Broad-Scale Interactions Between Fishing and Mammals, Reptiles and Birds in NSW Marine Waters

C. Ganassin and P. Gibbs

NSW Department of Primary Industries
Cronulla Fisheries Research Centre
P.O. Box 21, Cronulla, NSW, 2230

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Authors: Carla Ganassin and Philip Gibbs

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Cover image: Shearwaters foraging on trawler discards off Forster, NSW (C. Ganassin).

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PROJECT SUMMARY

This report describes a project funded by the NSW Biodiversity Strategy. As a whole of government document, the Biodiversity Strategy commits all government agencies to working cooperatively towards conserving the biodiversity of NSW. The Strategy outlines a framework for coordinating and integrating government and community efforts to conserve biodiversity across all landscapes.

Project objective/s

This project aimed to identify the extent and consequence of interactions that occur between the fisheries managed by NSW Department of Primary Industries (NSW DPI) and marine wildlife and recommend appropriate management to reduce any resulting negative impacts to marine wildlife. In this study, 'marine wildlife' includes all non-fish groups of marine vertebrates, such as mammals, reptiles and avifauna.

Methods

A review of world literature on the interactions between marine wildlife and fishing activities was done prior to describing the marine and estuarine fishing activities managed by NSW DPI and the marine wildlife species that occur in the waters off NSW. This information was then used in a qualitative assessment to document the extent and likely consequence of interactions between the described fishing activities and marine wildlife species. The report also assesses the adequacy of management arrangements contained in the current statutory management strategies for each fishery in NSW.

Key results

Four of the interactions covered in this report were found to have the potential to threaten the survival of some marine wildlife in NSW: (a) incidental capture of seabirds on pelagic fishing lines; (b) incidental capture of sea turtles in fishing gear used in northern NSW; (c) destruction of shorebird habitat by the shoreline activities of fishers; and (d) disturbance of birds by the shoreline activities of fishers. Some other interactions were found to have the potential to threaten the survival of some marine wildlife types in NSW, but the uncertainty was high due to a lack of data. The foraging by marine wildlife on the non-retained or non-landed catch from fishing activities in NSW and competitive / trophic interactions could result in some positive benefits for marine wildlife.

Implications for biodiversity conservation management

Recommendations are made to enhance the management of interactions between NSW DPI fishing activities and marine wildlife. These management arrangements reduce the negative consequences to marine wildlife and deal with issues that may arise in the future. These include the use of more responsible fishing practices through educating fishers, review of the use of certain gear types, and further documentation of an interaction before deciding upon its appropriate management.

1. INTRODUCTION

1.1. Background

It is widely recognised that many non-fish groups of marine vertebrates, such as mammals, reptiles and avifauna (hereafter referred to as marine wildlife) are incidentally captured during fishing activities or in lost fishing gear. Fishing activities can also indirectly impact marine wildlife by reducing their food availability, disturbing their essential habitat and altering their behaviour.

Most marine wildlife species in Australia are currently protected from any direct killing or harvesting, except for indigenous or permitted scientific purposes. Many populations of marine wildlife species are currently small and listed as being threatened on a state, national and/or international level, largely due to intense historical commercial harvesting activities (which ceased in the 1960s and 1970s) on these generally long-lived, slow growing species. It is these small populations that are most vulnerable to the many threatening processes they encounter, which include fishing-related processes. These marine wildlife populations are managed to enhance their recovery, which if successful could result in more regular interactions between marine wildlife and fishers.

The international studies on interactions between marine wildlife and fishing activities either focus on one type of interaction, one fishery or one type of marine wildlife. This project takes a broad-scale ecosystem-based approach and an assessment of the effect of all fishing activities managed by NSW DPI on all marine wildlife species is made. This information has not been previously documented, and will assist in the efficient and effective management of existing and future issues arising from the interactions assessed.

The management of these interactions in NSW is cross-jurisdictional as issues concerning marine wildlife within 3 nm off NSW are managed by the NSW Department of Environment and Conservation (DEC), beyond 3 nm are managed by the Commonwealth Department of Environment and Heritage (DEH), and the management of NSW state-level fishing activities is the responsibility of NSW Department of Primary Industries (NSW DPI).

The ‘waters off NSW’ that are assessed incorporate the estuarine, inshore and offshore waters out to 80 nm along the coast of NSW. The ocean waters from the NSW coastal baseline to 3 nm offshore are State waters and fall under the jurisdiction of NSW. The waters from 3 nm to the 4,000 m isobath (approximately 80 nm) are Commonwealth waters, but under an Offshore Constitutional Settlement established in 1991 NSW manages some of the fishing activities in those waters. Interaction, as defined for the purpose of this study, is where fishing activities either directly or indirectly affect marine wildlife or vice versa.

1.2. Project aims and overview

The aims of this project are to:

- Identify the extent and consequence of all interactions that could occur between marine wildlife and the fishing activities managed by NSW DPI, through the review and consolidation of the existing knowledge about these interactions; and
- Recommend apppropriate management responses that will reduce the impacts of any existing or future issues or threats to the survival of the marine wildlife species occurring in NSW and the operation of the fisheries managed by NSW DPI.

The cross-jurisdictional management and uncertainty of the nature and extent of these interactions in NSW was considered in the design of this report (Figure 1), which caters towards the needs of both marine wildlife and fisheries managers. Subsequently, this report is predominantly a reference manual where information about: the type and nature of interactions between marine wildlife and fishing activities that have been documented around the world is presented in Chapter 2; the aspects of the fisheries managed by NSW DPI that influence interactions with marine wildlife is presented in Chapter 3; and the aspects of marine wildlife species occurring in the waters off NSW that influence their interaction with fishing activities is presented in Chapter 4. The main assessment and findings of this report are in Chapter 5 and management recommendations are made in Chapter 6. Chapters 2, 3 and 4 provide valuable background information to the qualitative assessment in Chapter 5, but for readers only interested in the main findings and recommendations of this report, it is not essential to read these background chapters.

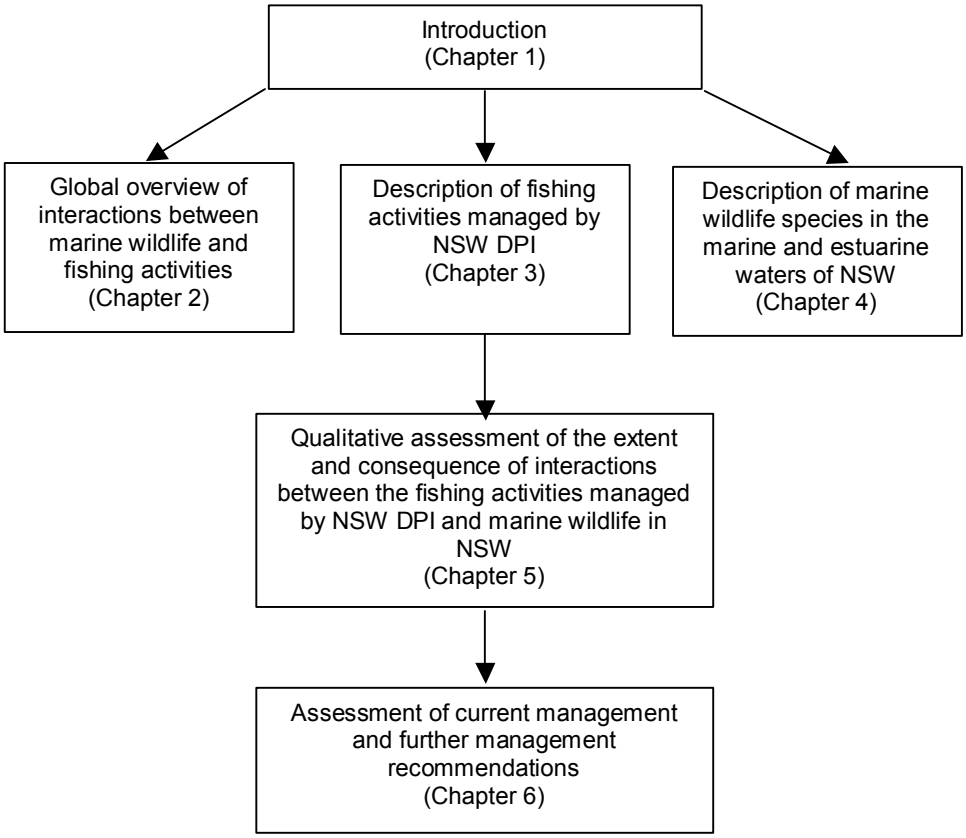

Figure 1: The study approach taken in this project to assess the interactions between marine wildlife and the fishing activities managed by NSW DPI.

2. INTERACTIONS BETWEEN MARINE WILDLIFE AND FISHING ACTIVITIES

This background chapter is an overview of reports from Australia and around the world to describe how marine wildlife interacts with different fishing operations and identify the consequences for both wildlife and fishers. The nature and frequency of interactions occurring in a given area are a function of local biological factors such as the abundance and behaviour of the wildlife species present, and fishing-related factors such as the area fished, gear types in use and how frequently they are used, thus some of the interactions described in this chapter may not necessarily occur in NSW.

Interactions occurring between marine wildlife and fishers can be categorised into two types - operational interactions and ecological interactions. Operational interactions result from the actual fishing activity itself and can only occur when marine wildlife and fishing activities occur in the same vicinity at the same time. The likelihood of the occurrence of operational interactions is increased by fishers operating in areas of high primary productivity where marine wildlife feed and by marine wildlife being attracted to fishing vessels for the regular concentrated food source they can provide. Ecological interactions result from the wider impacts of fishing on the ecosystem, generally at the trophic and habitat level. The types of operational and ecological interactions that occur between marine wildlife and fishers that are discussed in this chapter are identified in Table 1.

Table 1: The type of interactions that can occur between marine wildlife and fishing activities.

Operational interactions
• Deliberate harvest of marine wildlife • Marine wildlife feeding on bait, catch or discards • Incidental capture or entanglement in active fishing gear • Interactions with fishing debris • Collision • Noise, site access and physical presence of fishers
Ecological interactions
• Competitive and trophic interactions • Habitat interactions

2.1. Operational interactions

2.1.1. Deliberate harvest of marine wildlife

Marine wildlife can only be legally harvested for indigenous, subsistence or permitted scientific purposes. Legal culls of marine wildlife numbers in response to their competitive and trophic interactions with fishers are an exception (see section 2.2.1). Marine wildlife species harvested for indigenous purposes in Australian waters include the dugong, short-tailed shearwater (muttonbird), green, flatback, hawksbill, olive ridley and (rarely) loggerhead turtles, and the eggs of these turtle species (Marsh 1996, Skira 1996, Environment Australia 1998a). Excessive harvesting of green turtles in the South Pacific and dugongs in the Torres Strait has been suggested by some authors (Roberts *et al.* 1996, Marsh *et al.* 2003). While excessive indigenous harvesting may reduce the population of a species, it is sometimes difficult to attribute these declines to any one such cause (Marsh 1996).

In addition to illegally shooting the marine wildlife foraging around fishing activities (see section 2.1.2), fishers are also reported to illegally harvest some marine wildlife species, such as seals, dolphins, boobies and penguins, for use as bait in lobster traps (Ryan 1991, Shaughnessy 1999, Tasker *et al.* 2000, Shaughnessy *et al.* 2003), although the veracity of such reports has not been substantiated. Marine wildlife species, mainly seabirds, are sometimes also reportedly shot by fishers for sport or food (Tasker *et al.* 2000, Environment Australia 2001a). If excessive, this illegal deliberate killing by fishers may contribute to the decline of wildlife populations.

2.1.2. Marine wildlife feeding on bait, catch or discards

The bait, catch and discards from fishing provide an artificial concentrated food source upon which marine wildlife are pre-adapted to feed.

2.1.2.1. Bait and catch

Marine wildlife species have varying abilities to forage from different fishing activities (Table 2). When foraging on fishing bait and catches:

- wildlife feeds directly from hooks and fixed nets (Brothers 1991, Fertl and Leatherwood 1997);
- small pinnipeds can enter traps (Wickens et al. 1992, Wickens 1996, Shaughnessy 1999, Shaughnessy et al. 2003);
- bottlenose dolphins actively manipulate trawl codends (Broadhurst 1998);
- seals and birds feed on fish sticking out of hauled trawl codends (Wickens et al. 1992, Hickman 1999, Wienecke and Robertson 2002, David and Wickens 2003, Shaughnessy et al. 2003); and
- seals can move in and out of pursed nets (Shaughnessy 1985, David and Wickens 2003).

Generally only a few individual marine mammals attend fishing operations at any one time (Broadhurst 1998, David and Wickens 2003). However, large numbers of seals are occasionally seen at fishing operations off South Africa (David and Wickens 2003). Fishers have observed that seals and dolphins can take more than their fill from fishing catches and sometimes only play with the catch they take (Schlais 1984, Hickman 1999). The all day foraging of individual ‘rogue’ seals around fishing activities is a particular problem. This activity is sporadic, with fishers on the NSW south coast sometimes not seeing seals for weeks at a time (Hickman 1999).

Table 2: Marine wildlife groups that have been reported to feed on baited fishing gear and fishing catches.

n/a means 'not applicable' – this interaction is not possible.
✓ denotes that this interaction has been documented.
- denotes that this interaction has not been documented.

Fishing method	Marine wildlife group	Feeding on bait	Feeding on catch
Line fishing:			
- longlining	Dolphins	✓ (Harwood 1983)	-
	Killer whales	-	✓ (Yano and Dalheim 1995, Fertl and Leatherwood 1997, Nolan and Liddle 2000, Kock 2001, Darby 2002a)
	False killer whales	-	✓ (Nitta and Henderson 1993)
	Sperm whales	-	✓ (Kock 2001, The Associated Press 2004)
	Pilot whales	-	✓ (Queensland Department of Primary Industries & Fisheries 2004)
	Melon-headed whales	-	✓ (Queensland Department of Primary Industries & Fisheries 2004)
	Seals	✓ (Wickens *et al.* 1992)	-
	Turtles	✓ (Ferreira *et al.* 2001, Laurent *et al.* 2001)	-
	Seabirds	✓ (Brothers 1991)	✓ (Brothers *et al.* 1999, Commonwealth of Australia 2003)
- droplining	Killer whales	-	✓ (Shaughnessy *et al.* 2003)
	Seals	-	✓ (Hickman 1999, Shaughnessy *et al.* 2003)
- handlining	Dolphins	✓ (Schlais 1984, Nitta and Henderson 1993)	✓ (see references below)
	Seals	✓ (Hickman 1999)	✓ (Schlais 1984, Harwood and Greenwood 1985, Shaughnessy 1985, Nitta and Henderson 1993, Hickman 1999, David and Wickens 2003)
- trolling	Dolphins	✓ (Schlais 1984, Nitta and Henderson 1993)	-
	False killer whales	-	✓ (Nitta and Henderson 1993, David and Wickens 2003)
	Seabirds	✓ (Schlais 1984, Nitta and Henderson 1993)	-
- poling	Seals	✓ (Wickens *et al.* 1992)	-
- squid jigging	Seals	-	✓ (Arnould 2002, Shaughnessy *et al.* 2003)
Trapping:			
- lobster pots	Seals	✓ (Wickens *et al.* 1992, Wickens 1996, Shaughnessy 1999, Shaughnessy *et al.* 2003)	✓ (Hickman 1999)
- other traps	Seals	✓ (Shaughnessy *et al.* 2003)	✓ (Lunneryd *et al.* 2003)

Table 2 – continued

Fishing method	Marine wildlife group	Feeding on bait	Feeding on catch
Trawling:			
	Dolphins Seals Birds	n/a	✓ (Broadhurst 1998) ✓ (Wickens *et al.* 1992, Hickman 1999, Wienecke and Robertson 2002, David and Wickens 2003, Shaughnessy *et al.* 2003) ✓ (Environment Australia 2001a, Wienecke and Robertson 2002)
Net fishing:			
- drift, gill and other fixed nets	Dolphins Seals Birds	n/a	✓ (Fertl and Leatherwood 1997) ✓ (De Master *et al.* 1985, David and Wickens 2003, Shaughnessy *et al.* 2003) ✓ (Johnson 2002a)
- purse-seine nets	Seals	n/a	✓ (Wickens *et al.* 1992)

Economic losses for fishers result largely from catch losses, gear damage and lost fishing time while gear is being repaired or fishers move onto a different location. Foraging seals and sometimes dolphins have been reported to damage trawl and fixed nets, traps and line fishing gear (Shaughnessy 1985, Wickens *et al.* 1992, Fertl and Leatherwood 1997, Hickman 1999, Arnould 2002, David and Wickens 2003, Shaughnessy *et al.* 2003). Substantial economic losses have been reported from seals, dolphins, seabirds and cetaceans foraging on various line fishing gear (Schlais 1984, Brothers 1991, Hickman 1999, David and Wickens 2003, Shaughnessy *et al.* 2003, QDPI&F 2004). Fishers can also suffer losses when the marine wildlife scares away targeted catches, as reported for purse-seine, beach-seine, lobster trapping and line fishing operations (Kasuya 1985, David and Wickens 2003, Shaughnessy *et al.* 2003).

Mitigation measures trialed by fishers to reduce economic loss from this interaction, with varying success, include deterring mammals through acoustical methods such as pingers, feeding wildlife by hand to deter these animals from foraging on gear, and changes to gear design and fishing operations (Shaughnessy *et al.* 1981, Kasuya 1985, Kirkwood *et al.* 1992, Anon. 1996, Temby 1998, Hickman 1999, Løkkeborg 2003, Lunneryd *et al.* 2003). When all measures to deter problematic wildlife, such as rogue seals, fail, fishers sometimes return to port (Hickman 1999).

Fishers may also seek to reduce economic loss from this interaction by shooting at or near foraging animals. While such deliberate killing is illegal and difficult to quantify, the shooting of seals and dolphins around purse-seine and line fishing gear and birds around line fishing gear is known to occur (Schlais 1984, Shaughnessy 1999, Environment Australia 2001a, David and Wickens 2003, Shaughnessy *et al.* 2003, Votier *et al.* 2004). This illegal shooting activity can sometimes be considerable, as reported for albatrosses and fur-seals shot by the Tasmanian dropline fishery (Schlais 1984, Shaughnessy *et al.* 2003).

Marine wildlife involved in this interaction increase their risk of being caught on or entangled in fishing gear (section 2.1.3). Birds can be poisoned from ingesting lead sinkers when foraging on hooked bait. This is widely documented amongst loons, pelicans and swans in the U.S. and there is a single record of a little penguin in Australia being affected (Harrigan 1992, Franson *et al.* 2003). Apart from these negative consequences, marine wildlife should experience increased survival and fitness from feeding on fishing bait and catches (Tasker *et al.* 2000).

2.1.2.2. Discards

The bycatch and offal discarded from fishing activities provide a food source for marine wildlife. Most records of this interaction occur on trawl discards (Shoop and Ruckdeschel 1982, Ryan and Moloney 1988, Corkeron *et al.* 1990, Garthe and Hüppop 1994, Fertl and Leatherwood 1997, Martinez-Abrain *et al.* 2002). However, there are some accounts of wildlife foraging on the discards from lobster traps and various line and net fishing techniques (Wickens and Sims 1994, Brothers *et al.* 1999, Gray 2001, Arcos and Oro 2002, Johnson 2002a,b, Commonwealth of Australia 2003, Shaughnessy *et al.* 2003). In comparison to trawling discards, the discarding from other gear types can be quite irregular and may attract lower numbers of wildlife, as observed in the Mediterranean Sea (Arcos and Oro 2002).

The composition of marine wildlife species that regularly follow trawlers for food differs between locations and seasons (Oro and Ruiz 1997, Walter and Becker 1997, Valeiras 2003). The different species attracted to trawlers have varying feeding strategies and some species are more effective competitors for the discards (Hudson and Furness 1988, Garthe and Hüppop 1994, Garthe and Scherp 2003). Marine wildlife species that have been observed foraging on trawl discards include several seabird and waterbird species, seals, dolphins, other cetaceans and loggerhead turtles (Shoop and Ruckdeschel 1982, Furness *et al.* 1988, Jones and DeGange 1988, Ryan and Moloney 1988, Blaber and Wassenberg 1989, Corkeron *et al.* 1990, Hill and Wassenberg 1990, Wassenberg and Hill 1990, Thompson 1991, Garthe and Hüppop 1994, Blaber *et al.* 1995, Fertl and Leatherwood 1997, Oro and Ruiz 1997, Walter and Becker 1997, Bunce *et al.* 2002, Martinez-Abrain *et al.* 2002, Garthe and Scherp 2003, Votier *et al.* 2004). Other species, such as killer whales, are observed to be attracted to the food source created by scavengers feeding on trawl discards (Fertl and Leatherwood 1997).

Marine wildlife can derive a significant portion of their energy requirements from fishing discards and can become dependent on this regular food source (Thompson 1991, Oro and Ruiz 1997, Walter and Becker 1997, Chilvers and Corkeron 2001, Martinez-Abrain *et al.* 2002). The regular food source can benefit populations, especially scavenging seabirds, by increasing their numbers, expanding local distributions, altering foraging ranges and strategies, improving breeding success, reducing juvenile mortality and opening up new food niches, such as demersal prey species for wildlife that feed at the surface (Jones and DeGange 1988, Ryan and Moloney 1988, Blaber and Milton 1994, Garthe and Hüppop 1994, Blaber *et al.* 1995, Arcos and Oro 1996, Oro 1996, Oro *et al.* 1996, Chapdelaine and Rail 1997, Chilvers and Corkeron 2001, Bunce *et al.* 2002). If this food source ceased or was reduced, populations that depended upon it could experience negative consequences, such as a reduction in breeding success and population size as has been observed for some seabird populations (Oro 1996, Oro *et al.* 1996, Chapdelaine and Rail 1997). Predatory scavenging seabirds have been observed to switch their preferred prey to other smaller birds when reduced discarding rates are coupled with a reduced availability of small shoaling pelagic fish (Votier *et al.* 2004). Feeding on fishing discards for marine wildlife can also increase their likelihood of entanglement in fishing gear or collision with fishing gear or the vessel (Chilvers and Corkeron 2001, Environment Australia 2001a, Baker *et al.* 2002) (sections 2.1.3 and 2.1.5). For birds that feed on discards from longline operations, death can also result from ingesting hooks that may be embedded in discards (Environment Australia 2001a).

The perceived economic impact from wildlife consuming discarded undersized commercial species can motivate fishers to develop ways to increase discarded fish survival. For example estuarine net fishers in NSW, are seeking to increase bycatch survival by developing devices that release bycatch underwater, below the reach of foraging birds (Johnson 2002a, b). The success of such measures could also reduce the level of foraging activity around fishing operations.

2.1.3. Incidental capture or entanglement in active fishing gear

Around the world, incidental captures or entanglements of marine wildlife have been reported from the use of most fishing gear types (Table 3). The precise fishing method, effort and the local abundance and behaviour of marine wildlife are the main influences on the rate of capture and entanglement of these species.

For fishers, this interaction can directly result in economic losses from damaged or lost gear and lost fishing time, when they release captured or entangled animals. Some fisheries, for example purse-seine fisheries in Queensland and South Australia, have also been closed when fatal interactions with marine wildlife, most of which are protected, are frequent.

Table 3: A summary of the reported incidental capture or entanglement of marine wildlife groups on fishing gear around the world.

✓ indicates a wildlife group has been reported captured or entangled on a fishing gear type.

Fishing method	Marine wildlife group				Is this known to be a significant problem?
	Mammals	Turtles	Sea snakes	Avifauna	
Trawling	✓	✓	✓	✓	Yes – for all these wildlife groups, but less so for avifauna.
Longlining	✓	✓	-	✓	Yes – for turtles and seabirds, generally a rare event for mammals.
Handlining	✓	✓	-	✓	No - for mammals, turtles and some seabirds. Yes – for estuarine and coastal avifauna.
Trolling	✓	-	-	✓	No – for all these wildlife groups.
Jigging	✓	-	-	✓	No – for all these wildlife groups.
Gill, drift and set netting	✓	✓	-	✓	Yes – for all these wildlife groups.
Shark protection netting	✓	✓	-	-	Yes – for mammals. No – for turtles.
Purse-seining	✓	✓	-	✓	Yes – for mammals. No – for turtles and avifauna.
Trapping	✓	✓	-	-	Yes – for mammals. No – for turtles.

2.1.3.1. Trawling

Mammals

Incidental captures of marine mammals in trawl nets have been recorded in most areas of the world, including Australian waters (Northridge 1991, Fertl and Leatherwood 1997). Cetaceans and pinnipeds make themselves vulnerable to such incidental capture when they feed from or around trawl nets (Fertl and Leatherwood 1997, Morizur *et al.* 1999). These animals are trapped in the net once trawling stops or when the net is put back in the water for the next trawl shot (Pemberton *et al.* 1994, Fertl and Leatherwood 1997, Morizur *et al.* 1999). Cetaceans and pinnipeds mostly die once captured in trawl nets as they cannot surface to breathe, although a few individuals can be released alive (De Master *et al.* 1985, Wickens and Sims 1994, Fertl and Leatherwood 1997, Baird 2004). In South Africa, live

pinnipeds hauled onto trawlers were observed to leave the vessel of their own accord or were chased off by the crew (Wickens and Sims 1994).

Fertl and Leatherwood (1997) report that 25 cetacean species, both large and small, and pinnipeds have been killed in active or discarded trawl gear around the world. In Australia, there are only a few records of dolphins occasionally captured in trawl nets (Harris and Ward 1999, Shaughnessy *et al.* 2003). The Tasmanian trawl fishery for blue grenadier is reported to catch a considerably high number of seals when compared to those reported captured in other trawl fisheries (Shaughnessy and Davenport 1996, Harris and Ward 1999, Knuckey *et al.* 2002, Shaughnessy *et al.* 2003).

Fishing-related factors influencing marine mammal bycatch rates in trawl nets are the targeted species of fish, level of the tow in the water column, time of day and duration of the trawl shot, size of the net opening, haul-back speed and gear design (Fertl and Leatherwood 1997, Morizur *et al.* 1999, Hall *et al.* 2000). More mammals are incidentally caught in mid-water rather than demersal trawls as mid-water trawls have a wider opening, lower buoyancy, are towed at higher speeds, retrieved at slower speeds, tend to be trawled until the net reaches the vessel, and marine mammal prey species are more common at mid-water than demersal depths (Wickens and Sims 1994, Fertl and Leatherwood 1997). More cetaceans are also captured in trawls at night or close to dawn (Fertl and Leatherwood 1997, Morizur *et al.* 1999). It has been hypothesised that an increased bycatch of seals may result when trawl fishers continually catch smaller amounts of fish, as less fish are consequently spilled out of the net and this may force seals to feed from within the net where incidental capture is more likely (Pemberton *et al.* 1994).

Biological factors influencing a mammal species' ability to be captured in trawl nets are its distribution, size, social pattern, diet, foraging method and location within the water column, and behavioural traits such as its curiosity, exploration, attention, perception, and sensory capacities (Fertl and Leatherwood 1997, Morizur *et al.* 1999).

Seal Excluder Devices (SEDs) are one of the mitigation measures currently being trialed to reduce the incidental capture of pinnipeds in trawl nets. The high survival rate of seals observed captured in the Tasmanian trawl fishery (65%) (Tilzey 2001) may be a result of SEDs that were being trialed during the observer study (Shaughnessy *et al.* 2003).

Turtles

The incidental capture of sea turtles in trawling gear, mostly in demersal nets, has been reported around the world, including northern Australia (Henwood and Stuntz 1987, Chan *et al.* 1988, Poiner *et al.* 1990, Robins 1995, Poiner and Harris 1990, 1996, Marcano and Alio 1998, Laurent *et al.* 2001, Robins *et al.* 2002a). Captured sea turtles can die in the net, be comatose, injured or visibly unaffected. Animals returned to the water in a comatose state have a high probability of dying (Robins *et al.* 2002a).

The catch rate of sea turtles by trawlers is depth dependent. In northern Australia, most sea turtles are caught by trawlers operating in waters <30m deep and only a few are caught in waters >40m (Poiner *et al.* 1990, Robins 1995, Poiner and Harris 1990, 1996). Other fishing-related factors that influence the number of sea turtles captured in trawl nets include tow duration and the use of mitigation measures such as effective Turtle Exclusion Devices (TEDs), which allow sea turtles to escape from the net before entering the codend (Robins *et al.* 2002a). In Australia's Northern Prawn Fishery, trawls of 90 minutes or more in inshore waters caught the highest number of sea turtles (Poiner *et al.* 1990, Poiner and Harris 1990).

Fishing-related factors that influence the survival of incidentally trawled sea turtles include tow duration (Henwood and Stuntz 1987, Poiner *et al.* 1990, Poiner and Harris 1990, Robins 1995, Robins

et al. 2002a), the size of the catch and whether mitigation measures such as effective TEDs and turtle recovery procedures are used (Robins *et al.* 2002a). Sea turtles caught during tows of 60-90 minutes have been reported to have very low mortality rates; higher mortality rates are experienced when the trawling time is greater than this (Henwood and Stuntz 1987, Poiner *et al.* 1990). Sea turtles captured in trawl nets despite the use of TEDs, have the greatest chance of survival as they would have been caught just before the nets were hauled in (Robins *et al.* 2002a). Comatose sea turtles that are recovered using procedures such as those recommended in Ocean Watch (2003) also have an increased chance of survival (Robins *et al.* 2002a).

Biological factors influencing the number of sea turtles captured in trawl nets include local turtle distribution, density, seasonality, age structure and species (Robins 1995). The dominant species reported in trawl bycatch varies between locations, reflecting local species abundances (Robins 1995, Robins *et al.* 2002a). The catch rate of trawled sea turtles varies between species. The turtle species regularly reported in trawl catches include flatback, loggerhead, green, olive ridley and Kemp's ridley turtles; while hawksbill and leatherback turtles are mostly only reported in trawl nets in low-rare numbers (Henwood and Stuntz 1987, Poiner *et al.* 1990, Robins 1995, Poiner and Harris 1990, 1996, Robins *et al.* 2002a).

Biological factors influencing the survival of incidentally trawled sea turtles include the size of the individual (Hillstead *et al.* 1981), and morphology of the species. Smaller turtles tend to drown more quickly than larger turtles (Hillstead *et al.* 1981). Differences in mortality rates between species of trawled turtles have been observed, with loggerhead and hawksbill turtles identified as being particularly susceptible to mortality from trawling (Poiner and Harris 1990, 1996).

The threat from the incidental capture of sea turtles in trawl nets can be substantially alleviated through the widespread use of TEDs. This technology, now mandatory in some of the world's trawl fisheries including Australia's Northern Prawn and East Coast Otter Trawl fisheries, allows trawl fishers to satisfy sustainability legal requirements in an economically viable way. The number of sea turtles caught each year by Australia's Northern Prawn Fishery fleet decreased from 5,000 to less than 200 with the introduction of TEDs in the fishery (Robins *et al.* 2002a). The mortality rate of captured sea turtles in this fishery was estimated to be between 25-39% before the introduction of TEDs and other mitigation measures such as recovery procedures (Poiner and Harris 1996) and 22% afterwards (Robins *et al.* 2002a).

Sea Snakes

The incidental capture of sea snakes in demersal trawl gear can be a regular occurrence in areas of high sea snake abundance, as has been recorded in northern Australia (Wassenberg *et al.* 1994, Ward 1996a, b, 2000). Captured sea snakes can die from drowning in the net or from being killed once on board (Milton 2001). Survival rates vary among species and depend on the stage of the tow at which the sea snake entered the net, the duration of the tow, weight of the catch, how the animal is treated on deck and its morphology (Wassenberg *et al.* 2001). In northern Australia, a little less than half of the sea snakes incidentally caught in trawl nets die (Wassenberg *et al.* 2001). This activity could be placing the long-term viability of one sea snake species (*Hyrdophis pacificus*) and three northern Australian sea snake populations (*Disteria kingii, Aipysurus laevis* and *Astrotia stokesii*) at risk (Milton 2001).

Avifauna

Trawling may result in significant seabird mortality (Bartle 1991, Ministry of Fisheries and Department of Conservation 2000, Kock 2001). Seabirds often forage around trawl vessels in large numbers (Garthe and Hüppop 1994, Gales and Brothers 1996, Sagar *et al.* 2000) and can be injured, killed or directly unaffected when they come into contact with trawl gear either intentionally, by

feeding from the nets as they are hauled in, or unintentionally, by colliding with the fishing gear, mostly when they are feeding on discards (Bartle 1991, Ministry of Fisheries and Department of Conservation 2000). Seabird kills are more frequent in mid-water trawl fisheries than in bottom trawl fisheries (Commonwealth of Australia 2003). In New Zealand waters, high numbers of seabirds were observed killed by mid-water trawling activities (Ministry of Fisheries and Department of Conservation 2000). The few observations of Australian trawl fisheries show that albatross and petrel mortality does occur from trawling activity, although it appears to be a rare event (Baker *et al.* 2002). This rarity may represent reality, or be the result of insufficient data or the latent nature of interactions (Baker *et al.* 2002).

2.1.3.2. Longlining

Mammals

Captures or entanglements of marine mammals on longlines can result when they collide with or feed from the line. This interaction has been reported around the world, including Australian waters, with whales, dolphins and seals (Northridge 1991, Slater 1991a, Nitta and Henderson 1993, Harris and Ward 1999, Kock 2001, Baird *et al.* 2002, López *et al.* 2003, Shaughnessy *et al.* 2003, Baird 2004). While mammal mortality from this interaction has been reported (Baird *et al.* 2002), entangled animals can be released relatively unharmed (Harris and Ward 1999). Although this interaction is generally rare in most areas, the Hawaiian-based longline fishing fleet is reported to be killing the local population of false killer whales at nearly ten times the level the population can sustain (Earthjustice 2003).

Turtles

Sea turtles that are attracted to longline floats or the bait or light sticks used on this gear, can be captured by becoming hooked or entangled while foraging from or around this gear type (Skillman and Balazs 1992, Robins *et al.* 2002b). Incidental captures of sea turtles on longlines, mostly pelagic gear, have been recorded around the world (Witzell 1999, Achaval *et al.* 2000, Ferreira *et al.* 2001, Laurent *et al.* 2001, Oceans Fisheries Programme 2001, Stone and Dixon 2001). Australian pelagic longline fishing operations (the Eastern Tuna and Billfish Fishery and the Southern and Western Tuna and Billfish Fishery), are estimated to incidentally catch around 400 sea turtles a year, a figure considerably less than other world longline fisheries (Robins *et al.* 2002b).

Loggerhead and leatherback turtles are the species of reptiles most regularly reported captured on longline gear (Nitta and Henderson 1993, Witzell 1999, Achaval *et al.* 2000, Robins *et al.* 2002b). Olive, green and hawksbill turtles appear to be less regularly incidentally captured on this gear (Nitta and Henderson 1993, Robins *et al.* 2002b). Documented incidental turtle captures by the Australian pelagic longline fisheries are mostly of leatherback turtles and some green, olive ridley, loggerhead and hawksbill turtles (Robins *et al.* 2002b).

The configuration of longline gear, the local distribution and abundance of sea turtles and their foraging behaviour influences the number of sea turtles captured on this gear type (Robins *et al.* 2002b). Generally, more sea turtles are captured on this gear when it is set at shallow depths or a bait type that resembles the prey of sea turtles or light sticks is used (Skillman and Balazs 1992, Robins *et al.* 2002b, Polovina *et al.* 2003). The season can also influence the rate of sea turtle captures (Caminãs and De La Serna 1995, Ferreira *et al.* 2001).

The survival of an incidentally captured sea turtle is influenced by the location and nature of hook penetration, the time spent on the line, whether the turtle could surface to breathe, the environmental conditions at the time of capture, the turtle's behaviour on capture, the size and species of the turtle

and whether correct recovery and handling techniques to reduce post-hooking and entanglement injury were used (National Marine Fisheries Service 2001). Sea turtles are considered to be hardy animals and many longline fisheries, including the Australian pelagic longline fisheries, have reported that almost all incidentally hooked or entangled turtles are released alive (Ferreira *et al.* 2001, Laurent *et al.* 2001, Robins *et al.* 2002b).

Seabirds

The incidental capture of seabirds on both pelagic and demersal longline fishing gear has been widely documented around the world (Brothers 1991, Cherel *et al.* 1996, Barnes *et al.* 1997, Belda and Sánchez 2001, Jahncke *et al.* 2001, Baird and Griggs 2004; Baker and Wise 2005). As most seabirds are surface foragers, it is during the setting of the gear when baited hooks are at the water's surface, that most foraging birds are hooked (Brothers 1991, Commonwealth of Australia 2003). Birds can also hook up or entangle on longlines when they scavenge on unspent bait as the lines are hauled in (Brothers *et al.* 1999, Commonwealth of Australia 2003). Most of the birds hooked during line setting drown (Brothers 1991, Commonwealth of Australia 2003). However, some live releases of captured seabirds have been observed with the use of light longline gear (Brothers *et al.* 1999). The birds hooked during the hauling in of longlines either escape or are released alive, although it is not known if they survive any resulting injuries (Brothers 1991).

The likelihood of hooking depends upon such factors as the buoyancy of the line and bait, weight on the end of the line, speed and method of deployment, boat speed, the use of bird capture mitigation techniques, time and location of fishing, nature and abundance of seabird prey, demography of seabird population, weather and moon phase when night setting (Klaer and Polachek 1998, Brothers *et al.* 1999, Tasker *et al.* 2000, Commonwealth of Australia 2003). Birds most likely to swallow baited hooks are the larger, more aggressive species that tend to follow ships for food (Baker *et al.* 2002).

Longline seabird bycatch is widely known to occur mostly on pelagic gear (Brothers 1991, Gales *et al.* 1998, Commonwealth of Australia 2003, Baker and Wise 2005). However, significant seabird bycatch has also been recorded on demersal longlines off South Africa and Antarctica (Cherel *et al.* 1996, Barnes *et al.* 1997). The only significant observations of demersal longlining in Australian waters, occurring as part of the Commonwealth South-East Non-trawl Fishery, suggest that seabird bycatch may not be a significant problem for this gear type in Australian waters (Commonwealth of Australia 2003). Longlines that are set vertically, known as droplines, have a minimal likelihood of seabird bycatch, as the lines drop vertically and fast and baited hooks occupy a small area of surface waters and do not remain there for long. Observations of dropline fishing under the Commonwealth South-east Non-trawl Fishery support this claim (Commonwealth of Australia 2003).

Population declines of some seabird species, especially albatrosses and shearwaters, have been linked to this interaction (Weimerskirch and Jouventin 1987, Brothers 1991, Barnes *et al.* 1997, Baker and Wise 2005). Nearly all albatross and giant-petrel species and some petrel, shearwater, gannet and skua species that forage within Australian waters have been observed captured on longline fishing gear in Australian waters (Commonwealth of Australia 2003). The limited data on the mortality of seabirds in the world's longline fisheries show that catch rates of 0.4 birds per 1000 hooks, are typical (Barnes *et al.* 1997, Brothers *et al.* 1999). In Australian waters, measures have been undertaken to reduce seabird capture rates on longlines to 0.05 birds per 1000 hooks (Environment Australia 1998b). Various mitigation techniques are used in combination to achieve this aim and they seem to work well, at least for the larger species - albatrosses and giant-petrels (Priddel 2003). Some of the techniques used or being developed are night setting, bait thawing, strategic offal discharge, weighted lines, bait-casting machines, bird-scaring lines (tori poles), underwater setting chutes, spatial / temporal closures and education (Brothers 1996, Brothers *et al.* 1999, Commonwealth of Australia 2003, Løkkeborg 2003, Sánchez and Belda 2003).

2.1.3.3. Handlining

Mammals

The incidental capture or entanglement and resulting death or injury of marine mammals on handline gear is not widely documented. Deaths of a few bottlenose dolphins from ingested fishing line, probably of a recreational nature, have been recorded in Florida. However it is not known whether the lines were actively fishing or discarded when ingested (Gorzelany 1998, Wells *et al.* 1998).

Turtles

Although not a widely documented problem, some incidental captures of sea turtles on handlines have been documented in Greece (White 2002) and Hawaii (Nitta and Henderson 1993). The captured species were loggerhead and green turtles, but their survival was not documented (Nitta and Henderson 1993, White 2002).

Avifauna

Handlining was identified as a method that would probably not result in many interactions with albatross and petrel species by the Commonwealth of Australia (2003). However, this method, especially when used by recreational fishers, has been reported to entangle and hook coastal, estuarine and land-based birds (Ferris and Ferris 2002). Ferris and Ferris (2002) reported that active recreational fishing, both from attended handlines and unattended set lines, was the primary cause of this interaction. Within estuaries, they reported that jetties, wharfs, pontoons, boat ramps, fish cleaning tables and narrow watercourses were the areas where this interaction was most likely to occur. They found hooked or entangled birds can suffer life-threatening injuries, the rate of which could be reduced by fishers gently reeling in the bird and removing the hook or line (Anon. 2004). Around heavily populated towns in NSW, one-in-five Australian pelicans are found hooked or entangled in handline gear (Ferris and Ferris 2002).

2.1.3.4. Trolling

Mammals

The incidental capture of mammals on trolling gear is possible, as reported with pinnipeds in the U.S. (Baraff and Loughlin 2000). However, this interaction is seemingly rare when compared to the frequency of marine mammal bycatch reports from other fishing methods.

Avifauna

There are very few records of seabird captures on trolling gear. In Western Australia, shearwaters, albatrosses and pelicans were observed captured either on trolling lures or by colliding and then entangling with the gear, mostly when offal and/or bait was discharged (Commonwealth of Australia 2003). Captures of these species were mostly infrequent, except for the flesh-footed shearwater (Commonwealth of Australia 2003). Gannets have also been reported captured on troll lines, in Victoria (Norman 2000). As trolling is an active fishing method, the birds observed captured on this gear were quickly retrieved and released alive, the ultimate fate of these birds is unknown (Norman 2000, Commonwealth of Australia 2003).

2.1.3.5. Jigging

Mammals

Marine mammals may be caught on jigs presumably when foraging around this gear, but this is not widely reported. There are a few anecdotal reports of seals becoming hooked on jigs used in Australia's Southern Squid Fishery, but their ultimate survival was not reported (Harris and Ward 1999).

Avifauna

The capture of seabirds on squid jigs is possible. For example, four gentoo penguins were recorded caught and released alive on squid jigs in the Southern Ocean (Kock 2001). Albatrosses and the southern-giant petrel may also get caught on this gear type, as jigs were regularly found near the nests of these species (Kock 2001). The extent of this problem in the Southern Ocean is not yet fully known, but is a known problem in jig fisheries elsewhere (Kock 2001).

2.1.3.6. Gill, drift and set nets

Mammals

Marine mammals become accidentally entangled in gill, drift (a method banned worldwide in 1993) and set nets when they fail to detect the net in time to avoid it or as they attempt to feed on the fish captured in the net (Hofman 1990, Tregenza 2000). It is these passive fishing nets that most commonly capture cetaceans (Perrin *et al.* 1994), and this global widespread interaction also occurs in Australian waters (Northridge 1991, Larmour 1999, Powell and Rafic 2000, Powell 2001, 2002, Shaughnessy *et al.* 2003). Captures of many dolphin and porpoise species in these nets are commonly reported and are almost always fatal (Hall *et al.* 2000). There is a lower level of mortality for entangled large cetaceans, which can swim away with the gear and sometimes untangle themselves. Entanglement mortality is influenced by the size and behaviour of the animal when trapped, duration of entrapment and whether any assistance was given in releasing the animal (Lien 1994).

Large numbers of cetaceans are recorded captured in both offshore and coastal passive nets (including those off northern Australia) (Harwood *et al.* 1984, Harwood and Hembree 1987, Barlow *et al.* 1994, Lien 1994, Van Waerebeek *et al.* 1997, Julian and Beeson 1998, López *et al.* 2003). Some species and local populations are now threatened as a result of this interaction (Dawson 1991, Jefferson and Curry 1994, D'Agrosa *et al.* 2000, Kinas 2002). Dugongs, manatees and seals are other marine mammals that have been recorded incidentally captured in these passive nets (Northridge 1991, Barlow *et al.* 1994, Julian and Beeson 1998, Baraff and Loughlin 2000, Marsh *et al.* 2003, Shaughnessy *et al.* 2003).

Turtles

Entanglements of green, loggerhead, leatherback, hawksbill, flatback and olive ridely turtles have been recorded in gill nets (Margaritoulis 1986, Chan *et al.* 1988, Feldkamp *et al.* 1988, Nitta and Henderson 1993, Eckert 1997, Environment Australia 2003); loggerhead, leatherback, green and hawksbill turtles in drift nets (Wetherall *et al.* 1993, Eckert 1997, Silvani *et al.* 1999); and green, loggerhead, hawksbill and leatherback turtles in set nets (Cheng and Chen 1997). Generally, with turtles that are entangled in nets, if they are disentangled promptly after entanglement, impacts can be assumed to be minimal (Margaritoulis 1986, Cheng and Chen 1997, Silvani *et al.* 1999), otherwise they normally die (Margaritoulis 1986, Nitta and Henderson 1993, Wetherall *et al.* 1993, Eckert 1997). Gill nets have been identified as one of the fishing-related sources of mortality of sea turtles in Australian waters (Environment Australia 1998a).

Avifauna

The passive gill and drift nets are known to entangle and drown large numbers of birds, especially as birds and these passive net fishers can target the same schooling fish species (for examples, see Jones and De Gange 1988 and Tasker *et al.* 2000). This interaction can reduce local populations or species of birds, and sometimes threaten their survival (Takekawa *et al.* 1990, Piatt and Gould 1994). Most records of this interaction are from the northern hemisphere, from offshore drift and gill net fisheries, and also from coastal gill net fisheries (for examples, see Jones and DeGange 1988, Tasker *et al.* 2000). The incidence of this interaction in Australian waters is unknown (Baker *et al.* 2002). In Tasmania, several hundred shearwaters were observed killed in a single gillnet set (Hockin *et al.* 1992). Norman (2000), reported very small captures of cormorants and little penguins in inshore mesh nets in Victoria. Anecdotal reports in New Zealand suggest that many bird species are captured in amateur gillnets (including shearwaters, shags, penguins and grebes), occasionally in large numbers (Darby and Dawson 2000).

The bird species captured in passive nets and the rate at which this occurs is a function of fishing effort, weather conditions, local bird distribution and abundance, their foraging strategy (Carter and Sealey 1984, Piatt and Nettleship 1987), and location of nets. More birds are caught near breeding colonies and migratory concentrations (Piatt and Nettleship 1987). It is mostly the diving and pursuit plunging birds and some surface feeding birds, especially those that form high-density feeding aggregations, that have been reported captured (Piatt and Nettleship 1987, Jones and DeGange 1988, Tasker *et al.* 2000, Montevecchi 2002). Mortality from this interaction can be reduced through the use of effective mitigation measures, such as specific closures and gear modifications (Melvin *et al.* 1999), or by releasing birds shortly after they are entangled.

2.1.3.7. Shark control nets

Mammals and turtles

Shark control nets (a type of gill net), used in South Africa and Australia (NSW and Queensland only), have been reported to incidentally capture marine mammals and sea turtles (Cockcroft 1992, Krough and Reid 1996, Gribble *et al.* 1998). In Australia, catches of whales, dolphins, dugongs and sea turtles in these nets are generally reported to be low and should not significantly effect populations (Krough and Reid 1996, Gribble *et al.* 1998). In South Africa, local oceanographic conditions, prey distribution and bottlenose dolphin abundances result in concern for the large numbers of this species that are captured in shark control nets (Cockcroft 1992). This has resulted in the development of mitigation measures to reduce this capture rate, including seasonal net removal, reducing the numbers of nets, increasing the sonar reflectivity of the nets, and using alternative shark control measures (Cockcroft 1992, Peddemores, V.G., pers. comm. 2004).

2.1.3.8. Purse-seine nets

Mammals

Purse-seine fishers can use aggregations of marine mammals to locate schooling fish. Marine mammal bycatch can occur when these nets are set around aggregations of mammals and associated target species, and dolphins, whales and seals have been reported captured in these nets (Shaughnessy 1985, Hall *et al.* 2000, Norman 2000, Romanov 2001, Shaughnessy *et al.* 2003). Seals are quite adept at moving in and out of pursed nets when feeding (Shaughnessy 1985, David and Wickens 2003) and can therefore avoid capture. Whales too have been reported to escape from pursed nets (Romanov 2001).

In the eastern Pacific Ocean, the local dolphin populations that were depleted from this interaction in

the early 1990s are now recovering with the use of effective mitigation measures (Allen 1985, Bache 2000, Hall *et al.* 2000). The high dolphin mortality rates reported in the eastern Pacific Ocean is a function of the commonly occurring dolphin-tuna associations in the area (Hall *et* al. 2000). Purse-seine fisheries operating in areas where these associations are rare, such as the western Indian Ocean, do not have dolphin bycatch problems (Romanov 2001).

Turtles and seabirds

Other wildlife groups recorded as occasionally caught in purse-seine nets are sea turtles, little penguins, and terns (Hall 1998, Norman 2000, Romanov 2001).

2.1.3.9. Traps

Mammals

Marine mammals reported entangled in the lines and floats attached to fishing traps, include whales, dolphins, seals and manatees (Hofman 1990, Northridge 1991, Nitta and Henderson 1993, Barlow *et al.* 1994, Anon. 2002, Noke and Odell 2002, Shaughnessy *et al.* 2003). This interaction occurs when the gear is not detected in time to be avoided (Lien 1994) and has been recorded in estuaries, inshore and offshore waters (Hofman 1990, Noke and Odell 2002, López *et al.* 2003). When compared to the capture of marine mammals in nets, this interaction generally occurs at a low rate (Hofman 1990). Although most marine mammal entanglements in traps may never be observed (Darby 2002b), this interaction is thought to be rare in Australia (Harris and Ward 1999, Leadbitter 1999).

Factors such as excessive rope lengths, especially in shallow water, and high pot densities can increase the rate of this interaction (Noke and Odell 2002). Any resulting mortality is a function of the size and behaviour of the captured animal, duration of entrapment, and whether any assistance was given in releasing the animal (Lien 1994).

The only marine mammals reported captured in fishing traps themselves are juvenile seals that occasionally become stuck when they feed on bait (Warneke 1975, Lien *et al.* 1989, Gales *et al.* 1994, Norman 2000). For one Australian sea-lion colony, Gales *et al.* (1994) reported that a large number of the pups had drowned in crayfish pots.

Turtles

Sea turtles are reported to entangle in the buoy-lines attached to traps (Nitta and Henderson 1993, NSW DEC 2003, Environment Australia 1998a, 2003). Reports of this interaction in Australian waters, which are few in number, suggest that it is occurring at a low rate (Environment Australia 1998a). The resulting mortality of sea turtles involved in this interaction is poorly documented. Live releases of affected sea turtles are possible as demonstrated in Hawaii (Nitta and Henderson 1993). There is no information on the factors influencing this interaction. Presumably sea turtles can entangle in trap ropes when foraging on the animals attracted to the trap float or swimming through surface waters.

2.1.4. Interactions with fishing debris

2.1.4.1. The sources, types and distribution of fishing-related marine debris

Synthetic marine debris, including fishing-related items such as discarded or lost gear, gear fragments and plastic bait packaging (Laist 1987, Jones 1995, Laist 1995), has been identified as a threat to marine wildlife when they ingest or become entangled in it (Laist 1987, NSW Scientific Committee 2003, Threatened Species Scientific Committee 2003). Fishers can lose their gear as a result of unfavourable weather conditions, bottom snags, ship collisions, mobile fishing methods that inadvertently tow the gear or remove marker buoys, human error, vandalism and gear failure (Laist 1995, Editorial 2003). Other fishing-related debris items can also be either thoughtlessly or deliberately disposed of[1] into the sea or waterways. Amongst the types of plastic debris most dangerous to marine life, Laist (1987) has listed fishing nets and net fragments, strapping bands, bags, rope, line and objects that degrade into small floating fragments.

Marine debris can now be found in all waters and shorelines of the world (Faris and Hart 1996). Most studies of the debris found on Australian beaches have recorded fishing-related items (Slater 1991b, Haynes 1997, Herfort 1997, Whiting 1998, Cunningham and Wilson 2003, Kiessling 2003), indicating its presence in the surrounding ocean (Jones 1995). A study of selected ocean beaches in NSW reported 13% of the debris to be fishing related, 60% of which was thought to be from commercial origins and the remaining 40% recreational (Herfort 1997). The fishing-debris items recorded in NSW included those that marine wildlife could ingest or become entangled in (Herfort 1997).

2.1.4.2. The entanglement of marine wildlife in and their ingestion of marine debris

The marine wildlife species most likely to entangle in or ingest marine debris are those that mistake floating debris as prey, are attracted to the species that have aggregated around the debris, play with the debris item or rest on it (Laist 1987). The likelihood of these interactions depend upon the type, quantity and distribution of debris and the behaviour of the affected species (Laist 1987).

Entanglement

Marine wildlife that entangles in debris can drown, become strangled, incur injuries or wounds, or suffer from a reduced ability to travel, catch food or avoid predators (Laist 1987, Jones 1995). Marine wildlife mostly entangles in small pieces of fishing gear, although there are also some records of these species being caught in relatively intact derelict gear (Laist 1987, 1995).

Cetaceans have been reported entangled in fishing gear such as trap lines and nets (Wells *et al.* 1998), and it is usually difficult to determine whether such animals entangled in debris or active gear (Laist 1987, Jones 1995). In northern Australia, where derelict gear is common and debris issues are under investigation, anecdotal reports suggest that dolphins and other mammals like dugongs are becoming entangled in derelict fishing nets (Kiessling 2003).

Pinnipeds are especially prone to entanglement in debris when they investigate it. Mostly juvenile and sub-adult pinnipeds are reported to entangle in fishing gear such as bait box packing straps, trawl and monofilament net fragments, bags, rope and fishing line (Shaughnessy 1980, Fowler 1987, Stewart and Yochem 1987, Pemberton *et al.* 1992, Arnould and Croxall 1995, Hanni and Pyle 2000, Page *et al.* 2004). This interaction has contributed to a decline in some seal populations (Fowler 1987,

[1] The deliberate disposal of plastic and synthetic material into the sea is illegal under Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL).

Henderson 2001, Page *et al.* 2004). Although most reports of this interaction are of pinnipeds that have entangled in debris, Arnould and Croxall (1995) and Stewart and Yochem (1987) state that some of the entanglements may have resulted from interactions with active trawl or line fishing gear rather than debris.

