policy Unit
Austin Whitehead	Forestry Policy Unit
Minutes	
Ms Tracey McVea	NSW Department of Primary Industries
Apologies	
Dr Tim Ward	South Australian Research & Development Institute

A4 Recommendations and actions from the Scientific Shark Protection Summit

Scientific Shark Protection Summit, 10 April 2006, Medina Grand Harbourside Hotel, Aquarium Pier, Darling Harbour. Hosted by the NSW Department of Primary Industries and Sydney Aquarium.

Source: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/137294/Report-from-the-Scientific-Shark-Protection-Summit.pdf

- The Summit was generally supportive of the Government's beach-meshing program due to its very impressive historical record. Prior to the introduction of the SMP, there was, on average, one person taken by a shark each year, however, only one death has occurred on a netted beach since the SMP was introduced in 1937. However, the Summit recommends that the current beach-meshing contract be reviewed. The Summit suggests improvements can be made in the objectives of the SMP, the use of observers and the general operating conditions and, wherever possible, improvements made. The Summit recommends that the review be done by an independent group of experts who have experience in beach meshing programs (e.g. from QDPIF and South Africa). Areas for consideration by the review panel should include: the servicing regime of the nets (e.g. standardised soak times); high risk catching seasons and the bycatch caught at each location; using lifeguards to assist in performance monitoring of shark meshing contractors; and the return to researchers of captured sharks.
- The Summit recommends that all live sharks that are captured in the mesh nets be tagged and released whenever possible and NSW DPI should collect samples from dead sharks or lodge the specimens with the Australian Museum. The Summit believes that the information gained through such tagging will improve the understanding of shark movement and biology and hence the ability to reduce shark attack risk in the future.
- NSW DPI should follow-up on the results of the work done by QDPIF on the comparison of drumlines and mesh nets in pristine areas and these data should be used when reviewing the beach meshing program in NSW.
- The Summit found the benefits of aerial patrols were minimal and does not recommend this technique as a means of reducing the risk of shark attack in NSW.
- The Summit recommends increased funding for lifesavers, particularly for building more observation towers and for the purchase of more jet skis and polarized lenses in eyewear.
- Research on the migratory patterns and breeding behaviour of great white sharks indicates that sharks move south during September / October and the historical rate of attacks suggests there is a decreased risk of shark attack during this time. Bullsharks are also rarely caught during this period. NSW DPI is to examine the data on shark captures to determine if there are any spatial or temporal trends in shark abundances during September / October that would allow removing these months from the current beach-meshing program.
- NSW DPI to examine the data that are currently being collected by Surf Lifesaving organisations and determine how these data may be used by scientists to assist with reducing the risk of shark attack.
- NSW DPI to consider a project that involves using people in high-rise apartments to sight sharks.
- NSW DPI to complete the Response Plan on Shark Attack. In particular, the Summit noted that NSW can draw on the work done by the other states but it also needs to focus on providing the public with more information about the meshing program.
- The Summit recommends that a 'Chondrichthyes Science Group' be formed comprising the scientific representatives from this Summit and the group should meet on an ongoing basis to discuss recent issues regarding shark research and minimising risks of shark attack.

A5 Relevant policies of Surf Life Saving NSW

Shark Control Program, LS 10.3

SHARKS

No: LS 10.3

Section: C

Date: 1st August 2006 **Page:** 1 of 2

Purpose

This guideline is an aid to recognising and overcoming risks associated with sharks. It recognises the role of Lifesaving Services in managing an environment that sharks inhabit.

Procedure

For the purposes of this document the word shark is used in the broad sense to include all sharks, although it is recognised that not all sharks are dangerous with nearly all fatal attacks in coastal waters being attributed to just three species - Bull Sharks, Tiger Sharks and White Pointer Sharks (or Great Whites).

Personal Safety

Some simple rules for safe swimming apply to help reduce the risk of incidents involving sharks and humans, and should be promoted to the public so they can take appropriate self precautions:

- Always swim at a patrolled beach and between the flags.
- Leave the water immediately if a shark is sighted.
- Never swim alone.
- Never swim between dusk and dawn.
- Never swim in murky waters.
- Do not swim near schools of fish.
- Do not swim in canals or near a river mouth.
- Do not swim near, or interfere with, shark control equipment.
- Do not swim if bleeding.

Appendix 5 cont. - Shark Control Program, LS 10.3 cont.

Actions on Sightings

In the event of a (**lifesaver/lifeguard confirmed**) shark sighting close/in the patrolled area, the following procedure shall occur:-

1. Determine if water area is to be evacuated (considering size of shark, proximity to swimmers, level of confirmation of sighting, conduct of shark)
2. Activate the Emergency Evacuation Alarm
3. Inform everyone of the following:
   - Water area is being closed / recommended they leave the water
   - Reason for closure
4. Lower/remove Red and Yellow Flags
5. Raise Emergency Evacuation Flag (Red and White Quartered)
6. Remove all other flags
7. Post ‘Swimming Prohibited’ signs at identified beach access points
8. Continually monitor all areas
9. Do not attempt to kill, capture or injure the animal.
10. Contact SurfCom (or similar) and inform them of the shark sighting and all available information
11. Complete Shark Report Form

Actions in Event of Shark Attack

Shark or crocodile attack and powerboat injuries can result in massive tissue damage and severe blood loss. The following general treatment applies (specific information is contained within the SLSA training manual):

- Bring the patient to the beach as quickly as possible.
- Apply immediate first aid.
- Inform SurfCom / request Ambulance of them
- Co-ordinate pre-hospital emergency care.
- Follow precautions outlined in ‘Actions on Sightings’.
- SurfCom to Contact the Branch and SLSNSW Duty Officer who will advise
- appropriate authorities (i.e. Department of Primary Industries) and activate
- NSW Shark Safety Plan.
- Record as much detail regarding the incident as possible.

Appendix 5 cont. - Shark Control Program, LS 10.4

SHARK CONTROL PROGRAM

No: LS 10.4

Section: C

Date: 1st August 2006 **Page:** 1 of 3

Purpose

This document provides information relating to the recognition of and the overcoming of risks associated with deployment of a shark control program into the region of operations.

This policy aims to:-

- Help identify existing and potential health and safety issues.
- Raise the overall awareness of hazard identification and risk reduction.
- Assist in establishing risk management procedures.

The Shark Control Program

The NSW Department of Primary Industries shark control program consists of placing equipment which consists of nets, which are used according to the location of the beach, its environment, sea bed topography or local sea conditions.

Shark control equipment is aimed at limiting the contact between sharks and humans. Sharks are not prevented from entering a protected area; however the positioning of shark control equipment is believed to limit the presence of large sharks that may be a threat to humans.

SLSNSW supports the shark control program through the NSW Shark Safety Plan. SLSNSW is the author of the NSW Shark Safety plan and the SLSNSW Operations Manager (Lifesaving and Education) monitor issues relating to the shark control program across the state and make suggestions on the future direction of the program with the DPI.

Definitions

For the purposes of this document the term shark control program encompasses all equipment deployed by the NSW Department of Primary Industries, equipment at this time includes shark nets.

Rogue equipment is the term used to describe equipment from the shark control program including, but not restricted to, nets, lines, buoys and hooks that has moved from its site, in particular if the equipment is in a location that may present a hazard to people.

Appendix 5 cont. - Shark Control Program, LS 10.4 cont.

"Rogue" Equipment

In the event of "rogue" equipment being identified the following procedures shall be followed:-

- Undertake ‘Emergency Closing of Water Areas Procedure’
- Do not move or retrieve the equipment.
- SurfCom (or similar) is to contact the SLSNSW Duty Officer, who will call the DPI Shark Incident Officer.
- Record as much detail regarding the equipment as possible.

Entrapment of non-target species

From time to time other types of marine life may get caught in the shark control equipment. In the event of any non-target species being identified as caught in the shark control equipment and still alive the following procedures may be applied:

1. In the first instance the SLSNSW Duty Officer is to be contacted. He/she will be responsible for contacting the NSW DPI Shark Incident Officer

In the rare case the NSW DPI may request for assistance from the Surf Life Saving Club or Support Services. If this is the case, the following procedures must be followed:

- Control of the procedure is under the NSW Department of Primary Industries
- Only animals that are alive are to be released.
- A live animal trapped in a drum line and not penetrated by a hook may be released.
- If a net is cut or damaged in any way while releasing an animal, contact the DPI so that the net can be repaired ASAP.
- The set position of any fishing apparatus must not be altered in any way.
- Only suitably qualified and competent lifesavers should participate in operations involving IRBs, RWC’s, JRB’s or ORBs. The occupants of any craft are generally advised to remain within the confines of the hull when attempting to remove an animal.
- Notify the NSW DPI (through SurfCom) of the release of the animal and give details of the following:
    - Type of fishing apparatus animal released from
    - Location of fishing apparatus
    - Species of animal and/or description
    - Released alive or dead
    - If tagged, the tag number
    - If meshed in a net the location of in the net (inside = nearest the beach / outside = offshore of the net)
    - Any damage to fishing apparatus

Appendix 5 cont. - Shark Control Program, LS 10.4 cont.

Animals Coming Ashore

- In the event of any dead sharks that come ashore contact the SLSNSW Operations Manager (Lifesaving and Education) who shall liaise with the NSW DPI Shark Incident Officer

- In the event of any live or dead animals (specifically turtles, whales, dolphins, seals and dugongs) that come ashore contact the NSW Marine Parks.

Personal Safety

At all times safety to craft operators (lifesavers) and the public is to be considered the priority, while concern for the animal is warranted no actions should be taken that may expose the operators or the public to risk of injury.

Further Advice and Information

If you require further advice or assistance please contact Surf Life Saving NSW.

Appendix 5 cont. - Shark Control Program, LS 7.8

EMERGENCY CLOSURE OF BEACHES

No: LS 7.8

Section: C

Date: 1st August 2006 **Page:** 1 of 2

Purpose

Lifesavers and Patrol Captains are required to assess the conditions that present to them and determine if closing the beach (aquatic area) is an appropriate option. The aim of this guideline is to assist Patrol Captains by providing guidelines to determining their options and acting upon their decisions in a safe and efficient manner.

Processes

Lifesavers should consider closing the beach at any time that there is an unacceptable risk to the public or the patrol of injury, illness, substantial distress or at any time that the patrol is over committed and/or is unable to effectively perform water safety tasks.

The following are specific conditions under which beach closure may be considered (this list should not be considered to be exclusive):

Surf Conditions:	Heavily Dumping Surf
	Large Surf
	Rips/Strong Currents
	Debris
Marine Life:	Marine Stingers
	Sharks
	Crocodiles
Human Hazard:	Uncontrolled surf craft infringements
	Powercraft hazards
	Civil disturbance (public unrest, criminal activity)
	Equipment in surf/swimming area (lines, netting, buoys, etc.)
Weather:	Lightning
	Hail
	Cyclonic conditions
	Tsunami Warning
Chemical Hazard:	High Pollution Levels
	Chemical Spill
	Oil/Petrol Spills
	Biological Agent(s)
Other:	Dangerous Objects such as munitions
	Suspicious packages

Appendix 5 cont. - Shark Control Program, LS 7.8 continued

Procedure

Should the prevailing conditions warrant the closing of a beach, the local laws or regulations of the relevant authority where applicable, are to be applied.

The most senior person is to control the operation; patrols should conduct the operation in a firm but courteous manner in a way that will not unduly alarm the public.

Emergency Closing of Beach Procedure

1. Determine if water area is to be evacuated
2. Inform SurfCom that you about to close the beach
3. Activate the Emergency Evacuation Alarm
4. Inform everyone of the following: -
   - Water area is being closed
   - Reason for closure
5. Lower and remove the Red and Yellow flags
6. Raise Emergency Evacuation Flag (Red and White Quartered)
7. Remove all other flags
8. Post ‘Swimming Prohibited’ signs at identified beach access points
9. Continually monitor all areas
10. Maintain Lifesaver presence on-beach to advise/warn public.
11. An appropriate record should be made giving an outline of the incident.

Closure Periods

Generally the beach will remain closed until such time as the identified hazard is controlled or no longer presents a risk.

Recommended closure periods include:

- Crocodile - 72 hours from last confirmed sighting.
- Shark - Minimum 60 minutes from last confirmed sighting (or completion of search).
- Chemical Hazards - After confirmation from appropriate authorities that the area is safe.
- Dangerous Tropical Jellyfish – Until the following day and following a clear drag.

Reopening Procedure

Once it is determined that it is safe to reopen the beach then normal patrol procedures should be re-established under the direction of the senior responsible person. It is important to continue to inform the public of the patrols activities.

Appendix 5 cont. - Shark Control Program, LS 7.8 continued

SURF LIFE SAVING AUSTRALIA
SHARK REPORT LOG

Name of Service: ________________________

State: ________________________

Date: _____/_____/_______ **Time:** ___________ **am/pm** **Location of Shark:** ______________________________ **ABSAMP Beach Number:** _________ **Ocean:** ________ **Longitude and Latitude:** ______________ ___________	**Conditions at time of Incident:** **Wind:** _ Calm _ Slight _ Moderate **Weather:** _ Fine _ Overcast _ Rain **Seas:** _ Small _ Medium _ Large **Water Surface:** _ No Chop _ Avg Chop _ Large Chop **Water:** _ Salt _ Fresh _ Brackish **Water Temp:** _____ **C Tide: High**________ **Low**

Shark Identification:

Type: (If known)___________________
Length (approx) _____________m
Width (approx) ______________m

Main Colour
_ Light Grey _Dark Grey
_ Light Brown _Dark Brown
_ Spotted _Striped
_ Lumps _Patterns

Fin Colour (Tick twice if Tip of Fin)
_ _ Light Grey __ Dark Grey
_ _ Light Brown __ Dark Brown
_ _ Pink __ Black
_ _ White __ Purple

Snout:
_ Long _ Short
_ Narrow _ Pointed
_ Rounded _ Blunt
_ Flared Nostrils
_ Blade Like _ Triangular
_ Broad _ Conical
_ Hammer
_ Other________________________

Dorsal Fins (On the Back)
_ First Fin _ 2nd Fin (if valid)
_ Long _ Long
_ Short _ Short
_ Narrow _ Narrow
_ Pointed _ Pointed
_ Tall _ Tall
_ Spike _ Spike
_ Curved _ Curved
_ Pointy _ Pointy
_ Broad _ Broad

Pectoral Fins (On the Side)
_ Long _ Short
_ Narrow _ Pointed
_ Tall _ Spike
_ Curved _ Pointy
_ Broad

Tail
_ Long _ Short
_ Narrow _ Pointed
_ Rounded _ Blunt
_ Very Long _ Tall
_ Moon Shape _ Non Existent
_ Rounded _ Blunt
_ Blade Like _ Triangular

Sightings:
Number of Sharks: 1 2 3-5 5+

Traveling:
_ North _ South
_ East _ West
_ Circling _ Stationery

Water Clarity:
_ Clear _ Murky
_ Muddy _ Bait Fish

Distance from Shore:
_ 0-10m _ 10-50m
_ 50-100m _ 100-500m
_ 500m +

Beach Area Provisions
_ Emergency Evacuation Alarm
_ Emergency Evacuation Flag
_ Beach Closed

Swimmers in the area
_ 0-20 _ 20-50
_ 50-200 _ 200-500
_ 500 +

Board riders in the area
_ 0-20 _ 20-50
_ 50-200 _ 200-500
_ 500 +

Boats in the area
_ 0-5 _ 5-10
_ 10-15 _ 15-20
_ 20+

Divers in the area
_ 0-5 _ 5-10
_ 10-15 _ 15-20
_ 20+

Who first sighted the shark?
e.g. Lifesaver __________________
Person Completing the Form:
Name: ______________________
Contact Details:__________________
____
Signature:_____________________

