NSW Fisheries Threatened Species Recovery Planning Program

Grey Nurse Shark
(Carcharias taurus)

DRAFT RECOVERY PLAN

Prepared in accordance with the threatened species provisions of the
Fisheries Management Act 1994 **(NSW)**

Submissions close 28 June 2002

NSW Fisheries
Port Stephens Fisheries Centre
Private Bag 1
NELSON BAY NSW 2315
www.fisheries.nsw.gov.au

For further information contact
Threatened Species Unit
NSW Fisheries
Port Stephens Fisheries Centre
Private Bag 1
NELSON BAY NSW 2315

Cover photograph: grey nurse shark (*Carcharias taurus*)

Acknowledgments

This plan was developed with the assistance of many people. In particular:

Ms Nicola Benyon (Humane Society International)

Ms Kelly Waples (National Parks and Wildlife Service)

Dr John West (Taronga Zoo)

Dr Tim Anderson (Nature Conservation Council)

Mr Craig Woodfield (Marine and Coastal Community Network)

Mr Noel Hitchens (Dive shop operator)

Mr Chris McDonald (Sydney Aquarium)

Mr Mel Brown (Australian Underwater Federation)

Mr Peter Goadby (Advisory Council on Recreational Fishing)

Ms Sarah Williams (Environment Australia)

Mr David Harasti (Environment Australia/NSW Fisheries)

Dr Barry Bruce (CSIRO)

Dr John Stevens (CSIRO)

Mr Bill Talbot (NSW Fisheries)

Dr Nick Otway (NSW Fisheries)

Dr David Pollard (NSW Fisheries)

Mr Andrew Read (NSW Fisheries)

Ms Michelle Belcher (NSW Fisheries)

Table of Contents

List of Figures

List of Tables

AN OVERVIEW

Introduction

The grey *nurse* shark, *Carcharias taurus* (Rafinesque, 1810), has been listed by the NSW Government, on the advice of the Fisheries Scientific Committee, as an endangered species under the *Fisheries Management Act.*[1]

The grey nurse shark is a large species of shark native to subtropical to cool temperate waters in the Mediterranean Sea and the Atlantic, Indian and Pacific oceans. Once widely distributed, they are now restricted to waters off parts of the USA, Uruguay, Argentina, South Africa and Australia.

In all areas around the world where grey nurse sharks occur their numbers have declined.

In Australia, grey nurse sharks are now restricted to two separate populations, one on the east coast of NSW and southern Queensland, and the other in coastal waters off Western Australia. The east coast population has been listed by the Commonwealth as 'critically endangered' under the *Environment Protection and Biodiversity Conservation Act*, while the west coast population is listed as 'vulnerable'.

Their abundance in NSW waters has declined significantly in recent decades. This decline seems to have been mainly the result of commercial fishing, recreational spear and game fishing, and shark control activities such as beach meshing.

In response to this decline, grey nurse sharks were protected from fishing in NSW in 1984.

As yet there is no evidence that this has succeeded in stopping or reversing the decline in their numbers. Grey nurse sharks have a low rate of reproduction, which makes them very vulnerable to threatening processes and very slow to recover when their populations are reduced. They are still threatened by incidental capture by fishers and illegal fishing activities such as shark finning.

Through a series of surveys along the entire NSW coast, 13 key aggregation sites for grey nurse sharks have been identified in state waters. Three of these key 'aggregation sites' are already given high levels of protection within existing marine protected areas. The remainder are still exposed to a range of threats, mainly associated with fishing.

A draft recovery plan has been developed to assist the recovery of this species through implementation of a range of strategies. The draft plan describes our current state of knowledge of grey nurse sharks and the gaps that still remain in our understanding of their ecology, abundance, natural life history and population dynamics. It also discusses the major threats and issues affecting their conservation and management. The draft plan then identifies the actions required to improve this knowledge and reduce major threats to ensure the ongoing viability of grey nurse sharks in the wild.

Recovery objectives

The overall objective of this draft recovery plan is to ensure the recovery and ongoing viability in nature of grey nurse shark populations along the NSW coast. This requires their genetic diversity and structure to be maintained, and the population numbers to be increased.

[1] Under the NSW *Fisheries Management Act*, a person must not harm, buy, sell or possess a grey nurse shark. Maximum penalty is $220,000 and/or imprisonment for two years.

The specific objectives of the draft plan are to:

- improve our understanding of the abundance, reproductive biology, life history, ecology, migratory patterns and genetics of grey nurse shark populations;
- address the key threats to grey nurse sharks;
- provide enhanced protection for key grey nurse shark habitats;
- coordinate action by community groups, local councils, government agencies, scuba diving groups and other stakeholders;
- increase awareness of the status of and threats to grey nurse shark populations, and enhance community support for recovery actions; and
- establish an on-going monitoring program to document the status of grey nurse shark populations and habitat and evaluate the effectiveness of recovery actions.

Recovery criteria

The success of the plan will be evaluated against the criterion that:

- the status of grey nurse sharks is revised from 'endangered' to 'vulnerable' and eventually de-listed from the schedules of the *Fisheries Management Act.*

Specific recovery criteria, based on biological information including abundance and population trends, will be developed as the necessary data becomes available through research actions.

Recovery actions

The recovery actions identified under this plan are grouped into the following eight areas:

Fishing

The impact of commercial fishing on grey nurse sharks would be minimised through restrictions on fishing gear identified as having a significant chance of incidentally capturing grey nurse sharks e.g. through a maximum snood length.

At the 13 key sites where groups of grey nurse sharks are regularly found, new fishing rules would be put in place for methods that have a significant risk of incidentally capturing grey nurse sharks. This would involve bans on the use of drop and set-lines by commercial fishers and a ban on the use of wire trace on fishing lines by all fishers from vessels not underway (ie not trolling).

Illegal shark finning

NSW Fisheries will continue to enforce shark finning bans through cooperation with industry and effective compliance action. NSW Fisheries would seek to identify shark species currently for sale in the NSW shark fin market, to determine if grey nurse (or other threatened sharks) are present.

Shark control activities

NSW Fisheries would continue monitoring the numbers of grey nurse sharks caught in the beach safety shark meshing program and ensure that all grey nurse sharks caught live in beach mesh nets are released with minimal harm. Any grey nurse sharks incidentally killed in beach mesh nets will be retained for autopsy to help increase our understanding of grey nurse shark biology.

NSW Fisheries is committed to continuing the beach safety shark meshing program. A fisheries management strategy will be developed for the program and its environmental impact assessed in an environmental impact statement. When complete, NSW Fisheries will implement the approved fishery management strategy for shark meshing.

Research needs

With assistance from the scuba diving community, NSW Fisheries would continue to monitor the abundance of grey nurse sharks to establish spatial and temporal population trends and measure recovery. Further work is required on the biology and reproduction for grey nurse sharks in NSW waters and on estimates of survival/mortality rates.

Critical habitats

The 13 key "aggregation sites" for grey nurse sharks would be declared as critical habitat as these areas are seen as being of critical importance to the survival of the species. The areas are described in detail in Appendix 1 of this plan. Briefly they are at:

- Julian Rocks near Byron Bay;
- North Solitary Island in Solitary Islands Marine Park;
- South Solitary Island in Solitary Islands Marine Park;
- Green Island near South West Rocks (Mid North Coast);
- Fish Rock near South West Rocks (Mid North Coast);
- The Pinnacle near Forster;
- Big Seal at Seal Rocks;
- Little Seal at Seal Rocks;
- Little Broughton Island near Port Stephens;
- Magic Point near Maroubra;
- Bass Point near Shellharbour;
- The Tollgate Islands in Batemans Bay; and
- Montague Island near Narooma.

Regulations would be developed for critical habitat sites to modify fishing activities that are likely to have a significant risk of accidental capture of grey nurse shark, namely:

- prohibitions on commercial drop and setline fishing within critical habitat; and
- prohibitions on the use by all fishers of wire trace on fishing lines from vessels not underway (ie not trolling) in critical habitat.

Commercial aquaria

NSW Fisheries will retain the existing ban that prohibits grey nurse shark being taken from the wild. Aquariums are encouraged to continue the development of breeding techniques utilising existing captive grey nurse sharks and to increase public awareness of the endangered status of grey nurse sharks.

Ecotourism

NSW Fisheries have, in consultation with the dive industry, developed a draft code of conduct for scuba diving with grey nurse sharks. The draft code of conduct, when finalised, would be extensively promoted to the scuba diving community in NSW, and all scuba diving groups would be encouraged to adopt the code of conduct as part of their practice for diving with grey nurse sharks. It is proposed that relevant provisions of the code of conduct become mandatory in grey nurse shark critical habitat areas, namely the:

- prohibition on night dives;
- prohibition on blocking of entrances to caves or gutters;
- prohibition on feeding or touching the sharks; and
- prohibition on chasing or harassing the sharks, and would include a ban on mechanical apparatus eg. scooters, horns, etc.

Community awareness and support

A comprehensive community education strategy would be developed on grey nurse sharks, targeting the general public, anglers, divers and commercial fishers. Information would include identification, status, current threats and biology of the grey nurse shark. NSW Fisheries would encourage community involvement in the implementation of the recovery plan.

Implementation and costs

NSW Fisheries would lead the implementation of the recovery plan. However, the implementation of the plan is a broad community responsibility, and relies on the support of fishers, scuba divers, other government agencies, other stakeholders and the wider community.

Biodiversity benefits

As an 'apex' predator, grey nurse sharks are a significant component of the inshore marine ecosystem of NSW, and their recovery should help to restore ecological balance in these systems.

Increased protection for key grey nurse shark critical habitats and more effective control of fishing impacts would also benefit other species that share these habitats. In addition, community awareness and understanding of marine biodiversity and threatened species would be heightened, through conservation efforts for this high-profile and popular marine species.

Need More Information?

The full draft recovery plan and the critical habitat preliminary identification are available on the NSW Fisheries website at www.fisheries.nsw.gov.au. Alternatively, you can view it at any NSW Fisheries office during normal business hours. A paper or CD copy can be purchased for $15 (includes GST). For further information or to receive details of other locations where the full document is on display, please call 02 4916 3811.

Want to Comment?

The community is invited to have their say on the draft recovery plan for grey nurse sharks and also on the sites proposed to be declared as critical habitats (see Appendix 1).

Community open days will be held by NSW Fisheries at various sites along the coast to allow discussion of these proposals. All those interested in the conservation of grey nurse sharks are encouraged to attend. Written submissions are invited. They can be handed in at any of the open days or posted to:

Threatened Species Unit (Grey Nurse Shark)

NSW Fisheries

Private Bag 1

Nelson Bay NSW 2315

Fax: 02 4916 3880

An online submission can be made through the NSW Fisheries website (www.fisheries.nsw.gov.au).

If you wish your submission to remain confidential it should be so marked.

Comments must be received by Friday 28 June 2002.

1. INTRODUCTION

Grey nurse sharks, *Carcharias taurus* (Rafinesque, 1810), are a large species of shark native to subtropical to cool temperate waters in the Mediterranean sea and the Atlantic, Indian and Pacific oceans. Once widely distributed, they are now restricted to waters off parts of the USA, Uruguay, Argentina, South Africa and Australia.

In Australia, grey nurse sharks were previously found around most of the coastline including southern Queensland, New South Wales, Victoria, South Australia and southern Western Australia. They are now restricted to two separate populations, an east coast population off NSW and southern Queensland, and a west coast population off Western Australia.

Grey nurse sharks are regularly seen by divers in a number of areas along the NSW coastline, usually in or near deep, sandy-bottomed gutters or caves around rocky reefs or islands fairly close to shore. Despite their fierce appearance, grey nurse sharks are not a threat to divers or swimmers unless provoked. The combination of their placid nature and their preference for shallow inshore reef areas has allowed diving with grey nurse sharks to become a sizeable ecotourism industry.

Over the second half of the twentieth century, grey nurse shark numbers showed a serious decline, largely attributed to the impact of commercial fishing and recreational spear and game fishing, as well as shark control activities such as beach meshing. They were fully protected in NSW in 1984, but their numbers have continued to decline. As a result, the NSW Government has listed grey nurse sharks as an **endangered** species, and there are heavy penalties for harming, possessing, buying or selling them, or harming their habitat.

Current threats to grey nurse sharks include incidental capture by fishers and illegal fishing activities such as shark finning.

This recovery plan summarises the background to recovery plan development, and describes our current understanding of grey nurse sharks and the major threats and issues affecting their conservation and management. The plan then identifies the actions required to improve our knowledge of the species and ensure their ongoing viability in the wild.

1.1 Legislative context

In NSW, the *Fisheries Management Act 1994* provides the legislative framework for the protection and recovery of threatened species, populations and communities of fish, aquatic invertebrates and marine plants.

Grey nurse sharks are listed as an endangered species in schedule 4 of the *Fisheries Management Act*.

At a national level, the east coast population of grey nurse sharks is listed as critically endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, while the west coast population is listed as vulnerable.

1.1.1 Recovery planning

Recovery plans are prepared by NSW Fisheries for all species, populations and ecological communities listed as endangered or vulnerable on the schedules of the *Fisheries Management Act*.

The *Fisheries Management Act* includes specific requirements for the matters to be addressed by a recovery plan (see Appendix 3) as well as the process for preparing the plan.

Once it has been finalised and approved, a recovery plan is a statutory document. Public authorities must not undertake actions inconsistent with an approved recovery plan, and must not depart from this without consulting NSW Fisheries.

Under the *Environmental Planning and Assessment Act 1979* (NSW), relevant recovery plans must also be considered by consent authorities (eg. local councils), determining authorities (eg. State government agencies), and the Director of Fisheries (as a concurrence authority) when they are exercising a decision-making function under Part 3, 4 or 5 of the Act.

1.1.2 Critical habitat

The *Fisheries Management Act* requires, wherever possible, the identification and declaration of 'critical habitat' for endangered species, populations and ecological communities. Critical habitat is the whole or any part of the habitat of an endangered species, population or ecological community that is critical to its survival.

The declaration of critical habitat allows for increased protection of threatened species' habitat and provides the ability to regulate activities within the area. Once declared, it becomes an offence to damage critical habitat (unless the action is specifically exempted by the legislation) and a species impact statement is mandatory for all developments and activities (including fishing activities) that are likely to affect the declared critical habitat.

Preliminary identification of critical habitat for grey nurse sharks in NSW can be found in Appendix 1 of this plan. Public comment is sought on the proposal to list these areas as critical habitat.

1.1.3 Environmental planning and assessment

The *Environmental Planning and Assessment Act* sets out the planning and environmental assessment system in NSW. Under this Act, consent and/or determining authorities must consider the effect of a proposed development or activity on threatened species. Where there is likely to be a significant impact on a threatened species, a detailed species impact statement must be prepared, and the consent or determining authority must seek the concurrence of the Director of Fisheries, or in certain circumstances, consult with the Minister for Fisheries.

Even if a proposed action does not require approval under the *Environmental Planning and Assessment Act*, it may still require approval under the *Fisheries Management Act*. For actions that are likely to result in harm to threatened species, populations or ecological communities or their habitat, a specific licence may be required.

The *Environment Protection and Biodiversity Conservation Act* (Cth) also requires that where a development or activity is likely to have a significant effect on a nationally listed threatened species, the matter must be referred to the Commonwealth Minister for Environment and Heritage. If the Minister decides that the issue is a matter of national environmental significance, then assessment of the impacts and Commonwealth approval will be required. This is a separate process to the environmental assessment and approval process under NSW legislation.

1.2 Recovery plan preparation

This draft recovery plan has been developed in accordance with the requirements of the *Fisheries Management Act* (as outlined in section 220ZN; see Appendix 3).

The draft plan has been prepared by NSW Fisheries' Threatened Species Unit in consultation with a grey nurse shark working group. The working group was established to discuss and resolve issues relating to the management of the species and the actions required for its recovery. The group included staff representatives from NSW Fisheries and Environment Australia, which have responsibility for implementing the state and national plans respectively. Other members were included on the basis of their scientific expertise, their prior involvement and expertise in grey nurse shark conservation, or on the basis that they represented a significant stakeholder group (see 'Acknowledgments').

While the draft recovery plan is based on the input of the working group, individual components within the plan do not necessarily represent the views nor the official position of all individuals or agencies represented on the working group.

The information in this recovery plan was accurate to the best of the knowledge of NSW Fisheries at the time of preparation.

1.3 Recovery plan implementation

This recovery plan has been developed to guide action by government agencies and the community to conserve NSW populations of grey nurse sharks, protect their habitat and promote their recovery.

The lead agency responsible for coordinating the implementation of this recovery plan is NSW Fisheries. However, the success of the plan and the long-term recovery of grey nurse sharks would require action by many other organisations and individuals who either have an interest in the conservation of this species or whose actions and decisions have the potential to affect its survival.

The other NSW government agency with specific responsibility for implementing some of the actions in this plan is the Marine Parks Authority. The *Fisheries Management Act* requires that public authorities (other than local councils) that are identified in a recovery plan as responsible for certain measures must report on the actions that have been taken to implement these measures in their annual report to Parliament.

Other groups which have been identified as having a part to play in implementing some actions include recreational scuba diving groups and commercial shark dive-tour operators. Some actions will also require cooperation with agencies in other jurisdictions, specifically the Queensland Department of Primary Industries, the Western Australian Department of Fisheries, and the Commonwealth Department of Environment and Heritage (Environment Australia).

Recovery actions are outlined in section 7.

1.4 Linkages with other recovery and threat abatement plans

The areas occupied by grey nurse sharks may also support a number of other threatened species, including black cod and great white sharks (both listed as vulnerable species under the *Fisheries Management Act*) as well as several species of marine mammals and turtles listed as endangered or vulnerable under the *Threatened Species Conservation Act* (administered by the NSW National Parks and Wildlife Service).

Recovery plans have not yet been prepared for any of these species, but it is likely that there will be a number of cross-linkages between recovery actions for these species and grey nurse sharks.

1.5 Biodiversity benefits

As an 'apex' predator, grey nurse sharks are a significant component of the inshore marine ecosystem of NSW. While their ecological role is not fully understood and the impact of depleting these predators cannot currently be predicted, it is believed that sharks play a vital role in maintaining marine biodiversity. Work in less complex marine systems shows that biodiversity is reduced when key predators are removed.

The particular habitats where grey nurse sharks choose to aggregate contain a rich diversity of fish and marine vegetation, including (in some cases) other threatened, rare or protected species. Increased protection for these areas, and more effective control of the impacts of fishing, would also benefit other species that share the same habitat, including other sharks such as wobbegongs.

Grey nurse sharks are a high-profile species popular with divers, visitors to commercial aquaria and others who enjoy the State's marine environments. Efforts to protect and recover populations of this high-profile species should therefore produce other kinds of benefits for marine biodiversity in addition to those mentioned above. For example, increasing awareness of the plight of grey nurse sharks should help to raise the profile of threatened species among fishers, divers and the general community. This should in turn lead to greater opportunities for the conservation of threatened species and increased protection for all aquatic biodiversity.

2. BIOLOGY AND ECOLOGY

2.1 Names

Common:	Grey nurse shark.
Other names:	Ragged-tooth shark (South Africa)
	Sand-tiger shark (USA)
Scientific:	*Carcharias taurus* (Rafinesque, 1810)

2.2 Systematic position

Grey nurse sharks, *Carcharias taurus* (Rafinesque, 1810), are one of four species belonging to the family Odontaspididae [22].

There has been some confusion in the past over the nomenclature of this family. For example, because they are widely distributed across the Indian, Pacific and Atlantic oceans, grey nurse sharks have in the past been given a number of different species names including *taurus* (Rafinesque 1810), *americanus* (Mitchell 1815; Abbott 1861), *cinerea* (Macleay 1880) and *arenarias* (Ogilby 1911). It is now accepted that all these names refer to the same species.

The correct scientific name for grey nurse sharks is *Carcharias taurus*.

2.3 Description

Grey nurse sharks have large, stout bodies tapered at both ends with a pointed snout and small eyes. Unlike many other shark families, they do not have a 'nictitating membrane' – a transparent, moveable membrane inside the eyelid [55]. The mouth extends beyond the front of the eyes and contains long, slender spear-shaped teeth with one small point on either side.

Grey nurse sharks can be quickly identified by their two large upper (or dorsal) fins of similar size. The tail (or caudal) fin is also distinctive with the top lobe being larger than the bottom.

The upper (dorsal) surface of the shark is bronze coloured and the underside is paler. Juveniles have dark spots on the lower half of the body and on the caudal fin. These spots fade as the shark becomes larger, but they are sometimes still evident on adults [55] [80] [75].

Grey nurse sharks grow to over 3 metres total length. The largest specimens reported from each area have been 320 cm off South Africa, 318 cm off the east coast of the USA [7] [22] and 282 cm off Brazil [84]. In south-eastern Australia, grey nurse sharks grow to at least 320 cm total length.

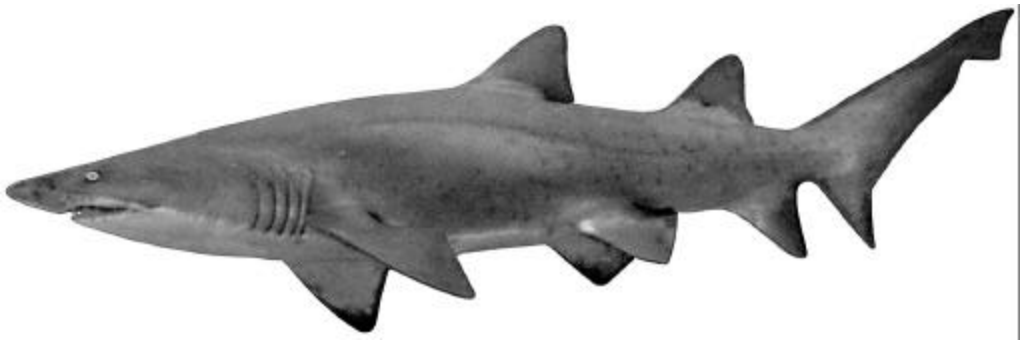

Fig. 1 The grey nurse shark, *Carcharias taurus* [55].

Photo by D. Harasti

2.4 Distribution

Grey nurse sharks once had a broad inshore distribution, primarily in sub-tropical to cool temperate waters around the main continents [22]. While grey nurse sharks have previously been recorded from the Mediterranean Sea and the Atlantic, Indian and Pacific Oceans, in more recent times they have only been sighted in a limited number of areas, namely:

- the east coast of the USA [92] [7];
- Brazil [84] [85], Uruguay [62] and Argentina [17];
- South Africa [4] [22]; and
- Australia [55].

In Australia, grey nurse sharks have been recorded from Mooloolaba in southern Queensland, around most of the southern half of the continent and northwards to Shark Bay in Western Australia [55]. They have also been caught on one occasion in the Arafura sea off the Northern Territory [81]. They do not occur in Tasmanian waters.

More recently, the distribution of grey nurse sharks appears to have become confined to the coastal waters off southern Queensland and along the NSW coast, and to the coastal waters off Western Australia.

2.5 Abundance

In the past, information on the abundance of grey nurse sharks in NSW has come from catch records from the beach safety shark meshing program [82] [53], catch records from the log books of gamefishers [79] and three limited, small-scale surveys [80] [77].

More recently, a series of quarterly underwater surveys have collected data on the abundances of grey nurse sharks at approximately 60 sites along the NSW coast [75] [73]. The results of the nine surveys carried out between November 1998 and December 2000 are summarised in Table 1. A maximum of 292 sharks were observed (in total) during any survey event.

Table 1. Summary of the abundances of grey nurse sharks observed over two years at sites along the entire NSW coast (After: [75]; [73]).