Sea turtles occur in areas where marine debris accumulates and they tend to mistake it for prey or feed on organisms growing on the debris (Carr 1987, Bjorndal *et al.* 1994, Kiessling 2003). Nearly all sea turtle species have been recorded entangled in fishing debris items including monofilament line, netting (trawl, drift and gill), rope and cloth (Balazs 1985, Environment Australia 2003, Kiessling 2003). This interaction is a particular threat to sea turtles in northern Australia (Kiessling 2003).

Entanglement in debris would pose less of a threat to seabirds than their incidental capture in active gear or ingestion of debris (Laist 1987). Dead seabirds have been recorded in derelict gillnets (De Gange and Newby 1980, Kiessling 2003) and driftnets (Jones and Ferrero 1985). There are also records of birds entangled in net fragments, line and rope from fishing gear (Schrey and Vauk 1987, Ferris and Ferris 2002). However, it is uncertain whether these fragments originated from active fishing gear or debris.

Ingestion

Marine wildlife that ingest debris can starve or have lessened feeding drives (Azzarello and Van Vleet 1987, Laist 1987, Jones 1995). Ingested plastics can also make an animal more buoyant and inhibit its diving ability (Kiessling 2003). The intake of polychlorinated biphenyls (PCBs) from ingested plastics can suppress an individual's reproductive ability and immunity and alter hormone levels (Ryan *et al.* 1988).

Ingestion of debris appears to be less of a problem for marine mammals than entanglement (Laist 1987). Ingested debris, mostly plastic material (Laist 1987, Eriksson and Burton 2003), has been documented in pinnipeds (Eriksson and Burton 2003), sirenians (Beck and Barros 1991) and cetaceans (Baird and Hooker 2000).

Sea turtles are threatened from actively ingesting plastic material they mistake for their preferred prey (Balazs 1985, Bourne 1985, Carr 1987). Plastic bags and rope are the debris items most frequently ingested, and other ingested items include monofilament line, net fragments, hooks, rubber, cloth, oil, tar and small pieces of hard plastic (Balazs 1985, Bjorndal *et al.* 1994, Bugoni *et al.* 2001, Tomás *et al.* 2002). All sea turtle species, particularly pelagic juveniles, have been found with ingested debris (Balazs 1985, Carr 1987).

The ingestion of floating plastic mistaken for food is a particular threat to seabirds (Azzarello and Van Vleet 1987, Laist 1987, Michael Fry *et al.* 1987, Derraik 2002). Birds that feed on plankton, squid and crustaceans are more likely to do this than birds that feed on fish (Azzarello and Van Vleet 1987). Also, surface feeding birds are likely to ingest more plastic than those that feed by diving below the surface (Day *et al.* 1985). Once ingested, plastics can only be expelled from birds by regurgitation (Laist 1987). Procellariiformes are particularly affected by plastic ingestion as anatomical differences make it more difficult for these species to regurgitate gizzard contents (Furness 1985, Azzarello and Van Vleet 1987). Chicks too accumulate plastics they have been fed, as they are unable to regurgitate for several weeks or months after hatching (Laist 1987, Michael Fry *et al.* 1987). The extent to which plastic ingested by seabirds consists of fishing-related material is not known but any plastic that looks like or floats alongside seabird prey could be ingested (Azzarello and Van Vleet 1987).

2.1.5. Collision

Marine wildlife, when near the water's surface, can collide with vessels like ships, fishing boats and recreational craft. Vessels and their propellers can be damaged by such a collision (Wickens *et al.* 1992), and marine wildlife can be killed, injured or remain seemingly unaffected (Ryan 1991, Wells and Scott 1997, Marsh *et al.* 2002, Anon. 2003). Death from boat-strike collision has sometimes been reported to be a significant threat to the survival of some marine wildlife populations. For example, boat-strike collision in Queensland, which mostly occurs next to heavily populated areas, is now the greatest cause of human-induced sea turtle mortality in the state (McPhee *et al.* 2002, Environment Australia 2003).

Marine wildlife species most likely to collide with vessels include those that are slow, spend much time at the water's surface, use habitats in the vicinity of major shipping lanes and boating areas, and are attracted to vessels for food (Ryan 1991, Environment Australia 1998a, Clapham *et al.* 1999). Diseased animals are also particularly vulnerable to vessel collision (Wells and Scott 1997, Environment Australia 1998a). The frequency of collisions between marine wildlife and vessels in a given area is influenced by the local abundance of vulnerable animals, the level and speed of boat traffic and whether the traffic occurs in important wildlife habitats such as calving and nursery sites and migration routes (Limpus and Reimer 1990, Bannister *et al.* 1996, Queensland Department of Environment 1997, Wells and Scott 1997, Marsh *et al.* 2003). How an animal is affected from colliding with a vessel depends upon the size of the animal, the size and speed of the vessel, what part of the vessel touches the animal and what part of the animal hits the vessel.

Marine wildlife groups reported to be killed and injured from vessel collisions include sea turtles (Limpus and Reimer 1990, Environment Australia 1998a), manatees (Beck and Reid 1995, Wright *et al.* 1995), dugongs (Marsh *et al.* 2002), seals (Wickens *et al.* 1992), baleen whales (Queensland Department of Environment 1997, Clapham *et al.* 1999, Rafic 1999, Knowlton and Kraus 2001, Laist *et al.* 2001), dolphins (Wells and Scott 1997, Anon. 2003), other cetaceans (Queensland Department of Environment 1997, Laist *et al.* 2001), and birds (Ryan 1991, Cunningham *et al.* 1993, Kock 2001). Marine mammals, sea turtles and penguins can collide with vessels when they fail to detect the approaching vessel in time to move away from it (Bannister *et al.* 1996) and when feeding around fishing vessels (Wickens *et al.* 1992). Aerial birds are reported to collide with fishing vessels at night when they are dazzled by the bright lights to which they are attracted (Ryan 1991, Kock 2001).

Apart from colliding with fishing vessels, marine wildlife can also collide with fishing gear when swimming or foraging on fishing bait, catch or discards (see section 2.1.2). Upon such collision, marine wildlife can entangle in or be hooked up on fishing gear (see section 2.1.3) or be relatively unaffected (Wienecke and Robertson 2002).

2.1.6. Noise, site access and physical presence of fishers

Other operational interactions that occur between fishing activities and marine wildlife include the effects of the noise from fishing vessels and gear operation, access to fishing sites and physical presence of fishers. The effects of these disturbance sources are often considered cumulatively with other similar sources of disturbance that occur in coastal and oceanic areas (Paton *et al.* 2000, Leung Ng and Leung 2003, Thomas *et al.* 2003, Simmonds *et al.* 2004).

2.1.6.1. Mammals

Cetaceans can sometimes tolerate vessel or boat noise, for example baleen whales have been observed feeding in areas where large numbers of trawlers operate (Richardson *et al.* 1995) and dolphins actively approach boats to ride on bow waves and feed (Williams *et al.* 1992, Broadhurst 1998). However, they can also avoid this disturbance, especially if it is too lengthy, intrusive or unpredictable (Au and Perryman 1996, Nowacek *et al.* 2001, Leung Ng and Leung 2003, Lusseau 2003a).

Short-term responses of cetaceans to disturbance from vessel / boat activity or noise include spatial avoidance, increased dive time and swimming speed, and changes in breathing patterns, group size and cohesion, and acoustic, foraging, socializing and resting behaviour (Richardson *et al.* 1995, Au and Perryman 1996, Nowacek *et al.* 2001, Leung Ng and Leung 2003, Lusseau 2003b). Cetaceans have lower tolerance to approaching, increasing or variable sounds than stationary, departing or steady sounds (Richardson and Würsig 1997, McCauley and Cato 2003). For example, dolphins in Scotland frequently exposed to boating traffic showed no significant response to most of the traffic, which was either fishing or yachting related and usually occurred in a predictable straight line. However, these dolphins did show significant avoidance reactions to the unpredictable and approaching movement of dolphin-watching vessels (Au and Perryman 1996). In the longer term, repeated exposure to human-induced noise including that from boats / vessels, can result in cetaceans avoiding areas where levels of this disturbance are high (Richardson *et al.* 1995). For example, in Hawaii, humpback whales have moved away from nearshore areas, a favoured resting site, apparently in response to disturbance from human activities (Salden 1988, Glockner-Ferrari and Ferrari 1990).

When at their breeding colonies, or hauling out on land, pinnipeds either tolerate or avoid disturbances from humans walking or driving vehicles or boats close to them (see references in Richardson *et al.* 1995). Tolerating behaviour results in pinnipeds becoming more alert, and exhibiting aggressive protective behaviour if breeding (Richardson *et al.* 1995). Pinnipeds avoid disturbance from humans by leaving the haul-out site, temporarily (Richardson *et al.* 1995, Shaughnessy 1999). This avoidance can reduce breeding success as feeding activity may be disrupted or mothers may be unable to relocate their pups, increase juvenile mortality as pups may get squashed from larger fleeing animals or may not be strong enough to swim back to the colony, and interfere with the energy balance of seals (Richardson *et al.* 1995, Shaughnessy 1999). While pinnipeds may habituate to regular human activities in their vicinity, especially when not breeding or if they are not directly threatened by the disturbance, they may also abandon a haul-out site at least partly in response to human disturbance (Richardson *et al.* 1995).

2.1.6.2. Reptiles

Activities that occur on or adjacent to shorelines, such as beach fishing, all-wheel driving and boating, affect the successful nesting of sea turtles (Environment Australia 2003). Sea turtles reaction to disturbance from human-induced noise varies with different frequencies and intensities of sound (Environment Australia 1998a). In response to low frequency sounds under experimental conditions sea turtles have at least startled (Lenhardt *et al.* 1983). The available information on the potential effects of persistent noise, such as that from boating and shipping, on sea turtles is inconclusive (Environment Australia 1998a).

2.1.6.3. Avifauna

It is mostly the colonial seabirds, shorebirds, waders and sea ducks that are affected by disturbance from fishing and boating activity and shore and land based activities such as walking, all-wheel driving, fishing and bait digging. The degree to which these animals are affected by these disturbances is influenced by the number of people in the vicinity, the proximity of people to the birds and the type of activity they are undertaking (Thomas *et al.* 2003). Excessive disturbance at beach-nesting sites, intertidal feeding grounds and high tide roosts is one of the five major threatening issues identified in relation to the conservation of waders at NSW wetlands (Smith 1991).

Avifauna moves away from the disturbances considered under this section (Kingsford 1990, Burger 1998, Skilleter 2004). This avoidance can reduce their foraging time, increase their energy expenditure and disrupt incubation, leaving eggs exposed (Burger 1991, Roberts and Evans 1993, Weston 2000). Human activities can also directly crush the eggs and chicks of avifauna. When human presence is frequent or it occurs for long periods of time around nesting avifauna, reduced breeding success and growth of avifauna and sometimes abandonment of breeding colonies can result (see references in Burger 1998, Weston 2000). If energetic requirements cannot be met because of sustained disturbance from human presence in an area, avifauna can shift to alternative, perhaps less favourable, feeding grounds (Vines 1992, Cayford 1993, Goss-Custard and Verboven 1993). Migratory shorebirds are particularly susceptible to disturbance from human presence in the few months before their migration. They require undisturbed feeding areas at this time so as to accumulate sufficient energy reserves for the journey (Smith 1991, Paton *et al.* 2000). Avifauna can habituate to levels of disturbance from human presence in an area (Parsons and Burger 1982, Weston 2000, Frederick 2000).

2.2. Ecological interactions

2.2.1. Competitive and trophic interactions

Most marine wildlife groups are higher order predators that occupy top trophic levels in the marine ecosystem. Competition between wildlife and fishers can occur when they take the same species (consumptive competition) or when wildlife feeds on lower trophic levels that harvested species use for prey (food-web competition). The degree of such competition in an area is influenced by the: overlap between wildlife prey species and the species fished; level and distribution of fishing effort; size of the wildlife population and its foraging range and behaviour, dietary requirements and diversity of prey species; and availability of prey items (Harwood 1983, Harwood and Croxall 1988, Baraff and Loughlin 2000, Environment Australia 2001a). This competition can result in increased foraging time, changes in dietary preferences, reduced breeding success and population declines for marine wildlife (Anderson *et al.* 1982, Shaughnessy 1985, Monagahan *et al.* 1989, Camphuysen and Garthe 2000). Fishers, especially those operating in enclosed waters, can suffer economic losses when foraging wildlife decrease stock levels (Montevecchi 2002). It is the wildlife species that feed upon fish, which are most likely to compete for harvested stocks.

There is a general belief amongst fishers that marine wildlife are their main competitors for fisheries resources (Kirkwood *et al.* 1992, Tasker *et al.* 2000, Goldsworthy *et al.* 2003). This results in calls to cull marine wildlife numbers, particularly when local populations are large or increasing (Kirkwood *et al.* 1992, Tasker *et al.* 2000, Goldsworthy *et al.* 2003, Lavinge 2003). While marine wildlife populations are sometimes reported to consume more fish resources than total fishing harvests in some areas (Kenney *et al.* 1997, Goldsworthy *et al.* 2003), carnivorous fish are also reported to be the main consumers of fish resources in the marine ecosystem (Bax 1991) and marine wildlife also feed upon non-commercial species (Trites *et al.* 1997). Despite the fact that marine wildlife are probably not

fishers' main competitors for fisheries resources, the culling debate is popular and will increase in the future as previously hunted wildlife populations recover (Kirkwood *et al.* 1992, De Master *et al.* 2001, Lavinge 2003).

Fishing can disrupt the trophic balance of an ecosystem through a process known as fishing down the food chain or by changing predator-prey relationships through the removal or depletion of key species within food webs (Christensen 1996, Pauly *et al.* 1998, Pitcher and Pauly 1998, Pitcher 2001, Reynolds *et al.* 2002). The changes in prey abundance and availability resulting from such trophic interactions can have both positive and negative consequences on marine wildlife populations (Furness 1982, 1984, Au and Pitman 1988, Alverson 1992, Goldsworthy *et al.* 2003). Such effects are often discussed alongside the closely linked effects resulting from competitive interactions (Furness 1982, Dans *et al.* 2003, Goldsworthy *et al.* 2003).

2.2.1.1. Mammals

The main concerns about competitive / trophic interactions between marine mammals and fisheries is that predation by marine mammals can significantly impact upon harvested stocks and that over-fishing may be limiting the size and/or recovery of marine mammal populations (Goldsworthy *et al.* 2003). The ecological role of marine mammals in marine ecosystems and their trophic interactions with fisheries has not been widely studied (Goldsworthy *et al.* 2003). Trites *et al.* (1997) found that as a group, the marine mammals in the Pacific Ocean mostly preyed upon species that cannot be harvested or consumed by humans, thus limiting the extent of consumptive competition between fisheries and marine mammals. They also reported that the mammal groups for which a high proportion of their prey species were also harvested by fishers were pinnipeds (60%) and small cetaceans (dolphins and porpoises) (50%) (Trites *et al.* 1997).

Many studies on this interaction with marine mammals have focussed on pinnipeds (David 1987, Alverson 1992, Butterworth *et al.* 1995, Punt *et al.* 1995, Goldsworthy *et al.* 2003). Pinnipeds are generally not significantly directly affected by consumptive competition with fishers as they can switch to alternative sources of prey (Shaughnessy 1985) and consume considerably different size-classes of fish to those harvested (Dans *et al.* 2003). The harvesting of the main competitor of seal prey resources (i.e. large fish) may benefit seal populations. For example, the recent recovery of fur-seal stocks in southern Australia may be partly due to the increased harvesting of demersal fish, many of which are competitors of seals (Goldsworthy *et al.* 2003). Goldsworthy *et al.* (2003) anticipate that fur-seal populations in Australia will recover to and perhaps even exceed pre-exploitation levels. It is predicted, with caution, that this increase in seal biomass will not impact the total fish biomass available to fisheries production overall, largely as the fish biomass available to some fisheries will decrease, while that available to other fisheries will increase (Goldsworthy *et al.* 2003).

Fishing activities are most likely to compete with whales, especially baleen and beaked whales, at the primary production levels of the food web (Trites *et al.* 1997). However, some consumptive competition for fish prey may occur with toothed whales when they feed on harvested fish species (Katona and Whitehead 1988).

2.2.1.2. Avifauna

In the open ocean, competitive / trophic interactions are more likely to affect seabirds than fishers. By removing large fish predators that compete with birds for common food resources an increase in small fish prey can result, leading to increases in seabird populations (Sherman *et al.* 1981, Furness 1982, 1984, Daan *et al.* 1990) and increased growth of chicks (Springer *et al.* 1986). If the large predatory fish removed by fishers are those that drive small fish to the water's surface (e.g. tuna), the availability of seabird prey can be reduced (Au and Pitman 1988). This may have a negative effect on seabird

populations, especially those that feed at the surface (Au and Pitman 1988).

Fishing harvests of the same size-classes of seabird prey can cause stocks of their prey to reduce or collapse, resulting in seabirds switching their prey preferences, spending more time foraging, abandoning nesting attempts, starving and eventually experiencing a population decline through reduced breeding success (Anderson *et al.* 1982, Montevecchi *et al.* 1988, Monagahan *et al.* 1989, Vader *et al.* 1990, Hamer *et al.* 1991, Montevecchi and Myres 1995, 1996, Camphuysen and Garthe 2000). The species most vulnerable to fishery-induced food shortages are those with energetically expensive foraging methods, those restricted to foraging close to breeding colonies, those limited to using a specialised and inflexible foraging method, those unable to dive below the surface, and those that are unable to allocate extra time to foraging if food were scarce (Furness and Tasker 2000).

In nearshore, semi-enclosed and enclosed bodies of water, the competitive predation of fish stocks by fish eating birds (e.g. cormorants) is thought to reduce potential fishing catches or damage fish (Britton *et al.* 2003, Wolter and Pawlizki 2003), potentially having economic implications for fishers (Cowx 2003). Cormorants can consume a considerable amount of commercial fish resources in these habitats (Coutin and Reside 2003, Eschbaum *et al.* 2003). While predation by piscivorous birds on fish in freshwater systems has been shown to result in substantial reductions of fish available to fishers, long-term reductions in the stocks of harvested fish in these habitats has not been proven (Wolter and Pawlizki 2003). Results from the numerous studies on the consequence of cormorant predation are ambiguous (Davies *et al.* 2003, Stempniewicz *et al.* 2003). However, Britton *et al.* (2003) found that cormorant predation in an English freshwater lake reduced the availability of fish for angler exploitation in subsequent years.

The harvesting of shellfish and other invertebrates from shorelines, for commercial and recreational purposes, can deplete the prey stocks of shorebirds, the extent of which is depends upon the resilience of the prey stock (Beukema and Cadée 1996, Shepherd and Sherman Boates 1999, Skilleter 2004). This can contract the foraging area of shorebirds, causing them to move to alternative foraging sites, switch to alternative sources of prey, suffer from a reduced foraging efficiency, starve or if such prey reduction occurs over a large area, increase the mortality of these species (Norris *et al.* 1998, Tasker *et al.* 2000, Camphuysen *et al.* 2002, Skilleter 2004). For migrating shorebirds, this interaction can delay their arrival on wintering grounds or force the birds to depart without sufficient fat loads (Shepherd and Sherman Boates 1999).

2.2.2. Habitat interactions

The loss of, or reduction in quality of, the breeding and feeding habitats of marine wildlife, especially that in well developed coastal and shoreline areas, is a major threat to the survival of many marine wildlife species (e.g. dugongs, shorebirds, waders and sea turtles). Activities or events, including fishing-related activities, which contribute to this threat include those that physically disturb the seabed or shoreline habitats, and spills of oil or fuel from vessels.

Fishing-related all-wheel driving, walking, bait digging, trawling and the construction of fishing-related coastal developments, such as boat ramps, moorings, jetties and pontoons, can physically modify, damage or destroy the sandy beach and shoreline habitats of shorebirds, waders and sea turtles and the seagrass habitats of sea turtles and sirenians (Kingsford 1990, Marsh *et al.* 2002, McPhee *et al.* 2002, Environment Australia 2003, Skilleter 2004). Of these activities, those occurring on shorelines can reduce the availability of invertebrates to foraging birds by compacting sand and destroying habitat (Kingsford 1990, Environment Australia 2003), damage or destroy suitable sea turtle and bird nesting habitats and the nests of these animals (Environment Australia 2003), and create barriers, for example wheel ruts, that may impede or stop the movement of turtle hatchlings towards the water (Environment Australia 2003). Bait digging, trawling and the construction of boating facilities can

damage or destroy seagrass habitat (Marsh *et al.* 2002, Skilleter 2004). The loss of seagrass habitat, is a major threat to dugong survival (Marsh *et al.* 2002).

Spilt oil and fuel can be a dramatic source of marine habitat degradation, especially if the spill is excessively large. While fishing vessels are not listed as a major source of oil pollution in the sea (World Resources Institute 1990), small spills do originate from these vessels. Avifauna, pinnipeds, sea turtles and cetaceans have varying responses to contact with oil spills, which are influenced by the type of oil spilt and the length of time the animals are in contact with the spill. The smothering of a bird's plumage with oil can reduce its insulation, waterproofing, buoyancy and mobility, and often results in mortality from increased heat loss, metabolism, starvation and drowning (Environment Australia 2001a). Pinnipeds too are vulnerable to negative effects from oil spills, especially fur-seals as they rely on clean fur for insulation (Shaughnessy 1999). Baleen whales do not appear to be directly affected by oil spills (Clapham *et al.* 1999). However, general concerns about oil pollution, such as prey contamination, irritation of skin and eyes and destruction or pollution of feeding habitats, could affect this and the other marine wildlife groups (Geraci and St. Aubin 1980, Geraci 1990, Environment Australia 2001a).

2.3. Chapter summary

The response of marine wildlife to interactions with fishing activities varies between and among species. Effects from these responses can range from being positive, through inconsequential to severe. The response of some animals may change over time as they adapt, familiarise or habituate to any resulting disturbances that are generally non-threatening. The effects experienced by fishers from interactions with marine wildlife, which can have inconsequential, positive or negative consequences for fishers, vary between areas, gear types and fisheries. For interactions that have negative consequences for fishers or directly threaten the survival of marine wildlife species, fishers have generally tried some form of mitigation or management measure to ameliorate the problem, some of which have been successful.

The fishing-related interactions discussed in this chapter that have been documented to threaten the survival of marine wildlife populations and/or result in significant impacts for fishers around the world are the foraging of marine wildlife from fishing activities, their incidental capture on fishing gear, competition and trophic interactions, disturbance from noise and the physical presence of fishers, and sometimes the collision of marine wildlife with fishing vessels (Table 4). In terms of incidental capture of marine wildlife in fishing gear, only some fishing methods have been reported to threaten the survival of marine wildlife populations, most notably trawling activities with mammals, reptiles and avifauna; longlining with sea turtles and seabirds; handlining with estuarine and coastal birds; passive net techniques with mammals and avifauna; purse-seine netting with mammals; and trapping with seals.

Table 4: A summary of the operational and ecological interactions that have been reported between marine wildlife and fishing activities around the world.

Fishery / Fishing gear type	**Wildlife group**	**Influencing factors:**		**Effects:**	
		Biological	***Fishing-related***	***On wildlife***	***On fishers***
Operational interactions					
Interaction: Deliberate harvest of marine wildlife *Brief description: The deliberate killing or harvesting of marine wildlife by fishers for food, sport, bait or indigenous purposes.*					
Indigenous fishing (legal); and all other fisheries (illegal).	Pinnipeds; dolphins; and seabirds are illegally shot. In Australia, indigenous harvests include dugongs; sea turtles and shearwaters.	Local spatial and seasonal distribution and abundance of marine wildlife species; suitability of the species for food and bait; the time the animals spend at or above the water's surface; their feeding and foraging strategies; their diet and energy requirements; and behaviour.	Targeted species; location, season and time of day fished; effort; perception of the animal by fishers; and management arrangements.	(-ve direct) Death of targeted animals. (-ve indirect) May contribute to decline of marine wildlife populations.	(+ve direct) Reduced losses from animals foraging around their activities.
Interaction: Feeding on bait catch or discards *Brief description: The foraging of marine wildlife on the regular concentrated food source created by fishing bait, catch and biological discards. When in the vicinity of fishing operations marine wildlife can scare away the targeted catch.*					
Trawls; traps (lobster, other); line techniques (longlining, droplining, handlining, trolling, poling, jigging); and nets (purse-seine, beach-seine, prawn-seine, haul, drift, gill and set).	Pinnipeds; odontocetes (dolphins, porpoises and killer, false killer, pilot, sperm, fin and bottlenose whales); minke whales; sea turtles (loggerhead); seabirds; and other avifauna.	Local spatial and seasonal distribution and abundance of marine wildlife species; their feeding and foraging strategies; and their diet and energy requirements.	Location, season and time of day fished; gear type used; species harvested, discarded or used as bait; length of time these food sources remain near the surface; amount discarded; and effort.	(+ve direct) Can obtain a significant portion of their energy requirements from this food source and become dependent on it; availability of otherwise unobtainable food niches; and increase in fitness and survival. (+ve indirect) For dependent populations: expanded local distribution; altered foraging range and strategy; improved breeding success; reduced juvenile mortality; and increased population. (-ve indirect) Increased risk of capture / entanglement, collision or being deliberately killed; poisoning from ingestion of lead sinkers; death from ingesting hooks embedded in discards; and a reduced breeding success and population numbers if food source is removed.	(-ve direct) Catch losses; gear damage; loss of fishing time; reduced fishing opportunities and survival of discarded commercial species; and damaged catch. (-ve indirect) Economic losses.

Table 4 - continued

Fishery / Fishing gear type	**Wildlife group**	**Influencing factors:**		**Effects:**	
		Biological	***Fishing-related***	***On wildlife***	***On fishers***
Operational interactions					
Interaction: Incidental capture or entanglement in active fishing gear *Brief description: The entanglement or capture of marine wildlife when feeding around or from fishing gear or swimming in its vicinity.*					
Trawls; line techniques (longlining, handlining, setlining, trolling, jigging); nets (purse-seine, drift, gill, set and mesh); and traps (lobster, crab and other).	Pinnipeds; cetaceans; sirenians; sea turtles; sea snakes; and avifauna.	Local spatial and seasonal distribution and abundance of marine wildlife species; their foraging strategy, locations and diet; behaviour; sensory capabilities; social pattern; preferred habitat; age; size; morphology; and activity being undertaken at time of interaction.	Location, season and time of day fished; gear type, design and dimension used; precise fishing method; species harvested; stage of fishing activity; effort; use of mitigation measures; and handling of animals once caught.	(-ve direct) Death; injury; and coma. (-ve indirect) Death; and population and species decline. (other) Relatively no effect.	(-ve direct) Damaged or lost gear; and lost fishing time. (-ve indirect) Economic losses; and perhaps closure of fishery if frequent fatal interactions threaten wildlife survival.
Interaction: Interactions with fishing debris *Brief description: The entanglement of marine wildlife in or their ingestion of fishing-related marine debris.*					
All fisheries, especially those using gear that can be lost or broken.	Pinnipeds; cetaceans; sirenians; sea turtles; and avifauna (especially seabirds, surface feeding birds and chicks).	Local distribution and abundance of marine wildlife species, especially in areas where debris accumulates; their diet and feeding strategy; their level of activity at the water's surface; and their behaviour.	Gear type used; amount of gear lost at sea; amount of other debris lost at sea; type of debris item; distribution of fishing activity; and effort.	(-ve direct) Death; injuries or wounds that may be infected; reduced ability to travel, catch food or avoid predators; lessened feeding drive; and inhibited diving ability. (-ve indirect) Reduced survival, reproductive ability, and immunity; and contribution to the decline of marine wildlife populations.	N/A

Table 4 – continued

Fishery / Fishing gear type	**Wildlife group**	**Influencing factors:**		**Effects:**	
		Biological	***Fishing-related***	***On wildlife***	***On fishers***
Operational interactions					
Interaction: Collision *Brief description: The physical encounter of marine wildlife with vessels and/or fishing gear whilst swimming or foraging.*					
All fisheries that use boats and/or gear that is set or towed through the water.	Pinnipeds; sirenians; baleen whales; cetaceans (dolphins, and pilot and sperm whales); sea turtles; and avifauna.	Local abundance of vulnerable marine wildlife species (i.e. those that are diseased, slow, spend much time at the water's surface, are attracted to vessels for food or use habitats in the vicinity of major shipping lanes or boating areas); the size of the animal; and the activity it is undertaking.	Location of boating and fishing activities; gear type used; size and speed of fishing vessel; effort; and other fishing-related factors influencing the feeding activity of marine wildlife around fishing gear (listed above).	(-ve direct) Death; and injury. (-ve indirect) Could be a significant threat to wildlife populations. (other) relatively no effect.	(-ve direct) Vessel and gear damage; and lost fishing time. (-ve indirect) Economic losses. (other) no effect.
Interaction: Noise, site access and physical presence of fishers *Brief description: The response of marine wildlife to the physical non-contact disturbance caused by noise from fishing vessels and gear operation, the access of fishing sites and the physical presence of fishers.*					
All fisheries, especially those operating on or near shorelines.	Pinnipeds; sea turtles; colonial nesting seabirds, shorebirds, waders and sea ducks (mostly when on or near land); and cetaceans.	Local spatial and seasonal distribution and abundance of marine wildlife species; the use of habitats in the vicinity of fishing activities; the activity they are undertaking; and their ability to tolerate or habituate to this disturbance.	Location and season fished; type of fishing activity, how it is being undertaken, the type of noise generated from it and its proximity to marine wildlife; type of vessel; and effort.	(+ve direct) Attracted species indicate some sort of gain. (-ve direct) Reduced foraging time; increased energy expenditure; disrupted incubation / nursing; changes in behaviour, activity or group size or cohesion; death; increased juvenile mortality; crushing of eggs and chicks; and shift to alternative feeding ground. (-ve indirect) Reduced breeding success and growth; breeding colony abandonment (sometimes); avoidance of highly disturbed areas; and reduced migratory ability of some species. (other) Relatively no effect; and may tolerate or habituate to the disturbance.	N/A

Table 4 – continued

Fishery / Fishing gear type	**Wildlife group**	**Influencing factors:**		**Effects:**	
		Biological	***Fishing-related***	***On wildlife***	***On fishers***
Ecological interactions					
Interaction: Competition and trophic interactions *Brief description: Marine wildlife and fishers competing for the same fish and invertebrate resources. Marine wildlife feeding on lower trophic levels that are the prey of harvested species. The trophic imbalances created from the removal or depletion of species within food webs.*					
All fisheries.	Pinnipeds; dolphins; whales; seabirds; shorebirds; waders; and other fish-eating birds.	Local distribution and abundance of marine wildlife; their diet and energy requirements; their foraging area and feeding strategy; and the availability of prey items.	Location and season fished; species, amount and size-class harvested; effort; and, if undertaken, the level of culling activity.	(+ve indirect) Increase in population numbers from increased populations of small fish prey. (-ve direct) Reduced / collapsed prey stocks result in: increased foraging time; contracted foraging area; movement to alternative foraging sites; decreased foraging efficiency; abandoned nesting attempts; and changes in diet. (-ve indirect) Reduced breeding success, population size and recovery, and migratory ability of some species; and death from culling. (other) Relatively no effect.	(+ve indirect) Economic gain from increased stock levels. (-ve indirect) Economic losses from reduced stock levels, fish availability and damage.
Interaction: Habitat interactions *Brief description: The destruction, degradation or modification of marine wildlife habitat as a result of fishing-related activities (includes the wider effects of oil spills, shoreline activities and destructive fishing methods such as trawling).*					
Fishing types that involve: accessing shore sites with all-wheel drives or by walking; bait digging; trawling; and the use of vessels and associated facilities (e.g. boat ramps, and jetties).	Cetaceans; sirenians; sea turtles; seabirds; shorebirds; and waders.	Local abundance and preferred feeding and breeding / nesting habitat of marine wildlife species; their diet and foraging method; and level of contact with oil spill.	The type of fishing activity; gear type used; vessel size and power; oil / fuel type used; area and habitat fished; effort; the use of oil spill cleanup measures; and the type and number of boating support facilities required.	(-ve direct) Reduced availability of food and suitable nesting habitats; destruction of nests; reduced insulation, waterproofing, buoyancy, and mobility; increased heat loss, metabolism and risk of starvation; irritation of skin and eyes; and contamination of prey and feeding habitat. (-ve indirect) Death. (other) Relatively no effect.	N/A

3. FISHING ACTIVITIES MANAGED BY THE NSW GOVERNMENT IN MARINE AND ESTUARINE WATERS

Aspects of the fisheries managed by NSW Department of Primary Industries (DPI) that influence their interaction with marine wildlife are summarised. Information on the existing reports of interactions between these fisheries and marine wildlife is also provided.

NSW DPI fishing activities that occur in marine and estuarine waters, where they could potentially interact with marine wildlife, comprise of eight commercial fisheries, a recreational fishery and beach protection netting (Table 5). Excluding closures in protected areas, the total area of operation of these fisheries is from the shores to 80 nm offshore, although the recreational fishery can operate beyond these limits (Table 5). Commonwealth managed fisheries also operate in the offshore waters off NSW from 3 – 200 nm. Under the Offshore Constitutional Settlement (OCS) of 1991, NSW manages all fishing activities within 3 nm, and the fishing for all species except tuna, billfish and some pelagic species from 3 to about 80 nm. Under the OCS, NSW DPI is also not responsible for the management of otter trawling activities outside of 3 nm south of Barrenjoey Point. Commonwealth fisheries are not assessed in this study, as NSW DPI has no statutory control over these fisheries.

Table 5: The area of operation of the fishing activities managed by NSW DPI that are assessed in this report.

Estuaries	**Coastal shores**	**Inshore waters (to 3 nm)**	**Offshore waters (from 3 – 80 nm)**
Estuary General Estuary Prawn Trawl Recreational	Estuary General Ocean Hauling Recreational	Ocean Hauling Ocean Trawl Ocean Trap and Line Lobster Abalone Sea Urchin and Turban Shell Recreational Beach Protection Netting	Ocean Trawl Ocean Trap and Line Lobster Recreational

3.1. Description of fishing activities

3.1.1. The Estuary General Fishery

This is a summary of a more detailed fishery description located within the '*Estuary General Fishery - Environmental Impact Statement'* (NSW Fisheries 2001).

Brief description: The Estuary General Fishery harvests approximately 90 species of finfish and shellfish from estuarine waters using 17 major gear types and takes beachworms and pipis by hand from ocean beaches.

Area of operation: This fishery occurs in 102 estuaries along the NSW coast between a line drawn across the entrance of the estuary to a line, upstream, identified as the tidal limit. In some estuaries, parts of this area are permanently closed to this fishery. The fishery can hand gather on all NSW ocean beaches, except where closures apply.

Season of operation: Nearly all gear types can be used throughout the year. However, weekend fishing closures are in force in many estuaries.

Gear used: Small 'run-about' or 'punt' style vessels (3 - 6 m in length) with outboard motors are used. A range of hauling and meshing nets to target finfish, nets to target prawns, traps to target finfish, crabs and eels (in all 14 types of nets and three types of traps), handlines and handgathering can be used in this fishery. The use of each gear type is restricted to specified estuaries and within some of these estuaries restricted to specific areas. Details about the permitted dimensions of each gear type, and its location and method of use are provided in Appendix 1.

Effort: There are approximately 723 fishing businesses, with large variations in activity levels, in this fishery. Fishers can only operate within specified regions the number endorsed to use each gear type in each region is illustrated in Table 6. The effort exerted on the gear in this fishery varies between fishing regions, estuaries and seasons. This fishery most frequently uses mesh nets, traps, hand gathering, general purpose hauling nets and the various prawn nets (NSW DPI fisheries catch statistics database 2003).

Table 6: The number of endorsements per gear type by region in the Estuary General Fishery (at August 2002).

Class of endorsement	Estuary general region							NSW total
	1 border to 29°15'S	2 29°15'S to 29°45'S	3 29°45'S to 31°44'S	4 31°44'S to 33°25'S	5 33°25'S to 34°20'S	6 34°20'S to 35°25'S	7 35°25'S to border	
Crab trap (authorises use of crab trap)	19	59	46	100	15	4	4	247
Eel trap (authorises use of eel trap)	6	46	29	60	14	18	19	192
Fish trap (authorises the use of fish trap and hoop or lift net)	4	24	32	103	33	5	10	211
Hand gathering	21	3	29	40	2	15	4	114
Handlining & hauling crew (authorises the commercial fisher to take fish for sale from estuaries using a handline or by assisting another commercial fisher with a category one or category two hauling endorsement)	46	149	69	239	85	59	56	703
Hauling Category 1 (authorises the use of general purpose hauling net, trumpeter whiting net, pilchard, anchovy and bait net, garfish hauling net, garfish bullringing net, bait net)	10	27	9	66	23	17	15	167
Hauling Category 2 (authorises the use of garfish hauling net, garfish bullringing net, bait net)	9	31	19	56	14	18	13	160
Meshing (authorises use of meshing and flathead net)	43	119	55	204	67	56	47	591
Prawning (authorises use of prawn hauling net, prawn seine net, prawn set pocket net, prawn running net, hand-hauled prawn net, push or scissor net and a dip or scoop net)	26	109	34	190	13	45	46	463

Targeted catch: The fishery harvests approximately 90 species, although 99% of the catch by total landed weight is comprised of 44 species or species groups (NSW DPI fisheries catch statistics database 2002/03). The top ten species targeted are sea mullet, luderick, yellowfin bream, school prawns, dusky flathead, blue swimmer crab, sand whiting, silver biddy, longfinned eels and pipis.

Discarding of biological material: Discards mostly consist of juveniles of commercial species and non-commercial species (Gray 2001, Gray *et al.* 2001, Gray 2002). Most bycatch is discarded when the catch is initially sorted and prawn fishers may also discard small prawns on another separate occasion, after riddling. The amount and composition of bycatch captured by the various estuary methods varies between years and estuaries (Gray 2001, 2002). The different gear types used in the fishery have varying selectivity and catch different amounts of bycatch. Bycatch studies on the various gear types in this fishery show that fewer discards appear to result from meshing activity than fish hauling activity (Gray *et al.* 2001, Gray 2002), less amounts of bycatch appear to result from prawn seine-net activities (Gray 2001), and small amounts of bycatch are captured in set pocket nets but this increases during flood events (Andrew *et al.* 1995). Methods in this fishery that usually capture no or very small amounts of bycatch and discards are hand gathering, handlines, mid-water hauling nets, prawn hauling and running nets and traps.

This fishery does not process its catch and is prohibited from doing so on or adjacent to water. Subsequently fish parts and offal are not directly discarded into waterways.

Debris and ghost fishing contribution: Nets from this fishery are unlikely to contribute to ghostfishing as they are set in sheltered waters where they can be easily retrieved if lost or are generally attended when used. Fishers may lose traps, especially if they are set in deep water and/or the headline is lost from the trap, the rate at which this occurs in this fishery is unknown. It is the head-gear from lost traps that poses a risk to marine wildlife. Sections of handlining gear can be released into the water column when they snag or break. Marine wildlife can become entangled in fragments of this gear.

Any dumping of debris or rubbish by this fishery into waterways is only likely to be minor and accidental and consist of small pieces or bags of plastic or fishing gear. The fishing process itself generally does not generate large volumes of debris and the incidence of it accidentally reaching waterways would be low.

Reported interactions with marine wildlife: Although the scientific observer studies on the bycatch from the gear types in this fishery were not specifically designed to document incidental captures of marine wildlife, no such captures were observed or reported in these studies (Andrew *et al.* 1995, Gray 2001, Gray *et al.* 2001, Gray 2002).

The development of discard chutes to increase bycatch survival by mesh net fishers in this fishery and the now mandatory requirement for these chutes to be used when mesh and flathead nets are used during daylight hours, suggests that these fishers have problems with birds feeding on their discards during daylight hours. These birds are mostly pelicans and Johnson (2002a) described them as a 'gill-netters worst enemy'. Apart from foraging on discards, Johnson (2002a) also stated that pelicans often remove fish from gill (mesh) nets and tear the nets in the process.

3.1.2. The Estuary Prawn Trawl Fishery

This is a summary of a more detailed fishery description located within the '*Estuary Prawn Trawl Fishery - Environmental Impact Statement'* (NSW Fisheries 2002).

Brief description: The Estuary Prawn Trawl Fishery uses otter trawl nets in the Clarence, Hunter and Hawkesbury Rivers and Port Jackson over a defined season to target prawns and also squid in the Hawkesbury River.

Area of operation: This fishery can only operate within defined areas of the Clarence, Hunter and Hawkesbury Rivers and Port Jackson. Trawling is prohibited in some of these defined areas, especially over *Zostera* and *Posidonia* seagrass beds.

Season of operation: Trawling activities on the Hawkesbury River are permitted throughout the year. In all other trawled estuaries, the fishery can only operate during defined seasons, generally from October to May. Trawling in estuaries is prohibited on weekends and public holidays.

Gear used: Vessels used in this fishery, of planning or displacement hull designs, range from 4 -17 m in length, and 6.3 – 156.6 kW in engine power. The otter trawl net used in this fishery is attached to the vessel by warps (wire ropes). The vessel is used to tow the net, which is held open by two small flat boards (otter boards) that are attached to the net with short ropes (ropes), along the seabed. There are restrictions on the size and number of otter trawl nets that can be used (Appendix 1). These nets, except those used in Broken Bay (Hawkesbury River), must be fitted with an approved bycatch reduction device. Trawling on the Clarence and Hunter Rivers is permitted during the daytime only, while that in Port Jackson is only permitted at night. Trawling on the Hawkesbury River is permitted during both the day and night.

Effort: There are 225 entitlements to fish, some of which are inactive or seldom used, held amongst 219 businesses in this fishery. The number of endorsements allocated to each estuary indicates the maximum number of boats that can trawl within that estuary (Table 7). Generally, most of the effort in the fishery is concentrated on the Clarence and Hawkesbury Rivers, the Hunter River and Port Jackson are trawled much less frequently (NSW DPI fisheries catch statistics database 2003).

Table 7: Number of prawn trawl endorsements per estuary (as at September 2002).

Estuary	Number of endorsements
Clarence River Access to Lake Wooloweyah and the Clarence River	112
Access to Lake Wooloweyah only	2
Hunter River	29
Hawkesbury River	61
Port Jackson	21

Targeted catch: This fishery targets school and eastern king prawns in all estuaries, and squid in the outer part of the Hawkesbury River. Target species accounted for 89% of the total annual reported landings by this fishery during 2002/03. This fishery can also land a further 24 non-target species, known as byproduct, in small quantities.

Discarding of biological material: Most bycatch in this fishery is discarded when the catch is initially sorted and small prawns are also discarded on another separate occasion, after riddling. The amount of bycatch currently discarded by this fishery is unknown as it has not been investigated since bycatch reduction devices were introduced. Studies completed before these devices were used found that this fishery discarded large quantities of bycatch (Liggins and Kennelly 1996, Liggins *et al.* 1996). This consisted of juveniles of commercial species, non-commercial species and species that cannot be landed by the fishery, such as those with a minimum size limit and generally included a few crustacean and mollusc species and many finfish species (Gray *et al.* 1990, Liggins and Kennelly 1996, Liggins *et al.* 1996).

This fishery does not process its catch and is prohibited from doing so on or adjacent to water. Subsequently fish parts and offal are not directly discarded into waterways.

Debris and ghost fishing contribution: Nets from this fishery are rarely lost as they are attached to the vessel, continually attended to by fishers and are used in sheltered waters where they can be easily retrieved if lost. While pieces of netting may be torn from the net if it becomes snagged on an object, these pieces are not likely to be large enough to contribute to the ghost fishing of marine wildlife. These animals may become entangled in or ingest the smaller net pieces or fragments that may be released into the water column.

Any dumping of debris or rubbish by this fishery into waterways is only likely to be minor and accidental. Fishers are encouraged fishers to retain any debris or rubbish they encounter during the fishing operation for on-land disposal. This includes the small amounts of debris or rubbish generated from the fishing activity itself and that trawled up from the estuary depths.

Reported interactions with marine wildlife: This fishery has only incidentally caught one marine wildlife animal whilst an observer was onboard vessels during the scientific observer studies (Gray *et al.* 1990, Liggins and Kennelly 1996, Liggins *et al.* 1996). This animal was a sea turtle captured in the mouth of the Hawkesbury in a trawler that was targeting squid (G. Liggins, NSW DPI, pers. comm. 2003).

The now mandatory use of discard chutes to release bycatch from prawn trawlers in the Hunter River suggests that birds such as pelicans feed on the discarded bycatch in this fishery.

3.1.3. The Ocean Hauling Fishery

This is a summary of a more detailed fishery description located within the '*Ocean Hauling Fishery - Environmental Impact Statement'* (NSW Fisheries 2003a).

Brief description: The Ocean Hauling Fishery uses purse-seine nets and a variety of hauling net types to target species such as sea mullet, luderick, yellowtail, blue mackerel, sea garfish and pilchards from ocean waters and beaches along the NSW coast.

Area of operation: This fishery may operate in ocean waters within 3 nm of the NSW coastline, and the waters of Jervis Bay and Coffs Harbour. Some ocean beaches and waters in NSW are closed to this fishery.

Season of operation: This fishery cannot operate on weekends from November to February. There is a weekend closure on garfish hauling activity throughout the year. This fishery is prohibited on some ocean beaches at certain times of the year.

Gear used: The gear type allowed is target specific and includes the general purpose hauling net, pilchard anchovy and bait net, garfish hauling net, purse-seine net and lift net. Purse-seine and lift nets can only be shot from boats at sea, while the other net types in this fishery can also be used on ocean beaches. Four-wheel drive vehicles are used to access beach sites. Details about the permitted dimensions of each gear type and method of use are provided in Appendix 1.

Small 'run-about' or 'punt' style vessels (3 - 6 m in length), either oar powered or with outboard motors up to 45 horsepower are used in the beach-haul sector of this fishery. Purse-seine vessels are often larger versions of the 'run-about' style or of displacement hull design (between 10 and 50 tonnes).

Effort: Approximately 327 fishers, that use varying levels of activity, are endorsed to operate in this fishery. These fishers are endorsed to take fish for sale from a particular region only. The maximum number of each gear type in this fishery that can be used in each region is illustrated in Table 8. The 17 purse-seine fishers can do so along the whole NSW coast, but most of this activity occurs south of Sydney. The two main methods used in this fishery, general purpose hauling and purse-seining, account for about 90% of its catch. The mullet season (March – June), is a definite season where beach based general purpose hauling nets are used more often.

Table 8: The number of endorsements per gear type by region in the Ocean Hauling Fishery (at September 2003).

Endorsement type		Number of businesses with endorsements							Total
		Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	
		Border to 29°15'S	29°15'S to 29°45'S	29°45'S to 31°44'S	31°44'S to 33°25'S	33°25'S to 34°20'S	34°20'S to 35°25'S	35°25'S to border	
Class A (skipper) **	General purpose hauling net	9	10	22	56	10	9	16	132
	Garfish hauling net	1	0	4	26	8	14	8	61
	Pilchard, anchovy and bait net	9	3	5	10	5	1	0	33
Class A (skipper) total		9	10	20	58	10	16	15	138
Class B (crew) total		15	21	20	66	10	16	24	172
Class C (purse-seine) total		N/A	N/A	N/A	N/A	N/A	N/A	N/A	17

Targeted catch: Approximately 99% of the ocean hauling catch by total landed weight is comprised of less than 20 finfish species (NSW DPI fisheries catch statistics database 2002/03). The catch from each of the methods used in the fishery is dominated by a small number of species and two or three species usually make up more than 80% of landings for each method. The species targeted by the Ocean Hauling Fishery are sea mullet, blue mackerel, jack mackerel, yellowfin bream, sand whiting, Australian salmon, luderick, dart, sea garfish, yellowtail, pilchards, sandy sprat and anchovy.

Discarding of biological material: An observer survey of this fishery is currently being undertaken to document, previously unknown, information about the composition, quantity, spatial and temporal aspects of the bycatch discarded in this fishery. Anecdotal reports suggest that only small amounts of fish and invertebrates would be discarded from this target specific fishery.

This fishery does not process its catch and is prohibited from doing so on or adjacent to water. Subsequently fish parts and offal are not directly discarded into waterways. Purse-seine fishers use burley made from baitfish retained from their catches to help aggregate their targeted catch.

Debris and ghost fishing contribution: These fishers are unlikely to lose their gear, and thus are unlikely to contribute to ghost fishing, as they use active methods that must be continually attended and used in areas free of snags or other impediments.

Any dumping of debris or rubbish by this fishery into waterways is only likely to be minor and accidental and consist of small pieces or bags, plastic or fishing gear. The fishing process itself generally does not generate large volumes of debris and the incidence of it accidentally reaching waterways would be very low.

Reported interactions with marine wildlife: No reported interactions between marine wildlife and this fishery have been reported. Rogue seals may occasionally sporadically forage on purse-seine net catches in this fishery, as indicated by the fact that one purse-seine fisher has recently asked management authorities for information about how to legally reduce the impact of such foraging (F. McKinnon, NSW DPI, pers. comm. 2004).

3.1.4. The Ocean Trawl Fishery

This is a summary of a more detailed fishery description located within the '*Ocean Trawl Fishery - Environmental Impact Statement'* (NSW DPI 2004a).

Brief description: The Ocean Trawl Fishery uses demersal otter trawl nets to target fish, crustaceans and molluscs from the marine waters off NSW.

Area of operation: The fishery operates along the whole coast of NSW. North of Barrenjoey Point (Sydney) it can operate from the coast to approximately 80 nm out at sea. South of Barrenjoey Point the fishery can only operate within 3 nm from the coast. Within this area, fish trawling activities are restricted to the area south of a line drawn east of Smoky Cape (South West Rocks), offshore and deepwater prawn trawling is restricted to the area north of a line drawn east of Barrenjoey Pt from 3 to approximately 80 nm and inshore prawn trawling can occur along the whole NSW coast within 3 nm. There are some spatial closures to this fishery within its operational area.

Season of operation: Fish trawling activities can occur throughout the year, so too can prawn trawling activities, except for a closure from September 30 to March 1 in certain north coast locations.

Gear used: This fishery uses otter trawl nets that are towed in a similar fashion to the nets used in the Estuary Prawn Trawl Fishery. Different designs of this gear type are used to target fish and prawns these are described in Appendix 1. All prawn trawl nets in this fishery must be fitted with one of eight approved bycatch reduction devices. Turtle exclusion devices are not mandatory in this fishery. Trawling for fish in this fishery may occur during the day or night, but most prawn trawling occurs at night. Vessels, of displacement hull design, used in this fishery range from 9 - 27 m in length with single or twin diesel engines used (60 - 400 kW, 80 - 540 horsepower).

Effort: Approximately 99 businesses hold fish-trawl endorsements to trawl for fish and 312 businesses hold prawn-trawl endorsements in this fishery (Table 9). Fishing is dependent on suitable weather and oceanographic conditions. Most ocean trawl vessels fish between 50 and 200 days per year.

Trawling for eastern king prawns is mostly concentrated north of Newcastle in depths from 20 to 200 m. Trawling for school prawns mainly occurs in the shallow waters near the north coast estuaries, although some fishing also occurs seasonally on southern grounds. Trawling for deepwater prawns mainly occurs off the central and lower north coasts, between 29°S and 35°S in water 400 – 600 m deep. Trawling targeted at school whiting occurs in depths of 20 - 80 m, mainly north of Sydney. Trawling for fish occurs throughout the range of the fishery on continental shelf and slope grounds in depths of 10 m to 1000 m.

Table 9: The number of businesses with each endorsement type available for trawling in NSW ocean waters (as at February 2003).

Endorsement type	Number of fishing businesses
Ocean prawn trawl (Inshore) – from coastal baseline to 3 nm along whole NSW coast, including waters of Jervis Bay and Coffs Harbour	267
Ocean prawn trawl (Offshore) – from 3 nm to approx. 80 nm, north of Barrenjoey Point	238
Ocean prawn trawl (Deepwater) - from 3 nm to approx. 80 nm, north of Barrenjoey Point (for taking deepwater prawns only)	63
Ocean fish trawl (North) – from coastal baseline to 80 nm between Smoky Cape and Barrenjoey Point	62
Ocean fish trawl (South) – from coastal baseline to 3 nm between Barrenjoey Pt and Victorian border	47

Targeted catch: The top seven species landed by fish trawlers in this fishery in 2002/03 comprised 70% of the landed catch from this gear type and included school whiting, silver trevally and tiger flathead. The top seven species landed by prawn trawlers in this fishery in 2002/03 comprised 88% of the landed catch from this gear type and included school whiting eastern king prawns, octopus, cuttlefish, royal red prawns and Balmain bugs.

Discarding of biological material: Most bycatch in this fishery is discarded when the catch is initially sorted after each trawl shot. Other biological material that can be discarded by this fishery includes the offal from fish that are processed at sea and the water used to cook prawns.

Large quantities of discarded bycatch, comprising of small commercial and non-commercial species of finfish and invertebrates, have been documented in this fishery before the introduction of bycatch reduction devices (BRDs) (Liggins 1996, Kennelly *et al.* 1998), with a spatial and temporal variability in the composition and size of bycatch from fish trawlers being noted (Liggins 1996). Since BRDs were made mandatory in prawn trawlers in 1999, it is possible that smaller quantities of bycatch are being discarded by this fishery, but this has not been scientifically documented. Some incidental captures of marine wildlife in the fish trawl nets of this fishery have been observed (Liggins 1996).

Debris and ghost fishing contribution: Although these nets are continually attended to by fishers, they can be lost when they 'hook up' on underwater impediments. The degree to which this rarely lost gear contributes to ghost fishing is minimised by fishers avoiding areas where net damage could result or, where possible, retrieving the lost net. The loss of large pieces of trawl gear and trawl net fragments by this fishery has been documented by Herfort (1997), although the rate at which this occurs is unknown.

Aside from net pieces, the only debris item originating from trawl vessels that could be of concern to marine wildlife are small pieces or bags of plastic. Any dumping of such items by this fishery is only likely to be minor or accidental as its activities do not generate rubbish.

Reported interactions with marine wildlife: Although not specifically targeted at recording interactions with marine wildlife, scientific observations of this fishery did document some incidental captures of these animals, all of which were in fish trawling gear (Liggins 1996). In all, three sea turtles (unspecified species) were caught in 590 observed tows north of Newcastle; two seals (unspecified species) were caught in 897 observed tows off Ulladulla; and 27 seals (unspecified species) were caught in 1109 observed tows off Eden (G. Liggins, NSW DPI, pers. comm. 2003). Some of the seals may have been caught in Commonwealth grounds.

Bottlenose dolphins have been documented feeding on the catch of this fishery both when it is discarded overboard during sorting and by actively manipulating the cod-end when at the seabed during towing and at the surface during retrieval (Broadhurst 1998). In his videographic observations, Broadhurst (1998) did not observe the dolphins to chase or consume any of the fish escaping from the bycatch reduction device. The observed foraging behaviour of bottlenose dolphins around trawling activities was indicated to be well established and the amount consumed could not be determined (Broadhurst 1998).