IF THERE IS A SHARK ATTACK PLEASE COMPLETE THE NEXT SECTION AND PAGE

Victims details: M / F

Name: __________________________

Age: _____ **D.O.B.** _____/_____/_____

Weight: _____kg **Height:** _______m

Address:________________________
____
Contact Details: ________________
____

Race:
_ Caucasian
_ Negroid
_ Mongolian / Oriental
_ Malayan / Polynesian
_ Middle Eastern
_ Indigenous

Main Language Spoken
___________________ or _ English
_ Non English Speaking _ Unknown

Clothing (and accessories) worn:
_ Wetsuit (Full Length)
_ Wetsuit (Half Length)
_ Swimmers _ Shorts
_ Long Pants _ Waders
_ Wet Shirt _ T-Shirt
_ Flippers _ Shoes/Sandals
_ Face Mask _ Snorkel
_ Oxygen Bottle _ Leg/arm rope
_ Gloves
_ Jewellery ____________________
_ Shark Deterrent _______________
_ Other: _______________________

Victim is:
_ International Visitor
_ Local Resident
_ Interstate Visitor
_ Intrastate Visitor
_ With Tour Group
_ Tour Operators
_ Boating Crew
_ Lifesaver/Lifeguard
_ Professional Fisherman
_ Recreational Fisherman
_ Diver
_ Diving Instructor
_ Camera Operator
_ Other _______________________

Appendix 5 cont. - Shark Control Program, LS 7.8 continued

SURF LIFE SAVING AUSTRALIA
SHARK REPORT LOG - Shark Attack

Shark behaviour prior to initial strike:
_ Circling victim
_ Following victim closely
_ Shark in position between victim and barrier or obstacle/beach/reef/boat, etc.
_ Shark not seen at all prior to contact with victim
_ Straightaway approach to victim
_ Straightway approach to victim, passed other(s) in water
_ Swimming erratically
_ Swimming normally
_ Behaviour unknown

Shark behaviour at time of initial strike:
_ Attack did not occur in water
_ Shark did not contact victim
_ Minimum of turmoil, victim initially unaware of situation
_ Sudden violent interaction between shark and victim
_ Behaviour unknown

Shark behaviour during subsequent strikes:
_ Attack did not occur in water
_ Shark made only one strike
_ Shark made multiple/repeated deliberate strikes
_ Frenzied behaviour
_ Released initial hold, quickly bit victim again
_ Behaviour unknown

Shark behaviour after final strike:
_ Attack did not occur in water
_ Shark remained attached to victim and had to be forcibly removed
_ Shark remained in immediate area of attack
_ Shark followed victim/rescuers towards shore
_ Shark seen to leave area of attack
_ Shark not seen after final strike
_ Shark remained attached to victim after final strike, released hold without use of force by victim/rescuer(s)
_ Behaviour unknown

Depth at which attack occurred:
_ Surface
_ 0-5m below surface
_ 5-15m below surface
_ 15-50m below surface
_ 50m + below surface

Type of activity at time of incident:
_ Swimming/wading
_ Floating
_ Erratic Splashing
_ Standing in Water
_ Body Boarding
_ Rock Fishing
_ Boat Fishing
_ Recreational Boat Use
_ Water Skiing
_ SCUBA / skin diving
_ Free diving
_ Pearl diving
_ Hard Hat diving
_ Wind/kite surfing
_ Surfing
_ Sailing
_ Patrolling in Craft (Rescue)
_ Attempting a rescue
_ Training
_ Water Safety
_ Filming
_ Entering water
_ Leaving water

Fishing activity by victim
_ Fish being hooked
_ Fish being netted
_ Spear fishing
_ Carrying/holding fish
_ Other________________________

Experience in activity:
_ No Experience
_ 1 year (or less)
_ 1-3 years
_ 3+ years

General Activity of other near victim
_ Same as victim
_ Normal bathing
_ Splashing/horseplay
_ Diving under water activities
_ Wading
_ Unusual loud noises
_ Surfing (of any type)
_ Other ______________________

Fishing activity by others near victim
_ Fish being hooked
_ Fish being netted
_ Spear fishing
_ Carrying/holding fish
_ Other________________________

Nature of Injury:
_ Abrasion/graze
_ Laceration/cut
_ Bruise/contusion
_ Swelling
_ Severe blood loss
_ Amputation
_ Dislocation
_ Concussion
_ Closed Fracture
_ Open Fracture
_ Cardiac problem
_ Respiratory problem
_ Loss of consciousness
_ Deceased (body with shark)
_ Deceased (after)

Body region injured

Initial Treatment
_ None given – not required
_ None given – patient refused
_ None given – referred elsewhere
_ Cleaned
_ Dressed (Bandage)
_ Sling/Splint
_ Stitches
_ Tourniquet
_ Analgesics
_ Ice

Resuscitation
(Please complete Part B of SLSA Resuscitation Report Form)
_ CPR
_ Oxygen Therapy
_ Airbag
_ Defibrillation

Treatment & Referral
_ No referral
_ Lifesaver/Lifeguard
_ Medical Practitioner
_ Hospital
_ Peer Support
_ Professional Counselling
_ Ambulance Transport to:
____

Other Services
_ Primary Industries/Fisheries
_ Police
_ Helicopter
_ ORB/JRB
_ RWC

A6 Extent & gear of Queensland's Shark Control Program

As of March 2006 (QDPIF 2006)

Region	Beach	Gear
Cairns	Ellis Beach	1 net; 5 drum lines
	Buchans Beach	2 drum lines
	Palm Cove	1 net; 7 drum lines
	Clifton Beach	1 net; 2 drum lines
	Trinity Beach	1 net; 3 drum lines
	Yorkeys Knob	1 net; 2 drum lines
	Holloways Beach	3 drum lines
	Total	5 nets; 24 drum lines
Townsville	Picnic Bay	5 drum lines
	Nelly Bay	9 drum lines
	Alma Bay	6 drum lines; 3 drum lines
	Florence Bay	5 drum lines
	Radical Bay	5 drum lines
	Horseshoe Bay	12 drum lines
	Palarenda Beach	3 drum lines
	Kissing Point	6 drum lines
	Total	54 drum lines
Mackay	Harbour Beach	2 nets; 9 drum lines
	Lamberts Beach	6 drum lines
	Blacks Beach	6 drum lines
	Eimeo Beach	1 net (net rotated for 6 drum lines in turtle season September to March each year)
	Bucasia Beach	2 nets; 6 drum lines
	Total	5 nets; 27 drum lines
Rockhampton	Emu Park	6 drum lines
	Fisherman's Beach	6 drum lines
	Tanby Beach	5 drum lines
	Mullambin Beach	5 drum lines
	Kemp Beach	6 drum lines
	Lammermoor Beach	10 drum lines
	Cooee Bay	6 drum lines
	Yeppoon Beach	5 drum lines
	Farnborough Beach	5 drum lines
	Total	54 drum lines
Tannum Sands	Tannum Sands	12 drum lines
	Total	12 drum lines
Bundaberg	Oak Beach	2 drum lines
	Neilson Park	6 drum lines
	Bargara Beach	3 drum lines
	Kelleys Beach	9 drum lines
	Total	20 drum lines
Rainbow Beach	Rainbow Beach	3 nets; 12 drum lines
	Total	3 nets; 12 drum lines
Sunshine Coast	Noosa	2 nets; 3 drum lines
	Sunshine Beach	3 drum lines
	Sunrise Beach	3 drum lines
	North Peregian	3 drum lines
	Glen Eden Beach	3 drum lines
	Peregian Beach	3 drum lines
	Coolum Beach	1 net

Appendix 6 cont.

Region	Beach	Gear
Sunshine Coast	Yaroomba Beach	4 drum lines
	Hyatt Resort	4 drum lines
	Marcoola Beach	1 net
	Surfair Resort	4 drum lines
	Mudjimba Beach	4 drum lines
	Twin Waters Resort	4 drum lines
	Maroochydore	2 net
	Alexandra Headland	2 nets
	Mooloolaba	1 net
	Point Cartwright	3 drum lines
	Buddina Beach	6 drum lines
	Wurtulla Beach	1 net
	Currimundi Beach	4 drum lines
	Moffat Beach	3 drum lines
	Caloundra Beach	1 net; 6 drum lines
	Bribie Island	18 drum lines
	Total	11 nets; 78 drum lines
Point Lookout	Amity Point	4 drum lines
	Cylinder Beach	12 drum line
	Ocean Beach	12 drum lines
	Total	28 drum lines
Gold Coast	Sheraton Mirage	5 drum lines
	Main Beach	1 net
	Narrowneck	2 drum lines
	Staghorn Avenue	2 drum lines
	Elkhorn Avenue	2 drum lines
	Surfers Paradise	1 net
	Northcliffe	3 drum lines
	Broadbeach	2 drum lines
	Kurrawa Beach	1 net
	Mermaid Beach	1 net
	Nobby's Beach	2 drum lines
	Miami Beach	1 net
	North Burleigh	2 drum lines
	Burleigh Beach	1 net
	Tallebudgera Beach	1 net
	Palm Beach	2 drum lines
	Currumbin Beach	1 net
	Tugun Beach	3 drum lines
	Bilinga Beach	1 net
	Kirra Beach	2 drum lines; 1 net
	Coolangatta Beach	1 net
	Greenmount	2 drum lines
	Rainbow Bay	6 drum lines
	Total	11 nets; 35 drum lines
	Grand Total	**35 nets; 344 drum lines**

A7 Analysis of Shark Attacks within the NSW Shark Meshing Program during the 2008-2009 Meshing Season

1. Context

Three highly publicised shark attacks occurred during the 2008-2009 shark meshing season at Garden Island (Sydney Harbour), Bondi Beach and Avalon Beach. The attacks occurred within 3 weeks (19 days) of one another and resulted in intense media coverage and public interest.

The timing of the attacks coincided with the planned exhibition of the Report into the NSW Shark Meshing (Bather Protection) Program (SMP) and Joint Management Agreements for the Management of the NSW Shark Meshing (Bather Protection) Program. In response to the community and media interest in the attacks, the public exhibition of the documents was postponed to allow the preparation of an analysis of the attacks, and to update shark attack statistics within the report to include all NSW attacks until 13 March 2009.

This analysis has been developed in response to community concern about the attacks. In the past reviews of this nature following non-fatal shark attacks have not been prepared. However, in the future, the new management arrangements for the shark meshing program will establish formal review processes if a performance indicator relating to human fatalities or serious injuries is triggered, such as these recent attacks.

2. Background

The SMP operates on 51 ocean beaches between Stockton Beach (near Newcastle) and South Wollongong Beach. The program is limited to ocean beaches, and does not operate within estuaries, channels, harbours or ports. Accordingly this analysis is focussed primarily on the attacks that occurred at Bondi and Avalon beaches as both of these are meshed as part of the SMP.

Summary details of the Garden Island incident will be presented, however that incident is currently the subject of a formal Navy inquiry and it is not intended for this analysis to duplicate or pre-empt any outcomes from that inquiry.

The provision and maintenance of meshed swimming enclosures within estuaries and harbours, and the provision and maintenance of ocean baths adjacent to some rocky headlands and beaches are the responsibility of local councils.

3. Garden Island, Sydney Harbour, 11 February 2009

3.1 Overview

The first attack occurred in Sydney Harbour on 11 February 2009 at approximately 6:55 am on a person swimming during naval exercises on the western side of Garden Island between Fleet Base South wharves and the Woolloomooloo Finger Wharf. The victim was swimming on the surface within open waters when the attack occurred. Substantial damage to the victim's upper right leg and right hand occurred during the attack, resulting in partial amputation of both limbs.

3.2 Species implicated in the attack

NSW DPI scientists inspected part of the victim's wetsuit and concluded that a bull shark (*Carcharhinus leucas*) of between 2.7 and 2.8 metres in length was most probably responsible for the attack after analysing tooth imprint shape, overlap and separation distances. Subsequent review of wound photographs reaffirmed the probable species and size.

3.3 Biology, ecology and distribution of bull sharks

Bull sharks, also known as river whalers or freshwater whalers are large, stout bodied sharks that attain a maximum size of approximately 340 cm. The species is widely distributed in tropical and warm temperate seas and in Australia occurs around the northern coast from Sydney to Perth.

Bull sharks have wide water quality tolerances, can occupy marine, estuarine and freshwater habitats, and have a preference for shallow, murky inshore habitats (Last and Stevens 2009). The species is omnivorous with a diet that includes turtles, birds, dolphins, terrestrial mammals, fish, rays and other sharks. Bull sharks are very dangerous due to their aggression, powerful jaws, dietary tolerance and habitat preference (Last and Stevens 2009). This species is probably responsible for most of the historical attacks in and around Sydney Harbour (Last and Stevens 2009) and is suspected of most historical attacks within canal estates in south-east Queensland. A bull shark was also suspected in the last fatal shark attack in Queensland at Amity Point, North Stradbroke Island in 2006, and in NSW at Lighthouse Beach, Ballina in 2008.

The abundance of bull sharks in Sydney Harbour and other NSW waters is unknown but they are thought to be more abundant at the southern limits of their distribution during the warmer summer and autumn months. Since 11 February 2009, at least three bull sharks have been positively identified to species level following capture in Sydney Harbour and a further three have been taken on ocean beaches in the SMP, confirming the species presence in the region around the time of the attack. since 11 February 2009.

3.4 Ongoing investigations

The Garden Island incident is subject to a formal inquiry by the Navy. NSW DPI will assist in any manner requested. Given the Navy's continued investigations, this incident will not be discussed further in this document. NSW DPI will seek Navy advice after the inquiry is complete for the purposes of information transfer.

4. Bondi Beach, 12 February 2009

4.1 Background

Bondi Beach is one of the most popular Sydney beaches. On 12 February 2009 at about 7:30 pm a male surfer was attacked by a shark at the southern end of Bondi Beach (Figure 1). The victim's left hand was almost severed from a bite through the wrist, eventually resulting in amputation.

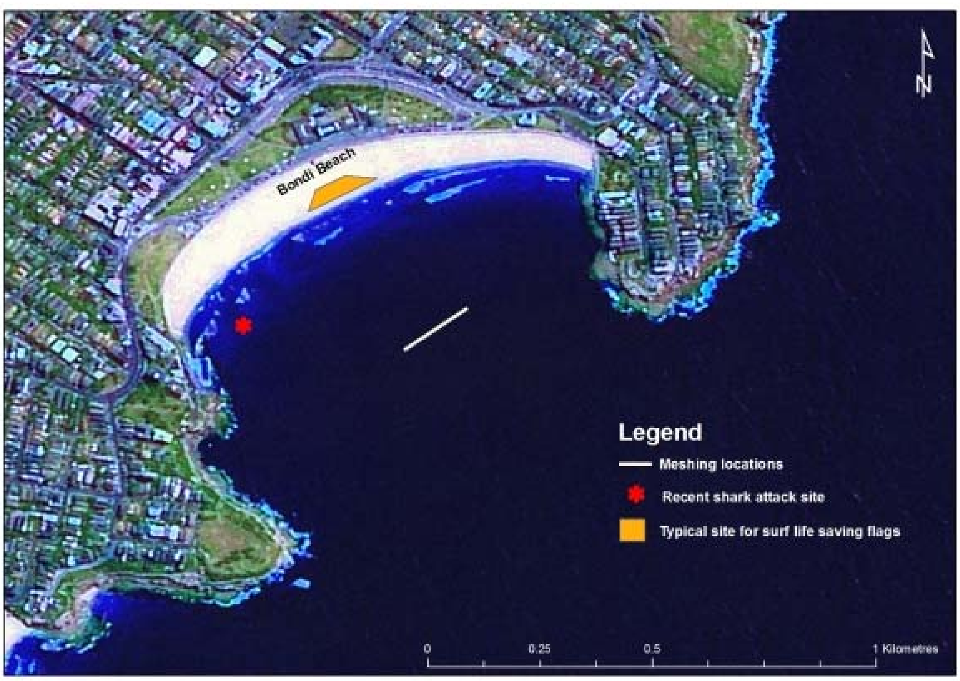

Figure 1 - Indicative position of the Bondi Beach shark net and attack site.