Survey number	Total number of sharks	Number of sites sampled	Number (%)of sites with no sharks	Sex Ratio (M : F)
1	136	61	37 (61)	01:02.2
2	129	51	35 (69)	01:03.6
3	207	50	25 (50)	01:00.9
4	187	44	24 (55)	01:04.1
5	132	58	36 (62)	01:01.8
6	149	64	49 (77)	01:01.9
7	292	62	31 (50)	01:01.1
8	146	57	39 (68)	01:02.5
9	120	63	46 (73)	01:02.5

An important finding of the underwater surveys was that 88 percent of the grey nurse sharks observed (on average) over the two year survey period were found in aggregations of five or more sharks at just 14 sites (see Table 2 and Appendix 1). Two of these sites, Pimpernel Rock and the Cod Grounds, occur in Commonwealth waters (ie. more than 3 nautical miles from the NSW coast).

Table 2. Mean number of grey nurse sharks observed in aggregations at 14 sites along the NSW coast, expressed as a percentage of the total sampled population averaged over 9 surveys.

Site	Nearest town	Mean percentage of sampled grey nurse shark population	Status of site
Julian Rocks	Byron Bay	3	Aquatic reserve
Pimpernel Rock *	Brooms Head	4	Marine park
Nth Solitary Is.	Nth Solitary Is.	2.8	Marine park
Sth Solitary Is.	Coffs Harbour	4.9	Marine park
Fish Rock & Green Is.	SW Rocks	14.1	Not protected
Cod Grounds *	Laurieton	12.7	Not protected
Pinnacle	Forster	12.3	Not protected
Big & Little Seal Rocks	Seal Rocks	12.3	Not protected
Broughton Is.	Nelson Bay	9.4	Not protected
Magic Point	Maroubra	3	Not protected
Tollgate Is.	Batemans Bay	8.4	Not protected
Montague Is.	Narooma	1.4	Not protected
TOTAL		**88.2**	

(After: [75] [73]).

*denotes sites located in Commonwealth waters

This figure exceeds 89 percent if Bass Point (Shellharbour) is added to this list of sites.

2.6 Habitat

Grey nurse sharks are a coastal species, found on the continental shelf from the surf zone down to at least 190 metres [22] [52] [55]. They are typically found in or near deep, sandy-bottomed gutters or in rocky caves around inshore rocky reefs and islands, at depths between 15 and 25 metres. They are a slow, strong-swimming species and are often seen hovering motionless near the bottom, although they

are also occasionally found in other parts of the water column [75]. They are thought to be more active at night [22] [80], but this needs to be verified.

Grey nurse sharks often form aggregations (groups of several individuals) at particular sites, and it is thought that such sites may be important for activities such as mating and/or pupping [22] [80], see Section 2.5).

2.7 Life history and ecology

There is limited information available on the life history of grey nurse sharks in Australian waters. However, some studies have been carried out for populations off South Africa and the east coast of the USA.

Current knowledge of the life history of grey nurse sharks (based largely on these US and South African studies) is summarised below. Many researchers have concluded that the low reproductive rate and other life history characteristics of grey nurse sharks make them extremely vulnerable to over-exploitation (eg. [22] [23] [8] [45] [17] [90]).

2.7.1 Reproductive biology

Reproduction in grey nurse sharks has been well documented for populations in the coastal waters off the USA [92] [38] [9] and South Africa [4]. They are regarded as having one of the most unusual reproductive strategies used by any shark [36].

Grey nurse sharks reach sexual maturity at total lengths of 190 - 195 cm (4 - 6 years) for males and 220 - 230 cm (6 - 8 years) for females [38] [9]. They are ovoviviparous, giving birth to pups after they have hatched from eggs within the uterus. Only two pups (occasionally one) are born per litter.

The female has no placental connection with the pups, unlike the carcharhinids (whaler sharks). Instead, the two most advanced embryos eat the other developing embryos and then the unfertilised eggs. These phenomena are known as intra-uterine cannibalism and oviphagy respectively [93] [4] [38] [22].

The gestation period of grey nurse sharks is about 9 - 12 months. Pupping occurs in late winter to early spring when the pups are approximately 100 cm in length [4] [38]. Pregnant females avoid giving birth in embayments or areas of low salinity, preferring coastal rocky reefs [4] [8].

After pupping, the females enter a resting stage lasting about a year [9]. As a result of this two-yearly reproductive cycle, females produce an average of only one pup per year. This makes them one of the least fecund of all sharks, and extremely vulnerable to human-induced pressures.

Little is known about the reproductive biology of grey nurse sharks in Australia. Some preliminary observations of pre-mating behaviour have been made in aquaria [39], but there has been no substantial work on wild populations.

For example, the timing of mating and pupping in Australian waters can only be inferred from a few observations of individuals in the wild. Many grey nurse sharks with mating scars (ie. bite marks around the head, pectoral and pelvic fins) have been observed during the months of March and April at Pimpernel Rock in the Solitary Islands Marine Park (D. White pers. comm. in [75]). Observations made during the coastwide diver surveys [75] suggest that female grey nurses probably give birth to their pups during winter. However, more work is needed to verify the timing of mating

and pupping, the duration of gestation and the age and size at which sexual maturity is reached in Australian waters.

2.7.2 Age, growth and longevity

Our current understanding of the age and growth of grey nurse sharks is based on studies from the east coast of the USA and South Africa. Age and growth estimates have been obtained from captive sharks held in aquaria in Florida [87], from wild sharks captured from the north-west Atlantic Ocean [9], and from captive sharks held in an aquarium in Durban [40].

Although the estimates obtained from the USA and South Africa differ slightly, these studies have shown that grey nurse sharks grow at an initial rate of 25 - 30 cm/year, slowing to less than 10 cm/year once sexual maturity is reached (see Table 3). This growth rate is considered slow relative to other sharks.

Life-history Stage	Rate of Growth (cm/year)	Age (years)
Pup	25-30	0-1
Juvenile	20-25	2-3
Juvenile/subadult	15-20	4-5
Subadult/adult	10-15	6-7
Adult	5-10	>8

Table 3. Rates of growth of grey nurse sharks from the east coast of the USA (After: [9]).

The longevity (life expectancy) of individuals in the wild is unknown, although a grey nurse shark has been documented as living for over 16 years in captivity in South Africa [40]. Originally, estimates of longevity of grey nurse sharks was thought to be 30 years for males and 35 years for females [9]. More recently however, it has been suggested that longevity of 20 years for males and 25 years for females may be more realistic [26]. There is no information on the age and growth of grey nurse sharks in the coastal waters of NSW. However, there may be some limited data for the captive individuals held in aquaria. For example, a female grey nurse shark currently held in captivity at a Sydney aquarium is at least 15 years old. Clearly, the complete absence of age and growth data for grey nurse sharks in NSW coastal waters needs to be addressed as a matter of urgency.

2.7.3 Diet

In South Africa, grey nurse sharks have been found to feed on a wide range of bony fish including herrings (Family Clupeidae), croakers (Sciaenidae), bluefishes (Pomatomidae), mackerels (Scombridae), butterfishes (Odacidae), snappers (Lutjanidae), eels (Muraenidae), wrasses (Labridae), mullets (Mugilidae), sea basses (Serranidae), flatfishes (Platycephalidae and Bothidae), jacks (Carangidae), as well as small and juvenile sharks (especially those of the families Carcharhinidae and Triakidae), eagle rays (Myliobatidae), squid, and on some occasions, crabs and lobsters [7] [4]; [22].

Although there is a lack of information on the diet of grey nurse sharks in NSW, it would be reasonable to assume that they consume fish from the same families, given that there are many similarities between the Australian and South African fish faunas. Thus, their diet probably consists of a broad range of species including pilchards, mulloway, snappers, tailor, bonito, morays, blue groper, sea mullet, wrasses, flatheads, yellowtail kingfish, small and juvenile sharks, squid and

possibly some crustaceans. However, this needs to be verified by analysing the gut contents of any incidentally caught and killed grey nurse sharks.

It is important to note that many of the species that make up the diet of grey nurse sharks are also harvested by fishers (eg. [61] [42] [76]).

2.7.4 Rates of mortality

Rates of natural mortality of grey nurse sharks have been estimated using statistical models (eg. [90] [67]). However, there are few, if any, reliable estimates based on experiments or actual observations. In addition, there are currently no published estimates of the annual rates of fishing-related mortality for any grey nurse shark populations.

There is a need to estimate the rate of mortality (natural and fishing-related) for sharks in each age-group, because this would show when most grey nurse shark deaths occur. This information could in turn help to identify whether deaths in any particular age-group are causing the population to decline [16]. Management actions could then focus on the threats that are having the greatest impact on the population.

2.7.5 Behaviour and movement

Many grey nurse sharks can be individually identified by unique markings such as scars, hooks or missing fins. This has allowed divers (eg. during the coastwide underwater surveys; [75] [73]) to notice that many grey nurse sharks occupy particular sites and then return to the same sites year after year. Similar observations have been made by researchers in South Africa (Smale pers. comm.). This tendency – known as 'site fidelity' – is one of the biological characteristics that makes grey nurse sharks vulnerable to localised pressures [33].

Relatively little is known about the migratory movements of grey nurse sharks in south-eastern Australian waters. At certain times of the year, some grey nurse shark aggregations are dominated by sharks of a single sex. For example, males are predominant in southern Queensland during July to October, whereas females are more prevalent in central NSW [75]. These patterns are also supported by data from the beach safety meshing program [82] [53].

It has been suggested that female grey nurse sharks migrate to the south coast of NSW in late spring and aggregate at two sites, the Tollgate Islands off Batemans Bay and Montague Island off Narooma [75]. They occupy these sites until mid autumn, then migrate northwards to sites off the mid north coast of NSW, between Forster and Coffs Harbour [75]

More information is needed on both the extent of site fidelity as well as the migratory movements of grey nurse sharks in NSW waters.

2.7.6 Natural predators

Previous research in South Africa has shown that juvenile grey nurse sharks (and other shark species) are eaten by great white sharks (*Carcharodon carcharias*), short-finned makos (*Isurus oxyrinchus*), tiger sharks (*Galeocerdo cuvier*) and bull sharks (*Carcharhinus leucas*) [3] [4] [19] [20] [18].

Analysis of the gut contents of great white, short-finned mako, tiger and bull sharks in south-eastern Australian waters [94] [55] has similarly shown that they eat a range of small sharks as well as the juveniles of larger sharks. The distributions of these four species also overlap the current distribution

of grey nurse sharks in NSW [55]. These four species are thus the most likely natural predators of grey nurse sharks.

3. CONSERVATION STATUS

3.1 Worldwide

Grey nurse sharks are currently listed on the IUCN 'red list' of threatened animals as vulnerable worldwide (Red List Number: VU A1ab+2d, Shark Specialist Group: World Conservation Monitoring Centre). Despite this, there is a limited amount of protection for grey nurse sharks around the world.

In South Africa, the commercial capture of grey nurse sharks is currently being phased out. They can still be caught and kept, but must not be sold for financial gain (Cliff pers. comm.). The Natal Sharks Board hopes that fishers who catch grey nurse sharks will return them to the water.

In the USA, grey nurse sharks (or 'sand tigers', as they are known locally) are being managed under a shark management plan drawn up by the National Marine Fisheries Service (NMFS). The plan aims to reduce catches of sharks by fishers. Grey nurse sharks are one of five large coastal species that have been protected from targeted fishing since 1997 [91].

In Brazil, Uruguay and Argentina, grey nurse sharks are harvested by commercial fishers as part of multi-species shark fisheries. However, they are only caught when these fishers work the areas close to shore. Catches are generally very low despite increasing fishing effort. Recreational fishers also target the species and there is now concern over the viability of the population [17].

In Japan, grey nurse sharks have been harvested extensively and used fresh, frozen, smoked and dried [22]. However, the population has now declined to a point where they are rarely caught by commercial fishers.

3.2 Australia

3.2.1 Listings

Grey nurse sharks were first listed as a protected fish in NSW (under the then *Fisheries and Oyster Farms Act*) in November 1984. This was in response to concerns over declining populations, and was the first time a shark species had been listed as protected anywhere in the world.

In October 1999, the NSW Government added grey nurse sharks to the list of vulnerable species under the *Fisheries Management Act* (Schedule 5). In April 2000, as a result of the coastwide diver surveys (see section 2.5), the NSW Government upgraded their status to endangered (Schedule 4, Part 2).

Grey nurse sharks were also listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act* (Cth) in August 2000. In October 2001 this was revised and they were listed as two separate populations. The east coast population has since been listed as critically endangered because of the serious decline in its numbers. The size of the west coast population is unknown, and it remains listed as vulnerable under this Act.

The current conservation status of grey nurse sharks in Australia is detailed in Table 4.

Table 4. Current conservation listings for grey nurse sharks in Australia.

Listing	Population	Status
¥ *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)	West coast population:	Vulnerable
	East coast population:	Critically endangered
¥ *Fisheries Management Act 1994* (NSW)		Endangered
¥ *Fisheries Act 1994* (Queensland)		Protected
¥ *Wildlife Conservation Act 1950* (WA)		Protected
¥ *Living Marine Resources Management Act 199* *and Fisheries Regulations 1996 (General and Fees)* (Tasmania)		Protected
á *Flora and Fauna Guarantee 1988* (Victoria)		Protected
á Australian Society for Fish Biology (ASFB)		Vulnerable
á World Conservation Union (IUCN)	East coast of Australia:	Endangered
	(Worldwide:	*Vulnerable)*

3.2.2 Reasons for concern

The life-history and reproductive strategies of grey nurse sharks make them particularly vulnerable to human-induced pressures. For example, their preference for inshore rocky reef habitats, and tendency to aggregate at particular sites, make them vulnerable to localised pressures such as incidental capture or injury by fishers. Their low reproductive rate and apparently slow growth also mean that their populations, once reduced, will take a long time to recover.

A severe decline in grey nurse shark numbers in south-eastern Australian waters has been documented over the last few decades from a variety of sources, including beach safety meshing data, gamefishing and spearfishing catches and anecdotal reports.

For example, there has been a dramatic decline in the number of grey nurse sharks caught in the beach safety meshing programs, despite an increase in the number of beaches meshed since the 1950s. In NSW, the number of grey nurse sharks caught in shark nets declined from 58 between October and December 1937 [24] to a total of only 65 in the 18 years between October 1972 and December 1990 [82]. Similarly, a total of 35 grey nurses were caught in the first two years of shark netting in Queensland (1962/63), while only 27 were caught between 1985 and 1999 (Shark Control Program, QDPI). Similar declines were also evident in the catches of gamefishers and spearfishers from the 1960s through to the 1970s (see Section 4.1.2).

Evidence of declining numbers of grey nurse sharks in south-eastern Australia, as well as the realisation that the species was not responsible for attacks on humans [80], led to calls for the species to be protected. As a result, grey nurse sharks were listed as a protected fish by the NSW Government in November 1984.

Unfortunately, grey nurse shark populations in NSW waters have failed to respond to the statewide protection that has been in place since this time [80]. Anecdotal evidence suggests there has been a continued decline in the number of grey nurse sharks along Sydney's coastline and at sites such as Seal Rocks [80] and that many sites along the NSW coast no longer support populations of grey nurse sharks [53] [75]. These anecdotal reports have been supported by the results of the recent

coastwide diver surveys (see section 2.5), in which a maximum of 292 individuals in total were observed at more than 60 known aggregation sites during any one of the surveys.

The low numbers of grey nurse sharks in south-eastern Australian waters, combined with evidence of continuing incidental and illegal captures of grey nurse sharks (see sections 4.1 – 4.3), are cause for great concern. Recent research has shown that even an 'undisturbed' grey nurse shark population (ie. one unaffected by fishing impacts) would require at least two decades to double in size [90]. The grey nurse shark population in NSW is clearly not an undisturbed population. Thus, all threatening processes would need to be effectively addressed if the species' population decline is to be halted and recovery achieved.

4. CURRENT ISSUES AND THREATS

The primary threats to grey nurse sharks appear to be incidental capture by fishers, illegal fishing and shark control activities. This section is divided into eight parts that discuss these and other major issues relevant to the conservation of grey nurse sharks:

- Fishing
- Shark finning
- Shark control activities
- Limitations in current understanding
- Limited habitat protection
- Commercial aquaria
- Ecotourism
- Community education and involvement

4.1 Fishing

Background

Commercial fishing

Although they are now protected, grey nurse sharks have been fished commercially in the past. From the 1850s onwards, grey nurse sharks were the source of lamp oil around Sydney and were fished by hook and line at "regular nurse grounds" off Dolls Point, Botany Bay [99] [41]. Between the months of October and December, the livers of grey nurse sharks yielded "a considerable quantity" of oil, "the quality of which is good, and excellent for burning in lamps" (Hill in [99]). In the 1920s, grey nurse sharks were the second most commonly caught shark (after whaler sharks) around Port Stephens [83]. Apart from their flesh, grey nurse sharks were also utilised for their fins and for the high quality leather that could be made from their skin [83].

While their threatened status means that they are no longer targeted by commercial fishers, grey nurse sharks are still under threat from accidental capture in some commercial fisheries. In NSW they are primarily caught by demersal gillnets, set and droplines, and other line fishing gear [80] [74] [75]. Fishers who accidentally catch grey nurse sharks are required by law to release them. Consequently, sharks are often seen with hooks embedded in their jaws and wire trace trailing from their mouths.

Anecdotal information indicates that grey nurse sharks have also been accidentally caught on baited setlines targeting wobbegong sharks (eg. [34] [63] [88]). These concerns are supported by diver surveys which have reported seeing hooks – of the size and type used in bottom setlines – embedded in the jaws of grey nurse sharks along the entire NSW coast, from the Julian Rocks Aquatic Reserve off Byron Bay to Montague Island off Narooma [80] [77] [75].

There has been a statistically significant increase over time in the number of sightings of grey nurse sharks with fishing gear protruding from their mouths, with a tripling of the rate from 2 percent in 1991 to 6 percent in 1999 [75].

Recreational fishing

Recreational fishing covers a broad range of activities, but recreational fishers can be broadly categorised as spearfishers or divers, gamefishers, or sportfishers.

Spearfishers: During the 1930s and 1940s, and even up to the 1980s, grey nurse sharks were seen by the public as man-eaters, mainly due to their fierce appearance [97]. This misunderstanding reportedly led to many grey nurse sharks being killed in the 1950s and 1960s by the intensive efforts of spearfishers and scuba divers using powerheads [48]. Divers also took grey nurse sharks alive, with lassos, to sell to aquariums [28].

Today, due to the protected status of grey nurse sharks and increased public awareness, there are very few reports of divers killing these sharks [80]. In fact many divers have been involved in conservation activities including the protection of grey nurse sharks and survey work.

Gamefishers: Gamefishers target a range of large species, including billfish, tuna and sharks, in deep water off the NSW coast. Although grey nurse sharks are known to be poor fighters, in the two decades from 1961 to 1980 (ie. before the species was protected in NSW), 405 grey nurse sharks were recorded as being taken by game fishing clubs along 460 km of the NSW coast north of Bermagui [79]. A decline in the proportion of grey nurse sharks caught by gamefishers was clearly evident over the period from 1960 to the 1970s [33]. Gamefishers voluntarily banned the capture of grey nurse sharks in 1979, well before the 1984 mandatory ban [63].

Sportfishers: Sportfishers use a variety of gear to catch a range of small pelagic and demersal species in coastal waters. They range from individuals to groups using middle sized boats and charter boats. It is not known how often sportfishers interact with grey nurse sharks, nor how much of an impact accidental capture by these fishers may be having on the species.

There have been some reports of impacts on grey nurse sharks from demersal recreational fishing gear. In particular, recreational fishing, using weighted lines with wire trace, can result in accidental capture of grey nurse shark.

Such fishing may also have less obvious impacts on the grey nurse shark. For example, a recent autopsy on a shark that died in captivity revealed that the stomach wall had been perforated by numerous fishing hooks; the resulting inflammation (peritonitis) was believed to have caused the shark's death (T. Long pers. comm. in [75]).

Recent diver surveys have also observed sharks at many sites trailing fishing gear of this kind. These observations suggest that it may also be necessary to protect key grey nurse habitat areas from the risk of accidental capture by recreational fishers targeting demersal species and from damage resulting from interactions with their recreational fishing gear.

Impacts of fishing

One problem with the accidental capture and release of grey nurse sharks is that a hooked shark, upon release, may swim away seemingly unharmed, only to die several days or even weeks later from internal bleeding or infection. For instance, peritonitis (an inflammation of the lining of the body cavity and organs) can often occur when the gut wall is pierced by a hook. Even superficial hook wounds can provide a site for infection, and if the hook remains embedded in tissue it can prevent healing and encourage the formation of ulcers, thus continuing to provide a site for infection for a considerable period of time (eg. [89]). Physical injuries may be obvious (as with a superficial hook wound) or be totally masked because the symptoms are all internal.

As well as causing physical injuries or infections, fishing can cause a number of physiological changes [30] [46] [21]. For example, the stress of capture may cause changes such as abnormally low heart rates (bradycardia), increased acidity of the blood, excessive blood sugar levels and muscle rigidity.

In some cases, the hooking of a shark may cause it to expel part of its stomach out of its mouth, presumably in an attempt to get rid of the hook [69]. However, in order to expel the stomach the shark must violently contract its body muscles, which can greatly reduce the blood supply to the gut. Worse still, the stomach wall can become impaled or torn on the shark's razor-sharp teeth, or the blood vessels that feed the internal organs can be ruptured.

On other occasions, hooking may only cause superficial injury. However, if the hooked shark is brought to the surface too rapidly, the air within its digestive tract expands rapidly under the reduced pressure, causing rupturing of the gut wall [89]. Left untreated, the shark will succumb to peritonitis and die within a week or so.

Accidental hooking could also be having sub-lethal effects on grey nurse sharks, for instance by affecting their ability to feed or mate, but the extent of any such effects is unknown.

The extent of hook related mortality is currently unknown. Anecdotal information suggests that stainless steel hooks and wire trace are particularly problematic due to their resistance to corrosion. Therefore they can remain embedded in the sharks jaw or body for an extended period of time, increasing the chance of infection or further injury. Further investigation would be required to assess the nature and extent of hook related injuries, including the different impacts of hook type and hooking technique.

Summary of issues

- Despite legal protection from fishing, grey nurse sharks are subject to impacts resulting from incidental capture by fishers targeting demersal species and from interactions with their fishing gear.
- Surveys indicate that some grey nurse sharks are showing evidence of interactions with fishing gear. Equipment associated with commercial drop and setline fishing, and some forms of recreational demersal fishing appear to have a significant incidence of accidental capture.
- Incidental capture can lead to stress, internal bleeding, infection and other problems, sometimes resulting in death.
- The risk of incidental capture and other interactions with fishing gear needs to be minimised through increased protection for key aggregation sites.

Recovery actions

- Minimise the impact of commercial fishing on grey nurse sharks through restrictions on fishing gear identified as having a significant chance of incidentally capturing grey nurse sharks e.g. through a maximum snood length and a ban on wire trace (Action 7.1.1).
-
- Protect grey nurse sharks at key aggregating sites from the risk of incidental capture by fishers and from interactions with fishing gear, i.e. by banning, in critical habitats, the use of

drop and set-lines by commercial fishers and ban the use of wire trace on fishing lines by all fishers from vessels not underway (ie not trolling). (Action 7.1.2).

- Maximise compliance by fishers with grey nurse shark protection measures (Action 7.1.3).
- Improve the collection of data on interactions between grey nurse sharks and fishers, including sightings, hook related injuries and all incidental captures (Action 7.1.4).

4.2 Shark finning

Background

There are currently some commercial fisheries in Australia that take shark fins as by-product. There is an ever-increasing demand for shark fins [96], and dried fins can attract high prices in Asian markets. However, shark finning is wasteful because generally the fins are removed and the carcass is discarded at sea.

Given the high prices paid for shark fins, it is highly likely that fishers will increasingly target sharks. In light of international activity and growing national pressures about the status of shark populations, as well as the animal welfare concerns associated with shark finning, Australia's approach to regulating shark finning needs to be reconsidered.

The practice of shark finning poses a threat to grey nurse sharks as well as other species. For example, there are several reliable reports from NSW divers (supported by photographs and underwater video footage) of grey nurse sharks that have survived the finning process. Similar reports have been made by commercial fishers working on the NSW south coast.