Seals on the NSW south coast were found to create problems for trawl fishers in the area when they forage on the catch sticking out of the nets, damaging the catch and nets in the process (Hickman 1999). Trawl fishers in the area also reported slight problems from seals being rarely hauled on board (Hickman 1999). Although the documented operational interactions in the area can be frequent, especially foraging interactions, overall trawl fishers on the NSW south coast generally did not consider these interactions with seals to significantly affect their activities (Hickman 1999).

3.1.5. The Ocean Trap and Line Fishery

This is a summary of a more detailed fishery description located within the '*Ocean Trap and Line Fishery - Environmental Impact Statement'* (NSW DPI, In Prep.).

Brief description: The Ocean Trap and Line Fishery uses demersal fish traps and numerous line methods to target demersal and pelagic fish along the NSW coast and spanner crabs north of Korogoro Point (near Hat Head).

Area of operation: This fishery can operate from the NSW coastal baseline seaward to approximately 60 – 80 nm offshore. Within this area, some protected areas may be closed to the activities of this fishery.

Season of operation: While this fishery can operate all gear types throughout the year, there are seasonal restrictions on some of the species it can take. The taking of spanner crabs is prohibited around 20 Nov – 20 Dec for males and 20 Oct – 20 Jan for females.

Gear used: This fishery uses demersal fish traps, spanner crab nets (dillies) and line fishing methods including setlines, trotlines, driftlines, handlines, droplines, trolling, jigging and poling. The line fishing techniques in this fishery are either actively fished, where fishers continually attend and work the gear (handlining, trolling, jigging and poling), or set and left to fish passively (setlines, trotlines, driftlines, and droplines). Although fishers do not continually attend passive lines, they are usually near the vicinity of the set lines. Fishers are presumably near the vicinity of set spanner crab nets. Fish traps are generally set overnight, although they may be set for up to two weeks if currents are strong. The line fishing techniques in this fishery that are generally used in pelagic (surface) waters are driftlining, handlining, trolling and poling. Setlines, trotlines, droplines, and jigged lines are usually set or fished in demersal or mid-pelagic waters by this fishery. Details about each permitted gear type and method of use are provided in Appendix 1.

The vessels used in the fishery average 6 – 8 m in length and range from small vessels to large ocean going vessels up to 20 m in length.

Effort: There are 522 businesses with entitlements to operate in this fishery. The maximum number of fishers that can operate each endorsement type in this fishery is illustrated in Table 10. The main fishing methods used in this fishery, ranked by 2002/03 product value were, fish trapping (27% of total), handline fishing (23%), spanner crab nets (16%), and dropline fishing (15%), with various other line fishing methods making up the remainder. Effort exerted in this fishery is dependent on suitable weather and oceanographic conditions and the availability of target species, which can be seasonal.

Table 10: The entitlements and endorsements in the Ocean Trap and Line Fishery (as at April 2003).

Endorsement type	Endorsement description	Number of entitlements
Spanner crab (northern zone)	A spanner crab net can be used to take spanner crabs for sale from ocean waters that are north of a line drawn east from the southern breakwall at Yamba	56
Spanner crab (southern zone)	A spanner crab net can be used to take spanner crabs for sale from ocean waters that are south of a line drawn east from the southern breakwall at Yamba	8
Line fishing (western zone)	Line methods can be used to take fish from ocean waters that are west of the 100 fathom (183 m) depth contour. Holders of this endorsement cannot take school or gummy sharks from waters that are south of a line drawn east from the northern point of the entrance to the Moruya River, or deepwater species (blue eye trevalla, ling, gemfish, hapuku and bass groper).	497
Line fishing (eastern zone)	Line methods can be used to take fish from ocean waters that are east of the 100 fathom (183 m) depth contour. Holders of this endorsement cannot take school or gummy sharks from waters that are south of a line drawn east from the northern point of the entrance to the Moruya River	110
Demersal fish trap	Bottom set fish traps can be used to take fish for sale from ocean waters	286
School and gummy shark	School shark and gummy shark can be taken by line methods south of a line drawn east from the northern point of the entrance to the Moruya River	30

Targeted catch: Around 200 species are taken in this fishery with the main species targeted being spanner crab, snapper, yellowfin bream, rubberlip morwong, bonito, yellowtail kingfish, blue-eye, bar cod, silver trevally, mixed species of leatherjacket, and school and gummy sharks.

Discarding of biological material: These fishers dispose of any unwanted catch when their gear is hauled in. Other biological material that can be discarded by this fishery includes the offal from fish that are processed at sea, unspent bait and burley.

Although there have not been any targeted surveys of discarding associated with the line component of this fishery, the level of discarded catches from these selective gear types is likely to be small. A study that was not designed to be a comprehensive assessment of discarding in the fish trap component of this fishery, which is a more non-selective fishing method than line fishing techniques, indicated that large numbers of small or undersized fish (for those that have a minimum legal size) are captured and subsequently discarded, with unknown mortality (Stewart and Ferrell 2001).

Debris and ghost fishing contribution: Anecdotal reports from trap fishers suggest that trap loss by this fishery could be considerable. The rate of gear loss by this fishery will be reduced from the retrieval of any lost gear, if possible. Herfort (1997) recorded lost trap and line fishing gear on NSW beaches that probably originated from fishing activities in NSW waters.

The debris items originating from this fishery that could be of concern to marine wildlife include line segments, ropes, floats and small pieces or bags of plastic. Any deliberate dumping of such items by this fishery is only likely to be minor or accidental as its activities do not generate large volumes of rubbish.

Reported interactions with marine wildlife: Between 1995 and 2005, ten humpback whales were reported entangled in ropes and buoys. Although the origin of these buoys was generally not determined, it is stated that a spanner crab and a leatherjacket trap may have been involved in this interaction on two of the reported instances (NSW DEC Marine Fauna Management Database). Beyond this database, the coverage and accuracy of which depends on reports of incidents, there is no continual documentation of interactions between marine wildlife and this fishery.

Ocean trap and line fishers on the NSW south coast experience significant problems from operational interactions with seals (Hickman 1999). Generally trap fishers in the area rated seals as the greatest problem in their industry, handline fishers also rated seals as a significant problem, and only some dropline fishers in the area had significant problems with seals (Hickman 1999). Dropline and handline fishers in the area can experience major problems from rogue seals sporadically foraging on their catch, which can reduce their landings, damage their catch, hinder the fishing process, but not damage the gear (Hickman 1999). Handline fishers in the area also reported that seals sometimes forage on their bait and can scare away the targeted catch (Hickman 1999). Trappers in the area reported a low frequency of interactions with seals which largely result from seals stealing their catch, the resulting gear damage was considered a major problem (Hickman 1999).

3.1.6. The Lobster Fishery

This is a summary of a more detailed fishery description located within the '*Lobster Fishery - Environmental Impact Statement'* (NSW DPI 2004b).

Brief description: The Lobster Fishery uses baited traps and some diving to harvest a pre-determined amount of lobster from waters along the NSW coast.

Area of operation: The fishery can operate in waters along the NSW coast, from shallow inshore waters out to around 80 nm. Within this area, protected areas are closed to this fishery.

Season of operation: This fishery can operate throughout the year, but the effort and catch in various components of the fishery tends to be seasonal.

Gear used: This fishery can hand pick or use commercial lobster traps to take their catch. When diving for lobsters, fishers are not permitted to use SCUBA gear or a hookah apparatus. Two different types of traps are used by this fishery. Any buoy lines attached to traps must be weighted under the float to prevent excess rope from floating on the surface of the water. Traps are baited internally, with wire, twine or a bait holder. Inshore traps are checked on a daily basis to every few days, weather permitting. Offshore lobster fishers deploy their traps seasonally, for up to two week periods.

Small 'run-about' vessels 4 – 6 m in length with outboard motors are used by inshore lobster fishers and vessels up to 8 m in length are used by offshore lobster fishers.

Effort: There are 149 fishers endorsed to fish in this fishery. Effort is focussed on baited traps and tends to be exerted in different intensities both along the NSW coast and across the depth ranges fished by the fishery (see Figure 2). In this fishery, inshore fishing is mostly concentrated from July to October / November and offshore fishing is mostly concentrated from October to February (G. Liggins, NSW DPI, pers. comm. 2004).

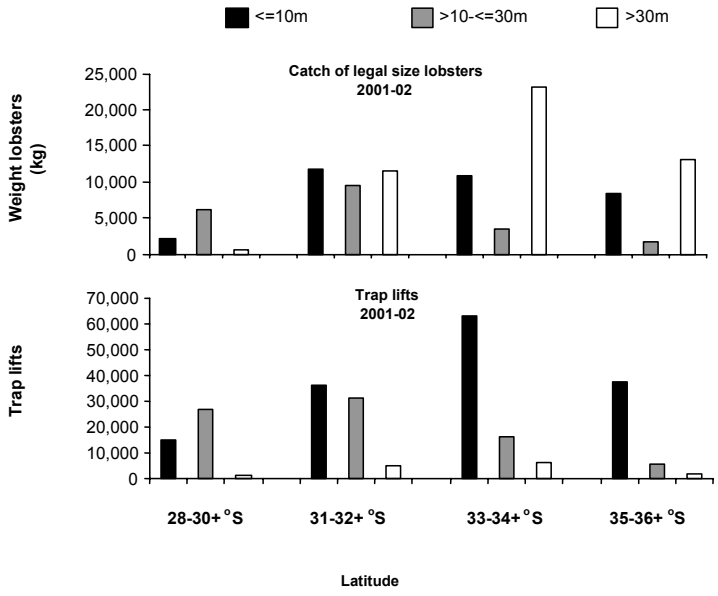

Figure 2: Reported catch (weight of eastern rock lobsters) and reported effort (number of trap lifts) during 2001-02, for three depth strata along the NSW coast by four latitude strata in the NSW Lobster Fishery. (source: Liggins *et al.* 2003)

Targeted catch: This fishery targets the eastern rock lobster, with catches of this species representing more than 99% (by weight) of its total rock lobster catch.

Discarding of biological material: Only small amounts of bycatch is discarded by this fishery (Liggins *et al.* In Prep.). Minimal amounts of offal may also be discarded at sea by this fishery when some of its byproduct is processed for sale.

Debris and ghost fishing contribution: Concerns regarding the loss of offshore traps in this fishery following their entanglement with pelagic longlines have been raised with management authorities (NSW DPI 2004b). The number of traps lost by this fishery has not been quantified. Lost trap fishing gear, probably from NSW fisheries, has been reported on NSW beaches (Herfort 1997). There is currently no information on the hazard-life (the period for which lost traps pose a ghost fishing hazard) of the traps used in this fishery. However, inshore traps are only likely to persist for a relatively short time before disintegrating. Anecdotal accounts from lobster fishers and researchers report that for the majority of lost gear that is eventually recovered, there are generally no animals remaining in the traps. Marine wildlife could become entangled in detached trap head gear.

Apart from lost traps and trap ropes, the other debris items originating from this fishery that could be of concern to marine wildlife is small pieces of bags of plastic. Any deliberate dumping of such items by this fishery is only likely to be minor or accidental as its activities do not generate large volumes of rubbish.

Reported interactions with marine wildlife: Direct captures of marine wildlife in traps used by this fishery were not observed during scientific observations from 1999/00 to 2001/02 (Liggins *et al.* In Prep).

Between 1995 and 2005, there is a single record of a marine wildlife species becoming entangled in the ropes attached to a trap used in this fishery (NSW DEC Marine Fauna Management Database). This involved a humpback whale that was released unharmed. There are nine other records in this database between 1995 and 2005 of humpback whales being entangled in ropes and buoys, but the origin of these buoys was generally not determined. Beyond this database, the coverage and accuracy of which depends on reports of incidents, there is no continual documentation of entanglements between marine wildlife and this fishery.

Trap fishers on the NSW south coast experience significant problems from operational interactions with seals, which largely result from seals stealing the catch from traps (Hickman 1999). Although these trappers reported a low frequency of such interactions with seals, the damage to traps created by such foraging was considered a major problem by fishers in the area.

3.1.7. The Abalone Fishery

This is a summary of a more detailed fishery description located within the '*Abalone Fishery - Environmental Impact Statement'* (The Ecology Lab 2005).

Brief description: The Abalone Fishery takes a pre-determined amount of blacklip abalone by hand from subtidal coastal reefs along the NSW coast.

Area of operation: This fishery can operate along the whole NSW coast, except in closure and protected areas. Fishers collect abalone from subtidal rocky reefs mostly in depths shallower than 40 m.

Season of operation: This fishery operates throughout the year.

Gear used: A hand held chisel-shaped iron is used to harvest catch. Abalone is taken mostly by using compressed air supplied from a hookah unit, and in some cases SCUBA or free diving gear. A typical commercial operation consists of one diver and one deckhand, although two divers may work from the same boat. Abalone fishers generally use a 6 m half-cabin boat, most with twin outboard motors.

Effort: There are approximately 42 fishers with endorsements in this fishery. In 2000, this fishery exerted just over 12 000 diving hours of effort. Most effort in this fishery is concentrated on the far south coast of NSW.

Targeted catch: This fishery can only take a predetermined amount of black-lip abalone each year.

Discarding of biological material: The target specific handpicking method used by this fishery does not take any bycatch to discard. No offal is discarded at sea by these fishers.

Debris and ghost fishing contribution: This fishery does not use any gear that could ghost fish if lost. Debris inputs from this fishery are likely to be very minimal and accidental as it does not use gear that could fragment and does not generate waste from its activities.

Reported interactions with marine wildlife: There are no reported interactions between marine wildlife and this fishery.

3.1.8. The Sea Urchin and Turban Shell Fishery

This is a summary of a more detailed fishery description located within the '*Sea Urchin and Turban Shell Fishery – Review of Environmental Factors'* (NSW DPI, In Prep.).

Brief description: The Sea Urchin and Turban Shell (SUTS) Fishery is a developmental fishery that takes sea urchins and turban shells by hand along the NSW coast.

Area of operation: This fishery can operate in all NSW waters except in closed and protected areas. The fishery harvests in nearshore reefs to a depth of 30 m.

Season of operation: While this fishery can operate throughout the year, the fishing season for sea urchins is constrained to that part of the year when urchin roe is well developed. It is only practicable to harvest purple sea urchins, the most abundant species harvested by this fishery, between January and June. The less abundant red sea urchin can be harvested year round.

Gear used: Fishers use compressed air supplied from a hookah unit or snorkelling to harvest. A large hook is used to collect sea urchins. A typical commercial operation consists of one diver and one deck hand, although some divers may work alone. Fishers generally use 3.3 m 'run-about' style boats with an outboard motor.

Effort: This fishery consists of 37 endorsement holders, less than ten of which are active in this fishery. The number of diver days fished by this fishery has been relatively small and concentrated around the south coast of NSW and Port Stephens.

Targeted catch: The fishery targets the purple sea urchin, a predetermined amount of red sea urchin and two species of turban shells.

Discarding of biological material: The target specific handpicking method used by this fishery does not take any bycatch to discard. No offal is discarded at sea by these fishers.

Debris and ghost fishing contribution: This fishery does not use any gear that could ghost fish if lost. Debris inputs from this fishery are likely to be very minimal and accidental as it does not use gear that could fragment and does not generate waste from its activities.

Reported interactions with marine wildlife: There are no reported interactions between marine wildlife and this fishery.

3.1.9. The Recreational Fishery

Brief description: The NSW Recreational Fishery can catch fish and invertebrates for food and sport from marine, estuarine and fresh waters in NSW by using a variety of methods. In marine and estuarine waters, the activities in this fishery are separated into the following components: estuarine; diving (including spearfishing); sportfishing; charter boat; and gamefishing.

Area of operation: The estuarine component of this fishery operates in estuarine waters; the diving component operates mostly on rocky coastlines and offshore islands and reefs; the sportfishing component mostly operates within 3 nm from shore but can get out as far as the continental slope; the charter boat component mostly operates in coastal waters; and the gamefishing component mostly operates around the continental slope, but can operate between the coastline and the edge of the Australian Fishing Zone. There are over 250 areas (including freshwaters areas) where recreational fishing activities in NSW are restricted or prohibited.

Season of operation: The NSW Recreational Fishery can operate throughout the year.

Gear used: In marine and estuarine waters of NSW, recreational fishers are allowed to take their catch with fishing line gear, traps, nets, spearguns, other hand held implements and by hand gathering. The dimensions and methods of use of this gear is described in Appendix 1.

A survey of recreational fishing across Australia found that the vessels used to fish recreationally ranged from non-powered canoes and dinghies to multi-purpose carriers (Henry and Lyle 2003). Of all the surveyed recreational vessels, 70% were in the 4 - 5 m range, 15% were under 4 m, 11% were in the 6 – 7 m range and under 2% were > 10 m. Nearly all (93%) of the surveyed recreational vessels were powered, 5% were paddled vessels and the remaining were sailing boats and jet skis (Henry and Lyle 2003).

While they are not a gear type used by recreational fishers as such, fish aggregating devices (FADs) are structures that are installed in NSW marine waters for recreational fishers, to create new fishing areas. These vertical structures are moored in various locations to attract pelagic fish such as kingfish and dolphinfish. NSW DPI only sets FADs during the warm water period, between September to May/June.

Effort: From *The National Recreational and Indigenous Fishing Survey* conducted from May 2000 to April 2001(Henry and Lyle 2003), it was estimated that around one million people in NSW recreationally fish. NSW was reported to have the greatest recreational fishing effort in Australia (6.9 million days, 7.7 million events or 30.4 million fisher hours a year). Most recreational fishing in NSW (76%) is concentrated in saltwater environments, mostly in estuaries and sometimes in coastal waters. Shore-based fishing represented 59% of the recreational effort in NSW and boat-based fishing 41%. Of the total number of fishing events conducted by recreational fishers in NSW, 90.2% was with line fishing gear, 3.9% with pots, 1.1% with nets, 1.0% by diving, mostly spearfishing, and 3.8% by hand collection or the use of a hand-held implement. On average, each time recreational fishers in NSW fished, they used various line fishing techniques for 3.52 to 4.61 hours, set-lines for 20.58 hours, passive traps for 12.62 hours, active traps for 9.20 hours, various net types between 2.42 to 4.36 hours, various diving methods between 1.92 to 2.46 hours, a pump/rake/spade for 0.87 hours, and hand collected for 1.42 hours.

Harvest: The ten most numerous finfish species caught by recreational fishers in NSW are flathead, bream, whiting, tailor, luderick, mullet, blue mackerel, leatherjacket, pink snapper and garfish (Henry and Lyle 2003). The marine non-fish species that dominate the NSW recreational catch are prawns, nippers, blue swimmer crab, squid/cuttlefish, mud crab, abalone and lobster (Henry and Lyle 2003).
Discarding of biological material: While they are comparatively quite selective fishing methods, nearly all methods allowed in this fishery could result in discarding. *The National Recreational and Indigenous Fishing Survey* showed that many of the species that are harvested by recreational fishers are also released or discarded (Henry and Lyle 2003). Recreational fishers in NSW can also discard offal from cleaning fish, unused bait and burley to help aggregate their target catch.

Debris and ghost fishing contribution: While the loss of gear and discarding of rubbish have been identified as issues of concern in this fishery, especially the gamefish, sportfish and estuarine components (NSW Fisheries 2003b), there is no information on gear loss rates or litter inputs by this fishery. Debris items that may originate from this fishery and be of concern to marine and estuarine wildlife include small pieces or bags of plastic, lures and pieces of torn fishing gear. Herfort (1997) found that 5% of debris items on selected NSW ocean beaches originated from recreational fishing activities in the state.

Reported interactions with marine wildlife: The only documented direct interaction between marine wildlife and this fishery is of birds becoming hooked and entangled in the fishing tackle used in this fishery (Ferris and Ferris 2002). Australian Seabird Rescue (ASR) frequently observed this interaction in estuaries to mostly occur with active recreational fishing gear (including setlines) and to a much lesser extent, discarded recreational fishing gear (Ferris and Ferris 2002). While this interaction is most regularly recorded with pelicans, the other affected birds ASR have also rescued are silver gulls, cormorants, crested terns, osprey, Australasian gannets, darters, brahminy kites, white-faced herons, great egrets and oystercatchers (Ferris and Ferris 2002). ASR identified pelicans as the birds most susceptible to this interaction, and they found that in most heavily populated areas up to one-in-five pelicans were hooked or entangled in fishing tackle (Ferris and Ferris 2002).

A similar issue has also been identified for seabirds attracted to the live bait or burley used in the gamefishing component of this fishery (NSW Fisheries 2003b). While this interaction has never been quantified it is suspected to be minor (NSW Fisheries 2003b).

3.1.10. The Beach Protection Netting Program

Brief description: The Beach Protection Netting Program in NSW is a protective measure against shark attack along beaches in the most heavily populated areas along the coast. It involves setting mesh nets along these beaches only during the warmer months of the year when swimming activities are most popular.

Area of operation: Beach protection nets are temporarily set along 49 ocean beaches between Newcastle and Wollongong. For management purposes, this area is separated into five regions – Newcastle, Central coast, Sydney north, Sydney south and Wollongong.

Season of operation: This activity is seasonal in NSW, the nets are set from September 1 to April 30.

Gear used: The nets are rectangular (150 m x 6 m) with a mesh size of 50-60 cm knot to knot (Krough and Reid 1996). They are set in about 10 m of water with the footline on the seabed and floatline usually 4 m below the water's surface. The nets are set in a straight line parallel to the shore about 500 m form the beach, usually in line with the surf clubhouse but this varies between locations.

Effort: One beach protection netting contractor operates in each region. Every month, each contractor must deploy nine weekday standard sets (one net soaked for minimum of 12 hours) and four weekend standard sets (one net soaked for minimum of 48 hours) on all meshed beaches within their region (Krough and Reid 1996). The maximum number of standard set nets that can be deployed in each beach protection netting region each month are shown in Table 11. Contractors can complete no more than 70% of their standard sets in either the first or second half of the month for each beach.

Table 11: The maximum number of standard set nets that can be deployed in each NSW beach protection netting region in each month.

Beach protection netting region	Number of netted beaches	Maximum number of weekday sets (9 per beach)	Maximum number of weekend sets (4 per beach)
Newcastle	10	90	40
Central Coast	9	81	36
Sydney North	15	135	60
Sydney South	10	90	40
Wollongong	5	45	20

Catch: Beach protection nets are set to protect swimmers and deter sharks from popular swimming areas. While contractors do not specifically target sharks, some are caught in this protective measure. The contractors are accompanied by a NSW DPI observer to collect data on species that are retained in the nets. The top 11 shark species caught in beach protection nets from 1950/51 to 2003/04 are whalers (several species), white pointer, hammerhead (several species), tiger, seven gill, Port Jackson, angel, grey nurse, wobbegong, mako and thresher sharks. Of the sharks caught in these mesh nets, the grey nurse, white pointer, Port Jackson, angel and wobbegong sharks are usually released alive. Excluding sharks, the other species that are incidentally caught in beach protection nets include rays, mulloway, tuna, kingfish and species of marine wildlife (e.g. dolphins and sea turtles) (Krough and Reid 1996). The incidental capture or entanglement of marine wildlife in beach protection nets in NSW will be detailed in the section below entitled ‘Reported interactions with marine wildlife’.

Discarding of biological material: Dead animals in these nets are generally released, except for a few individuals kept for identification and scientific purposes. The level of discarding has not been documented, but it is likely to be infrequent.

Debris and ghost fishing contribution: Beach protection nets are sometimes lost during storms. Contractors usually try to minimise such loss by bringing the nets in before storms and actively searching to retrieve lost nets. Less than one beach protection net is lost in NSW each year. These lost nets will tend to roll up and sit on the seabed, minimising their ability to ghost fish. Other than the occasional lost net this activity does not generate any debris.

Reported interactions with marine wildlife: Records have always been kept of the catch in beach protection nets, including marine wildlife. These records are most reliable since 1950/51. The reported incidental captures of marine wildlife in beach protection nets in NSW are presented in Table 12. These captures are mostly of dolphins and seaturtles which have fluctuated during the 57 years of the program. Over the past ten years, dolphins have been captured each year with numbers ranging between one and seven individuals per year, and sea turtles have been captured nearly every year with numbers ranging between one and five individuals per year. The survival of captured marine wildlife has only been recorded over the past ten years of the program. Most of the reported captures of dolphins and sea turtles over this time were of dead animals, although some live releases of captured

sea turtles were reported. The majority of dolphins caught in these nets were probably bottlenose and/or common dolphins, although this requires further verification (Krough and Reid 1996). The sea turtle species captured in these nets are green, loggerhead and leatherback turtles. The effect of these catches on local dolphin and sea turtle populations cannot be determined as the species composition and number of individuals in these populations is not known.

The number of individuals from the other marine wildlife groups reported captured in these nets in NSW over the past 57 years (whales, dugongs, and seabirds) is small and such captures would probably not significantly impact local populations.

Table 12: The marine wildlife incidentally captured in beach protection nets off NSW between 1947 and 2004.

Marine wildlife group	Number of animals caught
Dolphins	128
Whales (killer, false killer, humpback, and minke)	6
Dugongs	5
Turtles	83
Seabirds (little penguin)	1

3.2. Measures taken by these fisheries to reduce interactions with marine wildlife

NSW DPI is currently preparing and implementing management strategies for each of the commercial fisheries and the recreational fishery in NSW, and the measures from these strategies that seek to reduce interactions between these fisheries and marine wildlife are outlined in Table 13. These measures can be grouped into those that seek to: directly reduce interactions; gather more information on the interactions that are actually occurring or on some of the factors leading to interactions; indirectly reduce interactions; commit to ameliorate any problematic interactions that may become apparent in the future; and try to instil more environmentally sensitive fishing practices.

The management strategies that have reached implementation stage (by mid 2005) are for the Estuary General, Estuary Prawn Trawl and Ocean Hauling Fisheries. The strategies for the other fisheries are currently in various stages of drafting, with the Ocean Trawl, Lobster and Abalone fisheries Environmental Impacts Statements having completed the public exhibition stage. All the management strategies for the commercial fisheries managed by NSW DPI are due for completion before December 2006.

The Beach Protection Netting Program is the only fishing activity in NSW that has continually documented incidental captures of marine wildlife, since 1950. From 2000, this program has sought to minimise the incidental entanglement of dolphins in its nets by using pingers. These pingers, which make the nets more detectable by emitting high pitched beeps, are fixed along the float line of the net every 50 m. The effectiveness of pingers diminishes in rough weather. During the 2004/05 season pingers for whales will be trailed in accordance with whale migration patterns.

Table 13: The management measures currently used by NSW DPI to reduce interactions between the commercial and recreational fisheries it manages and marine wildlife.

This table summarises the management measures in the management strategies, or draft management strategies, for the following fisheries managed by NSW DPI: The Estuary General Fishery (eg); The Estuary Prawn Trawl Fishery (ept); The Ocean Hauling Fishery (oh); The Ocean Trawl Fishery (ot); The Ocean Trap and Line Fishery (otl); The Lobster Fishery (lob); The Abalone Fishery (ab); The Sea Urchin and Turban Shell Fishery (suts); and The Recreational Fishery (rec).

(Note: As of May 2005, the management strategies for the suts and rec fisheries have not reached first draft stage).

Management measure	Fishery
Fishers are prohibited from taking any species of marine wildlife (mammals, reptiles and birds)	All Fisheries
Mandatory use of discard chutes when mesh and flathead nets are used during daylight hours and prawn trawling occurs on the Hunter River	eg; ept
Document interactions with threatened or protected species through a scientific survey and/or mandatory reporting on monthly catch returns	eg; ept; oh; ot; otl; lob
Document any occurrences of lost fishing gear through an observer study or mandatory reporting	eg; otl; lob
Document the level of interaction between the fishery and sea turtles and seals to assess the need for Turtle or Seal Excluder Devices, or other measures to mitigate impacts on these species	ot
Mapping of the area fished	lob; ot; otl
A commitment to reduce bycatch and associated discarding	eg; ept; ot; otl
Spatial, seasonal and diurnal closures	eg; ept; oh; ot; rec
A commitment to ameliorate any problems with marine wildlife by modifying fishing practices and gear, and/or implementing closures	eg; ept; oh; otl; lob
A commitment to implement the provisions of any threatened species recovery plans or threat abatement plans	eg; ept; oh; ot; otl; lob
The use of best practice handling techniques for captured animals	eg; ept; oh; ot; otl; lob
A Code of Practice for operating in the vicinity of migratory bird and threatened species habitat; to ensure fishers minimise the accidental capture of marine mammals and any threatened or protected species; and/or to ensure the best practice in the disposal of debris and gear	eg; ept; oh; otl; lob
A prohibition on the processing or mutilation of catch on or adjacent to water	eg; ept
A ban on the use of firearms, explosives or electrical devices to take fish	eg; ept; oh
Review the quantum of beach available to hauling in the Ocean Hauling Fishery and develop performance measures for monitoring and modifying that amount over time	oh
Educate recreational fishers about responsible fishing practices around marine wildlife	rec

3.3. Chapter summary

Eight activities managed by NSW DPI could potentially interact with marine wildlife based on aspects of the fisheries as described in this chapter (i.e. gear type used, species targeted, and the discarding of biological and man-made material) and the possible interactions between marine wildlife and fishing activities (described in Chapter 2). These activities include the Estuary General, Estuary Prawn Trawl, Ocean Hauling, Ocean Trawl, Ocean Trap and Line, Lobster, and Recreational Fisheries and the Beach Protection Netting Program. Current records, which are anecdotal, opportunistic or only cover one type of marine wildlife group or part of the state, indicate that wildlife in the marine and estuarine waters of NSW are interacting with all of these activities.

The Abalone Fishery and Sea Urchin and Turban Shell (SUTS) Fishery harvest species that are not normally preyed upon by marine wildlife by using a method that generally does not generate bycatch or debris and could not incidentally capture or entangle marine wildlife. Subsequently, the way these fisheries could interact with marine wildlife is from vessels travelling to and from fishing grounds, generally in nearshore waters. Marine wildlife could be struck be these vessels or disturbed by the noise emanating from them and their physical presence. As only a small number of fishers operate in these fisheries and their area of operation is restricted, the effects of such interactions from the fishery should not significantly affect marine wildlife. Conversely, the harvesting activity of these fisheries should not significantly be affected by any disturbance from marine wildlife. Such interactions on these fishers could occur when marine wildlife, especially seals, disturb fishers whilst diving. However, this is not a known problem in the Abalone and SUTS fisheries. As the potential for interaction between these fisheries and marine wildlife is nil-low, and no interactions have been documented in these fisheries so far, these fisheries will not be further assessed in this study.

4. WILDLIFE IN THE MARINE AND ESTUARINE WATERS OF NSW

The aspects of marine wildlife species that occur in the marine and estuarine waters off NSW that influence their interactions with fishing activities are summarised. Records of any fishing-related incidents with these species in NSW, the source of which is not known, are also documented. Wildlife species found in this area whose populations are not likely to be significantly affected by NSW fishing activities, such as those that are common elsewhere but only occur in these habitats in NSW on a rare to uncommon basis, are identified and excluded from further assessment in this study.

4.1. Marine mammals

4.1.1. Cetaceans

4.1.1.1. Overview of cetacean (whale, dolphin and porpoise) biology

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

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

4.1.1.2. Cetaceans off NSW

Species excluded from detailed assessment

Of the 36 cetacean species recorded off NSW, 17 species will not be further assessed in this report (Table 14). The occurrence off NSW of three of these species, the sei whale, fin whale and dusky dolphin, is uncertain as they are only known from one or two unconfirmed records (Smith 2001, DEC Atlas of NSW Wildlife 02/03/2003). As these species are exceptionally rare off NSW they are unlikely to be affected by fishing activities in the area.

Some cetacean species are known to commonly occur in the tropical and sub-tropical waters of northern Australia and only occur occasionally or as vagrants in the temperate waters off NSW. These include the rough-toothed dolphin (two NSW records), Indo-Pacific humpbacked dolphin (three NSW records), spinner dolphin (six NSW records), Fraser's dolphin (six NSW records) and the Bryde's whale (five NSW records) (Bannister *et* al. 1996, Smith 2001, DEC Atlas of NSW Wildlife 02/03/2003). These common tropical species are thought to occur off NSW in such low numbers that the few potential interactions that may occur with fishing activities in the area would not significantly impact the populations of these species. Similarly, cetacean species that are known to be more

common off the southern Australian coast and are only known in waters off NSW from a few records are also not likely to be significantly impacted by fishing activities off NSW. These species include the pygmy right whale (four NSW records), long-finned pilot whale (five NSW stranding events), Gray's beaked whale (eight NSW records) and the southern right whale dolphin (two NSW records) (Smith 2001, DEC Atlas of NSW Wildlife 02/03/2003).

Some deep oceanic species are only known in Australian waters, including those off NSW, from a small number of scattered records, mostly stranding events. These species include the Blainville's beaked whale (one NSW record), Cuvier's beaked whale (one NSW record), dwarf sperm whale (four NSW records), southern bottlenose whale (four NSW records), pygmy killer whale (eight NSW records), gingko-toothed beaked whale (three NSW records) and the Andrew's beaked whale (two NSW records) (Smith 2001, DEC Atlas of NSW Wildlife 02/03/2003). These records probably reflect a very low occurrence of these species off NSW, especially as other deep oceanic cetaceans (e.g. strap-toothed beaked whale) are known to be more numerous in the area. Also, as the Blainville's beaked whale, Cuvier's beaked whale, dwarf sperm whale, southern bottlenose whale and pygmy killer whale are known to concentrate in other areas around the world (Australian Museum 2003, Whale and Dolphin Conservation Society 2003a, b, c, d), NSW does not seem to be a major location for these species and they are not likely to be significantly impacted by fishing activities in the area.

Table 14: The cetaceans found in waters off NSW and their conservation status.

Note: In constructing this table, information was sourced from Smith (2001).
* The species listed under Part B will not be further assessed in this report.
✦ denotes baleen species.
Descriptions of the threatened species categories are provided in Appendix 2.75

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Commonwealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
A) Common species				
Risso's dolphin	*Grampus griseus*	Protected	Protected	Data deficient
Bottlenose dolphin (inshore and offshore form)	*Tursiops truncatus*	Protected	Protected	Data deficient
Pantropical spotted dolphin	*Stenella attenuata*	Protected	Protected	Lower Risk, conservation dependent
Striped dolphin	*Stenella coeruleoalba*	Protected	Protected	Lower Risk, conservation dependent
Common dolphin	*Delphinus delphis*	Protected	Protected	Not in database
Melon-headed whale	*Peponocephala electra*	Protected	Protected	Not in database
False killer whale	*Pseudorca crassidens*	Protected	Protected	Not in database
Killer whale	*Orcinus ocra*	Protected	Protected	Lower Risk, conservation dependent
Short-finned pilot whale	*Globicephala macrorhyncus*	Protected	Protected	Lower Risk, conservation dependent
Arnoux's beaked whale	*Berardiux arnuxii*	Protected	Protected	Lower Risk, conservation dependent
Strap-toothed beaked whale	*Mesoplodon layardii*	Protected	Protected	Data deficient
Sperm whale	*Physter macrocephalus*	Vulnerable	Protected	Not in database
Pygmy sperm whale	*Kogia breviceps*	Protected	Protected	Not in database
Southern right whale✦	*Eubalaena australis*	Vulnerable	Endangered	Lower Risk, conservation dependent
Minke whale✦	*Balaenoptera acutorostrata*	Protected	Protected	Lower risk, near threatened
Blue whale✦	*Balaenoptera musculus*	Endangered	Endangered	Endangered
Humpback whale✦	*Megaptera novaeangliae*	Vulnerable	Protected	Vulnerable

Table 14 – continued

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Commonwealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
B) Vagrant / Occasional species *				
Rough-toothed dolphin	*Steno bredanensis*	Protected	Protected	Data deficient
Indo-pacific humpbacked dolphin	*Sousa chinensis*	Protected	Protected	Data deficient
Dusky dolphin	*Lagenorhynchus obscurus*	Protected	Protected	Not in database
Spinner dolphin	*Stenella longirostris*	Protected	Protected	Lower Risk, conservation dependent
Fraser's dolphin	*Lagenodelphis hosei*	Protected	Protected	Data deficient
Southern right whale dolphin	*Lissodelphis peronii*	Protected	Protected	Data deficient
Pygmy killer whale	*Feresa attenuata*	Protected	Protected	Data deficient
Long-finned pilot whale	*Globicephala melas*	Protected	Protected	Not in database
Blainville's beaked whale	*Mesoplodon densirostris*	Protected	Protected	Data deficient
Gray's beaked whale	*Mesoplodon grayi*	Protected	Protected	Data deficient
Cuvier's beaked whale	*Ziphius cavirostris*	Protected	Protected	Data deficient
Andrews' beaked whale	*Mesoplodon bowdoini*	Protected	Protected	Data deficient
Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*	Protected	Protected	Data deficient
Southern bottlenose whale	*Hyperoodon planifrons*	Protected	Protected	Lower Risk, conservation dependent
Dwarf sperm whale	*Kogia simus*	Protected	Protected	Not in database
Pygmy right whale✦	*Caperea marginata*	Protected	Protected	Not in database
Sei whale✦	*Balaenoptera borealis*	Protected	Vulnerable	Endangered
Bryde's whale✦	*Balaenoptera edeni*	Protected	Protected	Data deficient
Fin whale✦	*Balaenoptera physalus*	Protected	Vulnerable	Endangered

Species to be assessed

The 17 cetacean species to be further assessed in this report are identified in part A Table 14.

Habitat

Some of the commonly occurring cetaceans off NSW are predominantly oceanic and generally occur in waters beyond the continental shelf (Table 15). Most of these species (except the melon-headed whale, pygmy sperm whale and minke whale) are also known to congregate on or adjacent to the continental slope (Bannister *et al.* 1996). The false killer whale, melon-headed whale and sperm whale occasionally travel over the continental slope onto the shelf and are sometimes seen in coastal waters (Bannister *et al.* 1996). The minke whale also occurs in coastal waters, and does so off NSW more frequently than the other common oceanic species (Bannister *et al.* 1996).

Some of the other commonly occurring cetaceans off NSW move between oceanic and coastal waters (Table 15), generally in response to changes in prey abundances, and it is not known if they prefer one habitat over the other. Amongst these species, the blue whale is known to occur mostly at the shelf edge (Bannister *et al.* 1996).

Migrating humpback and southern right whales and the inshore form of the bottlenose dolphin most commonly occur in coastal and estuarine waters, with the whales doing so on a seasonal basis (Smith 2001). However, southern right whales can also occur in more offshore waters, especially on their southern migration (Smith 2001).

Distribution

The distribution of the commonly occurring cetaceans along the NSW coast can be inferred from the location of sighting and stranding records summarised in Table 15. Generally, sighting records of live animals give a more accurate account of a species distribution than stranding records of animals that may have drifted some way before landing on the coast. Also, the distribution of species that are regularly reported and/or easily seen is likely to be more accurate than that of those with few records or those that rarely surface. The distribution of the commonly occurring cetacean species along the NSW coast that are only known to occur in this area from stranding events and, in the case of the Arnoux's beaked whale, regular unconfirmed sighting records (Smith 2001), should therefore be treated with some caution.

The bottlenose dolphin (inshore form), common dolphin, humpback whale, sperm whale and pygmy sperm whale are known to occur along the entire length of the NSW coast. These species are either regularly sighted or frequently strand in the area (Smith 2001). Species that have been recorded along most of the NSW coast, except its far north, include the southern right whale, minke whale and killer whale. These species are also either regularly sighted or frequently strand in the area (Smith 2001). Species that have not been recorded from the more southern regions of the state, but otherwise seem to occur along the rest of the NSW coast include the strap-toothed beaked whale, false killer whale, striped dolphin and short-finned pilot whale. Most of these species, except the false killer whale, are known to occur off NSW only from stranding records (Smith 2001). The offshore form of the bottlenose dolphin, pantropical spotted dolphin and the melon-headed whale are species that appear to only occur in the northern half of the state. Most of these species, except the offshore from of the bottlenose dolphin, are known to occur off NSW only from stranding records (Smith 2001). Those commonly occurring species that have only been sighted in the southern half of the state include the Arnoux's beaked whale and the blue whale in the far south coast only (Smith 2001). The Risso's dolphin has stranded along most of the NSW coast excluding the most northern and southern parts (Smith 2001).

There are some specific key localities in Australia, including the waters off NSW, where some cetacean species regularly occur. Permanent resident populations of the inshore form of the bottlenose dolphin are found at Jervis Bay, Port Stephens, Twofold Bay and other sites along the NSW coast (Moller and Beheregaray 2001, Smith 2001). Humpback whales regularly occur off the NSW south coast, Coffs Harbour and Cape Byron (Bannister *et al.* 1996). The waters off the far south coast of NSW and adjacent Victorian waters are one of three recognised aggregation areas for blue whales in Australia (Environment Australia 2001b). Sperm whales commonly occur off the NSW coast, especially near Wollongong (Bannister *et al.* 1996). Southern right whales frequently use the area 5km north and south of Twofold Bay (Burnell and McCulloch 2001).

Seasonal occurrence

Cetaceans that are known to commonly occur off NSW throughout the year are the inshore and offshore forms of the bottlenose dolphin and the common dolphin (Smith 2001). Pygmy sperm whales and killer whales also occur off NSW throughout the year, but they are mostly recorded in the area during certain seasons (Table 15). Records of the striped dolphin, melon-headed whale and short-finned pilot whale off NSW are scattered throughout most months of the year (Table 15). The seasonal occurrence of sperm whales and Arnoux's beaked whales off NSW is difficult to determine as observations of these species may be seasonally biased (Smith 2001).

The baleen whales commonly occurring off NSW (Table 15) do so, on a seasonal basis. Each year members of these species migrate from their summer feeding grounds in Antarctic waters to breed in warmer waters during the winter. Humpback whales tend to only use the waters off NSW as a migration passage, although there is some evidence of some individuals calving off northern waters when migrating north and also of feeding behaviour off Eden during their southern migration (Bannister *et al.* 1996, Smith 2001). When migrating to and from tropical waters, humpbacks pass through the waters off NSW during winter and spring staying close to the coast, with numbers peaking in June and July on their northward migration and during September to November on their southward migration (Smith 2001). Central NSW was traditionally recognised as the northernmost limit of the southern right whale migration along Australia's eastern coastline, although this appears to be extending further north to Byron Bay (Smith 2001). The southern right whale is regularly observed migrating close to the NSW coast mostly between May and November, although a more offshore route can be taken when migrating south (Smith 2001). The species does not feed near the coast during winter (Smith 2001). New-born calves are regularly sighted in NSW coastal waters (Smith 2001). Blue whales migrate to breed in tropical and subtropical waters (Bannister *et al.* 1996). Their migration paths are widespread and do not obviously follow coastlines or oceanographic features (Bannister *et al.* 1996). Off NSW, they are sighted mostly in October and November and only in the far south of the state (Smith 2001). Minke whales breed in tropical and temperate waters and occur off NSW from June to November (Smith 2001). Other commonly occurring cetaceans off NSW that appear to migrate here on a seasonal basis include the false killer whale, strap-toothed beaked whale, and Risso's dolphin (Table 15).

Conservation status

Of all commonly occurring cetacean species off NSW, the populations of the blue, southern right, sperm and humpback whales in the area are listed as being under threat (Table 14). The recovery of these populations, since their dramatic reduction by whaling operations that ceased in the 1960s or 1970s, is likely to be slow as these species are long-lived, calve every few years and only produce one or two offspring at a time. As an example, Australian populations of humpback whales have been increasing at a rate of 10% per year (Bannister *et al.* 1996). Where the current population size in Australian waters of these threatened species has been determined, it appears to be small compared to the likely size before exploitation (Bannister *et al.* 1996, Smith 2001). The survival of all other commonly occurring cetacean species off NSW is not considered to be currently under threat (Table

14), but these species are still protected in these waters under both the *NPW Act 1974* and *EPBC Act 1999*.

Threats

Human-induced threats that can immediately kill or injure cetaceans include illegal direct killing, entanglement or incidental capture in fishing gear and boat-strike (Bannister *et al.* 1996). Medium-term threats include impacts on prey availability from fishing activities, degradation of cetacean habitat, exposure to infectious human disease organisms and disturbance and harassment (from acoustic disturbance resulting from seismic and military operations, whale watching vessels and aircraft and tourism centred feeding) (Bannister *et al.* 1996). Over the longer-term, pollution can degrade the marine environment and threaten cetaceans when organochlorines and heavy metals accumulate in their body tissues (Kemper *et al.* 1994, Bannister *et al.* 1996). Human induced climate change and commercial harvesting of cetaceans can also threaten them in the longer term (Bannister *et al.* 1996). Cetaceans can also be threatened by plastic debris in the ocean when they ingest or become entangled in it (Bannister *et al.* 1996), and this is listed as a key threatening process in NSW (NSW Scientific Committee 2003, Threatened Species Scientific Committee 2003). Populations of cetaceans that have been severely depleted by historical harvesting are placed at more risk from the reduced genetic variation in the current population (Bannister *et al.* 1996).

Fishing-related incidents reported in NSW

The nature and frequency of interactions between cetaceans and fishing activities in the waters off NSW are poorly known. The NSW DEC Marine Fauna Management Database has records (49 in all from 1995-2005) of humpback whales, minke whales, bottlenose dolphins and common dolphins entangled in pieces of fishing gear such as anchor ropes, trap ropes and buoys, netting, steel cables, and a tuna longline hook. Some of these animals were cut free while others died. At least another 11 cetaceans were reported entangled in fishing gear from the mid- and far- north coast of NSW in 2004, but the animals were not resighted after initial reports and further details about these entanglements could not be obtained (NSW DEC Marine Fauna Management Database 2005). The frequency at which cetaceans are being reported entangled in pieces of fishing gear, excluding beach protection nets, appears to have increased over the last two years (NSW DEC Marine Fauna Management Database 2005). A melon-headed whale found stranded and subsequently released in NSW had a longline hook embedded near its mouth (Marshall 2002). There is a single record of a bottlenose dolphin being captured in a trawl net off northern NSW - this animal was released alive (Waples 2005). Between 1947-2004 128 dolphins, three false killer whales, one minke whale, one killer whale and one humpback whale have been caught in beach protection nets in NSW (D. Reid, NSW DPI, unpubl. data. 2004). The humpback whale was released alive, so too was another that had travelled from Queensland dragging entangled shark control nets and buoys (NSW DEC Marine Fauna Management Database 2005). The only actual record of a boat striking a cetacean in waters off NSW is from Eden where a fishing vessel collided with a Bryde's whale (NSW DEC Marine Fauna Management Database 2005). A bottlenose dolphin, three humpback whales and a minke whale have been recorded in NSW with boat strike injuries, the source of which is unknown (NSW DEC Marine Fauna Management Database 2005). Bottlenose dolphins were observed to actively feed from the contents of a prawn-trawl codend whilst towing in NSW (Broadhurst 1998). There is one record of deliberate fishing-related injuries to cetaceans in NSW: a common dolphin found with a hook in its mouth and stab wounds (NSW DEC Marine Fauna Management Database 2005).

Table 15: An overview of the distribution off NSW of the commonly occurring cetacean species in the area.

Note: The information presented in this table was sourced from Bannister *et al.* (1996), Smith (2001), and the DEC Atlas of NSW Wildlife 02/01/2003.

The location and then timing of NSW records are given in brackets.
* indicates species have been sighted in waters off NSW, otherwise they are only known in NSW from stranding events.

Mostly oceanic waters		**Both oceanic and coastal waters**		**Mostly coastal waters**	
Species	**Distribution off NSW**	**Species**	**Distribution off NSW**	**Species**	**Distribution off NSW**
striped dolphin	(Byron Bay to Sussex Inlet) (records every month of the year, except during April and June)	Risso's dolphin	(Brooms Head to Eurobodalla National Park) (mostly December to June)	bottlenose dolphin* - inshore form	(entire NSW coast) (throughout the year)
melon-headed whale	(Tweed Heads to Sydney) (records every month, except March, May, June and October)	bottlenose dolphin* - offshore form	(Tweed Heads to Port Macquarie) (throughout the year)	southern right whale*	(mostly Newcastle to Green Cape, furthest north Byron Bay) (generally May to November)
false killer whale*	(Tweed Heads to Jervis Bay) (May to January, excluding September)	pantropical spotted dolphin	(Coffs Harbour to Sydney) (January-March, June and September)	humpback whale*	(entire NSW coast) (between June and November)
Arnoux's beaked whale* (unconfir-med sightings only)	(Wollongong to Eden) (between November and February, may be biased)	common dolphin*	(entire NSW coast) (throughout the year)		
strap-toothed beaked whale	(Byron Bay to Kioloa) (From December to July, except during January and June)	killer whale*	(mostly Broken Bay to Green Cape, furthest north Byron Bay) (throughout most of the year, mostly between May and November)		
sperm whale*	(entire NSW coast) (mostly between August and April, may be biased)	short-finned pilot whale	(Brunswick Heads to Culburra) (January, February, April, June, July and October)		
pygmy sperm whale	(entire NSW coast) (throughout the year, mainly October to March)	blue whale*	(Bermagui to Green Cape) (mostly October and November)		
minke whale*	(Minnie Water to Twofold Bay) (June to November)				

4.1.2. Pinnipeds

4.1.2.1. Overview of pinniped (seal and sea-lion) biology[2]

Pinnipeds (seals and sea-lions) spend most of their time feeding at sea and come ashore (haul-out) to breed at preferred localities, forming colonies, moult and rest. Like the Australian fur-seal, most other pinnipeds occurring in Australian waters are probably long-lived, as they become sexually mature after 4 - 9 years. All species of seal in Australian waters produce one pup annually during spring - summer. Pinnipeds are agile fast swimmers and usually feed on fish, squid and seabirds and for the Antarctic species krill, mostly in the waters near breeding and haul-out sites.

4.1.2.2. Pinnipeds off NSW

Species excluded from detailed assessment

Many of the seven pinniped species reported in NSW occur in NSW as occasional stragglers (Shaughnessy 1999) (Table 16). These species include the Australian sea-lion (four NSW records), subantarctic fur-seal (seven NSW records), southern elephant seal (six NSW records) and the crab-eater seal (two NSW records) (DEC Atlas of NSW Wildlife 02/01/03). They are mostly found closer to their breeding range which lies in Antarctic or subantarctic regions or along Australia's southern coastline (Shaughnessy 1999). As these species rarely occur in NSW, species survival is not likely to be affected by any fishing activities in the state.

Leopard seals are mostly found in Antarctic and subantarctic regions (Shaughnessy 1999). They haul-out almost annually along the NSW coast mostly south of the Hunter River between July to October (Smith 2001). These records are largely of juveniles around one to two years old that frequently visit southeastern Australia during the winter haul-out season (Smith 2001). The DEC Atlas of NSW Wildlife (02/01/2003) lists an average of less than four records of leopard seals in NSW annually. This represents a very small percentage of the total population, which was estimated to be a minimum of 300,000 in 1990 (Erikson and Hanson 1990). As only small numbers of leopard seals occur in the waters off NSW, and their population is not threatened, fishing activities in the state are unlikely to have a significant impact on this species.

[2] The information in this section has been sourced from *The Action Plan for Australian Seals*, Shaughnessy (1999).

Table 16: The pinnipeds found in waters off NSW and their conservation status.

Note: In constructing this table, information was sourced from Smith (2001).
* The species listed under this section will not be further assessed in this report.
Descriptions of the threatened species categories are provided in Appendix 2.

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Commonwealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
A) Common species off NSW				
New Zealand fur-seal	*Arctocephalus forsteri*	Vulnerable	Protected	Not in database
Australian fur-seal	*Arctocephalus pusillus*	Vulnerable	Protected	Not in database
B) Vagrant species off NSW *				
Australian sea-lion	*Neophoca cinera*	Protected	Protected	Not in database
Subantarctic fur-seal	*Arctocephalus tropicalis*	Protected	Vulnerable	Not in database
Southern elephant seal	*Mirounga leonina*	Protected	Vulnerable	Not in database
Leopard seal	*Hydrurga leptonyx*	Protected	Protected	Not in database
Crab-eater seal	*Lobodon carcinophagus*	Protected	Protected	Not in database

Species to be assessed: Australian and New Zealand fur-seals

Distribution

Fishing activities in NSW are most likely to interact with the commonly occurring Australian and New Zealand fur-seals. These species occur within continental shelf waters and haul-out on islands and coastline in inshore regions (Shaughnessy 1999). Their range includes the waters off NSW where they regularly haul-out on Montague Island (Shaughnessy 1999). It is here where the largest aggregation of Australian and New Zealand fur-seals occurs in NSW (Shaughnessy *et al.* 2001). Outside of Montague Island, there are scattered records of New Zealand fur-seals along the NSW coast north to Yamba (Smith 2001). Australian fur-seals are also known to regularly haul-out at Steamers Beach and Green Cape in southern NSW, and to come ashore at irregular sites along the whole NSW coast (Smith 2001).

Montague Island colony

Both the Australian and New Zealand fur-seal haul-out on Montague Island mostly during winter (July to October), although they occur on the island throughout the year in varying numbers (Shaughnessy *et al.* 2001). There are currently two seal haul-out sites on Montague Island, one site is situated on the northern side of the island and consists mostly of Australian fur-seals, the other site on the western side of the island is newly established and consists mostly of New Zealand fur-seals (D. Priddel, NSW DEC, pers. comm. 2005). It is suspected that male and females of both species haul-out on the island (Shaughnessy *et al.* 2001). While the island is considered a non-breeding colony, rare and largely unsuccessful breeding events have been recorded (Shaughnessy *et al.* 2001). Any fur-seal pups born on the island would probably not survive the weaning period, as haul-out sites on the island lack rock pools and offshore reefs that are the main features of known breeding colonies of this species

(Shaughnessy *et al.* 2001).

Breeding

Currently seals do not regularly breed in NSW, although Seal Rocks on the central coast of NSW was once a regular breeding site for the Australian fur-seal (Shaughnessy 1999).

Conservation status

Although the populations of Australian and New Zealand fur-seals are increasing, they are still lower now than they were before being dramatically reduced by historical commercial sealing operations (Shaughnessy 1999). These smaller populations are considered to be vulnerable in NSW waters under the *TSC Act 1995*.

Threats

The small population of fur-seals in NSW is considered to be under threat from commercial and recreational fishing operations - mostly through bycatch and reduced prey availability, entanglement or ingestion of plastic debris and stochastic events such as oil spills (NSW Scientific Committee 2002a, b). Although unclear in NSW, Australian and New Zealand fur-seals are also likely to be threatened by illegal shooting activity (Shaughnessy 1999). Fishing gear types that have been identified as a threat to the seals occurring in Australian waters include set nets, purse-seine nets, trawl nets, shark control nets, lobster traps, droplines and trolling lines (Shaughnessy 1999). Other threats to seals in Australian waters include disturbance to breeding and haul-out sites, disease, seismic survey activity, chemical contamination and climate change (Shaughnessy 1999).