4.2 Species implicated in the attack

NSW DPI scientists reviewed photographs of the injury and characteristics of tooth impressions on the upper forearm and wrist region. The injuries suggest that a white shark was responsible for the attack. Inter-tooth and jaw width measurements suggest the shark was approximately 2.5 m in length.

4.3 Biology, ecology and distribution of white sharks

The white shark (*Carcharodon carcharius*), also known as the white pointer, great white shark, or white death, are large, moderately stout torpedo-shaped sharks, coloured grey to grey-brown on the upper surface and white below. They have large, serrated triangular teeth, very small second dorsal and anal fins, and a distinct keel before the broad crescent-shaped tail. They have large, serrated triangular teeth, very small second dorsal and anal fins, and a distinct keel before the broad crescent-shaped tail. They are closely related to mako sharks but can be distinguished by their grey-brown (rather than blue) colour dorsally, dusky tips on the white underside of their pectoral fins and that mako sharks are less robust for the same size and have non serrated, slender teeth.

White sharks occur world-wide, primarily in coastal temperate and subtropical regions but they are also visitors to tropical areas (Bruce 2008). In Australian waters they have been recorded from southern Queensland to northwest Western Australia, but may occur further north on both coasts (Last and Stevens 2009).

White sharks measure around 120 - 150 cm at birth and are believed to grow to at least six metres in length, although there are unconfirmed reports of individuals up to seven metres. Males mature at 3.6 - 3.8 m (7 - 9 years) and females at 4.5 - 5.0 m (12 - 17 years) (Bruce 2008).

White sharks can be found from close inshore around rocky reefs and surf beaches to outer shelf and slope areas. However, they can make open ocean excursions, can cross ocean basins and both adults and juveniles have been recorded diving to depths of 1000 m (Bruce and Bradford 2008; Weng et al. 2007). Juvenile white sharks can sometimes occur very close to shore in surf zones. Recent tracking work by CSIRO (and supported by NSW DPI) has shown that juveniles in the Port Stephens region move frequently between the shore and the 100 - 120 m depth zone some 10 - 15 km offshore. These juveniles are only temporary residents in the region and have been tracked as far north as Fraser Island (Qld), south to eastern Bass Strait and northern Tasmania and across the Tasman Sea to New Zealand (Bruce and Bradford 2008).

White sharks do not live in one area or territory but travel great distances. In Australia, adult white sharks tagged in South Australia have travelled as far north as Exmouth Gulf in Western Australia and Rockhampton in Queensland with individuals subsequently returning to South Australia during the course of a year (Bruce et al. 2006).

White sharks are versatile predators that feed primarily on fish, rays and other sharks as juveniles (< 3 m). White sharks larger than three metres in length start adding larger prey to their diet for example marine mammals such as seals, dolphins and dead whales, although even large adult white sharks will still feed on fish such as salmon, jewfish and snapper (Bruce 2008, Malcolm et al. 2001).

White shark populations have significantly declined globally, and the species is now fully protected in NSW and listed as a threatened species (vulnerable) under both the NSW *Fisheries Management Act 1994*, and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

4.4 Geographic features

Bondi Beach is a south-easterly facing beach at the head of an embayment located in the eastern suburbs of Sydney. The beach is located in Waverley Council, and is approximately 6.5 km south of the entrance to Sydney Harbour. Bondi Beach is the most northerly of the eastern suburbs beaches. The coastline to the north of Bondi Beach consists of rocky shoreline and cliffs until the Sydney Harbour entrance. The beach describes an arc approximately 900 metres long.

4.5 Environmental conditions

The Bondi attack occurred in the late afternoon. Meteorological records from Sydney weather observation stations on 12 February 2009 show that the temperature was 21.4^{o}C at 3 pm with winds south-south-east at 31 km/h. The barometric pressure was 1018.7 hPa. On the day of the attack there was 0.6 mm of precipitation. In the preceding days there was 3.4 mm and 5.6 mm on Tuesday 10 and Wednesday 11, respectively. Sunrise was at 6:01 am and sunset occurred at 8:18 pm.

Tidal movements are shown in Table 1. The attack occurred during a falling tide. Media coverage of the incident included accounts suggesting that the waters in the vicinity of the attack were “teeming with bait fish” and that the water was “full of little fish and shredded pieces of jellyfish” (Sydney Morning Herald 16 February 2009).

Table 1 - Tidal movements – 12 February 2009 (Fort Denison)

Tidal movements	
Time (AEDST)	**Height (m)**
04:54	0.30
11:10	1.77
17:31	0.23
23:42	1.56

4.6 History of shark attack at Bondi Beach

Review of the Australian Shark Attack File (ASAF) indicates that there have been 8 unprovoked shark attacks at Bondi Beach including 2 fatal and 6 non-fatal attacks since records have been kept, with the first recorded attack occurring in 1928 (Table 2).

Table 2 - Summary of all unprovoked shark attacks at Bondi Beach 1928 - 2009

Date	Time	Activity	Injury	Suspected species	Comments
14/04/1928	16:00	Swimming	Leg - left calf	Unknown	
12/01/1929	18:30	Swimming	Fatal - major trauma to right thigh	Unknown	
8/02/1929	16:00	Swimming	Fatal - major trauma to right thigh	Unknown	
01/01/1936	N.R.	Surf ski	Uninjured	White shark	
01/02/1951	N.R.	Swimming	Leg	Unknown	
27/11/1960	N.R.	Swimming	Injured	Unknown	
15/03/2006	16:20	Surfing	Uninjured	Bronze whaler	Baitfish reported in vicinity
12/02/2009	19:30	Surfing	Loss of left hand	White shark	Baitfish reported in vicinity

4.7 Operation of the SMP at Bondi Beach

Bondi Beach has been meshed as part of the SMP since the commencement of the program in 1937. The Bondi mesh net is sited approximately 500 m off the beach in approximately 12 m depth of water. The indicative location of the net is shown in Figure 1. The shark meshing contracts currently require that a minimum of 10% and a maximum of 30% of meshings constitute “double sets”. A double set meshing involves the placement of 2 nets end to end forming a 300 metre long net. On the date of the attack, the mesh nets at Bondi Beach were single set.

A review of catch data from the SMP over the last decade to 2007/08 shows that the Bondi mesh nets have accounted for 5 potentially dangerous sharks (target species) and 23 non-dangerous sharks (non-target species) (Table 3). Target species are whaler sharks (including bull and tiger sharks), white sharks, mako (shortfin) sharks, and broad-nosed seven-gill sharks. Non-target species include hammerheads, Port Jackson shark, grey nurse shark and angel sharks.

A review of February catches for the same period (1998/99 – 2007/08) shows that the Bondi mesh net has not accounted for any target species of dangerous sharks in January or February, but has caught 1 whaler shark in March over the decade long period.

Table 3 – Shark captures 1998/99 - 2007/08 – Bondi Beach nets

Meshing Season	Date	Common Name	Length (m)	Target species
1998/99	25-Apr-99	Whaler	3.7	Yes
1999/00	06-Dec-99	Tiger	3	Yes
	21-Feb-00	Hammerhead	5.5	No
	27-Mar-00	Angel	0.9	No
2000/01	20-Sep-00	Port Jackson	1	No
	20-Sep-00	Port Jackson	1.2	No
	11-Jan-01	Hammerhead	1.3	No
2001/02	11-Mar-02	Hammerhead	3.2	No
2002/03	16-Sep-02	Grey nurse	2	No
	25-Nov-02	Angel	1	No
	12-Dec-02	Grey nurse	1.34	No
	30-Dec-02	Hammerhead	1.3	No
	20-Jan-03	Hammerhead	1.3	No
	26-Mar-03	Hammerhead	1.6	No
	13-Apr-03	Angel	1	No
2003/04	24-Sep-03	Port Jackson	0.7	No
	10-Dec-03	Hammerhead	1.1	No
	24-Dec-03	Angel	0.9	No
	27-Apr-04	Tiger	3.2	Yes
2004/05	27-Sep-04	Angel	0.95	No
2005/06	19-Sep-05	Angel	1.1	No
	15-Nov-05	Angel	1	No
	15-Nov-05	Port Jackson	0.93	No
	15-Nov-05	Angel	1	No
	06-Dec-05	White	1.9	Yes
2006/07	02-Oct-06	Grey nurse	3	No
2007/08	20-Dec-07	Grey nurse	2.87	No
	18-Mar-08	Whaler	2.7	Yes

4.8 Other Bather Safety Measures

Waverley Council provides professional lifeguards at Bondi Beach. The service operates 7 days a week, 365 days/year. Bondi Beach is patrolled by Council lifeguards from 6 am – 7 pm each day in summer. In addition to the Council provided lifeguard service, volunteer patrols by the Bondi Surf Bathers' Life Saving Club also occur on weekends. Bondi Beach was not patrolled at the time of the attack however off-duty lifeguards were still in the vicinity. The popular nature of Bondi Beach and its close proximity to emergency and medical services contributed to a rapid emergency response.

Lifeguards have a range of complimentary measures to the SMP, including establishing safe swimming “flagged” areas, use of temporary signage warning of hazards, use of shark alarm sirens, loudspeakers, and deployment of jet skis and rigid inflatable boats.

Permanent signage advising on ways to reduce the risk of shark attack is not present at Bondi Beach. Beach safety advice is provided on the websites of Waverley Council, the Bondi Surf Bathers’ Life Saving Club, Surf Life Saving NSW and Surf Life Saving Australia. In addition, Surf Life Saving Australia and affiliated surf life saving clubs run a range of beach safety initiatives and provide shark fact sheets (http://www.slsa.asn.au/site/_content/resource/00000348-docsource.pdf). The fact sheet provides information to identify risk factors and actions to reduce the risk of incidents. The information is available online and in hardcopy.

NSW DPI provides advisory materials on ways to reduce the risk of shark attack (http://www.dpi.nsw.gov.au/fisheries/info/shark), and general information about the operation of the SMP (http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0014/101327/NSW-shark-meshing-program.pdf). Material is available online and in hard copy.

5. Avalon Beach, 1 March 2009

5.1 Background

The third attack occurred at the northern end of Avalon Beach (Figure 2) on 1 March 2009 at about 6:45 am, also on a surfer. The shark bit the victim’s shin and thigh, leaving lower jaw tooth imprints in the underside of the surfboard.

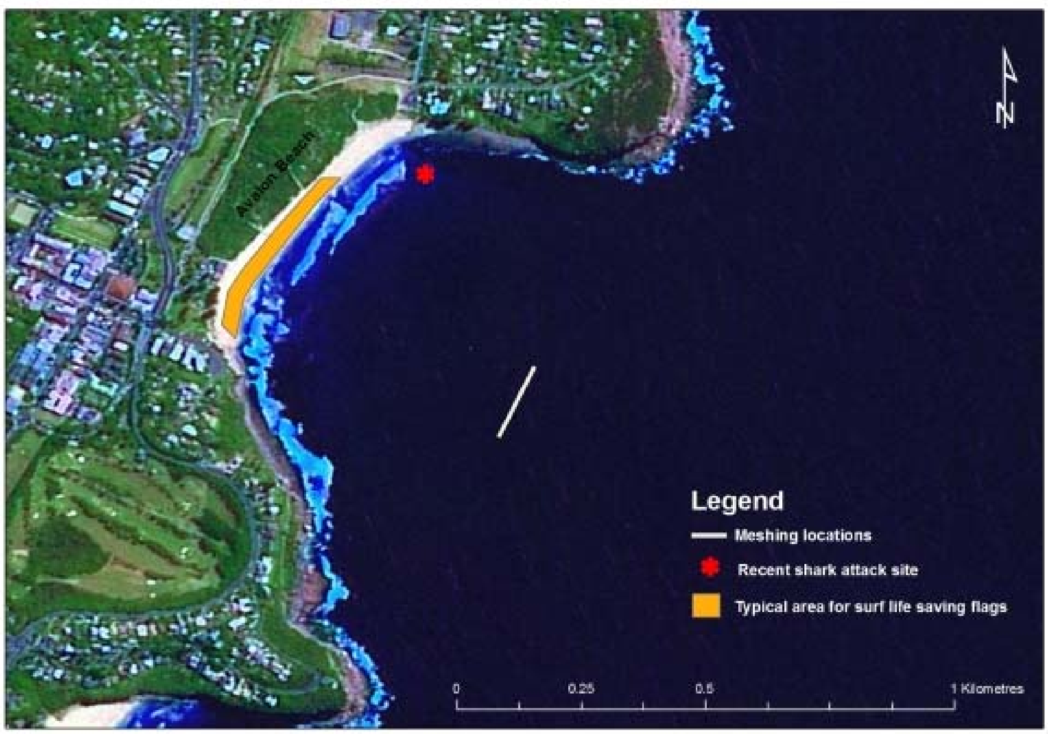

Figure 2 - Indicative location of the Avalon Beach shark net and attack site.

5.2 Species Implicated in the attack

NSW DPI scientists obtained access to the victim’s surfboard, wetsuit and photographs of the injuries. The bite marks in the wetsuit suggested that a white shark was probably responsible for the attack. Initial analysis of photographs of the bite wounds suggested the shark was larger than

2.5 m in length, and subsequent analysis of the tooth impressions from the underside of the surfboard reaffirmed that a 2.6 m white shark was probably responsible.

5.3 Biology, ecology and distribution of white sharks

Refer to section 4.3.

5.4 Geographic features

Avalon Beach is a south-easterly facing beach in Sydney's northern beaches district. The beach is located in Pittwater Council, and is approximately 6.5 km south of the entrance to Broken Bay. Avalon Beach is located between Whale Beach to the north, and Bilgola Beach to the south. The beach describes an arc approximately 600 metres long, and has an area of shallow rocky reef at the northern end extending parallel to North Avalon Point.

5.5 Environmental conditions

Meteorological records from Sydney weather observation stations on 1 March 2009 show that the temperature was 23.1^{o}C at 9 am with winds easterly at 9 km/h. The barometric pressure was 1010.7 hPa. No rainfall had been recorded on the day of the attack or the two days preceding the attack. Sunrise was at 6:17 am and sunset occurred at 7:58 pm.

A NSW DPI fisheries officer attended the scene at approximately 9 am on the day of the attack and observed that the water visibility was slightly reduced. The reef and sand line extending from the beach out along the headland towards North Avalon Point was not visible on the day (these features are normally visible when the water is clear).

A medium level of surf, chop and white water was present along the beach and a rip was observed working from the northern end of the beach and running parallel and adjacent to North Avalon headland.

Tidal movements on the day of the attack are shown in Table 4.