To stop this wasteful practice, the NSW Government banned shark finning in NSW waters in 1999. The possession of any shark fin that is not attached to the whole carcass (other than for heading, gilling and gutting) or a portion of the carcass is now prohibited on board any vessel in NSW waters. However, the entire carcass of a shark (other than a protected shark) can still be landed and the fins sold.

Given that illegal finning of grey nurse sharks may still occur, it is important to document the frequency with which grey nurse shark fins occur in the marketplace. Unfortunately, the necessary technology to accurately identify which fins are grey nurse shark fins does not yet exist. The development of protein assays or DNA tests (see Appendix 2) would aid in monitoring the presence of grey nurse shark fins among other shark fins submitted for sale. Such tests may need to be developed so that monitoring of the shark-fin trade can be carried out routinely.

It would also be beneficial if other State, Territory and Commonwealth fisheries management agencies could be encouraged to consider complementary shark finning bans.

Summary of issues

- Shark finning, though now banned in NSW waters, continues to occur elsewhere.
- It is not known whether grey nurse shark fins are still present in the marketplace.

Recovery actions

- Maximise compliance with shark finning bans through cooperation with industry and effective law enforcement (Action 7.2.1).

- Identify shark species currently for sale in the NSW shark fin market, to determine if grey nurse (or other threatened sharks) are present (Action 7.2.2).

4.3 Shark control activities

Background

Meshing of Australian beaches is used in NSW and Queensland (but not elsewhere) as a protective measure against shark attack on swimmers and surfers [82] [78]. Beach safety meshing was first introduced in NSW in 1937. There has only been one fatal shark attack on a netted beach since the program began, compared to 27 attacks in the 30 years before the program commenced.

Shark nets are usually 150 m long and six metres high with a mesh size of 50 to 60 cm [53]. The nets are set parallel to the shore in around 10 to 15 metres water depth with the bottom of the net resting on the ocean floor and the top supported by a series of floats [53]. At present there are 49 beaches meshed around Newcastle, Sydney and Wollongong, a stretch of coast approximately 200 km long.

The idea of shark nets is not to stop sharks coming to the beaches, but to reduce local populations by intercepting and catching them on their regular feeding and territorial runs [31]. Beach safety mesh nets are not selective, however, and some non-target species (including threatened species) are caught, in addition to dangerous sharks [54].

In NSW, up to 36 grey nurse sharks were caught in safety mesh-nets each year during the early 1950s [82]. By the 1980s, this average had decreased to three or less per year [80], while only three grey nurse sharks in total have been caught over the last decade. A similar trend has been detected in Queensland with 90 grey nurse sharks captured between 1962 and 1972, and only 21 grey nurse sharks captured over the last decade (data from the Shark Control Program, Queensland). However, detailed information from Queensland is currently unavailable.

While the beach safety shark meshing program has obviously been responsible for capture of numerous grey nurse sharks in the past, the extremely low rates of capture in recent years are likely to continue until the population increases substantially in the coastal waters of NSW [74] [75]. It is currently the policy of NSW Fisheries that, where possible, all grey nurse sharks caught in the beach safety shark nets are transported away from the beaches and released alive.

The *Fisheries Management Act* requires the development of a fisheries management strategy for the shark meshing program, while the *Environmental Planning and Assessment Act* requires its environmental impact to be assessed in an environmental impact statement (EIS). NSW Fisheries is committed to continuing the beach safety shark meshing program.

Summary of issues

- Shark control data is not readily available throughout the range of the east coast grey nurse population.
- Beach safety shark mesh nets are not selective, consequently a range of other species are caught.
- The shark netting program began in 1937. There has only been one fatal shark attack on a netted beach since the program began, compared to 27 attacks in the 30 years before the program commenced.

- The number of grey nurse sharks captured in beach mesh nets has declined significantly since the 1950s.
- The significance of the impact of beach safety shark meshing on the grey nurse shark population of NSW is not known.

Recovery actions

- Continue quantifying the numbers of grey nurse sharks caught in the beach safety shark meshing program in NSW (Action 7.3.1).
- Ensure that all grey nurse sharks caught live in beach mesh nets are released with minimal harm (Action 7.3.2).
- Ensure that the contracts between NSW Fisheries and shark meshing contractors require that any grey nurse sharks killed in beach mesh nets are retained and forwarded to NSW Fisheries for autopsy (Action 7.3.3).
- Implement any approved fishery management strategy for shark meshing (Action 7.3.4).

4.4 Limitations in current understanding

Background

As discussed, there is a critical lack of information about many aspects of the life history and abundance of grey nurse sharks in NSW waters (section 2), as well as the impacts of fishing (sections 4.1 – 4.3) and other human activities. Further research to obtain this information is urgently required, as it would assist managers to make informed decisions about the best ways to ensure the recovery of the species and to evaluate the success of recovery actions.

Key research needs for grey nurse sharks are outlined in Appendix 2. They include research on long-term patterns of abundance, reproductive biology, population demography, migratory patterns and localised movements, population genetics, and the effects of fishing and other human activities on the species.

This information would be obtained from a number of sources. The underwater surveys have already provided much-needed data on the distribution and abundance of grey nurse sharks in NSW coastal waters. Ongoing monitoring of these sites would provide longer-term data on spatial and temporal patterns of abundance, as well as a source of observations on shark behaviour, reproduction and condition. A tagging program also needs to be initiated to allow the total grey nurse shark population to be estimated, rates of natural and fishing-related mortality to be determined, and migratory and localised movements to be tracked.

Other types of biological information, including data on diet, reproduction, and age and growth, need to be obtained by examination of dead sharks. The only ethical way of obtaining such information, without resorting to sampling (killing) individuals in the remaining population, will be to autopsy any grey nurse sharks which are accidentally caught and killed (eg. through the beach safety shark mesh netting program). Consequently, it would be important to establish protocols to ensure that all dead grey nurse sharks are sent to NSW Fisheries without delay.

If a carcass is not forwarded to NSW Fisheries, the shark's death would represent a 'double loss' to the remaining population because of the lost biological data. This would, in turn, delay the provision of biological information necessary for the management and recovery of the species.

There is also a need to establish the effects of fishing and other human activities on grey nurse sharks, but these information needs are addressed in sections 4.1 (fishing), 4.2 (shark finning), 4.3 (shark control activities) and 4.7 (ecotourism).

Summary of issues

- There are many gaps in our understanding of the abundance, reproductive biology, life history and ecology, migratory patterns and population genetics of grey nurse sharks. These information needs are outlined in Appendix 2.
- Continuation of the coastwide underwater surveys, and initiation of a tagging program, would provide important long-term data on abundance, movements, mortality and other factors.
- Autopsies on any sharks which are accidentally caught and killed provide an important opportunity to gain other much-needed biological information.

Recovery actions

- Monitor abundance of grey nurse sharks in NSW waters to establish spatial and temporal population trends and measure recovery (Action 7.4.1).
- Identify the diet of grey nurse sharks (Action 7.4.2).
- Develop population modelling to enable assessments of population status, rates of recovery and population structure and distribution (Action 7.4.3).
- Develop an understanding of the reproductive biology of grey nurse sharks (Action 7.4.4).
- Develop an understanding of age, growth and longevity of grey nurse sharks (Action 7.4.5).
- Estimate survival/mortality rates of grey nurse sharks in NSW waters (Action 7.4.6).
- Develop an understanding of grey nurse shark migration and movements in NSW waters (Action 7.4.7).
- Determine genetic variability of populations of grey nurse sharks in NSW waters (Action 7.4.8).

4.5 Critical habitat protection

Background

Grey nurse sharks have been protected from fishing since 1984, and have been listed as a threatened species since 1999. However, there is no evidence as yet that these actions have succeeded in halting or reversing the decline in grey nurse shark numbers (see section 3.2).

One reason for this may be that, while grey nurse sharks can no longer be taken, they are continuing to suffer from hooking injuries and other impacts associated with incidental capture. This problem suggests that additional strategies, such as habitat protection and removal of incidental fishing pressure, are needed (eg. [63] [34]).

Coastwide underwater surveys identified a number of sites of key importance to grey nurse sharks [75] [73]. Specifically, there were 15 sites along the coast (13 of these in state waters) which

supported aggregations of sharks and together accounted for around 88 percent of the total number of grey nurse sharks observed during the surveys.

The coastwide surveys also found that a significant number of the grey nurse sharks observed had interacted with fishing gear, as evidenced by hooks embedded in their jaws. Although it was not possible to be certain where these interactions had taken place, it is likely that they occurred at the aggregation sites because these areas are also often heavily fished. For example, commercial and recreational fishing effort is high at Fish Rock (South West Rocks), and as many as 75 percent of grey nurse sharks at this site exhibit fishing-related injuries. There are also anecdotal reports of divers witnessing the capture of grey nurse sharks by fishers in a number of grey nurse shark aggregating areas.

Consequently, the direct threats to grey nurse sharks from the impacts of fishing need to be addressed in all of the key sites.

Another issue, which is less well understood, is why grey nurse sharks choose to aggregate in these particular places rather than in other sites with similar physical characteristics [75]. As yet there is no clear scientific evidence to indicate which particular habitat attributes are responsible for attracting and supporting these aggregations.

Identification of critical habitat

Under the *Fisheries Management Act*, NSW Fisheries [2] is required, where possible, to identify and declare 'critical habitat' for endangered species (as well as endangered populations and ecological communities) (see section 1.1.2 and Appendix 1). Critical habitat is defined any habitat critical to the survival of the species. 'Habitat' can consist of any area occupied by the species, even if only occasionally. It can include any biotic (living) component, such as other animals and plants, or abiotic (non-living) component, such as landscape features or sediments.

NSW Fisheries has, in consultation with the Fisheries Scientific Committee, made a preliminary identification of grey nurse shark critical habitat. The next step is for the community to have an opportunity to make submissions on the sites identified. This process is taking place now, concurrently with the exhibition of this draft recovery plan (see Appendix 1).

Following this, the Minister for Fisheries, the Hon. Eddie Obeid MLC will decide whether or not the area(s) should be declared as critical habitat, taking into account likely social and economic consequences, all of the formal submissions made by members of the community, as well as the advice of the Fisheries Scientific Committee and any submissions received.

Once critical habitat has been listed, it is an offence to do anything that causes damage to the critical habitat, unless appropriate approval (eg. a permit, licence or development consent under the *Environmental Planning and Assessment Act*) has been given. There are significant penalties for this offence. In addition, public authorities (such as local councils and government agencies) must consider the existence of critical habitat when they are carrying out their responsibilities.

The presence of critical habitat also automatically triggers environmental assessment requirements under the *Environmental Planning and Assessment Act* for development consents and approvals. These requirements apply to fishing as well as to other activities. As the preparation of management strategies and environmental impacts statements is already underway for commercial fisheries, recreational fishing and shark meshing in NSW, if critical habitat is declared for grey nurse

[2] As the delegate of the Minister for Fisheries

sharks, this will feed into the existing environmental assessment process rather than triggering new requirements. The declaration of critical habitat does not automatically mean that an activity will be banned.

Fishing restrictions in critical habitat

Specific regulations to manage the impacts of fishing in identified critical habitat would be needed to limit fishing-related impacts. These regulations would provide the grey nurse shark protection from those activities that pose a significant risk of accidental capture, including commercial set and drop line fishing and some forms of recreational demersal fishing.

These regulations are proposed:

- a ban on all commercial drop and set line fishing in critical habitat areas; and
- a ban on the use of wire trace on fishing lines from vessels not underway (ie not trolling) in critical habitat areas.

Summary of issues

- There are thirteen key sites in inshore coastal waters where grey nurse sharks regularly aggregate.
- It is unknown why these sites are chosen over other sites with apparently similar physical characteristics.
- At the majority of aggregation sites grey nurse sharks are not currently protected from incidental fishing impacts.
- Incidental fishing impacts would need to be controlled at all significant grey nurse shark aggregation sites.
- NSW Fisheries is required, where possible, to declare critical habitat. New fishing regulations specific to critical habitat sites can then be implemented.

Recovery actions

- Declare the sites nominated in Appendix 1 as critical habitat and ensure the effective management of the declared area through a ban on all commercial drop and set line fishing in critical habitat and a ban on the use of wire trace on fishing lines from vessels not underway (ie not trolling) (Action 7.5.1).

4.6 Commercial aquaria

Background

Grey nurse sharks are well suited to captive display because of their large size, slow movement, long lifespan, relatively docile nature and slow metabolic rate (which reduces their food requirements). They are very popular with the public due to their size and fierce appearance. As early as the 1950s and 1960s, grey nurse sharks that were captured alive were sometimes sold to aquaria for display [99] [32].

At present there are 32 grey nurse sharks on display in commercial aquaria in Australia (Table 5) and 24 of these have been taken from the east coast population. However, the grey nurse shark

population on the east coast of Australia has declined to the point where it is no longer seen as ecologically sustainable to take them from the wild. For this reason, NSW Fisheries has declared a State-wide moratorium on the capture of grey nurse sharks for display in commercial aquaria. Although there is no official moratorium in Queensland, the Queensland Department of Primary Industries is no longer issuing permits to take grey nurse sharks from the wild.

Table 5. Number of grey nurse sharks held in commercial aquaria in Australia (Feb 2002).

Aquarium	Males	Females	Total
Seaworld, Qld	0	0	0
Underwater World, Qld	3	4	7
Underwater World, WA	1	7	8
Sydney Aquarium, NSW	2	3	5
Manly Oceanworld, NSW	4	5	9
Melbourne Aquarium, Vic	1	2	3
Total	**11**	**21**	**32**

Commercial aquaria are also involved in captive breeding programs. To date, six grey nurse sharks have been born at Underwater World in Queensland and two at Manly Oceanworld in NSW. In future, it may be possible to meet all demands for grey nurse sharks for display from those bred in captivity.

Another positive role for commercial aquaria in the recovery of grey nurse sharks is as a highly effective vehicle for public education. For example, public awareness of the plight of grey nurse sharks can be raised by placing information on the biology, status and conservation of the species in close proximity to the aquaria housing the sharks. Management agencies can assist commercial aquaria in this role through the provision of relevant information (eg. the results of ongoing research and current management initiatives) and additional educational materials.

Summary of issues

- Grey nurse sharks are a popular aquarium species and in the past have been taken from the wild for this purpose.
- There is currently a moratorium on the taking of any further grey nurse sharks from the wild in NSW.
- Captive breeding programs by commercial aquaria have had limited success.
- Commercial aquaria are an important vehicle for public education.

Recovery actions

- Retain the existing prohibition on the taking of grey nurse from the wild in NSW (Action 7.6.1).
- Encourage the development of breeding techniques utilising existing captive grey nurse sharks to supply future needs of aquaria (Action 7.6.2).
- Work with commercial aquaria to increase public awareness of the endangered status of grey nurse sharks (Action 7.6.3).

4.7 Ecotourism

Background

The placid nature of grey nurse sharks and the accessibility of their habitats have led to the development of a sizeable ecotourism industry, based on scuba diving and shark viewing operations.

Grey nurse sharks were once very commonly seen by divers in NSW. For example, Valerie Taylor has noted that during the 1950s, packs of 30 to 50 grey nurse sharks could be seen at almost every reef and island along the NSW coast. By contrast, during a week-long trip to film the species in 1973, she only saw 11 individuals [33].

In recent times, it has been relatively rare for divers to have the opportunity to interact with such large packs of grey nurse sharks [80] [75]. Despite this, grey nurse sharks are a major attraction for scuba divers and increasing pressure has been placed on operators to take divers to places where they can encounter these sharks [74] [75].

It is possible that poorly managed shark diving operations at popular sites may deter site-attached populations from residing in the area. There have been reports from Seal Rocks of scuba divers disturbing grey nurse sharks, either accidentally or deliberately [80]. However, if divers continue to keep their distance whilst diving with the sharks, experience suggests that it is unlikely that scuba diving *per se* would have any detrimental effects on the sharks' survival [74] [75].

Scuba divers are clearly in the best position to observe grey nurse sharks and many have shown a genuine interest in being involved through surveys, education and conservation of the species. Regular viewing trips, when properly managed, offer a good opportunity for the collection of data on the biology and ecology of sharks [11].

However, while ecotourism is not currently perceived as a major threat to grey nurse shark populations, growth of this industry is expected and pre-emptive actions would likely mitigate any possible impacts in the future.

NSW Fisheries and Environment Australia, in consultation with the dive industry, have developed a draft code of conduct for scuba diving with grey nurse sharks (see Appendix 4). The code of conduct, when finialised, would be extensively promoted to the scuba diving community in NSW, and all scuba diving groups would be encouraged to adopt the code of conduct as part of their practice for diving with grey nurse sharks. It is proposed that relevant provisions of the code of conduct become mandatory in critical habitat areas, namely the:

- prohibition on night dives;
- prohibition on blocking of entrances to caves or gutters;
- prohibition on feeding or touching the sharks; and
- prohibition on chasing or harassing the sharks, and would include a ban on mechanical apparatus eg. scooters, horns, etc.

Research is also needed to determine whether scuba divers affect the behaviour and general biology of grey nurse sharks. This information could be readily obtained by using acoustic telemetry and smart tags (eg. [49] [50]) to assess whether the behaviour of grey nurse sharks is affected by varying numbers of scuba divers or the behaviour of the scuba divers whilst observing the sharks.

Summary of issues

- Ecotourism activities such as scuba diving with grey nurse sharks are becoming increasingly popular in NSW.
- These activities, if not managed effectively, have the potential to affect shark behaviour and/or localised abundances.
- Scuba divers play an important role in the monitoring of grey nurse shark populations.
- A code of conduct for scuba diving with grey nurse sharks has been developed (Appendix 4) and needs to be widely promoted and adopted.

Recovery actions

- Implement and promote the code of conduct to minimise disturbance to grey nurse sharks by ecotourism activities and by individual recreational divers and include relevant provisions of the code of conduct in the regulations for critical habitat areas. (Action 7.7.1).
- Encourage tour operators to report grey nurse sightings to NSW Fisheries (Action 7.7.2).
- Establish monitoring programs to assess the impact of diver presence on shark behaviour and biology (Action 7.7.3).

4.8 Community education and involvement

Background

Grey nurse sharks once had an undeserved reputation as a man-eater in Australia, due to their fierce appearance and confusion with other species [10] [22]. According to the Australian Shark Attack File, however, there have only ever been four positively identified cases of attacks by grey nurse sharks, none of which were fatal [98]. Furthermore, all of these incidents involved divers feeding the sharks [63]. It is important for the public to be aware that if left undisturbed grey nurse sharks are not a threat but, as with all wild animals, they should be treated with care.

Community education is key part of the recovery process. For example, educational material can expose many of the myths surrounding sharks and completely change people's attitudes towards sharks [64]. A key part of the recovery plan would be to increase community awareness of the plight of grey nurse sharks, particularly their population status, current threats and the actions required to ensure their recovery and long-term conservation. The publication of articles in magazines, the distribution of posters and the production of other educational and advisory materials could all be used to reach a wide audience.

Community involvement can also play a major role in the recovery process. For example, the coastwide surveys of grey nurse sharks in NSW could not have been carried out as extensively without the participation of scuba divers from universities, dive clubs, commercial aquaria and scuba diving schools. It will be important to foster and maintain community involvement in recovery actions, and to ensure that information is fed back to contributors and the wider community.

Summary of issues

- Education is an important key to changing public attitudes towards sharks and increasing awareness of the threats they face.

- Community involvement and support will be crucial to the success of the recovery plan.

Recovery actions

- Develop a comprehensive community education strategy aimed at the general public, anglers, divers and commercial fishers including: identification, status, current threats and biology (Action 7.8.1).
- Enhance advisory activities, including production of information brochures and related advisory materials (Action 7.8.2).
- Encourage community involvement in the implementation of the recovery plan (Action 7.8.3).

5. SOCIAL AND ECONOMIC ISSUES

Submissions from the community regarding the issues listed below and other likely social and economic consequences of implementing this plan are particularly encouraged during the draft exhibition period.

The following sections outline some of the potential adverse social and economic consequences which may result from the development and implementation of this plan, and the ways in which these can be minimised or ameliorated. The objectives and actions of this plan (see sections 6 and 7) have also been formulated with the aim of minimising adverse social and economic impacts.

The recovery plan is likely to have a number of positive outcomes, such as increased recognition of the ecological values of their marine waters, increased protection for habitats and biodiversity, and enhanced recreational and tourism opportunities.

The plan would see certain commercial fishing activities (commercial drop and setline fishing) and recreational fishing activities (the use of wire trace on fishing lines from vessels not trolling) banned in grey nurse shark critical habitat. Impacts on fishers will be relatively minor, and most fishers are likely to support reforms intended to improve the sustainability of their activity.

The major economic consequences of the recovery plan relate to the costs of implementation, and as such will be borne mostly by NSW Fisheries, although there may also be some economic consequences resulting from reduced opportunities for, or increased costs associated with, some forms of fishing.

These issues are discussed below.

5.1 Commercial fishing

Currently, several commercial fishing activities occur over, adjacent to or near known grey nurse shark sites. In particular, trap and line fishers are most likely to come in direct contact with the shark through incidental capture.

The impacts of all NSW commercial fisheries on the environment (including threatened species) are currently being assessed and comprehensive management plans developed. This is an existing requirement under the *Environmental Planning and Assessment Act*, although the provisions of the recovery plan (and any declared critical habitat) will also need to be taken into account.

Nonetheless, there is a potential for some changes to the way that commercial fisheries are managed in key grey nurse shark habitats, either through the environmental assessment and management strategy process, or through regulations designed to protect critical habitat under this recovery plan. Some sectors of the commercial fishing industry will also be impacted through the need to quantify grey nurse bycatch.

Economic impacts relating to restrictions on commercial fishing in grey nurse shark critical habitat are expected to be minimal. The commercial fishers who undertake drop and setlining have access to a wide variety of fishing grounds. In many cases, such commercial fishers are also engaged in fish trapping within the areas proposed as critical habitat. It is not proposed that fish trapping be banned.

Regular, face-to-face contact with fishers will be a key strategy in encouraging awareness, support and involvement in the recovery effort. Commercial fishers have generally been supportive of measures designed to promote the sustainability of their industry.

5.2 Recreational fishing

Recreational demersal fishing also have the potential to impact on grey nurse sharks and their habitat, and it is proposed to prohibit the use of wire trace on fishing lines from vessels not underway (i.e. not trolling) in grey nurse shark critical habitat.

Recreational fishers have generally been supportive of measures designed to ensure their sport is sustainable.

Regular contact and consultation with fishers will be a key strategy in encouraging awareness, support and involvement in the recovery effort.

5.3 Tourism and recreation

Offshore islands and other known grey nurse shark habitats are important drawcards for tourists and provide recreational opportunities for local communities. In addition to recreational fishing (discussed above), these can include quality opportunities for scuba diving with the sharks, an activity that is becoming increasingly popular.

Efforts to minimise degradation of grey nurse shark critical habitat within these areas will have important socio-economic benefits by protecting the aesthetic values of these areas and enhancing recreational and tourism opportunities. However, in some cases public access to some key areas that are known to support grey nurse shark populations may need to be controlled, for example through limits on diver numbers. Any such restrictions would need to be developed in consultation with the dive industry.

The involvement of dive groups and aquaria in recovery actions such as educational programs and survey work requires an in-kind contribution of time and potentially some costs, but this is recognised by participants, all of whom are involved on a voluntary basis.

5.4 General community attitudes and involvement

There are likely to be few negative social or economic consequences of the recovery plan.

In general, recovery efforts are expected to be viewed in a positive light. Local communities are usually quick to support conservation efforts for such an identifiable and important species. The recovery program will also provide opportunities for local communities to get involved in shark conservation.

Continued liaison with the local community and relevant stakeholders will help to minimise any adverse social impacts of the plan and maximise community participation in the conservation of grey nurse sharks.

5.5 Costs of implementation

The main costs associated with the implementation of this recovery plan relate to research, community liaison and education, and monitoring of populations and habitats.

Most of these costs will be borne by NSW Fisheries, although some funding may also be sought through external grants (eg. Natural Heritage Trust). Some actions, particularly some survey

and monitoring actions, will involve volunteer dive groups and as such may be funded by grants received by these groups as well as their in-kind contributions.