Fishing-related incidents reported in NSW

Fishing-related impacts on seals in the waters off NSW have not been quantified on a large scale. There are scant records in the NSW DEC Marine Fauna Management Database (four between 1995-2005) of Australian fur-seals found off NSW entangled in beach protection nets or fishing line, or with an embedded fishing hook. The only documented incidental catches of seals in fishing gear off NSW are from observations of fish trawling activity where two seals were caught in the 897 observed trawl shots (0.22%) off Ulladulla and 27 seals were caught in the 1109 observed trawl shots (2.43%) off Eden (species were not recorded). The mortality rates of these captures are unknown (G. Liggins, NSW DPI, pers. comm. 2003). Shaughnessy *et al.* (2001) observed that some fur-seals on Montague Island had either rope, strap or portions of trawl net around their necks. Hickman (1999) found that seals hinder commercial fishing activities on the far south coast of NSW. The seals were found to interfere mostly with trapping, handlining, droplining and some trawling activities in the area. In Jervis Bay over the past ten years there have been three reported episodes of seals being shot, perhaps by professional fishers (M. Fortescue, Dept. of Environment and Heritage, pers. comm. 2004). The breeding colony of Australian fur-seals that was historically located on Seal Rocks (NSW) is said to have been removed through regular illegal shooting (Kirkwood *et al.* 1992).

4.1.3. Sirenians

4.1.3.1. Overview of sirenian (dugong) biology[3]

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

4.1.3.2. Sirenians off NSW

Species to be assessed: The dugong

Distribution

Only one sirenian, the dugong (*Dugong dugon*), is found in tropical Australian waters from Shark Bay (WA) to Moreton Bay (Qld) (Smith 2001). The species usually only occurs in NSW as an occasional straggler from the more northern populations, usually in waters north of Jervis Bay, although they have also been reported as far south as Twofold Bay (Smith 2001). Dugongs are also known to move into NSW following unfavourable natural events in Queensland (Smith 2001). Vagrant dugongs tend to be sighted in areas where seagrasses occur, and in NSW this includes estuarine waters (Allen *et al.* 2004).

Conservation status

This use of NSW coastal waters as a refuge area coupled with a recent population decline of the species in southern Queensland has resulted in the listing of dugongs as being endangered in NSW waters under the *TSC Act 1995*. The status of dugongs internationally is considered to be vulnerable under the IUCN Redlist. Although the species is not considered to be under threat nationally it is still protected under the *EPBC Act 1999*.

Threats

Threats to the species include large-scale destruction of seagrass resulting from many processes and activities including trawling, incidental mortality in commercial gill and mesh nets and shark protection nets, indigenous hunting, boat strike and disturbance (Allen *et al.* 2004). A listed key threatening process that may affect this species is its entanglement in or ingestion of marine debris (NSW Scientific Committee 2003, Threatened Species Scientific Committee 2003). As these fishing-related threats occur in NSW, fishing activities in this state could potentially interact with this endangered species.

[3] The information in this section has been sourced from *Conservation and management of the dugong in Queensland 1999-2004*, Queensland Environmental Protection Agency (1999).

Fishing-related incidents reported in NSW

The only documented records of dugongs interacting with fishing activities in NSW are of individuals that were entangled in beach protection netting. In total, five dugongs have been caught in these nets between 1950-2004 (Krough and Reid 1996, D. Reid, NSW DPI, pers. comm. 2004).

4.2. Marine Reptiles

4.2.1. Sea Turtles

4.2.1.1. Overview of sea turtle biology[4]

Sea turtles are very long-lived, grow slowly and reach sexual maturity at 30 - 50 years of age. They almost always live entirely in the marine environment, only coming ashore onto to nest on sandy beaches. After hatching young sea turtles drift in open ocean currents until they are large enough to settle into inshore feeding grounds. The exception is the leatherback turtle, which remains in oceanic waters throughout its life. In general, every two to seven years, adult turtles migrate over large distances from their feeding grounds to nesting grounds where they nest a number of times before the return journey. Clutch sizes range from 115 - 130 eggs. Sea turtles do not form obvious social groups and feed as individuals on algae, seaweed, seagrasses, sponges and other invertebrates. They do not usually feed on fish. They have well developed colour vision, an acute sense of smell, can only hear low frequencies and have no sense of taste (Environment Australia 2003).

4.2.1.2. Sea turtles off NSW

Species excluded from detailed assessment

Of the six sea turtle species found in Australian waters, five occur in NSW (Table 17). One of these, the flatback turtle (*Natator depressus*), is endemic to the Australian region but occurs in NSW only as a rare extralimital vagrant from its more northern, predominantly tropical population (Cogger 2000). As the species rarely occurs in NSW (three records to date) (Cogger, 2000, DEC Atlas of NSW Wildlife 20/02/2003), its survival is not likely to be affected by any fishing activities in the state.

Species to be assessed

The four sea turtle species that regularly occur in NSW (Table 17) are residents (Cogger 2000) that are more likely to potentially interact with fishing activities.

Sea turtle populations

The green, loggerhead and hawksbill turtles feed and breed in Australian waters (Environment Australia 1998a). The leatherback turtle mostly nests in the Asia-Pacific region and generally only feeds in and migrates through Australian waters, although some rare nesting events also occur on Australian shores (Environment Australia 1998a). The Australian breeding populations of the green, loggerhead and hawksbill turtles are genetically distinct from those in other countries (Environment Australia 1998a) and separate sub-populations of these species have been recognised in Australia (Environment Australia 2003).

[4] Unless stated otherwise the information in this section has been sourced from the *Draft Recovery Plan for Marine Turtles in Australia*, Environment Australia (1998a).

Table 17: The sea turtles found in waters off NSW and their conservation status.

Note: In constructing this table, information was sourced from Cogger 2000.
* The species listed under this section will not be further assessed in this report.
Descriptions of the threatened species categories are provided in Appendix 2.

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Commonwealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
A) Common species off NSW				
Green turtle	*Chelonia mydas*	Vulnerable	Vulnerable	Endangered
Loggerhead turtle	*Caretta caretta*	Endangered	Endangered	Endangered
Leatherback turtle	*Dermochelys coriacea*	Vulnerable	Vulnerable	Critically Endangered
Hawksbill turtle	*Eretmochelys imbricata*	Protected	Vulnerable	Critically Endangered
B) Vagrant species off NSW *				
Flatback turtle	*Natator depressus*	Protected	Vulnerable	Data deficient

Distribution

The abundance of sea turtles off NSW is much lower than that off Queensland. Sea turtles occur in the waters off NSW throughout the year, mostly in inshore waters in the northern half of the state (Cogger 2000). Some species, notably the green turtle, appear to be attracted to estuaries with warm water outfalls, such as Lake Macquarie (Environment Australia 2003). The green turtle is a relatively common resident of inshore waters off NSW, with small numbers occurring from central NSW north (Cogger 2000). Evidence also suggests that some individual green turtles regularly visit the more southern estuaries along the NSW coast (Environment Australia 2003). Loggerhead turtles are also relatively common residents of inshore waters off NSW, occurring in moderate numbers in the far north and occasionally reaching the southern waters of the state (Cogger 2000). Only small numbers of hawksbill turtles have been found in NSW (11 records to date - DEC Atlas of NSW Wildlife 20/02/2003), these occur in inshore waters mostly in northern NSW where the species is resident around Julian Rocks, near Byron Bay (L. Tarvey, NSW Dept. of Environment and Conservation (DEC), pers. comm. 2003). Leatherback turtles are rare in Australian waters where they are found in oceanic temperate waters as far south as Tasmania (Environment Australia 1998a). Small numbers occur in deep offshore waters along the whole NSW coast (Cogger 2000).

Nesting

Each year there is a scattering of sea turtle nesting events on the north coast of NSW, mostly of loggerhead turtles and some green turtles (L. Tarvey, NSW DEC, pers. comm. 2005). Successful hatchings of these species are routine, provided the nest temperature is generally maintained above 24^{o}C (L. Tarvey, NSW DEC, pers. comm. 2005). They have been recorded nesting as far south as Newcastle, but the southernmost record for a successful hatching in NSW is further north near Taree (L. Tarvey, NSW DEC, pers. comm. 2005). Nesting mostly occurs during summer and there are no specific locations for this activity in NSW (L. Tarvey, NSW DEC, pers. comm. 2005). In NSW, hatching turtles, generally males, mostly emerge in April or May (L. Tarvey, NSW DEC, pers. comm. 2005). Rare nestings of leatherback turtles have also been recorded on the NSW coast on two occasions, near Ballina in 1993 and Forster in 1995, the latter of which was unsuccessful due to cold conditions (Tarvey 1993).

Conservation status

Sea turtles are vulnerable to depletion as they are long-lived, breed only occasionally and few hatchlings survive to adulthood (Bache 2003a). Subsequently, the recovery of depleted sea turtle populations would be slow. The survival of all four sea turtle species commonly occurring in NSW is considered to be under threat both nationally under the *EPBC Act 1999* and internationally under the IUCN Redlist (Table 17). The loggerhead, green and leatherback turtles occurring in NSW waters are also listed as being threatened under the NSW *TSC Act 1995* (Table 17). While the survival of hawksbill turtles is not considered threatened by activities occurring in NSW waters, they are still protected in these waters under the *NPW Act 1974* (Table 17).

The threatened populations of sea turtle species commonly occurring off NSW are not yet recovering. The eastern Australian population of loggerhead turtles has declined 86% over the past 23 years to less than 500 nesting females (C. Limpus, Qld EPA, pers. comm. 2003). The eastern Australian populations of green turtles are in the early stages of decline (Environment Australia 1998a). The population of hawksbill turtles based around the northern Great Barrier Reef has declined in the last decade (Environment Australia 1998a). A noted decline in the Queensland breeding population of leatherback turtles is consistent with the major declines of this species observed in the northern hemisphere (C. Limpus, Qld EPA, pers. comm. 2003).

Threats

Factors contributing to the decline of sea turtle populations in Australia include fishing activities, shark control activities, boat strike, disease, tourism, indigenous harvesting, synthetic debris, coastal development, defence activities and predation of eggs by feral animals (Environment Australia 1998a). In Australian waters, sea turtles have been reported incidentally caught or entangled by trawl nets, gillnets, crab traps, trap ropes and floats, pelagic longlines, shark control nets and lost netting (Environment Australia 1998a). There are also some records of intentional killing of sea turtles by fishers (Environment Australia 1998a).

Fishing-related incidents reported in NSW

The nature and frequency of interactions between sea turtles and fishing activities off NSW are not known with certainty. However, they do not appear to be as frequent as those occurring in other states. The few records in the NSW DEC Marine Fauna Management Database between 1995-2005 show that sea turtles off NSW (19 in total) have been found entangled in beach protection nets, fishing nets and crab traps, and washed up on the coastal shores of NSW entangled in synthetic rope, with ingested fishing hook and line or boat strike injury. Between 2002-2004, there is also an additional record of a loggerhead turtle found in Sydney tangled in a crab net and rope on Taronga Zoo's Wildlife Rehabilitation Database. A low number of sea turtles are caught in beach protection nets in NSW each year (Krough and Reid 1996), with 84 sea turtles, including green, loggerhead and leatherback turtles, captured in these nets between 1950-2004 (D. Reid, NSW DPI, pers. comm. 2003). In 850 commercial fish trawl fishing-days observed off the NSW coast by NSW DPI, three sea turtles (species unspecified) were captured on separate occasions, all north of Newcastle (G. Liggins, NSW DPI, pers. comm. 2003). One sea turtle was also observed captured in a prawn trawl net set up to harvest squid in the mouth of the Hawkesbury River at Patonga during 1991 (G. Liggins, NSW DPI, pers. comm. 2003). The mortality rates associated with these captures are unknown (G. Liggins, NSW DPI, pers. comm. 2003).

4.2.2. Sea snakes

4.2.2.1. Sea snakes off NSW

The 33 species of sea snakes known to occur in Australia are generally found in warm temperate and subtropical waters. In NSW, 11 true sea snake (purely aquatic snakes in that they complete their lifecycle and always remain at sea) and one sea krait (amphibious snakes that come ashore to lay eggs and drink freshwater) species have been recorded (Table 18). Sea snakes occur very infrequently in NSW, the sparse records show that generally less than five individual sea snakes are recorded in NSW each year (Cogger 2000). All sea snake species occurring off the coast of NSW are protected under the *NPW Act 1974* and *EPBC Act 1999*. No sea snake species in Australia is currently threatened.

Species excluded from detailed assessment

Most of the species that occur in the waters off NSW (Table 18), except the yellow-bellied sea snake, are vagrants that have drifted outside their core tropical range with the assistance of warm southward-flowing summer currents (Cogger 2000). Fishing activities in NSW are therefore unlikely to significantly impact upon these species.

Species to be assessed: The yellow-bellied sea snake

The surface-dwelling yellow-bellied sea snake, found in tropical and warm temperate waters, is commonly recorded along the whole NSW coast in the open ocean and large estuaries (Cogger 2000), where it could potentially interact with NSW fishing activities. This species is probably a permanent year-round resident in the waters off the NSW coast (Cogger 2000). Gravid females have been found in NSW, suggesting that individuals in NSW contribute to the Australian stock of the species (Cogger 2000). It feeds on fish found near floating items on the surface of the ocean (Cogger 2000). The most likely potential interaction of this species with fishing activities would be its incidental capture in active and derelict trawl nets, as such capture of sea snakes is regularly recorded in northern Australia where sea snakes are common (Ward 1996a, b, 2000, Kiessling 2003). There is no evidence of any significant human-induced mortality on this species (Cogger 2000).

Table 18: The sea snakes found in waters off NSW and their conservation status.

Note: In constructing this table, information was sourced from Cogger 2000.
* The species listed under this section will not be further assessed in this report.
Descriptions of the threatened species categories are provided in Appendix 2.

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Commonwealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
A) Resident species off NSW				
Yellow-bellied sea snake	*Pelamis platurus*	Protected	Protected	Not in database
B) Vagrant species off NSW *				
Horned sea snake	*Acalyptophis peronii*	Protected	Protected	Not in database
Reef shallows sea snake	*Aipysurus duboisii*	Protected	Protected	Not in database
Olive sea snake	*Aipysurus laevis*	Protected	Protected	Not in database
Stokes' sea snake	*Astrotia stokesii*	Protected	Protected	Not in database
Spectacled sea snake	*Disteria kingii*	Protected	Protected	Not in database
Olive-headed sea snake	*Disteria major*	Protected	Protected	Not in database
Turtle-headed sea snake	*Emydocephalus annulatus*	Protected	Protected	Not in database
Elegant sea snake	*Hydrophis elegans*	Protected	Protected	Not in database
Plain sea snake	*Hydrophis inornatus*	Protected	Protected	Not in database
Spotted sea snake	*Hydrophis ornatus/ocellatus* complex	Protected	Protected	Not in database
Yellow-lipped sea krait	*Laticaudata colubrina*	Protected	Protected	Not in database

4.3. Avifauna

4.3.1.1. Overview of the biology of birds found in marine and estuarine habitats

Birds that depend upon marine and estuarine habitats include seabirds, shorebirds, waders, waterfowl and some birds of prey. Nearly all these birds, except penguins, are aerial species that forage and rest on water surfaces and nest, rest and perhaps also forage on land, including shoreline habitats. Penguins are flightless and forage within the water column and nest and rest on land. Procellariform seabirds (e.g. albatrosses and petrels) are long-lived, mature late (at around 7-12 years), produce one or two offspring either annually or biennially, have a low natural mortality and a high adult survival rate. Other seabirds, waders, shorebirds and waterfowl generally have a higher reproductive output than Procellariform seabirds, as they produce bigger clutches and mature earlier, and they have a higher adult mortality. The success of breeding events is dependent upon many factors, especially the availability of enough food resources in areas adjacent to breeding colonies to cater for the high metabolic rate of birds. It is easier for birds that forage at sea to join a bird that has already found a food source than to find an alternative food source (Commonwealth of Australia 2003). The diets of these birds are described in detail below.

4.3.1.2. Birds found on NSW estuaries, coastal shores and adjacent ocean

Species excluded from detailed assessment

Around 205 bird species have been recorded in the estuarine, coastal shore and adjacent oceanic habitats in NSW (Marchant and Higgins 1990, 1993, Higgins and Davies 1996, Higgins 1999). Of these species, those that are uncommon in NSW, but are common elsewhere (50 species in all) are unlikely to be significantly affected by fishing activities. This includes species that are vagrant, accidental, rare, uncommon or occasional to Australia and species that are common in their main Australian range, but are vagrant, uncommon, occasional, scarce or sporadic in NSW that lies outside of this range (Table 19). Other bird species found on the estuaries, coastal shores and ocean of NSW on a rare, unusual or occasional basis that are also unlikely to be significantly affected by fishing activities in these areas include those that generally favour the more terrestrial habitats of NSW, such as freshwater and saline wetlands and dams. These 33 species are listed in Table 19.

Table 19: Birds found in NSW estuaries, coastal shores and adjacent ocean that are excluded from further assessment in this study.

Note: The information presented in this table was sourced from Marchant and Higgins (1990, 1993) and Higgins and Davies (1996) and Higgins (1999). Information for albatrosses was also sourced from Environment Australia (2001b).

The species names and order used in this table are from *The Draft Working List of Birds of Australia and Australian Territories (Birds Australia 2003)*.

* These species occur in the waters off NSW as vagrants outside of their main range in Australia.

Common name	Scientific name	Common name	Scientific name
Vagrant / accidental species to Australia (including NSW)			
Fiordland penguin	*Eudyptes pachyrhynchus*	Pink-footed shearwater	*Puffinus creatopus*
South Georgian diving-petrel	*Pelecanoides georgicus*	Audobon's shearwater	*Puffinus lherminieri*
Mottled petrel	*Pterodroma inexpectata*	Ringed plover	*Charadrius hiaticula*
Juan Fernandez petrel	*Pterodroma externa*	Buff-breasted sandpiper	*Tryngites subruficollis*
Tristan albatross	*Diomedea dabbenena*	Sabine's gull	*Larus sabini*
Pacific albatross	*Thallasarcrche platei*	Black tern	*Childonias niger*
Species that are rare visitors / uncommon / occasional in Australia (including NSW)			
Kerguelen petrel*	*Pterodroma brevirostris*	Atlantic yellow-nosed albatross	*Thalassarche chlororhynchos*
Tahiti petrel	*Pseudobulweria rostrata*	Black-bellied storm-petrel	*Fregetta tropica*
Herald petrel*	*Pterodroma arminjoniana*	Wandering tattler	*Heteroscelus incana*
Cook's petrel	*Pterodroma cookii*	Asian dowitcher	*Limnodromus semipalmatus*
Blue petrel*	*Halobaena caerulea*	Little stint	*Calidris minuta*
Broad-billed prion*	*Pachyptila vittata*	White-rumped sandpiper	*Calidris fuscicollis*
Westland petrel	*Procellaria westlandica*	Ruff	*Philomachus pugnax*
Black petrel	*Procellaria parkinsoni*	Arctic tern	*Sterna paradisaea*
Species that occur in NSW as vagrants outside their main Australian range, where they are more common			
Soft-plumaged petrel	*Pterodroma mollis*	Red-footed booby	*Sula sula*
White-chinned petrel	*Procellaris aequinoctialis*	Brown booby	*Sula leucogaster*
Grey-headed albatross	*Thalassarche chrysostoma*	Black-faced cormorant	*Phalacrocorax fuscescens*
Grey-backed storm petrel	*Oceanites nereis*	Fairy tern	*Sterna nereis*
Species that are regular in other parts of Australia, but are uncommon, occasional, scarce or sporadic in NSW			
Common diving-petrel	*Pelecanoides urinatrix*	Masked booby	*Sula dactylatra*
Southern fulmar	*Fulmarus glacialoides*	Great frigatebird	*Fregata minor*
White-headed petrel	*Pterodroma lessonii*	Long-toed stint	*Calidris minuta*
Salvin's prion	*Pachyptila salvini*	Banded stilt	*Cladorhynchus leucocephalus*
Slender-billed prion	*Pachyptila belcheri*	Grey plover	*Pluvialis squatarola*
Light-mantled sooty albatross	*Phoebetria palpebrata*	Oriental plover	*Charadrius hiaticula*
White-tailed tropicbird	*Phaethon lepturus*	Black noddy	*Anous minutus*

Table 19 – continued

Common name	Scientific name	Common name	Scientific name
Species in NSW that are common on the terrestrial habitats they prefer (e.g. wetlands and coastal forest) and also occur on estuarine, shoreline and/or offshore habitats on occasion, rarely or unusually			
Wandering whistling-duck	*Dendrocygna arcuata*	Brown falcon	*Falco berigora*
Freckled duck	*Stictonetta naevosa*	Australian hobby	*Falco longipennis*
Maned duck	*Chenonetta jubata*	Australian kestrel	*Falco cenchroides*
Mallard	*Anas platyrhynchos*	Baillon's crake	*Porzana pusilla*
Australian shoveler	*Anas rhynchotis*	Purple swamphen	*Porphyrio porphyrio*
Pink-eared duck	*Malacorhynchus membranaceus*	Dusky moorhen	*Gallinula tenebrosa*
Hardhead	*Aythya australis*	Eurasian coot	*Fulica atra*
Pacific heron	*Ardea pacifica*	Latham's snipe	*Gallinago hardwickii*
Intermediate egret	*Ardea intermedia*	Sharp-tailed sandpiper	*Calidris acuminata*
Little bittern	*Ixobrychus minutus*	Bush stone-curlew	*Burhinus grallarius*
Australasian bittern	*Botarus poiciloptilus*	Black-winged stilt	*Himantopus himantopus*
Glossy ibis	*Plegadis falcinellus*	Red-necked avocet	*Recurvirostra novaehollandiae*
Straw-necked ibis	*Threskiornis spinicollis*	Black-fronted plover	*Elseyornis melanops*
Yellow-billed spoonbill	*Platalea flavipes*	Red-kneed dotterel	*Erthrogonys cinctus*
Swamp harrier	*Circus approximans*	Whiskered tern	*Childonias hybridus*
Wedge-tailed eagle	*Aquila audax*	Collared kingfisher	*Todiramphus chloris*
Little eagle	*Hieraaetus morphnoides*		

Species to be assessed

The 122 birds that commonly occur on NSW estuaries, coastal shores and adjacent ocean (Table 20) are those most likely to potentially interact with fishing activities in these areas.

Table 20: Birds that commonly occur on NSW estuaries, coastal shores and adjacent ocean.

Note: In constructing this table, information was sourced from Marchant and Higgins (1990, 1993), Higgins and Davies (1996) and Higgins (1999). Information for albatrosses was also sourced from Environment Australia (2001).

The species names and order used in this table are from *The Draft Working List of Birds of Australia and Australian Territories* (Birds Australia 2003).

Descriptions of the threatened species categories are provided in Appendix 2.

Common name	**Scientific name**	**Conservation status**		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	**Common-wealth (*EPBC Act 1999*)**	**International (IUCN Redlist 2004)**
Musk duck	*Biziura lobata*	Protected	Protected	Not in database
Black swan	*Cygnus atratus*	Protected	Protected	Not in database
Australian shelduck	*Tadorna tadornoides*	Protected	Protected	Not in database
Pacific black duck	*Anas superciliosa*	Protected	Protected	Not in database
Grey teal	*Anas gracilis*	Protected	Protected	Not in database
Chestnut teal	*Anas castanea*	Protected	Protected	Not in database
Hoary-headed grebe	*Poliocephalus poliocephalus*	Protected	Not protected under this Act	Not in database
Great crested grebe	*Podiceps cristatus*	Protected	Not protected under this Act	Not in database
Little penguin	*Eudyptula minor*	Protected; Endangered Population at Manly	Protected	Not in database
Southern giant-petrel	*Macronectes giganteus*	Endangered	Endangered	Vulnerable
Northern giant-petrel	*Macronectes halli*	Protected	Vulnerable	Lower Risk, near threatened
Cape petrel	*Daption capense*	Protected	Protected	Not in database
Great-winged petrel	*Pterodroma macroptera*	Protected	Protected	Not in database
Providence petrel	*Pterodroma solandri*	Vulnerable	Protected	Vulnerable
Kermadec petrel	*Pterodroma neglecta*	Vulnerable	Vulnerable	Not in database
White-necked petrel	*Pterodroma cervicalis*	Protected	Protected	Vulnerable
Black-winged petrel	*Pterodroma nigripennis*	Vulnerable	Protected	Not in database
Gould's petrel	*Pterodroma leucoptera leucoptera*	Endangered	Endangered	Vulnerable
Antarctic prion	*Pachyptila desolata*	Protected	Protected	Not in database
Fairy prion	*Pachyptila turtur*	Protected	Protected	Not in database
Streaked shearwater	*Calonectris leucomelas*	Protected	Protected	Not in database
Wedge-tailed shearwater	*Puffinus pacificus*	Protected	Protected	Not in database
Buller's shearwater	*Puffinus bulleri*	Protected	Protected	Vulnerable
Flesh-footed shearwater	*Puffinus carneipes*	Vulnerable	Protected	Not in database
Sooty shearwater	*Puffinus griseus*	Protected	Protected	Not in database

Table 20 – continued

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Common-wealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
Short-tailed shearwater	*Puffinus tenuirostris*	Protected	Protected	Not in database
Fluttering shearwater	*Puffinus gavia*	Protected	Protected	Not in database
Hutton's shearwater	*Puffinus huttoni*	Protected	Protected	Endangered
Little shearwater	*Puffinus assimilis*	Vulnerable	Protected	Not in database
Wandering albatross	*Diomedea exulans*	Endangered	Vulnerable	Vulnerable
Antipodean albatross	*Diomedea antipodensis*	Vulnerable	Vulnerable	Vulnerable
Gibson's albatross	*Diomedea gibsoni*	Vulnerable	Vulnerable	Not in database
Southern royal albatross	*Diomedea epomophora*	Protected	Vulnerable	Vulnerable
Northern royal albatross	*Diomedea sanfordi*	Protected	Endangered	Endangered
Black-browed albatross	*Thalassarche melanophris*	Vulnerable	Vulnerable	Vulnerable
Campbell albatross	*Thalassarche impavida*	Protected	Vulnerable	Vulnerable
Buller's albatross	*Thalassarche bulleri*	Protected	Vulnerable	Vulnerable
Shy albatross	*Thalassarche cauta*	Vulnerable	Vulnerable	Lower Risk, near threatened
White-capped albatross	*Thalassarche steadi*	Protected	Vulnerable	Not in database
Salvin's albatross	*Thalassarche salvini*	Protected	Vulnerable	Vulnerable
Indian yellow-nosed albatross	*Thalassarche carteri*	Protected	Vulnerable	Vulnerable
Sooty albatross	*Phoebetria fusca*	Vulnerable	Vulnerable	Vulnerable
Wilson's storm-petrel	*Oceanites oceanicus*	Protected	Protected	Not in database
White-faced storm-petrel	*Pelagodroma marina*	Protected	Protected	Not in database
White-bellied storm-petrel	*Fregetta grallaria*	Vulnerable	Vulnerable	Not in database
Red-tailed tropicbird	*Phaethon rubricauda*	Vulnerable	Protected	Not in database
Australasian gannet	*Morus serrator*	Protected	Protected	Not in database
Darter	*Anhinga melanogaster*	Protected	Not protected under this Act	Lower Risk, near threatened
Little pied cormorant	*Phalacrocorax melanoleucos*	Protected	Not protected under this Act	Not in database
Pied cormorant	*Phalacrocorax varius*	Protected	Not protected under this Act	Not in database
Little black cormorant	*Phalacrocorax sulcirostris*	Protected	Not protected under this Act	Not in database
Great cormorant	*Phalacrocorax carbo*	Protected	Not protected under this Act	Not in database
Australian pelican	*Pelecanus conspicillatus*	Protected	Protected	Not in database
Least frigatebird	*Fregata ariel*	Protected	Protected	Not in database
White-faced heron	*Egretta novaehollandiae*	Protected	Not protected under this Act	Not in database
Little egret	*Egretta garzetta*	Protected	Protected	Not in database
Eastern reef egret	*Egretta sacra*	Protected	Protected	Not in database
Great egret	*Ardea alba*	Protected	Protected	Not in database
Striated heron	*Butorides striatus*	Protected	Not protected under this Act	Not in database
Nankeen night heron	*Nycticorax caledonicus*	Protected	Protected	Not in database
Black bittern	*Ixobrychus flavicollis*	Vulnerable	Not protected under this Act	Not in database

Table 20 – continued

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Common-wealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
Australian white ibis	*Threskiornis molucca*	Protected	Protected	Not in database
Royal spoonbill	*Platalea regia*	Protected	Not protected under this Act	Not in database
Black-necked stork	*Ephippiorhynchus asiaticus*	Protected	Not protected under this Act	Lower Risk, near threatened
Osprey	*Pandion haliaetus*	Vulnerable	Protected	Not in database
Brahminy kite	*Haliastur indus*	Protected	Protected	Not in database
Whistling kite	*Haliastur sphenurus*	Protected	Protected	Not in database
White-bellied sea-eagle	*Haliaeetus leucogaster*	Protected	Protected	Not in database
Peregrine falcon	*Falco peregrinus*	Protected	Protected	Not in database
Buff-banded rail	*Gallirallus philippensis*	Protected	Protected	Not in database
Lewin's rail	*Rallus pectoralis*	Protected	Not protected under this Act	Not in database
Australian crake	*Porzana fluminea*	Protected	Protected	Not in database
Spotless crake	*Porzana tabuensis*	Protected	Protected	Not in database
Black-tailed godwit	*Limosa limosa*	Vulnerable	Protected	Not in database
Bar-tailed godwit	*Limosa lapponica*	Protected	Protected	Not in database
Little curlew	*Numenuis minutus*	Protected	Protected	Not in database
Whimberel	*Numenius phaeopus*	Protected	Protected	Not in database
Eastern curlew	*Numenius madagascariensis*	Protected	Protected	Lower Risk, near threatened
Marsh sandpiper	*Tringa stagnatilis*	Protected	Protected	Not in database
Common greenshank	*Tringa nebularia*	Protected	Protected	Not in database
Terek sandpiper	*Xenus cinereus*	Vulnerable	Protected	Not in database
Common sandpiper	*Actitis hypoleucos*	Protected	Protected	Not in database
Grey-tailed tattler	*Heteroscelus brevipes*	Protected	Protected	Not in database
Ruddy turnstone	*Arenaria interpres*	Protected	Protected	Not in database
Great knot	*Calidris tenuirostris*	Vulnerable	Protected	Not in database
Red knot	*Calidris canutus*	Protected	Protected	Not in database
Sanderling	*Calidris alba*	Vulnerable	Protected	Not in database
Red-necked stint	*Calidris ruficollis*	Protected	Protected	Not in database
Pectoral sandpiper	*Calidris melanotos*	Protected	Protected	Not in database
Curlew sandpiper	*Calidris ferruginea*	Protected	Protected	Not in database
Broad-billed sandpiper	*Limicola falcinellus*	Vulnerable	Protected	Not in database
Beach stone-curlew	*Esacus magnirostris*	Endangered	Protected	Lower Risk, near threatened
Pied oystercatcher	*Haematophus longirotris*	Vulnerable	Not protected under this Act	Not in database
Sooty oystercatcher	*Haematopus fuliginosus*	Vulnerable	Not protected under this Act	Not in database
Pacific golden plover	*Pluvialis fulva*	Protected	Protected	Not in database
Red-capped plover	*Charadius ruficapillus*	Protected	Protected	Not in database
Double-banded plover	*Charadrius bicinctus*	Protected	Protected	Not in database
Lesser sand-plover	*Charadrius mongolus*	Vulnerable	Protected	Not in database
Greater sand-plover	*Charadrius leschenaultii*	Vulnerable	Protected	Not in database
Hooded plover	*Thinornis rubricollis*	Endangered	Protected	Lower Risk, near threatened
Masked lapwing	*Vanellus miles*	Protected	Protected	Not in database

Table 20 – continued

Common name	Scientific name	Conservation status		
		NSW (*TSC Act 1995* or *NPW Act 1974*)	Common-wealth (*EPBC Act 1999*)	International (IUCN Redlist 2004)
Brown skua	*Catharacta lonnbergi*	Protected	Protected	Not in database
South polar skua	*Catharacta maccormicki*	Protected	Protected	Not in database
Pomarine jaeger	*Stercorarius pomarinus*	Protected	Protected	Not in database
Arctic jaeger	*Stercorarius parasiticus*	Protected	Protected	Not in database
Long-tailed jaeger	*Stercorarius longicauda*	Protected	Protected	Not in database
Pacific gull	*Larus pacificus*	Protected	Protected	Not in database
Kelp gull	*Larus dominicanus*	Protected	Protected	Not in database
Silver gull	*Larus novaehollandiae*	Protected	Protected	Not in database
Gull-billed tern	*Sterna nilotica*	Protected	Protected	Not in database
Caspian tern	*Sterna caspia*	Protected	Protected	Not in database
Crested tern	*Sterna bergii*	Protected	Protected	Not in database
White-fronted tern	*Sterna striata*	Protected	Protected	Not in database
Common tern	*Sterna hirundo*	Protected	Protected	Not in database
Little tern	*Sterna albifrons*	Endangered	Protected	Not in database
Sooty tern	*Sterna fuscata*	Vulnerable	Protected	Not in database
White-winged black tern	*Chlidonias leucopterus*	Protected	Protected	Not in database
Common noddy	*Anous stolidus*	Protected	Protected	Not in database
Grey ternlet	*Procelsterna albivittata*	Vulnerable	Protected	Not in database
White tern	*Gygis alba*	Vulnerable	Protected	Not in database
Azure kingfisher	*Ceyx azurea*	Protected	Not protected under this Act	Not in database
Sacred kingfisher	*Todiramphus sanctus*	Protected	Protected	Not in database

Habitat, foraging and diet

The fishing activities occurring on and in marine and estuarine waters managed by NSW DPI can be grouped into the following zones: those occurring in estuaries; on coastal shores; and inshore and offshore marine waters. The birds that commonly occur where this fishing takes place (Table 20) are highly mobile and can forage across the waters and/or shores of these zones. The species whose food availability could potentially be affected by these fishing activities are those that feed on harvested groups such as fish, molluscs and crustaceans from estuarine and oceanic waters and molluscs and crustaceans from shorelines. Table 21 illustrates the habitats in which the birds listed in Table 20 can be found and outlines their diet and foraging method.

The bird species that predominantly occur in the estuarine and coastal shore zones of NSW (Table 20) are mostly shorebirds and wading birds. Most of the birds found only on estuaries and only on estuaries and coasts forage around or near the edge of the water in the shallows and/or on the shoreline and do not dive far from the surface whilst foraging (Table 21). The exception is the hoary-headed grebe that forages on open water up to 3m deep (Marchant and Higgins 1990). The availability of food to the hoary-headed grebe and Australian shelduck should not be directly affected by fishing activities on NSW estuaries and coasts, as these species do not feed on harvested groups. The diet of all other species in this grouping includes groups of species that are harvested by fishers (Table 21).

Some of the species listed in Table 20 occur on estuaries, coastal shores and also inshore waters (Table 21). All these species feed on fish to some extent and forage from and around surface waters and/or on shorelines and/or in shallow water (Table 21). Of these species, those that dive to forage in the upper depths of the water column are the cormorants and the great crested grebe (Table 21). Some of the

estuarine species listed in Table 20 can also occur on inshore waters. Of these six species, the black swan and grey teal are predominantly herbivores whose food availability should not be directly affected by fishing activities in these areas (Table 21). The other four species feed on groups harvested by fishers, two of which, the darter and musk duck, can obtain their prey by diving to the upper depths of the water column (Table 21). The silver gull, crested, white-fronted and common terns occur across all coastal and oceanic habitat types and can feed on fish from or around surface waters (Table 21).

The birds that predominantly occur in oceanic habitats are species of seabirds. Of the birds listed in Table 20 that are found only in oceanic habitats, the Australasian gannet mostly occurs in inshore waters; the prions, some petrel species and the red-tailed tropicbird mostly occur in offshore waters; and the other seabird species occur across both of these habitats (Table 21). Nearly all these species predominantly feed on fish and/or cephalopods. The exceptions are the largely krill-feeding prions and the scavenging giant-petrels, jaegers and skuas that feed on a wide variety of animal groups (Table 21). Excluding the little penguin, which occurs in pelagic waters foraging to a depth of at least 30 m, all birds that commonly occur in the ocean off NSW mostly feed from and around the ocean surface (Table 21). Some of these, including the Australasian gannet, red-tailed tropicbird and most shearwater species, commonly plunge and dive to feed on fish and/or cephalopods at greater depths (Table 21).

Table 21: An overview of the habitat, foraging area, foraging method and diet of birds that are commonly found on NSW estuaries, coastal shores and adjacent waters.

Note: The information presented in this table was sourced from Marchant and Higgins (1990, 1993), Higgins and Davies (1996), Higgins (1999), Milledge (1977) and Wood (1989, 1990, 1992).

'Estuaries' includes open estuarine waters, lagoons, tidal reaches of rivers, saltmarsh, mangroves and estuarine shorelines. 'Coasts' includes beaches, rock platforms, adjacent reefs and intertidal shorelines. 'Inshore' includes inshore waters and islands to 3nm. 'Offshore' includes waters and islands from 3nm to 80nm.

Only foraging methods that are used on water or shorelines are given. (nb. not all species within a foraging group use all given foraging methods).

🚢 indicates species is known to associate with fishing vessels, gear and/or ships.

The composition of a species diet is indicated after the species name by:
⊙ - predominantly fish and/or cephalopods.
⩛ - fish, crustaceans or molluscs, and perhaps a few other groups.
◆ - largely krill with small amounts of fish, cephalopods and gastropods.
▪ - many groups including fish and/or cephalopods, which can be important for these species at different times and locations.
★ - many groups including fish and either molluscs and/or crustaceans.
⅄ - many groups, not including fish, but including molluscs and/or crustaceans.
'no symbol' – predominantly aquatic vegetation or arthropods.

Species and diet	Foraging area	Foraging method
Birds that only occur in estuaries		
Black bittern⩛	shallow water	method not described
Chestnut teal⅄ Australian shelduck	shallow water to shallow substrates (to 1m deep)	up-end, dab, peck, paddle, sift
Royal spoonbill⩛	shallow water, intertidal mudflats	probe, grab, sweep, search, drag
Gull-billed tern⩛	surface waters and the air above, intertidal shoreline	surface methods, plunge, hawk
Curlew sandpiper★ Lewin's rail⅄ Australian crake⅄ Spotless crake⅄ Pectoral sandpiper⅄	shoreline substrates, shallow water	probe, peck, drill, glean, scratch
Broad-billed sandpiper⅄	shoreline substrates (mostly intertidal)	probe, glean, peck
Birds that only occur in estuaries and on coasts		
Hoary-headed grebe	open water (0.5 – 3m deep)	deep diving
🚢Azure kingfisher★ 🚢Sacred kingfisher★	edges of waterways	surface-plunging
Little egret⩛ Eastern reef egret⩛ Great egret⩛ Striated heron⩛ Nankeen night heron⩛ Black-necked stork⩛	shallow water	snatch, flick, stir, plunge, stalk, stab, probe
Marsh sandpiper⅄	shallow water	glean, lunge, grab, pick

Table 21 – continued

Species and diet	Foraging area	Foraging method
White-faced heron★ Australian white ibis★ Bar-tailed godwit★ Common greenshank★ Common sandpiper★ Grey-tailed tattler★ Buff-banded rail ⅄ Black-tailed godwit⅄ Great knot⅄ Red-necked stint⅄ Masked lapwing⅄	shoreline substrates, shallow water	probe, glean, peck, lunge, flick, mow, grab, snatch
Whimberel★ Red knot★ Sanderling★ Pied oystercatcher★ Pacific golden plover★ Eastern curlew⅄ Terek sandpiper⅄ Ruddy turnstone⅄ Beach stone-curlew⅄ Red-capped plover⅄ Double-banded plover⅄ Lesser sand-plover⅄ Greater sand-plover⅄ Hooded plover⅄	shoreline substrates (mostly intertidal)	probe, glean, peck, dig, jab
Sooty oystercatcher★	rocky intertidal shores	stab, prise, lever, hammer, scissor
Little curlew	does not forage on water or shorelines	
Birds that only occur in estuaries and on inshore waters		
Darter⩛ Musk duck★	open water, from shallows to upper depths in deep water	dive
Pacific black duck⅄ Black swan Grey teal	surface waters to shallow substrates (to 1m deep), muddy shores	up-end, dab, dredge
White-winged black tern▪	surface waters, shoreline and the air above	hawk, plunge, surface methods
Birds that only occur in estuaries, on coasts and on inshore waters		
▁◢Australian pelican★	surface waters or just below	plunge, scoop, stab
Great crested grebe ⩛ Little pied cormorant⩛ ▁◢Pied cormorant⩛ Little black cormorant⩛ Great cormorant⩛	surface waters and upper depths	pursue, dive
Osprey⩛ ▁◢White-bellied sea eagle★	surface waters or just below, shorelines	plunge, dive, seize
▁◢Brahminy kite▪ Whistling kite▪	surface waters or just below, shorelines	snatch, pirate
Peregrine falcon	surface waters or just below, shorelines, air above	method not adequately described
▁◢Kelp gull★	surface waters or just below, intertidal shores	dive, snatch, seize, plunge

Table 21 – continued

Species and diet	Foraging area	Foraging method
Pacific gull★	intertidal shorelines to inshore waters	hunt, pirate, dive, foot-tremble, prise, drop
Caspian tern⊙ Little tern⩛	shallow water	plunge, peck, probe, tremble
Birds that occur in estuaries, on coasts and on inshore and offshore waters		
Crested tern⊙ White-fronted tern⊙ Common tern⩛	surface waters or just below	dive, plunge, surface methods
Silver gull★	surface waters or just below, intertidal shores	seize, surface methods, dive, hawk
Birds that only occur on inshore waters		
Australasian gannet	ocean waters, upper depths	plunge
Birds that only occur on inshore and offshore waters		
Cape petrel⊙ Wedge-tailed shearwater⊙ Buller's shearwater⊙ Little shearwater⊙ Wandering albatross⊙ Southern royal albatross⊙ Northern royal albatross⊙ Black-browed albatross⊙ Buller's albatross⊙ Shy albatross⊙ Indian yellow-nosed albatross⊙ Wilson's storm-petrel⊙ Southern giant-petrel▪ Northern giant-petrel▪	ocean surface or just below	seize, plunge, dive, pursue, other surface methods
Sooty tern⊙ Common noddy⊙	ocean surface or just below	seize, plunge, other surface methods, aerial pursuit
Great-winged petrel⊙ White-necked petrel⊙ Sooty albatross⊙ White-faced storm-petrel⊙ Grey ternlet⊙	ocean surface or just below	seize, other surface methods
Providence petrel⊙ Gould's petrel⊙ Streaked shearwater⊙ Antipodean albatross⊙ Gibson's albatross⊙ Campbell albatross⊙ White-capped albatross⊙ Salvin's albatross⊙	ocean surface or just below	method not described

Table 21 – continued

Species and diet	Foraging area	Foraging method
Hutton's shearwater⊙	ocean surface and upper depths	dive, plunge
Flesh-footed shearwater⊙ Sooty shearwater⊙ Short-tailed shearwater⊙ Fluttering shearwater⊙	ocean surface and upper depths (>10 m)	plunge, dive, pursue, seize, hydroplane
South polar skua▪ Pomarine jaegar▪ Arctic jaegar▪ Long-tailed jaegar▪	ocean surface and air above it	pirate, seize, dive, plunge
Brown skua▪	ocean surface and air above it	hunt, pirate, seize
Least frigatebird⊙	ocean surface and air above it	flight feed, surface methods, pirate
Little penguin⊙	ocean waters to 30 m deep	pursuit-diving
Birds that only occur on offshore waters		
White tern⊙ Antarctic prion◆ Fairy prion◆	ocean surface or just below	seize, dive, plunge, other surface methods
Kermadec petrel⊙ Black-winged petrel⊙ White-bellied storm-petrel⊙	ocean surface or just below	other surface methods
Red-tailed tropicbird⊙	ocean surface and upper depths	plunge

Distribution

The range of most birds commonly occurring on the coastal and oceanic habitats of NSW incorporates the length of the state. Exceptions are given in Table 22. Important sites for wading birds along the NSW coast include the estuaries of the Hunter, Richmond, Clarence, Shoalhaven, Tweed, Hastings, Manning, Hawkesbury, Parramatta, and Corindi Rivers, Botany Bay, Lake Macquarie, Tuggerah Lakes, Brisbane Water, Long Reef, Lake Illawarra, Bellambi Point, the Ulladulla coastline and Sussex Inlet beaches.

Table 22: The birds commonly occurring on NSW estuaries, coastal shores and adjacent ocean whose range does not incorporate the length of the state.

Note: The information presented in this table was sourced from Marchant and Higgins (1990, 1993), Higgins and Davies (1996), and the DEC atlas of NSW wildlife (21/11/03).

Distributional range in NSW	**Species found only within this range**
From Queensland border to a location on the south coast (whole coast except far south coast)	red-tailed tropicbird; Lewin's rail; greater sand-plover; bar-tailed godwit; black-tailed godwit; eastern curlew; sanderling; Terek sandpiper; common sandpiper; ruddy turnstone; grey-tailed tattler; great knot; red-necked stint; pectoral sandpiper; gull-billed tern; sooty tern; grey ternlet; spotless crake
From Queensland border to Sydney or a location in between (north coast only)	kermadec petrel; streaked shearwater; white-bellied storm-petrel; least frigatebird; black-necked stork; brahminy kite; beach stone-curlew; white tern
Whole coast except far north and far south coast	little curlew; broad-billed sandpiper
From Victorian border to a location on the north coast (whole coast except far north coast)	Antipodean albatross; Gibson's albatross; northern royal albatross; southern royal albatross; Buller's albatross; Indian yellow-nosed albatross; sooty albatross; white-faced storm-petrel; kelp gull
From near Sydney to Victorian border (south coast only)	hooded plover; Pacific gull

Seasonal occurrence

Many of the birds commonly occurring in coastal and oceanic habitats of NSW are seasonal (Table 23). This includes birds that breed in the far northern hemisphere and migrate to the warmer climes of Australia during the northern winter, generally arriving from August-November and departing from March-May. Black-winged, great-winged and white-necked petrels are also only found in Australian waters at this time, but they do not breed in the northern hemisphere. As a group, the shearwater species listed in Table 23 are seasonally abundant off NSW, being most common generally between September-December and February-May (Table 23). Of the birds listed in Table 23, those that only occur in Australian waters during winter (arriving from March-June and departing from September-November) include the double-banded plover, Cape and providence petrels, Wilson's and white-bellied storm-petrels, giant-petrels and brown skua. Albatrosses are also known to be most abundant in Australian waters during winter and spring, but some individuals of these species remain in Australian waters throughout the year (Table 23). Observations of albatrosses, petrels, shearwaters, skuas and jaegars from locations off NSW found a similar seasonal occurrence of these birds to that described for Australian waters above (Milledge 1977, Wood 1989, 1990, 1992).

Table 23: The birds commonly occurring on NSW estuaries, coastal shores and adjacent ocean that do so on a seasonal basis.

Season in Australia	**Species that only occur in Australian waters during this season**
Mostly summer: from July-December to March-June	black-winged petrel; pectoral sandpiper; curlew sandpiper; broad-billed sandpiper; marsh sandpiper; black-tailed godwit; common greenshank; grey-tailed tattler; great knot; whimberel; Terek sandpiper; red knot; Pacific golden plover; lesser sand-plover; greater sand-plover; little curlew; white-winged black tern; common tern; great-winged petrel; white-necked petrel; pomarine jaegar; Arctic jaegar; long-tailed jaegar
Winter: from March-June to September-November	white-bellied storm-petrel; double-banded plover; Cape petrel; southern giant-petrel; northern giant-petrel; Wilson's storm petrel; providence petrel; brown skua
Most abundant during winter, but some individuals are known to remain in Australian waters throughout the year	wandering albatross; southern royal albatross; black-browed albatross; Shy albatross; Indian yellow-nosed albatross; sooty albatross; antipodean albatross; Campbell albatross
Seasonally abundant off NSW, generally between September-December and February-May	wedge-tailed shearwater; Buller's shearwater; streaked shearwater; Hutton's shearwater; flesh-footed shearwater; sooty shearwater; short-tailed shearwater; fluttering shearwater

Breeding

Of all the birds commonly occurring on the marine and estuarine environments of NSW, 44 species use these areas to breed and another ten species may do so (Table 24). The habitats these species breed on include offshore islands, coastal and estuarine rocky and sandy shores and fringing estuarine habitats. Lord Howe, Norfolk, Muttonbird, Solitary, Cook, Moon, Bird, Cabbage Tree, Broughton, Boondelbah, Lion, The Five, The Tollgate and Montague Islands are the main offshore breeding islands for birds in NSW. The current status of the breeding populations on most of these islands is generally poorly known.

Table 24: Birds commonly found on NSW estuaries, coastal shores and adjacent ocean that nest on these habitats in NSW.

← denotes that the species also breeds inland.
× denotes the species is known to breed on coastal / estuarine habitats, its range includes NSW, but no specific site in NSW has been identified.

Birds that breed on the marine and estuarine habitats of NSW (including Lord Howe and Norfolk Islands)			
Pacific black duck←×	Little shearwater	Striated heron×	Red-capped plover←
Chestnut teal←×	White-faced storm-petrel	Australian white ibis←×	Hooded plover
Little penguin	White-bellied storm-petrel	Royal spoonbill←	Kelp gull
Providence petrel	Red-tailed tropicbird	Black-necked stork←	Silver gull←
Kermadec petrel	Little pied cormorant←	Osprey	Caspian tern←
Black-winged petrel	Pied cormorant←	Brahminy kite←	Crested tern
Gould's petrel	Great cormorant←×	White-bellied sea-eagle←	Little tern
Wedge-tailed shearwater	Australian pelican←	Peregrine falcon←	Sooty tern
Flesh-footed shearwater	Little egret←	Beach stone-curlew	Common noddy
Sooty shearwater	Great egret←	Pied oystercatcher	Grey ternlet
Short-tailed shearwater	Eastern reef egret	Sooty oystercatcher	White tern
Birds that breed on the inland habitats of NSW that may also breed on the coastal habitats of NSW			
Black swan	Little black cormorant	Black bittern	Buff-banded rail
Australian shelduck	White-faced heron	Whistling kite	Spotless crake
Darter	Nankeen night heron		

Conservation status

The bird species that commonly occur on the marine and estuarine habitats of NSW are protected under the relevant State and Commonwealth legislation (Table 20). Many of these species (47 in all) are listed as being threatened under at least one of the threatened species listings on a State, Commonwealth and international level (Table 20). Of these threatened species, 32 are seabirds, the majority of which are found on the oceanic habitats of NSW. The other 13 threatened birds (Table 20) are mostly found on the shorelines of coasts and estuaries, and the osprey is mostly found on the open waters of these habitats.

Threats

Overall, human activities that have been identified as threats to the birds listed in Table 20 are those that result in the destruction or modification of nesting and foraging habitats, disturbance of breeding

birds, their direct death or injury, changes in their food supply and contamination of their body tissues and habitat. Such activities include land clearing, grazing, burning and development, flood mitigation works, reclamation of tidal land, predation on breeding islands by introduced predators, boating, four-wheel driving, fishing, tourism and recreational activities, pollution of waterways with oil, plastics, chemicals and heavy metals, shooting of birds during hunting and fishing activities, illegal chick harvesting and egg collecting, collision with human objects and human activities that can result in climate change (Marchant and Higgins 1990, 1993, Higgins and Davies 1996, Higgins 1999, Garnett and Crowley 2000).

Fishing activities have been identified to threaten some of the birds listed in Table 20 when: the food reserves of these species, especially those near breeding colonies, are over harvested; they are incidentally killed or injured from being caught on or entangled in both active and discarded fishing gear or from colliding with fishing gear or vessels; and they are illegally shot to protect bait or for use as bait (Marchant and Higgins 1990, 1993, Higgins and Davies 1996, Gales 1998, Higgins 1999, Garnett and Crowley 2000). The fishing gear that the birds listed in Table 20 are known to interact with includes longlines, trolling lines, trawl nets, other nets, handlines and discarded fishing line, including that of recreational fishers (Marchant and Higgins 1990, 1993, Higgins and Davies 1996, Higgins 1999, Garnett and Crowley 2000, Ferris and Ferris 2002, Commonwealth of Australia 2003). Birds listed in Table 20 identified as being threatened by their capture on or entanglement in fishing gear include the musk duck, little penguin, giant-petrels, Cape and great-winged petrels, flesh-footed, wedge-tailed, sooty and short-tailed shearwaters, all albatross species, Australasian gannet, Australian pelican, osprey, white-bellied sea-eagle, Pacific and kelp gulls, and Caspian and white-fronted terns (Marchant and Higgins 1990, 1993, Higgins and Davies 1996, Environment Australia 1998a, Gales 1998, Higgins 1999, Garnett and Crowley 2000, Ferris and Ferris 2002). The incidental capture of seabirds on longlines and the ingestion of or entanglement in marine debris, some of which originates from fishing activities, have been identified as key threatening processes that can impact upon birds (Endangered Species Scientific Subcommittee 1995, NSW Scientific Committee 2003, Threatened Species Scientific Committee 2003).

Fishing-related incidents reported in NSW

Birds that have been observed feeding on the offal discarded from trawling and/or survey vessels in the marine waters off NSW (around Sydney and Wollongong), include wandering, black-browed, yellow-nosed, Buller's, grey-headed and shy albatrosses, Cape petrels, flesh-footed, wedge-tailed, Buller's and occasionally fluttering shearwaters, silver gulls, crested terns, pomarine and, rarely, long-tailed jaegers (Milledge 1977, Wood 1989, 1990, 1992). Northern and southern giant-petrels, brown skuas, sooty shearwaters and common terns were observed to follow or come up to the survey vessels, but were not observed to feed on discards (Milledge 1977, Wood 1989, 1990). It is not known to what extent the populations of these species have adapted to feeding on the discards from fishing activities in NSW. Additional species to those listed above, that are most likely to associate with and/or forage from fishing vessels or gear in NSW are those that are known to do so in other areas (see Table 21).