Table 4 - Tidal movements – 1st March 2009 (Fort Denison)

Tidal movements	
Time (AEDST)	**Height (m)**
05:50	0.41
11:54	1.47
17:58	0.40

5.6 History of shark attack at Avalon Beach:

Review of the ASAF indicates that prior to the attack on 1 March 2009, there had been no unprovoked shark attacks at Avalon Beach since records have been kept. The ASAF does list a provoked attack in March 1951 at Avalon, when a swimmer grabbed a wobbegong by the tail and was subsequently bitten on the chest.

5.7 Operation of the SMP at Avalon Beach

Avalon Beach has been meshed as part of the SMP since the commencement of the program in 1937. The Avalon mesh net is sited approximately 500 m off the beach in approximately 12 m of water (Figure 2). On the date of the attack, the mesh net at Avalon Beach was a single set.

A review of the catch data from the SMP over the decade 1998/99 – 2007/08 shows that the Avalon mesh nets have accounted for 3 potentially dangerous sharks (target species), and 6 non-dangerous sharks (non-target species) (Table 5).

A review of catches in the month of March for the same period (1998/99 – 2007/08) shows that the Avalon mesh net has caught 1 whaler shark (Table 5).

Table 5 – Shark captures 1998/99 - 2007/08 – Avalon Beach nets

Meshing Season	Date	Common Name	Length (m)	Target species
1998/99	28-Sep-98	Angel	1.2	No
1999/2000	24-Feb-00	Angel	1.3	No
	04-Apr-00	Hammerhead	1.7	No
2000/2001	26-Sep-00	Hammerhead	1.5	No
	14-Mar-01	Hammerhead	1.4	No
2002/2003	11-Mar-03	Whaler	2.8	Yes
2004/2005	16-Sep-04	Hammerhead	1.5	No
	14-Dec-04	White	2	Yes
2007/2008	15-Jan-08	Whaler	0.65	Yes

5.8 Other Bather Safety Measures

Pittwater Council employs lifeguards at Avalon Beach. The service operates between the hours of 9 am and 6 pm, 5 days a week (Mon – Fri) during Australian Eastern Daylight Time. Volunteer patrols by the Avalon Beach Surf Life Saving Club provide coverage during the same hours over the weekend. Avalon Beach was not patrolled at the time of the attack as it occurred prior to the commencement of the day's patrols.

Lifeguards have a range of complimentary measures to the SMP, including establishing safe swimming "flagged" areas, use of temporary hazard signage, use of shark alarm sirens, loudspeakers, and deployment of rigid inflatable boats. The lifeguards have the capacity to install temporary "blackboard" type signage in response to hazards such as rips, bluebottles, and sharks. Permanent signage advising on ways to reduce the risk of shark attack is not present at Avalon Beach.

Pittwater Council provides extensive beach safety advice on their website. This does not include general advice about ways to reduce the risk of shark attack, however Pittwater Council does post specific shark warning advices in response to some shark sightings e.g. Narrabeen Lagoon. See 4.8 above for other sources of advisory material regarding reducing the risk of shark attack.

6. Operational response to the attacks

6.1 Shark attack response plan

Operational response to shark attacks is undertaken on accordance with the NSW Shark Attack Response Plan. The plan is a working agreement between NSW DPI and the NSW Police Marine Area Command. The plan seeks to clarify the lines of responsibility and the procedures to be adopted in respect of shark-related incidents and to co-ordinate NSW Government responses to shark attack.

Development of the plan was a recommendation of the Shark Summit (2006) and was finalised in March 2008. The plan has been invoked several times since its adoption, including after the Garden Island, Bondi and Avalon attacks.

Under the plan, the NSW Police Force, with its wide deployment of officers and operational capacity to respond promptly to various public order disturbances and emergencies, assumes the lead agency role in respect of any shark-related incident posing a threat to life or limb.

NSW DPI manages the Shark Meshing Program but does not have a statutory role in beach surveillance or shark monitoring. Generally speaking, NSW Surf Life Saving and local government authority-funded lifeguards carry out beach surveillance and associated shark monitoring.

NSW DPI (in conjunction with Surf Life Saving NSW and local government) provides assistance to NSW Police in dealing with a shark attacks through the provision of:

- logistical support
- biological and technical advice
- special permit(s), if required for the capture or destruction of a specific shark which poses a serious and imminent threat to life.

The NSW Police Force has standard operating procedures (SOP's) for responding to shark attack (*Police response to shark attack*). The purpose of the SOP's is to define the guidelines in relation to Police investigations and evidence gathering after a shark attack, and to assist Police Commanders in decision-making (e.g. whether to consider capturing or destroying a shark responsible for an attack).

Aims of the Police procedures include:

- To determine if a Police response is required to a reported shark attack - and to guide how a response/investigation is conducted.
- To quickly determine the species and size of the shark to assess and minimise any ongoing threat to public safety – and to help formulate options and strategies under the Shark Attack Response Plan (if necessary).
- To promote accurate and timely information and identify pertinent evidence for the Coroner (and completion of the Coroner's Report) following a fatal attack.
- To assist relevant organisations with ongoing research about shark behaviour and the development of measures to improve responses to shark attacks.

In response to each of the recent attacks NSW DPI initiated the Shark Attack Response Plan to the extent that communication lines were quickly established and expert advice was conveyed to NSW Police to assist in decision-making and threat abatement.

After assessing the available information on each occasion it was determined by NSW Police, following advice from NSW DPI, that there was limited value in initiating a 'shark hunt'. Despite intense aerial surveillance by the media, private operators and Police the sharks involved in all three attacks were not positively sighted again. The chance of each animal being positively identified from the air was remote, particularly given visibility (dusk in the case of Bondi) and water quality (in the case of Garden Island and Avalon). Conducting a shark hunt following an attack has, in most circumstances, lost favour internationally as it is unlikely to catch the shark responsible for the attack and has potential to mistakenly kill other sharks.

6.2 NSW Government response

Following each of the attacks the Minister for Primary Industries, Ian Macdonald MLC provided numerous television and radio media interviews to remind the public of the risks (e.g. swimming at dusk and dawn, near schools of fish etc). In addition Minister Macdonald organised an audit of swimming enclosures in Sydney Harbour by NSW DPI fisheries officers to ascertain their general condition and wrote to all councils recommending they install shark warning signs at swimming entry points. Minister Macdonald also reminded all coastal councils which have swimming enclosures designed to exclude sharks of the importance of keeping the nets well monitored and maintained.

The Minister for Primary Industries engaged NSW DPI scientists to expedite research on sharks in the Sydney region (discussed below). More recently, the Minister for Primary Industries met with surf life saving organisations and NSW police to discuss shark attack risk reduction.

6.3 NSW DPI response

NSW DPI provided specialist shark biologist advice to quickly determine the species likely to be responsible for the attacks and provided media releases to keep the public apprised of what species of sharks may have been involved. The Department also provided information to the media to convey the safe swimming message and ways to reduce shark attack risks.

In response to the attacks, the NSW Minister for Primary Industries, Ian Macdonald MLC engaged NSW DPI scientists to expedite research on sharks in the Sydney region to assess their behaviours and movement patterns, particularly in Sydney Harbour.

The research involves catching sharks and tagging them with state-of-the-art acoustic tags. The tags give out an acoustic signal (for up to 5 years) which is detected by strategically located listening stations. NSW DPI and the Australian Acoustic Tracking and Monitoring System currently has a network of more than 180 of these listening stations along the NSW coast which are part of a national program of acoustic listening stations placed around Australia. Any of these stations are able to pick up signals from any tagged shark or fish that swims within range of the receiver. In recent weeks an additional 26 such stations have been deployed throughout Sydney Harbour to detect fine-scale movements of tagged sharks in the Harbour. When these animals move out to sea, the offshore array of listening stations will detect their movements.

The data from the listening stations will be downloaded to provide detailed movement patterns of sharks and identify whether there are particular "hotspots" or times of shark activity. The tagging is dangerous and specialised work that involves catching the sharks and surgically inserting the tag in the underside of the animal (Photo 1).

In addition to the work on sharks in Sydney Harbour, other species of dangerous and non-dangerous sharks have been tagged including grey nurse sharks, white sharks, bull sharks, dusky whalers, and a school shark as part of on-going NSW DPI research.

Photo 1 - A bull shark (2.8 m) being tagged in Sydney Harbour

7. Observations from the Bondi and Avalon attacks

7.1 The attacks at Bondi and Avalon beaches are both suspected to have involved juvenile white sharks approximately 2.5 – 2.6 m in length. There is no evidence to suggest that the same shark was involved in both attacks. Further, while there was intense media coverage and public interest in the series of attacks, the occurrence of multiple shark attacks within relatively short periods of time within the waters of the SMP is not exceptional. For example, review of the ASAF reveals there were 5 non-provoked attacks in Sydney between 7 February and 3 March in 2000.

7.2 Both attacks occurred on days when the shark nets were in place and operational and serves as a reminder that the nets do not create a physical barrier between bathers and sharks. Similarly, the nets are not an exclusion or separation device, and are not in place at all times. Sharks can, and do, move along and in and out of beaches despite the presence of nets.

Review of catch data indicate that dangerous sharks are occasionally caught off both beaches. Currently it is not possible to estimate how many dangerous sharks are not caught by the nets. On-going and future research on abundance, movement and distribution of dangerous sharks may provide an improved understanding of this in the future. However, comparison with recorded catches from the SMP since its inception suggests that the number of sharks has significantly declined. For example, approximately 88 sharks per month were taken on average in the Sydney region during the first 17 months of the SMP, declining to an average of approximately 6 sharks per month over the period 1990/91 – 2007/08.

7.3 Juvenile white sharks were implicated in both attacks (Bondi and Avalon). The diet of juvenile white sharks predominantly consists of fish, rays, and small sharks. White sharks do not generally begin to regularly prey on larger marine mammals until approximately 3 m or larger (Bruce 2008, Estrada et al. 2006, Malcolm et al. 2001). Notwithstanding this fact, even juvenile white sharks are capable of inflicting serious injuries.

Ultimately, the reason for each attack is unknown, however one possible scenario given the circumstances around both attacks, combined with the size and dietary preferences of the sharks involved is that the attacks occurred as part of “test and reject” behaviour, i.e. a theory amongst some shark scientists that white sharks take an initial bite on objects and decide whether or not to continue feeding. It follows that the majority of bites on humans are a one-off and that the shark subsequently swims away. Alternatively, a range of other behavioural characteristics or environmental factors could have contributed to the attacks.

7.4 Both attacks occurred within an hour of sunrise or sunset. However the significance of this fact warrants further analysis. Review of the ASAF reveals that attacks occur throughout the day and that many have occurred in the middle of the day and early in the morning. These figures may be more a reflection of the number of bathers in the water at those times than they are of shark behaviour. The species implicated in both attacks (white sharks) are known to feed during daylight hours and have been observed in surf zones during the middle of the day, sometimes in association with schooling fish, but often not.

The juvenile white sharks implicated in these attacks were likely to have been feeding on schools of baitfish, particularly in case of the Bondi attack. The association with dawn and dusk may be more reflective of the increased activity of prey species (i.e. baitfish) during these hours and dietary preferences of juvenile white sharks than any definitive link to increased predatory behaviour of white sharks at these times.

7.5 Reduced visibility was a factor in both attacks. Visibility is affected by light intensity which is reduced in near dawn and dusk conditions when the sun is low in the sky. In addition eyewitness reports suggest water clarity at Avalon was somewhat reduced, and visibility may have also been impaired at Bondi from schools of baitfish and shredded jellyfish.

Reduced visibility increases the chances of an accidental interaction occurring. Visibility also affects the ability of bathers, lifeguards, and aerial surveillance to see sharks in the water, and to respond. For example, for bathers to see a shark and voluntarily leave the water, or for authorities to respond with jet skis or rigid inflatable boats to “chase off” the shark (see next point). Also, despite extensive helicopter activity following the Avalon attack, the suspected shark was not sighted.

7.6 Both attacks occurred outside the hours of operation of lifeguard services. Extensive professional and volunteer lifeguard services are provided on both Avalon and Bondi Beach, with both beaches covered with a 7 day/week service during the months when the

attacks occurred. However, the actual attacks occurred outside of the patrolled hours on each day. Bathing hours are not regulated and it is not practical to provide lifeguard services at all hours of the day and night. Further, even if services were provided at the times of the attacks, it is not clear that they would have been prevented due to the limited visibility discussed above, and the fact that the attacks did not occur in close proximity to flagged bathing area that are the focus of greater surveillance.

7.7 The victims of both attacks were surfing. Surfers are frequently in the water early in the morning or late in the afternoon. A range of factors contribute to this including leisure time opportunity, desire to utilise the beach when less populated, or to capitalise on wind, tide, current or swell conditions prevailing at the time.

Despite advisory materials suggesting that people avoid swimming at dawn or dusk, surfers as a group are considered unlikely to substantially modify behaviour, and are generally aware of the risk of shark attack and make considered decisions accordingly. Consequently, other options such as adoption of shark avoidance technology (e.g. electrical shark repelling devices) may be relevant for certain groups such as surfers or divers that may be at greater risk due to the times they choose to enter the water.

Greater effort may also be required in educating all water user groups to avoid swimming or surfing in, or near to, schools of bait fish and/or larger migrating fish such as mullet and salmon that are prey items of dangerous sharks. Advisory materials should also provide guidance on how to recognise schooling bait fish and migrating fish.

7.8 Aerial surveillance was unlikely to have prevented or warned of the attacks at Bondi and Avalon. This is due to the short periods of surveillance that can be provided at any one beach coupled with the intrinsic difficulty in identifying (from the air) potentially dangerous sharks in choppy, or low light conditions, such as those experienced at the times of these attacks (near dawn and dusk).

During December 2006 and January 2007, NSW DPI trialled the effectiveness of helicopter surveillance for shark spotting by providing $50,000 to Surf Lifesaving NSW who sub-contracted the work. The flights covered all 51 netted beaches, but equated to about 2.5 minutes surveillance time per beach, providing a snapshot of conditions at the beach at that time. Considering that in summer swimmers are in the water for 14-15 hours per day, these flights were considered to have limited value as a preventative mechanism.

7.9 Community education and awareness materials about minimising the risk of shark attack are available from a range of sources. It is noted that access to these resources generally involves use of the internet or visiting an office. Multilingual shark education and awareness materials are generally not provided.

Shark signage at beaches has been raised as a way to increase awareness in proximity to the source of the risk, however local councils have identified a range of cost, logistical, and legal issues associated with broad-scale installation of signage. The net benefit from signage should be explored in terms of the opportunity cost for alternative risk reduction strategies.

8. Outcomes

8.1 Shark education and awareness

Several species of dangerous sharks occur in NSW waters, and there are periodic interactions between humans and these sharks. However, the risk of an interaction resulting in injury or fatality remains extremely small, particularly when compared to other sources mortality in the community. It is not possible to totally eliminate risk of an interaction with a shark when swimming in oceanic and estuarine waters. The only way to totally remove risk of an encounter with a shark is to not swim in any waters where sharks occur. However, there are a range of simple measures to further reduce the already small risk of shark attack. Several of these measures were of

relevance to the Bondi and Avalon attacks, highlighting the important role of education and awareness.

NSW DPI, the Surf Living Saving Clubs of NSW and other authorities provide education and awareness raising materials regarding ways to reduce the risk of shark attack. Continued emphasis on shark education and awareness is one of the few ways that individuals can reduce their risk of shark attack.