5.6 Summary

- Social consequences of the recovery plan may include dissatisfaction from commercial and recreational fishers over possible restrictions to their fishing activities and support for grey nurse shark conservation actions from the general community and scuba divers.
- Economic consequences of the recovery plan may be both positive and negative. Positive consequences may include enhanced tourism potential, especially through scuba diving operations. Negative impacts may result from restrictions on commercial and recreational fishing.
- Economic costs associated with the implementation of the plan will be borne by NSW Fisheries or other government departments but may include in-kind assistance from local community or scuba diving groups.

6. OVERALL RECOVERY OBJECTIVES AND PERFORMANCE CRITERIA

6.1 Recovery plan objectives

The overall objective of this recovery plan is to prevent the extinction and ensure the recovery and ongoing viability in nature of grey nurse shark populations along the entire NSW coast. This will include maintaining the existing genetic diversity and genetic structuring of wild grey nurse shark populations, which is critical to ensuring their long-term viability in nature.

The plan aims to achieve recovery of the species to such an extent that it can be down-listed (from 'endangered' to 'vulnerable') and eventually de-listed from the schedules of the *Fisheries Management Act*.

The major specific objectives of the recovery plan are to:

- Improve our understanding of the abundance, reproductive biology, life history, ecology, migratory patterns and genetics of grey nurse shark populations;
- Address the key threats to grey nurse sharks, particularly the impacts of harmful fishing practices;
- Provide enhanced protection for key grey nurse shark habitats (aggregation sites);
- Coordinate action by community groups, local councils, government agencies, scuba diving groups and other stakeholder groups;
- Increase awareness of the status of and threats to grey nurse shark populations, and enhance community support for recovery actions; and
- Establish an on-going monitoring program to document the status of grey nurse shark populations and habitat and evaluate the effectiveness of recovery actions.

6.2 Performance criteria

The overall success of the recovery plan would be assessed against the criterion that:

- the status of grey nurse sharks is revised from 'endangered' to 'vulnerable' and eventually de-listed from the schedules of the *Fisheries Management Act*.

However, in order to evaluate whether the species has recovered to the extent that it can be down-listed, it would be necessary to develop a range of detailed, scientifically sound recovery criteria for the species.

It is likely that these recovery criteria would be based on the results of demographic analyses (see Section 3.5.3). Such analyses use information on reproduction, age, growth and mortality to estimate the rate of increase (or decrease) of the population. This would provide the only unequivocal means of documenting the recovery (or otherwise) of the grey nurse shark population in NSW waters, and hence the success of the recovery plan.

In the absence of detailed biological and ecological information for grey nurse sharks in NSW waters, these criteria can only be developed as pertinent data become available. Thus, the research actions required to obtain this information need to be given a high priority. This is imperative given

that it has been shown that an undisturbed (ie. unfished) grey nurse shark population would require at least two decades to double in size [90]. Since the NSW grey nurse shark population is not undisturbed, its recovery is likely to take even longer.

Criteria for evaluating the effectiveness of individual components of the recovery plan are outlined under each recovery action.

7. RECOVERY ACTIONS

7.1 Fishing

[Refer to section 4.1]

7.1.1 Minimise the impact of commercial fishing on grey nurse sharks through restrictions on fishing gear identified as having a significant chance of incidentally capturing grey nurse sharks.	
¥ Regulate commercial set line fishing throughout NSW waters to modify or remove techniques with high likelihood of incidentally capturing grey nurse sharks (eg through a maximum snood length and a ban on wire trace).	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Techniques reviewed in consultation with industry and modified or removed where necessary.*

7.1.2 Protect grey nurse sharks at key aggregation sites from the risk of incidental capture by fishers and from interactions with fishing gear.	
¥ Declare nominated sites as critical habitat.	
¥ Impose regulations on critical habitat sites that modify methods with high likelihood of incidentally capturing grey nurse sharks: that is, ban the use of drop and set-lines by commercial fishers and ban the use of wire trace on fishing lines by all fishers from vessels not underway (ie not trolling).	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Critical habitat sites declared.*
	Regulations imposed which modify or remove fishing methods that pose a high risk of incidental capture of grey nurse sharks from critical habitat sites.

7.1.3 Maximise compliance by fishers with grey nurse shark protection measures	
¥ Maximise commercial fishersÕ compliance with grey nurse shark protection measures by working cooperatively with the fishing industry and through effective law enforcement.	
¥ Maximise recreational fishersÕ compliance with grey nurse protection measures by working cooperatively with recreational fishing clubs and through effective law enforcement.	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Grey nurse shark educational material provided to commercial fishers and recreational fishers and published in recreational fishing media.*
	Targeted grey nurse shark law enforcement actions carried out.

7.1.4 Improve the collection of data on interactions between grey nurse sharks and fishers, including sightings, hook related injuries and all incidental captures	
• Encourage fishers to record the capture location, length and sex of any grey nurse sharks incidentally caught in State waters.	
• Ensure that observer programs in identified fisheries include the collection of information about grey nurse shark interactions.	
• Initiate research into hook related mortality and injury, with the view to regulating hook type and hooking technique used within key aggregation sites.	
• Address identification issues by developing and distributing practical identification materials for use by fishers.	
Responsibility:	*NSW Fisheries*
Performance criteria	*Volunteer program for fishers established.*
	Observer programs collect data on grey nurse shark interactions.
	Research into hook related injury initiated.
	Grey nurse shark sighting program developed for recreational fishers.
	Practical identification materials distributed.

7.2 Shark finning

[Refer to section 4.2]

7.2.1 Maximise compliance with shark finning bans through cooperation with industry and through effective law enforcement	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Ongoing targeted educational and law enforcement actions.*

7.2.2 Identify shark species currently for sale in the NSW shark fin market, to determine if grey nurse (or other threatened sharks) are present	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Techniques developed to identify shark fins to species level.*
	Survey of species identification of shark fins for sale in the NSW shark fin market complete.

7.3 Shark control activities

[Refer to section 4.3]

7.3.1 Continue quantifying the numbers of grey nurse sharks caught in the beach safety shark meshing program in NSW	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Ongoing collection and assessment of meshing data.*

7.3.2 Ensure that all grey nurse sharks caught live in beach mesh nets are released with minimal harm	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Shark meshing contractors advised of appropriate handling procedures.*
	Released sharks tagged and mortality rate monitored.

7.3.3 Ensure that the contracts between NSW Fisheries and shark meshing contractors require that any grey nurse sharks caught in the beach mesh nets are retained and forwarded to NSW Fisheries for autopsy	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Contracts with shark meshing contractors modified to require retention and delivery to NSW Fisheries of all grey nurse sharks caught and killed in beach safety mesh nets.*

7.3.4 Implement any approved fishery management strategy for shark meshing	
Responsibility:	*NSW Fisheries*
Performance criteria:	*Any approved fishery management strategy implemented.*

7.4 Research needs

[Refer Section 4.4 & Appendix 2]

NB: Appendix 2 provides details on identified gaps in existing knowledge and priority areas for further research.

7.4.1 Monitor abundance of grey nurse sharks in NSW waters to establish spatial and temporal population trends and measure recovery	
¥ Continue the existing research/monitoring program with recreational divers.	
¥ Set up an autopsy program to ensure all accidentally caught and killed grey nurse sharks are autopsied to increase the biological knowledge of the species.	
¥ Periodically estimate the abundance of grey nurse sharks at known aggregation sites.	
¥Sample the abundance of grey nurse shark pups at known aggregation sites during winter to establish the location of nursery grounds and annual levels of recruitment.	
¥ Establish a tagging program to, estimate the size of the total grey nurse population in NSW; estimate rates of mortality; document migratory movements; and estimate the levels of bycatch.	
Responsibility:	*NSW Fisheries, recreational SCUBA diving groups, Environment Australia*
Performance criteria:	*Monitoring program established to assess abundance of adult grey nurse sharks and pups at key aggregation sites.*
	Majority of grey nurse sharks encountered dead in NSW are autopsied.
	Tagging program developed and implemented.

7.4.2 Identify the diet of grey nurse sharks	
¥ Analyse the gut contents of accidentally caught and killed grey nurse sharks.	
¥ Compare the range of species consumed to dietary analysis of grey nurse sharks in South Africa and elsewhere.	
¥ Quantify degree of overlap between the diet of grey nurse sharks and the catches of commercial and recreational (spear and line) fishers.	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Dietary preferences established.*

7.4.3 Develop population modelling to enable assessments of population status, rates of recovery and population structure and distribution	
¥ Using data obtained in NSW surveys, together with other biological information, develop a preliminary model that might describe the grey nurse shark population along the NSW coast[75].	
¥ Use population modelling to calculate an estimated extinction date, if the current rates of decline continue, in order to provide information on the available timeframes for effective threat abatement	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Population model available to assist management decision making.*

7.4.3 Develop population modelling to enable assessments of population status, rates of recovery and population structure and distribution	
¥ Using data obtained in NSW surveys, together with other biological information, develop a preliminary model that might describe the grey nurse shark population along the NSW coast[75].	
¥ Use population modelling to calculate an estimated extinction date, if the current rates of decline continue, in order to provide information on the available timeframes for effective threat abatement	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Population model available to assist management decision making.*

7.4.4 Develop an understanding of the reproductive biology of grey nurse sharks
¥ Verify the locations utilised for mating and pupping through more intense diver surveys at an appropriate time of the year.
¥ Utilise accidentally caught and killed grey nurse sharks to document: - size of reproductive maturity - the timing of mating - fecundity - the duration of gestation - the timing of pupping - the duration of the resting period.
Responsibility: **NSW Fisheries**
Performance criteria: *Knowledge of reproductive biology of grey nurse sharks improved.*

7.4.5 Develop an understanding of age, growth and longevity of grey nurse sharks	
¥ Regularly and accurately measure identified grey nurse sharks in the field.	
¥ Carry out microscopic examination of growth bands in vertebrae obtained via autopsies of incidentally killed grey nurse sharks.	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Methodology for field measurement of grey nurse sharks identified and shark measurements regularly undertaken at selected sites.*
	Ages estimated for the majority of incidentally caught and killed grey nurse sharks.

7.4.6 Estimate survival/mortality rates of grey nurse sharks in NSW waters	
¥ Initiate a tagging study to provide information on shark survival after hooking and/or associated trauma.	
¥ Initiate an Òaccidental captureÓ reporting program.	
¥ Establish protocols to ensure commercial and recreational fishers report captures of grey nurse sharks to NSW Fisheries, in order to allow estimates of the fishing effort and degree of reporting from each fishing sector.	
¥ Require compulsory reporting of any accidentally captured grey nurse sharks and compulsory provision of any dead sharksÕ carcass to NSW Fisheries to enable autopsies to be undertaken.	
¥ Analyse the gut contents of the great white, short-finned mako, tiger and bull shark to identify whether grey nurse sharks are included in their prey.	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Tagging program developed and implemented.*
	Accidental capture reporting system in place and the majority of accidentally captured grey nurse shark reported to NSW Fisheries.

7.4.7 Develop an understanding of grey nurse shark migration and movements in NSW wat	
¥ Establish a tagging study to document the localised movements of grey nurse sharks in relation to the aggregating sites.	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Tagging program developed and implemented.*

7.4.8 Determine genetic variability of populations of grey nurse sharks in NSW waters	
¥ Apply a range of genetic techniques to enable discrimination of the different populations such as those in NSW and WA waters.	
¥ Compare the genetic variability between past and present populations of grey nurse sharks using tissue samples from the different times.	
¥ Establish a register of all jaws and other artefacts of grey nurse sharks to enable samples of DNA to be obtained.	
¥ Establish a DNA storage facility.	
¥ Use genetic techniques to assist in identifying and monitoring the presence of grey nurse shark fins among other shark fins submitted for sale.	
Responsibility:	**NSW Fisheries, Queensland Department of Primary Industries, Environment Australia, Western Australian Department of Fisheries**
Performance criteria:	*Genetic material collected and processed.*
	Population genetics clarified by analysis of data.

7.5 Habitat protection

[Refer Section 4.5]

7.5.1 Declare the sites nominated in Appendix 1 as critical habitat and ensure the effective management of the declared area through a ban on all commercial drop and set line fishing in critical habitat and a ban on the use of wire trace on fishing lines from vessels not underway (ie not trolling)	
Responsibility:	**NSW Fisheries**
Performance criteria:	*All nominated sites declared as critical habitat.*
	Measures in place to ameliorate impacts on grey nurse sharks and their habitat.

7.6 Commercial aquaria

[Refer to section 4.6]

7.6.1 Retain the existing prohibition on the taking of grey nurse from the wild in NSW	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Prohibition retained.*

7.6.2 Encourage the development of breeding techniques utilising existing captive grey nurse sharks to supply future needs of aquaria	
Responsibility:	**NSW Fisheries, Queensland Department of Primary Industries, Environment Australia, Western Australian Department of Fisheries**
Performance criteria:	*Successful captive breeding program established.*

7.6.3 Work with commercial aquaria to increase public awareness of the endangered status of grey nurse sharks	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Appropriate education programs and displays implemented in commercial aquaria currently displaying grey nurse sharks.*

7.6.1 Retain the existing prohibition on the taking of grey nurse from the wild in NSW	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Prohibition retained.*

7.6.2 Encourage the development of breeding techniques utilising existing captive grey nurse sharks to supply future needs of aquaria	
Responsibility:	**NSW Fisheries, Queensland Department of Primary Industries, Environment Australia, Western Australian Department of Fisheries**
Performance criteria:	*Successful captive breeding program established.*

7.6.3 Work with commercial aquaria to increase public awareness of the endangered status of grey nurse sharks	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Appropriate education programs and displays implemented in commercial aquaria currently displaying grey nurse sharks.*

7.7 Ecotourism

[Refer to section 4.7]

7.7.1 Implement and promote the code of conduct to minimise disturbance to grey nurse sharks by ecotourism activities and by individual recreational divers and include relevant provisions of the code of conduct in the regulations for critical habitat areas	
Responsibility:	**NSW Fisheries, commercial shark dive-tour operators, Environment Australia**
Performance criteria:	*Code of conduct implemented, and adopted by industry*

7.7.2 Encourage tour operators to report grey nurse sightings to NSW Fisheries	
Responsibility:	**NSW Fisheries, commercial shark dive-tour operators**
Performance criteria:	*Majority of grey nurse shark sightings by tour groups reported.*

7.7.3 Establish monitoring programs to assess the impact of diver presence on shark behaviour and biology	
Responsibility:	**NSW Fisheries, commercial shark dive-tour operators**
Performance criteria:	*Assessment of effect of diver presence on shark behaviour and biology completed.*

7.8 Community awareness, involvement and support

[Refer to section 4.8]

7.8.1 Develop a comprehensive community education strategy aimed at the general public, anglers, divers and commercial fishers including: identification, status, current threats and biology	
Responsibility:	**NSW Fisheries, Environment Australia**
Performance criteria:	*Community education strategy and initiatives developed and implemented.*

7.8.2 Enhance advisory activities, including production of information brochures and related advisory materials	
Responsibility:	**NSW Fisheries, Environment Australia**
Performance criteria:	*Advisory materials prepared and distributed.*
	Evidence of increased community awareness.

7.8.3 Encourage community involvement in the implementation of the recovery plan	
Responsibility:	**NSW Fisheries**
Performance criteria:	*Continuation of volunteer dive surveys.*
	Other opportunities for community involvement in recovery actions assessed.

8. IMPLEMENTATION

As outlined in section 1.1, Part 7A of the *Fisheries Management Act* requires that a government agency must take any appropriate action available to them to implement the measures included in a recovery plan and not undertake actions inconsistent with a recovery plan.

Under the *Environmental Planning and Assessment Act*, consent and determining authorities must consider relevant recovery plans when exercising a decision making function under Parts 4 & 5 of the Act. Such authorities, when considering an activity in an area of known or potential grey nurse shark habitat which may affect the species, must consider the conservation strategy outlined in this plan.

Most of the costs associated with implementing the plan will be borne by NSW Fisheries, although some actions will also involve the participation of fishers and volunteer dive groups. Grants under the Natural Heritage Trust have funded some previous research actions, and additional funding may be sought from this and other external grant schemes to assist in plan implementation.

9. REVIEW

The *Fisheries Management Act* requires that recovery plans must state the date by which the plan should be subject to review. This date is usually set at 5 years after the final plan has been approved.

REFERENCES

1. Bailey, N.T.J. (1951). On estimating the size of mobile populations from recapture data. *Biometrika* **38:** 293-306.

2. Bailey, N.T.J. (1952). Improvements in the interpretation of recapture data. *Journal of Animal Ecology* **21:** 120-127.

3. Bass, A.J., D'Aubrey, J.D. and Kistnasamy, N. (1973). Sharks of the east coast of southern Africa. I. The genus *Carcharhinus* (Carcharhinidae). *Oceanographic Research Institute Investigational Report* **33:** 1-168.

4. Bass, A.J., D'Aubrey, J.D., and Kistnasamy, N. (1975). Sharks of the east coast of Southern Africa IV. The families, Odontaspididae, Scaponorhynichidae, Isuridae, Cetorhinidae, Alopiidae, Orectolobidae and Rhiniodontidae. *Oceanographic Research Institute Investigational Report* **39:** 6-16.

5. Beamish, R.J., and McFarlane, G.A., (1983). The forgotten requirement for age validation in fisheries biology. *Trans. Am. Fish. Soc.* **112(6):** 735-743.

6. Beamish, R.J., and McFarlane, G.A., (1985). Annulus development in the second dorsal spine of the spiny dogfish (*Squalus acanthias*) and its validity for age determination. *Canadian Journal of Fisheries and Aquatic Sciences* **42:** 1799-805.

7. Bigelow, H.B., and Schroeder, W.C. (1948). Fishes of the western north Atlantic. Part 1. Lancelets, Cyclostomes and Sharks. *Mem. Sears Fdn. Mar. Res*. 1-576.

8. Branstetter, S. (1990). Early life-history implications of selected carcharhinoid and lamnoid sharks of the northwest Atlantic. **In:** Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries. H. L. Pratt, Jr., S. H. Gruber & T. Taniuchi, eds. U.S. Dept. Commerce, NOAA Tech. Rep. NMFS 90, pp. 17-28.

9. Branstetter, S., and Musick, J.A. (1994). Age and growth estimates for the sand tiger in the North-western Atlantic Ocean. *Transactions of the American Fisheries Society* **123**: 242-254.

10. Brown, T.W. (1973). Sharks – A Search For a Repellent. Angus and Robertson, Sydney.

11. Bruce, B.D. (1995). The protection of white shark. A research perspective. *Southern Fisheries* **3(2):** 10 - 15. Department of Primary Industries and Fisheries

12. Cailliet, G.M. (1992). Demography of the central California population of the leopard shark (*Triakis semifasciata*). *Australian Journal of Marine and Freshwater Research* **43:** 183-193.

13. Cailliet, G.M., Martin, L.K., Harvey, J.T., Kusher, D., and Welden, B.A. (1983). Preliminary studies on the age and growth of the blue, *Prionace glauca*, common thresher, *Alopias vulpinus*, and shortfin mako, *Isurus oxyrinchus*, sharks from California waters. U.S.Dep.Commer., NOAA Tech.Rep.NMFS 8: 179-188.

14. Cailliet, G.M., Mollet, H.F., Pittinger, G.G., Bedford, D., and Natanson, L.J. (1992). Growth and demography of the Pacific angel shark (*Squatina californica*), based upon tag returns off California. *Australian Journal of Marine and Freshwater Research* **43:** 1313-1330.

15. Caswell, H. (2000). Matrix Population Models. Sinauer Associates Inc, MA, 01375, USA. 722pp.

16. Caughley, G. (1977). Analysis of vertebrate populations. John Wiley & Sons, New York.

17. Chiaramonte, G.E. (1998). Shark fisheries in Argentina. *Marine and Freshwater Research* **49:** 601-9.

18. Cliff, G., and Dudley, S.F.J. (1991). Sharks caught in the protective gill nets off Natal, South Africa. 4. The bull shark *Carcharhinus leucas* (Valenciennes). *South African Journal of Marine Science* **10:** 253-270.

19. Cliff, G., Dudley, S.F.J., and Davies, B. (1989). Sharks caught in the protective nets off Natal, South Africa. 2. The great white shark *Carcharodon carcharias* (Linnaeus). *South African Journal of Marine Science* **8:** 131-144.

20. Cliff, G., Dudley, S.F.J., and Davies, B. (1990). Sharks caught in the protective gill nets off Natal, South Africa. 3. The shortfin mako shark *Isurus oxyrinchus* (Rafinesque). *South African Journal of Marine Science* **9:** 115-126.

21. Cliff, G., and Thurman, G.D. (1984). Pathological and physiological effects of stress during capture and transport in the juvenile dusky shark, *Carcharinus obscurus. Comparative Biochemistry and Physiology* **78A:** 167-73.

22. Compagno, L.J.V. (1984). FAO Species Catalogue, Vol. 4. Sharks of the World. An annotated and illustrated catalogue of shark species known to date. Part 1, Hexanchiformes to Lamniformes. *FAO Fisheries Synopsis, No. 125,* 4(1): 249.

23. Compagno, L.J.V. (1990). Shark exploitation and conservation. **In:** Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries. H. L. Pratt, Jr., S. H. Gruber & T. Taniuchi, eds. U.S. Dept. Commerce, NOAA Tech. Rep. NMFS 90, pp. 391-414.

24. Coppleson, V.M. (1962). Shark Attack (2nd Ed.). Angus and Robertson, Sydney.

25. Cortes, E. (1995). Demographic analysis of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, in the Gulf of Mexico. *Fisheries Bulletin* **93:** 57-66.

26. Cortes, E. (2000). Life history patterns and correlations in sharks. *Reviews in Fisheries Science* **8(4):** 299-344.

27. Cortes, E., and Parsons, G.R. (1996). Comparative demography of two populations of the bonnethead shark (*Sphyrna tiburo). Canadian Journal of Fisheries and Aquatic Sciences* **53:** 709-718.

28. Cropp, B. (1964). Shark Hunters. Rigby, Adelaide.

29. Davies, D. H. and Joubert, L.S. (1966). Tag evaluation and shark tagging in South African waters. Investigational Report of the Oceanographic Research Institute, **12:** 1-36.

30. De Roos, R., and De Roos, C. (1978). Elevation of plasma glucose levels by catecholamines in elasmobranch fish. *General and Comparative Endocrinology* **34:** 447-452.

31. Eckersley, Y. (1996). Shark meshing: is the net result justifiable? *GEO Australia* **18(5):** 17-26.

32. Edwards, H. (1997). Shark: the shadow below. Harper Collins Publishers, Sydney.

33. Environment Australia (1997). Report to the Minister - Public nomination to the *Endangered Species Protection Act 1992*: Great white shark and grey nurse shark - recommended by the *Endangered Species Scientific Subcommittee* in the Threatened Species and Communities Section.

34. Garbutt, R. (1995). Sharks under attack: Grey nurse numbers take a dive in fishing conflict. *GEO Australia* **17:** 26-38.

35. Gardner, M.G. and Ward, R.D. (1998). Population structure of the Australian gummy shark (Mustelus antarcticus Gunther) inferred from allozymes, mitochondrial DNA and vertebrae counts. *Marine and Freshwater Research* **49**: 733-745.

36. Gilbert, P.W. (1981). Patterns of shark reproduction. *Oceanus* **24:** 30-39.

37. Gillanders, B.M., Ferrell, D.J., and Andrew, N.L. (2001). Estimates of movement and life-history parameters of yellowtail kingfish (*Seriola lalandi*): how useful are data from a cooperative tagging program? *Marine and Freshwater Research* **52:** 1-14.

38. Gilmore, R.G., Dodrill, J.W., and Linley, P.A. (1983). Reproduction and embryonic development of the sand tiger shark, *Odontaspis taurus* (Rafinesque). *Fisheries Bulletin* **81(2):** 201-225.