In NSW estuaries, the entanglement and hooking of birds in fishing tackle, predominantly that of a recreational nature, has been identified as a particular problem by Australian Seabird Rescue (ASR) (Ferris and Ferris 2002). ASR frequently observed this interaction to mostly occur with active recreational fishing gear (including setlines) and to a much lesser extent, discarded recreational fishing gear (Ferris and Ferris 2002). While this interaction is most regularly recorded with pelicans, the other affected birds ASR have rescued are silver gulls, cormorants, crested terns, osprey, Australasian gannets, darters, brahminy kites, white-faced herons, great egrets and oystercatchers (Ferris and Ferris 2002). The Taronga Zoo Wildlife Rescue Clinic also rescues many birds entangled in fishing line. Between 2002-2004, this clinic encountered eight silver gulls, six Australian pelicans, four pied cormorants, a little penguin, a bar-tailed godwit, a fluttering shearwater, a little pied cormorant, a tawny frogmouth, and an Australian magpie lark that were entangled in fishing tackle (Taronga Zoo

Wildlife Rehabilitation Database 2004). Apart from these accounts of this interaction, five pied and two sooty oystercatchers on the NSW south coast were reported entangled in fishing line (NSW NPWS 2003), two seabirds from the genus *Puffinus* and *Phalacrocorax* were found dead on NSW beaches from balloons that were entwined around the birds (Herfort 1997), and little penguins in NSW were reported to die from entangled fishing lines (Cunningham *et al.* 1993).

Another documented interaction between fishing activities off NSW and birds is their incidental capture on Commonwealth domestic pelagic longline fishing gear. This is a particular problem during the Australian summer for flesh-footed shearwaters and small numbers of wedge-tailed shearwaters and great-winged petrels mostly between the latitudes of 30°S and 32°S (Commonwealth of Australia 2003). The flesh-footed shearwaters affected by this interaction probably originate from the Lord Howe Island or New Zealand breeding populations (Priddel 2003).

Excluding the concentrated efforts of ASR, the Commonwealth's observer program, and the documented observations of birds feeding from discarded offal around Sydney and Wollongong there are only a few incidental reports of interactions between the fishing activities in the marine and estuarine waters of NSW and birds. From 2002-2004, a little penguin and a darter were treated at the Taronga Zoo Wildlife Rescue Clinic from being entangled in fishing netting (Taronga Zoo Wildlife Rehabilitation Database 2004). Priddel (2003) reported that flesh-footed shearwater chick carcasses on Lord Howe Island often contain substantial quantities of plastic. A pied cormorant, found in Sydney, may have been struck by a boat (Taronga Zoo Wildlife Rehabilitation Database, 2004). There are records of the intentional shooting of wandering albatrosses off the NSW east coast (Blakers *et al.* 1984, Tomkins 1985). One bird, a little penguin, has been captured in beach protection nets since 1947. No birds were captured during 440 trawl shots off NSW performed as part of a fishery-independent survey (K. Graham, NSW DPI, pers. comm. 2004). During this survey, it was incidentally noted that shearwaters would very occasionally collide with the trawling warps, but the effect of this collision on the bird was not noted (K. Graham, NSW DPI, pers. comm. 2004).

4.4. Chapter summary

Of all the marine wildlife species occurring in the marine and estuarine habitats of NSW, 149 species could potentially interact with fishing activities in these habitats and will be further assessed in this study. Fishing activities in NSW could potentially interact with 80 of these species in estuaries (4 marine mammal, 4 marine reptile, and 72 avifauna species), 59 of these species on coastlines (2 marine mammal, 3 marine reptile and 54 avifauna species), 85 of these species in inshore waters (14 marine mammal, 4 marine reptile, and 67 avifauna species), and 74 of these species in offshore waters (17 marine mammal, 5 marine reptile, and 52 avifauna species). The varying biological factors of these species that would influence how they interact with fishing activities are their spatial and seasonal distribution and abundance, habitat, diet, foraging area, diving ability, sensory and behavioural capabilities, and the main activities undertaken in a fished area.

Fishing-related activities have been listed as a direct and/or indirect threat to nearly all species to be further assessed in this report. Most of these species have k-selected life history characteristics (i.e. long-lived, late maturity, low fecundity, or long breeding interval) that make their populations susceptible to decline from human-induced mortality. Some of these species have stronger k-selected characteristics than others. Of all the species to be further assessed in this study, populations of the 7 mammal, 4 reptile, and 38 avifauna species that are listed as threatened under NSW (*TSC Act 1995*) and/or National (*EPBC Act 1999*) threatened species legislation would have the lowest resilience to negative effects from interactions with fishing-activities as their populations are small. Although not directly studied in NSW, opportunistic and anecdotal reports show that 44 of the species to be further assessed have been found in NSW to interact with fishing-related activities.

5. OVERVIEW OF THE INTERACTIONS BETWEEN MARINE WILDLIFE AND THE FISHERIES MANAGED BY THE NSW DPI

This chapter identifies the interactions (operational and ecological) that occur between the fishing activities in NSW (identified in Chapter 3)[5] and the wildlife species commonly occurring in the marine and estuarine waters of NSW (identified in Chapter 4). Any current or future areas of risk from these interactions will be identified and prioritised by considering the potential effects of the interactions on both marine wildlife species and fishers.

Existing information on the interactions occurring between marine wildlife and the fishing activities in NSW as documented in Chapters 3 and 4 is sparse. As there are large gaps in this information it is possible that some interactions that are actually occurring in NSW have never been documented. The assessment in this chapter is therefore, largely qualitative. Information on the local fishing-related and biological factors influencing the interactions occurring in NSW (detailed in Chapters 3 and 4) is used to answer a series of questions to determine the potential extent and consequence of these interactions in NSW. Interactions that are known to currently occur in NSW, including the results of a pilot observer study and diet analysis study conducted as part of this project, are highlighted as an indication of whether the potential identified interactions are likely to occur in NSW.

5.1. Operational interactions

5.1.1. Deliberate harvest of marine wildlife

Brief description: The deliberate killing or harvesting of marine wildlife by fishers for food, sport, bait, commercial or indigenous purposes.
Factors influencing this interaction:

Factors influencing this interaction:
Biological: local spatial and seasonal distribution and abundance of marine wildlife species; suitability of the species for food and bait; the time the animals spend at or above the water's surface; their feeding and foraging strategies; their diet and energy requirements; and behaviour.

Fishing-related: targeted species; location, season and time of day fished; effort; perception of the animal by fishers; and management arrangements.

Is this interaction legally possible in NSW? NO
This is the only type of operational interaction that should not occur in NSW as the deliberate killing of marine wildlife by fishers is currently prohibited by law in NSW. This prohibition is likely to continue into the future.

[5] The fishing activities in NSW considered in this chapter only include those managed by NSW DPI. Commonwealth fishing activities that occur off NSW are not considered in this assessment.

5.1.2. Marine wildlife feeding on bait, catch or discards

Brief description: The foraging of marine wildlife on the regular concentrated food source created by fishing bait, catch and biological discards.

Factors influencing this interaction:
Biological: Local spatial and seasonal distribution and abundance of marine wildlife species; their feeding and foraging strategies; and their diet and energy requirements.

Fishing-related: Location, season and time of day fished; gear type used; species harvested, discarded or used as bait; length of time these food sources remain near the surface; amount discarded; and effort.

Is this interaction possible in NSW? YES
The bait from traps and line fishing techniques and catch from trawls, traps, line techniques and nets used by NSW fisheries could potentially act as a source of food for marine wildlife species. The discards from nearly all methods considered in this assessment, except hand gathering and spear fishing, could also act as a food source for these species. The marine wildlife species that could potentially feed on these food sources from each NSW fishery are identified in Table 25. The wildlife species listed are those known to forage on fish and crustaceans. However, as the species composition of both the diet of many of these species and the discards and bait from some NSW fisheries is unknown or uncertain, it is possible that some of the species listed in Table 25 may not forage from these fishing activities.

Table 25: The marine wildlife species that could potentially feed on the bait, catch or discards from NSW fisheries.

✠ Indicates species that are listed as threatened under NSW or Australian legislation.

Fishery (and main gear types used)	Marine wildlife species
Estuary General (traps; line fishing methods; passive nets; active nets; hand gathering)	Mammals: bottlenose dolphin (inshore form). Reptiles: ✠loggerhead turtle. Avifauna: ✠black bittern; royal spoonbill; gull-billed tern; little egret; eastern reef egret; great egret; striated heron; nankeen night heron; black-necked stork; white-faced heron; Australian white ibis; bar-tailed godwit; common greenshank; common sandpiper; grey-tailed tattler; azure kingfisher; sacred kingfisher; great crested grebe; great cormorant; pied cormorant; little pied cormorant; little black cormorant; white-bellied sea eagle; whistling kite; brahminy kite; kelp gull; Pacific gull; Caspian tern; ✠little tern; Australian pelican; ✠osprey; peregrine falcon; crested tern; common tern; white-fronted tern; silver gull; darter; white-winged black tern; musk duck; Pacific black duck.
Estuary Prawn Trawl (trawl nets)	Mammals: bottlenose dolphin (inshore form). Reptiles: ✠loggerhead turtle. Avifauna: As per the Estuary General Fishery, except for the Pacific gull.
Ocean Hauling (active nets)	Mammals: bottlenose dolphin (inshore form); bottlenose dolphin (offshore form); common dolphin; Risso's dolphin; pantropical spotted dolphin; killer whale; short-finned pilot whale; ✠Australian fur-seal; ✠New Zealand fur-seal. Reptiles: ✠loggerhead turtle. Avifauna: great crested grebe; great cormorant; pied cormorant; little pied cormorant; little black cormorant; white-bellied sea eagle; whistling kite; brahminy kite; kelp gull; Pacific gull; Caspian tern; ✠little tern; Australian pelican; ✠osprey; peregrine falcon; crested tern; common tern; white-fronted tern; silver gull; darter; white-winged black tern; musk duck; Australasian gannet; Cape petrel; ✠providence petrel;

Table 25 – continued

Fishery (and main gear types used)	Marine wildlife species
Ocean Hauling (active nets) - *continued*	✠Gould's petrel; Wilson's storm-petrel; wedge-tailed shearwater; Buller's shearwater; ✠little shearwater; Hutton's shearwater; ✠fluttering shearwater; ✠flesh-footed shearwater; sooty shearwater; short-tailed shearwater; streaked shearwater; ✠wandering albatross; ✠southern royal albatross; ✠northern royal albatross; ✠Indian yellow-nosed albatross; ✠shy albatross; ✠Buller's albatross; ✠black-browed albatross; ✠antipodean albatross; ✠Gibson's albatross; ✠white-capped albatross; ✠campbell albatross; ✠Salvin's albatross; ✠sooty tern; ✠grey ternlet; common noddy; great-winged petrel; white-necked petrel; white-faced storm-petrel; ✠sooty albatross; least frigatebird; ✠southern giant-petrel; ✠northern giant-petrel; south polar skua; arctic jaegar; pomarine jaegar; long-tailed jaegar; brown skua; little penguin.
Ocean Trawl (trawl nets)	Mammals: bottlenose dolphin (inshore form); bottlenose dolphin (offshore form); common dolphin; Risso's dolphin; pantropical spotted dolphin; killer whale; short-finned pilot whale; striped dolphin; Arnoux's beaked whale; gingko-toothed beaked whale; strap-toothed beaked whale; Andrew's beaked whale; melon-headed whale; ✠sperm whale; pygmy sperm whale; false killer whale; ✠Australian fur-seal; ✠New Zealand fur-seal. Reptiles: ✠loggerhead turtle; ✠leatherback turtle. Avifauna: great crested grebe; great cormorant; pied cormorant; white-bellied sea eagle; brahminy kite; kelp gull; Pacific gull; Australian pelican; ✠osprey; crested tern; common tern; white-fronted tern; silver gull; darter; white-winged black tern; Pacific black duck; musk duck; Australasian gannet; Cape petrel; ✠providence petrel; ✠Gould's petrel; Wilson's storm-petrel; wedge-tailed shearwater; Buller's shearwater; ✠little shearwater; Hutton's shearwater; ✠fluttering shearwater; ✠flesh-footed shearwater; sooty shearwater; short-tailed shearwater; streaked shearwater; ✠wandering albatross; ✠southern royal albatross; ✠northern royal albatross; ✠Indian yellow-nosed albatross; ✠shy albatross; ✠Buller's albatross; ✠black-browed albatross; ✠antipodean albatross; ✠Gibson's albatross; ✠white-capped albatross; ✠campbell albatross; ✠Salvin's albatross; ✠sooty tern; ✠grey ternlet; common noddy; great-winged petrel; white-necked petrel; white-faced storm-petrel; ✠sooty albatross; least frigatebird; ✠southern giant-petrel; ✠northern giant-petrel; south polar skua; arctic jaegar; pomarine jaegar; long-tailed jargar; brown skua; little penguin; ✠white tern; ✠red-tailed tropicbird; Antarctic prion; fairy prion; ✠kermadec petrel; ✠black-winged petrel; ✠white-bellied storm-petrel.
Ocean Trap and Line (traps; line fishing methods)	Mammals: As per the Ocean Trawl Fishery. Reptiles: ✠loggerhead turtle; ✠leatherback turtle. Avifauna: As per the Ocean Trawl Fishery plus the little pied cormorant; little black cormorant; whistling kite; Caspian tern; ✠little tern.
Lobster (traps)	Mammals: As per the Ocean Trawl Fishery. Reptiles: ✠loggerhead turtle. Avifauna: As per the Ocean Trap and Line Fishery.
Recreational (traps; line fishing methods; active nets – for prawns only); hand gathering; spearfishing)	Mammals: As per the Ocean Trawl Fishery. Reptiles: ✠loggerhead turtle; ✠leatherback turtle. Avifauna: As per the Estuary General and Ocean Trap and Line Fisheries.
Beach Protection Netting (passive nets)	Mammals: bottlenose dolphin (inshore form); bottlenose dolphin (offshore form); common dolphin; Risso's dolphin; pantropical spotted dolphin; killer whale; short-finned pilot whale; false killer whale; ✠Australian fur-seal; ✠New Zealand fur-seal. Reptiles: Marine reptiles are unlikely to feed upon the catch or discards from beach protection nets in NSW. Avifauna: Avifauna species are unlikely to feed upon the catch or discards from beach protection nets in NSW.

What is the extent of this interaction in NSW?

Bait and catch

Juvenile seals may commonly forage from the traps used by NSW fishers that are set in the southern half of NSW within the diving range of these animals.

The bait and catch from the line fishing techniques used in NSW could be regularly foraged upon by small numbers of all marine mammal species listed under the relevant fisheries in Table 25, but this foraging is most likely to occur at sporadic intervals. Avifauna is likely to forage from pelagic line methods in NSW. This foraging would be regular as handline type gear is used widely and regularly in the pelagic waters of NSW. Sea turtle foraging on this gear type in NSW should only be infrequent, considering their local abundance and preferred diet.

Cormorants and perhaps also bottlenose dolphins are most likely to forage upon the mesh nets catches in NSW estuaries. The extent of this foraging should be small as this gear type is mostly used at night, when cormorants do not forage. Considering the size of their catch and limited use beach protection nets should only be an irregular food source for the marine mammals in NSW.

Marine mammals, and when small fish are targeted, birds, can be regular foragers on the catch of the active nets used in NSW. Sea turtles are highly unlikely to forage upon these nets in NSW.

Dolphins, seals, seabirds and some waterbirds (e.g. cormorants, darters) listed under the trawl fisheries in Table 25, can regularly forage upon the regularly available trawl catches in NSW.

Discards

This food source is available throughout all marine and estuarine waters off NSW, in varying concentrations. The most concentrated, regular discard food sources in NSW will be available from the waters where trawling and general purpose hauling activities are conducted. Discards from the other more selective gear types used by NSW fisheries will be widely and regularly available, but the quantity discarded is likely to be small and irregular. All of the species listed in Table 25 could feed upon this food source. Avifauna, especially those that can dive may do so in large numbers, especially during daylight. Some species listed in Table 25 either due to competitive inadvantages, low abundances, behaviour and diet preferences are only likely to irregularly forage upon this food source. These species include the beaked whales and sea turtles.

How does this interaction affect the marine wildlife in NSW?

Marine wildlife can obtain a significant portion of their energy requirements from this concentrated food source. It can create a dependency in marine wildlife populations or individuals if their foraging upon this food source is frequent.

Marine wildlife involved in this interaction increase their risk of incidental capture on / entanglement in active fishing gear, collision with fishing vessels or gear, and being deliberately killed by fishers. Birds can be poisoned from ingesting lead sinkers or die from ingesting hooks embedded in discards.

What are the consequences of this interaction for marine wildlife in NSW?

It can increase the survival and fitness of marine wildlife individuals and populations and increase the numbers of individuals in dependent marine wildlife populations. The negative consequence of this dependency is that if this food source is removed, dependent populations may experience a reduction in breeding success and population numbers. The existence of dependent populations in NSW has not been documented, but is possible.

The rates of marine wildlife deaths in NSW from deliberate killing and the ingestion of lead sinkers or hooks and the age of affected animals are unknown. As a result, the consequences of these deaths on local marine wildlife populations cannot be determined.

How does this interaction affect the fisheries managed by NSW DPI?
All the fisheries considered in this assessment can experience reduced or damaged fishing catches, gear damage and lost fishing time from this interaction. However, Estuary General mesh net fishers and trawl fishers on the Hunter River have mitigated some of these effects. While fishers do not positively benefit from wildlife foraging around their activities, they may also be seemingly unaffected by this interaction. The losses from this interaction may foster a negative attitude towards marine wildlife by fishers that can result in the shooting of these animals.

What are the consequences of this interaction for the fisheries managed by NSW DPI?
This interaction can result in economic losses for the fishers at both the individual and fishery level. These losses may sometimes be significant, especially for the trap, trawl and line fisheries. Fishers may suffer severe legal consequences if the illegal killing of marine wildlife is found to be a frequent occurrence.

Has this interaction been reported in NSW?
This was the most common interaction documented during the pilot observer study of the NSW fisheries conducted as part of this report (section 5.1.7). It was observed to occur around trawling, beach hauling, handlining, droplining and trapping activities. The marine wildlife types observed to be involved in this interaction were mostly birds (gulls, cormorants, pelicans, terns, gannets, shearwaters, albatrosses and sea-eagles), and some mammals (common and bottlenose dolphins and fur-seals).

Other accounts of this interaction in NSW that have been previously documented in Chapters 3 and 4 include the foraging of dolphins on trawl catches and discards, seals on trawl, trap, purse-seine, handline and dropline catches, and birds on trawl and mesh net discards.

5.1.3. Incidental capture / entanglement in active fishing gear

Brief description: The entanglement or capture of marine wildlife when feeding around or from active fishing gear or swimming in its vicinity.

Factors influencing this interaction:
Biological: local spatial and seasonal distribution and abundance of marine wildlife species; their foraging strategy and diet; behaviour; sensory capabilities; social pattern; preferred habitat; age; size; morphology; and activity being undertaken at time of interaction.

Fishing-related: location, season and time of day fished; gear type, design and dimension used; precise fishing method; species harvested; stage of fishing activity; effort; use of mitigation measures; and handling of animals once caught.

Is this interaction possible in NSW? YES
Gear types used in NSW fisheries that could incidentally capture or entangle marine wildlife include trawl nets, demersal longline fishing methods, passive pelagic line fishing methods, active line fishing methods, mesh nets, set pocket nets, purse-seine nets, hauling nets and traps. The marine wildlife species that could be involved in this interaction with each NSW fishery (and susceptible gear types) are listed in Table 26.

Table 26: The marine wildlife species that could potentially entangle in or be captured on the fishing gear used in NSW.

✠ Indicates species that are listed as threatened under NSW or Australian legislation.

Set pocket nets are only used in the Estuary General Fishery. All of the species listed next to the Estuary General Fishery in the passive net section could potentially be captured or entangled in the mesh nets used in this fishery. However, only those species marked with an '*' could potentially be captured or entangled in set pocket nets.

Only the species marked with '>' could potentially be captured or entangled in the hauling nets used in the Ocean Hauling Fishery.

Gear type	Fishery	Marine wildlife species
Trawl nets	Estuary Prawn Trawl	Mammals: bottlenose dolphin (inshore form). Reptiles: yellow-bellied sea snake; ✠green turtle; ✠loggerhead turtle. Avifauna: great crested grebe; great cormorant; pied cormorant; little pied cormorant; little black cormorant; white-bellied sea eagle; kelp gull; Australian pelican; ✠osprey; peregrine falcon; crested tern; common tern; white-fronted tern; silver gull; darter; musk duck.
	Ocean Trawl	Mammals: bottlenose dolphin (inshore form); Risso's dolphin; bottlenose dolphin (offshore form); pantropical spotted dolphin; common dolphin; striped dolphin; killer whale; short-finned pilot whale; ✠sperm whale; pygmy sperm whale; false killer whale; melon-headed whale; minke whale; ✠Australian fur-seal; ✠New Zealand fur-seal. Reptiles: yellow-bellied sea snake; ✠hawksbill turtle; ✠green turtle; ✠loggerhead turtle; ✠leatherback turtle. Avifauna: The avifauna species listed under this fishery in Table 25 could potentially entangle in or be captured in its trawl nets.
Passive demersal longline fishing methods (setlining; trotlining; droplining)	Ocean Trap and Line	Mammals: All mammal species considered in this assessment, except the dugong. Avifauna: The incidental capture of birds on demersal longline fishing gear has not been observed to be a significant problem in Australian waters.
Passive pelagic line fishing method (driftlining)	Ocean Trap and Line	Mammals: As per the Ocean Trawl Fishery. Reptiles: ✠green turtle; ✠loggerhead turtle; ✠leatherback turtle. Avifauna: All bird species that occur in inshore and offshore waters and forage on fish by diving and/or plunging; little penguin.
Active line fishing methods (handlining; trolling; jigging; poling)	Estuary General Recreational (in estuarine waters only)	Mammals: bottlenose dolphin (inshore form). Reptiles: ✠green turtle; ✠loggerhead turtle. Avifauna: As per the Estuary Prawn Trawl Fishery (above), plus the Pacific gull.
	Ocean Trap and Line Recreational (in inshore and offshore waters only)	Mammals: As per the Ocean Trawl Fishery. Reptiles: ✠green turtle; ✠loggerhead turtle; ✠leatherback turtle. Avifauna: All bird species that occur in inshore and offshore waters and forage on fish by diving and/or plunging; little penguin.

Table 26 – continued

Gear type	Fishery	Marine wildlife species
Passive net method (mesh nets; set pocket nets – only used in Estuary General Fishery)	Estuary General	Mammals: bottlenose dolphin (inshore form)*; ✠southern right whale; ✠humpback whale; ✠dugong*. Reptiles: ✠hawksbill turtle; ✠green turtle*; ✠loggerhead turtle*. Avifauna: little egret; eastern reef egret; great egret; striated heron; nankeen night heron; black-necked stork; great crested grebe*; great cormorant*; pied cormorant*; little pied cormorant*; little black cormorant*; white-bellied sea eagle*; kelp gull*; Pacific gull*; Caspian tern*; ✠little tern*; Australian pelican*; ✠osprey*; peregrine falcon*; crested tern*; common tern*; white-fronted tern*; silver gull*; darter*; white-winged black tern*; musk duck*.
	Beach Protection Netting Program	Mammals: bottlenose dolphin (inshore form); ✠southern right whale; ✠humpback whale; Risso's dolphin; bottlenose dolphin (offshore form); pantropical spotted dolphin; common dolphin; killer whale; short-finned pilot whale; minke whale; ✠Australian fur-seal; ✠New Zealand fur-seal; ✠dugong. Reptiles: ✠green turtle; ✠loggerhead turtle; ✠leatherback turtle. Avifauna: little penguin.
Active net methods (hauling nets; purse-seine nets – used only in the Ocean Hauling Fishery)	Estuary General	Mammals: Bottlenose dolphin (inshore form); Reptiles: ✠hawksbill turtle; ✠green turtle; ✠loggerhead turtle. Avifauna: As per the avifauna species listed under this fishery in passive net methods.
	Ocean Hauling	Mammals: bottlenose dolphin (inshore form)>; Risso's dolphin; bottlenose dolphin (offshore form); pantropical spotted dolphin; common dolphin>; killer whale; short-finned pilot whale; ✠Australian fur-seal>; ✠New Zealand Fur-seal>. Reptiles: ✠green turtle>; ✠loggerhead turtle>; ✠leatherback turtle. Avifauna: All bird species that occur in inshore waters and forage on fish by diving and/or plunging>; little penguin.
Traps	Estuary General Recreational (in estuarine waters only)	Mammals: bottlenose dolphin (inshore form); ✠southern right whale; ✠humpback whale; ✠dugong. Reptiles: ✠green turtle; ✠loggerhead turtle.
	Ocean Trap and Line Lobster Recreational (in inshore waters generally less than 10m only)	Mammals: All mammal species considered in this assessment, for the Ocean Trap and Line and Lobster Fisheries. Those mammals that occur in inshore waters for the Recreational Fishery. Reptiles: ✠green turtle; ✠loggerhead turtle; ✠leatherback turtle.

What is the extent of this interaction in NSW?
Of all the gear types used in NSW Fisheries that could potentially be involved in this interaction, only trawling nets, active pelagic line fishing methods, beach protection nets, and perhaps also traps are likely to capture or entangle considerable numbers of the marine wildlife types listed Table 26. More specifically:

- trawling activities off the NSW north coast could potentially capture low-medium numbers of green and loggerhead turtles;
- low-medium numbers of fur-seals could be captured in trawl nets when these activities sporadically occur within 3 nm off the NSW south coast;
- the pelagic line fishing techniques that are frequently used by a large number of fishers in NSW could frequently entangle foraging birds;
- beach protection nets in NSW can capture a small amount of dolphins and green and loggerhead turtles;
- and the frequency at which mammals entangle in fishing traps in NSW may be greater than the previously thought low rate of occurrence.

All other combinations of gear types and marine wildlife that could potentially be involved in this interaction off NSW (Table 26) are occurring at a rare – negligible rate. This is largely influenced by factors concerning the operation of fishing gear, local abundance and behaviour of marine wildlife and general nature of the specific interaction.

How does this interaction affect the marine wildlife in NSW?
The general survival rate of marine wildlife following this interaction with each main fishing gear type has been discussed in Chapter 2. Of all the gear types considered in this assessment, the actively fished line and net gear types used by fishers in NSW are least likely to result in the direct death of marine wildlife that become captured or entangled in fishing gear in NSW.

What are the consequences of this interaction for marine wildlife in NSW?
Local population declines can result from this interaction. In NSW this is most likely to occur for populations of the green and loggerhead turtles and diving / plunging avifauna. However, it is difficult to determine whether the potential death rate resulting from this interaction is having this effect, as the local population size of these species is unknown.

How does this interaction affect the fisheries managed by NSW DPI?
This interaction can damage gear or result in its loss and reduce the fishing time of fishers. These effects can occur across all gear types listed in Table 26.

What are the consequences of this interaction for the fisheries managed by NSW DPI?
Economic losses at an individual or fishery level can result from this interaction. The NSW fisheries that are most likely to experience such loss are the: Ocean Trawl Fishery (trawl gear), and Ocean Trap and Line, Recreational and Estuary General Fisheries (active line fishing methods).

Has this interaction been reported in NSW?
From the records provided in Chapters 3 and 4, this interaction has been directly reported to occur with the Ocean Trawl Fishery (seals and sea turtles), Estuary Prawn Trawl Fishery (turtles), and Beach Protection Netting Program (dolphins, sea turtles, whales, dugongs, and a little penguin). This interaction was also directly observed during an observer study conducted as part of this report it involved the entanglement of a gannet in handline gear used in the Ocean Trap and Line Fishery. Indirect accounts of this interaction in NSW involve trawlers and seals, the Lobster Fishery and humpback whales, and handline gear, especially of a recreational nature, and birds.

5.1.4. Interactions with fishing debris

Brief description: The entanglement of marine wildlife in or their ingestion of fishing-related marine debris.

Factors influencing this interaction:
Biological: local distribution and abundance of marine wildlife species, especially in areas where debris accumulates; their diet and feeding strategy; their level of activity at the water's surface; and their behaviour.

Fishing-related: gear type used; amount of gear lost at sea; amount of other debris lost at sea; type of debris item; distribution of fishing activity; and effort.

Is this interaction possible in NSW? YES
As all the fisheries considered in this assessment could potentially dump fishing-related debris or lose fishing gear in areas where marine wildlife occur, this interaction is possible in the estuarine and marine waters off NSW. The types of debris items from these fisheries which could potentially interact with marine wildlife include traps, line, nets, net fragments, ropes, floats, plastic bags, lures and light sticks. The type of gear these fishers in NSW are most likely to lose are fishing lines and associated gear (from the Estuary General, Ocean Trap and Line and Recreational Fisheries), net fragments (from the Ocean Trawl and Estuary Prawn Trawl Fisheries) and fishing traps and trap headgear (from the Ocean Trap and Line, Lobster and Recreational Fisheries). This interaction could potentially occur with all marine wildlife species considered in this assessment.

What is the extent of this interaction in NSW?
Any dumping of rubbish into waterways by fishers in NSW is only likely to be minor, rare or accidental. The rate of gear loss by these fishers is generally unknown. The rate at which this interaction is occurring in NSW is difficult to determine. The action of fishers in NSW to reduce gear damage and retrieve lost gear is likely to minimise debris interactions with marine wildlife. Of all the marine wildlife types that could be involved in this interaction in NSW, fur-seals and birds (diving, surface-feeding, shore and sea birds) are most likely to ingest and/or become entangled in fishing-related marine debris.

How does this interaction affect the marine wildlife in NSW?
Marine wildlife involved in this interaction can die from: drowning; being strangled; injuries or wounds incurred that may become infected; a reduced ability to travel, catch food, dive or avoid predators; starvation; or reduced immunity; and reduced ability to reproduce.

What are the consequences of this interaction for marine wildlife in NSW?
This interaction can contribute to the decline of marine wildlife populations. The wildlife populations occurring in NSW most likely to experience such a decline from this interaction are those that are threatened and those for which this interaction could be a frequent occurrence, i.e. fur-seals and some bird species.

How does this interaction affect the fisheries managed by NSW DPI?
As fishing-related debris is usually well away from fishing activities when marine wildlife become entangled in or ingest this gear, NSW fishers should not be directly affected by this interaction. These fishers may be indirectly affected by this interaction, from a negative public image and tighter management controls, if debris originating from these fisheries were found to significantly contribute to the decline of a marine wildlife population.

What are the consequences of this interaction for the fisheries managed by NSW DPI?
The Threat Abatement Plan (TAP) for the Key Threatening Process of marine wildlife becoming entangled in or ingesting debris, once released, may result in some changes to fishing operations in NSW, and fishers must comply to this TAP.

Has this interaction been reported in NSW?
As reported in Chapters 3 and 4, fur-seals at Montague Island have been observed entangled in pieces of fishing gear, the origin of which, whether it was from active gear or debris, is unknown. Also birds in the estuaries of NSW have been noted to entangle or hook up in discarded recreational fishing line.

5.1.5. Collision

Brief description: The physical encounter of marine wildlife with vessels and/or fishing gear whilst swimming or foraging near the water's surface.

Factors influencing this interaction:
Biological: Local abundance of vulnerable marine wildlife species (e.g. those that are diseased, slow, spend much time at the water's surface, are attracted to vessels for food or use habitats in the vicinity of major shipping lanes or boating areas); the size of the animal; and the activity it is undertaking.

Fishing-related: Location of boating and fishing activities; gear type used; size and speed of fishing vessel; effort; and other fishing-related factors influencing the feeding activity of marine wildlife around fishing gear (see above).

Is this interaction possible in NSW? YES
All the vessels and fishing gear used by NSW fishers could be involved in this interaction in all marine and estuarine waters off NSW. This interaction could potentially occur with all marine mammal and sea turtle species that commonly occur off NSW. The species of avifauna commonly occurring off NSW that could potentially be involved in this interaction are those that forage from fishing vessels, especially at night, and little penguins.

What is the extent of this interaction in NSW?
This interaction is likely to be greater in the areas where vessels are frequently used by NSW fishers. Considering the number of endorsements / permits in each NSW fishery, most boats are used by the Estuary General, Estuary Prawn Trawl, Ocean Trawl, Ocean Trap and Line, Lobster and Recreational Fisheries. The vessels from these fisheries are most likely to be involved in this interaction, the probability of which should be greater in the northern half of the state.

Collision with fishing vessels is probably occurring at a low, generally infrequent rate for any mammal and reptile species occurring off NSW due to the small size and slow speed of vessels used by NSW fisheries. The marine mammals and reptiles most likely to collide with vessels in NSW are dugongs, large cetaceans and sea turtles. The extent to which these groups could be involved in this interaction is rare for dugongs, low for sea turtles, and low for large cetaceans, due to their sparse abundance in the waters off NSW. The bird species most likely to collide with NSW fishing vessels are those that regularly forage around these vessels at night.

The rate at which marine wildlife collide with the fishing gear used by NSW fishers is strongly influenced by the extent of their foraging around these gear types.

How does this interaction affect the marine wildlife in NSW?
This interaction may kill, knock unconscious, injure, bump, or have no apparent effect on marine wildlife. Species that collide with fishing gear can become entangled or hooked up in it or be relatively

unaffected by this interaction.

What are the consequences of this interaction for marine wildlife in NSW?
Considering that the extent of this interaction with NSW fisheries is possibly occurring at a rare-low rate none of the populations of species listed as being most vulnerable to this interaction should be significantly affected. However, considering that many of these species are listed as being threatened in NSW, especially sea turtles, any deaths resulting from this interaction could be impairing the recovery of these species, or along with other human-induced deaths occurring in the area, contributing to its further decline.

How does this interaction affect the fisheries managed by NSW DPI?
This interaction can result in vessel damage, especially propellers. Fishers can also lose some fishing time when avoiding such collisions. This interaction would, otherwise, have no effect on fishers.

What are the consequences of this interaction for the fisheries managed by NSW DPI?
Economic losses may result from this interaction. However considering its frequency in NSW and that fishers may not be affected by this interaction every time it occurs, this loss is likely to be rare, short-term and felt at the individual fisher level.

Has this interaction been reported in NSW?
As stated in Chapters 3 and 4, there are only two accounts of the occurrence of this interaction in NSW, involving a whale and fishing vessel and shearwaters and trawl warps.

5.1.6. Noise, site access and physical presence of fishers

Brief description: The response of marine wildlife to the physical non-contact disturbance caused by noise from fishing vessels and gear operation, the access of fishing sites and the physical presence of fishers.

Factors influencing this interaction:
Biological: local spatial and seasonal distribution and abundance of marine wildlife species; the use of habitats in the vicinity of fishing activities; the activity they are undertaking; and their ability to tolerate or habituate to this disturbance.

Fishing-related: location and season fished; type of fishing activity, how it is being undertaken, the type of noise generated from it and its proximity to marine wildlife; type of vessel; and effort.

Is this interaction possible in NSW? YES
All the marine mammals considered in this assessment could be affected by the noise generated from the boats used by all NSW fisheries. Pinnipeds can be disturbed by the Ocean Hauling, Ocean Trawl, Ocean Trap and Line, Lobster and Recreational Fisheries operating near the vicinity of their haul-out sites in NSW. Sea turtles can be disturbed by the physical presence of Estuary General, Ocean Hauling and Recreational fishers when they occur on the coastal shores of northern NSW, and they can be disturbed when they are in water by the noise originating from the vessels used by NSW fisheries. The colonial nesting seabirds, shorebirds, waders and sea ducks occurring in estuaries and on shorelines can be affected by this interaction with all fisheries considered in this assessment. This would result from the boating activity adjacent to shorelines and walking, all-wheel driving, fishing and bait digging on shorelines.

What is the extent of this interaction in NSW?
The marine mammal species that are most likely to be involved in this interaction in NSW are the

bottlenose and common dolphins, southern right and humpback whales and Australian and New Zealand fur-seals. The Ocean Hauling Fishery is least likely to be involved in this interaction as this fishery only uses a small number of powered vessels. The commercial vessels used by NSW fisheries may be less disturbing to marine mammals than recreational vessels.

The extent to which seals are affected by this interaction is limited due to the limited fishing activities that occur near the main seal haul-out sites. The level of fishing activity next to Montague Island, is restricted in the critical habitat area which is located on the northern side of the island next to the longer-established seal colony. The Ocean Hauling and Lobster fisheries are most likely to operate on or adjacent to mainland shores on the south coast of NSW but only a few fishers in these fisheries operate in this area. The recreational fishing effort around the seal haul-out areas in NSW has not been directly documented, but Montague Island is known to be a popular fishing location.

As sea turtles rarely come ashore in NSW, and wildlife managers promptly implement buffer zones around these animals when they are found on NSW shores, sea turtles are unlikely to be significantly affected by the land-based component of this interaction in NSW. Given the low abundance of sea turtles in NSW waters, the extent to which they are disturbed by fishing-related boating noise when in water should only be small.

Physical non-contact disturbance, including that resulting from fishing-related activities, is one of the five major threatening issues identified in relation to wader conservation in NSW. The activities of the Estuary General, Estuary Prawn Trawl, Ocean Hauling and Recreational fisheries on and around shorelines may be contributing to a significant level of such disturbance to the susceptible species of avifauna in NSW.

How does this interaction affect the marine wildlife in NSW?
Marine wildlife can experience positive or negative effects from this interaction or not be affected by it at all. For example, cetaceans attracted to the noise originating from fishing vessels can benefit from feeding on any food discarded from this noise source or riding the bow-wave of vessels.

What are the consequences of this interaction for marine wildlife in NSW?
Where this interaction is long-term or frequent, cetaceans can avoid or abandon such areas. This will subsequently reduce local habitat availability. In NSW, such areas are most likely to include the estuarine and inshore waters around urban areas. The long-term consequence of this interaction for seals in NSW is that it can affect survival or contribute to the abandonment of seal haul-out sites. Considering the extent of this interaction in NSW, the chance of such abandonment occurring in NSW is very small. This interaction is unlikely to have any significant long-term consequences for sea turtles in NSW. For avifauna, if this interaction is frequent or sustained, these birds may not be able to meet their energy requirements, experience a reduced breeding success and growth, and could shift to alternative, perhaps less favourable breeding grounds. If migratory shorebirds are frequently disturbed in the few months before their migration, they might not be able to accumulate sufficient energy reserves for the journey.

How does this interaction affect the fisheries managed by NSW DPI?
As this is a non-contact interaction that does not have subsequent effects on harvested fish stocks fishers should not be affected by this interaction.

What are the consequences of this interaction for the fisheries managed by NSW DPI?
This interaction should have no direct long-term consequences for fishers.

Has this interaction been reported in NSW?
During the pilot field study conducted as part of this report, dolphins were observed bow-wave riding

on a vessel used in the Ocean Trawl Fishery. The noise generated by the moving vessel may have attracted these animals. This is a common occurrence in NSW.

5.1.7. Pilot field study

5.1.7.1. Aims

The 'desktop' review of available information revealed a lack of documented data on the interactions occurring between marine wildlife and fishing activities in NSW. To begin to redress this problem, a pilot observer study was conducted as part of this project to:

- investigate the feasibility of using observer studies to assess the nature and frequency of operational interactions between marine wildlife and NSW fisheries;
- help assess the feasibility of any monitoring and risk mitigation measures that might be envisaged (see Chapter 6); and
- document any observed operational interactions with marine wildlife.

5.1.7.2. Methods

The observations in this study were conducted from commercial and recreational fishing vessels and focussed on the gear types used by NSW fishers considered most likely to interact with marine wildlife. In an effort to cover interactions that could potentially occur with all types of marine wildlife, this pilot study was conducted in three areas along the NSW coast. Zone 1 (from the Clarence River to the Queensland border) was selected as marine reptiles are most abundant on the far north coast of NSW. Zone 2 (from Crowdy Head to Tuggerah Lakes) was selected as there is a resident population of dolphins in Port Stephens, the endangered Gould's petrel breeds on islands off Port Stephens, and the Hunter River is a significant site for migratory shorebirds. Zone 3 (from Ulladulla to the Victorian border) was selected as fur-seals are most abundant on the south coast of NSW. To cover any seasonal changes in the distribution and abundance of marine wildlife in NSW, two sets of observations were conducted during summer and winter. Observations were conducted over two weeks in each zone during these seasons. In this two-week period, an effort was made to observe up to three fishing methods twice with the same fisher. However, weather and current conditions, and fisher availability often limited this survey design.

The specific aspects of the fishing activities observed during this study were: how the gear was used, any discarding of bycatch or offal from the processing of fish, the use and disposal of plastic, how fishers operate around marine wildlife, and the ways in which fishers avoid or prevent interactions with marine wildlife. The study also documented the marine wildlife species that were attracted to fishing vessels, their behaviour around these vessels, attempts to forage on the bait, catch or discards from these vessels and any other direct operational interactions that were observed.

In all, 23 observation trips of six main gear types were conducted during this pilot study. These gear types were mesh nets, trawl nets, hauling nets, handlines, droplines and traps. The spatial and seasonal distribution of these observations, the fishery that was observed, and the number of observations made are given in Table 27.

Table 27: The distribution and number of observation trips of the fishing activities in NSW made during this pilot study.

* The observation of this fishery was made during the winter (June) of 2004.
N/a means 'not applicable' – this fishery did not operate in the observation zone at this time.

Observation zone	Fishery and gear type	Number of observations made	
		Winter (Jun – Aug 2003)	Summer (Jan – Feb 2004)
1 – Clarence River to Queensland border	Estuary General (mesh netting)	-	1
	Estuary Prawn Trawl (trawling)	N/a	2
	Ocean Trawl (trawling)	1	2
	Ocean Trap and Line (handlining)	2	-
2 – Crowdy Head to Tuggerah Lakes	Estuary General (trapping)	1	-
	Estuary Prawn Trawl (trawling)	N/a	2
	Ocean Trawl (trawling)	-	1
	Recreational – charter boat (handlining)	1	2
3 – Ulladulla to the Victorian border	Estuary General (mesh netting)	2	-
	Ocean Hauling (beach hauling)	2	-
	Ocean Trap and Line (droplining)	1*	-
	Recreational – charter boat (handlining)	2	1

5.1.7.3. Results

The only operational interaction that occurred across the observed gear types, except mesh netting, was the foraging of marine wildlife on the bait, catch or discards from fishing vessels (see Appendix 3 for details). Birds were the main type of marine wildlife observed to be involved in this interaction; other observations were of dolphins foraging around oceanic trawling and beach hauling operations and a fur-seal around droplining operations.

The degree to which the birds were attracted to fishing vessels and the extent to which they foraged from these vessels seemed to be largely influenced by the amount of biological material discarded. Large flocks of birds were attracted to both oceanic and estuarine trawlers and regularly fed on the discards and/or catch. The foraging of birds around line fishing and beach hauling gear was sporadic, and birds were only attracted to this fishing activity in small numbers. Numerous pelicans were attracted to estuarine trapping operations, even though there was minimal discarding. This may be a result of their seasonal and local abundance and the low levels of fishing effort at the time rather than being a typical response to this method. The bird types observed to forage from the vessels used by all NSW fisheries were gulls, cormorants, pelicans, terns, gannets, shearwaters, albatrosses and sea-eagles. The species composition around each fishing vessel appeared to be influenced by the habitat in which the fishing was occurring and local bird abundance.

The other operational interactions observed during this pilot study were the entanglement of a gannet in a commercial handline off Evans Head and common dolphins riding the bow waves of a trawler off Forster (see Appendix 3 for details). The gannet became entangled whilst feeding on a baited line, and it was subsequently untangled by the fisher and flew away seemingly uninjured. Apart from the synthetic fishing gear and plastic crates used by the fishers observed they did not use any other form of plastic.

During this pilot study fishers sometimes used the following measures to mitigate against operational interactions with marine wildlife:

- the use of discards chutes by trawl fishers on the Hunter River, which successfully released live discards beyond the reach of foraging pelicans;
- handline fishers successfully scaring away birds foraging near their lines by yelling and waving their arms in the air;
- beach hauling fishers regularly leaving some of their catch on shore to perhaps deter sea-eagles from foraging on their encircled catch;
- purse-seine fishers restrianing from operating in areas were the large numbers of seals and dolphins were spotted to be foraging on the targeted species of these fishers; and
- a recreational fishing vessel changing its course to avoid colliding with a humpback whale.

5.1.7.4. Conclusion

Even considering the fact that fishers may alter their behaviour in the presence of observers, the results from this study indicate that some species of marine wildlife commonly feed from the vessels used by NSW fishers. No other conclusions about the occurrence of other operational interactions between marine wildlife and NSW fisheries can be drawn from this small pilot study.

5.1.7.5. Discussion of the feasibility of observer studies to document interactions between marine wildlife and NSW fisheries

Observer studies are only useful for recording operational interactions between fishing activities and marine wildlife. The data quality that can be obtained from observer studies is limited by the fact that the presence of an on-board observer may result in fishers deliberately or unintentionally altering their usual activities (Karp and Ferdinand 2004). Therefore it is not feasible to use an observer study to document the rate at which fishers in NSW illegally kill marine wildlife, thoughtlessly dispose of debris into the water, or release entangled animals in a way that may increase their survival. However, what could be documented by this type of study, is the operational interactions that occur adjacent to fishing vessels and can be physically observed, such as the foraging of marine wildlife around fishing vessels, their incidental capture / entanglement in fishing gear, and collision of these animals with vessels. It is not feasible to use observer studies to document collision interactions with fishing vessels due to their infrequent occurrence.

Observer studies are useful tools for documenting the rate and effect of the incidental capture / entanglement of marine wildlife in a fishery. However, the implementation of these types of studies can be difficult as fishers may refuse to take observers on board for fear of repercussions from the documentation of such interactions with threatened or protected species (Bache 2003b, Karp and Ferdinand 2004). These problems were generally not encountered when finding fishers to participate in this pilot observer study. These fishers did not perceive their methods to be a threat to the survival of marine wildlife. Considering the general rare-low rate of occurrence of this interaction with NSW fisheries, the most feasible way to document this interaction in NSW would be to include it amongst the aims of scientific observer studies of these fishers that are predominantly conducted for other purposes.

5.2. Ecological interactions

5.2.1. Competitive and trophic interactions

Brief description: Marine wildlife and fishers competing for the same marine resources. Marine wildlife feeding on lower trophic levels that are the prey of harvested fish species. The trophic imbalances created by the removal or depletion of species within food webs.

Factors influencing this interaction:
Biological: local distribution and abundance of marine wildlife; their diet and energy requirements; their foraging area and feeding strategy; and the availability of prey items.

Fishing-related: location and season fished; species, amount and size-class harvested; effort; and, if undertaken, the level of culling activity.

Is this interaction possible in NSW? YES
There is potential for this interaction to occur with nearly all NSW fisheries as they harvest from the shorelines and estuarine, inshore and offshore waters of NSW in which marine wildlife species forage. These fisheries may be harvesting species groups that are directly preyed upon by marine wildlife species or be harvesting large fish predators that compete with marine wildlife for common food resources. The fisheries most likely to be involved in such consumptive or food-web competition are:

- the Estuary General and Recreational Fisheries when they harvest invertebrates from shorelines;
- the Estuary General, Estuary Prawn Trawl and Recreational Fisheries when they harvest fish and invertebrates from estuarine waters;
- the Ocean Hauling, Ocean Trap and Line, Ocean Trawl, Lobster and Recreational Fisheries when they harvest fish and invertebrates from inshore waters; and
- the Ocean Trap and Line, Ocean Trawl, Lobster and Recreational Fisheries when they harvest fish and invertebrates from oceanic waters.

As some of the fish resources harvested by NSW fisheries are fully or over fished, these fisheries may be involved in the process known as fishing down the food chain, whereby progressively smaller less valuable fish species are taken as larger species are over fished.

What is the extent of this interaction in NSW?
It is difficult to determine the extent of this interaction in NSW due to a lack of information on many of the influencing factors. Obtaining the detailed information required was beyond the scope of this broad-scale study. However, during the course of this study any opportunities to gather information on the diet of marine wildlife species occurring in NSW were used (see below).

Beyond the above-mentioned uncertainty, there are some competitive / trophic interactions between marine wildlife and NSW fisheries that may be occurring at some regular, common or large extent. These are:

- the harvesting of invertebrates by fishers from shorelines;
- predation on the fish stocks in enclosed or semi-enclosed estuarine waters by flocks of piscivorous birds that feed co-operatively (e.g. cormorants and pelicans);
- the harvest of large fish predators from the open ocean that compete with marine wildlife species for common food resources and/or drive small fish to the waters surface where they can be accessed by predatory seabirds; and
- the harvest of the same species and size classes of fish preyed upon by marine wildlife.

How does this interaction affect the marine wildlife in NSW?
Marine wildlife can experience positive or negative effects from these interactions or be relatively unaffected. The type of effects exhibited in a marine wildlife population depends upon the main factors driving the interaction and local conditions, many of which for the estuarine, inshore and offshore waters off NSW are unknown.

What are the consequences of this interaction for marine wildlife in NSW?
This interaction can eventually increase the populations of affected marine wildlife species if the size of their prey stocks are increased, or decrease these populations if the size or availability of their prey stocks is reduced. Such reduction in prey stocks can also reduce the recovery and migratory ability of

some marine wildlife species.

How does this interaction affect the fisheries managed by NSW DPI?
Foraging marine wildlife may decrease the levels and availability of harvested stocks and damage fish. These effects are more pronounced when foraging effort is intense and concentrated in enclosed or semi-enclosed water bodies. In NSW, the foraging of cormorants and similar birds that are known to feed intensively in co-operative flocks in the estuaries of NSW may be a problem for fishers in the Estuary General and Recreational Fisheries. Such foraging could result in losses of fish that may reduce the availability of fish stocks in the short-term, but such reductions and their long-term impacts have not been proven.

Some NSW fisheries may experience increased harvested stock levels as a result of the trophic interactions that are occurring from harvesting pressure and the foraging activity of marine wildlife populations. As it is the harvested stocks of small pelagic species that are most likely to be increasing as a result of these interactions, the Ocean Hauling Fishery is most likely to benefit from such increased stock levels.

An increase in the number of individuals in marine wildlife populations, as is occurring for fur-seals in south eastern Australia, can change the levels of harvested stocks.

What are the consequences of this interaction for the fisheries managed by NSW DPI?
The fisheries whose harvested stock levels are reduced by this interaction may experience economic losses, while those fisheries whose harvested stock levels are increased may experience economic gains.

Has this interaction been reported in NSW?
No studies have investigated the overlap between the diet of the marine wildlife species occurring off NSW and the species harvested by fishers in NSW.

An effort was made during this study to collect some dietary information required to assess such overlap occurring with the cetaceans off NSW. Over a 24 month period (2002-2004) samples of cetacean stomachs were opportunistically collected when animals became stranded on beaches around Sydney or were incidentally captured in beach protection nets. During this time, samples from three common and one striped dolphin were collected. These samples were sent to Macquarie University for analysis and reports of their methodology and findings are presented in Appendix 4. The results are briefly described below.

The common dolphins analysed in this study mostly fed upon nannygai, snapper and yellowtail. All of these fish are harvested in large numbers by NSW fisheries. The average fork length of the nannygai (17.5 cm SD ± 1.322) and snapper (26.3 cm ± SD 6.506) consumed by these dolphins is larger than the size of these fishes when harvested by fishers. The common dolphins had also consumed three species of squid, but these were not numerous or high in biomass. The variation in prey consumed by the common dolphin is most likely due to variation in distribution and abundance of prey species. The stomach contents of the stranded striped dolphin were quite degraded and could only be identified to family level. Numerous otoliths from the Carangidae (jacks and trevallies) and Scorpididae (sweep) families were found in this animal.

5.2.2. Habitat interactions

Brief description: The destruction, degradation or modification of marine wildlife habitat as a result of fishing-related activities (includes the wider effects of oil spills, shoreline activities and physically destructive fishing methods such as trawling).

Factors influencing this interaction:
Biological: local abundance and preferred feeding and breeding / nesting habitat of marine wildlife species; their diet and foraging method; and their level of contact with the oil spill.

Fishing-related: the type of fishing activity; gear type used; vessel size and power; oil / fuel type used; area and habitat fished; effort; the use of oil spill cleanup measures; and the type and number of boating support facilities required.

Is this interaction possible in NSW? YES
All the fisheries considered in this assessment use vessels from which oil or fuel spills could originate. These spills can occur on the surface of estuarine, inshore and offshore waters in NSW and the shorelines on which they settle where they could potentially affect all marine wildlife species considered in this assessment.

Activities including: All-wheel driving and walking along sandy beaches to access fishing sites by Ocean Hauling, Estuary General and Recreational fishers, hauling on sandy shorelines by Ocean Hauling and Estuary General fishers, and the construction of fishing-related boating facilities can modify, damage or destroy the shoreline habitat that can be used by the marine wildlife species listed in Table 28.

The construction of approved fishing-related boating facilities and driving through or anchoring in seagrasses could damage this habitat in NSW and affect dugongs and green and hawksbill turtles in NSW.

Table 28: The marine wildlife species commonly occuring in nsw that use shoreline habitats in NSW for nesting and/ or feeding.

✠ Indicates species that are listed as threatened under NSW or Australian legislation.
○ Indicates species that use sandy shorelines in NSW for nesting.

Species that forage from the shorelines of estuaries only: ✠black bittern; royal spoonbill; gull-billed tern; Lewin's rail; Australian crake; spotless crake; pectoral sandpiper; ✠broad-billed sandpiper; curlew sandpiper.
Species that forage from the shorelines of estuaries and coasts: white-faced heron; Australian white ibis; bar-tailed godwit; ✠black-tailed godwit; common greenshank; grey-tailed tattler; buff-banded rail; ✠great knot; red knot; red-necked stint; masked lapwing; whimberel; ✠sanderling; ○✠pied oystercatcher; ○✠sooty oystercatcher; eastern curlew; ○✠beach-stone curlew; ruddy turnstone; ○red-capped plover; double-banded plover; ○✠hooded plover; Pacific golden plover; ✠lesser sand-plover; ✠greater sand-plover; ✠Terek sandpiper; common sandpiper.
Species that use shorelines for nesting and not foraging: ○✠green turtle; ○✠loggerhead turtle; ○✠leatherback turtle; ○kelp gull; ○Caspian tern; ○crested tern; ○sooty tern; ○✠little tern; ○Australian pelican.

What is the extent of this interaction in NSW?
Oil / fuel spills that originate from fishing vessels in NSW should only occur rarely. These spills should generally be small as the vessels used in NSW fisheries are relatively small and do not carry large supplies of fuel or oil. The extent to which marine wildlife are affected by these spills is minimised by the evaporative ability of the light distillate fuel used. Any containment or clean up of oil spills should further minimise the extent of this interaction.