A key recommendation of this analysis is to develop a broader shark education and awareness program designed to improve understanding of sharks, their behaviours, the low likelihood of shark attack and the simple precautions that can further reduce this risk, by:

- Using an optimal mix of educational strategies and media to disseminate information (print, web, strategic media campaigns and targeted education packages). The role of signage should be reviewed as part of this process.
- Helping people to quickly recognise higher-risk situations, allowing them to make informed decisions and take personal responsibility in an unpredictable environment.
- Targeting the general swimming public - including people who choose to swim outside of controlled environments (e.g. surfers and divers).
- Educating younger and impressionable people (e.g. nippers and tourists) without turning them off water sports and enjoyment of the marine environment in NSW.
- Focusing on modifying risky swimmer behaviour thereby reducing likelihood of shark attack.
- Drawing on new and emerging shark attack prevention measures resulting from research.
- Reinforcing partnership arrangements (e.g. Surf Life Saving and local government) and where possible, linking with other water safety initiatives.
- Matching peak swimming periods with the provision of sound and timely advice about shark safety measures including an emphasis on preventative rather than responsive advice.

This is expected to deliver benefits including:

- Improving the public's understanding of shark attack risk, putting it into perspective, and enhancing people's confidence to control the risk.
- Increasing support, awareness and understanding of the safety measures in place (e.g. shark meshing program, Surf Life Saving services and other safer swimming areas).
- Fostering an appreciation that healthy shark populations mean healthy oceans.
- Renewing confidence in NSW beaches as a safe place to visit and enjoy.

8.2 Implementation of the SMP

The SMP has been effective in reducing the number of shark attacks within the area of operation of the program. The recent attacks at Bondi and Avalon beaches highlight that the SMP does not prevent any possibility that shark attack will occur. Rather it remains the case that it is a tool to reduce the risk of an interaction occurring.

The SMP establishes a comprehensive management framework including a research and monitoring program, reporting and review arrangements, and includes provisions to monitor and review developments in shark attack prevention nationally and internationally.

The research and monitoring program within the SMP includes commitments to undertake a scientifically based shark attack risk assessment to improve bather safety. The outcomes of the research and monitoring program provide objective information upon which informed decisions regarding the management of the SMP and shark attack can be made.

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A8 Catch data for sharks in the SMP, 1950/51 - 2007/08

Year	Hammerhead	Whalers	Angel sharks	Port Jackson	Great white	Grey nurse	Tiger	Sevengill	Mako	Thresher	Wobbegong	Other	Total
50/51	17	87	59	5	8	34	21	0	12	1	12	0	256
51/52	9	140	106	6	15	29	13	1	14	2	3	0	338
52/53	14	78	129	6	16	34	8	0	21	3	0	0	309
53/54	14	87	89	5	21	26	5	4	5	4	2	0	262
54/55	13	107	27	5	14	17	1	1	7	2	2	0	196
55/56	6	150	25	0	18	14	4	0	1	3	1	0	222
56/57	6	113	45	5	17	8	7	1	4	2	1	0	209
57/58	3	55	48	3	10	13	0	0	1	2	0	0	135
58/59	10	54	78	3	17	7	1	0	1	4	0	0	175
59/60	11	50	52	5	15	10	2	0	1	0	0	0	146
60/61	29	31	113	6	10	9	4	0	0	1	1	0	204
61/62	55	46	60	10	10	7	7	1	1	3	0	0	200
62/63	90	70	75	12	10	7	13	2	6	5	0	0	290
63/64	122	62	59	36	13	11	3	1	2	3	0	0	312
64/65	105	44	38	33	8	3	1	1	1	1	0	0	235
65/66	98	63	49	14	11	9	0	0	5	5	0	0	254
66/67	80	47	38	16	13	8	0	0	6	1	0	0	209
67/68	62	61	45	28	12	14	0	1	6	4	0	1	234
68/69	35	48	62	41	11	17	3	0	0	3	3	1	224
69/70	78	28	46	20	8	6	3	0	0	5	0	0	194
70/71	63	48	30	34	15	8	5	3	1	7	0	0	214
71/72	78	38	41	42	7	6	8	0	0	1	2	0	223
72/73	308	122	108	34	27	18	22	1	0	5	5	0	650
73/74	282	107	104	13	18	14	9	5	0	1	0	0	553
74/75	202	41	93	3	28	8	4	3	0	1	1	0	384
75/76	244	55	27	6	18	6	8	2	0	0	0	0	366
76/77	214	36	45	3	13	3	9	0	2	0	0	0	325
77/78	93	20	13	2	21	3	1	2	0	0	1	0	156
78/79	118	25	61	17	6	0	4	0	2	0	0	0	233
79/80	136	63	20	78	8	0	12	2	0	0	0	0	319
80/81	84	38	19	2	4	0	11	0	2	0	1	0	161
81/82	139	16	18	28	4	0	11	3	1	1	0	0	221
82/83	92	28	71	0	7	2	5	2	1	1	0	0	209
83/84	91	27	88	4	5	0	8	9	1	11	2	0	246
84/85	75	50	29	8	6	2	8	2	2	1	3	0	186
85/86	62	47	25	3	5	2	24	7	1	1	0	0	177
86/87	68	68	10	0	14	1	29	6	2	1	0	0	199
87/88	56	51	4	0	5	1	17	4	1	0	0	0	139
88/89	57	45	4	3	5	3	5	0	1	0	2	0	125
89/90	55	67	1	5	4	2	7	2	2	0	0	0	145
90/91	101	35	2	1	0	0	3	0	2	0	0	0	144
91/92	98	54	7	2	5	0	3	6	4	0	0	0	179
92/93	106	43	33	4	2	0	7	3	0	2	0	0	200
93/94	124	49	19	23	7	0	7	2	1	2	0	0	234
94/95	85	21	11	19	7	0	2	2	1	2	0	0	150
95/96	114	34	21	3	6	0	3	14	1	8	0	0	204
96/97	77	29	21	8	3	0	1	6	2	2	0	0	149
97/98	78	16	10	4	3	1	3	1	1	1	0	1	119
98/99	97	21	7	4	3	0	1	13	2	2	0	1	151
99/00	63	36	32	1	8	3	3	3	3	6	0	0	158
00/01	47	17	12	3	3	0	1	0	0	0	0	0	83
01/02	40	14	3	6	6	0	6	1	0	0	0	0	76
02/03	74	22	12	9	6	3	2	8	0	6	0	0	142
03/04	39	20	14	5	5	1	2	3	3	1	0	0	93
04/05	57	22	15	7	10	2	1	15	4	3	0	1	137
05/06	40	31	15	2	8	1	3	6	3	0	0	0	109
06/07	34	37	10	4	11	2	1	0	3	2	0	0	104
07/08	18	35	15	2	7	2	0	9	1	3	0	0	92
Total	4666	2949	2313	651	577	377	352	158	144	125	42	5	12359

A9 Risk analysis methodology

Risk analysis is the culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects (AS/NZS 4360). Risk analysis is an iterative process that has three main steps: risk assessment, risk management and risk communication (see Figure A1). The process is intended to provide insights about sources of risk and their potential impacts, which then enables managers to take action to mitigate the threats to avoid undesirable outcomes.

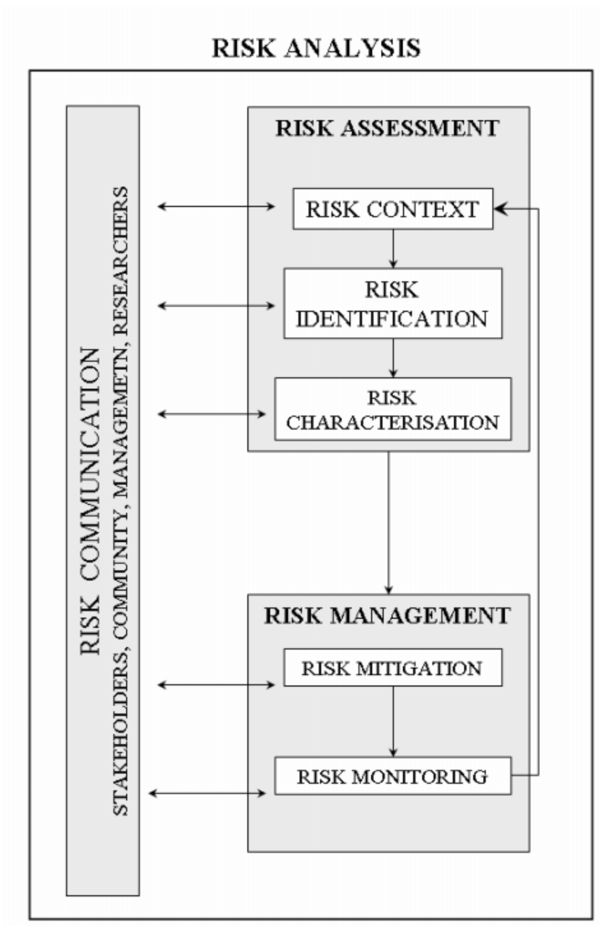

Figure A1 Framework of the risk analysis (Astles et al. 2006).

Risk is defined as the probability or likelihood of an undesirable event happening. This definition requires that an *a priori* definition of consequence be given for the undesirable event that is being analysed. In this way, the definition of risk combines the consequence and likelihood of the undesirable event and avoids the confounding problem characterised by other definitions used in qualitative assessments that determine risk by multiplying likelihood and consequence.

1.1 Risk assessment

Risk assessment is the first main step in the risk analysis process. It contains three parts: risk context, risk identification, and risk characterisation.

1.1.1 Risk context

Risk context is the first step in risk assessment and establishes the structure and scope of the analysis and the criteria against which risk will be assessed. It also identifies stakeholders and defines the

communication and consultation policies. The context can be clearly defined by specifying three main elements:

- The risk that is to be analysed (which requires a description of the undesirable event that is to be avoided and the consequence of that event);
- The relevant temporal extent of the risk analysis; and
- The spatial extent of the risk analysis.

1.1.2 Risk identification

Risk identification is the second part of risk assessment. The aim is to generate a comprehensive list of the sources of risk. This can be done using a variety of methods that include: literature reviews, examination of historical records, expert panels, and stakeholder consultation. The results of this risk identification step are often presented as lists, tables, decision factor hierarchies (e.g. Saaty 1980) or component trees (e.g. Fletcher et al. 2002).

1.1.3 Risk characterisation

Risk characterisation is the third part of risk assessment. The aim of characterisation is to estimate the probability or likelihood that the various sources of risk will indirectly or directly cause the undesirable event that has been previously defined. It is an iterative process that involves: (a) the integration of qualitative and/or quantitative information, including the associated uncertainties, about the sources of risk; (b) the separation of the sources of risk into categories according to their estimated probability of causing the previously specified undesirable event; (c) the acceptance of low or negligible risks with a justification supporting the conclusions reached; and (d) acknowledgment that the moderate and higher sources of risk require some form of mitigation.

To standardise Part A of the process, each species/group potentially affected by the activity will be described in terms of its biological and ecological requirements, and its potential overlap and interaction with the activity based on the best available information. The degree of extent and magnitude of potential impact on each species (and thus level of risk) will be based on a suite of criteria, including:

- status (is the threat a recognised Key Threatening Process (KTP) for the species);
- extent (what range of the species is affected, are there refuges from the threat, does it occur in critical habitat);
- severity (does it affect individuals or the entire population);
- effect (does it prevent range extension, recruitment, individual survival);
- response (is the species resistant and/or resilient to the threat, how and to what degree is the species and/or its habitat recovery rate or potential affected by the threat);
- frequency (how regularly does it occur and what is the proportional effect relative to other threats);
- form (what is the nature of the disturbance – pulse [acute/short term], press [sustained/chronic], or catastrophic [major/widespread]); and
- historical context (period of significance: more than 100 years ago; 50 - 100 years; last 50 years).

A Delphic ranking assessment (0 = not applicable or negligible, 1 = low, 2 = moderate, 3 = high) will be applied to each of these criterion and then summed to determine the overall level of risk to each species by the existing activity of shark meshing. The best available information is used to assess the relevance of and thus determine the rank for each criterion.

For example, for status, if the threat is a recognised KTP for a species, then it would score a 3. If not, are there records or information to indicate that the species has in some way been directly affected by the threat, such as through capture, mortality or some other form of recorded interaction. If yes, it would score a 2. If the species has never been recorded as affected by the threat, but its distribution or biological or ecological traits suggest that it could be affected then it scores a 1. If none of the above apply, then it would score a 0.

The use of eight criteria provides an overall risk scale of 0 (negligible risk) to 24 (highest risk), and on that basis risk levels can be categorised as:

- LOW RISK – score of 0 to 12;
- MODERATE RISK – score of 13 to 18; and
- HIGH RISK – score of 19 to 24.

Species scoring less than eight are actually at negligible risk, but for the purposes of this analysis have been grouped with the low risk species to account for the considerable uncertainty associated with distribution, abundance and population estimates for most threatened species.

1.2 Risk management

Risk management is the second step in the risk analysis process. Risk management contains two parts: risk mitigation and risk monitoring.

1.2.1 Risk mitigation

Risk mitigation aims to minimise the risk of the undesirable events defined in the risk context. This is done by implementing regulatory and/or non-regulatory (e.g. code of practice) management actions that will remove or reduce the pressure imposed by the activity.

1.2.2 Risk monitoring

Risk monitoring aims to collect information to determine whether implementation of the mitigative measures were effective in minimising the risk of the undesirable event. Risk monitoring uses performance criteria or indicators and may include the use of trigger points. Risk monitoring is a valuable and important tool as it both validates management actions that have been effective and highlights aspects that need revised mitigative actions when previous initiatives have been ineffective.

There should be a readily identifiable link between the threat, management actions and their performance criteria, which need to be measurable and interpretable (i.e. any changes can be unambiguously interpreted as a result of the management action). Risk monitoring provides an appraisal of management actions and an opportunity to modify the JMA in a timely manner.

1.3 Risk communication

Risk communication provides the basis for information flow between stakeholders, managers and scientists. Risk is communicated in several ways including by:

- Development, statutory consultation and implementation of the JMA and management plan,
- Implementation reporting processes, and
- Advisory and community education materials.

A10 Species descriptions of affected marine mammals, reptiles and birds

The following species descriptions have been excerpted from "Descriptions of the Wildlife Species that Commonly Occur in the Marine and Estuarine Waters of NSW (Ganassin and Gibbs 2005)".

Cetaceans

Unless otherwise specifically referenced, the following information on cetaceans was obtained from *The Action Plan for Australian Cetaceans* (Bannister et al. 1996).

Risso's dolphin (*Grampus griseus*)

Distribution: Risso's dolphin occurs in all oceans across both hemispheres from the equator to about 60^o (Kruse et al. 1999). In Australia, this dolphin has been recorded from southwestern Western Australia, South Australia, Victoria, New South Wales and Queensland. Stranding records range from approximately 23^{o}S to 39^{o}S. In NSW, the species has been recorded from 15 strandings, mostly between December and June (Smith 2001). It has been suggested that this species undertakes a seasonal migration, in association with changing sea surface temperatures (Leatherwood et al. 1980).

General comments: Risso's dolphin occurs in tropical, subtropical, temperate and subantarctic waters. This pelagic species occurs well offshore in deep oceanic and continental shelf waters (Leatherwood et al. 1980) and is seen in inshore waters and frequently over the continental slope. It is found where sea temperatures are 15^o-30^{o}C. Fraser Island has the only known 'resident' population in Australia. The maximum age of this species is >17 years and it grows to a maximum of 4.1 m. It is said to be sexually mature at 2.6-3.0 m. It feeds in pelagic waters primarily on squid (both pelagic and neritic), some octopus and possibly fish. It lives in groups of 25 to several hundred individuals but may also be solitary. It dives long and deep, and is not a regular bow-rider. It has been seen in company with striped dolphins, pilot whales, common dolphins and other pelagic cetaceans. Although no abundance estimates are available for Australian waters, it is believed to be reasonably abundant throughout the main part of its range.