39. Gordon, I. (1992). A new record extending the southerly distribution of shark ray (*Rhina ancylostomus*), and notes on the behaviour of the specimen in captivity. *Australian Journal of Marine and Freshwater Research* **43:** 319-323.

40. Govender, N., Kistnasamy, N., and Van der Elst, R.P. (1991). Growth of spotted ragged-tooth sharks *Carcharias taurus* (Rafinesque) in captivity. *South African Journal of Marine Science* **11:** 15-19.

41. Grant, E. M. (1982). Guide to fishes. Department of Harbours and Marine, Brisbane, QLD.

42. Gray, C.A., and Otway, N.M. (1994). Spatial and temporal differences in assemblages of demersal fishes on the inner continental shelf off Sydney, south-eastern Australia. *Australian Journal of Marine and Freshwater Research* **45:** 665-676.

43. Gruber, S.H. (1984). Bioenergetics of the captive and free-ranging lemon shark, pp.340-373. **In:** AAZPA 1984 Annual Conference Proceedings, September 9-13, Miami, Florida.

44. Hoenig, J.M., Barrowman, N.J., Hearn, W.S., and Pollock, K.H. (1998). Multiyear tagging studies incorporating fishing effort data. *Canadian Journal of Fisheries and Aquatic Sciences* **55:** 1466-76.

45. Hoenig, J.M., and Gruber, S.H. (1990). Life-history patterns in the elasmobranchs: implications for fisheries management. **In:** Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries. H. L. Pratt, Jr., S. H. Gruber & T. Taniuchi, eds. U.S. Dept. Commerce, NOAA Tech. Rep. NMFS 90, pp. 1-16.

46. Holeton, G., and Heisler, N. (1978). Acid-base regulation by bicarbonate exchange in the gills after exhausting activity in the larger spotted digfish *Scyliorhinus stellaris. Physiologist* **21:** 56.

47. IMCRA Technical Group (1998). *Interim Marine and Coastal Regionalisation Australia: an ecosystem-based classification for marine and coastal environments.* Version 3.3. Environment Australia, Commonwealth Department of the Environment, Canberra.

48. Ireland, D. (1984). The grey nurse shark. *Underwater* **11:** 10-13.

49. Klimley, A.P. (1987). The determinants of sexual segregation in the scalloped hammerhead shark, *Sphyrna lewini*. *Environmental Biology of Fishes* **18:** 27-40.

50. Klimley, A.P. (1993). Highly directional swimming by scalloped hammerhead sharks, *Sphyrna lewini*, and subsurface irradiance, temperature, bathymetry, and geomagnetic field. *Marine Biology* **117:** 1-22.

51. Klimley, A.P., and Brown, S.T. (1983). Stereophotography for the field biologist: measurement of lengths and three-dimensional positions of free-swimming sharks. *Marine Biology* **74:** 175-185.

52. Klippel, K. (1992). Wildlife Data Search: Threatened Animal Species of New South Wales. Total Environment Centre Inc., Sydney, NSW, Australia.

53. Krogh, M. (1994). Spatial, seasonal and biological analysis of sharks caught in the NSW protective beach meshing program. *Australian Journal of Marine and Freshwater Research* **45:** 1087 - 1106.

54. Krogh, M., and Reid, D. (1996). Bycatch in the protective shark meshing program off south-eastern New South Wales, Australia. *Biological Conservation* **77:** 219 - 226.

55. Last, P.R., and Stevens, J.D. (1994). *Sharks and Rays of Australia.* CSIRO Division of Fisheries, Australia.

56. Lavery, S. (1992). Electrophoretic analysis of phylogenetic relationships among Australian carcharhinid sharks. *Australian Journal of Marine and Freshwater Research* **43:** 97-108.

57. Lavery, S., and Shaklee, J.B. (1989). Population genetics of two tropical sharks, *Carcharhinus tilstoni* and *C. sorrah*, in northern Australia. *Australian Journal of Marine and Freshwater Research* **40:** 541-57.

58. Lavery, S. and Shaklee, J.B. (1991). Genetic evidence of separation of two sharks, *Carcharhinus limbatus* and *C. tilstoni*, from northern Australia. *Marine Biology (Berlin)* **108:** 1-4.

59. Leslie, P.H. (1945). On the use of matrices in certain population mathematics. *Biometrika* **33:** 183-212.

60. Leslie, P.H. (1948). Some further notes on the use of matrices in certain population mathematics. *Biometrika* **35:** 213-245.

61. Lincoln-Smith, M.P., Bell, J.D., Pollard, D.A., and Russell, B.C. (1989). Catch and effort of competition spearfisherman in south-eastern Australia. *Fisheries Research* **8:** 45-61.

62. Marin, Y.H., Brum, F., Barea, L.C., and Chocca, J.F. (1998). Incidental catch associated with swordfish longline fisheries in the south-west Atlantic Ocean. *Marine and Freshwater Research* **49**: 633-640.

63. Marsh, N. (1995). A grey future for the grey nurse shark. *Underwater Geographic* **39:** 39-42.

64. Martin, A. P. (1990). Molecular Evolution in Sharks. *Pacific Science*, **44 (702)**, 191-192.

65. Martin, A.P. (1992). Mitochondrial DNA in sharks: molecular evolution and evolutionary inferences. Ph.D. diss., Univ. of Hawaii, Honolulu, HI, 216pp.

66. Martin, A.P. (1993). Application of mitochondrial DNA sequence analysis to the problem of species identification of sharks. **In:** Conservation biology of elasmobranchs, p. 53-59. U.S. Dep. Commerce, NOAA Technical Report NMFS 115.

67. Mollet, C. (2001). Demgraphy of the Sandtiger shark *Caracharias taurus* (Rafinesque, 1810). Aka Grey Nurse Shark in Australia, Spotted ragged-tooth shark in South Africa. http://homepage.mac.com/mollett/c+DemographyCT.html

68. Moritz, C., Dowling, T., and Brown, W. (1987). Evolution of animal mitochondrial DNA: relevance for population biology and systematics. *Ann. Rev. Ecol. Syst.* **18:** 269-292.

69. Moss, S.A. (1984). Sharks: An introduction for the amateur naturalist. Prentice-Hall, New Jersey.

70. Naylor, G.J.P. (1989). The phylogenetic relationships of Carcharhiniform sharks inferred from electrophoretic data. Ph.D. diss., Univ.Maryland, 131pp.

71. Nelson, D.R. (1990). Telemetry studies of sharks: a review, with applications in resource management. pp. 239-256. **In:** Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the status of the Fisheries, H.L. Pratt, S.H. Gruber & T. Taniuchi (eds.). U.S. Dep. Commer., NOAA Tech. Rep. NMFS 90.

72. Olsen, A.M. (1954). The biology, migration, and growth rate of the school shark, *Galeorhinus australis* (MacLeay) (Carcharhinidae) in southeastern Australian waters. *Australian Journal of Marine and Freshwater Research* **5:** 353-410.

73. Otway, N.M. and Morrison, N.S (in prep.). Monitoring and identification of NSW Critical Habitat Sites for conservation of Grey Nurse Sharks. *NSW* EA Project No. 22499. Fisheries Final Report Series.

74. Otway, N.M., and Parker, P.C. (1999). A review of the biology and ecology of the grey nurse shark (*Carcharias taurus)* Rafinesque 1810. *NSW Fisheries Research Report Series 1.* NSW Fisheries, Sydney, NSW, Australia.

75. Otway, N. M., and Parker, P. C. (2000). The biology, ecology, distribution and abundance, and identification of marine protected areas for the conservation of threatened Grey Nurse Sharks in south east Australian waters. *NSW Fisheries Final Report Series No. 19*. NSW Fisheries, Sydney, NSW, Australia. 132 pp.

76. Otway, N.M., Sullings, D.J., and Lenehan, N.W. (1996). Tropically-based assessment of the impacts of deepwater sewage disposal on a demersal fish community. *Environmental Biology of Fishes* **46:** 167-183.

77. Parker, P. and Bucher, D. J. (2000). Seasonal Variation in abundance and sex ratio of Grey Nurse (Sand Tiger) Sharks *Carcharias taurus* in northern New South Wales, Australia: a survey based on observations of recreational scuba divers.

78. Paterson, R.A. (1990). Effects of long-term anti-shark measures on target and non-target species in Queensland, Australia. *Biological Conservation* **52:** 147 - 159.

79. Pepperell, J.G. (1992). Trends in the Distribution, Species Composition and Size of sharks caught by Gamefish Anglers off South-eastern Australia, 1961-90. *Australian Journal of Marine and Freshwater Research* **43:** 213-225.

80. Pollard, D.A., Lincoln Smith, M.P., and Smith, A.K. (1996). The biology and conservation status of the grey nurse shark (*Carcharias taurus* Rafinesque 1810) in New South Wales, Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems* **1(177):** 1-20.

81. Read, A. D., and Ward, T. (1986). Taiwanese longliners off northern Australia. *Australian Fisheries* **August:** 6-8.

82. Reid, D.D., and Krogh, M. (1992). Assessment of catches from protective shark meshing off New South Wales beaches between 1950 and 1990. *Australian Journal of Marine and Freshwater Research* **43:** 283-96.

83. Roughley, T.C. (1955). Fish and fisheries of Australia. Angus and Robertson, Sydney.

84. Sadowsky, V. (1970). On the dentition of the sand shark, *Odontaspis taurus*, from the vicinity of Cananeia, Brazil. *Bol. Inst. Oceanogr. S.Paulo* **218:** 37-44.

85. Sadowsky, V., Arfelli, C.A., Amorin, A.F., Rodrigues, E.S., and Oliveira, M.A.M. (1989). Aspectos sobre a biologia pequeira da magona, *Eugomphodus taurus*, capturada na reiao de Canneia-SP. IV GTPPTRB, Resumos, Tamandare, 04-07 de julho de 1989, 20. (Abstract).

86. Saiki, R.K., Gelfand, D.H., Stoffe, S., Scharf, S.J., Higuchi, R., Horn, G.T., Mullis, K.B., and Erlich, H.A. (1988). Primer-directed enzymatic amplification of DNA with a thermostable DNA polymerase. *Science* **239:** 487-491.

87. Schmid, T.H., Murru, F.L., and McDonald, F. (1990). Feeding habits and growth rates of bull (*Carcharhinus leucas* (Valenciennes)), sandbar (*Carcharhinus plumbeus* (Nardo)), sandtiger (*Eugomophodus taurus* (Rafinesque)) and nurse (*Giglymostoma cirratum* (Bonnaterre)) sharks maintained in captivity. *Journal of Aquariculture and Aquatic Sciences* **5(4):** 100-105.

88. Scott, L. (1995). The ultimate dive. *Sportdiving in Australia and the South Pacific* **48:** 39-43.

89. Smith, M.F.L. (1992). Capture and transportation of elasmobranches, with emphasis on the grey nurse shark (*Carcharias taurus*). *Australian Journal of Marine and Freshwater Research* **43:** 325 - 343.

90. Smith, S.E., Au, D.W., and Show, C. (1998). Intrinsic rebound potentials of 26 species of Pacific sharks. *Marine and Freshwater Research* **49:** 663-78.

91. Smullen, S. (1997). NMFS Protects Sharks in Bid to Halt Overfishing. NOAA Media Release 2nd April 1997.

92. Springer, S. (1948). Oviphagous Embryos of the Sand Tiger Shark, *Carcharias taurus*. *Copeia* **1948(3):** 153-157.

93. Stead, D.G. (1963). Sharks and rays of Australian seas. Angus and Robertson, Sydney.

94. Stevens, J.D. (1984). Biological observations on sharks caught by sport fisherman off New South Wales. *Australian Journal of Marine and Freshwater Research* **35**: 573-590.

95. Stillwell, C.E., and Kohler, N.E. (1982). Food, feeding habits, and estimates of daily ration of the shortfin mako *(Isurus oxyrinchus)* in the northwest Atlantic. *Canadian Journal of Fisheries and Aquatic Sciences* **39(3):** 407-414.

96. Stossell, T. (1993). Investigation of the international shark fin trade. Unpublished Report, TRAFFIC USA.

97. Taronga Zoo (1996). Comments in support of the nomination of the grey nurse shark, *Carcharias taurus* and the great white shark, *Carcharodon carcharias* to be included in *Part 2 of Schedule 1 of the Commonwealth Endangered Species Act, 1992.*

98. West, J.G. (1991). The Australian Shark Attack File with notes on preliminary analysis of data from Australian waters. Shark Conservation Workshop, Taronga Zoo, 1991.

99. Whitley, G.P. (1940). The Fishes of Australia. Part 1. The Sharks, Rays, Devilfish and other Primitive Fishes of Australia and New Zealand. pp. 1-280. Royal Zoological Society of New South Wales: Sydney.

APPENDIX 1 PRELIMENARY IDENTIFICATION OF CRITICAL HABITAT

The *Fisheries Management Act* provides for the identification and declaration of critical habitat for listed threatened species, populations and ecological communities. Critical habitat is the whole or any part of the habitat of an endangered species, population or ecological community that is critical to its survival.

The declaration of critical habitat allows for increased protection of threatened species' habitat. Once declared, it becomes an offence to damage critical habitat (unless the action is specifically exempted by the *Fisheries Management Act*) and a species impact statement is mandatory for all developments and activities that affect declared critical habitat.

Regulations may be prepared for critical habitat to prohibit or restrict any activity that has the potential to directly or indirectly damage the declared habitat or injure the endangered species that utilise it.

Through repeated coastwide surveys of the state [75] [73], a number of sites have been identified as of critical importance to grey nurse sharks. These are major aggregation sites for the species and are also likely to be important sites for mating and pupping. Details of each site are provided in Table 6.

While all the sites are considered critical to the species' survival, different sites are important for different reasons. For example, of those sites in State waters, Fish Rock, the Pinnacle, Big Seal, Broughton Island and the Tollgate Islands are particularly significant due to the large numbers of sharks consistently encountered at these sites. There is also some evidence that these sites may be important for mating or as a refuge for pregnant females.

The location and features of each site are outlined on the following pages.

Table 6. Summary of key information on critical habitat.

General location	Critical habitat site	Coordinates	Jurisdiction	Mean % of observed grey nurse shark population	Aggregation consistency (% usage)	Mean % of observed male / female population	Legislative status of site	Current management arrangements
Byron Bay	Julian Rocks – Cod Hole	153º 37' 45" E 28º 36' 40" S	New South Wales	2.7	30.0	8.5% Male 0.6% female (Pupping witnessed at this site)	Aquatic reserve	Recreational line fishing only within 500m radius. No commercial fishing or spearfishing permitted.
Solitary Islands Marine Reserve	Pimpernel Rock	153º 23' 55" E 29º 41' 55" S	Commonwealth	4.6	75.0	13.4% male 2.3% female	Commonwealth marine reserve	Sanctuary zone
Solitary Islands Marine Park	North Solitary Island (Anemone Bay)	153º 23' 25" E 29º 55' 20" S	New South Wales	2.5	40.0	4.2% male 1.8% female	Solitary Islands Marine Park (SIMP)	The proposed critical habitat is zoned either as sanctuary or habitat protection zones in the marine park; where zoned habitat protection, additional restrictions apply to protect grey nurse sharks. . (New zoning comes into effect on 1 August 2002, see www.mpa.nsw.gov.au).
Solitary Islands Marine Park	South Solitary Island (Manta Arch)	153º 16' 05" E 30º 12' 10" S	New South Wales	4.4	80.0	7.6% male 4.0% female	Solitary Islands Marine Park (SIMP)	The proposed critical habitat is zoned either as sanctuary or habitat protection zones in the marine park; where zoned habitat protection, additional restrictions apply to protect grey nurse sharks. . (New zoning comes into effect 1 August 2002, see www.mpa.nsw.gov.au).
South West Rocks	Green Island	153º 05' 30" E 30º 54' 40" S	New South Wales	1.6	80.0	3.1% male 0.8% female	None	No specific management rules

South West Rocks	Fish Rock	153º 06' 05" E 30º 56' 25" S	New South Wales	11		17% male 6.1% female	Drop line fisheries closure	Restrictions on spearfishing (species list).
Laurieton	Cod Grounds	152º 54' 30" E 31º 40' 55" S	Commonwealth	11.8	100.0	8.0% male 16.0% female	None	No specific management rules
Forster	Pinnacle	152º 36' 00" E 32º 13' 40" S	New South Wales	12.7	100.0	13.4% male 11.3% female	None	No specific management rules
Seal Rocks	Big Seal	152º 33' 15" E 32º 27' 50" S	New South Wales	10	80.0	6.5% male 10.7% female	None	No specific management rules
Seal Rocks	Little Seal	152º 32' 55" E 32º 28' 30" S	New South Wales	4		5.4% male 6.8% female	None	No specific management rules
Port Stephens	Little Broughton Island	152º 20' 00" E 32º 37' 05" S	New South Wales	9.5	90.0	2.2% male 13.7% female	None	No specific management rules
Sydney	Maroubra – Magic Point	151º 15' 50" E 33º 57' 20" S	New South Wales	3.5	55.6	1.3% male 4.1% female	None	No specific management rules
Shellharbour	Bass Point	150°54'57" E 34°35'54" S	New South Wales	1.0	10.0	0.4% male 0.7% female	None	No specific management rules
Bateman's Bay	Tollgate Islands	150º 15' 45" E 35º 44' 50" S	New South Wales	8.9	90.0	2.7% male 15.4% female	None	No specific management rules
Narooma	Montague Island	150º 13' 40" E 36º 14' 30" S	New South Wales	1.3	20.0	0.67% male 1.8% female	None	No specific management rules
TOTAL				89.6		90.5% male 93.2% female		

Note: Critical habitat coordinates were obtained from a variety of sources. These were subsequently checked against a number of data layers (eg Nautical Charts, AMBIS2001), and have been rounded to the nearest 5" (approximately +/- 75m) to indicate their likely level of accuracy. Latitudes and longitudes have been determined by reference to GDA94.

The NSW coastline is divided into five distinct bioregions based on biological and physical characteristics [47].

Far North Coast (Tweed - Moreton Bioregion)

The Tweed-Moreton Bioregion begins at Nambucca Heads and extends north into Queensland.

Preliminary assessments have identified four areas of critical habitat in the NSW section of the Tweed-Moreton Bioregion. All are important aggregation sites for the grey nurse shark. These sites are illustrated in Figure 1.

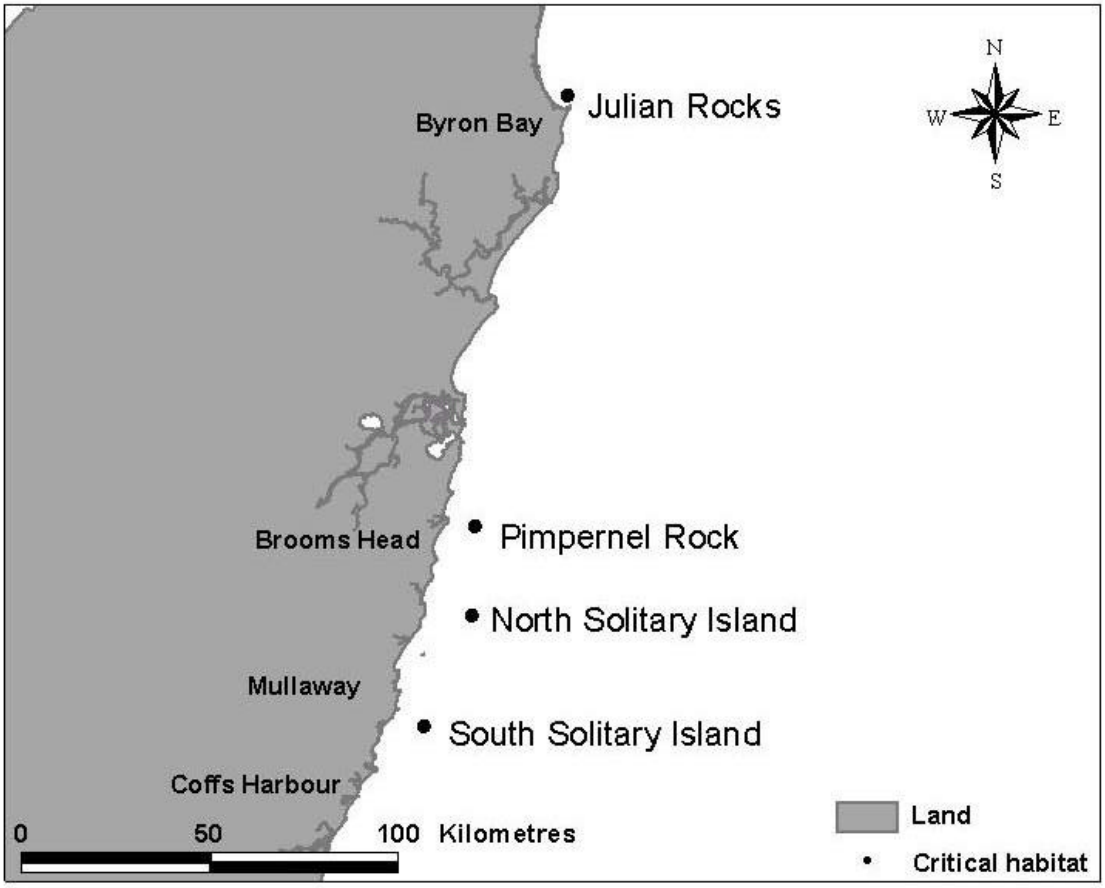

Fig. 1 Critical habitat sites identified on the far north coast (Tweed-Moreton Bioregion) of NSW.

Julian Rocks

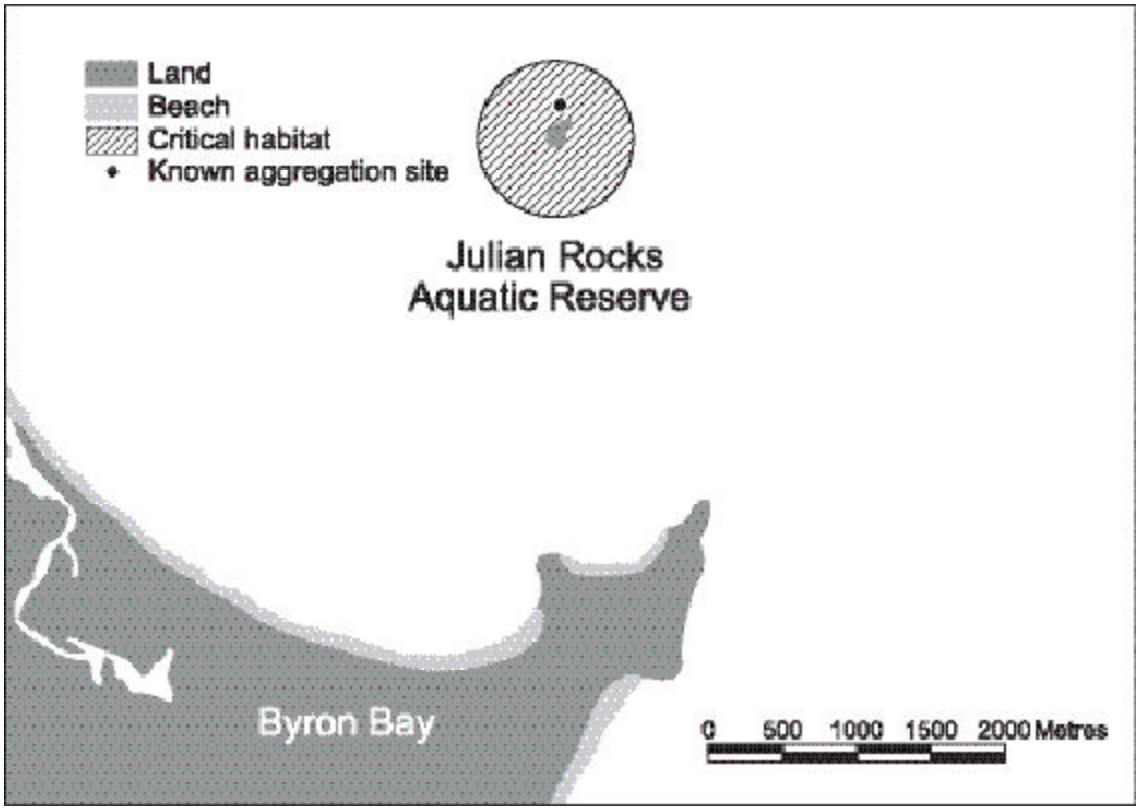

Fig. 2 Critical habitat at Julian Rocks

Juan and Julian Rocks, collectively known as Julian Rocks, are located approximately 3km north of Byron Bay. Grey nurse sharks are commonly sighted at four main sites at Byron Bay, with Julian Rocks providing the majority of sightings.