Four-wheel drive vehicles can only be used by Ocean Hauling, Estuary General and Recreational fishers on some sandy beaches in NSW. However, the extent to which these fishers use four-wheel drive vehicles on these NSW beaches is not documented.

The physical destruction of seagrass and shoreline habitats from the future construction of fishing-related boating facilities may potentially occur in NSW for recreational fishing purposes only. All proposed boating facility developments in NSW are currently assessed to minimise their impact on seagrass and shoreline habitats by the relevant government authorities. NSW DPI generally only approves these facilities when resulting impacts on *Zostera* seagrass habitat is minimal compared to the regional availability of this habitat and measures have been employed to minimise these impacts. Applications that may damage *Posidonia* seagrass are generally not approved. Codes of Practice within NSW fisheries should help minimise any damage of seagrass habitat through fishers driving through or anchoring in seagrasses.

How does this interaction affect the marine wildlife in NSW?
Avifauna and fur-seals are the types of marine wildlife that are most likely to be negatively affected from being in contact with the light oil spilt by NSW fisheries. The effects of being smothered in oil include reduced insulation and mobility and, in avifauna especially, eventual mortality. On contact with oil spills, all the marine wildlife types occurring in NSW can immediately experience an irritation of their skin and eyes.

The compaction of shoreline sediments and the damage of nesting shorebird habitat by the shoreline activities of the Ocean Hauling, Estuary General and Recreational fisheries can reduce the availability of food and suitable nesting sites and destroy the nests of the avifauna listed in Table 28. Such activity on the intertidal zone of coastal beaches in NSW is not likely to reduce food availability for shorebirds because this is a high-energy environment in NSW and shoreline sediments are regularly disturbed by wave action. The sandy shore activities of these fisheries may also damage sea turtle nests on the NSW coast and impede the movement of hatchlings into the sea. A reduction in the area of seagrass in NSW from the construction of recreational fishing-related boating facilities can reduce the availability of the foraging habitat of dugongs and green and hawksbill turtles in NSW.

What are the consequences of this interaction for marine wildlife in NSW?
Given the low frequency, relatively small size and nature of oil / fuel spills from NSW fishing vessels, only the occasional individual bird or fur-seal could die from being in contact with such spills.

The consequence of fishing-related activities on the sandy shorelines of NSW to the avifauna listed in Table 28 cannot be determined due to the lack information on the spatial and seasonal distributional overlap between these species and the shoreline activities of the Ocean Hauling, Estuary General and Recreational fisheries, the level and location of shoreline use by these fisheries and the degree to which these activities disturb shoreline habitat. A Code of Practice for shoreline use in the Ocean Hauling Fishery may be minimising disturbances to these habitats. This interaction should not significantly affect sea turtle populations due to their rare occurrence on the shores of NSW. As NSW fisheries destroy very little seagrass habitat, populations of the relatively small number of dugongs and green and hawksbill turtles that occur in NSW should not be affected by this interaction.

How does this interaction affect the fisheries managed by NSW DPI?
Due to the mostly small size of the oil / fuel spills that may originate from NSW fisheries and the evaporative ability of the light distillate fuel they use, these fishing activities should not be affected by this interaction.

The Ocean Hauling, Estuary General and Recreational fisheries may only be affected by the habitat disturbance resulting from their activities on sandy shorelines when access to fishing sites or beaches in an area is restricted for habitat protection. As seagrasses are important nursery habitats for juvenile fish, a reduction in the area of this habitat in NSW can result in reduced stocks of the species harvested by NSW fisheries.

What are the consequences of this interaction for the fisheries managed by NSW DPI?
Oil / fuel spills that may originate from NSW fisheries should have minimal to no consequences for these fishers.

The economic losses experienced by the Ocean Hauling, Estuary General and Recreational fisheries from reduced fishing opportunities on shorelines is difficult to determine as the extent to which sandy beach access points in NSW have been closed for wildlife conservation purposes is unknown. As NSW fisheries destroy very little seagrass habitat, these fisheries should experience virtually no economic loss from this interaction.

Has this interaction been reported in NSW?
Other than anecdotal reports this interaction has not been documented in NSW.

5.3. Chapter summary

Existing reports and anecdotal accounts show that marine wildlife and fishers in NSW are interacting, even though much of the required information to determine the extent of these interactions in NSW is not known. This chapter made qualitative estimates of the extent, effects and consequences of these interactions using the limited information that is available. However, some of the interactions considered in this assessment - debris, competition / trophic, and noise interactions with cetaceans, were particularly data poor and it was difficult to predict or extrapolate the extent to which these interactions and their consequences actually occur in NSW.

5.3.1. Interactions that may threaten the survival of marine wildlife in NSW

The qualitative assessment found that some of the interactions considered in this assessment could potentially threaten the survival of some marine wildlife types in NSW. These are:

- The incidental capture of birds (e.g. pelicans, cormorants, shearwaters and gannets) on the pelagic line fishing techniques (handlining, trolling, jigging, poling and setlining) used by the Recreational, Ocean Trap and Line, and Estuary General fisheries.
- The incidental capture of sea turtles, mainly green and loggerhead turtles, in the fishing gear used in NSW, mostly oceanic trawling gear.
- The destruction of the nesting and modification of the foraging habitat of shorebirds / waders from the shoreline activities of the Ocean Hauling, Estuary General and Recreational fisheries. These activities include the use of 4WD vehicles, hauling onto sandy shores and walking along shores to access fishing sites.
- The disturbance of birds (colonial seabirds, shorebirds, waders and sea ducks) in the estuaries and on the shorelines of NSW from the physical presence of fishers in their vicinty. The Recreational, Ocean Hauling and Estuary General fisheries are most likely to conduct their activities on or adjacent to these areas. These activities include bait digging, shoreline fishing, the use of 4WD

vehicles, walking on shores and boating. Although little is known about the extent and consequence of this interaction in NSW it is included here as it could be contributing to disturbance responses in wading birds which is listed as one of five major threats to the survival of these birds in NSW.

5.3.2. Interactions for which their effect on the survival of marine wildlife in NSW is uncertain

It is also possible that other interactions considered in this assessment may be threatening the survival of some marine wildlife types in NSW. However, this is difficult to determine as the information required to do so is not available and may be difficult to obtain. These interactions and wildlife types are:

- The entanglement of fur-seals and birds (seabirds, diving birds, surface feeding birds and shorebirds) in debris from fishing activities in NSW, and the ingestion of this debris by these birds.
- Negative effects on cetaceans from the noise created by fishing-related boat traffic.
- A decline of the size of marine wildlife populations that forage on fish and squid from competitive / trophic interactions with NSW fisheries.
- The illegal killing of marine wildlife by fishers in NSW in response to both negative beliefs about these animals and the nuisance factor created by the foraging of these animals from fishing activities and competitive / trophic interactions.
- The ingestion of hooks and sinkers by birds that forage around line fishing gear used by NSW fisheries, and the eventual poisoning of these animals.
- The incidental capture of dolphins, most probably common and bottlenose dolphins, on the fishing gear used in NSW.
- The entanglement of whales in traps used by NSW fisheries.

5.3.3. Interactions that can positively benefit marine wildlife in NSW

The foraging of marine wildlife on the bait, catch or discards of fishing activities in NSW was found in this assessment to be a frequently occurring interaction that can result in positive benefits for individuals and populations that may have become dependent on this food source. This interaction is the most commonly reported interaction between fishing activities and marine wildlife in NSW. The species most likely to be dependent on the food source from fishing vessels in NSW are local populations of dolphins (mostly common and bottlenose dolphins), Australian and New Zealand fur-seals and birds (pelicans, cormorants, gulls, terns, gannets, petrels, shearwaters, albatrosses, jaegers, skuas and birds of prey). These species would regularly forage from the trawling, hauling, trapping (juvenile seals only), line fishing and mesh net activities in NSW. Competitive / trophic interactions with NSW fisheries could also positively benefit some marine wildlife populations, but the species that may be affected and the extent to which they are affected is unknown.

5.3.4. Interactions that have negligible effects on marine wildlife in NSW

The interactions considered in this assessment that occur with NSW fisheries at such a low extent that they should only be having minor or no negative effects or consequences on marine wildlife are:

- the deliberate harvest of marine wildlife;
- the collision of marine wildlife with fishing vessels and gear;
- the contact of marine wildlife with oil spills;
- the disturbance of sea turtles and seals from noise, site access and the physical presence of these fishers; and
- the destruction of habitats below low tide from fishing-related activities.

5.3.5. Issues that may arise from these interactions in the future

It is possible that in the future increases in the size of local marine wildlife populations (e.g. as is currently occurring with fur-seals in NSW) could result in the interactions considered in this assessment to occur at an increased rate. This needs to be especially considered in the recovery planning of marine wildlife species that are listed as threatened. Currently the economic losses experienced by fishers in NSW from the interactions considered in this assessment are not of the frequency and magnitude that would force an individual fisher or fishery out of business. Some minor losses can be frequently experienced (e.g. the cost of replacing damaged handline gear from foraging wildlife), and some fishers can experience significant short-term losses on an irregular basis (e.g. the reduced fishing opportunities for Estuary General and Recreational Fishers that can result from the co-operative foraging of bird flocks in enclosed or semi-enclosed estuarine waters). In the future, fishers in NSW might experience greater economic losses from the interactions considered in this assessment if the rate at which they occurred increased significantly.

6. MANAGEMENT RECOMMENDATIONS

The management measures currently used by NSW DPI that could directly or indirectly affect marine wildlife are outlined in section 3.2 of this report. The adequacy of those measures is assessed below.

6.1. Management of the risk areas and issues identified in this report

6.1.1. Priority interactions that may threaten the survival of marine wildlife in NSW

In addressing the issues and reducing the risk identified in Chapter 5 of this report, management attention should be focussed on those interactions that were identified as potentially threatening the survival of marine wildlife in NSW (section 5.3.1). The adequacy of the direct and indirect current management used by NSW DPI to reduce the risk resulting from these interactions and any proposed changes to this management, are presented in Table 29.

Table 29: An assessment of the adequacy of current management measures used by NSW DPI to reduce the main areas of risk and issues identified in this report.

Risk area / issue: *The incidental capture of birds on pelagic line fishing techniques used by the (a) Recreational, and (b) Ocean Trap and Line and Estuary General commercial fisheries*	
Current management:	(a) Recreational: Educate recreational fishers about responsible fishing practices around marine wildlife. The preparation of public discussion papers reviewing NSW recreational fishing rules and regulations and a statement of the environmental effects of this fishery. (b) Commercial: Document interactions with threatened or protected species through an observer survey and mandatory reporting on monthly catch returns. A commitment to reduce bycatch and associated discarding, and to ameliorate any problems with marine wildlife by modifying fishing practices and gear, and/or implementing closures. The use of best practice handling techniques for captured animals. A Code of Practice to ensure fishers minimise the accidental capture of marine wildlife.
Adequacy of management:	(a) Recreational: • Education is the main way to reduce the incidental capture or entanglement of birds on recreational lines. NSW DPI has produced in association with Australian Seabird Rescue (ASR) a pamphlet to inform recreational fishers about this interaction. A poster about this interaction had also been produced. The adequacy of this educational material is largely influenced by its distribution, which currently includes the fisheries website, educational activities of ASR and Fish Care Volunteers and distribution to groups requesting the pamphlets. • ASR, a volunteer wildlife rescue group that focuses on rescuing birds affected by this interaction, is in a rapid phase of expansion, establishing rescue groups throughout NSW and Australia. NSW DPI acknowledges the importance of such wildlife groups with respect to this interaction, as recreational fishers may not be able to release entangled birds in a sensitive manner, and has sought to ensure the continuation of this group by providing them with equipment and support. • ASR has identified fish cleaning tables at boat ramps as areas within NSW where this interaction frequently occurs. It is difficult for NSW DPI to ban fishing in these areas due to conflicting local interests. However, NSW DPI

Table 29 – continued

	is improving these facilities to help ensure that offal is discarded in an environmentally sensitive manner. • ASR have documented that birds in NSW frequently become entangled in fishing lines when swimming and foraging around unattended setlines, especially those set from jetties and similar structures in estuarine waters. There are current restrictions on how unattended setlines can be used in NSW estuarine waters, but these measures do not prevent the entanglement of birds when swimming near these lines. (b) Commercial: The management measures should document the rate of this interaction with these fisheries provided observer surveys of the pelagic line fishing techniques are conducted and fishers self-report any captured birds. Adequate measures are in place to address any issues that may arise from such reporting.
Improvements to current management:	(a) Recreational: • Increase coverage of education about this interaction by placing information about responsible fishing practices around birds in the next issue of the NSW Recreational Fishing Guides, and at all fisheries offices. • Investigate adequacy of various forms of instruction to minimise the feeding of birds and encourage the use of offal tubes at fish cleaning facilities. • Minimise the effect of unattended setlines. • Gain information on the rate of this interaction by requesting from ASR information on the number and species of wildlife affected by this interaction they rescue. (b) Commercial: • Employ some precautionary measure to reduce the rate of this interaction by educating fishers to avoid this interaction and release affected birds in a manner which maximises their survival (e.g. sending the pamphlet used for the NSW Recreational Fishery to commercial fishers).
Risk area / issue: *The incidental capture of sea turtles on the fishing gear used in NSW, mostly oceanic trawling gear*	
Current management:	Document interactions with threatened or protected species through a scientific observer survey and/or mandatory reporting on monthly catch returns for all commercial fisheries. Document the level of interaction between the Ocean Trawl Fishery and sea turtles and seals to assess the need for turtle or seal excluder devices, or other measures to mitigate impacts on these species. Map the area fished by the Ocean Trawl, Ocean Trap and Line and Lobster fisheries. Spatial, seasonal and diurnal closures. A commitment to ameliorate any problems with marine wildlife by modifying fishing practices and gear, and/or implementing closures. The use of best practice handling techniques for captured animals.
Adequacy of management:	Provided the observer survey of the Ocean Trawl Fishery is undertaken, and in subsequently considering the need for turtle excluder devices (TEDs) that the success of these devices in the Queensland Trawl Fishery is considered, these measures should adequately ameliorate this problem with this fishery.
Improvements to current management:	If the observer survey is not implemented in the near future, other measures to address this interaction should be implemented, such as: a precautionary introduction of TEDs in the trawlers in far northern NSW in waters < 30 m in depth; or improved effort to gather more information about the extent of this interaction across the fishery, before deciding upon further management.

Table 29 – continued

Risk area / issue: *The destruction of nesting and modification of foraging habitat of shorebirds / waders from the shoreline activities of the Ocean Hauling, Estuary General and Recreational fisheries*	
Current management:	The following measures relate to the commercial fisheries listed above: Spatial, seasonal and diurnal closures; A commitment to ameliorate any problems with marine wildlife by modifying fishing practices and gear, and/or implementing closures; Review the quantum of beach available to hauling in the Ocean Hauling Fishery and develop performance measures for monitoring and modifying that amount over time; and A Code of Practice to minimise disturbance to this habitat. Closures / access restrictions in the recreational fishery.
Adequacy of management:	These management measures should ameliorate this problem with commercial fisheries. However, performance information on the overlap of the area of operation of these fisheries with shorebird distribution in NSW, and the effort exerted and nature of activities undertaken by these fisheries on sandy shores is required to determine the effectiveness of these measures. Due to a lack of similar information on the Recreational Fishery, it is not known whether the current closures / access restrictions in this fishery reduce the extent to which it is contributing to this interaction.
Improvements to current management:	A commitment to gather the performance information for the relevant commercial and recreational fisheries to determine the effectiveness and need, if any, for further management action.
Risk area / issue: The disturbance of birds in estuaries and on shorelines of NSW from the physical presence of fishers in their vicinity	
Current management:	Mapping of the area fished by the Lobster, Ocean Trawl and Ocean Trap and Line fisheries. Plus the measures that relate to the destruction of shorebird habitat (listed above).
Adequacy of management:	More information on the extent and consequence of this interaction to the avifauna occurring in NSW is required to determine appropriate management responses. Until this information is obtained, the extent to which this problem is ameliorated by the current management measures cannot be determined.
Improvements to current management:	A commitment to gather the necessary information to determine what sort of further management action is required. Much of this information should be gathered by wildlife managers and, along with fishing-related sources of this disturbance, include other sources of this disturbance to these birds.

6.1.2. Interactions for which their effect on the survival of marine wildlife in NSW is uncertain

Some of the other interactions considered in this report might threaten the survival of some marine wildlife types in NSW (section 5.3.2). Of these interactions, management should be focussed on those interactions that are part of or related to a key threatening process (KTP) for marine wildlife. These include debris-type interactions (listed as a KTP under both the *EPBC Act 1999* and the *TSC Act 1995*), and the incidental capture of dolphins in beach protection nets (listed as a KTP under the *TSC Act 1995*). Largely as part of the formulation of the threat abatement plan for interactions with marine debris, NSW DPI is currently part of a taskforce that is determining how to reduce this key threatening process. A measure that could be implemented at a local level with respect to debris interactions is to establish incentives to ensure that fishing nets and other rubbish are discarded at land-based facilities

and not at sea. NSW DPI is also seeking to reduce the incidental capture of dolphins in beach protection nets by trailing the use of pingers on these nets.

These uncertain types of interactions are just one source of these types of disturbances to marine wildlife. Management of these disturbances to marine wildlife should consider all sources of disturbance, be cross-jurisdictional in nature and include the involvement of NSW DPI. This is also the case for the more direct interactions in this grouping, i.e. ingestion of hooks and sinkers by birds and incidental capture of dolphins on NSW fishing gear, as the effective management of these interactions also requires the participation of wildlife managers in NSW Department of Environment and Conservation (DEC).

The management measures currently used by NSW DPI allow for the documentation of some of these uncertain interactions with marine wildlife through an observer survey or mandatory reporting. This may provide useful information for the management of the incidental capture rate of dolphins on fishing gear and, for some fisheries only, the amount of debris they add to the marine environment when their fishing gear is lost. This, along with the documentation of their landings, is the only type of information that can contribute to the management of these interactions, which can be directly obtained from NSW commercial fishers. A commitment is made in each completed statutory fishery management strategy for NSW commercial fisheries to ameliorate any problems with marine wildlife by modifying fishing practices and gear, and/or implementing closures proposes to adequately reduce any detrimental consequences that become obvious as information is collected on the interactions.

6.1.3. Interactions that can positively benefit marine wildlife in NSW

There is little acknowledgement in the current management strategies for NSW commercial fisheries of the populations of marine wildlife that forage from fishing activities for food. Appropriately the focus in these strategies is to reduce the level of bycatch and subsequent discarding in these fisheries to ensure the protection of biodiversity and sustainability of fish stocks. In some of these strategies, there is a focus on capping and sometimes reducing effort within these fisheries. However, the effect of such reductions in discards on wildlife populations that forage on this food source is appropriately not directly addressed in these strategies. NSW DPI is primarily concerned with developing and maintaining sustainable fish stocks. Hence its management focus is on reducing the wider impacts of fishing on the ecosystem and increasing the survival of released fish.

6.1.4. Adaptability of current management to future issues

The current management proposed in each completed statutory NSW fishery management strategy is adaptive. The management actions proposed in the fishery management strategies commit to ameliorate any problems with marine wildlife by modifying fishing practices and gear, and/or implementing closures. This action should adequately deal with any problem between marine wildlife and fishing activities in NSW that may become more evident or arise in the future.

The documentation of interactions between marine wildlife and the fisheries managed by NSW DPI is largely proposed through an observer study and mandatory self-reporting by fishers. These measures are considered to be the most feasible management options in NSW considering the cost of these measures and the relatively low frequency of most interactions considered in this study.

NSW DPI is proposing to monitor interactions with marine wildlife in the long-term through mandatory self-reporting by fishers. Such self-reporting focuses only on the information that can be easily documented by fishers, such as incidental capture of marine wildlife or the rate at which they lose fishing gear. This reliance on self-reporting includes some bias as such reporting, especially when it could result in negative consequences for fishers, may not be consistently applied across all fisheries

and if conducted alone, may do little to accurately document these interactions in a publicly acceptable transparent manner. More frequent use of independent observers is therefore required from time to time to assess the effectiveness of self-reporting and provide a process of quality control.

6.2. Management of marine wildlife required under threatened species legislation

Under the relevant NSW (*TSC Act 1995*) and national (*EPBC Act 1999*) threatened species legislation, NSW DPI is required to comply with any relevant management measures set by the relevant state and national agencies to protect and rehabilitate threatened species, populations or communities. These will include measures that are outlined in threat abatement plans, recovery plans and critical habitat declarations that seek to reduce fishing-related impacts on threatened marine wildlife.

There are three fishing-related key threatening processes (KTPs) listed under the *TSC Act 1995* and *EPBC Act 1999* that can affect the survival of marine wildlife species and involve NSW fishing activities. These processes, listed in Table 30, include the debris and some incidental capture type interactions that have been considered in this assessment. Only one threat abatement plan has been prepared for these processes to date - on the incidental capture of seabirds on longlines. Of the fishing activities managed by NSW DPI, this plan covers the longline techniques of the Ocean Trap and Line Fishery (demersal longlining) when used in Commonwealth waters (i.e. beyond 3 nm). This plan proposes to document rates of seabird bycatch on demersal longline gear in the Australian Fishing Zone (AFZ) and apply appropriate mitigation methods to this gear where necessary. However, this plan does not implicate state fishery agencies in the proposed actions of these measures. NSW DPI will comply with this measure by documenting these interactions through mandatory reporting by this fishery and including appropriate categories in the proposed observer program.

Table 30: The key threatening processes to marine wildlife listed under state (*TSC Act 1995*) and national (*EPBC Act 1999*) threatened species legislation that relate to NSW fishing activities.

Key threatening process	Legislation
The incidental catch (or bycatch) of seabirds during oceanic longline fishing operations.	EPBC Act
The injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris; The entanglement in or ingestion of anthropogenic debris in marine and estuarine environments.	EPBC Act; TSC Act
The death or injury to marine species following capture in shark control programs on ocean beaches.	TSC Act

At the individual species level, recovery plans have been prepared for 36 species and one population of the 63 species and one population that are considered in this assessment and listed as threatened under both the *TSC Act 1995* and/or *EPBC Act 1999*. Fishing-related activities off NSW have been identified as a threat to all species in most of the recovery plans for the species that regularly occur in NSW. These threats include interactions considered in this assessment, such as the incidental capture of marine wildlife in fishing gear, debris type interactions, collision of marine wildlife with fishing vessels, competition for marine (food) resources, and physical non-contact disturbances on and around shorelines. Management measures proposed in these recovery plans that require NSW DPI to take some action are outlined in Table 31. NSW DPI is currently complying with these measures.

Table 31: The management measures in recovery plans for marine wildlife prepared under the *TSC Act 1995* and *EPBC Act 1999* that require some action by NSW DPI.

Management measure	Recovery plan
*NSW DPI is required to determine the mortality and species composition of marine turtle bycatch in shark control activities. *State agencies are required to implement legislation for the prevention of garbage discharge from vessels of all sizes. *State fisheries agencies are to require licensed fishers to record all interactions with marine turtles.	Marine Turtle Recovery Plan
*In areas that are critical to these species (around Twofold Bay, Eden) the encouragement of best practice techniques that will reduce the likelihood of entanglement in debris or marine industry equipment and application of national standards for disentangling large cetaceans.	Humpback Whale and Southern Right Whale draft Recovery Plans
*In this recovery plan, NSW DPI has responsibilities to protect and manage the food sources of this species, and ensure that fishing operations are undertaken in accordance with the relevant fisheries management strategies, particularly where they relate to shorebirds.	Little Tern Recovery Plan
*NSW DPI will collect data on commercial fishing effort and catches of baitfish (of importance to the little penguin) in Sydney Harbour and adjacent waters, and record any incidental catches of little penguins from fishing nets used in Sydney Harbour and make this data available to the recovery team. *NSW DPI is to consider the impacts of commercial fishing on the little penguin population in North Sydney Harbour when developing management plans for the estuary general and ocean hauling fisheries.	Manly Point Little Penguin Population Recovery Plan

The critical habitat declaration for the endangered population of little penguins at Manly also calls for NSW DPI to undertake action to help conserve this habitat. Fishing (both commercial and recreational) has subsequently been banned in the critical habitat in Sydney Harbour between sunset and sunrise during the breeding season of the little penguin population (July 1 to February 28).

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The decline of many marine wildlife populations resulting from their interactions with fishing activities has been frequently documented around the world. This study is the first time a NSW regional assessment of all interactions between the fisheries that operate and marine wildlife that lives in NSW estuarine and marine waters has been undertaken.

The broad-scale ecosystem-based approach used in this study identified four key interactions that require direct management by marine wildlife and fisheries managers in NSW. The effectiveness of the current fisheries management regulations to minimise and mitigate impact of fishing on the marine wildlife in NSW is documented for both the four key interactions and those interactions of an unknown status.

7. REFERENCES

Achaval, F., Marín, Y. H., and Barea, L. C. (2000). Incidental capture of turtles with pelagic longline. In *Proceedings of the 18th International Symposium on Sea Turtle Biology and Conservation* (eds. Abreu-Grobois, F. A., Briseño, R., Márquez, R., and Sarti, L.) pp. 261. Mazatlan, Sinaloa, Mexico, 3-7 March.

Allen, R. L. (1985). Dolphins and the purse-seine fishery for yellowfin tuna. In *Marine Mammals and Fisheries* (eds. Beddington, J. R., Beverton, R. J. H., and Lavigne, D. M.) pp. 236-252. George Allen and Unwin, London.

Allen, S., Marsh, H., and Hodgson, A. (2004). Occurrence and conservation of the dugong (Sirenia: Dugongidae) in New South Wales. *Proceedings of the Linnean Society of NSW* 125,211-216.

Alverson, D. L. (1992). A review of commercial fisheries and the stellar sea lion (*Eumetopias jubatus*): the conflict arena. *Reviews in Aquatic Sciences* 6,203-256.

Anderson, D. W., Gress, F., and Kais, F. (1982). Brown pelicans: influence of food supply on reproduction. *Oikos* 39,23-31.

Andrew, N. L., Jones, T., Terry, C., and Pratt, R. (1995). By-catch of an Australian stow net fishery for school prawns (*Metapenaeus macleayi*). *Fisheries Research* 22,119-136.

Anon. (1996). "Seal friendly" lobster potting. *Southern Fisheries* 4(3),2.

Anon. (2002). Rescue squad races to another mammal in distress. *Sydney Morning Herald*, Sydney.

Anon. (2004). Responsible fishing to reduce wildlife injuries - a guide for fishers. NSW Fisheries and Australian Seabird Rescue.

Anon. (2003). Adelaide dolphin deaths update. *South Australian Regional Ripples* 9(3),8.

Arcos, J. M., and Oro, D. (1996). Changes in foraging range of Audouin's gulls *Larus audouinii* in relation to a trawler moratorium in the western Mediterranean. *Colonial Waterbirds* 19,128-131.

Arcos, J. M., and Oro, D. (2002). Significance of nocturnal purse seine fisheries for seabirds: a case study off the Ebro Delta (NW Mediterranean). *Marine Biology* 141,277-286.

Arnould, J. P. Y. (2002). *Southern Squid Gig Fishery - Seal Interaction Project: Report on Observations of Interactions between Fur Seals and Fishing Vessels*. Australian Fisheries Management Authority, Melbourne.

Arnould, J. P. Y., and Croxall, J. P. (1995). Trends in entanglement of Antarctic fur seals *(Arctocephalus gazella)* in man-made debris at South Georgia. *Marine Pollution Bulletin* 30,707-712.

Au, D., and Perryman, W. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science* 12,597-602.

Au, D. W. K., and Pitman, R. L. (1988). Seabird relationships with tropical tunas and dolphins. In *Seabirds and Other Marine Vertebrates* (ed. Burger, J.) pp. 174-212. Columbia University Press, New York.

Australian Museum. (2003). Australian Museum Fact Sheet - Southern Bottlenose Whale. www.amonline.net.au, 15/5/03.

Azzarello, M. Y., and Van Vleet, E. S. (1987). Marine birds and plastic pollution. *Marine Ecology Progress Series* 37,295-303.

Bache, S. J. (2000). Current legal developments: 1998 agreement on the international conservation program. *The International Journal of Marine and Coastal Law* 15,393-412.

Bache, S. J. (2003a). Bycatch mitigation tools: selecting fisheries, setting limits, and modifying gears. *Ocean and Coastal Management* 46,103-125.

Bache, S. J. (2003b). *Marine Wildlife Bycatch Mitigation - Global Trends, International Actions and the Challenges for Australia*. Ocean Publications, Centre of Maritime Policy, University of Wollongong, Wollongong.

Baird, R. W., and Hooker, S. K. (2000). Ingestion of plastic and unusual prey by a juvenile harbour porpoise. *Marine Pollution Bulletin* 40,719-720.

Baird, R. W., Stacey, P. J., Duffus, D. A., and Langelier, K. M. (2002). An evaluation of gray whale (*Eschrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada. *Journal of Cetacean Research and Managment* 4,289-296.

Baird, S. J. (2004). *Estimation of the Incidental Capture of Seabird and Marine Mammal Species in Commercial Fisheries in New Zealand waters, 1999-2000*. New Zealand Fisheries Assessment Report 2004/41, Ministry of Fisheries, Wellington.

Baird, S. J., and Griggs, L. H. (2004). *Estimation of Within-Season Chartered Southern Bluefin Tuna* (Thunnus maccoyi) *longline seabird incidental captures, 2002*. New Zealand Fisheries Assessment Report 2004/42, Ministry of Fisheries, Wellington.

Baker, G. B., and Wise, B. S. (2005). The impact of pelagic longline fishing on the flesh-footed shearwater *Puffinus carneips* in Eastern Australia. *Biological Conservation* 126, 306-316.

Baker, G. B., Gales, R., Hamilton, S., and Wilkinson, V. (2002). Albatrosses and petrels in Australia: a review of their conservation and management. *Emu* 102,71-97.

Balazs, G. (1985). Impact of ocean debris on marine turtles: entanglement and ingestion. In *Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984* (eds. Shomura, R. S. and Yoshida, H. O.) US Department of Commerce, Honolulu.

Bannister, J. L., Kemper, C. M., and Warneke, R. M. (1996). *The Action Plan for Australian Cetaceans*. Australian Nature Conservation Agency, Canberra.

Baraff, L. S., and Loughlin, T. R. (2000). Trends and potential interactions between pinnipeds and fisheries of New England and the U. S. west coast. *Marine Fisheries Review* 62,1-39.

Barlow, J., Baird, R. W., Heyning, J. E., Wynne, K., Manville, A. M. I., Lowry, L. F., Hanan, D., Sease, J., and Burkanov, V. N. (1994). A review of cetacean and pinniped mortality in coastal fisheries along the west coast of the USA and Canada and the east coast of the Russian Federation. *Report of the International Whaling Commission* Special Issue 15,405-426.

Barnes, K. N., Ryan, P. G., and Boix-Hinzen, C. (1997). The impact of the hake *Merluccius* spp. longline fishery off South Africa on Procellariiform seabirds. *Biological Conservation*

82,227-234.

Bartle, J. A. (1991). Incidental capture of seabirds in the New Zealand subantarctic squid trawl fishery, 1990. *Bird Conservation International* 1,351-359.

Bax, N. J. (1991). A comparison of the fish biomass flow to fish, fisheries, and mammals in six marine ecosystems. *ICES Marine Science Symposium* 193,217-224.

Beck, C. A., and Barros, N. B. (1991). The impact of debris on the Florida manatee. *Marine Pollution Bulletin* 22,508-510.

Beck, C. A., and Reid, J. P. (1995). An automated photo-identification catalog for studies of the life history of the Florida manatee. In *Population biology of the Florida manatee* (eds. O'Shea, T. J., Ackerman, B. B., and Percival, H. F.) pp. 120-134. National Biological Service, Information and Technology Report 1.

Belda, E. J., and Sánchez, A. (2001). Seabird mortality on longline fisheries in the western Mediterranean: factors affecting bycatch and proposed mitigating measures. *Biological Conservation* 98,357-363.

Beukema, J. J., and Cadée, G. C. (1996). Consequences of the sudden removal of nearly all mussels and cockles from the Dutch Wadden Sea. *P.S.Z.N.I. Marine Ecology* 17,279-289.

Birds Australia (2003). Draft Working list of birds of Australia and Australian territories. 10 September 2003.

Bjorndal, K. A., Bolten, A. B., and Lagueux, C. J. (1994). Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Marine Pollution Bulletin* 28,154-158.

Blaber, S. J. M., and Milton, D. A. (1994). Distribution of seabirds at sea in the Gulf of Carpentaria, Australia. *Australian Journal of Marine and Freshwater Research* 45,445-454.

Blaber, S. J. M., and Wassenberg, T. J. (1989). Feeding ecology of the piscivorous birds *Phalacrocorax varius, P. melanoleucos* and *Stena bergii* in Moreton Bay, Australia: diets and dependence on trawler discards. *Marine Biology* 101,1-10.

Blaber, S. J. M., Milton, D. A., Smith, G. C., and Farmer, M. J. (1995). Trawl discards in the diets of tropical seabirds of the northern Great Barrier Reef, Australia. *Marine Ecology Progress Series* 127,1-13.

Blakers, M., Davies, S. J. J. F., and Reilly, P. N. (1984). *The Atlas of Australian Birds*. Melbourne University Press, Melbourne, 738 pp.

Bourne, W. R. P. (1985). Turtles and pollution. *Marine Pollution Bulletin* 28,154-158.

Britton, J. R., Harvey, J. P., Cowx, I. G., Holden, T., Feltham, M. J., Wilson, B. R., and Davies, J. M. (2003). Key factor analysis to assess cormorant depredation on inland fisheries in the UK. In *Interactions Between Fish and Birds: Implications for Management* (ed. Cowx, I. G.) pp. 14-27. Blackwell Publishing, Oxford.

Broadhurst, M. K. (1998). Bottlenose dolphins, *Tursiops truncatus,* removing by-catch from prawn-trawl codends during fishing in New South Wales, Australia. *Marine Fisheries Review* 60,9-14.

Brothers, N. (1991). Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. *Biological Conservation* 55,255-268.

Brothers, N. (1996). *Catching Fish not Birds - A Guide to Improving your Longline Fishing Efficiency. Parks & Wildlife Service*. Tasmania, Hobart.

Brothers, N., Gales, R., and Reid, T. (1999). The influence of environmental variables and mitigation measures on seabird catch rates in the Japanese tuna longline fishery within the Australian Fishing Zone, 1991-1995. *Biological Conservation* 88,85-101.

Bugoni, L., Krause, L., and Petry, M. V. (2001). Marine debris and human impacts on seaturtles in southern Brasil. *Marine Pollution Bulletin* 42,1330-1334.

Bunce, A., Norman, F. I., Brothers, N., and Gales, R. (2002). Long-term trends in the Australasian gannet *(Morus serrator)* population in Australia: the effects of climate change and commercial fisheries. *Marine Biology* 141,263-269.

Burger, J. (1991). Foraging behaviour and the effect of human disturbance on the piping plover (*Charadrius melodus*). *Journal of Coastal Research* 7,39-52.

Burger, J. (1998). Effects of motorboats and personal watercraft on flight behaviour over a colony of common terns. *The Condor* 100,528-534.

Burnell, S. R., and McCulloch, R. E. (2001). Draft recovery plan for southern right whales in Australian waters. Environment Australia, Canberra.

Butterworth, D. S., Punt, A. E., Oosthuizen, W. H., and Wickens, P. A. (1995). The effects of future consumption by the Cape fur seal on catches and catch rates of the Cape hakes. 3. Modelling the dynamics of the Cape fur seal *Arctocephalus pusillus pusillus*. *South African Journal of Marine Science* 16,161-183.

Caminãs, J. A., and De La Serna, J. M. (1995). The loggerhead distribution in the western Mediterranean Sea as deducted from captures by the Spanish longline fishery. *Scientia Herpetologica* 1995,316-323.

Camphuysen, C. J., and Garthe, S. (2000). Seabirds and commercial fisheries: population trends of piscivorous seabirds explained? In *Effects of Fishing on Non-Target Species and Habitats* (eds. Kaiser, M. J. and de Groot, S. J.) pp. 163-184. Blackwell Science, London.

Camphuysen, C. J., Berrevoets, C. M., Cremers, H. J. W. M., Dekinga, A., Dekker, R., Ens, B. J., van der Have, R. K. H., Kuiken, T., Leopold, M. F., van der Meer, J., and Piersma, T. (2002). Mass mortality of common eiders (*Somateria mollissima*) in the Dutch Wadden Sea, winter 1999/2000: starvation in a commercially exploited wetland of international importance. *Biological Conservation* 106,303-317.

Carr, A. (1987). Impact on nondegradable marine debris on the ecology and survival outlook of sea turtles. *Marine Pollution Bulletin* 18,352-356.

Carter, H. R., and Sealey, S. G. (1984). Marbled murrelet mortality due to gill-net fishing in Barkley Sound, British Columbia. In *Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships* (eds. Nettleship, D. N., Sanger, G. A., and Springer, P. F.) pp. 212-220. Special Publication of the Canadian Wildlife Service, Ottawa.

Cayford, J. (1993). Wader disturbance: a theoretical overview. In *Disturbance to Waterfowl on Estuaries* (eds. Davidson, N. and Rothwell, P.) pp. 3-5. Wader Study Group Bulletin.

Chan, E. H., Liew, H. C., and Mazlan, A. G. (1988). The incidental capture of sea turtles in fishing gear in Terengganu, Malaysia. *Biological Conservation* 43,1-7.

Chapdelaine, G., and Rail, J. (1997). Relationship between cod fishery activities and the population of herring gulls on the North Shore of the Gulf of St Lawrence, Québec, Canada. *ICES Journal of Marine Science* 54,708-713.

Cheng, I. J., and Chen, T. (1997). The incidental capture of five species of sea turtles by coastal setnet fisheries in the eastern waters of Taiwan. *Biological Conservation* 82,235-239.

Cherel, Y., Weimerskirch, H., and Duhamel, G. (1996). Interactions between longline vessels and seabirds in Kerguelen waters and a method to reduce seabird mortality. *Biological Conservation* 75,63-70.

Chilvers, B. L., and Corkeron, P. J. (2001). Trawling and bottlenose dolphins' social structure. *Proceedings of the Royal Society of London B* 268,1901-1905.

Christensen, V. (1996). Managing fisheries involving predator and prey species. *Reviews in Fish Biology and Fisheries* 6,417-442.

Clapham, P. J., Young, S. B., and Brownell, R. L. J. (1999). Baleen whales: conservation issues and the status of the most endangered populations. *Mammal Review* 29,35-60.

Cockcroft, V. G. (1992). Incidental capture of bottlenose dolphins (*Tursiops truncatus*) in shark nets: an assessment of some possible causes. *Journal of the Zoological Society of London* 226,123-134.

Cogger, H. G. (2000). *The Status of Marine Reptiles in New South Wales*. A report prepared for the NSW National Parks and Wildlife Service.

Commonwealth of Australia (2003). *Seabird Interactions with Longline Fisheries in the Australian Fishing Zone: Assessment Report for the National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries*. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra.

Corkeron, P. J., Bryden, M. M., and Hedstrom, K. E. (1990). Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia. In *The Bottlenose Dolphin* (eds. Leatherwood, S. and Reeves, R. R.) pp. 329-336. Academic Press, Inc.

Coutin, P. C., and Reside, J. (2003). Fish predation by great cormorants, *Phalacrocorax carbo carboides*, in the Gippsland Lakes, south-eastern Australia. In *Interactions Between Fish and Birds: Implications for Management* (ed. Cowx, I. G.) pp. 196-210. Blackwell Publishing, Oxford.

Cowx, I. G. (2003). Interactions between fisheries and fish-eating birds: optimising the use of shared resources. In *Interactions Between Fish and Birds: Implications for Management* (ed. Cowx, I. G.) pp. 361-372. Blackwell Publishing, Oxford.

Cunningham, D. J., and Wilson, S. P. (2003). Marine debris on beaches of the greater Sydney region. *Journal of Coastal Research* 19,421-430.

Cunningham, M., Gibbs, P., Rogers, T., Spielman, D., and Walraven, E. (1993). *Ecology and Health of the Little Penguin* Eudyptula minor *near Sydney*. A report by Taronga Zoo, prepared for the Water Board, Sydney.

Daan, N., Bromley, P. J., Hislop, J. R. G., and Nielsen, N. A. (1990). Ecology of North Sea fish. *Netherlands Journal for Sea Research* 26,343-386.

D'Agrosa, C., Lennert-Cody, C. E., and Vidal, O. (2000). Vaquita bycatch in Mexico's artisanal gillnet fisheries: driving a small population to extinction. *Conservation Biology* 14,1110-1119.

Dans, S., Alonso, M., Crespo, E., Pedraza, S., and Garcia, N. (2003). Interactions between marine mammals and high seas fisheries in Patagonia: An integrated approach. In *Marine Mammals: Fisheries, Tourism and Management Issues* (eds. Gales, N., Hindell, M., and Kirkwood, R.) pp. 100-115. CSIRO Publishing, Melbourne.

Darby, A. (2002a). Free Willy? It's more like free lunch, say robbed fishermen. *The Sydney Morning Herald*, Sydney. 7/10/02, page 5.

Darby, A. (2002b). The nets that punish leviathan. *The Sydney Morning Herald*, Sydney. 3/9/02, page 12.

Darby, J. T., and Dawson, S. M. (2000). Bycatch of yellow-eyed penguins *(Megadyptes antipodes)* in gillnets in New Zealand waters 1979-1997. *Biological Conservation* 93,327-332.

David, J. H. M. (1987). Diet of the south african fur seal (1974-1985) and an assessment of competition with fisheries in southern Africa. *South African Journal of Marine Science* 5,693-713.

David, J., and Wickens, P. (2003). Management of Cape fur seals and fisheries in South Africa. In *Marine Mammals: Fisheries, Tourism and Management Issues* (eds. Gales, N., Hindell, M., and Kirkwood, R.) pp. 116 - 135. CSIRO Publishing, Melbourne.

Davies, J. M., Holden, T., Feltham, M. J., Wilson, B. R., Britton, J. R., Harvey, J. P., and Cowx, I. G. (2003). The relationship between cormorant and fish populations at two fisheries in England: an overview. In *Interactions Between Fish and Birds: Implications for Management* (ed. Cowx, I. G.) pp. 28-42. Blackwell Publishing, Oxford.

Dawson, S. M. (1991). Incidental catch of Hector's dolphins in inshore gillnets. *Marine Mammal Science* 7,283-295.

Day, R. H., Wehle, D. H. S., and Coleman, F. C. (1985). Ingestion of plastic pollutants by marine birds. In *Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984,* (eds. Shomura, R. S. and Yoshida, H. O.) pp. 344-386. US Dep. Commer. NOAA Tech. Memo., NFMS. NOAA-TM-NMFS-SWFC-54, Honolulu, Hawaii.

De Gange, A. R., and Newby, T. C. (1980). Mortality of seabirds and fish in a lost salmon driftnet. *Marine Pollution Bulletin* 9,289-295.

De Master, D., Miller, D., Henderson, J. R., and Coe, J. M. (1985). Conflicts between marine mammals and fisheries off the coast of California. In *Marine Mammals and Fisheries* (eds. Beddington, J. R., Beverton, R. J. H., and Lavigne, D. M.) George Allen and Unwin, London.

De Master, D. P., Fowler, C. W., Perry, S. L., and Richlen, M. F. (2001). Predation and competition: the impact of fisheries on marine mammal populations over the next one hundred years. *Journal of Mammalogy* 82,641-651.

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin* 44,842-852.

Earthjustice (2003). Federal fisheries agency sued for failure to protect Hawai'i's false killer whales from longliners. www.earthjustice.org, 21/11/2003.

Eckert, S. A. (1997). Distant fisheries implicated in the loss of the world's largest leatherback nesting population. *Marine Turtle Newsletter* 78,2-7.

Editorial (2003). The catching capacity of lost static fishing gears: introduction. *Fisheries Research* 64,101-105.

Endangered Species Scientific Subcommittee (1995). Commonwealth listing advice on incidental catch (or bycatch) of seabirds during oceanic longline fishing operations.

Environment Australia (1998a). *Draft Recovery Plan for Marine Turtles in Australia*. Environment Australia, Canberra.

Environment Australia (1998b). *Threat Abatement Plan for the Incidental Catch (or by-catch) of Seabirds during Oceanic Longline Fishing Operations*. Environment Australia - Biodiversity Group, Canberra.

Environment Australia (2001a). *Recovery Plan for Albatrosses and Giant-petrels*. Environment Australia, Natural Heritage Division, Canberra.

Environment Australia (2001b). *Draft Guidelines on the Application of the Environment Protection and Biodiversity Conservation Act to Interactions between Offshore Seismic Operations and Whales (large cetaceans)*. Environment Australia, Canberra.

Environment Australia (2003). *Recovery Plan for Marine Turtles in Australia*. Environment Australia, Canberra.

Erikson, A. W., and Hanson, M. B. (1990). Continental estimates and population trends of Antarctic ice seals. In *Antarctic Ecosystems: Ecological Change and Conservation* (eds. Kerry, K. R. and Hempel, G.) pp. 253-264. Springer-Verlag, Berlin.

Eriksson, C., and Burton, H. (2003). Origins and biological accumulation of small plastic particles in fur seals from Macquarie Island. *Ambio* 32,380-384.

Eschbaum, R., Veber, T., Vetemaa, M., and Saat, T. (2003). Do cormorants and fishermen compete for fish resources in the Väinameri (eastern Baltic) area? In *Interactions Between Fish and Birds: Implications for Management* (ed. Cowx, I. G.) pp. 72-83. Blackwell Publishing, Oxford.

Faris, J., and Hart, K. (1996). *Seas of Debris: A Summary of the Third International Conference on Marine Debris*. In Miami, Florida, 8-13 May 1994. pp. 54. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle.

Feldkamp, S. D., Costa, D. P., and DeKrey, G. K. (1988). Energetic and behavioural effects of net entanglement on juvenile northern fur seals, *Callorhinus ursinus*. *Fishery Bulletin* 87,85-94.

Ferreira, R. L., Martins, R. H., Da Silva, A. A., and Bolten, A. B. (2001). Impact of swordfish fisheries on sea turtles in the Azores. *Arquipelago. Life and Marine Sciences* 18A,75-79.

Ferris, L., and Ferris, R. (2002). *The Impact of Recreational Fishing on Estuarine Birdlife in Central and North Coast Districts of New South Wales*. Australian Seabird Rescue Inc., Ballina.

Fertl, D., and Leatherwood, S. (1997). Cetacean interactions with trawls: A preliminary review. *Journal of Northwest Atlantic Fisheries Science* 22,219-248.

Fowler, C. W. (1987). Marine debris and northern fur seals: a case study. *Marine Pollution Bulletin* 18,326-335.

Franson, J. C., Hansen, S. P., Creekmore, T. E., Brand, C. J., Evers, D. C., Duerr, A. E., and DeStafano, S. (2003). Lead fishing weights and other fishing tackle in selected waterbirds. *Waterbirds* 26,345-352.

Frederick, P. C. (2002). Wading birds in the marine environment. In *Biology of Marine Birds* (eds. Schreiber, E. A. and Burger, A. E.) pp. 617-655. CRC Press, London.

Furness, R. W. (1982). Competition between fisheries and seabird communities. *Advances in Marine Biology* 20,225-397.

Furness, R. W. (1984). Seabird-fisheries relationships in the northeast Atlantic and North Sea. In *Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships* (eds. Nettleship, D. N., Sanger, G. A., and Springer, P. F.) Canadian Wildlife Service Special Publication, Dartmouth, Nova Scotia.

Furness, R. W. (1985). Ingestion of plastic particles by sea-birds at Gough Island, South Atlantic Ocean. *Environmental Pollution Series A* 38,261-272.

Furness, R. W., and Tasker, M. L. (2000). Seabird-fishery interactions: quantifying the sensitivity of seabirds to reductions in sandeel abundance, and identification of key areas for sensitive seabirds in the North Sea. *Marine Ecology Progress Series* 202,253-264.

Furness, R. W., Hudson, A. V., and Ensor, K. (1988). Interactions between scavenging seabirds and commercial fisheries around the British Isles. In *Seabirds and Other Marine Vertebrates - Competition Predation and Other Interactions* (ed. Burger, J.) pp. 240-268. Columbia University Press, New York.

Gales, R. (1998). Albatross populations: status and threats. In *Albatross, Biology and Conservation* (eds. Robertson, G. and Gales, R.) pp. 20-45. Surrey, Beatty and Sons, Chipping Norton, Australia.

Gales, R., and Brothers, N. (1996). *Status and Conservation of Albatrosses on Macquarie Island*. SCA10636, Report to the Australian Nature Conservation Agency.

Gales, N. J., Shaughnessy, P. D., and Dennis, T. E. (1994). Distribution, abundance and breeding cycle of the Australian sea lion *Neophoca cinera* (Mammalia: Pinnipeda). *Journal of Zoology, London* 234,353-370.

Gales, R., Brothers, N., and Reid, T. (1998). Seabird mortality in the Japanese tuna longline fishery around Australia, 1988-1995. *Biological Conservation* 86,37-56.

Garnett, S. T., and Crowley, G. M. (2000). *The Action Plan for Australian Birds*. Environment Australia, Canberra.

Garthe, S., and Hüppop, O. (1994). Distribution of ship-following seabirds and their utilization of discards in the North Sea in summer. *Marine Ecology Progress Series* 106,1-9.

Garthe, S., and Scherp, B. (2003). Utilization of discards and offal from commercial fisheries by seabirds in the Baltic Sea. *ICES Journal of Marine Science* 60,980-989.

Geraci, J. R. (1990). Physiologic and toxic effects of oil on cetaceans. In *Sea Mammals and Oil: Confronting the Risks* (eds. Geraci, J. R. and St. Aubin, D. J.) pp. 167-197. Academic Press, San Diego, California.

Geraci, J. R., and St. Aubin, D. J. (1980). Offshore petroleum resource development and marine

mammals: A review and research recommendations. *Marine Fisheries Review* 42,1-12.

Glockner-Ferrari, D. A., and Ferrari, M. J. (1990). Reproduction in the humpback whale (*Megaptera novaengliae*) in Hawaiian waters, 1975-1988: the life history, reproductive rates, and behaviour of known individuals identified through surface and underwater photography. *Report of the International Whaling Commission* Special Issue No. 12,161-169.

Goldsworthy, S. D., Bulman, C., He, X., Larcombe, J., and Littnan, C. (2003). Trophic interactions between marine mammals and Australian fisheries: an ecosystem approach. In *Marine Mammals: Fisheries, Tourism and Management Issues* (eds. Gales, N., Hindell, M., and Kirkwood, R.) pp. 62-99. CSIRO Publishing, Collingwood, Victoria.

Gorzelany, J. F. (1998). Unusual deaths of two free-ranging atlantic bottlenose dolphins (*Tursiops truncatus*) related to ingestion of recreational fishing gear. *Marine Mammal Science* 14,617-627.

Goss-Custard, J. D., and Verboven, N. (1993). Disturbance and feeding shorebirds on the Exe estuary. *Wader Study Group Bulletin* 68,59-66.

Gray, C. A. (2001). Spatial variation in by-catch from a prawn seine-net fishery in a south-east Australian coastal lagoon. *Marine and Freshwater Research* 52,987-993.

Gray, C. A. (2002). Management implications of discarding in an estuarine multi-species gill net fishery. *Fisheries Research* 56,177-192.

Gray, C. A., Kennelly, S. J., Hodgson, K. E., Ashby, C. J. T., and Beatson, M. L. (2001). Retained and discarded catches from commercial beach-seining in Botany Bay, Australia. *Fisheries Research* 50,205-219.

Gray, C. A., McDonall, V. C., and Reid, D. D. (1990). By-catch from prawn trawling in the Hawkesbury River, New South Wales: species composition, distribution and abundance. *Australian Journal of Marine and Freshwater Research* 41,13-26.

Gribble, N. A., McPherson, G., and Lane, B. (1998). Effect of the Queensland Shark Control Program on non-target species: whale, dugong, turtle and dolphin: a review. *Marine and Freshwater Research* 49,645-651.

Hall, M. A. (1998). An ecological view of the tuna-dolphin problem: impacts and trade-offs. *Reviews in Fish Biology and Fisheries* 8,1-34.

Hall, M. A., Alverson, D. L., and Metzulas, K. I. (2000). By-catch: problems and solutions. *Marine Pollution Bulletin* 41,204-219.

Hamer, K. C., Furness, R. W., and Caldow, R. W. G. (1991). The effects of changes in food availability on the breeding ecology of great skuas *Catharacta skua* in Shetland. *Journal of Zoology, London* 223,175-183.

Hanni, K. D., and Pyle, P. (2000). Entanglement of pinnipeds in synthetic materials at south-east Farallon Island, California, 1976-1998. *Marine Pollution Bulletin* 40,1076-1081.

Harrigan, K. E. (1992). Causes of mortality of little penguins *Eudyptula minor* in Victoria. *Emu* 91,273-277.

Harris, A., and Ward, P. (1999). *Non-target Species in Australia's Commonwealth Fisheries*. *A critical review*. Bureau of Resource Sciences, Canberra.

Harwood, J. (1983). Interactions between marine mammals and fisheries. *Advances in Applied Biology* 8,189-215.

Harwood, J., and Croxall, J. P. (1988). The assessment of competition between seals and commercial fisheries in the North Sea and the Antarctic. *Marine Mammal Science* 4,13-33.

Harwood, J., and Greenwood, J. J. D. (1985). Competition between British grey seals and fisheries. In *Marine Mammals and Fisheries* (eds. Beddington, J. R., Beverton, R. J. H., and Lavigne, D. M.) pp. 153-169. George Allen and Unwin, London.

Harwood, M. B., and Hembree, D. (1987). Incidental catch of small cetaceans in the offshore gillnet fishery in northern Australian waters: 1981-1985. *Report of the International Whaling Commission* 37,363-367.

Harwood, M. B., McNamara, K. J., Anderson, G. R. V., and Walter, D. G. (1984). Incidental catch of small cetaceans in a gillnet fishery in northern Australian waters. *Report of the International Whaling Commission* 34,555-559.

Haynes, D. (1997). Marine debris on continental islands and sand cays in the far northern section of the Great Barrier Reef Marine Park, Australia. *Marine Pollution Bulletin* 34,276-279.

Henderson, J. R. (2001). A pre- and post-MARPOL annex V summary of Hawaiian monk seal entanglements and marine debris accumulation in northwestern Hawaiian Islands, 1982-1998. *Marine Pollution Bulletin* 42,584-589.

Henry, G. W., and Lyle, J. M. (2003). *The National Recreational and Indigenous Fishing Survey*. Project No. 99/158, Fisheries Research and Development Corporation, Cronulla.