Identified threats: Current threats to the Risso's dolphin include their incidental capture in the Sri-Lankan gill-net fishery and northern Australian waters, direct capture of a small number of individuals in Indonesia and the Solomon Islands, and illegal capture in northern Australian waters.

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Data deficient.

Bottlenose dolphin (*Tursiops truncatus*)

Distribution: The bottlenose dolphin is a cosmopolitan species, and it is not found in polar seas (i.e. between 65^{o}N and 55^{o}S). It occurs in all Australian states, the Northern Territory and Norfolk Island. There are separate inshore and offshore forms of this species. The offshore *T. t. truncatus* occurs in New South Wales north of Port Macquarie, through Queensland and Northern Territory into Western Australia, south to Perth. The inshore *T. t. aduncus* occurs in southern Queensland, north to at least Hervey Bay, through New South Wales, Victoria, Tasmania, South Australia, and in Western Australia at least to Albany. Both forms of the species occur widely in NSW waters, and are regularly observed (Smith 2001). It is the most frequent cetacean species to strand in NSW (Smith 2001). The species can be migratory in temperate waters.

General comments: Bottlenose dolphins occur from tropical to temperate and occasionally subantarctic waters. Inshore forms occur as resident groups with a limited home range in very shallow coastal water, often entering bays, estuaries, coastal lagoons and the tidal reaches of rivers (Wells and Scott 1999). Offshore forms occur in continental shelf and slope waters or well beyond, where individuals range widely and may undertake regular seasonal migrations, apparently to follow their prey (Walker 1981). They are common in several locations including Shark Bay and Cockburn Sound (WA), Moreton Bay and adjacent offshore waters (Queensland), Jervis Bay (NSW), Port Phillip Bay (Victoria), and Adelaide (SA). In NSW, there are resident, breeding populations of the species at Port Stephens, Jervis Bay, Twofold Bay and many other sites (Smith 2001). Their maximum age is around 42 years (male) and 43 years (female) and maximum length around 3.12 m (male) or 2.92 m (female). Males are sexually mature at 14.5 years / 2.4 m and females at 9-11 years / 2.27-2.38 m. They calve every three to six years in summer after a 12.3 month gestation period. They have a broad diet including teleosts, cephalopods, elasmobranchs and crustaceans. Demersal, benthic and reef-associated species are taken. They may feed in association with human

activities such as prawn trawling or fish farming. Their ability to echolocate has been demonstrated experimentally. They can occur in groups of >1000 individuals, however in NSW they are mostly observed in groups of one to fifty animals. The mean group size from studies in Australia was between five and ten individuals. Only local population estimates are available for Australian waters. In NSW, the resident population of Jervis Bay has been estimated at about 47 individuals (Mandelc 1995).

Identified threats: Bottlenose dolphins are currently threatened by habitat destruction and degradation, noise pollution, boat-strike (Smith 2001), harassment or disturbance (particularly close to major cities), incidental capture in aquaculture nets, shark nets, trawl-nets and drift-nets, illegal killing, live capture in Queensland and overfishing of prey species. Bottlenose dolphins are illegally killed for sport, bait or their perceived predation on commercial fish stocks. The species is also potentially threatened by pollution, disease, and tourism including dolphin watching, feeding and swims.

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Data deficient.

Pantropical spotted dolphin (*Stenella attenuata*)

Distribution: The pantropical spotted dolphin can be found in both hemispheres in all oceans between 40^{o}N and 40^{o}S (Perrin and Hohn 1994). In Australia, it has been recorded off the Northern Territory, Western Australia (south to Augusta), Queensland and New South Wales. In NSW, the species has been recorded from six strandings, the most recent in February 1998, and two unconfirmed sightings (Smith 2001). Seasonal movements north / south are known off Japan and inshore / offshore in the eastern tropical Pacific.

General comments: Pantropical spotted dolphins are found in tropical and subtropical waters (22^{o}C or greater) and occasionally in temperate waters. They are pelagic, oceanic and can be found on the continental shelf and along the continental slope. They live to a maximum of 50 years and reach a maximum length of 2.57 m (male) and 3.4 m (female). Males are sexually mature at 12-15 years / 1.9-2.0 m and females at 10-12 years / 1.8-2.0 m. They calve every two to four years, after an 11.2-11.5 month gestation period. Calving season peaks in spring and autumn. They feed near the surface and mostly eat epipelagic and mesopelagic fish, and squid. Other foods such as worms and crab larvae are also eaten. Their diet varies with region and reproductive state, with lactating females eating a greater proportion of fishes than squids. Their diet has also been noted as overlapping greatly with yellowfin tuna. They can occur in groups of a few individuals to over 1000, and average <100 individuals in a group. Offshore pods are usually larger than coastal ones. They are often seen with other species of dolphin, tuna and seabirds, probably feeding in aggregations. They ride bow waves. Home range is several hundred kilometres or more and daily movements of 30-50 km are made. Sharks are known to take dolphins in association with purse-seining operations. There are no population estimates for Australian waters.

Identified threats: The main threat to this species occurs from fishing activities outside Australian waters. In particular, the Taiwanese gill-net shark fishery incidentally captures large numbers of the populations found in Australian waters, and the species is directly caught in the Philippines and Solomon Islands. Shark meshing activities in Australia capture low numbers of the species.

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Lower risk, conservation dependent.

Common dolphin (*Delphinus delphis*)

Distribution: The common dolphin occurs across both hemispheres in all oceans. It is not found in the higher latitudes, with the Subtropical Convergence being the furthest record south. In Australia, the species has been recorded from all states and the Northern Territory. They occur along the whole NSW coast, throughout the year, with no obvious seasonal changes in abundance and are often observed (Smith 2001). It is one of the most frequent cetacean species to strand (Smith 2001). It is not known to be migratory, but seasonal movements have been reported. Two species of the common dolphin have been distinguished in Australian waters, the short-beaked common dolphin (*D. delphis*), and the long-beaked common dolphin (*D. capensis*).

General comments: Common dolphins are pelagic and occur in temperate to tropical waters, both inshore and offshore (Evans 1994). The species may be associated with high topographical relief of the ocean floor, escarpments and areas of upwelling. Males of the species live to 22 years while females reach a maximum

age of 20 years. The maximum length of the species is 2.32 m (male) and 2.18 m (female). For males sexual maturity is reached at 3-12 years / 1.7-2.0 m and for females at 2-7 years / 1.5-1.9 m. They calve every 1.3-2.6 years after a 10-11 month gestation period. The species calves all year with peaks in spring and autumn. They are opportunistic feeders, feeding at the surface and at depth (to at least 280 m) on small shoaling and mesopelagic fish and cephalopods. Their diet varies with stock and season. They may feed from human fishing operations and aggregate with tuna possibly in a feeding association. Some aggregations observed in Australian waters number thousands. They ride the bow waves of boats and large whales. They are seen with other dolphin species and larger cetaceans (fin, humpback, blue, southern right whales). Although there are no population estimates for Australian waters, they are considered common.

Identified threats: Current threats to the species include intentional killing (usually by shooting), incidental catches in the eastern tropical pacific, Australia and possibly other regions, small direct captures in some fisheries around the world, and accumulation of organochlorines and heavy metals in some dolphins from Australian waters.

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Not in database

False killer whale (*Pseudorca crassidens*)

Distribution: False killer whales have a circumglobal distribution between 60^{o}N and 50^{o}S (Odell and McClune 1999). North-south and inshore seasonal movements appear to occur in the north-eastern Pacific and in some other areas, apparently associated with warm currents and seasonal availability of prey. The species occurs in all Australian states and the Northern Territory. The species has been recorded stranded in NSW 14 times, between Tweed Heads and Jervis Bay, the most recent in May 1997 (Smith 2001). A pod of about 50 false killer whales have been seen swimming close to the shore off Coffs Harbour in October 1991 (Smith 2001). A seasonal movement inshore or along the continental shelf of the species in Australia is indicated by the majority of herd strandings occurring from May to September on the south and south-eastern coasts. Strandings in NSW have occurred between May to January, excluding September (Smith 2001).

General comments: False killer whales prefer tropical to temperate oceanic waters, and only approach close to land where the continental shelf is narrow. They are possibly attracted to zones of enhanced prey abundance along the continental slope. Males reach a maximum length of 5.96 m and females 5.06 m. Their age at sexual maturity varies between populations, generally between 8-14 years for both sexes. They calve every 6.9 years throughout the year after a 15.1-15.6 month gestation period. They feed on squid and large pelagic fish. They can also attack stressed dolphins escaping tuna purse-seine nets. They occur in herds of 20 to 50 individuals. Large aggregations of 100 to 800 individuals can occur when smaller herds congregate to exploit locally abundant prey. They are often seen with other cetaceans, approach vessels and ride bow-waves. Although the species is widely distributed, they are apparently not abundant anywhere. There are no population estimates for the species in the Southern Hemisphere.

Identified threats: Current threats to the species include culling off western Japan to protect their finfish fishery, incidental capture in tuna purse-seine and other nets and long-line fisheries elsewhere in the Pacific Ocean, and possible entanglement in drift-nets set in international waters and in lost or discarded netting.

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Not in database.

Killer whale (*Orcinus orca*)

Distribution: Killer whales have a cosmopolitan distribution and occur from the polar regions to the equator in all oceans. In Australia, they have been reported from all states, but not the Northern Territory. They are believed to concentrate around Tasmania and are frequently sighted in South Australia, Victoria and the Antarctic south of 60^{o}S. Smith, in 2001, noted that there were 24 records of killer whales in NSW. Most of the records originate from south of Broken Bay, between May and November, although there are also records during the other months except February and December (Smith 2001). Following a reduction of their numbers from whaling activities, the numbers visiting NSW waters appears to be increasing (Smith 2001). They are not known to migrate, but seasonal movements in response to food supply are possible.

General comments: The pelagic killer whale is found in oceanic and shelf waters. While the species is found in both warm and cold waters, it may be more common in cold, deep water. Off Australia, they are

often seen along the continental slope and on the shelf, and near seal colonies. Macquarie Island is a key locality for the species in the Australian region as it is regularly sighted there. In the Southern Hemisphere, most killer whales occur in relatively warm waters in winter, and then migrate to the Antarctic in summer (Mikhalev et al. 1981). They reach a maximum age of 40 years and a maximum length of 9.8 m for males and 8.5 m for females. Males are sexually mature at 16 years / 5.2-6.2 m while females are sexually mature at 10 years / 4.6-5.4 m. They calve every 3-8 years after a 12-17 month gestation period. Killer whales are a top-level carnivore and often hunt in packs. Their diet differs seasonally and regionally. The specific diet of Australian killer whales is not known but there are reports of attacks on dolphins, young humpbacks, blue whales, sperm whales, dugongs and Australian sea lions. They are also known to herd bottlenose dolphins and common dolphins. Stomach contents from the Antarctic contained fish, minke whales, pinnipeds and squid. They are usually sighted in groups of less than 30. Off southern Australia, group sizes of up to 52 have been reported with most sightings being in groups of less than ten. There are reported cases of killer whales forming a symbiotic relationship with whalers at Eden (NSW), where killer whales received tongues of other whales caught by humans in return for help with procuring whales. There are no population estimates for continental Australian waters. In the Antarctic south of 60^{o}S, the population has been preliminarily estimated at 70,000.

Identified threats: The species is currently threatened from illegal shooting of individuals plundering catch, and incidental deaths, although none of these have been reported in Australian waters.

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Lower risk, conservation dependent.

Shortfinned pilot whale (*Globicephala macrorhyncus*)

Distribution: Shortfinned pilot whales have a circumglobal distribution from the equator to 41^{o}S and 45^{o}N. In the Australian region they occur in oceanic waters and continental seas and have been recorded from the Northern Territory and all states except Victoria. Records on the southern coasts may reflect the influence of warm, south-flowing Indian and Pacific Ocean currents. In NSW, the species has been recorded from 11 strandings, including two mass strandings, between Brunswick Heads to Culburra, the most recent in April 2000 (Smith 2001). They are known to seasonally move between inshore and offshore areas in response to prey abundance, however this is not apparent from the meagre Australian data.

General comments: Shortfinned pilot whales occur in tropical to temperate oceanic waters, and approach coastal seas. Their maximum age is 46 years (males) and 63 years (females) and their maximum length is 5.89 m (male) and 4.8 m (female). Males are sexually mature at 14.6 years / 4-5 m while females are sexually mature at 9 years / 2.9-3.6 m. Females calve every five years until they become 34 years old. Calving peaks in July to August after a 14.9 month gestation period. They feed mainly on squid, cuttlefish, octopus and some fish. They occur in groups of 10 to 30, but commonly occur in herds of several hundreds often accompanied by dolphins. They are capable of diving to at least 600 m. They have been seen with the appearance of squid feeding tuna, and herd and possibly attack *Stenella* and common dolphins escaping tuna purse-seine nets in eastern tropical Pacific. They are widespread and apparently common, however there are no estimates of Southern Hemisphere populations taken.

Identified threats: They are currently threatened by entanglement in drift-nets set, lost or discarded in international waters. There are active fisheries of this species in Japanese and Caribbean waters (Smith 2001).

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Lower risk, conservation dependent.

Sperm whale (*Physeter macrocephalus*)

Distribution: Sperm whales are found throughout the world's oceans in deep water off the continental shelf, i.e. in water >200 m deep. Females and young males are restricted to warmer waters north of around 45oS in the Southern Hemisphere, and adult males travel to and from colder waters. In Albany (WA), the species is concentrated in a narrow area only a few miles wide at the shelf edge and move westward throughout the year. Similar concentrations are known elsewhere. Off the west coast of Western Australia, where the shelf slopes less steeply, sperm whales are less concentrated close to the shelf edge and are more widely dispersed offshore. In the open ocean, sperm whales in the Southern Hemisphere generally move southwards in summer and northwards in winter. Northern Hemisphere sperm whales have a separate migration that consists of similar seasonal movements to those in the south. Key localities for the species in

Australia are near the continental shelf between Cape Leeuwin and Esperance (WA), southwest of Kangaroo Island (SA), off Tasmania's west and south coasts, off New South Wales (including Wollongong), and off Stradbroke Island (Queensland). They occur in all Australian states. The sperm whales off eastern Australia (Division 6 stock) are said to be a separate stock than those off western Australia (Division 5 stock) (Smith 2001). Sperm whales are commonly sighted off NSW out to the edge of the Australian Exclusive Economic Zone, mostly between August and April (Smith 2001), however this seasonality may represent a bias towards the tuna fishing season when observations were made (Paterson 1982). The species rarely occurs within the 5 km limit of NSW waters. Small groups of the species have been sighted twice in such waters, off Eden and Broken Bay (DEC Atlas of NSW Wildlife 02/01/2003). The species has stranded 22 times along most of the coast of NSW, (Smith 2001). The population of sperm whales dramatically declined during historical whaling operations that ceased in 1978. The current number of sperm whales is unknown, however the 'Australian' population of the species is likely to be in the tens of thousands.