Approximately 2.7 percent of the total numbers of grey nurse sharks sampled have been observed at Julian Rocks. These aggregations consistently occur over the winter months, with aggregations of the sharks recorded during 30 percent of the surveys conducted between 1998-2001 [75] [73]. Although this site has been identified as being important to male grey nurse sharks (8.5 percent of the sampled male population have been sighted at this location), pupping has also been witnessed here, suggesting it is an important site for both sexes (Otway pers. comm.).

Julian Rocks was declared an aquatic reserve in 1982 and covers an area of about 80 hectares, below mean high water and within a 500 m radius from a trigonometric station located on the largest of the rocks (Juan). No commercial fishing or spearfishing is permitted within the aquatic reserve. Recreational line fishing is permitted. While anchoring is permitted in the reserve, a number of moorings are in place which assist in the protection of habitat.

It is proposed that the same reserve area be declared as critical habitat (Fig. 2). This would include waters below mean high water and within a 500 m radius of the official trig station located on Juan Rock.

Pimpernel Rock

Pimpernel Rock is a submerged reef over 3 nautical miles offshore from Sandon Bluff in the northern section of the Commonwealth Solitary Islands Marine Reserve. The site is a large pinnacle of rock, its base at 50 m depth and rising to within 12 m of the sea surface. The site is characterised by a large cavern approximately 10-15 m deep and 20-25 m long with gutters extending from both entrances. Grey nurse sharks are consistently seen inside the cavern and gutters. Aggregations of the sharks have been observed during 75 percent of the surveys conducted between 1998-2001, mainly during autumn, winter and spring. Some evidence of mating activity has been observed in the months of autumn [74].

Approximately 4.6 percent of the total sampled population of grey nurse sharks have been observed at Pimpernel Rock. The site is believed to be of high importance to both sexes due to evidence of mating activities in the area. In particular, however, a large proportion of the sampled male population (13.4 percent) has been sighted at Pimpernel Rock.

Pimpernel Rock is located in the Commonwealth Solitary Islands Marine Reserve. Under a new management plan for the reserve, Pimpernel Rock has been zoned a sanctuary area. This zone encompasses a 500 m radius around the site. No commercial or recreational fishing is permitted in this area.

As this site is located within Commonwealth waters (ie. more then 3 nautical miles from the NSW coast), no action is required by NSW Fisheries. Under the draft recovery plan prepared by Environment Australia, this site is proposed for critical habitat listing under Commonwealth legislation. NSW Fisheries would endeavour to work with the Commonwealth in order to achieve the best possible protection of grey nurse sharks in this area.

Solitary Islands Marine Park

North Solitary Island and **South Solitary Island** are located in the NSW Solitary Islands Marine Park. A new zone plan for the marine park has recently been announced and will come into effect on 1 August 2002 (see www.mpa.nsw.gov.au for details). Under the new plan, sanctuary zones (in which fishing is prohibited) have been increased from 0.4% to 12% of the park. Setlines have also been banned throughout the park. These measures provide significant levels of protection for grey nurse sharks.

The zoning plan also includes restrictions on the use of wire traces for bottom fishing in habitat protection zones[3] in the waters surrounding North Solitary and South Solitary islands out to 500m. These areas correspond to the areas identified below as proposed critical habitat.

[3] The use of wire traces is banned except for trolling purposes, but only whilst a vessel is underway (it is banned totally in sanctuary zones).

North Solitary Island

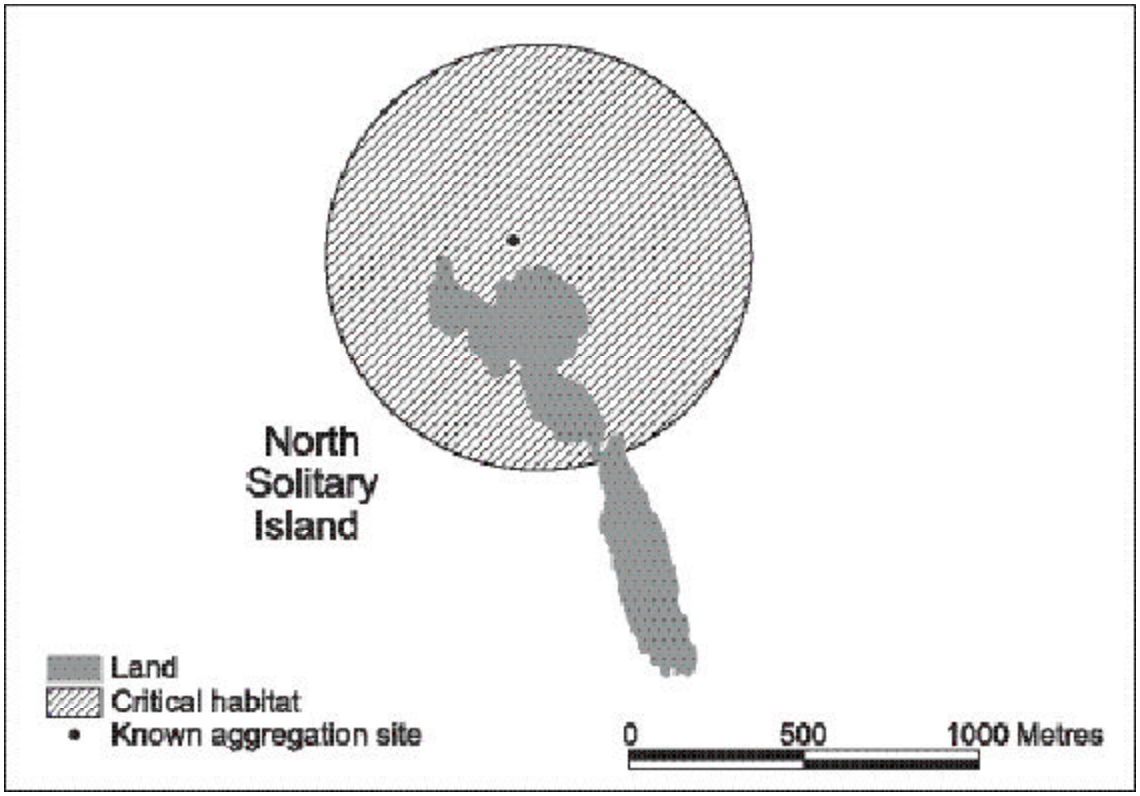

Fig. 3 Proposed critical habitat for North Solitary Island

Grey nurse sharks have been encountered at several sites in this section of the marine park. The Bay of Anemones is located on the north-eastern tip of the island and is characterised by a 30 m deep gutter where the sharks are most frequently sighted. Relatively large aggregations of sharks have been recorded during 40 percent of the coastwide surveys, mainly over winter and spring [75] [73].

Approximately 2.5 percent of the total sampled population of grey nurse sharks have been observed at North Solitary Island. The majority of these sharks have been males, with an average of 4.2 percent of the sampled male population observed at this site [75] [73].

Under the new zoning plan a sanctuary zone extends from mean high water mark at a point 50 m north of the eastern side of Anemone Bay, due west to approximately 200 m west of North Solitary Island and includes the western side of the island from mean high water to approximately 200 m offshore. The southern boundary extends from the most south westerly point of the island, due west.

It is proposed that critical habitat be declared over the waters below, and within a 500m radius of, mean high water on North Solitary Island. (Fig. 3).

South Solitary Island

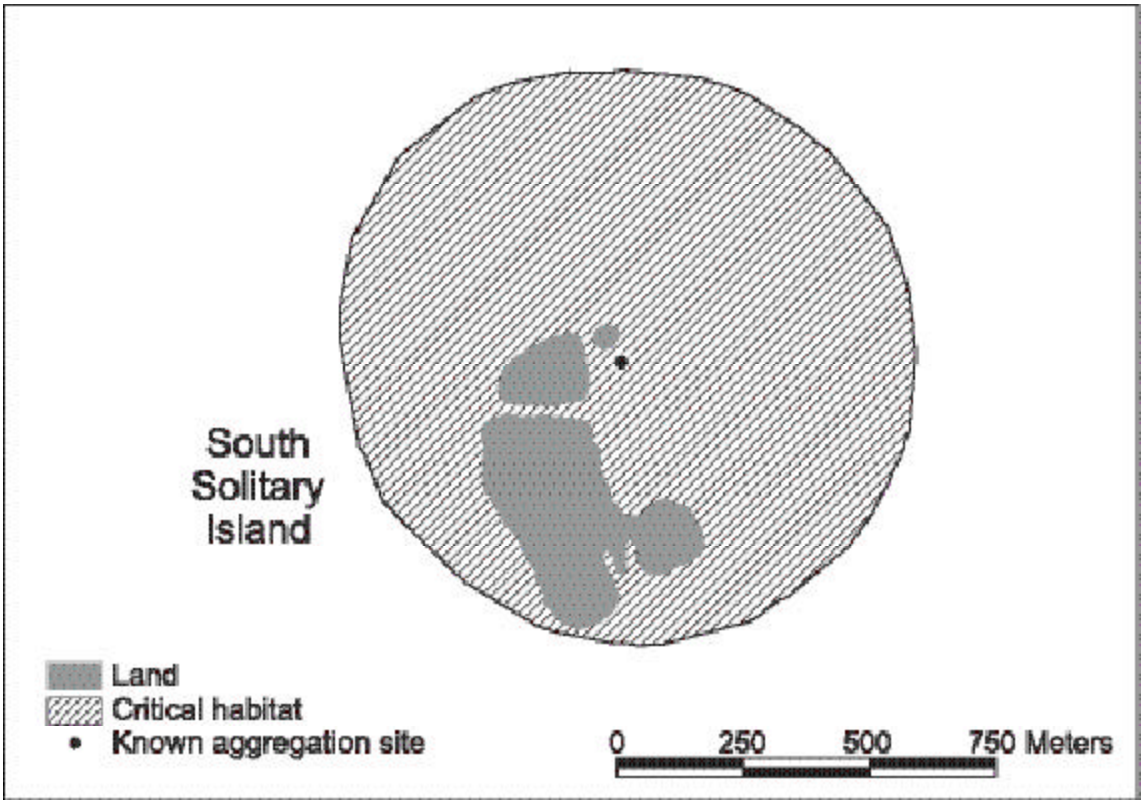

Fig. 4 Proposed zoning scheme and critical habitat for South Solitary Island

Grey nurse sharks have been seen at three main sites around the island: the 'Manta Arch', the 'Shark Gutters' and 'Buchannans Wall'. Manta Arch is located at the north eastern tip of the Island and is the most important aggregation site for grey nurse sharks at South Solitary Island.

Aggregations have been consistently observed at Manta Arch, with 80 percent of the surveys conducted between 1998 and 2001 recording relatively large numbers of sharks here [73]. Approximately 4.4 percent of the total sampled population of grey nurse sharks have been observed at South Solitary Island, the majority of which are male (7.6 percent of the sampled male population) [75] [73].

Under the new zoning plan, a sanctuary zone extends from mean high water mark to 100 m around "Birdie" (the small islet off the north eastern tip of South Solitary Island), then extends from the mean high water mark to approximately 200 m on the western side of the island. The southern boundary extends from the most south westerly point of the island due west.

The known occurrence of grey nurse sharks at a number of sites surrounding the island suggests the sharks are likely to move from site to site.

It is proposed that critical habitat be declared over the waters below, and within a 500m radius of, mean high water on South Solitary Island (Fig. 4). This would incorporate all three aggregation sites.

Mid-North Coast (Manning Shelf Bioregion)

The Manning Shelf Bioregion starts at Nambucca Heads and extends south to Port Stephens. Preliminary identification of critical habitat has established that seven sites in the Manning Shelf Bioregion are important aggregation sites for grey nurse sharks. These sites are illustrated in Figure 5.

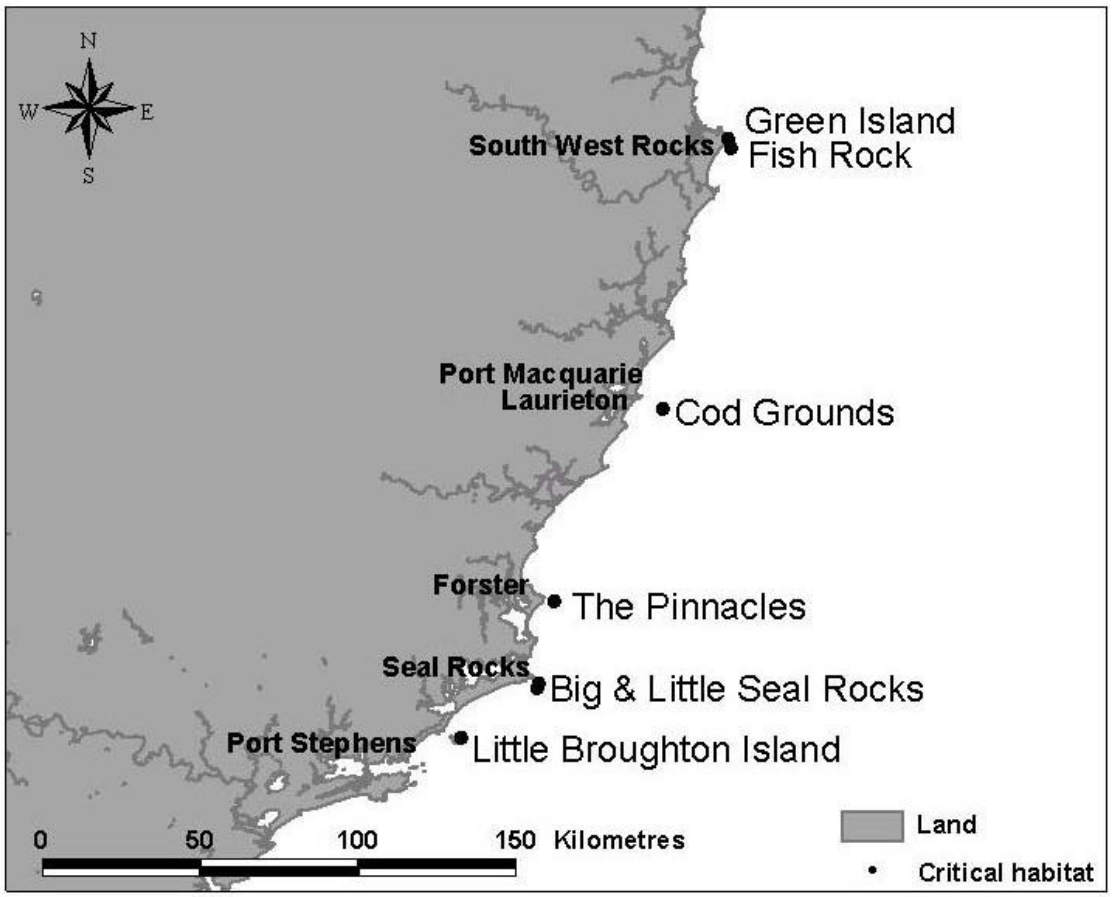

Fig. 5 Critical habitat sites identified on the mid north coast (Manning Shelf Bioregion)

Green Island (South West Rocks)

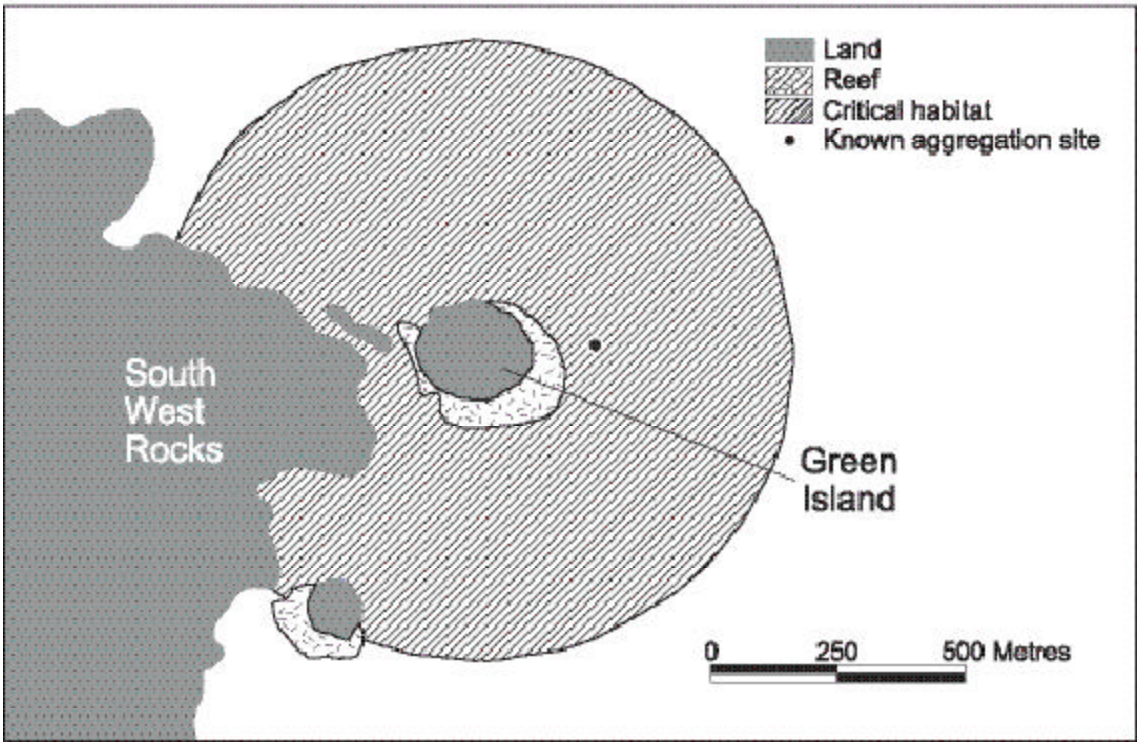

Fig. 6 Critical habitat at Green Island

Green Island is a relatively shallow site at a depth of 15 m, with a gutter on the eastern side. Large numbers of grey nurse sharks have been sighted in this gutter. Approximately 1.6 percent of the total sampled population of grey nurse sharks have been observed in this site, the majority of which were males. While this site is believed to be of secondary importance to another South West Rocks site, Fish Rock, migration between the two sites is likely. There are no specific management measures currently in place at Green Island.

It is proposed that critical habitat be declared over the waters below, and within a 500m radius of, mean high water on Green Island (Fig. 6).

Fish Rock (South West Rocks)

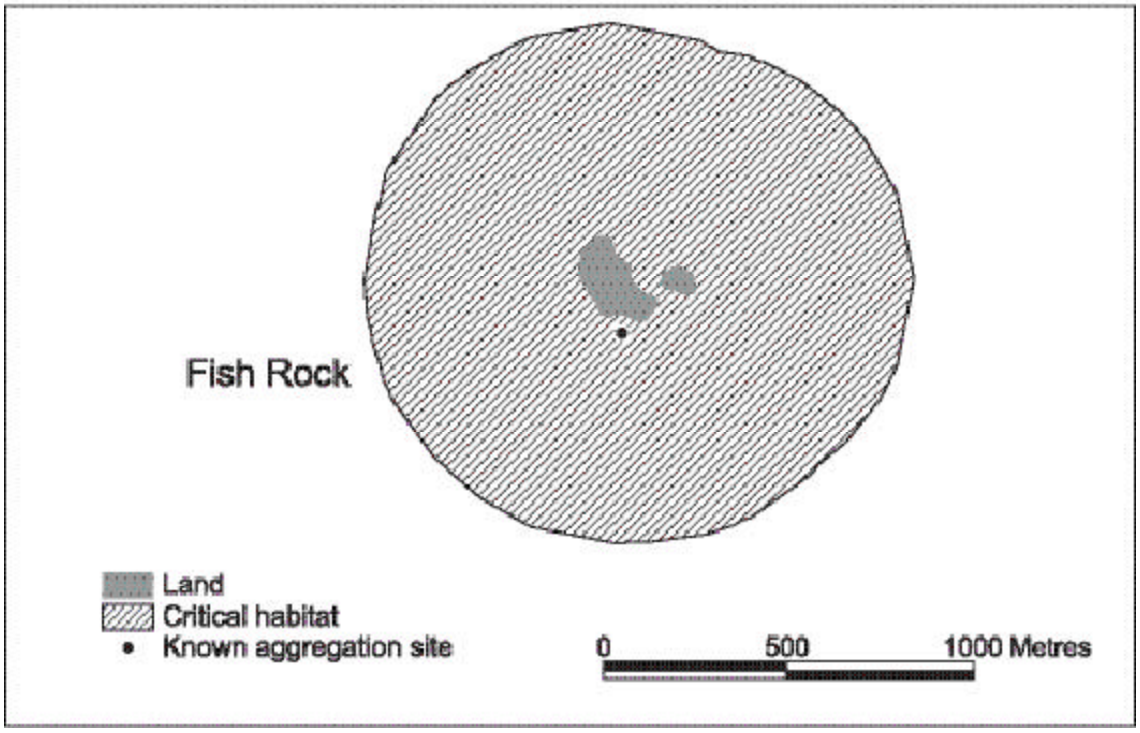

Fig. 7 Critical habitat at Fish Rock

South West Rocks is a well-known area for grey nurse sharks during winter and spring. The sharks frequent two sites around Fish Rock: the 'Gutters' and the 'Pinnacle'. The Pinnacle is located on the north eastern side of the island and is comprised of a pinnacle of rock and a series of gutters with sandy bottoms. The sharks are frequently sighted swimming through the 25 m deep gutters around the pinnacle. The 'Gutters' are located on the southern end of the island. They comprise a series of gutters running east-west at a depth of 18 m [75].

Alongside the Cod Grounds, the Pinnacle and Big Seal, Fish Rock is one of the most important sites on the east coast for consistently large aggregations of grey nurse sharks, with 11 percent of the total sampled population observed in the area. Fish Rock is a highly significant site for male grey nurse sharks, with 17 percent of the sampled male population observed at this site, making it the largest aggregation site for males in the state. A number of the sharks observed in this area showed signs of interactions with fishing gear, such as imbedded hooks and scars.

Fish Rock is currently protected by a prohibition on commercial drop line fishing within a 500 m radius of the island. Spearfishing is also restricted in this area to a species list of mainly pelagic species.

There is considerable evidence that this site is not only a major site for aggregation but also a significant site for interaction between sharks and fishers.

It is proposed that critical habitat be declared over the waters below, and within a 500m radius of, mean high water on Fish Rock (Fig. 7).

Cod Grounds

The Cod Grounds are directly east of Perpendicular Point, near Laurieton, and comprise a series of three pinnacles rising to approximately 18 m from the seabed in 40 m of water. Grey nurse sharks have been seen in relatively large numbers swimming between and hovering among the pinnacles and boulders throughout the year, but especially during the winter and spring months [75]. This site is used extremely consistently by grey nurse sharks, with aggregations recorded during all (100 percent) of the surveys conducted between 1998 and 2001 [73].

The grey nurse sharks which periodically inhabit the Cod Grounds make up 11.8 percent of the sampled population. The Cod Grounds are believed to be especially significant for female grey nurse shark aggregations with 16 percent of the sampled female population known to utilise this area [73].

The Cod Grounds are located in Commonwealth waters, approximately 4 nautical miles off the NSW coast. No specific management measures are currently in place. However, the recovery plan prepared by Environment Australia recommends the listing of this site as critical habitat under Commonwealth legislation. As this site is located within Commonwealth waters (ie. more then 3 nautical miles from the NSW coast), no action is required by NSW Fisheries. NSW Fisheries will endeavour to work with the Commonwealth in order to achieve the best possible protection for grey nurse sharks in this area.