Henwood, T. A., and Stuntz, W. E. (1987). Analysis of sea turtle captures and mortalities during commercial shrimp trawling. *Fishery Bulletin* 85,813-817.

Herfort, A. (1997). *Marine debris on beaches in New South Wales*. Ocean Watch Australia Ltd., Sydney .

Hickman, L. J. (1999). *Effects of Fur Seals on Fishing Operations along the New South Wales South Coast*. Honours Thesis. The University of New South Wales - Australian Defence Force Academy, Canberra.

Higgins, P. J. (1999). *Handbook of Australian, New Zealand and Antarctic Birds. Volume 4 - parrots to dollarbird*, Oxford University Press, Melbourne, 1248 pp.

Higgins, P. J., and Davies, S. J. J. F. (1996). *Handbook of Australian, New Zealand and Antarctic Birds. Volume 3 - Snipe to Pigeons*, Oxford University Press, Melbourne, 1028 pp.

Hill, B. J., and Wassenberg, T. J. (1990). Fate of discards from prawn trawlers in Torres Strait. *Australian Journal of Marine and Freshwater Research* 41,53-64.

Hill, B. J., and Wassenberg, T. J. (2000). The probable fate of discards from prawn trawlers fishing near coral reefs a study in the northern Great Barrier Reef, Australia. *Fisheries Research* 48,277-286.

Hillstead, H., Richardson, J., McVea, C., and Watson, J. (1981). Worldwide incidental capture of sea turtles. In *Biology and Conservation of Sea Turtles. Proceedings of the World Conference on Sea Turtle Conservation* (ed. Bjorndal, K. A.) pp. 489-495.

Hockin, D., Ounsted, M., Gorman, M., Hill, D., Keller, V., and Barker, M. A. (1992). Examination of

the effects of disturbance on birds with reference to its importance in ecological applications. *Journal of Environmental Management* 36,253-286.

Hofman, R. J. (1990). Cetacean entanglement in fishing gear. *Mammal Review* 20,53-64.

Hudson, A. V., and Furness, R. W. (1988). Utilization of discarded fish by scavenging seabirds behind whitefish trawlers in Shetland. *Journal of the Zoological Society of London* 215,151-166.

Jahncke, J., Goya, E., and Guillen, A. (2001). Seabird by-catch in small-scale longline fisheries in northern Peru. *Waterbirds* 24,137-141.

Jefferson, T. A., and Curry, B. E. (1994). A global review of porpoise (Cetacea: Phocoenidae) mortality in gill nets. *Biological Conservation* 67,167-183.

Johnson, D. (2002a). Hungry pelicans. *Catch - NSW Seafood Industry Magazine* 5, 6.

Johnson, D. (2002b). NSW Haul fisher's work to save discards. *SeaNet Smarter Fishing for Industry* December 2002, 8.

Jones, L. L., and DeGange, A. R. (1988). Interactions between seabirds and fisheries in the North Pacific Ocean. In *Seabirds and Other Marine Invertebrates - Competition, Predation and Other Interactions* (ed. Burger, J.) pp. 269-290. Columbia University Press, New York.

Jones, L. L., and Ferrero, R. C. (1985). Observations of net debris and associated entanglements in the North Pacific Ocean and Bering Sea, 1978-84. In *Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984* (eds. Shomura, R. S. and Yoshida, H. O.) pp. 183-196. US Dep. Commer. NOAA Tech, Memo., NFMS. NOAA-TM-NMFS-F/NWC-71, Honolulu, Hawaii

Jones, M. M. (1995). Fishing debris in the Australian marine environment. *Marine Pollution Bulletin* 30,25-33.

Julian, F., and Beeson, M. (1998). Estimates of marine mammal, turtle, and seabird mortality for two California gillnet fisheries: 1990-1995. *Fishery Bulletin* 96,271-284.

Karp, W., and Ferdinand, J. (2004). Observer sampling bias: causes, consequences and solutions. In *Proceedings of the 4th International Observer Conference* (eds McVea, T.A., and Kennelly, S.J.) pp. 30-31. 8-11 November 2004. Sydney, Australia.

Kasuya, T. (1985). Fishery-dolphin conflict in the Iki Island area of Japan. In *Marine Mammals and Fisheries* (eds. Beddington, J. R., Beverton, R. J. H., and Lavigne, D. M.) pp. 253-272. George Allen and Unwin, London.

Katona, S. K., and Whitehead, H. (1988). Are Cetacea ecologically important? *Oceanography and Marine Biology Annual Review* 26,553-568.

Kemper, C., Gibbs, P., Obendorf, D., Marvanek, S., and Lenghaus, C. (1994). A review of heavy metal and organochlorine levels in marine mammals in Australia. *Science of the Total Environment* 154,129-139.

Kennelly, S. J., Liggins, G. W., and Broadhurst, M. K. (1998). Retained and discarded by-catch from oceanic prawn trawling in New South Wales. *Fisheries Research* 36,217-236.

Kenney, R. D., Scott, G. P., Thompson, T. J., and Winn, H. E. (1997). Estimates of prey consumption and trophic impacts of cetaceans in the USA northeast continental shelf ecosystem. *Journal of Northwest Atlantic Fisheries Science* 22,155-171.

Kiessling, I. (2003). *Finding Solutions: Derelict Fishing Gear and Other Marine Debris in Northern Australia*. National Oceans Office, Darwin.

Kinas, P. G. (2002). The impact of incidental kills by gill nets on the franciscana dolphin (*Pontoporia blainvillei*) in southern Brazil. *Bulletin of Marine Science* 70,409-421.

Kingsford, R. T. (1990). The effects of human activities on shorebirds, seabirds and waterbirds of Comerong Island, at the mouth of the Shoalhaven River. *Wetlands (Australia)* 9,7-12.

Kirkwood, R., Pemberton, D., and Copson, G. (1992). *The Conservation and Management of Seals in Tasmania*. Department of Parks, Wildlife and Heritage, Hobart.

Klaer, N., and Polachek, T. (1998). The influence of environmental factors and mitigation measures on by-catch rates of seabirds by Japanese longline fishing vessels in the Australian region. *Emu* 98,305-316.

Knowlton, A. R., and Kraus, S. D. (2001). Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. *Journal of Cetacean Research and Management* 2,193-208.

Knuckey, I. A., Eayrs, S., and Bosschietter, B. (2002). *Options for Reducing Incidental Catch of Seals on Wet-boats in the SETF: A Preliminary Assessment*. Final report to the Australian Fisheries Management Authority. Marine and Freshwater Resources Institute, Queenscliff, Victoria.

Kock, K. (2001). The direct influence of fishing and fishery-related activities on non-target species in the Southern Ocean with particular emphasis on longline fishing and its impact on albatrosses and petrels - a review. *Reviews in Fish Biology and Fisheries* 11,31-56.

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

Laist, D. W. (1987). Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin* 18,319-326.

Laist, D. W. (1995). Marine debris entanglement and ghost fishing: a cryptic and significant type of bycatch? In *Solving Bycatch: Considerations for Today and Tomorrow* pp. 33-39. University of Alaska, Sea Grant College Program, Seattle, Washington

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S., and Podesta, M. (2001). Collisions between ships and whales. *Marine Mammal Science* 17,35-75.

Larmour, G. (1999). *Australia. Progress Report on Cetacean Research, January 1999 to December 1999, with Statistical Data for the Calendar Year 1999*. Environment Australia, Canberra.

Laurent, L., Caminãs, J. A., Casale, P., Deflorio, M., De Mertico, G., Kapantagakis, A., Margaritoulis, D., Politou, C., and Valeiras, J. (2001). *Assessing Marine Turtle Bycatch in European Drifting Longline and Trawl Fisheries for Identifying Fishing Regulations*. Project EC-DG Fisheries 98-008, Joint project of BIOINSIGHT, IEO, IMBC, STPS and University of Bari, Villeurbanne, France.

Lavinge, D. (2003). Marine mammals and fisheries: The role of science in the culling debate. In *Marine Mammals: Fisheries, Tourism and Management Issues* (eds. Gales, N., Hindell, M., and Kirkwood, R.) pp. 31-47. CSIRO Publishing, Melbourne.

Leadbitter, D. (1999). *Bycatch Solutions: A Handbook for Fishers in Non-trawl Fisheries*. FRDC Report No. 1998/201., Ocean Watch Australia Ltd., New South Wales, Australia.

Lenhardt, M. I., Bellmund, S., Byles, R. A., Harkins, S. W., and Musick, J. A. (1983). Marine turtle reception of bone conducted sound. *The Journal of Auditory Research* 23,119-125.

Leung Ng, S., and Leung, S. (2003). Behavioural response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Marine Environmental Research* 56,555-567.

Lien, J. (1994). Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979-1990). *Report of the International Whaling Commission* Special Issue 15,149-157.

Lien, J., Stenson, G. B., and Hsun Ni, I. (1989). A review of incidental entrapment of seabirds, seals and whales in inshore fishing gear in Newfoundland and Labrador: a problem for fishermen and fishing gear designers. In *Proceedings of the world symposium on fishing gear and fishing vessels* (ed. Campbell, C. M.) pp. 67-71. Marine Institute, St. Johns, NF, Canada.

Liggins, G. W. (1996). *The Interaction between Fish Trawling (in NSW) and Other Commercial and Recreational Fisheries*. Final Report to Fisheries Research and Development Corporation. Project No. 92/79, NSW Fisheries.

Liggins, G. W., and Kennelly, S. J. (1996). By-catch from prawn trawling in the Clarence River estuary, New South Wales, Australia. *Fisheries Research* 25,347-367.

Liggins, G. W., Kennelly, S. J., and Broadhurst, M. K. (1996). Observer-based survey of by-catch from prawn trawling in Botany Bay and Port Jackson, New South Wales. *Marine and Freshwater Research* 47,877-888.

Liggins, G. W., Scandol, J. P., Montgomery, S., Craig, J., and Macbeth, W. (2003). An assessment of the NSW eastern rock lobster resource for 2003-2004. NSW Fisheries Resource Assessment Series No. 8, NSW Fisheries, Sydney.

Limpus, C., and Reimer, D. (1990). The loggerhead turtle, *Caretta caretta*, in Queensland: a population in decline. In *Proceedings of the Australian Marine Turtle Conservation Workshop.* (ed. James, R.) pp. 39-47. ANCA, Sea World Nara Resort, Gold Coast.

Løkkeborg, S. (2003). Review and evaluation of three mitigation measures - bird-scaring line, underwater setting and line shooter - to reduce seabird bycatch in the north Atlantic longline fishery. *Fisheries Research* 60,11-16.

López, A., Pierce, G. J., Santos, M. B., Gracia, J., and Guerra, A. (2003). Fishery by-catches of marine mammals in Galician waters: results from on-board observations and an interview survey of fishermen. *Biological Conservation* 111,25-40.

Lunneryd, S. G., Fjälling, A., and Westerberg, H. (2003). A large-scale salmon trap: a way of mitigating seal impact on a coastal fishery. *ICES Journal of Marine Science* 60,1194-1199.

Lusseau, D. (2003a). The effects of tour boats on the behaviour of bottlenose dolphins: Using Markov chains to model anthropogenic impacts. *Conservation Biology* 17,1785-1793.

Lusseau, D. (2003b). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress Series* 257,267-274.

Marcano, L. A., and Alio, J. J. (1998). Incidental capture of sea turtles by the industrial shrimping fleet off northeastern Venezuela. In *Proceedings of the 18th International Symposium on Sea Turtle Conservation.* March 1998.

Marchant, S., and Higgins, P. J. (1990). *Handbook of Australian, New Zealand and Antarctic Birds. Volume 1 - Ratites to Ducks*, Oxford University Press, Melbourne, 735 pp.

Marchant, S., and Higgins, P. J. (1993). *Handbook of Australian, New Zealand and Antarctic Birds - Raptors to Lapwings*, Oxford University Press, Melbourne, 984 pp.

Margaritoulis, D. N. (1986). Captures and strandings of the leatherback sea turtle, *Dermochelys coriacea*, in Greece (1982-1984). *Journal of Herpetology* 20,474-475.

Marsh, H. (1996). Progress towards the sustainable use of dugongs by indigenous peoples in Queensland. In *Sustainable Use of Wildlife by Aboriginal Peoples and Torres Strait Islanders* (eds. Bomford, M. and Caughley, J.) pp. 139-151. Australian Government Publishing Service, Canberra.

Marsh, H., Penrose, H., Eros, C., and Hughes, J. (2002). *Dugong Status Report and Action Plans for Countries and Territories*. United Nations Environment Program - Early Warning and Assessment Report Series, Nairobi, Kenya.

Marsh, H., Penrose, H., and Eros, C. (2003). A future for the dugong? In *Marine Mammals: Fisheries, Tourism and Management Issues* (eds. Gales, N., Hindell, M., and Kirkwood, R.) pp. 383-399. CSIRO Publishing, Melbourne.

Marshall, A. (2002). Report from the NPWS controller at the melonheaded whale (*Peponocephala electra*) stranding at Crowdy Head, 10th August 2002. *The ORRCA Newsletter* Spring 2002, 4-5.

Martinez-Abrain, A., Maestre, R., and Oro, D. (2002). Demersal trawling waste as a food source for Western Mediterranean seabirds during the summer. *ICES Journal of Marine Science* 59,529-537.

McCauley, R., and Cato, D. (2003). Acoustics and marine mammals: Introduction, importance, threats and potential as a research tool. In *Marine Mammals: Fisheries, Tourism and Management Issues* (eds. Gales, N., Hindell, M., and Kirkwood, R.) pp. 344-365. CSIRO Publishing, Melbourne.

McPhee, D. P., Leadbitter, D., and Skilleter, G. A. (2002). Swallowing the bait: is recreational fishing in Australia ecologically sustainable? *Pacific Conservation Biology* 8,40-51.

Melvin, E. F., Parrish, J. K., and Conquest, L. L. (1999). Novel tools to reduce seabird bycatch in coastal gillnet fisheries. *Conservation Biology* 13,1386-1397.

Michael Fry, D., Fefer, S. I., and Sileo, L. (1987). Ingestion of plastic debris by laysan albatrosses and wedge-tailed shearwaters in the Hawaiian Islands. *Marine Pollution Bulletin* 18,339-343.

Milledge, D. (1977). One year's observation of seabirds in continental shelf waters off Sydney, NSW. *Corella* 1,1-12.

Milton, D. A. (2001). Assessing the susceptibility to fishing of populations of rare trawl bycatch: sea snakes caught by Australia's Northern Prawn Fishery. *Biological Conservation* 101,281-290.

Ministry of Fisheries and Department of Conservation (2000). *Seabird Interaction with Fisheries in*

the New Zealand Exclusive Economic Zone. A Review and National Plan of Action. Ministry of Fisheries and Department of Conservation, Wellington, New Zealand.

Moller, L. M., and Beheregaray, L. B. (2001) Coastal bottlenose dolphins from south eastern Australia are *Tursiops aduncus* according to sequences of the mitochondrial dna control region. *Marine Mammal Science* 17, 249-263.

Monagahan, P., Uttley, J. D., and Burns, M. D. (1989). The relationship between food supply, reproductive effort and breeding and success in Arctic terns *Sterna paradisaea*. *Journal of Animal Ecology* 58,261-274.

Montevecchi, W. A. (2002). Interactions between fisheries and seabirds. In *Biology of Marine Birds* (eds. Schreiber, E. A. and Burger, J.) pp. 527-557. CRC Press, London.

Montevecchi, W. A., and Myres, R. A. (1995). Prey harvests of seabirds reflect pelagic fish and squid abundance on multiple spatial and temporal scales. *Marine Ecology Progress Series* 117,1-9.

Montevecchi, W. A., and Myres, R. A. (1996). Dietary changes of seabird reflect with shifts in pelagic food webs. *Sarsia* 80,313-322.

Montevecchi, W. A., Birt, V. L., and Cairns, D. K. (1988). Dietary changes of seabirds associated with local fisheries failures. *Biological Oceanography* 5,153-161.

Morizur, Y., Berrow, S. D., Tregenza, N. J. C., Couperus, A. S., and Pouvreau, S. (1999). Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. *Fisheries Research* 41,297-307.

National Marine Fisheries Service (2001). *Stock Assessments of Loggerhead and Leatherback Sea Turtles and an Assessment of the Impact of the Pelagic Longline Fishery on the Loggerhead and Leatherback Sea Turtles of the Western North Atlantic*. NOAA Tech. Memo. NMFS-SEFSC-455.

Nitta, E. T., and Henderson, J. R. (1993). A review of interactions between Hawaii's fisheries and protected species. *Marine Fisheries Review* 55,83-92.

Noke, W. D., and Odell, D. K. (2002). Interactions between the Indian River lagoon blue crab fishery and the bottlenose dolphin, *Tursiops truncatus*. *Marine Mammal Science* 18,819-832.

Nolan, C. P., and Liddle, G. M. (2000). Interactions between killer whales (*Orcinus orca*) and sperm whales (*Physter macrocephalus*) with a longline fishing vessel. *Marine Mammal Science* 16,658-664.

Norman, F. I. (2000). Preliminary investigation of the bycatch of marine birds and mammals in inshore commercial fisheries, Victoria, Australia. *Biological Conservation* 92,217-226.

Norris, K., Bannister, R. C. A., and Walker, P. W. (1998). Changes in the number of oystercatchers *Haematopus ostralegus* in the Burry Inlet in relation to the biomass of cockles *Cerastoderma edule* and its commercial exploitation. *Journal of Applied Ecology* 35,75-85.

Northridge, S. P. (1991). An updated world review of interactions between marine mammals and fisheries. *FAO Fisheries Technical Paper* No. 251,58.

Nowacek, S. M., Wells, R. S., and Solow, A. R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus,* in Sarasota Bay, Florida. *Marine Mammal Science* 17,673-688.

NSW Department of Environment and Conservation (NSW DEC). (2003). Rare turtle released in

Sydney after crab pot tangle. Media Release, 20/03/03.

NSW Department of Primary Industries (NSW DPI) (2004a). *Ocean Trawl Fishery - Environmental Impact Statement*. *Public Consultation Document*. NSW DPI, Cronulla.

NSW Department of Primary Industries (NSW DPI). (2004b). *Lobster Fishery -Environmental Impact Statement*. *Public Consultation Document*. NSW DPI, Cronulla.

NSW Fisheries (2001). *Estuary General Fishery - Environmental Impact Statement. Public Consultation Document*. NSW Fisheries, Cronulla.

NSW Fisheries (2002). *Estuary Prawn Trawl Fishery - Environmental Impact Statement. Public Consultation Document*. NSW Fisheries, Cronulla.

NSW Fisheries (2003a). *Fishery Management Strategy for the Ocean Hauling Fishery*. NSW Fisheries, Cronulla, Australia.

NSW Fisheries (2003b). *Status of Fisheries Resources 2001/2002*. NSW Fisheries, Cronulla.

NSW National Parks and Wildlife Service. (2003). *South Coast Shorebird Recovery Newsletter*, April 2003.

NSW Scientific Committee (2002a). Australian fur-seal - vulnerable species listing. NSW Scientific Committee - final determination. 3 pp.

NSW Scientific Committee (2002b). New Zealand fur-seal - vulnerable species listing. NSW Scientific Committee - final determination. 3 pp.

NSW Scientific Committee (2003). Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments - proposed key threatening process declaration. 8pp.

Ocean Watch Australia (2003). *Circle of Dependence - Protected Species Handling Manual*. Ocean Watch, Pyrmont, NSW.

Oceans Fisheries Programme (2001). *A Review of Turtle Bycatch in the Western and Central Pacific Ocean Tuna Fisheries*. A report prepared for the South Pacific Regional Environmental Programme (SPREP). Secretariat of the Pacific Community, New Caledonia.

Oro, D. (1996). Effects of trawler discard availability on egg laying and breeding success in the lesser black-backed gull *Larus fuscus* in the Western Mediterranean. *Marine Ecology Progress Series* 132,43-46.

Oro, D., Jover, L., and Ruiz, X. (1996). Influence of trawling activity on the breeding ecology of a threatened seabird, Audouin's gull *Larus audouinii*. *Marine Ecology Progress Series* 136,19-29.

Oro, D., and Ruiz, X. (1997). Exploitation of trawler discards by breeding seabirds in the north-western Mediterranean: differences between the Erbo Delta and the Balearic Islands areas. *ICES Journal of Marine Science* 54,965-707.

Page, B., McKenzie, J., McIntosh, R., Baylis, A., Morissey, A., Calvert, N., Hasse, T., Berris, M., Dowie, D., Shaughnessy, P. D., and Goldsworthy, S. D. (2004). Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Marine Pollution Bulletin* 49,33-42.

Parsons, K. C., and Burger, J. (1982). Human disturbance and nestling behaviour in Black-crowned Night-herons. *Condor* 84,184-187.

Paton, D. C., Ziembicki, M., Owen, P., and Heddle, C. (2000). *Disturbance Distances for Water Birds and the Management of Human Recreation with Special Reference to the Coorong Region of South Australia*. National Wetlands Program, Adelaide.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., and Torres, F. (1998). Fishing down marine food webs. *Science* 279,860-863.

Pemberton, D., Brothers, N. P., and Kirkwood, R. (1992). Entanglement of Australian fur seals in man-made debris in Tasmanian waters. *Wildlife Rescue* 19,151-159.

Pemberton, D., Merdsoy, B., Gales, R., and Renouf, D. (1994). The interaction between offshore cod trawlers and harp *Phoca groenlandica* and hooded *Cystophora cristata* seals off Newfoundland, Canada. *Biological Conservation* 68,123-127.

Perrin, W. F., Donovan, G. P., and Barlow, J. (1994). *Gillnets and Cetaceans*. International Whaling Commission, Cambridge. 629 pp.

Piatt, J. F., and Nettleship, D. N. (1987). Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. *Marine Pollution Bulletin* 18,344-349.

Piatt, J. F., and Gould, P. J. (1994). Endangered Japanese murrelets: incidental catch in high seas drift nets and post breeding dispersal. *Auk* 111,953-961.

Pitcher, T. J. (2001). Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. *Ecological Applications* 11,601-617.

Pitcher, T. J., and Pauly, D. (1998). Rebuilding ecosystems, not sustainability as the proper goal of fisheries management. In *Reinventing Fisheries Management* (eds. Pitcher, T. J., Hart, P. J. B., and Pauly, D.) pp. 311-330. Kluwer Academic Publishers, Dordrecht.

Poiner, I. R., and Harris, A. N. (1990). The incidental capture and mortality of sea turtles in Australia's northern prawn fishery. In *Proceedings of the Australian Marine Turtle Conservation Workshop.* (ed. James, R.) pp. 127-135. ANCA, Sea World Nara Resort, Gold Coast

Poiner, I. R., and Harris, A. N. M. (1996). Incidental capture, direct mortality and delayed mortality of sea turtles in Australia's Northern Prawn Fishery. *Marine Biology* 125,813-825.

Poiner, I. R., Buckworth, R. C., and Harris, A. N. M. (1990). Incidental capture and mortality of sea turtles in Australia's northern prawn fishery. *Australian Journal of Marine and Freshwater Research* 41,97-110.

Polovina, J. J., Howell, E., Parker, D. M., and Balazs, G. H. (2003). Dive-depth distribution of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific: Might deep longline sets catch fewer turtles? *Fisheries Bulletin* 101,189-193.

Powell, S. (2001). *Australia. Progress Report on Cetacean Research, January 2001 to December 2001, with Statistical Data for the Calendar Year 2001*. Environment Australia, Canberra.

Powell, S. (2002). *Australia. Progress Report on Cetacean Research, January 2002 to December 2002, with Statistical Data for the Calendar Year 2002*. Environment Australia, Canberra.

Powell, S., and Rafic, M. (2000). *Australia. Progress Report on Cetacean Research, January 2000 to*

December 2000, with Special Statistical Data for the Calendar Year 2000. Environment Australia, Canberra.

Priddel, D. (2003). Our seabirds at risk. In *Conserving Marine Environments. Out of Sight Out of Mind.* (eds. Hutchings, P. and Lunney, D.) pp. 73-80. Royal Zoological Society of NSW, Mosman.

Punt, A. E., David, J. H. M., and Leslie, R. W. (1995). The effects of future consumption by the Cape fur seal on catches and catch rates of the Cape hakes. 2. feeding and diet of the Cape fur seal *Arctocephalus pusillus pusillus*. *South African Journal of Marine Science* 16,85-99.

Queensland Department of Environment (1997). *Conservation and Management of Whales and Dolphins in Queensland 1997-2001*. Queensland Department of Environment, Brisbane.

Queensland Department of Primary Industries & Fisheries (QDPI&F) (2004). Toothed whale depradation mitigation. www.dpi.qld.gov.au, 5/10/04.

Queensland Environmental Protection Agency (QEPA) (1999). *Conservation and Management of the Dugong in Queensland 1999-2004*. Queensland Environmental Protection Agency, Brisbane.

Rafic, M. (1999). *Draft Recovery Plan for Blue Whales* Balaenoptera musculus *in Australian Waters*. Environment Australia, Canberra.

Reynolds, J. D., Dulvy, N. K., and Roberts, C. M. (2002). Exploitation and other threats to fish conservation. In *Handbook of Fish Biology and Fisheries* (eds. Hart, P. J. B. and Reynolds, J. D.) pp. 320-340. Blackwell Science, Oxford.

Richardson, W. J., and Würsig, B. (1997). Influences of man-made noise and other human actions on cetacean behaviour. *Marine and Freshwater Behaviour and Physiology* 29,183-209.

Richardson, W. J., Greene, C. R. J., Malme, C. I., and Thomson, D. H. (1995). *Marine Mammals and Noise*. Academic Press, San Diego, 576 pp.

Roberts, A., Klomp, N., and Birckhead, J. (1996). Monitoring marine and terrestrial hunting in an Aboriginal community in North Queensland. In *Sustainable Use of Wildlife by Aboriginal Peoples and Torres Strait Islanders* (eds. Bomford, M. and Caughley, J.) pp. 152-166. Australian Government Publishing Service, Canberra.

Roberts, G., and Evans, P. R. (1993). Responses of foraging sanderlings to human approaches. *Behaviour* 126,29-43.

Robins, C. M., Goodspeed, A. M., Poiner, I. R., and Harch, B. D. (2002a). *Monitoring the Catch of Turtles in the Northern Prawn Fishery*. Fisheries Research and Development Corporation, Canberra.

Robins, C. M., Bache, S. J., and Kalish, S. R. (2002b). *Bycatch of Sea Turtles in Pelagic Longline Fisheries - Australia*. Bureau of Rural Sciences Final Report to the Fisheries Resources Research Fund, Agriculture, Fisheries and Forestry - Australia, Canberra.

Robins, J. B. (1995). Estimated catch and mortality of sea turtles from the east coast otter trawl fishery of Queensland, Australia. *Biological Conservation* 74,157-167.

Romanov, E. V. (2001). Bycatch in the tuna purse-seine fisheries of the western Indian Ocean. *Fisheries Bulletin* 100,90-105.

Ryan, P. G. (1991). The impact of the commercial lobster fishery on seabirds at the Tristan da Cunha

Islands, South Atlantic Ocean. *Biological Conservation* 57,339-350.

Ryan, P. G., Connell, A. D., and Gardner, B. D. (1988). Plastic ingestion and PCBs in seabirds: is there a relationship? *Marine Pollution Bulletin* 19,174-176.

Ryan, P. G., and Moloney, C. L. (1988). Effect of trawling on bird and seal distributions in the southern Benguela region. *Marine Ecology Progress Series* 45,1-11.

Sagar, P. M., Molloy, J., Weimerskirch, H., and Warham, J. (2000). Temporal and age-related changes in survival rates of Southern Buller's Albatrosses (*Thalassarche bulleri bulleri*) at the Snares, New Zealand, 1948 to 1997. *Auk* 117,699-708.

Salden, D. R. (1988). Humpback whale encounter rates offshore of Maui, Hawaii. *Journal of Wildlife Management* 52,301-304.

Sánchez, A., and Belda, E. J. (2003). Bait loss caused by seabirds on longline fisheries in the northwestern Mediterranean: is night setting an effective mitigation measure? *Fisheries Research* 60,99-106.

Schlais, J. F. (1984). Thieving dolphins: a growing problem in Hawaii's fisheries. *Sea Frontiers* 30,293-298.

Schrey, E., and Vauk, G. J. M. (1987). Records of entangled gannets *(Sual bassana)* at Helgoland, German Bight. *Marine Pollution Bulletin* 18,350-352.

Shaughnessy, P. D. (1980). Entanglement of Cape fur seals with man-made objects. *Marine Pollution Bulletin* 11,332-336.

Shaughnessy, P. D. (1985). Interactions between fisheries and Cape fur seals in southern Africa. In *Marine Mammals and Fisheries* (eds. Beddington, J. R., Beverton, R. J. H., and Lavigne, D. M.) pp. 119-134. George Allen and Unwin, London.

Shaughnessy, P. D. (1999). *The Action Plan for Australian Seals*. Environment Australia, Canberra.

Shaughnessy, P. D., and Davenport, S. R. (1996). Underwater videographic observations and incidental mortality of fur seals around fishing equipment in South-eastern Australia. *Marine and Freshwater Research* 47,553-556.

Shaughnessy, P. D., Semmelink, A., Cooper, J., and Frost, P. G. H. (1981). Attempts to develop acoustic methods of keeping Cape fur seals *Arctocephalus pusillus* from fishing nets. *Biological Conservation* 21,141-158.

Shaughnessy, P. D., Briggs, S. V., and Constable, R. (2001). Observations on seals at Montague Island, New South Wales. *Australian Mammalogy* 23,1-7.

Shaughnessy, P. D., Kirkwood, R., Cawthorn, M., Kemper, C., and Pemberton, D. (2003). Pinnipeds, cetaceans and fisheries in Australia: A review of operational interactions. In *Marine Mammals: Fisheries, Tourism and Management Issues* (eds. Gales, N., Hindell, M., and Kirkwood, R.) pp. 136-152. CSIRO Publishing, Melbourne.

Shepherd, P. C. F., and Sherman Boates, J. (1999). Effects of a commercial baitworm harvest on semipalmated sandpipers and their prey in the Bay of Fundy Hemispheric Shorebird Reserve. *Conservation Biology* 13,347-356.

Sherman, K., Jones, C., Sullivan, L., Smith, W., Berrien, P., and Ejsymonmt, L. (1981). Congruent shifts in sand eel abundance in western and eastern North Atlantic ecosystems. *Nature*

291,486-489.

Shoop, C. R., and Ruckdeschel, C. (1982). Increasing turtle strandings in Southeast United States: a complicating factor. *Biological Conservation* 23,213-215.

Silvani, L., Gazo, M., and Aguilar, A. (1999). Spanish driftnet fishing and incidental catches in the western Mediterranean. *Biological Conservation* 90,79-85.

Simmonds, M., Dolman, S., and Weilgart, L. (2004). *Oceans of Noise*. A WDCS science report. Whale and Dolphin Conservation Society, Wiltshire.

Skilleter, G. A. (2004). *Assessment of the Impacts Associated with the Harvesting of Marine Benthic Invertebrates for Use as Bait by Recreational Anglers*. University of Queensland, Marine and Estuarine Ecology Unit, Brisbane.

Skillman, R. A., and Balazs, G. H. (1992). Leatherback turtle captured by ingestion of squid bait on swordfish longline. *Fishery Bulletin* 90,807-808.

Skira, I. (1996). Aboriginal people and muttonbirding in Tasmania. In *Sustainable Use of Wildlife by Aboriginal Peoples and Torres Strait Islanders* (eds. Bomford, M. and Caughley, J.) pp. 166-175. Australian Government Publishing Service, Canberra.

Slater, J. (1991a). *Flotsam and Jetsam. Marine Debris Bulletin 1. Beach Survey Results January 1990 - June 1991*. Tasmanian Department of Parks, Wildlife and Heritage, Hobart.

Slater, J. (1991b). Leopard seal entanglement in Tasmania, Australia. *Marine Mammal Science* 7,323.

Smith, P. (1991). *The biology and management of Waders (Suborder Charadrii) in NSW*. NSW National Parks and Wildlife Service, Hurstville, NSW.

Smith, P. J. (2001). *Review of the Conservation Status of Marine Mammal Species in NSW*. A report to the NSW Scientific Committee, NSW National Parks and Wildlife Service, Hurstville NSW.

Springer, A. M., Roseneau, D. G., Lloyd, D. S., McRoy, C. P., and Murphy, E. C. (1986). Seabird responses to fluctuating prey availability in the eastern Bering Sea. *Marine Ecology Progress Series* 32,1-12.

Stempniewicz, L., Martyniak, A., Borowski, W., and Goc, M. (2003). Fish stocks, commercial fishing and cormorant predation in the Vistula Lagoon, Poland. In *Interactions Between Fish and Birds: Implications for Management* (ed. Cowx, I. G.) pp. 51-64. Blackwell Publishing, Oxford.

Stewart, B. S., and Yochem, P. K. (1987). Entanglement of pinnipeds in synthetic debris and fishing net and line fragments at San Nicolas and San Miguel Islands, California, 1978-1986. *Marine Pollution Bulletin* 18,336-339.

Stewart, J., and Ferrell, D. J. (2001). *Mesh Selectivity in the NSW Demersal Trap Fishery*. FRDC Project No. 98/138. NSW Fisheries Final Report Series No. 35. NSW Fisheries, Cronulla.

Stone, H. H., and Dixon, L. K. (2001). A comparison of catches of swordfish, *Ziphias gladius*, and other pelagic species from Canadian longline gear configured with alternating monofilament and multifilament nylon gangions. *Fishery Bulletin* 99,210-216.

Takekawa, J. E., Carter, H. R., and Harvey, T. E. (1990). Decline of common murre in central California, 1980-1986. *Studies in Avian Biology* 14,149-163.

Tarvey, L. (1993). First nesting records for the leatherback turtle *Dermochelys coriacea* in northern New South Wales Australia, and field management of nest sites. In *Herpetology in Australia: A Diverse Discipline* (eds. Lunney, D. and Ayres, D.) pp. 233-237. Surrey Beatty and Sons, Chipping Norton.

Tasker, M. L., Camphuysen, C. J., Cooper, J., Garthe, S., Montevecchi, W. A., and Blaber, S. J. M. (2000). The impacts of fishing on marine birds. *ICES Journal of Marine Science* 57,531-547.

Temby, I. (1998). *Problems Caused by the Australian Fur Seal*. Flora and Fauna Notes, Series no. FF0101. Department of Natural Resources and Environment, Victoria.

The Associated Press (2004). Giant sperm whales pluck god from fishing lines. www.cnn.com, 16/02/04.

The Ecology Lab (2005). *Abalone Fishery - Environmental Impact Statement. Public Consultation Document.* The Ecology Lab (on behalf of NSW Department of Primary Industries and Shareholders of the NSW Commercial Abalone Fishery), Sydney.

Thomas, K., Kvitek, R. G., and Bretz, C. (2003). Effects of human activity on the foraging behaviour of sanderlings *Calidris alba*. *Biological Conservation* 109,67-71.

Thompson, K. R. (1991). Quantitative analysis of the use of discards from squid trawlers by Black-browed Albatrosses *Diomedea melanophris* in the vicinity of the Falkland Islands. *Ibis* 134,11-21.

Threatened Species Scientific Committee (2003). Commonwealth listing advice for injury and fatality to vertebrate marine life caused by ingestion of or entanglement in harmful marine debris. 8 pp.

Tilzey, R. (2001). *Seal Bycatch Mitigation in the Blue Grenadier Fishery off West Tasmania in Winter 2000*. Report to the Australian Fisheries Management Authority and Environment Australia. Bureau of Rural Sciences Australia, Canberra.

Tomás, J., Guitart, R., Mateo, R., and Raga, J. A. (2002). Marine debris ingestion in loggerhead sea turtles, *Caretta caretta*, from the Western Mediterranean. *Marine Pollution Bulletin* 44,211-216.

Tomkins, R. J. (1985). Reproduction and mortality of wandering albatrosses on Macquarie Island. *Emu* 85,40-42.

Tregenza, N. J. C. (2000). Fishing and cetacean by-catches. In *Effects of Fishing on Non-Target Species and Habitats* (eds. Kaiser, M. J. and de Groot, S. J.) pp. 269-280. Blackwell Science, London.

Trites, A. W., Christensen, V., and Pauly, D. (1997). Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *Journal of Northwest Atlantic Fisheries Science* 22,173-187.

Vader, W. R. T., Barrett, R. T., Ericstad, K. E., and Strann, K. B. (1990). Differential responses of Common and Thick-billed Murres to a crash in the capelin stock in the southern Baerents Sea. *Studies in Avian Biology* 14,175-180.

Valeiras, J. (2003). Attendance of scavenging seabirds at trawler discards off Galicia, Spain. *Scientia Marina* 67,77-82.

Van Waerebeek, K., Van Bressem, M., Félix, F., Alfaro-Shigueto, J., García-Godos, A., Cháves-Lisambart, L., Ontón, K., Montes, D., and Bello, R. (1997). Mortality of dolphins and porpoises in coastal fisheries off Peru and southern Ecuador in 1994. *Biological Conservation* 81,43-49.

Vines, G. (1992). Florida shorebird forced to flee. *New Scientist* 135,14.

Votier, S. C., Furness, R. W., Bearhop, S., Crane, J. E., Caldow, R. W. G., Catry, P., Ensor, K., Hamer, K. C., Hudson, A. V., Kalmbach, E., Klomp, N. I., Phillips, R. A., Prieto, I., and Thompson, D. R. (2004). Changes in fisheries discard rates and seabird communities. *Nature* 427,727-730.

Walter, U., and Becker, P. H. (1997). Occurrence and consumption of seabirds scavenging on shrimp trawler discards in the Wadden Sea. *ICES Journal of Marine Science* 54,684-694.

Waples, K. (2005). NSW contribution to *'Australia. Progress report on cetacean research, January 2004 to December 2004, with statistical data for the calendar year 2004*'. NSW Department of Environment and Conservation, Hurstville.

Ward, T. M. (1996a). Sea snake by-catch of prawn trawlers on the northern Australian continental shelf. *Marine and Freshwater Research* 47,631-635.

Ward, T. M. (1996b). Sea snake by-catch of fish trawlers on the northern Australian continental shelf. *Marine and Freshwater Research* 47,625-630.

Ward, T. M. (2000). Factors affecting the catch rates and relative abundance of sea snakes in the by-catch of trawlers targeting tiger and endeavour prawns on the northern Australian continental shelf. *Marine and Freshwater Research* 51,155-164.

Warneke, R. M. (1975). Dispersal and mortality of juvenile fur seals *Arctocephalus pusillus doriferus* in Bass Strait, southeastern Australia. *Rapports et Procès-Verbaux des Réunions Conseil International pour l'Exploration de la Mar* 169,296-302.

Wassenberg, T. J., and Hill, B. J. (1990). Partitioning of material discarded from prawn trawlers in Moreton Bay. *Australian Journal of Marine and Freshwater Research* 41,27-36.

Wassenberg, T. J., Salini, J. P., Heatwole, H., and Kerr, J. D. (1994). Incidental capture of sea-snakes (Hydrophiidae) by prawn trawlers in the Gulf of Carpentaria, Australia. *Australian Journal of Marine and Freshwater Research* 45,429-443.

Wassenberg, T. J., Milton, D. A., and Burridge, C. Y. (2001). Survival rates of sea snakes caught by demersal trawlers in northern and eastern Australia. *Biological Conservation* 100,271-280.

Weimerskirch, H., and Jouventin, P. (1987). Population dynamics of the wandering albatross, *Diomedea exulans*, of the Crozet Islands: causes and consequences of the population decline. *Oikos* 49,315-322.

Wells, R. S., and Scott, M. D. (1997). Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. *Marine Mammal Science* 13,475-480.

Wells, R. S., Hofman, S., and Moors, T. L. (1998). Entanglement and mortality of bottlenose dolphins, *Tursiops truncatus,* in recreational fishing gear. *Fishery Bulletin* 96,647-650.

Weston, M. A. (2000). *The Effect of Disturbance on the Breeding Biology of Hooded Plovers*. Thesis. University of Melbourne, Melbourne, Victoria.

Wetherall, J. A., Balazs, G. H., Tokunaga, R. A., and Yong, M. Y. Y. (1993). Bycatch of marine turtles in North Pacific high-seas driftnet fisheries and impacts on the stocks. *North Pacific Commission* 53,519-538.

Whale and Dolphin Conservation Society (2003a). Species distribution and threats - Blainville's beaked whale. www.wdcs.org, 15/5/03.

Whale and Dolphin Conservation Society (2003b). Species distribution and threats - dwarf sperm whale. www.wdcs.org, 15/5/03.

Whale and Dolphin Conservation Society. (2003c). Species distribution and threats - pygmy killer whale. www.wdcs.org, 15/5/03.

Whale and Dolphin Conservation Society (2003d). Species distribution and threats - Cuvier's beaked whale. www.wdcs.org, 15/5/03.

White, M. (2002). Observation of accidental capture of a loggerhead turtle by hand-line fishing in Kefalonia, Greece. *Marine Turtle Newsletter* 98,8.

Whiting, S. D. (1998). Types and sources of marine debris in Fog Bay, northern Australia. *Marine Pollution Bulletin* 36,904-910.

Wickens, P. A. (1996). Fur seals and lobster fishing in South Africa. *Aquatic Conservation: Marine and Freshwater Ecosystems* 6,179-186.

Wickens, P. A., and Sims, P. F. (1994). Trawling operations and South African (Cape) fur seals, *Arctocephalus pusillus pusillus*. *Coastal Management* 56,1-12.

Wickens, P. A., Japp, D. W., Shelton, P. A., Kriel, F., Goosen, P. C., Rose, B., Augustyn, C. J., Bross, C. A. R., Penney, A. J., and Krohn, R. G. (1992). Seals and fisheries in South Africa - competition and conflict. *South African Journal of Marine Science* 12,773-789.

Wienecke, B., and Robertson, G. (2002). Seabird and seal - fisheries interactions in the Australian Patagonian toothfish *Dissostichus eleginoides* trawl fishery. *Fisheries Research* 54,253-265.

Williams, T. M., Friedl, W. A., Fong, M. L., Yamada, R. M., Sedivy, P., and Haun, J. E. (1992). Travel at low energetic cost by swimming and wave-riding bottlenose dolphins. *Nature (London)* 355,821-823.

Witzell, W. N. (1984). The incidental capture of sea turtles in the Atlantic U.S. fishery conservation zone by the Japanese tuna longline fleet, 1978-91. *Marine Fisheries Review* 46,56-58.

Witzell, W. N. (1999). Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. *Fishery Bulletin* 97,200-211.

Wolter, C., and Pawlizki, R. (2003). Seasonal and spatial variation in cormorant predation in a lowland floodplain river. In *Interactions Between Fish and Birds: Implications for Management* (ed. Cowx, I. G.) pp. 178-186. Blackwell Publishing, Oxford.

Wood, K. A. (1989). Seasonal abundance, marine habitats and behaviour of skuas off central New South Wales. *Corella* 13,97-103.

Wood, K. A. (1990). Seasonal abundance and marine habitats of *Procellaria* fulmarine and gadfly petrels off central New South Wales. *Notornis* 37,81-105.

Wood, K. A. (1992). Seasonal abundance and spatial distribution of albatrosses off central New South Wales. *Australian Bird Watcher* 14,207-225.

World Resources Institute (1990). *World Resources 1990-91*. World Resources Institute in collaboration with the United Nations Environment Program and the United Nations Development Program. Oxford University Press, Oxford.

Wright, S. D., Ackermen, B. B., Bonde, R. K., Beck, C. A., and Banowetz, D. J. (1995). Analysis of watercraft-related mortality of manatees in Florida, 1979-1991. In *Population Biology of the Florida Manatee* (eds. O'Shea, T. J., Ackerman, B. B., and Percival, H. F.) National Biological Service, Information and Technology Report 1.

Yano, K., and Dalheim, M. E. (1995). Killer whale, *Orcinus orca*, depredation on longline catches of bottomfish in the southeastern Bering Sea and adjacent waters. *Fishery Bulletin* 93,355-372.

APPENDICES

APPENDIX 1: Descriptions of the gear types used by some fisheries managed by NSW DPI.

TABLE A: THE USE OF PERMITTED GEAR TYPES IN THE ESTUARY GENERAL FISHERY.

The information in this table mostly originates from the Environmental Impact Statement for this fishery (NSW Fisheries 2001).

Gear type	Gear details
Traps	
Fish trap *Used to mainly catch yellowfin bream, blue swimmer crab, silver trevally*	Gear dimensions: Wire mesh of no less than 50 mm supported by a timber frame, maximum dimensions for which are 2 m long, 1.5 m wide and 1 m high. Tapered funnel trap entrance. Rope and float attached to trap; Method of use: Baited traps set on estuary bed and generally checked daily or every two to three days; Estuaries in which gear permitted: Allowed in all estuaries, except those closed to trapping activity, Arrawarra and Berrara Creeks.
Crab trap *Used to mainly catch mud crab*	Gear dimensions: Wire mesh of no less than 50 mm supported by a solid frame, maximum dimensions for which are 1.2 m long, 1 m wide (or a diameter of no more than 1.6 m if trap is round) and 0.5 m high with four or less entrance funnels. Rope and float attached to trap; Method of use: Baited traps are set generally in the middle to lower estuarine reaches on the estuary bed, particularly around mangrove areas, and are generally checked daily or every two to three days; Estuaries in which gear permitted: Allowed in all estuaries, except those closed to trapping activity, Arrawarra and Berrara Creeks.
Eel trap *Used to mainly catch longfinned eel and shortfinned eel*	Gear dimensions: Wire mesh between 20 mm and 40 mm supported by a frame (either solid or collapsible), maximum dimensions for which are either 2 m long, 0.5 m wide and 0.5 m high or 1 m long, 1 m wide and 0.5 m high, tapered entrance funnel must not be > 100 mm in diameter. Soft mesh cod-end attached to rear of trap. Rope and float attached to trap; Method of use: Baited traps set throughout estuaries and generally checked daily or every two to three days; Estuaries in which gear permitted: Allowed in all estuaries, except those closed to trapping activity, Arrawarra and Berrara Creeks.
Meshing nets	
Meshing net *Used to mainly catch sea mullet, luderick, bream, flathead, blue swimmer crab*	Gear dimensions: Mesh size of up to 95 mm secured between a buoyant headline on the top and a weighted footline on the bottom, maximum length of net 725 m; Method of use: One end of the net is secured to the shoreline or attached to a float and anchor in water away from the shore. From there the net is set from a small travelling boat and the opposite end is secured to a float and anchor line. Net can either be set and left in the water for a period of time between sunset and sunrise only, or placed into the water where splashing is used to lead fish into the net before it is immediately retrieved. Nets can be set either near the surface of the water or bed of the estuary; Estuaries in which gear permitted: Allowed in 48 estuaries.
Flathead net *Used to mainly catch dusky flathead*	Gear dimensions: Mesh size of up to 80 mm secured between a buoyant headline on the top and a weighted footline on the bottom; Method of use: Net is set in a similar way to a meshing net; Estuaries in which gear permitted: Allowed in Wallis Lake, Smiths Lake, Tuggerah Lakes and Lake Illawarra only.

Table A – continued

Gear type	Gear details
Hoop or lift net *Used to mainly catch blue swimmer crab, mud crab*	Gear dimensions: Generally one (and no more than two) hoops or rings no greater than 1.25m in diameter, attached net with < 13 mm mesh size must not extend > 1m from the hoop(s); Method of use: Either hoop(s) set on seabed with baited net being held away by a float or net held open by baited hoop on seabed, catch is entangled when net is lifted. Nets generally checked daily or sometimes more than once a day; Estuaries in which gear permitted: Allowed in 68 estuaries.
Fish hauling net	
General purpose hauling net *Used to mainly catch mullet, bream, tarwhine, silver biddy*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. Overall maximum length generally 375 m, although 500 m allowed in some larger estuaries, specific size and mesh restrictions on the various parts of the net apply; Method of use: With one end of the net or hauling line attached to a fixed point the net is shot from a boat that continuously travels in a circular direction back to the starting point. Net is then immediately retrieved to shore or boat by hand or a motorised line hauler. Net > 500 m can only be hauled once a day by each hauling crew. Estuaries in which gear permitted: Allowed in 39 estuaries.
Pilchard, anchovy and bait net *Used to mainly catch anchovy, whitebait*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. Overall maximum length of 250 m, specific size and mesh restrictions on the various parts of the net apply; Method of use: With one end of the net or hauling line attached to a fixed point the net is shot out from a boat that continuously travels in a circular direction back to the starting point. Net is then immediately retrieved to shore or boat by hand or a motorised line hauler; Estuaries in which gear permitted: Allowed in Hawkesbury River, Pittwater and Sydney Harbour only.
Trumpeter whiting net *Used to mainly catch trumpeter whiting*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. Overall maximum length of 275 m, specific size and mesh restrictions on the various parts of the net apply; Method of use: With one end of the net or hauling line attached to a fixed point the net is shot out from a boat that continuously travels in a circular direction back to the starting point. Net is then immediately retrieved to shore or boat by hand or a motorised line hauler. Net is negatively buoyant maintains contact with the bed of the estuary when set; Estuaries in which gear permitted: Allowed in parts of Port Stephens only.
Garfish hauling net *Used to mainly catch sea garfish and river garfish*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. No maximum length applicable, mesh between 28 mm and 36 mm; Method of use: With one end of the net or hauling line attached to a fixed point the net is shot out from a boat that continuously travels in a circular direction back to the starting point. Net is then immediately retrieved to shore or boat by hand or a motorised line hauler. Net is positively buoyant and set close to the surface of the water; Estuaries in which gear permitted: Allowed in Port Stephens, Sydney Harbour, Broken Bay and Jervis Bay only.

Table A – continued

Gear type	Gear details
Garfish bullringing net *Used to mainly catch river garfish*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom and sits vertically in the water, close to the surface. Maximum length of 275 mm with 25 m hauling lines, mesh between 28 mm and 36 mm; Method of use: With one end of the net secured to a fixed point (with headline attached to a float and footline attached to an anchor), it is then shot in a circular motion until the school of fish is encircled from where it is retrieved. Net is positively buoyant and set close to the surface of the water; Estuaries in which gear permitted: Allowed in 45 estuaries.
Prawn nets	
Prawn hauling net *Used to mainly catch school prawn*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. Maximum length of net is 40 m with mesh between 30 mm and 36 mm, maximum length of hauling line is 130 m; Method of use: With one end of the net or hauling line attached to a fixed point the net is shot out from a boat that continuously travels in a circular direction back to the starting point. Net is then immediately retrieved to shore or boat by hand or a motorised line hauler. Used throughout upper and lower reaches of estuaries; Estuaries in which gear permitted: Allowed in 48 estuaries.
Prawn seine net *Used to mainly catch greasyback prawn, school prawn*	Gear dimensions: Net secured between a buoyant headline on the top and a weighted footline on the bottom, has attached hauling lines and sits vertically in the water. Maximum length of 140 m with mesh between 30 mm and 36 mm; Method of use: With a float attached to one end of a hauling line, a boat is used to employ the net in a teardrop shape until the ends of both hauling lines can be attached to the boat. The hauling lines are then towed close to the net before the lines and net are hauled onto the boat. The fishers in Wallis Lake can use additional 'clover leafing' techniques. This can involve re-opening the net once closed to remove prawns while the net and hauling lines remain in the water. Another 'clover leafing' method involves conducting a number of sets and tows before the catch is removed from the water. Prawn seine nets are negatively buoyant and maintain contact with the bed of the estuary when set. Estuaries in which gear permitted: Allowed in Macleay River, Camden Haven River, Wallis Lake, Smiths Lake, Tuggerah Lakes and Lake Illawarra only.
Prawn set pocket net *Used to mainly catch school prawn, eastern king prawn*	Gear dimensions: Net consists of a tapered conical shape funnel of mesh that ends in a cod-end. No hauling lines are attached. Headline length varies throughout different estuaries between 5 m to 63 m, mesh between 30 mm to 36 mm; Method of use: The net is staked in estuaries, where the movement of water, leads the prawns into the cod-end until the net is landed onto a boat and catch removed. Net is usually set for the period of the outgoing tide and must not be left unattended. Net can be set along the estuary bed or near the water surface. In the Clarence River, fishers can use the propeller of a moored boat to assist water motion through the net; Estuaries in which gear permitted: Allowed in Clarence River, Lake Cathie, Camden Haven River, Wallis Lake, Smiths Lake, Myall River, Tuggerah Lakes and Lake Illawarra only.

Table A – continued

Gear type	Gear details
Prawn running net *Used to mainly catch eastern king prawn, school prawn*	Gear dimensions: Net secured between a buoyant headline on the top and a weighted footline on the bottom and sits vertically in the water when set. Maximum length either 75 m or 140 m (estuary dependent), mesh between 25 mm to 36 mm; Method of use: Net is staked and shot from a boat at an angle across water that has a current or tide running through it. Prawns run along the up current side of the net until its end where the catch is hauled onto a boat. When the net reaches the other side of a channel, it can be retrieved onto the shore where the other end of the net is attached; Estuaries in which gear permitted: Allowed in Tuggerah Lakes, Lake Illawarra, Lake Wollumboola, Swan Lake, Durras Lake, Coila Lake, Lake Brou, Corunna Lake, Tilba Tilba Lake, Wallaga Lake, Cuttagee Lake and Middle Lake only.
Hand-hauled prawn net *Used to mainly catch school prawn*	Gear dimensions: Maximum length of 6 m, mesh size between 30 mm and 36 mm. Net held open by a weighted footline, buoyant headline and staked ends; Method of use: Two people on either side of the net pull it through the water, only used in relatively shallow water; Estuaries in which gear permitted: Allowed in 78 estuaries.
Push or scissor prawn net *Used to mainly catch school prawn*	Gear dimensions: Net up to 2.75 m long with 30 mm to 36 mm mesh attached to a scissor shaped frame; Method of use: One person pushes the net through the water ensuring it maintains contact with seabed; Estuaries in which gear permitted: Allowed in 74 estuaries.
Other methods	
Handgathering *Used to mainly catch pipi, beachworm*	Gear dimensions: Fish taken by hand with the assistance of a pump (up to 85 mm in diameter), tube (up to 250 mm long and 85 mm in diameter), single long thin blade knife, spade or fork and pliers; Method of use: Collection of individual animals by hand on ocean beaches, estuarine shores or while diving in estuaries; Estuaries in which gear permitted: Allowed in all estuaries and ocean beaches not closed to the activity.
Handlining *Used to mainly catch mulloway, hairtail*	Gear dimensions: Fishing line on a spool or rod and reel, up to ten set lines with no more than six hooks on each line allowed; Method of use: Lines are cast from the shore or vessels (both moving or anchored) and are fished conventionally; Estuaries in which gear permitted: Allowed in all estuaries.