General comments: Sperm whales are pelagic and are found offshore only in deep water. Their population is centred in temperate or tropical waters where breeding / nursing schools, and groups of young males occur. They concentrate in areas where the seabed rises steeply from great depth, this is probably associated with concentrations of their major food source in areas of upwelling. They reach a maximum age of around 60 years and a maximum length of 18.3 m (males) or 12.5 m (females). Males are sexually mature at 18-21 years / 11.0-12.0 m while females are sexually mature at 7-13 years / 8.3-9.2 m. They calve every four to six years between November – March after a 14-15 month gestation period. They feed mostly on oceanic cephalopods that are taken at depth, and some deep-sea angler fish and mysid shrimps are also eaten. At the surface, their swimming speed rarely exceeds 7.5 km / hr, however they can swim to 30 km / hr when disturbed. They are deep divers and can do so for over 60 minutes. Maximum diving depths between 1135 m to 3195 m have been recorded, although the mean diving depth is much shallower. They probably use echolocation. Breeding schools of sperm whales include females of all ages and immature and younger pubertal males. Large, socially mature males accompany schools only during the breeding season, and then for short periods of possibly only a few hours. The average school size of such a group is 25 animals, although they have been reported to number up to the low thousands. Bachelor schools of sperm whales consist of older pubertal males and sexually, but not socially, mature males, all of similar size and age. Socially mature males leave such schools to associate with breeding schools, either alone or in small groups of usually less than six animals.

Identified threats: The species is currently threatened from direct disturbances such as collision with large vessels on shipping lanes beyond the edge of the continental shelf, seismic operations in this area, net entrapment in deep-sea gill-nets and pollution leading to accumulation of toxic substances in the body.

Conservation status: NSW (TSC Act) - Vulnerable; Commonwealth (EPBC Act) – Protected; International (IUCN) – Not in database.

Southern right whale (*Eubalaena australis*)

Distribution: Southern right whales occur across the Southern Hemisphere between around 30^{o} and 60^{o}S. They feed in summer in the higher latitudes of their range (between about 45^{o}S and 55^{o}S) and generally move to the lower latitudes for breeding in winter. They approach coasts in winter. In Australia, the species is a winter-spring visitor, occurring around the southern coastline from Perth (WA) to Sydney (NSW), including Tasmania. Their Australian range is possibly extending further north as sightings have been reported from Shark Bay and North West Cape (WA) and Byron Bay (NSW).

The species is regularly observed close to shore along the NSW coast between May and November, and there are a couple of January records (Smith 2001). The species has mostly been sighted in southern and central NSW (south of Newcastle), although there are some records further north, the furthest from Byron Bay (Smith 2001). The draft recovery plan for the species identifies Twofold Bay and coastal waters 5 km north and south as an area of frequent use by the species, however the plan acknowledges that other areas may become important as the population recovers (Burnell and McCulloch 2001). New-born calves are regularly sighted in NSW waters (Smith 2001). After calving in NSW waters, the population perhaps moves offshore before migrating to more southerly waters in summer (Smith 2001).

The population of southern right whales dramatically declined during historical whaling operations that ceased in the 1960s. Population estimates are difficult for this species, given its irregular movement and calving cycle. The numbers of southern right whales off southern Western Australia have increased since

1977 at around 10% per year. The Australian population remains small compared with its likely size before exploitation (Smith 2001). The numbers of southern right whales that visit NSW in any one year is probably less than ten (Warneke 1996).

General comments: In summer, southern right whales are pelagic and feed in the open Southern Ocean. In winter, they occur close to the coast, particularly calving females. Data from South Africa indicates that over the winter, females with calves generally occur in shallow waters, sometimes less than 5 m deep, and that all whales generally occur within 1.85 km of the shore (Best 1990). Consistent calving locations in Australia in recent years have been at Doubtful Island Bay and east of Israelite Bay (WA), the head of the Great Australian Bight (SA), and off the South Australian gulfs and Warrnambool (Victoria). They live to a maximum of 50+ years and reach a maximum length of 17.5 m. Sexual maturity is reached around nine to ten years / 12-13 m. They generally calve every three years in preferred onshore localities during June-August after an 11-12 month gestation period. They mate from July-August. The data implies that there is no feeding near the coast in winter, calving females effectively fast for a little over four months. These baleen whales feed mainly on smaller plankton and copepods, taken primarily in the open ocean, presumably south of 40^{o}S, in summer at or near the surface. Near shore, their swimming speeds are generally slow, however they are capable of reaching 15+ km / hr over short distances.

Identified threats: Southern right whales are threatened by direct disturbance, especially when they are close to the coast. The disturbance can result from whale watching activities, recreational and research related boating activities, collision with large vessels, swimmers, divers, low-flying aircraft, coastal industrial activity, defence operations, entanglement in fishing gear, plastic debris, and pollution leading to the accumulation of toxic substances in body tissues. Ingestion of or entanglement in harmful marine debris also affects this species (Threatened Species Scientific Committee 2003).

Conservation status: NSW (*TSC Act*) - Vulnerable; Commonwealth (EPBC Act) – Endangered; International (IUCN) **–** Lower risk, conservation dependent.

Minke whale (*Balaenoptera acutorostrata*)

Distribution: Minke whales occur worldwide. There appears to be three subspecies of minke whales based in the North Atlantic, North Pacific and Southern Hemisphere (‘dark-shoulder form’). They migrate between cold water feeding grounds and warmer water breeding grounds. However, this migration is not necessarily predictable as they possibly do not migrate far into warm waters and populations in the North Pacific apparently do not migrate at all. Dark-shoulder minke whales feed on major grounds in Antarctic waters, and they migrate further south than most baleen whales, except the blue whale. There is also a dwarf form of minke whale reported throughout the Southern Hemisphere. Off Australia, this dwarf form seems to extend southwards to 12^{o}S on the east coast and 20^{o}S on the west coast. It generally does not travel to the Antarctic, although it has been recorded as far as 58-65^{o}S. Off eastern Australia, the dark-shoulder form may not migrate as far north as the dwarf form, with its most northerly record being 21^{o}S. Minke whales have been recorded from all Australian states, but not the Northern Territory.

Both the dark-shoulder and dwarf forms of minke whales occur off NSW. In NSW, they have been reported stranded and have been observed close to the shore along the coast on a number of occasions (Smith 2001). Minke whales have been reported to occur in NSW from June to November, between Twofold Bay and Minnie Water (Smith 2001).

General comments: Minke whales are oceanic, but are not restricted to deep water and do occur close to coasts. They are widely distributed in tropical, temperate and polar waters. The dark-shoulder form reaches a maximum age of <50 years and maximum length of 9.8 m (male) and 10.7 m (female). Males are sexually mature at five to eight years / 7.3 m, females are sexually mature at six to eight years / 7.9 m. They calve every year in temperate to tropical waters in June-July after a ten month gestation period. They mate from August-September. The dwarf form calves in May-June. Dark-shoulder minke whales feed mostly on krill. Dwarf minke whales have been found to feed on myctophids, fish and krill. Minke whales have been reported to evade moving ships and seek out and approach stationary or slow moving vessels. They occur singly or in groups of two or three, though feeding concentrations of the dark-shoulder form may be encountered. The Southern Hemisphere population was recently estimated to be 700,000 animals in total. The population of the species in Area V (130-170^{o}W) on the east coast of Australia is around 210,000 animals. Estimates exclude the dwarf form.

Identified threats: Threats include seismic operations, collision with large vessels, entanglement in fishing gear, defence operations, and pollution leading to the accumulation of toxic substances in body tissues. The minke whale is a commercially harvested species. The Japanese can catch around 300 animals per year in areas IV and V for scientific purposes (Smith 2001).

Conservation status: NSW (*NPW Act*) - Protected; Commonwealth (EPBC Act) – Protected; International (IUCN) – Lower risk, near threatened.

Blue whale (*Balaenoptera musculus*)

Distribution: Occurring throughout the world's oceans, blue whales migrate between warm water breeding grounds in tropical and subtropical waters and cold water feeding grounds in polar and subpolar waters. There are three subspecies of blue whale, the spatially disjunct northern and southern 'true' blue whale and the pygmy blue whale (Smith 2001). In the Southern Hemisphere, 'true' blue whales occur between 20oS and 60-70^{o}S. Pygmy blue whales only occur in the Southern Hemisphere, particularly in the Indian Ocean, and migrate to north of 50^{o}S in summer. Blue whales have been recorded from all Australian states. Recent strandings in Australia have mostly been pygmy blue whales. Their migration paths are widespread and do not obviously follow coastlines or oceanographic features.

The waters off the far south coast of NSW, and the adjacent waters off Victoria, are one of only three recognised aggregation areas for blue whales in Australia (Environment Australia 2001a). Blue whales have been sighted in NSW waters on a number of occasions mostly between Bermagui and Green Cape, mostly in October and November (Smith 2001). While there are no confirmed records of pygmy blue whales in NSW waters, it is likely that some NSW sightings of blue whales may have been this species as it is the more common subspecies in adjacent Victorian waters.

The population of 'true' blue whales dramatically declined during historical whaling operations that fully ceased in the early 1970s. The current Southern Hemisphere population of 'true' blue whales has been estimated at 610 and pygmy blue whales at 4,300 (Smith 2001). This is only a small proportion of the original population.

General comments: Blue whales mostly occur along the edges of continental shelves and along ice fronts, and also in both deep oceanic waters and shallow inshore zones (Smith 2001). 'True' blue whales reach a maximum age of 80-90 years and a maximum length of 30.5 m. 'True' blue males reach sexual maturity at 22 m and females at 23-24 m (5-10 years of age). They give birth to a single calf every two to three years in the tropical open ocean in winter after a 10-11 month gestation period (Rafic 1999). They mate in winter. Pygmy blue whales reach a maximum age of less than 50 years and a maximum length of 24.4 m. Pygmy blue whales calve every two to three years in tropical open oceans in winter after a 10-11 month gestation period. They mate in winter. 'True' blue whales feed almost exclusively on one species of krill in Antarctic waters. Pygmy blue whales feed further north on smaller krill, and have been reported feeding off southern Australia. They exhibit both shallow and deep diving behaviour, and can dive for up to 30 minutes. They are usually solitary animals or occur in groups of two to three. In one day they may consume two to four tonnes of food.

Identified threats: The numbers of blue whales have been so severely depleted that the species vulnerability to other threats is exacerbated (NSW Scientific Committee 2002a). The species is threatened by seismic operations, collision with large vessels, entanglement in fishing gear, defence operations, pollution leading to the accumulation of toxic substances in body tissues and anthropogenic climate change (NSW Scientific Committee 2002a). Ingestion of or entanglement in harmful marine debris also affects this species (Threatened Species Scientific Committee 2003).

Conservation status: NSW (TSC Act) - Endangered; Commonwealth (EPBC Act) – Endangered; International (IUCN) – Endangered

Humpback whale (*Megaptera novaeangliae*)

Distribution: Humpback whales occur throughout the world's oceans. Northern and Southern Hemisphere populations are distinct, because of seasonal migration separation. Humpback whales are found off coastal Australia in winter and spring and are recorded from all states, except the Northern Territory. They migrate annually between warm water breeding grounds in winter, at around 15-20^{o}S, to cold water (Antarctic) feeding grounds in summer, to 60-70^{o}S. Off Australia, wintering animals off the west coast (Group IV population) are shown to be distinct from those off the east coast (Group V population). The latter is more

closely related to those wintering off Tonga. Humpback whales may occur close to the coast on migration. Not all animals migrate south each year there are some summer sightings in the Coral Sea. There is a reported sex ratio bias towards males in the east coast migration perhaps not all females migrate north each year.

Humpback whales are regularly sighted in NSW waters when migrating (Smith 2001). They generally pass close to the coast (rarely venturing >10 km from shore) (Bryden 1985), mainly between June and November on their northward migration (peaking in June-July) and September and November on the southward migration (Smith 2001).

The humpback whale population has been greatly reduced by historical whaling activities that ceased in 1963. Recent estimates of the population migrating along the east coast (Group IV) were between 3,000-4,000 and that along the west coast (Group V) were between 14,000-19,000. Australian populations of the species are increasing at a rate of around 10% per year.

General comments: Humpback whales are pelagic and are found in Antarctic waters during summer and temperate-subtropical / tropical coastal waters in winter. Key localities for the east coast population are the south coast of New South Wales, off Coffs Harbour, Cape Byron, Stradbroke Island, Hervey Bay and islands in the Great Barrier Reef, especially the Whitsunday passage area. The exact location of breeding grounds is unknown, although much breeding of the east coast population occurs in central Great Barrier Reef area. However, there is probably a wide range of opportunity for breeding, over several degrees of latitude on each coast. There is evidence that some animals calve in northern NSW waters when migrating north (Smith 2001). They live to a maximum of 50 years and reach a maximum length of 18 m. Males reach sexual maturity at 11.6 m and females at 13.7 m (4-10 years of age). They calve every two to three years, sometimes twice every three years, or even annually. They calve in tropical coastal waters between June-October after an 11–11.5 month gestation period. Mating occurs between June-October. Feeding areas are concentrated in Antarctic waters, where they almost exclusively feed on Antarctic krill. There is some evidence of them feeding on fish and plankton swarms in warmer waters, for example off Eden in NSW. Feeding behaviour off Eden has been repeatedly observed in recent years during the southward migration (Warneke 1996). Only negligible amounts of food are taken while in NSW waters (Chittleborough 1965). Feeding in subtropics off northwest Western Australia and eastern Australia is uncertain, however it is unlikely. The species exhibits both shallow and deep diving behaviour, and can dive for up to 15 minutes.

Identified threats: Humpback whales are more likely to be directly disturbed when they are closer to human activities on their migration and in breeding areas. Whale watching, research and pleasure vessels, aircraft, swimmers, divers, coastal seismic activity, defence operations, collision with large vessels, entanglement in fishing gear or shark nets and pollution leading to the accumulation of toxic substances in body tissues can all directly disturb humpback whales. Ingestion of or entanglement in harmful marine debris affects this species (Threatened Species Scientific Committee 2003).

Conservation status: NSW (*TSC Act*) - Vulnerable; Commonwealth (EPBC Act) – Protected; International (IUCN) – Vulnerable.

Pinnipeds

Unless otherwise specifically referenced, the following information on seals was obtained from *The Action Plan for Australian Seals* (Shaughnessy 1999).

Australian fur-seal (*Arctocephalus pusillus*)

Distribution: The Australian fur-seal breeds on five Bass Strait islands, and a small breeding colony is becoming established at Wright Rock. Their range extends to South Australia, south Tasmania and New South Wales and several haul-out sites are known in each state. The species once bred more widely with breeding colonies at Seal Rocks in NSW and southern Tasmania. In NSW, Montague Island is the main site for the species. The species predominantly hauls-out on the northern side of the island, throughout the year, but mostly during winter (July to October) when the highest numbers are found (Shaughnessy et al. 2001). A maximum of 540 Australian fur-seals were recorded on Montague Island in October 1998 (Shaughnessy et al. 2001). Although it is generally thought that only male fur-seals haul-out on Montague Island, there are indications that the island is also used by female fur-seals (Shaughnessy et al. 2001). The colonies of Australian fur-seals on the island are non-breeding, although there are records of odd unsuccessful breeding events, the vicinity lacks important features of other breeding colonies, and any fur-seal pups born on the island would probably not survive the weaning period (Shaughnessy et al. 2001). Steamers Beach and

Green Cape are other sites in NSW where Australian fur-seals regularly haul-out. Seals also come ashore irregularly at other sites all along the coast from Nadgee Nature Reserve to Tweed Heads. This occurs throughout the year, but most frequently between July and November (Smith 2001).

The Australian fur-seal population was dramatically reduced from commercial sealing activities. In 1991, the total population size for Australian waters was estimated at between 47,000 and 60,000, with pup production estimated at 13,335. Despite some recent increases, the overall population level in Australia is likely to be much lower now than it was historically.