The Pinnacle

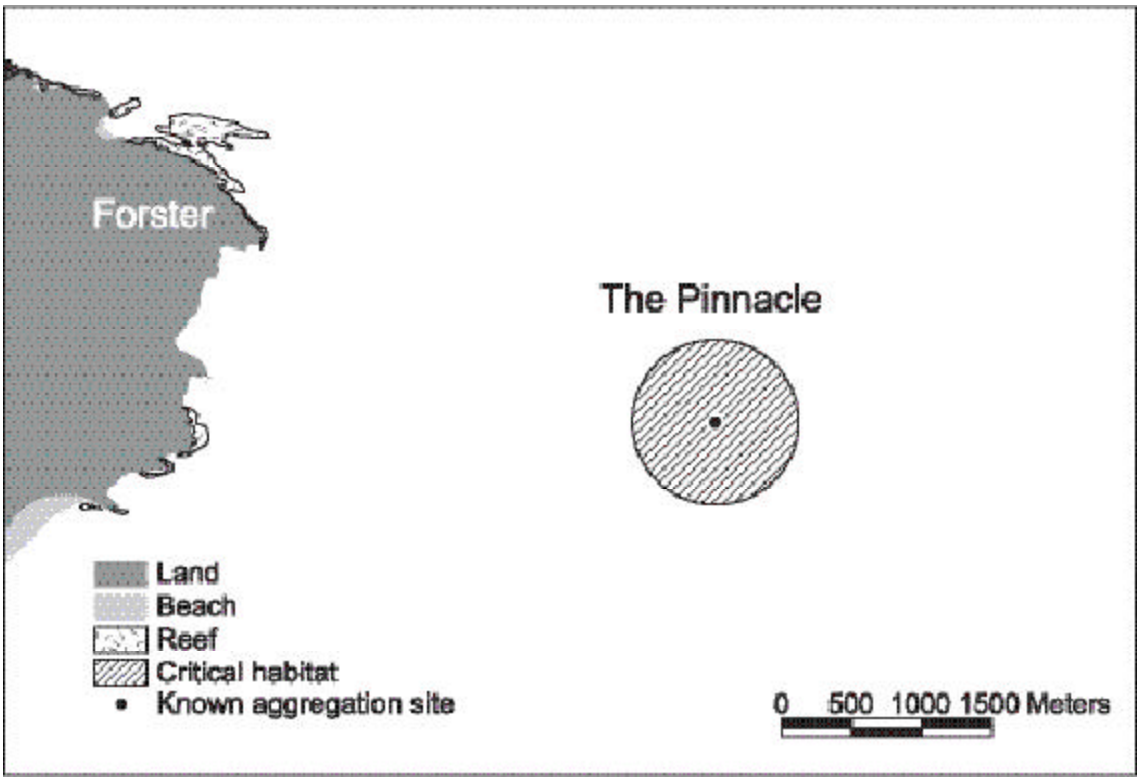

Fig. 8 Critical habitat at the Pinnacle

The Pinnacle consists of a pinnacle of rock that rises approximately 24 m from the seabed in 46 m of water. Grey nurse sharks have been sighted at various locations around this large area. The

site has a few large gutters where grey nurse sharks (individually or in large groups) are frequently seen hovering and swimming amongst the boulders [75]. The use of this area by the sharks is extremely consistent, with aggregations recorded here during all (100 percent) of the surveys conducted between 1998 and 2001 [73].

Approximately 12.7 percent of the total sampled population of grey nurse sharks have been observed around the Pinnacle, suggesting that this site is consistently important as the largest aggregation site in the state. It is of high significance to both male and female grey nurse sharks with a large proportion of both sexes observed in this area (13.4 percent of the sampled male population and 11.3 percent of the sampled female population) [73]. This may indicate the site is a possible location for mating activity. There are no specific management measures currently in place for the Pinnacles.

It is proposed that critical habitat be declared over the waters within a 500m radius of the known aggregation site (GPS position 152°36'00"E, 32°13'40") (Fig. 8).

Big Seal Rock

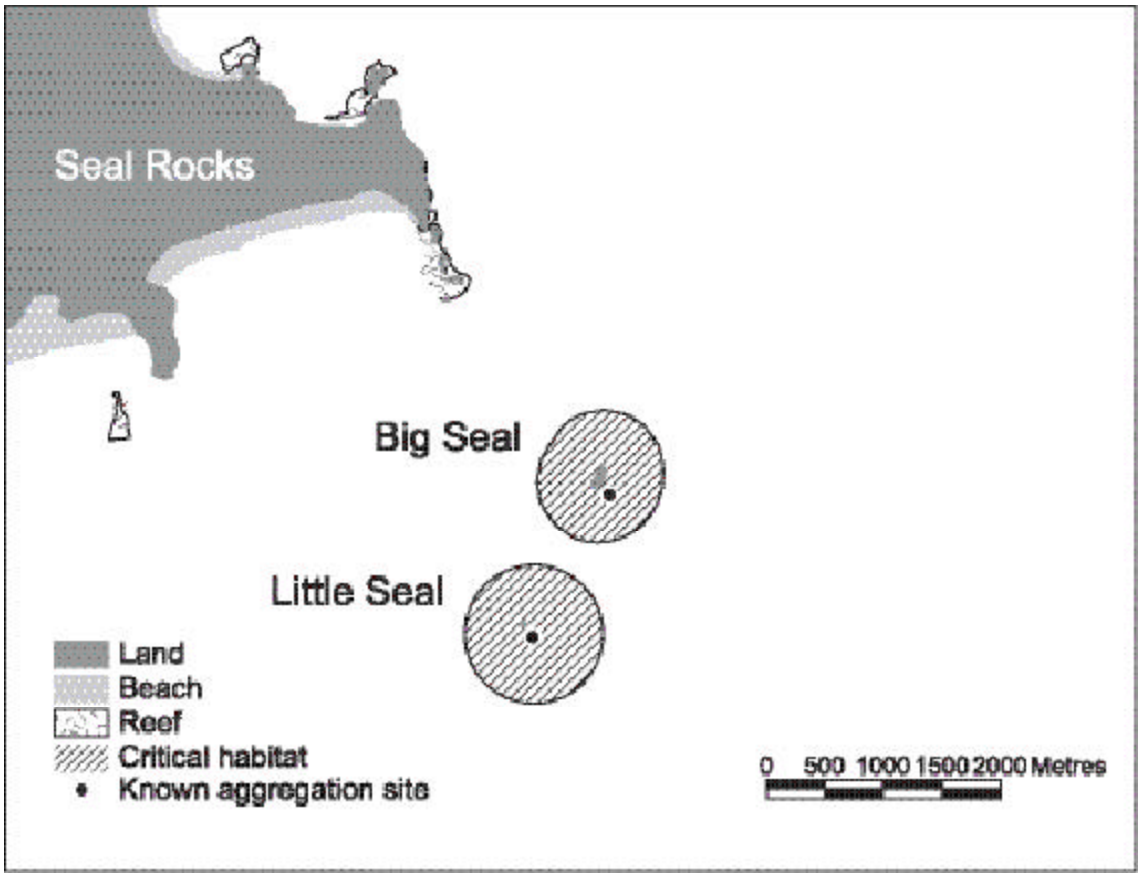

Fig. 9 Critical habitat for Big and Little Seal Rocks

Big Seal and Little Seal are two islands offshore from Sugerloaf Point at Seal Rocks. It is a barren rocky outcrop that has extensive surrounding reefs. The main site for grey nurse sharks is a large overhang where a number of sharks can be seen milling around, hovering under the overhang or swimming along a nearby gutter at a depth of 20 m [75].

Historically, Big Seal has been known to be significant for the species, with a number of habitat types known to be preferred by the species existing within this area, including overhangs and deep sandy bottomed gutters. Several decades ago, the species occupied this site in large aggregations and sharks were observed throughout the year.

In recent years, only small aggregations of sharks are seen sporadically. Despite this, the grey nurse sharks which periodically inhabit Big Seal still make up 10 percent of the total sampled population, making it one of the largest and most consistent sites for aggregation in the state.

There are no specific management measures currently in place for Big Seal Rock.

It is proposed that critical habitat be declared over the waters below, and within a 500m radius of, mean high water on Big Seal (Fig. 9).

Little Seal Rock

Little Seal Rock is a barren rock outcrop with extensive surrounding reef, offshore from Sugarloaf Point at Seal Rocks [75]. While coastwide survey data have indicated that Little Seal is possibly of secondary importance to Big Seal as an aggregation site, with approximately 4 percent of the total sampled population observed there, significant migration is believed to occur between the two sites. There are no specific management measures currently in place for Little Seal Rock.

It is proposed that critical habitat be declared over the waters below, and within a 500m radius of, mean high water on Little Seal (Fig. 9).

Little Broughton Island

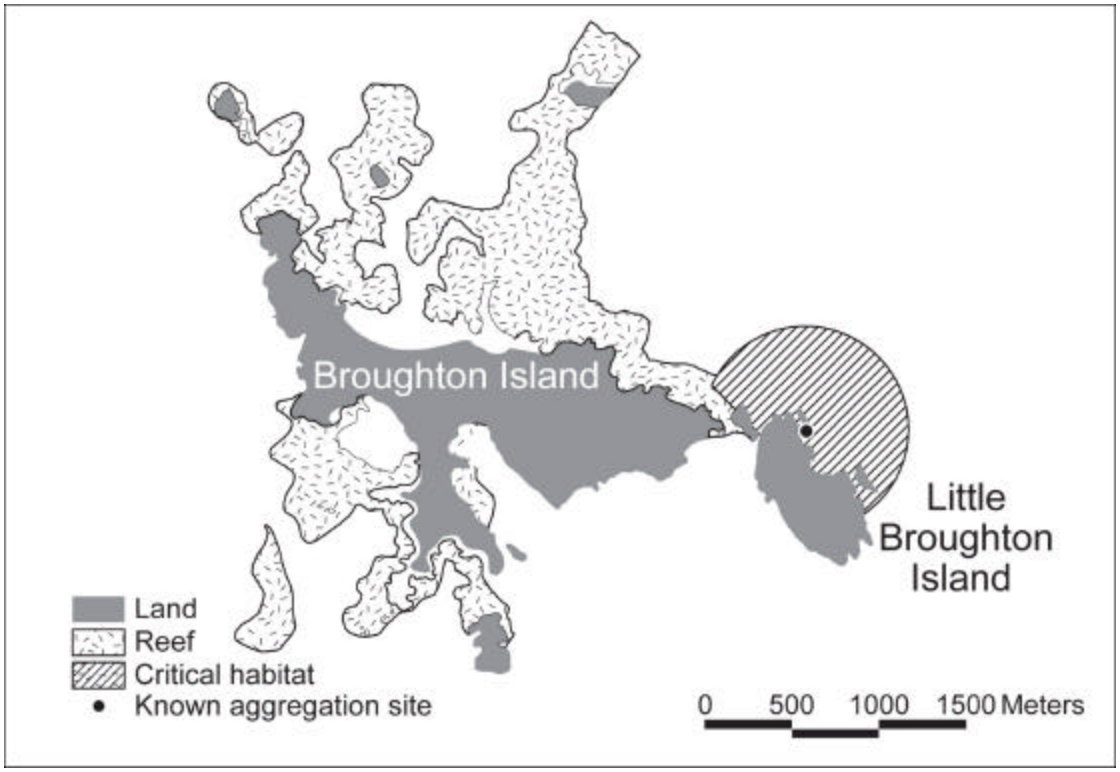

Fig. 10 Critical habitat at Little Broughton Island

There are several sites at Broughton Island that have gutters and overhangs where grey nurse sharks have been seen. The sharks are often observed throughout the year, but are especially prevalent from late summer to winter when large aggregations consistently occur. These aggregations have been recorded during 90 percent of the surveys conducted between 1998 and 2001 [75] [73].

Approximately 9.5 percent of the total sampled population of grey nurse sharks have been observed at Little Broughton Island. This site is believed to be a highly important site for females, with 13.7 percent of the sampled female population observed in this area. This suggests it is one of the most significant aggregation sites for female grey nurse sharks in the state. There are no specific management measures currently in place for grey nurse sharks at Little Broughton Island.

It is proposed that critical habitat be declared over the waters below mean high water and within a 500m radius of the known aggregation site (GPS position 52º 20' 00" E, 32º 37' 05" S) and on the northern side of Little Broughton Island (Fig. 10).

Central Coast & Sydney area (Hawkesbury Shelf Bioregion)

The Hawkesbury Shelf Bioregion extends from Port Stephens south to Shellharbour, near Lake Illawarra. Preliminary identification of critical habitat has established that one site in the Hawkesbury Shelf Bioregion is an important aggregation site for grey nurse sharks. These sites are illustrated in Figure 11.

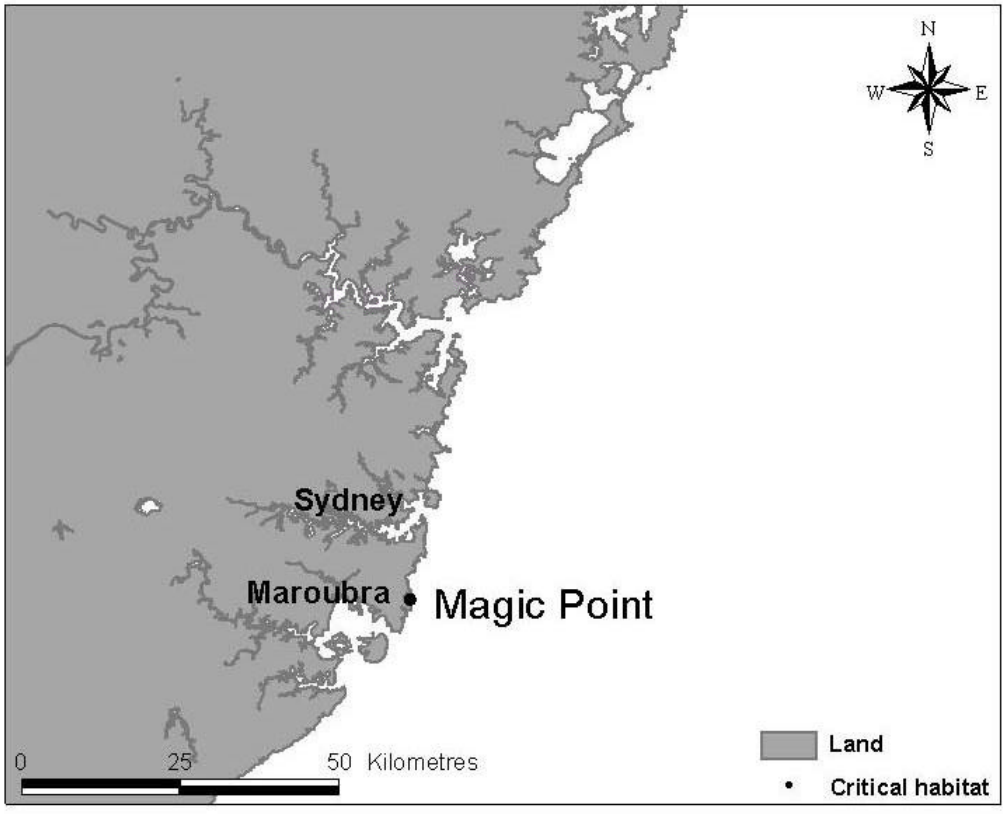

Fig. 11 Critical habitat identified on the central coast, including Sydney (Hawkesbury Shelf Bioregion)

Magic Point (Maroubra)

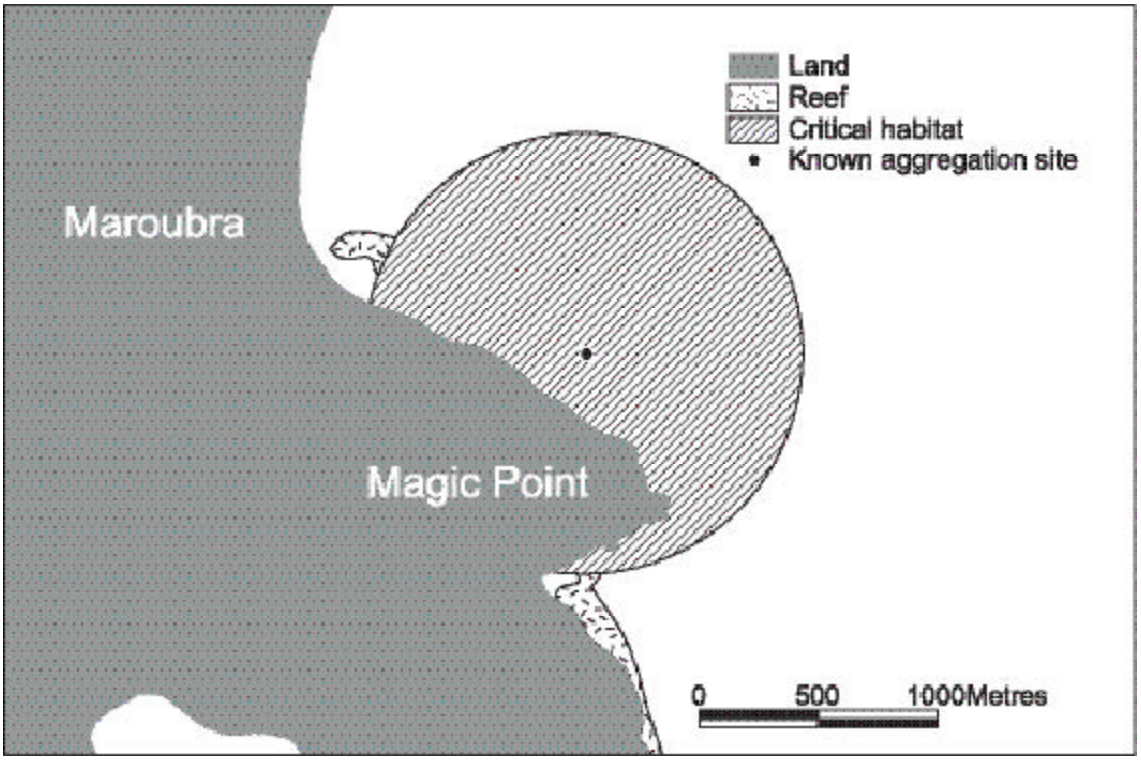

Fig.12 Critical habitat at Magic Point

Magic Point consists of an overhang and nearby gutter-like formations that are part of the reef system extending from the headland. These features occur at a depth of around 14 m. Aggregations have been observed here during 55.6 percent of the surveys conducted between 1998 and 2001, especially during winter [75] [73].

Approximately 3.5 percent of the total sampled population of grey nurse sharks have been observed at Magic Point. Slightly higher numbers of female sharks have been observed in this site (4.1 percent of the sampled female population). There are no specific management measures currently in place for grey nurse sharks at Magic Point.

It is proposed that critical habitat be declared over the waters below mean high water and within a 500m radius of the known aggregation site (GPS position 151°15'50"E, 33°57'20") (Fig. 12).

South Coast (Batemans Shelf Bioregion)

The Batemans Shelf Bioregion extends from Shellharbour south to Tathra, near Bega. Preliminary identification of critical habitat has established that three sites in the Batemans Shelf are important aggregation sites for grey nurse sharks. These are Bass Point, Tollgate Islands and Montague Island (Figure 13).

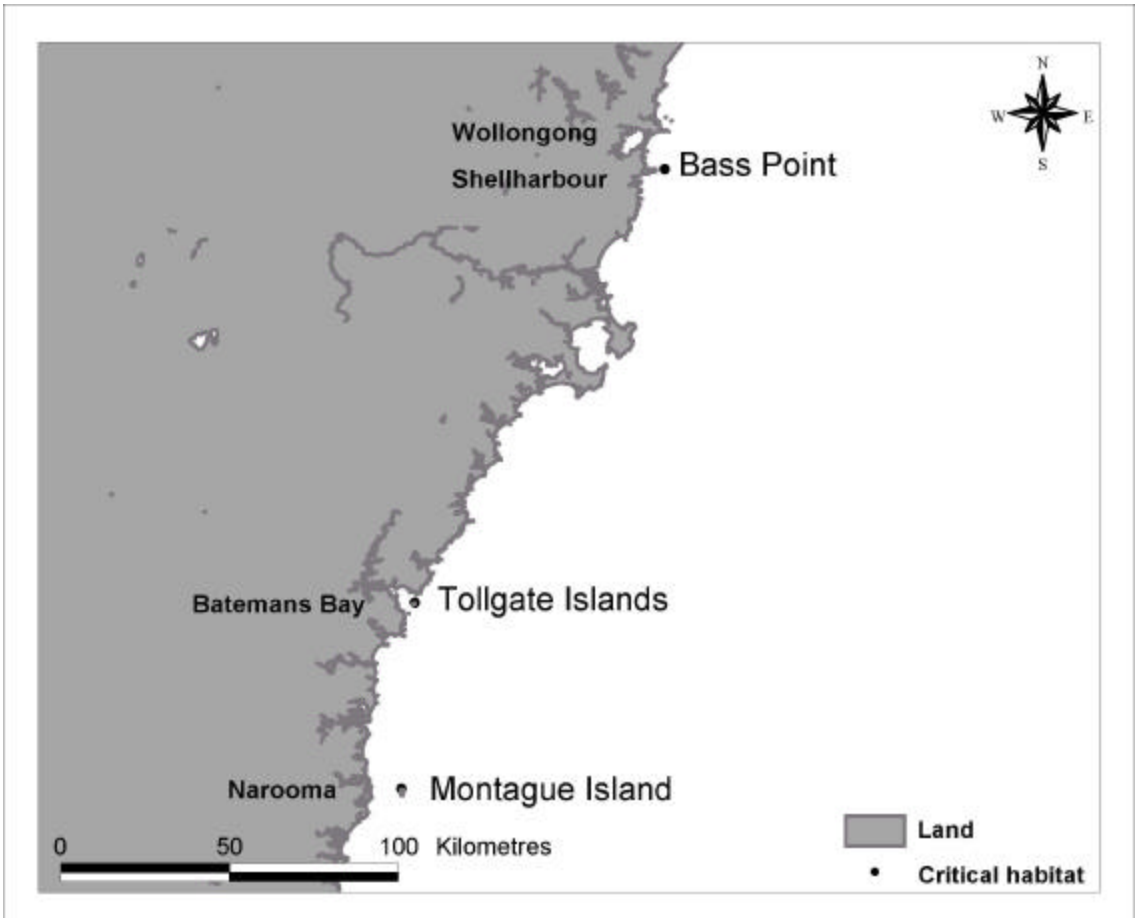

Fig. 13 Critical habitat sites identified on the south coast (Batemans Shelf Bioregion)

Bass Point

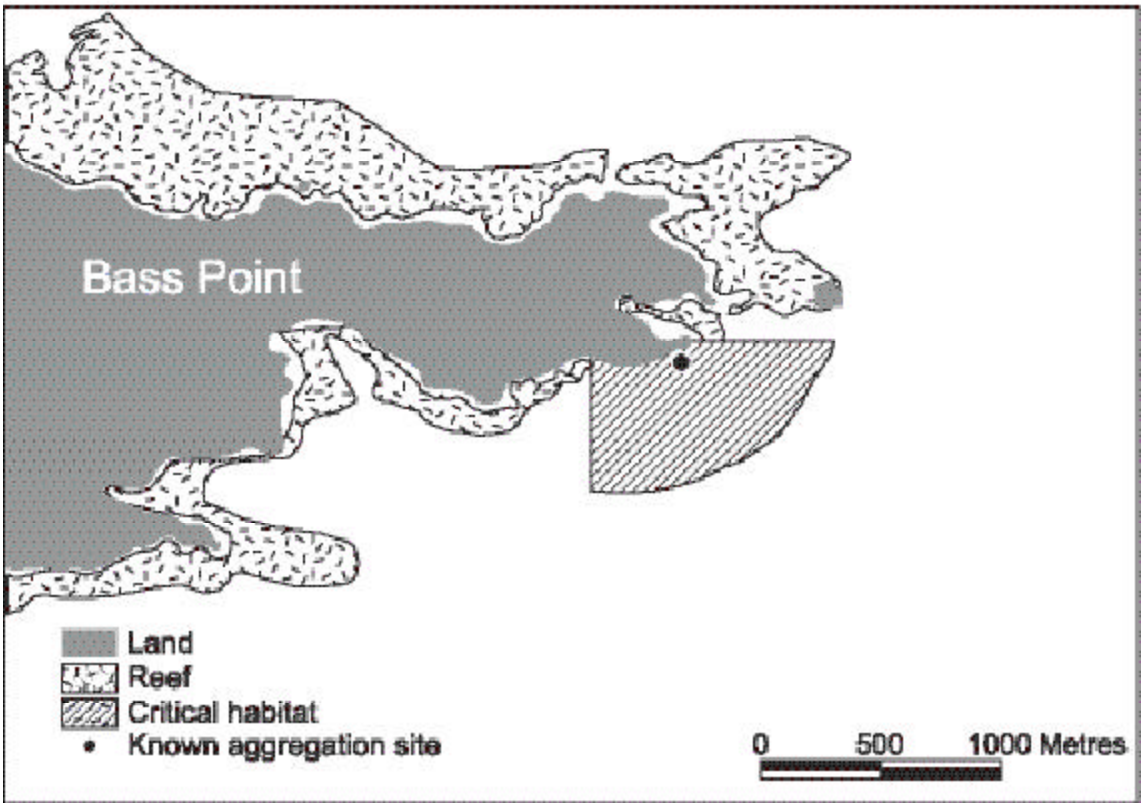

Fig. 14 Critical habitat at Bass Point

Grey nurse sharks have been observed at two main sites located at Bass Point, near Shellharbour. The Gutter is a reef system extending off the northern most tip of Bass Point near Lou's Reef, with a deep sand-filled gutter that reaches a depth of 38 m. The Arch and Cave are located on the southern side of Bass Point and are part of a reef system that reaches a depth of 30 m. Grey nurse sharks are observed swimming or hovering inside or near the Cave or Arch.

Aggregations have been recorded at these sites during 10 percent of the surveys conducted between 1998 and 2001, mainly between December and June [73].

Approximately 1 percent of the total sampled population of grey nurse shark have been observed at Bass Point. An equal proportion of the sampled male and female populations aggregate at this site [73].

A 'no take' aquatic reserve exists in Bushrangers Bay at Bass Point, however this is not believed to incorporate any important grey nurse shark habitat.

It is proposed that critical habitat be declared over the waters below, and within 500m of the mean high water mark on the shore, and south of a line extending east of the southern headland of Bushrangers Bay and east of a line extending south from a place 360 m west of this headland (GPS position 34º 35• 58"S, 150º 53' 54"E) (Fig. 14).

The Tollgate Islands

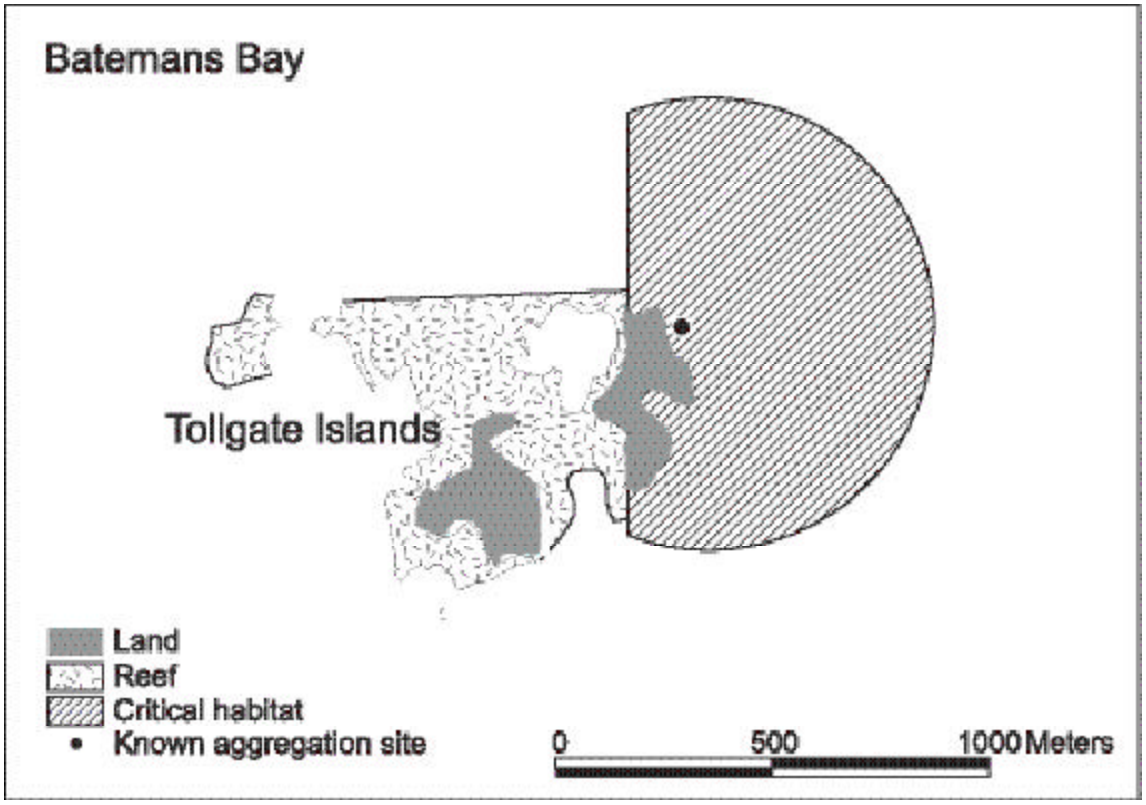

Fig. 15 Critical habitat at Tollgate Islands

The Tollgate Islands are located at the mouth of Batemans Bay. Grey nurse sharks are most commonly observed at the "Tollgate Islands Shark Gutter" during summer and autumn. "The Gutter" is on the north-eastern tip of the island and reaches a maximum depth of 18 m. Sharks consistently aggregate at this site, with 90 percent of surveys conducted between 1998 and 2001 recording relatively high numbers of sharks [73].

Approximately 8.9 percent of the total sampled population of grey nurse sharks have been observed at Tollgate Islands. The site is the most important known aggregation site for female sharks, with 15.4 percent of the sampled female population observed here. It is likely that a number of these females may be gestating (pregnant) during these periods. There are no specific management measures for grey nurse sharks currently in place around the Tollgate Islands.

It is proposed that critical habitat be declared over the waters below mean high water on the eastern side of Tollgate Islands, and within a 500m radius of the known aggregation site (GPS position 150º 15' 45" E, 35º 44' 50" S) (Fig.15).

Montague Island

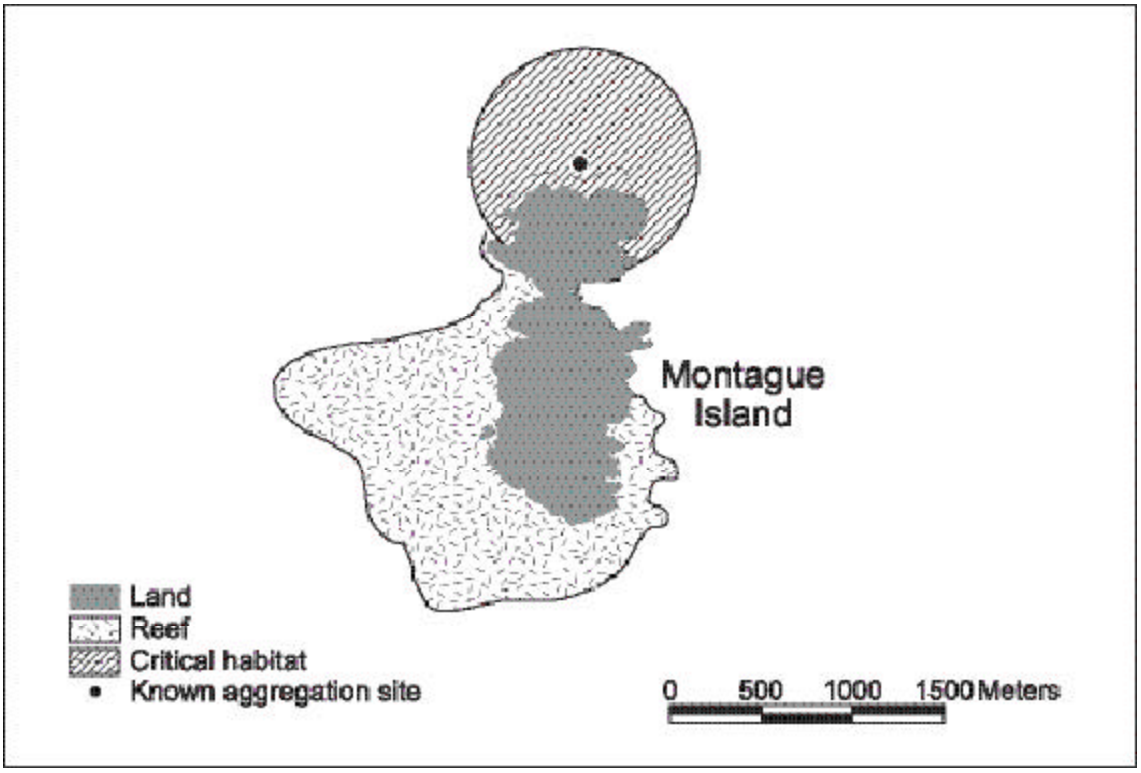

Fig. 16 Critical habitat at Montague Island

Grey nurse sharks are observed at four sites at Montague Island off Narooma. The main site is called the "Shark Gutters" and is located on the northern tip of Montague Island. It comprises a reef with a series of sand-filled gutters at depths of approximately 18 m. The other three sites are the "Bubble Cave", the "Pinnacles" and "The Gut", and are located on the western side of Montague Island on submerged reef extending from the island. Aggregations of grey nurse sharks consistently occur at Montague Island, particularly during late summer and early autumn, with 20 percent of surveys conducted between 1998 and 2001 recording significant numbers of sharks [73].

Approximately 1.3 percent of the total sampled population of grey nurse sharks have been observed at Montague Island. The majority of sharks sighted in this location have been females (1.8 percent of the sampled female population), a number of which may be pregnant. There are no specific management measures currently in place for grey nurse sharks in the waters surrounding Montague Island.

It is proposed that critical habitat be declared over the waters below mean high water and within a radius of 500m of the known aggregation site (GPS position 150°13'40"E, 36°14'30"S) (Fig. 16).

APPENDIX 2 RESEARCH NEEDS

Population abundance

Several sets of data have been used to document the decline of grey nurse sharks in NSW waters, including: (1) the NSW beach meshing programs [82] [53]; (2) the log books of gamefish anglers [79]; (3) a small survey in the Solitary Islands Marine Park and adjacent areas in 1992-1993 (Pickering & Wilkinson unpubl. data); (4) a survey at Seal Rocks in 1991 [80]; (5) a study in northern NSW waters in 1996-1997 [77]; and (6) the recent diver surveys of grey nurse sharks along the entire NSW coast [75] [73].

This last dataset, with 12 surveys to date, provides the most comprehensive evaluation of the grey nurse shark population in NSW with an average of 57 sites sampled per survey. While the number of grey nurse sharks observed varied greatly along the length of the coast, the total number of grey nurse sharks observed did not exceed 292 individuals [75] (see Tables 1 and 2 in section 2.5). These results clearly indicate that the population has not recovered since it was protected in 1984. Given these results, there is a clear need to ensure that spatial and temporal patterns of abundance of the grey nurse shark in NSW waters are monitored on a regular basis.

A fundamental requirement of any long-term monitoring program is the collection of consistent data for the duration of the program. Ideally, the data should be collected from sites covering the entire range of the species. Valuable information on population trends for grey nurse sharks would, in all probability, take years of consistent monitoring effort to obtain. Otway has shown that to achieve a statistically powerful test that can detect a doubling (or halving) in the numbers of grey nurse sharks, a decade or more of sampling effort would be required. It would be important to continue to document, with the assistance of recreational scuba divers, numbers of grey nurse sharks at all the sites sampled by Otway and Parker (2000). More importantly, it would be essential to monitor the numbers of sharks at the 13 key sites where the sharks aggregate, because their combined abundances represent 88.2 percent of the observed population in NSW waters.

Unfortunately, it was not possible to estimate what proportion of the total grey nurse shark population was observed in the NSW coastwide surveys [75]. However, the regular observation of finned grey nurse sharks, together with individually-recognisable sharks with hooks and wire traces, suggests that the total population could be as low as 500 individuals. Consequently, it is crucial that a tagging study be initiated as this would permit the number of grey nurse sharks in the total population to be estimated using standard mark-recapture techniques (eg. [1] [2] [16] [44] [37]).

Diet

In the absence of detailed dietary information for grey nurse sharks in NSW waters, it would be necessary to analyse the gut contents of accidentally caught and killed grey nurse sharks. This would allow researchers to identify whether the range of species consumed is similar to or differs from grey nurse sharks in South Africa and elsewhere. More importantly, the gut content analysis would permit the degree of overlap between the diet of grey nurse sharks and the catches of commercial and recreational (spear and line) fishers to be quantified.

Population demography

Reproduction

As little is known about the reproductive biology of grey nurse sharks in NSW waters, it would be necessary to use the opportunistic examination of accidentally caught and killed grey nurse sharks to document: (1) size at reproductive maturity; (2) the timing of mating; (3) fecundity; (4) the duration of gestation; (5) the timing of pupping; and (6) the duration of the resting period. The locations utilised for mating and pupping would also need to be verified by more intense diver surveys at appropriate times of the year. This reproductive information is crucial as it forms one of the components of a demographic analysis.

Age, growth and longevity

Given the absence of data on the age, growth and longevity of grey nurse sharks in NSW coastal waters, estimates of these demographic parameters would need to be obtained as a matter of urgency. This information, together with estimates of fecundity and rates of mortality, would enable the finite rate of increase of the population in NSW waters to be estimated using standard demographic analyses (eg. life tables – [16] [12] [14]; [25]; [27]; and Leslie matrices – [59] [60] [15]). This would be the only unequivocal means of documenting the recovery (or otherwise) of the species in NSW waters.

Determination of the age and rates of growth of individuals would require: (1) regular, precise measurements of the length of grey nurses in the field, and (2) microscopic examination of growth bands in vertebrae. Initially, length measurements of some grey nurse sharks can be obtained when the animals are tagged. Subsequently, the lengths of the sharks could be determined stereophotographically using the same techniques adopted for hammerhead sharks in the Gulf of Mexico (eg. [51] [49]). The most ethical and cost-effective means of obtaining vertebrae for the determination of age would be via autopsies of incidentally caught and killed grey nurse sharks.

As with otoliths, spines and other bony parts, the use of vertebrae for ageing requires validation of the technique [5]. This may be done in several ways, but oxy-tetracycline has been the most readily used (eg. [13] [6]). Validation using wild caught individuals would have to rely on the incidental capture and death of tetracycline-treated individuals. To increase the likelihood of obtaining such individuals, many sharks would need to be injected initially. This clearly causes ethical problems given the current conservation status of grey nurse sharks. Validation using the grey nurse sharks currently held in aquaria provides an alternative, but the vertebrae would not become available until after the animals' natural death. Hence, it may take many years to obtain validation using oxy-tetracycline.

Survival/mortality

Given the absence of empirical estimates of natural and fishing mortality for grey nurse sharks in NSW waters, it is essential to initiate a tagging study. An "accidental capture" reporting program should also be initiated concurrently, because together these programs would enable estimates of mortality to be obtained and partitioned among the various fishing sectors. However, it would also be necessary to estimate the fishing effort and degree of reporting from each fishing sector. To this end, protocols should be developed to ensure commercial and recreational fishers report captures of grey nurse sharks to NSW Fisheries.

Further research is needed to determine the extent of accidental hooking and the effects that this is having on individual sharks and the population overall. For example, the use of acoustic tags

would enable accidentally caught grey nurse sharks to be tracked over time to document whether the shark survives or dies as a result of hooking and/or associated trauma.

Given that great white, short-finned mako, tiger and bull sharks are known to eat juvenile grey nurse sharks in South Africa, it is most likely that these four species would also be the natural predators of grey nurse sharks in NSW waters. This prediction would need to be examined by analysing the gut contents of great white, short-finned mako, tiger and bull sharks.

Since the prey items consumed by sharks are generally digested quite rapidly [95] [69] [43], often all that remains in the stomach of the larger shark predator are teeth, vertebrae and partially-digested muscle tissue. Identifying the species of shark or fish consumed requires a suite of forensic tools. For example, the teeth of sharks are a useful taxonomic tool. On the other hand, when only partially-digested muscle remains it is necessary to use a range of genetic techniques to identify the prey species, including allozyme electrophoresis [70] [57] [58] [56] [35] and mitochondrial DNA analysis [68] [65] [35].

Migration and localised movement

While data suggest that grey nurse sharks migrate along the NSW coast [75], more data are required to properly document their migratory movements. The aggregation of grey nurse sharks at various sites along the NSW coast ([75], and Table 2 in Section 2.5) suggests that the species also exhibits a considerable degree of site fidelity. Consequently, it would also be necessary to document the localised movements of grey nurse sharks in relation to the aggregating sites. This would require a tagging program for grey nurse sharks using standard tags (ie. cattle ear tags – [72] [29]) and smart tags (ie. acoustic telemetry – [49] [50] [71] for a review).

Use of both types of tag would enable: (1) the identification of migratory patterns; (2) the documentation of localised movements; and (3) the identification of possible home-ranges. This information could then be used to determine the optimal size of marine protected areas for the grey nurse shark.

Population genetics

There is a lack of detailed information on the population genetics of grey nurse sharks in NSW waters and elsewhere in the world. To redress this, and to enable the discrimination of the different populations (such as those in NSW and WA waters), it would be necessary to apply a range of genetic techniques including: allozyme electrophoresis [70] [57] [58] [56] [35]; restriction fragment length polymorphism (RFLP mtDNA) analysis [68] [65] [35]; and polymerase chain reaction restriction fragment length polymorphism (PCR-RFLP mtDNA) analysis [86] [65] [66].

Given the history of human intervention, it is also possible that genetic variability within the grey nurse shark population in NSW waters has declined over time. Loss of genetic variability can have dramatic consequences for the recovery of a species. Many of the techniques listed above permit comparisons of the genetic variability between past and present populations. All that is required are tissue samples from the different times.

DNA samples from present populations could be obtained from the "plugs" of tissue removed from the fins when the grey nurse sharks are tagged. Past populations are less easily sampled. However, DNA samples from past populations (ie. approximately 40 – 50 years ago) could be obtained from the cartilage of shark jaws obtained when grey nurse sharks were killed by spearfishers. As people who currently possess the jaws of a grey nurse shark (even if they were obtained prior to 1984) are now in breach of section 220ZB of the *Fisheries Management Act*, it would be reasonable to register all jaws

and other artefacts of grey nurse sharks. This would serve a dual purpose by enabling: (1) samples of DNA to be obtained; and (2) permits for the possession of jaws and other artefacts obtained prior to the protection of the species to be issued.

The genetic techniques listed above could also be used to assist in identifying and monitoring the presence of grey nurse shark fins among other shark fins submitted for sale. This would provide for increased detection of offences and enhance the enforcement abilities of NSW Fisheries.

Population modelling

Management of grey nurse sharks would benefit greatly from decision-making tools such as population models. Population modelling is a tool that can provide useful indications of population status, rates of recovery and population structure and distribution. Current knowledge of grey nurse sharks in NSW is inadequate for the development of a population model, but this would change as more information becomes available on the spatial structure of these populations, including the extent of segregation by size and sex and their migratory patterns.

A preliminary model to describe the grey nurse shark population along the NSW coast could be developed using data obtained in NSW surveys together with other available biological information [75]. Such a model could also assist in developing indicators to measure the recovery of grey nurse shark populations.

By running a series of scenarios simulating recovery, it might be possible to identify appropriate indicators of change that would be easier to monitor than spatial and temporal variation in abundance [75]. However, such a model would require the input of data from regular surveys and demographic research to enable the testing of predictions and refinement of the model.

APPENDIX 3 REQUIRED CONTENTS OF A RECOVERY PLAN

Extract from NSW *Fisheries Management Act 1994*, Part 7A

220ZN Contents of recovery or threat abatement plans

(1) Recovery plans

A recovery plan must:

a) identify the threatened species, population or ecological community to which it applies, and

b) identify any critical habitat declared in relation to the threatened species, population or ecological community, and

c) identify any threatening process or processes threatening the threatened species, population or ecological community, and

d) identify methods by which adverse social and economic consequences of the making of the plan can be minimised, and

e) state what must be done to ensure the recovery of the threatened species, population or ecological community, and

f) state what must be done to protect the critical habitat (if any) identified in the plan, and

g) state, with reference to the objects of this Part:

(i) the way in which those objects are to be implemented or promoted for the benefit of the threatened species, population or ecological community, and

(ii) the method by which progress towards achieving those objects is to be assessed, and

h) identify the persons or public authorities who are responsible for the implementation of the measures included in the plan, and

i) state the date by which the recovery plan should be subject to review by the Director.

APPENDIX 4 SCUBA-DIVING DRAFT CODE OF CONDUCT

NSW Fisheries and Environment Australia, in consultation with the dive industry, have developed the following draft code of conduct for diving with grey nurse sharks.

- Do not conduct night dives on known aggregation sites
- Do not block entrances to cave or gutter
- Do not interrupt the swimming pattern of the sharks
- Do not feed or touch the sharks
- Do not chase or harass the sharks – no mechanical apparatus ie. scooters, horns
- Group must be no more than 10 divers
- A dive brief to be given by the dive leader before each dive
- All commercial operators to be signatories to the Code of Conduct
- Code of Conduct to be displayed in the boat or shop
- All divers to comply with the Code of Conduct
- Dive operators to participate in scientific research

APPENDIX 5 NOTICE OF PRELIMINARY IDENTIFICATION OF CRITICAL HABITAT

- Under section 220R of the *Fisheries Management Act* (the Act) it is a requirement for a copy of the notice of the preliminary identification of critical habitat to be given to all affected persons and for the public to be given an opportunity to make submissions.

The following text is a copy of the notice which will appear in state-wide newspapers (in accordance with section 284 of the Act).

Notice of Preliminary Identification of Critical Habitat

Grey Nurse Sharks

Have your say on the preliminary identification of critical habitat for the grey nurse shark.

The grey nurse shark is listed as an endangered species in NSW. Written submissions are now invited on the preliminary identification of critical habitat along the NSW coast.

Thirteen key aggregation sites for the grey nurse shark have been identified in state waters. It is proposed to declare these sites as critical habitat. They are:

- Julian Rocks (Byron Bay)
- North Solitary Island (Coffs Harbour)
- South Solitary Island (Coffs Harbour)
- Fish Rock (South West Rocks)
- Green Island (South West Rocks)
- The Pinnacle (Forster)
- Big and Little Seal Rocks (Seal Rocks)
- Little Broughton Island (Port Stephens)
- Magic Point (Maroubra)
- Bass Point (Shellharbour)
- Tollgate Islands (Batemans Bay)
- Montague Island (Narooma)

Details of the preliminary identification of critical habitat is available on the NSW Fisheries website at www.fisheries.nsw.gov.au. Alternatively, it can be viewed at any NSW Fisheries office, or phone (02) 4916 3811 to receive a list of other locations where it is on display, or to receive written details.

Community information days will be held throughout the public comment period. Members of the community are welcome to come along and discuss the critical habitat preliminary identification. Phone (02) 4916 3811 for details of the dates and locations of the information days.

Written submissions should be:

- posted to: Threatened Species Unit (Grey Nurse Shark), NSW Fisheries, Private Bag 1; Nelson Bay NSW 2315; or
- faxed to NSW Fisheries on (02) 4916 3880; or
- made by using the online submission form available at www.fisheries.nsw.gov.au.

The closing date for submissions is 28 June 2002.