General comments: Australian fur-seals prefer rocky parts of islands with flat, open terrain. At sea, they remain mainly within continental shelf waters (Smith 2001). On average, females reach a maximum length of 157 cm and males 216 cm. The maximum age for females is >21 years and males >19 years. After females reach sexual maturity at three to six years (males reach sexual maturity at around five years) they breed annually between October to December after an eight to nine month gestation period. They principally feed on fish and cephalopods, and also seabirds. In Tasmanian waters, they predominantly feed in winter on adult fish, such as redbait, leatherjackets and jack mackerel and, in summer on adult squid, primarily Gould’s squid. Australian fur-seals also feed at fishing boats.

Identified threats: The species is threatened by reduced prey item availability from fishing operations, illegal shooting of seals that compete with fishing activities and entanglement in fishing gear debris (NSW Scientific Committee 2002a). Entanglement in and ingestion of plastic debris is a threat to this species (NSW Scientific Committee 2002a).

Conservation status: NSW (*TSC Act*) - Vulnerable; Commonwealth (EPBC Act) – Protected; International (IUCN) – Not in database.

New Zealand fur-seal (*Arctocephalus forsteri*)

Distribution: In Australia, New Zealand fur-seals breed in southern Australia on the south coasts of Western Australia, South Australia and on Maatsuyker Island (Tasmania). They have recently been reported breeding on a couple of islands in north-eastern Bass Strait (Arnould et al. 2000). They also breed in New Zealand and Macquarie Island. There are >30 breeding populations in Australian waters. Non-breeding New Zealand fur-seals are occasionally reported from the west coast of Western Australia, Victoria, Bass Strait, New South Wales (mainly Montague Island), Queensland (south of Fraser Island) and New Caledonia. Montague Island is the only known regular haul-out site for New Zealand fur-seals in NSW. Here the highest numbers of this species occur between July to October (Shaughnessy et al. 2001). A newly established seal colony of the western side of this island is said to mostly consist of New Zealand fur-seals, these seals can also be found in the colony on the northern side of this island which predominantly consists of Australian fur-seals (D. Pridell, NSW DEC, pers. comm. 2005). Although considered a non-breeding colony a New Zealand fur-seal pup was born on Montague Island over the summer of 1999/2000, and survived for at least four months (Shaughnessy et al. 2001). It is suspected that both male and female fur-seals haul-out on the island (Shaughnessy et al. 2001). Outside of Montague Island, there are scattered records of New Zealand fur-seals hauling-out along the NSW coast north to Yamba (Smith 2001). They generally do not stay at such locations for extended periods (Smith 2001). Animals on the east coast of Australia may have moved there from New Zealand or from South Australia. Seals tagged at Kangaroo Island have been reported at Tathra, Montague Island, Jervis Bay and Sydney.

New Zealand fur-seals in Australian waters suffered a severe decline in numbers from commercial sealing operations in the late 18th and early 19th centuries. Their former range used to extend to the Furneaux Group in eastern Bass Strait where it was quite abundant. New Zealand fur-seals in Australian waters were recently estimated to number 34,700 in the early 1990s. The population of this species in Australian waters is increasing, however it is probably still lower now than it was historically. The recolonisation of Bass Strait breeding sites illustrates the increasing population of this species (Arnould et al. 2000).

General comments: New Zealand fur-seals prefer rocky parts of islands with mixed terrain and boulders. At sea, they seem to occur only within continental shelf waters. They reach a maximum length of 100-150 cm (females) or 150-250 cm (males). After females reach sexual maturity at six years, they breed every year after an eight to nine month gestation period. Their breeding season is from November-January. They principally feed on fish and cephalopods, and also seabirds. They also feed at fishing boats.

Identified threats: Threats to this species include the illegal shooting of seals that interact with commercial and recreational fishing gear, entanglement or capture of seals in fishing gear, such as nets used in tuna

farming and deep water trawl nets (from the hoki fishery in New Zealand, and perhaps also the Australian south east trawl fishery), and reduced prey item availability from fishing operations (NSW Scientific Committee 2002b). Entanglement and ingestion of plastic debris also threatens this species (NSW Scientific Committee 2002b).

Conservation status: NSW (*TSC Act*) - Vulnerable; Commonwealth (EPBC Act) – Protected; International (IUCN) – Not in database.

Sirenians

Dugong (*Dugong dugon*)

Unless otherwise specifically referenced, the following information on the dugong was obtained from the *Review of the Conservation Status of Marine Mammal Species in New South Wales* (Smith 2001).

Distribution: The dugong occurs in the Indian and western Pacific Oceans, between about 27^{o}N and 27^{o}S. It is now found in small relict populations separated by large areas where it is extinct or close to extinction. The resident populations around the northern shoreline of Australia from Shark Bay (WA) to Moreton Bay (Qld) support most of the current world population of the species. Dugongs usually only occur in NSW as occasional stragglers usually in waters north of Jervis Bay, although they have been reported as far south as Twofold Bay. In 1992-93, there was an influx of dugongs (many of them dead) from Hervey Bay in NSW waters. This was due to a large loss of habitat following floods and a cyclone. NSW waters act as a refuge area for Queensland's dugongs. The minimum size of the Australian population of dugongs was estimated to be 85,000. Populations in the southern Barrier Reef and Hervey Bay area have declined in recent years.

General comments: Dugongs are found in the shallow coastal parts of tropical and subtropical waters. They feed on a wide variety of seagrass species and algae, although usually only in very small amounts if seagrasses are abundant. They live for up to 70 years, reach sexual maturity after nine years and calve every three to seven years (Marsh et al. 1984).

Identified threats: Dugongs are threatened by coastal development, poor catchment management leading to siltation and the loss of seagrass beds, traditional hunting, collision with boats and incidental mortality in gillnets and shark protection nets. Isolated dugong populations are vulnerable to local extinction following stochastic events such as floods or cyclones (NSW Scientific Committee 2002c). The dugong could also be affected by human induced climate change (Threatened Species Scientific Committee 2001).

Conservation status: NSW (*TSC Act*) - Endangered; Commonwealth (EPBC Act) – Protected; International (IUCN) – Vulnerable.

Turtles

Unless otherwise specifically referenced, the following information on turtles was obtained from the *Draft Recovery Plan for Marine Turtles in Australia* (Environment Australia 1998).

Green turtle (*Chelonia mydas*)

Distribution: Green turtles occur worldwide and are found in tropical and subtropical waters, with vagrants extending to higher latitudes (Cogger 2000). In Australia, green turtles live year round in coastal waters from central Western Australia, through the Northern Territory and Queensland to central New South Wales. Breeding is largely restricted to areas north of 27^{o}S (Cogger 2000), and they are most abundant within 1000 km of their nesting beaches. In NSW, they are found in small numbers in coastal waters (Cogger 2000). The species is the most frequently recorded marine reptile in NSW (328 records on the DEC Atlas of NSW Wildlife 10/12/2007). It is probably relatively common in northern NSW waters, from where there are records of mostly unsuccessful nestings (Cogger 2000). A nesting record, near Coffs Harbour was successful (NSW NPWS 2002).

Green turtles have been hunted intensively in the past, except in Australia where it was, and continues to be hunted in relatively small numbers by indigenous communities (Cogger 2000). Recent downward trends in nesting rates for the Queensland stock may be the result of intense hunting pressure in non-Australian waters (Cogger 2000).

General comments: Green turtles inhabit subtidal and intertidal seagrass beds and coral reefs with a good cover of seaweed. Adult turtles feed on seaweeds and seagrasses, whereas immature turtles feed on jellyfish, small molluscs, crustaceans and sponges. They do not form obvious social groups and feed as

individuals. Green turtles are long-lived species that become sexually mature after 50 years when they are generally between 91.5–122.5 cm CCL. Adult females breed about every six years. On average, 115 eggs are laid in a clutch. They may migrate up to 2,600 km from feeding grounds in Indonesia, Papua New Guinea, New Caledonia, Fiji, Queensland, Northern Territory, Western Australia and New South Wales to breed and nest in southern and northern Great Barrier Reef, northwest Northern Territory, Gulf of Carpentaria, Western Australia, Coral Sea and Ashmore Reef. Nesting generally occurs from late November to January and earlier in the Northern Territory from July to December. The Australian nesting populations are genetically distinct from those in neighbouring countries. Some green turtles that feed in Australia are part of stocks that breed in other countries and vice versa.

Identified threats: Green turtles are taken as bycatch in trawl fisheries, gill nets, shark meshing operations and can become entangled in trap ropes. Other influences include boat strike, disease, tourism activities, indigenous harvesting and ingestion of fishing line.

Conservation status: NSW (*TSC Act*) - Vulnerable; Commonwealth (EPBC Act) – Vulnerable; International (IUCN) – Endangered.

Loggerhead turtle (*Caretta caretta*)

Distribution: Loggerhead turtles are found worldwide, inhabiting tropical and warmer temperate waters, often straying into higher latitudes (Cogger 2000). In Australia, loggerhead turtles live year round in coastal waters from southern Western Australia, through the Northern Territory and Queensland to southern New South Wales.

Breeding is largely restricted to areas north of 27^{o}S (Cogger 2000), and they are most abundant within 100 km of their nesting beaches. In NSW coastal waters, they occur in moderate numbers in the far north and are far less numerous in the southern parts of the State (Cogger 2000). Successful breeding events have been recorded in far northern NSW (NSW NPWS 2002). The eastern Australian population of loggerhead turtles is in severe decline, it has reduced by 86% over the past 23 years to less than 500 breeding females (C. Limpus, Queensland EPA, pers. comm., 2003).

General comments: Loggerhead turtles occur within continental shelf waters and forage over coral reef, rocky reef, bay or estuarine habitats. They also forage on the deeper soft-bottomed habitats throughout the coastal waters of the continental shelf. Adult and large immature turtles eat shellfish and crabs, while immature turtles eat sea urchins, jellyfish and sea anemones. They do not form obvious social groups and feed as individuals. They feed off the substrate surface, from within the water column, and at or near the surface on floating prey and discarded trawl bycatch (C. Limpus, Queensland EPA, pers. comm., 2003). They reach sexual maturity at about 30 years or more and grow to an average of one metre in size. On average, 127 eggs are laid in a clutch. Loggerhead turtles migrate 2,600 km from feeding grounds in the Northern Territory, New South Wales and Queensland to traditional nesting sites on the eastern and western Australian coastlines. Some nesting turtles also migrate from as far as Indonesia, Papua New Guinea, Solomon Islands and New Caledonia. Australian nesting populations are genetically distinct from those in other countries. The southern Great Barrier Reef and adjacent mainland near Bundaberg is the breeding centre of the eastern Australian population. Mating occurs from late October to early December, followed by nesting from late October to early March. Breeding and nesting occurs on average every 2-5 years.

Identified threats: The loggerhead turtle is threatened by fishing interactions, ingestion of synthetic materials, boat strike, predation at rookeries, disease, coastal development, tourism and indigenous harvesting. Fishing interactions include incidental capture in trawling, gill netting, pelagic long line and shark meshing gear and entanglement in float lines from traps.

Conservation status: NSW (*TSC Act*) - Endangered; Commonwealth (EPBC Act) – Endangered; International (IUCN) – Endangered.

Leathery turtle (*Dermochelys coriacea*)

Distribution: Leathery turtles (formerly known as leatherback turtles) occur across the world's tropical waters and adults are frequently recorded from higher latitudes (Cogger 2000). In Australia, adult and large immature leathery turtles are most regularly encountered in temperate waters of Queensland and Western Australia and in New South Wales, Victoria and Tasmania. Small numbers are found in coastal NSW waters (Cogger 2000). There is possibly one or more resident communities in far northern NSW (Cogger

2000). Breeding events in NSW have been recorded near Ballina in 1993 (Tarvey 1993) and near Forster in 1995, the latter was unsuccessful (NSW NPWS 2002). In Australia, the species may have always occurred in small numbers.

General comments: Leathery turtles are the largest of the marine turtles, with shells averaging 1.6 metres in length and with a total weight of up to 500 kg. They may reach sexual maturity at around 10 years of age and produce an average of 90 eggs per clutch. They are oceanic and feed on jellyfish and other soft bodied invertebrates within the water column. The major breeding and nesting sites in the Asia / Pacific occur in Indonesia, Malaysia, Papua New Guinea and the Solomon Islands. Animals from these nesting aggregations use the continental waters of Australia to feed and migrate to temperate waters where they feed within the water column. Leathery turtles rarely nest in Australian waters, there are perhaps fewer than 40 nesting records in total (NSW NPWS 2002). Annual nesting attempts in eastern Australia occur near the Bundaberg coastline and sporadic nesting occurs at other widely scattered sites in Queensland, New South Wales and the Northern Territory.

Identified threats: The leathery turtle has been incidentally caught in trawling, gill netting and offshore long line fishing gear. They are also occasionally entangled in trap buoy-lines. Ingestion of synthetic materials, predation at rookeries and some indigenous harvesting also threaten the species.

Conservation status: NSW (*TSC Act*) - Vulnerable; Commonwealth (EPBC Act) – Endangered; International (IUCN) – Critically endangered.

Birds

The following information on the little penguin was obtained from the Handbook of Australian, New Zealand and Antarctic Birds (Marchant and Higgins 1990).

Little penguin (*Eudyptula minor*)

Distribution: Little penguins, found only in Australia and New Zealand, once ranged from Swan River in Western Australia through Tasmania and up to Moreton Bay in Queensland, and may still occasionally venture that far. They are relatively common in the waters of southern Australia, breeding mainly on offshore islands. In NSW, they are increasingly reported southwards along the coast and there are few reports of the species north of Port Stephens.

General comments: Little penguins occur in temperate seas within the summer isotherms of 20°C in the north and 13°C in the south. They generally breed from August to February on the coastal mainland or islands of Australia and New Zealand. Breeding locations in Australia range from Port Stephens in NSW along the eastern and southern coasts, including around Tasmania, and as far north as Fremantle on the west coast. There are approximately 19 breeding locations in NSW. The birds are often found in bays, harbours and estuaries and feed mainly in inshore waters around the mainland coast of breeding islands and also out to the continental shelf and slopes. Observations of little penguins in the Tasman Sea found 2% were over the open ocean, 10% were over the continental slope and 88% were over the continental shelf (Reid et al. 2002). Adults tend to remain centred on their breeding colonies throughout the year, while immature animals are dispersive. Little penguins appear to be opportunistic feeders, foraging in relatively shallow waters. When feeding their young, they generally do not disperse far from their colonies and their daily foraging range is usually between 10-30 km. They usually feed by pursuit-diving up to depths of 30 m on small shoaling fish or cephalopods, less often crustaceans. Their diet consists mainly of small schooling fish, like anchovies (*Engraulis australis*), pilchards (*Sardinops neopilchardus*), squid (Order Teuthida) and to a lesser extent krill. When swimming in search of food, little penguins are unlikely to swim faster than 6 km/h. They usually feed singly, occur in pairs within breeding colonies and at sea are either solitary or occur in small groups.

Identified threats: Threats include the alteration of breeding habitat, residential development, disturbance, trampling of burrows by cattle, predation of birds by introduced foxes, dogs and cats, oil pollution, plastic pollution, capture in fishing nets, the killing of birds for use as crayfish bait and commercial fishing activities that harvest penguin food resources (NSW NPWS 2000).

Conservation status: NSW (*NPW Act*) – Protected (The population of this species in the Manly Point area is listed as an Endangered Population under the *TSC Act*); Commonwealth (EPBC Act) – Protected; International (IUCN) – Not in database.