Otter trawl net restrictions in the Estuary Prawn Trawl Fishery: The mesh size of the net must be 40-60 mm and that of the codend 40-50 mm. The maximum headline length must not exceed 11 m or 7.5 m if twin gear is used on the Clarence River. Although two nets may be towed at once in Broken Bay and Port Jackson almost all vessels in these estuaries use only one net. Most trawlers in the Clarence River tow two nets at once.

TABLE B: THE USE OF PERMITTED GEAR TYPES IN THE OCEAN HAULING FISHERY.

The information in this table mostly originates from the Environmental Impact Statement for this fishery (NSW Fisheries 2002).

Gear type	Gear details
Hauling nets	
General purpose hauling net *Used to target sea mullet, blue mackerel, yellowfin bream, sand whiting, Australian salmon, luderick, dart*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. Minimum mesh restrictions of 50 mm in the bunt and 80 mm in the wings of the net. Different mesh size restrictions apply from 1 March to 31 July and maximum length of net at this time must not exceed 400 m. Different dimension restrictions apply to the gear type when used in Jervis Bay; Method of use: The net is shot from the stern of a small boat, which continuously travels away from the beach, then returns in a semi-circle back to the beach. The net is then immediately retrieved onto the beach or shallow water in a continuous operation by hand or with a motorised line hauler; Where used: Ocean waters and sea beaches.
Pilchard, anchovy and bait net *Used to target blue mackerel, yellowtail, pilchard, sandy sprat, anchovy*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. Overall maximum length of 300 m, minimum mesh size 13 mm; Method of use: With one end of the net or hauling line attached to a fixed point the net is shot out from a boat that continuously travels in a circular direction back to the starting point. Net is then immediately retrieved to shore or a stationary boat by hand or a motorised line hauler; Where used: Ocean waters and sea beaches.
Garfish hauling net *Used to target sea garfish*	Gear dimensions: Mesh secured between a buoyant headline on the top and a weighted footline on the bottom, net consists of a codend, bunt and wings, with long hauling ropes attached. Overall maximum length of 300 m, minimum mesh size between 28 mm and 85 mm; Method of use: With one end of the net or hauling line attached to a fixed point the net is shot out from a boat that continuously travels in a circular direction back to the starting point. Net is then immediately retrieved to shore or a stationary boat by hand or a motorised line hauler. Net is positively buoyant and set close to the surface of the water; Where used: Ocean waters and sea beaches.
Other methods	
Purse-seine net *Used to target blue mackerel, yellowtail, pilchard, Australian salmon, jack mackerel, anchovy, bonito, silver trevally, sweep*	Gear dimensions: A wall of netting is hung between a buoyant floatline on the top and a weighted leadline on the bottom. Rings are hung from the leadline every five to eight metres. A purseline (rope) passes through these rings. Maximum length of net 1000 m, maximum mesh size 150 mm. Different dimension restrictions apply to the gear type when used in Jervis Bay and Twofold Bay; Method of use: The net is shot from a boat that continuously travels in a circular direction around a school of fish. The net is secured underneath the school when the rings are pulled together by the purseline. The net is then immediately hauled back onto the boat; Where used: Ocean waters.
Lift net *Used to target bait for tuna fishing, including pilchard, blue mackerel, yellowtail*	Gear dimensions: Netting no longer than 15 m is suspended from a rigid frame no greater than 15 m wide. Permitted mesh size is between 13 mm and 25 mm; Method of use: The net is submerged below the vessel. Fish are attracted to the area using light and/or burly. Once sufficient baitfish have been attracted to the area immediately above the net, it is raised and the fish removed from the net; Where used: Ocean waters.

TABLE C: THE NET TYPES PERMITTED IN THE OCEAN TRAWL FISHERY.

The information in this table mostly originates from the Environmental Impact Statement for this fishery (NSW DPI 2004).

Gear type	Gear details
Otter trawl net (Prawns)	Mesh size between 40-60 mm, except for codend mesh size here 40-50 mm. Headline of net must not exceed 33 m, except in the offshore prawn trawl nets where it can range from 33 – 60 m. Sweep length must not exceed 5 m. 'Triple gear' where three nets are towed side by side are used almost universally to trawl for prawns in this fishery.
Otter trawl net (Fish)	Maximum mesh size of 90 mm throughout net. Headline and sweep length are not specified. Sweeps are generally much longer than those used on prawn trawl nets. South of a line drawn east from Seal Rocks, bobbin gear may be used on the ground rope of the net.
Danish seine net (Fish)	Maximum mesh size of 83 mm throughout net. Headline length not specified. Otter boards or sweeps are not used on this net, long lengths of rope are attached to the net by short bridles. The gear is set in a large triangular shape on the bottom and the ropes are slowly retrieved, closing the gear and herding the fish into the path of the net.

TABLE D: THE GEAR TYPES PERMITTED IN THE OCEAN TRAP AND LINE FISHERY.

The information in this table mostly originates from the Environmental Impact Statement for this fishery (NSW DPI *In Prep*.).

Gear type	Gear details
Fish trap (bottom / demersal) *Used to target species such as snapper, silver trevally, rubberlip morwong, bream and leatherjacket*	Gear dimensions: Wire mesh of no less than 50 mm supported by a timber frame, maximum dimensions for which are 2 m x 2 m x 2 m, although most traps used in the fishery measure 2 m x 1 m x 1 m. Wire funnel entrances. Rope and marker float attached to trap; Method of use: Baited traps are set on the seabed adjacent to reefs at 10 – 150 m depth. Traps must be set >5 m apart, and are usually checked each day. A maximum of 30 traps can be used at any one time.
Spanner crab net ('dillies') *Used to target spanner crab*	Gear dimensions: Flat rectangular steel frame 1.6 m x 1 m with a net over it that does not extend >0.1 m beneath the frame when held horizontally. The draft management strategy for this fishery will propose to increase the maximum area of this net to 1.6 m^2. Multiple crab nets are often set along one line. Rope, marker float and flag attached to trap; Method of use: Baited traps are left for about an hour before being lifted by a line hauler into the boat. Multiple crab nets are often set along one line. Maximum of 20 nets set at once or carried on a vessel by one fisher, 30 nets if a crew member is also fishing.
Line methods – The use of on-board automatic baiting machines is prohibited in this fishery. *The regulations set out controls on the number of lines and hooks used in commercial line methods within 3nm of the NSW coast. Beyond 3nm, there are currently no limits on the number of hooks or lines that can be used for commercial purposes. However, the draft management strategy for this fishery proposes to restrict each endorsement holder operating beyond 3 nm to using a maximum of 1000 hooks at a time.*	
Setline / trotline *Setlines are used to target snapper and wobbegong shark* *Trotlines are used to target redfish, blue-eye, hapuku, ocean perch, wobbegong shark, school shark and gummy shark*	Gear dimensions: These lines are set horizontally either attached to a row of floated lines and suspended below the waters surface, or weighted to the seabed with a series of weights, mooring rope and buoy attached to one end of the line. Hooks are attached to the main line by snoods (shorter lines). The draft management strategy for this fishery will propose to make the use of circular hooks mandatory on setlines; Method of use: These freestanding lines are baited and set from fishing vessels. These lines are set in demersal waters in this fishery. The setting of setlines near the waters surface is managed by the Commonwealth and does not form part of this fishery. A maximum of 10 set lines with 6 hooks on each line within 3 nm is allowed to be used at any one time (except when shark fishing south of Moruya when hooks of size 9/0 or greater are being used).
Driftline *Used to target spotted mackerel, snapper, kingfish and sharks.*	Gear dimensions: A baited hook or gang of hooks suspended by line from a single float or buoy that drifts freely on the ocean surface. A maximum of 30 driftlines with one hook attached, or 1 gang of no more than 5 hooks can be used at a time. Each line must not be attached to another driftline or other object that prevents it from floating freely; Method of use: These lines are baited and set from vessels where they are left to drift in pelagic (surface) waters, generally in currents, for a relatively short period of time before being gathered by fishers. Fishers do not continually attend these freestanding lines once set.

Table D – continued

Gear type	Gear details
Handline *Used to target species such as kingfish, mulloway and bonito*	Gear dimensions: Single lines with hooks or gangs of hooks lowered into the water by a rod or by hand; Method of use: Lines are cast from the shore or vessels (both moving or anchored), are attended by fishers and fished conventionally. Hooks are usually baited and fishers may also use burley.
Dropline *Used to target species such as blue-eye, hapuku, yellowtail kingfish, snapper and ocean and orange perch.*	Gear dimensions: Vertically set lines with hooks attached by approx. 50-150 snoods (shorter lines). A marker float is attached to the top of the line and a weight to the bottom; Method of use: Mostly used in deepwater areas (>183 m deep) generally adjacent to offshore drop-offs and submarine canyons. Lines are baited and set from fishing vessels. They are generally left to fish for a few hours before being hauled in again by fishers. Fishers do not continually attend these freestanding lines once set.
Trolling *Used to target yellowtail kingfish, mackerel, bonito and tuna*	Gear dimensions: A line is used to tow lures or baited hooks behind a moving vessel. The line is sometimes weighted to target fish lower down in the water column; Method of use: The bait or lure is pulled through pelagic (surface) waters on lines that are attached to a moving vessel. Fishers continually attend these lines during fishing.
Jigging *Used to target species such as kingfish and bonito*	Gear dimensions: A line with a large weighted lure; Method of use: This line is manually jigged from a vessel whilst drifting or anchored. There is no limit on the depth at which these lines can be jigged. Fishers continually attend these lines during fishing.
Poling *Used to target species such as tuna and bonito*	Gear dimensions: Hooks or lures are attached to lines on the end of poles. Lines can be attached to single or double poles; Method of use: These baited hooks or lures are manually lowered into a feeding school of fish usually in pelagic (surface) waters and the hooked fish are then lifted into the boat. Fishers usually use a chum of live bait to attract and aggregate their catch. Fishers continually attend these lines during fishing. A maximum of 6 single or 3 double poles are allowed in use at a time.

TABLE E: GEAR TYPES PERMITTED IN THE NSW RECREATIONAL FISHERY (saltwater and estuarine areas only).

The information in this table mostly originates from the NSW Recreational Saltwater Fishing Guide 2003-2004 (NSW Fisheries 2003).

Gear type	Gear details
Line fishing	
Fishing line gear *Used to catch fish*	Gear dimensions: No more than three gangs of hooks, with no more than five hooks per gang, can be attached to a fishing line. When hang jigging, one line can have six single hooks with a lure attached. Lures are regarded as hooks, no more than three treble hooks can be attached to these; Method of use: Baited lines or lines with lures must be held or fixed to a boat or the shore. Drift lines are banned. Each fisher can set a maximum of four rods or lines at any time. Attempting to hook a fish anywhere other than the mouth is illegal.
Passive traps	
Bait trap *Generally used to catch small fish for live bait*	Gear dimensions: Cylindrical shaped traps a maximum 350 mm in diameter and 450 mm long, entrance funnel no bigger than 60 mm; Method of use: Only one trap can be used at any one time.
Crab trap *Used to catch crab*	Gear dimensions: Rectangular trap 1.2 m long x 1 m wide x 0.5 m deep or a circular trap with a diameter not exceeding 1.6 m at the bottom or top. Minimum mesh size 50 mm. Maximum of four entrances. Buoy and rope attached; Method of use: Each fisher can only use (or have in possession) one net at any one time. Not allowed in ocean waters. Trap is left in the water unattended for a considerable length of time.
Lobster trap *Used to catch lobster*	Gear dimensions: Trap base can be rectangular (not exceeding 1.2 m x 1.2 m) or circular (diameter not exceeding 1.2 m). Must be fitted with one or two escape gaps. Buoy and rope attached; Method of use: Each fisher can only use (or have in possession) one net at any one time. Must be used in waters less than 10 m deep. Trap is left in the water unattended for a considerable length of time.
Active traps	
Hoop net *Used to catch crab*	Gear dimensions: Cylindrical shaped mesh nets held in shape with one or two hoops per net no greater than 1.25 m in diameter, maximum length 1 m. Mesh size not less than 13 mm; Method of use: Must be dropped and raised vertically through the water by hand. Not allowed in ocean waters. Each fisher can use (or have in possession) no more than five nets at any one time. This trap type is generally attended and set for a relatively short period of time.
Spanner crab net *Used to catch spanner crab only*	Gear dimensions: Flat rectangular steel frame 1.6 m x 1 m with a net attached to it that does not extend >0.1 m beneath the frame when held horizontally; Method of use: Must be dropped and raised vertically through the water by hand. Each fisher can only use (or have in possession) one net at any one time. Can only be used north of Korogoro Point (Hat Head). This trap type is generally attended and set for a relatively short period of time.

Table E – continued

Gear type	Gear details
Nets	
Hand-hauled prawn net *Used to catch prawns*	Gear dimensions: Rectangular length of net (maximum length 6 m, mesh size 30-36 mm). Floatline and leadline attached; Method of use: Must be pulled through water continuously and manually. Cannot be attached to a hauling line, another net or be staked or set.
Scissors (push) net *Used to catch prawns*	Gear dimensions: Cone shaped net attached to a scissors-type frame. Length of bottom line between poles must no be longer than 2.75 m. Mesh size between 30-36 mm; Method of use: Must be pulled through water continuously and manually. Cannot be attached to a hauling line, another net or be staked or set. Each fisher can only use one net at a time.
Scoop net *Used to catch prawns*	Gear dimensions: A funnel shaped net (minimum mesh size of 20 mm, and length of drop no more than 1.25 m) attached to a hoop (maximum diameter 0.6 m) with a attached handle attached (maximum length 1.2 m); Method of use: Must be used by hand. Cannot be staked, set, joined or placed with any other net. Each fisher can only use one net at a time.
Other recreational fishing techniques	
Diving and spearfishing	Whilst on snorkel, fish can be caught with a spear or spear gun without the use of a light, lobsters and abalone can be taken by hand. Only scallops and sea urchins can be taken whilst scuba diving. Spear fishing is not permitted on ocean beaches (except the last 20 m at each end of the beach). All non-tidal waters are closed to spearfishing.
Collection of invertebrates from intertidal shores	Animals are generally gathered by hand. Specific tools are allowed in some circumstances. For example: a single bladed knife can be used to collect cockles from sand or mud areas; pliers can be used to catch beachworms; a yabby pump, upturned tin can, spade or fork can be used to gather nippers; only a single bladed knife can be used on rock platforms. Digging or the use of yabby pumps is not permitted in seagrass areas, mangroves or saltmarshes.

Bibliography

NSW Department of Primary Industries (DPI) (*In Prep*.). Environmental Impact Statement - Ocean Trap and Line Fishery (public consultation document). NSW Department of Primary Industries, Cronulla, Australia.

NSW Department of Primary Industries (DPI) (2004). Environmental Impact Statement - Ocean Trawl Fishery (public consultation document). NSW Department of Primary Industries, Cronulla, Australia.

NSW Fisheries (2003). NSW Recreational Saltwater Fishing Guide 2003/2004. NSW Fisheries, Australia.

NSW Fisheries (2002). Environmental Impact Statement - Ocean Hauling Fishery (public consultation document). NSW Fisheries, Cronulla, Australia.

NSW Fisheries (2001). Environmental Impact Statement - Estuary General Fishery (public consultation document). NSW Fisheries, Cronulla, Australia.

APPENDIX 2: Descriptions of the threatened species categories under each threatened species legislation.

Definitions of the status of threatened / protected species listed under the relevant NSW (*TSC Act 1995*; *NPW Act 1974*), Commonwealth (*EPBC Act 1999*) and International (IUCN Redlist 2004) threatened and protected species legislation are provided in the following:

**** Threatened Species Conservation (TSC) Act 1995***
'Endangered' The species is likely to become extinct in nature if threats continue, or its numbers are reduced to a critical level, or its habitat is reduced.
'Endangered population' The population has been reduced to such a critical level, or its habitat has been so drastically reduced, that it is in immediate danger of extinction. It will be geographically isolated and near the limit of the species' natural range, or will be genetically distinct, or will have some other conservation significance.
'Vulnerable' The species is likely to become endangered if threats continue.

**** National Parks and Wildlife (NPW) Act 1974***
'Protected' All native birds, reptiles, amphibians and mammals, except the dingo, are protected in NSW from harm under this legislation.

**** Environment Protection and Biodiversity Conservation (EPBC) Act 1999***
'Endangered' A native species is eligible to be included in this category at a particular time if, at that time, it is not critically endangered and it is facing a very high risk of extinction in the near future, as determined in accordance with the prescribed criteria.
'Vulnerable' A native species is eligible to be included in this category at a particular time if, at that time, it is not critically endangered or endangered and it is facing a high risk of extinction in the medium-term future, as determined in accordance with the prescribed criteria.
'Protected' All listed migratory species, listed marine species and cetaceans in Commonwealth waters and outside Australian waters are protected from harm under this legislation.

**** 2004 IUCN Redlist of Threatened Species***
'Critically Endangered' A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see www.redlist.org), and it is therefore considered to be facing an extremely high risk of extinction in the wild.
'Endangered' A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see www.redlist.org), and it is therefore considered to be facing a very high risk of extinction in the wild.
'Vulnerable' A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see www.redlist.org), and it is therefore considered to be facing a high risk of extinction in the wild.
'Lower risk, near threatened' A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
'Data deficient' A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between Data Deficient and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.
'Not in database' The species was not listed in this database of threatened species.

APPENDIX 3: Observations of the fishing activities managed by NSW DPI and any associated interactions with marine wildlife (June 2003 – June 2004).

These observations were conducted from fishing vessels during summer and winter in three zones:
Zone 1 – Clarence River to the Queensland border;
Zone 2 – Crowdy Head to Tuggerah Lakes; and
Zone 3 – Ulladulla to the Victorian border.

Fishing method: TRAWLING	
Description of observed effort:	Estuarine: During the summer of 2004, four observation trips of the Estuary Prawn Trawl Fishery were conducted (two in zone 1 on the Clarence River; two in zone 2 on the Hunter River). Trawling was conducted during daylight and was almost continuous, except for the short periods when the nets were hauled in and cleared. In all, nine trawl shots were observed on the Clarence River each shot lasting an average of 58.4 ± 7 mins, and eight trawl shots were observed on the Hunter River each shot lasting an average of 51.7 ± 21.7 mins. Oceanic: During the winter of 2003, one observation trip of the Ocean (prawn) Trawl Fishery was conducted in zone 1 off Yamba. During the summer of 2004, three observation trips of the Ocean (prawn) Trawl Fishery were conducted (two in zone 1 off Yamba and one in zone 2 off Forster). Trawling was conducted at night. Beyond the period of motoring to and from fishing sites, trawling was almost continuous, except for the short periods when the nets were hauled in and cleared. In all, three trawl shots were observed off Forster each shot lasting an average of 119.7 ± 5.0 mins, and nine trawl shots were observed off Yamba each shot lasting an average of 169.9 ± 31.4 mins.
Level of discarding:	Estuarine: The amount of bycatch observed captured and discarded was small on the Hunter River and small – medium on the Clarence River. Oceanic: A large amount of bycatch was captured and discarded in all observed oceanic prawn trawl shots.
Plastic use and disposal:	Beyond the synthetic trawling nets, no plastics were used or disposed of by the trawl fishers. A plastic bag that became caught up in an estuarine trawl net was kept on board.
Marine wildlife species observed around fishing vessels and their behaviour:	Estuarine: Birds were attracted to vessels as the nets were being pulled up. Very little foraging was observed during this process, sometimes a few birds (either little black and great cormorants, silver gulls or terns) attempted to feed from the net itself or the fish escaping from it. While the nets were emptied and cleaned they stopped actively foraging for a while and returned, in greater numbers when the bycatch was discarded. The species that foraged upon discards in both estuaries included the Australian pelican, silver gull, little black and great cormorants, and in the Clarence River only terns, pied and little pied cormorants. This foraging activity can be described as a 'frenzy' on the Clarence River with large numbers of up to 40 birds foraging on discards. The number of birds foraging upon the discards in the Hunter river was small, generally from 5 – 20 birds, and the foraging activity was sporadic. Foraging activity on both estuaries stopped once discarding was complete and the number of birds following the vessel at this time decreased. Some birds continued to follow the vessels until their decks were washed down after each shot and fed amongst this wash. After this, while the vessel was only trawling, the birds did not follow the vessel and were not disturbed or interested in the vessel as it passed them. On the Clarence River, the fisher also discarded small prawns on a separate occasion to when the other bycatch was discarded. A small number of pelicans and silver gulls were observed to aggregate and forage upon these discards. On the Clarence River, a great egret and white-faced heron occasionally landed on the boat. The egret successfully fed from the sorting tray on one occasion when the fisher was not nearby.

Appendix 3 – continued

Marine wildlife species observed around fishing vessels and their behaviour:	Oceanic: No wildlife species were observed to actively follow the vessel while motoring out to the fishing site or only trawling. When the nets were pulled up under darkness around five to ten birds were attracted to the vessel each time. These birds foraged sporadically while the nets were being pulled in. When the bycatch was discarded, they foraged more intensely until the discarding was completed. Bird species that foraged under darkness included silver gulls, terns and, on one occasion during summer, shearwaters. Off Yamba, during two fishing trips, bottlenose and common dolphins also fed on the discards from when the net was first cleared for the evening. On daybreak the nets were hauled in for the last time. During the subsequent process of cleaning the nets and discarding the bycatch, the number of birds foraging on these discards increased with increasing daylight and discarding. The maximum number of birds foraging at this time reached 50 – 200. Although this number decreased once the bycatch was discarded, the foraging activity continued until the water from cooking prawns was discarded and the deck was washed. The birds observed foraging in the greatest numbers under daylight were the terns, shearwaters (during summer only) and silver gulls (off Yamba only). As these vessels approached the shore, small numbers of the more land-based birds such as little black, pied and great cormorants and pelicans also joined in this foraging activity. During daylight, one dolphin (both a common and a bottlenose) was observed to forage on the discards amongst the birds on two occasions off Yamba. At Forster, common dolphins were observed bow wave riding when the vessel was almost at port.
Observed operational interactions:	Estuarine: Apart from birds foraging on trawl catch and discards (mentioned above), no operational interactions were observed. Oceanic: Apart from birds foraging on trawl discards and the bow wave riding of common dolphins (mentioned above), no other operational interactions were observed.
Observed mitigation measures:	Estuarine: Bycatch Reduction Devices were used in these nets. Discard chutes were used on the Hunter River to successfully discard live bycatch (fish) beyond the reach of foraging pelicans. Oceanic: Bycatch Reduction Devices were used in these nets off Yamba.
Fishing method: DROPLINING	
Description of observed effort:	During the winter of 2004, one observation trip of the Ocean Trap and Line Fishery was conducted in zone 3 off Bermagui. In all, 11 lines were set, seven before daybreak and four well after sunrise. Three of these lines were hauled in before sunrise all other lines were hauled in under daylight. The lines dropped vertically and fast and were set in deep offshore waters. Before setting the lines baited hooks remained on the side of the vessel for some time. On average, each line was set for 89 $\pm$ 27.4 mins. The current was strong that day and seemed to have an effect on the length of fishing time.
Level of discarding:	No bycatch was captured or discarded by this fisher.
Plastic use and disposal:	Beyond synthetic fishing line, no plastics were used or disposed of by this fisher.
Marine wildlife species observed around fishing vessels and their behaviour:	While the lines were set or hauled in a small number of albatrosses (yellow-nosed) or gannets flew by the vessel on occasion. They never attempted to actively feed on the bait or catch. On one occasion a fish fell off the hook and a juvenile yellow-nosed albatross pecked at it. The fisher retrieved this fish as quickly as possible it was not damaged by the albatross. The bird life appeared to be more active shortly after sunrise, especially when a Commonwealth pelagic longline fisher was operating in the area. The birds appeared to actively forage around this pelagic gear type. A fur-seal foraged around the vessel on two occasions when the line was hauled in. It fed on a fish either directly from one of these lines or a fish that had fallen off this line. No marine wildlife species appeared to actively follow the vessel when it motored to and from the fishing site. When offal was discarded on returning to port, up to three birds appeared to be foraging on this in the distance.

Appendix 3 – continued

Observed operational interactions:	Apart from the feeding on catch and discards (described above), no other operational interactions were observed.
Observed mitigation measures:	This fisher did not use any measures to mitigate against interactions with marine wildlife.
Fishing method: HANDLINING	
Description of observed effort:	Recreational: During the winter of 2003, three observation trips of the Recreational (charter boat) Fishery were conducted (one in zone 2 off Port Stephens and two in zone 3 off Bermagui). During the summer of 2004, three observation trips of the Recreational (charter boat) Fishery were conducted (two in zone 2 off Port Stephens and one in zone 3 off Bermagui). The fishing lines were baited and burley was only used at Port Stephens at the beginning of the day to catch bait. There were between 4 – 11 fishers on these vessels at any one time. Their lines were set at a demersal level. Numerous sites were fished each day in inshore waters during daylight. Each day, the average time fished was 200.7 ± 91.1 mins. The success of fishing effort influenced the amount of time spent at each site. Commercial: During the winter of 2003, two observation trips of the Ocean Trap and Line Fishery were conducted in zone 1 off Evans Head. The fishing lines were baited and burley (dead scad/ pilchards) were used. Between two to four lines were set at any one time in nearshore waters during daylight hours. These lines were set mostly at a mid-pelagic or demersal level. Each day the average time fished was 191.5 ± 80 mins at an average of four fishing sites each day. The success of fishing effort influenced the amount of time spent at each site.
Level of discarding:	Recreational: A very small amount of bycatch was observed captured and discarded by these fishers. Commercial: A very small amount of bycatch was observed captured and discarded by this fisher.
Plastic use and disposal:	Recreational: Beyond synthetic fishing line, no plastics were used or disposed of by these fishers. Commercial: Beyond synthetic fishing line, no plastics were used or disposed of by this fisher.
Marine wildlife species observed around fishing vessels and their behaviour:	Recreational: Many of the birds observed whilst motoring were not interested in or disturbed by the vessel. These birds included gannets, shearwaters, albatrosses, little penguins, terns, silver gulls, little black cormorants, white-bellied sea eagles and kelp gulls and were usually observed some distance from the vessel. On a few occasions, a few silver gulls (no more than 12), actively followed the vessel whilst it was motoring between sites. This usually occurred on occasions when the birds fed on unspent bait or offal from captured baitfish discarded by fishers. Many of the birds observed from the vessel whilst fishing appeared to be disinterested in the fishing vessel and not disturbed by its activities. These birds included silver gulls, gannets, terns, shearwaters, albatrosses (mollymawk), white-bellied sea eagles and little black cormorants. Some of these birds (silver gulls and terns) occasionally appeared to be interested in the vessel when they sat in the waters alongside it or flew over the vessel. These birds were mostly associated with the vessel at times when small amounts of unspent bait were discarded, or burley was being used to catch baitfish at the start of the day. They were attracted to the vessel in small numbers only. Silver gulls were observed to successfully forage on the discards from this fishery on eight occasions. This foraging activity did not occur every observation day. On one day shearwaters were observed to peck at burley and discarded bait on three occasions. Terns were observed to feed on discarded bait on one occasion. A crested tern was also observed to attempt to feed on a baited line when it was sitting out of the water. A white-bellied sea eagle fed on a dead fish that was discarded by a fisher. On one occasion a yellow-nosed albatross came up to the vessel but was scared away by the enthusiasm of the fishers. The humpback whales and fur-seals

Appendix 3 – continued

	observed during the fishing process itself also seemed to be uninterested in or not disturbed by the vessel. No interactions with these mammals were observed. The differences observed between fishing sites and seasons, largely reflect the differences in the species abundances observed between fishing sites and between seasons.
Marine wildlife species observed around fishing vessels and their behaviour:	Commercial: The gannets or cormorants observed whilst the vessel was motoring around fishing sites were not interested in or disturbed by the vessel. Neither was a short-finned pilot whale observed one day when the vessel was close to port. Most of the birds observed whilst fishing (gannets, terns, silver gulls, white-bellied sea-eagle) appeared to be not interested in or disturbed by the activity. These birds were generally observed in small numbers at any time and were often observed to be some distance from the vessel itself. Some of the birds were observed to be occasionally attracted to the vessel whilst fishing was occurring. These species (including terns, silver gulls, gannets and a shearwater) flew by the vessel a few times, sat by the vessel for a little while, or attempted to forage upon the baited hooks or burley. In all 11 feeding attempts by these birds were observed (most of which involved silver gulls), three of which were successful. When gannets attempted to feed on a baited line, they seemed to come from nowhere and quickly dive-bombed onto the bait. On one occasion a gannet became entangled in the fishing line during this process. It flew away seemingly without injury once the fisher un-entangled the bird.
Observed operational interactions:	Recreational: Apart from the foraging activity mentioned above, no other operational interactions were observed. Commercial: Apart from the foraging activity and entanglement of a gannet mentioned above, no other operational interactions were observed.
Observed mitigation measures:	Recreational: On the only occasion when humpback whales surfaced close to the vessel the skipper altered the direction of the vessel so as to avoid colliding with the whale. Fishers sometimes tried to scare birds away when they were foraging close to the vessel by yelling and waving their hands. Commercial: The fisher yelled and waved his hands around in the air to scare foraging birds away. The fisher un-entangled and released the gannet without any attached lines or embedded hooks.
Fishing method: MESH NETTING	
Description of observed effort:	During the winter of 2003, two observation trips of the Estuary General Fishery were conducted in zone 3 around Narooma. During the summer of 2004, one observation trip of the Estuary General Fishery was conducted in zone 1 on the Clarence River. The setting of two 725 m mesh nets was observed around Narooma, in Corunna and Nangudga Lakes. Each net was set shortly after sunset, hauled in shortly before sunrise and was left unattended by the fisher for about nine hours overnight. In the Clarence River, the fisher took a more active approach to mesh netting, setting his net once under darkness and hauling it in a few minutes later.
Level of discarding:	Bycatch was only observed captured and discarded on one netting occasion. The amount discarded was very small.
Plastic use and disposal:	Beyond synthetic fishing nets, no plastics were used or disposed of by these fishers.
Marine wildlife species observed around fishing vessels and their behaviour:	No marine wildlife species were observed to be attracted to or disturbed by the mesh netting activity itself. On motoring to fishing sites, some birds (pelicans, darters, white ibis, great egrets and ducks) were observed either flying by or resting on the shore. These animals were not interested in or disturbed by the fishing vessel. Marine wildlife species did not appear to be active during the night.
Observed operational interactions:	No operational interactions were observed.
Observed mitigation measures:	These fishers did not use any measures to mitigate against interactions with marine wildlife.

Appendix 3 – continued

Fishing method: BEACH HAULING	
Description of observed effort:	During the winter of 2003, two observation trips of the Ocean Hauling Fishery were conducted in zone 3 in Twofold Bay. During this time, one beach hauling event was observed. Following the beach hauling itself, the netted catch was transported a short distance to the vessel where it was loaded on board. In all, the hauling process itself was complete in 80 minutes and the process of loading the catch onto the vessel took another 90 minutes.
Level of discarding:	A very small amount of bycatch was observed captured and discarded by this fisher.
Plastic use and disposal:	Beyond the synthetic fishing net, no plastics were used or disposed of by this fisher.
Marine wildlife species observed around fishing vessels and their behaviour:	While the vessel was stationary or motoring to and from fishing sites, marine wildlife appeared to be not interested in or disturbed by the vessel at this time. The wildlife species (including silver gulls, crested terns, white-bellied sea-eagles, little black cormorants, crested terns and bottlenose dolphins) foraged around this vessel occasionally throughout this time in very small numbers. No birds attempted to feed on the catch of salmon during the hauling process. However, four crested terns fed occasionally some distance from the net on the small scad regurgitated by the salmon. A silver gull was also amongst these terns but it did not attempt to feed. Two white-bellied sea-eagles that nest on an adjacent beach were observed to forage upon four salmon purposely left on the beach by fishers. While the codend contents were being loaded onto the vessel, around 15 bottlenose dolphins foraged upon the small number of salmon that escaped from this net. These dolphins then joined others that were feeding on another passing school of salmon. This foraging activity was not affected by the stationary presence of the fishing vessel.
Observed operational interactions:	Apart from the foraging activities described above, no other operational interactions with marine wildlife were observed.
Observed mitigation measures:	The fishers purposefully left some food for the white-bellied sea-eagles. This appeared to be common practise, perhaps an effort to prevent the eagles from foraging upon the encircled catch during hauling. Fishers did not attempt to fish in areas where fur-seal and dolphin foraging was particularly abundant. The fishers knew that they would eventually obtain their share of the stock after these animals had obtained their fill in waters where these mammals were less abundant.
Fishing method: TRAPPING	
Description of observed effort:	During the winter of 2003, one observation trip of the Estuary General Fishery was conducted in zone 2 on Wallis Lake. The hauling in and re-setting of five crab traps was observed. These traps were previously set two days before this observation trip.
Level of discarding:	A small amount of rotten bait was discarded from each trap.
Plastic use and disposal:	Beyond synthetic trap ropes, no plastics were used or disposed of by this fisher.
Marine wildlife species observed around fishing vessels and their behaviour:	The only birds that were interested in the fishing vessel whilst it was motoring to and from the fishing site were pelicans and silver gulls. These birds followed the vessel when it was going to the site and for a short period on its return. The birds stopped following the vessel once they realised it was discontinuing its fishing operations. While the traps were being checked, around 30 pelicans and 12 silver gulls waited by the vessel to feed on the minor amounts of discarded bait. Many of the feeding attempts of the pelicans were successful.
Observed operational interactions:	Apart from the foraging on discarded bait (described above), no other operational interactions were observed.
Observed mitigation measures:	This fisher did not use any measures to mitigate against interactions with marine wildlife.

APPENDIX 4: Results from dolphin stomach content study

Stomach contents of two stranded common dolphins (*Delphinus delphis*) off the coast of New South Wales.

Dr R. G. Harcourt and J. L. van den Berg
Marine Mammal Research Group, Macquarie University, Sydney, NSW, 2109, Australia.
E-mail: rharcour@gse.mq.edu.au
Ph: (+02) 9850 7970

Introduction

Diet studies on marine animals have occurred for many different reasons (Barros and Odell 1990, Das *et al*. 2000, Fea *et al.* 1999, Law *et al.* 2003, Silva 1999). Diet studies are especially important for marine mammals in determining whether there are any interactions with fisheries (Silva 1999) and if incidental deaths can be reduced or better managed (Barros and Odell 1990).

Determining the diet of small cetaceans is particularly difficult because they are wholly aquatic animals (Hoelzel 2002). Scat and regurgitate analysis cannot be used as it is in studies of marine vertebrates which come ashore, such as sea birds and pinnipeds (Fea *et al.* 1999).

Diet studies for small cetaceans are often undertaken by the use of whole stomach contents after death (Barros and Odell 1990, Silva 1999). Causes of death include strandings, incidental net capture and intentional killing (Barros and Odell 1990, Silva 1999). Biases may arise as necropsy data is often limited or incomplete and sex, age and cause of death are often difficult to infer (Barros and Odell 1990). Stomach contents may also be biased as stranded animals may not have been foraging at a normal capacity or may be starved (empty stomach) (Silva 1999). Incidental deaths through interactions with fisheries can show a bias towards the fishery target species, although whether this is because the target species is in high abundance, or the animals are scavenging from fisheries is sometimes not known (Silva 1999).

Diet studies involve separating the stomach contents and identifying the hard parts such as otoliths and cephalopod beaks (Barros and Odell 1990). The difficulty with these types of diet studies is that otoliths are often digested and there is no way of knowing by exactly how much (Fea and Harcourt 1997). Therefore only minimum prey biomass estimates can be obtained. Stomach contents may also only reveal the animal's last meal and may not be representative of the regular diet (Das *et al.* 2000).

For questions of feeding ecology fatty-acid and stable isotope analysis can be used and is an easier method that requires only a small tissue sample (Das *et al.* 2000). These types of analysis also give an idea of what was assimilated and not just ingested (Das *et al.* 2000). However for studies looking at interactions with fisheries, stomach contents are useful because they are used to identify prey down to a genus or species level (Barros and Odell 1990, Silva 1999). Biomass estimates can reveal what percentage of their diet is made up of individual prey species. A study by Silva (1999) revealed that anchovy was the main fish consumed by *Delphinus delphis* in the waters off Portugal and this species was also the main target species of the fishery.

The implications for interactions with fisheries may be of some import, especially in areas where endangered animals are being incidentally killed. There have been few published studies on the diet of small cetaceans in Australia in recent years (Law *et al.* 2003).

The common dolphin *Delphinus delphis* is widely distributed throughout temperate and tropical waters (Silva 1999). *D. delphis* is known as a pelagic species (Silva 1999) although it can often be seen inshore and even in bays (Law *et al.* 2003). The diet of *D. delphis* is of near surface pelagic, schooling fish and squid and octopus species (Law *et al.* 2003).

This study aims to identify the prey species eaten by *Delphinus delphis* in waters off the coast of New South Wales through analysis of stomachs collected from two stranded animals.

Methods and Materials

Stomach contents from two common dolphins (*Delphinus delphis*) were examined. The first dolphin (C3) was collected from entanglement in a beach protection net on Maroubra beach on the 10th November 2003. The second dolphin (C4) was collected from stranding on Bondi beach on the 12th November 2003.

The dolphin stomachs were stored at -20ºC. The stomach and intestine contents of both stomachs were emptied using the same technique. The stomach contents were washed with gently running water through four stacked sieves with decreasing mesh sizes from 5mm to 1mm. All hard parts were collected, sorted and stored individually. Individual prey items were refrozen for later identification.

Teleost fish species were identified by comparison of otoliths with a reference book (Smale *et al.* 1995) and a reference collection from the Australian Museum in Sydney. Cephalopod beaks were identified using a key from the Museum Victoria. Left and right otoliths were counted separately as were upper and lower cephalopod beaks; the greater number of these was used to represent the minimum number of prey species consumed. Measurements of unbroken cephalopod beaks and sagittal otoliths were made with digital callipers to the nearest 0.01mm. Otoliths were only measured if they appeared intact and were not obviously eroded. Calculations of minimum prey number and minimum original prey biomass were made from the total numbers obtained as above. Determination of original prey biomass for cephalopod beaks was from regression equations from Lu and Ickeringill (2002).

Individual prey items were identified through comparison of various intact features such as jaw structure, gill covers and eye socket size. Individual prey items were also identified by removing otoliths if they were present, although these otoliths are not included in the measurements.

Results

Initial examination of the stomach from C3 after thawing revealed that the stomach was still intact and that decomposition was minimal. Initial reports on collection of C3 state that the animal was found after being entangled for no more than a few days, as decomposition was minimal and bloating was not yet present. Initial examination of C4 stomach after thawing showed that the stomach was highly decomposed and prey items were only loosely held in a thin web of decaying tissue. Initial reports on collection of C4 state that the animal was found washed up on Bondi beach and may have been dead for several weeks. The animal was bloated and had what appeared to be a bullet wound in its side, which may indicate cause of death. The sex of either dolphin was not known.

The number of otoliths in the stomach from C4 was much lower than the otoliths found in the stomach of C3 (Table 1). The greatest number of otoliths found in the stomach from C4 was from the species *Pagrus auratus* (Table 1), commonly known as snapper or in the juvenile form as red bream.

The partially digested prey items were also found to be of the same species, *Pagrus auratus*. The average fork length of prey items was 26.3 (SD±6.506).

The greatest number of otoliths found in the stomach of C3 was from the species *Centroberyx affinis* (Table 1), commonly known as redfish or Nannygai. The half digested prey items were identified as *Centroberyx affinis* also. The average fork length of prey items was 17.5cm (SD±1.322).

The *Neobythites spp* could only be identified down to the genus as reference otoliths were only identified to the genus and no literature was available on this species for otolith identification. *Pseudophycis breviuscula* was originally identified as *Austrophycis megalops*, as taxonomic reclassification of this species had not yet been transferred to the otolith reference collection.

Table 1: Fish species and Otolith occurrence in the Stomach Contents of *Delphinus delphis*. Where N=total number of otoliths, P=total number of Prey (including whole prey items), MOL=mean otolith length, SE=standard error for otolith length.

Species	Common Name	N	P	MOL		SE	
Dolphin C3				left	right	left	right
Centroberyx affinis	Nannygai	27	18	7.68	7.59	0.0906	0.1189
Neobythites spp	Ray finned fish	1	1	7.14	-	-	-
Unidentified		6	3	2.38	2.35	0.4350	0.4147
Not identifiable		4	-	-	-	-	-
Dolphin C4							
Pagrus auratus	Snapper	4	5	5.25	5.07	0.3000	0.2050
Pseudophycis breviuscula	Northern bastard codling	1	1	4.14	-	-	-

There were few squid beaks found in both stomachs with two upper and two lower beaks found in C3 and two upper and one lower beak found in C4 (Table 2). The more common *Sepioteuthis australis* or Southern reef squid was identified as the only species found in the C4 sample. The less common *Eucliotheuthis luminosa* or luminous flying squid was found to be the only species represented in the C3 sample.

Table 2: Cephalopod biomass estimates from the stomach of *Delphinus delphis*. Where N=total number of beaks, Wt=fresh weight kg.

Species	Common Name	N		Wt
		upper	lower	
Eucliotheuthis luminosa	striped squid/luminous flying squid	2	2	0.026
Sepioteuthis australis	Southern reef squid	2	1	0.034

Discussion

These results show that *Delphinus delphis* fed both on fish and cephalopods. The variation in prey species consumed by *D. delphis* was most likely due to variation in distribution and abundance of prey species, as was found by Silva (1999).

The presence of reef dwelling fish (*Pagrus auratus*) and reef dwelling squid (*Sepioteuthis australis*) suggest that C4 may have been feeding in the vicinity of a reef shortly before it died, although no further inference can be made from this data.

The small number of otoliths found in C4 as compared to C3 may be explained by the degradation of the stomach itself. The stomach of C3 was in very good condition and still had the

intestine attached. A large number of the otoliths found in this stomach occurred in the vast number of folds within the stomach. Because the stomach of C4 was so degraded it is possible that many of the otoliths were lost as the stomach itself decomposed.

The main fish species found in C3, *Centroberyx affinis* is a pelagic fish, with a main fishery off the coast of New South Wales. The juveniles inhabit shallower inshore waters and adults are found deeper (Morison and Rowling 2001). Although biomass could not be calculated from otolith length or weight, measurement of the undigested prey items showed that the average fork length was 17.5cm (SD±1.322). This average length puts them in an age class of 3-5 years (Morison and Rowling 2001). *C. affinis* of this length are usually thrown back by fishers (Morison and Rowling 2001).

The abundance of squid in the diet of *Delphinus delphis* has been reported as being high in number but accounts for a low percentage of the biomass (Silva 1999). In this study squid was not found to be numerous or high in biomass. The presence of a large amount of *C. affinis* in the stomach of C3 may indicate that there was no requirement for large amounts of squid as *C. affinis* was so abundant.

No important conclusions can be made about the interaction of *Delphinus delphis* with NSW fisheries because the sample size is too small. Amalgamation of the data from other such studies may provide a better indicator of the overall diet of *Delphinus delphis*.

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References

Barros, N.B., D.K. Odell. 1990. Food Habits of Bottlenose dolphins in the Southeastern United States. *The bottlenose dolphin*, Academic Press Inc. p 309-328.

Das, K., G. Lepoint, V. Loizeau, V. Debacker, P. Dauby, J.M. Bouquegneau. 2000. Tuna and Dolphin Associations in the North-East Atlantic: Evidence of different ecological niches from stable isotope and heavy metal measurements. *Marine Pollution Bulletin* 40(2): 102-109.

Fea, N., R. Harcourt. 1997. Assessing the use of faecal and regurgitate analysis as a means of determining the diet of New Zealand fur seals. *Marine mammal research in the Southern Hemisphere: Status, Ecology and Medicine.* M. Hindell. C. Kemper (eds) Surrey Beatty and Sons Ltd. Chipping Norton, p143-150.

Fea, N., R. Harcourt, C. Lalas. 1999. Seasonal variation in the diet of New Zealand fur seals (*Arctocephalus forsteri*) at Otago Peninsula, New Zealand. *Wildlife Research* 26:147-160.

Hoelzel, A.R. (ed) 2002. *Marine Mammal Biology: An evolutionary approach.* Blackwell Science. UK.

Law, R.J, R.J. Morris, C.R. Allchin, B.R. Jones, M.D. Nicholson. 2003. Metals and organochlorins in small cetaceans stranded on the coast of Australia. *Marine Pollution Bulletin* 46:1200-1211

Lu, C.C., R. Ickeringill. 2002. Cephalopod beak identification and biomass estimation techniques: tools for dietary studies of Southern Australian finfishes. *Museum Victoria Science Reports* 6:1-65.

Morison, A.K., K.R. Rowling. 2001. Age, growth and mortality of redfish *Centroberyx affinis*. *Marine and Freshwater Research* 52:637-649.

Silva, M.A. 1999. Diet of common dolphins, *Delphinus delphis*, off the Portugese continental coast. *Journal of the Marine Biological Association of the United Kingdom* 79:531-540.

Smale, M.J., G. Watson, T. Hecht. 1995. Otolith Atlas of Southern African Marine Fishes. *Ichthyological monographs No. 1*, JLB Smith Institute of Ichthyology, Grahamstown, South Africa.

Stomach contents of a common dolphin (*Delphinus delphis*) and a striped dolphin (*Stenella coeruleoalba*) collected off the coast of New South Wales.

Dr R. G. Harcourt and C. Huveneers
Marine Mammal Research Group, Macquarie University, Sydney, NSW, 2109, Australia.
E-mail: charlie.huveneers@gse.mq.edu.au
Ph: (+02) 9850 7980

Introduction

Diet studies of higher marine vertebrate predators assist us in understanding the ecological role of these higher predators in marine ecosystems (Barros and Odell 1990, Das *et al.* 2000, Fea *et al.* 1999, Law *et al.* 2003, Silva 1999). An understanding of the dietary composition can be especially important for marine mammals as a means of determining whether there are any interactions with fisheries (Silva 1999). The consequences may lead to improvements in the management of these interactions and even help reduce incidental kills (Barros and Odell 1990).

Determining the diet of small cetaceans is particularly difficult because they are wholly aquatic animals (Hoelzel 2002). Scat and regurgitate analysis cannot be used as it is in studies of marine vertebrates which come ashore, such as sea birds and pinnipeds (Fea *et al.* 1999).

One approach to determining the diet of small cetaceans is the examination of whole stomach contents after death (Barros and Odell 1990, Silva 1999). Causes of death include strandings, incidental net capture and intentional killing (Barros and Odell 1990, Silva 1999). Biases may arise as necropsy data is often limited or incomplete and sex, age and cause of death are often difficult to infer (Barros and Odell 1990). Stomach contents may also present a non-representative sample of prey contents as stranded animals may not have been foraging at a normal capacity or may be starved (empty stomach) (Silva 1999). Incidental deaths through interactions with fisheries can show a bias towards the fishery target species, although whether this is because the target species is in high abundance, or the animals are scavenging from fisheries is sometimes not known (Silva 1999).

Diet studies involve separating the stomach contents and identifying the hard parts such as otoliths and cephalopod beaks (Barros and Odell 1990). The difficulty with these types of diet studies is that otoliths are often digested and there is no way of *a priori* adjusting for differential digestion (Fea and Harcourt 1997). Furthermore, otoliths found in dolphin stomachs could come from larger prey items themselves and should potentially be considered as secondary otoliths. Therefore only minimum prey biomass estimates can be obtained. Stomach contents may also only reveal the animal's last meal and may not be representative of the regular diet (Das *et al.* 2000).

For questions of feeding ecology fatty-acid and stable isotope analysis can be used in conjunction with stomach contents and provide further information on the history of prey uptake by determining what has been assimilated and not just that recently ingested (Das *et al.* 2000). However, these alternative methods have their own limitations, are expensive and require validation studies. The most economical means of looking at interactions with fisheries is to examine stomach contents as this can rapidly identify prey down to a genus or species level (Barros and Odell 1990, Silva 1999). Biomass estimates can be calculated and reveal what percentage of the diet is made up of individual prey species. For example, Silva (1999) revealed that anchovy was the main fish consumed by *Delphinus delphis* in the waters off Portugal and this species was also the main target species of the fishery.

The implications for interactions with fisheries may be of some import, especially in areas

where endangered animals are being incidentally killed. There have been few published studies on the diet of small cetaceans in Australia in recent years (Law *et al.* 2003).

The common dolphin *Delphinus delphis* is widely distributed throughout temperate and tropical waters (Silva 1999). *D. delphis* is known as a pelagic species (Silva 1999) although it can often be seen inshore and even in bays (Law *et al.* 2003). The diet of *D. delphis* is of near surface pelagic, schooling fish and squid and octopus species (Law *et al.* 2003).

The striped dolphin *Stenella coeruleoalba* is a cosmopolitan cetacean with a wide distribution range from tropical to temperate areas (Cebrian, 1995). It is considered to be the most abundant dolphin in the Mediterranean (Evans, 1987; Bompar *et al.*, 1991). The diet of *S. coeruleoalba* is composed of various fish, cephalopods and sometimes crustaceans (Carwardine *et al.*, 1998).

This study aims to identify the prey species eaten by *Delphinus delphis* and *Stenella coeruleoalba* in waters off the coast of New South Wales through analysis of stomachs collected from one stranded animal of each species.

Methods and Materials

Stomach contents from one common dolphin (*Delphinus delphis*) and one striped dolphin (*Stenella coeruleoalba*) were examined. The common dolphin (C1) was collected from entanglement in a beach protection net on Coogee beach on the 16th September 2003. The striped dolphin (C2) was collected from stranding on Balmoral beach on the 17th August 2001.

The dolphin stomachs were stored at -20ºC. The stomach and intestine contents of both stomachs were emptied using the same technique. The stomach contents were washed with gently running water through four stacked sieves with decreasing mesh sizes from 5mm to 1mm. All hard parts were collected, sorted and stored individually. Individual prey items were refrozen for later identification.

Teleost fish species were identified by comparison of otoliths with a reference book (Smale *et al.* 1995) and a reference collection from the Australian Museum in Sydney. Cephalopod beaks were identified using a key from the Museum Victoria. Left and right otoliths were counted separately as were upper and lower cephalopod beaks; the greater number of these was used to represent the minimum number of prey species consumed. Measurements of unbroken cephalopod beaks and sagittal otoliths were made with digital callipers to the nearest 0.01mm. Otoliths were only measured if they appeared intact and were not obviously eroded. Calculations of minimum prey number and minimum original prey biomass were made from the total numbers obtained as above. Determination of original prey biomass for cephalopod beaks was from regression equations from Lu and Ickeringill (2002).

Individual prey items were identified through comparison of various intact features such as jaw structure, gill covers and eye socket size.

Results

Initial examination of both stomachs after thawing revealed that the stomachs were still intact and that decomposition was minimal. Initial reports on collection of the common dolphin state that the animal was found after being entangled. The duration of the entanglement before the dolphin was found is unknown. The striped dolphin was found washed up on a beach with possible evidence of old net scar injury, although not clear which might have potentially caused the death of this dolphin. The

sex of either dolphin was not known.

The number of otoliths in the stomach from the common dolphin was much lower than the otoliths found in the stomach of the striped dolphin (Table 1). The greatest number of otoliths found in the stomach of C1 was from the species *Trachurus novaezelandiae* or yellowtail. However one otolith from *Centroberyx affinis*, commonly known as redfish or Nannygai was also found (Table 1). Some partially digested prey items were found in C1's stomach and could not be identified due to the stage of digestion. The total weight of those unidentified digested prey items was 13.07g.

Unfortunately, the greatest number of otoliths found in the stomach from C2 were too eroded to identify the prey items down to species. However, those otoliths were most likely to come from the Perciformes order, either carangidae or scorpidae family (Table 1).

In all cases, otoliths were too eroded to measure them accurately.

Table 1: Fish species and Otolith occurrence in the Stomach Contents of *Delphinus delphis* and *Stenella coeruleoalba*. Where N=total number of otoliths, P=total number of Prey (including whole prey items), MOL=mean otolith length, SE=standard error for otolith length.

Species	Common Name	N	P
Common Dolphin C1			
Trachurus novaezelandiae	Yellowtail	23	13
Centroberyx affinis	Nannygai	1	1
Not identifiable		3	3
Broken		10	
Striped Dolphin C2			
Perciformes (carangidae or scorpidae)		150-200	Approx. 80

There were a few squid beaks found in the common dolphin's stomach with four upper and two lower beaks (Table 2). The common *Nototodarus gouldi* or Gould's flying squid was identified as the only species found in the stomach. No cephalopods were present in the striped dolphins stomach or intestinal tract.

Table 2: Cephalopod biomass estimates from the stomach of *Delphinus delphis* and *Stenella coeruleoalba*. Where N=total number of beaks, Wt=fresh weight g, ML=mantle length cm.

Species	Common Name	N		Wt		ML	
		upper	lower	Mean	SE	Mean	SE
Nototodarus gouldi	Gould's flying squid	2	4	108.3 8	5.4	18.60	4.8

Discussion

These results show that *Delphinus delphis* fed both on fish and cephalopods whereas *Stenella coeruleoalba* fed on teleosts only. However, the otoliths found in *S. coeruleoalba* were much smaller than those in *D. delphis* and could be secondary otoliths originating from prey items. No primary prey items or half digested remains were found in *S. coeruleoalba*'s stomach.

The level of erosion of all otoliths was relatively strong especially in the striped dolphin making prey identification difficult. The analysis provided here should therefore be looked at carefully keeping in mind the difficulties encountered during identification.

Both teleost species identified in the common dolphin's stomach are pelagic fishes (*C. affinis*

and *T. novaezelandiae*) and coincide with the pelagic habits of common dolphins. Similarly, Gould's flying squid is also known to disperse throughout the water column at night.

The main fish species found in C1, *T. novaezelandiae* is a pelagic fish that form large schools in marine inshore areas such as bays and estuaries. Yellowtails are traditionally used as bait for recreational and commercial fishers. Some are also sold for human consumption caught with handlines or seine nets, mainly off the coast of New South Wales and Western Australian.

Unfortunately, biomass could not be calculated from otolith length or weight. Measurement of the undigested prey items was also not possible as there was no tail present on the prey items making it impossible to locate the end of body and beginning of the prey's tail.

The abundance of squid in the diet of *Delphinus delphis* has been reported as being high in number but accounts for a low percentage of the biomass (Silva 1999). In this study squid was not found to be numerous or high in biomass. The presence of a large amount of *T. novaezelandiae* in the stomach of C3 may indicate that there was no requirement for large amounts of squid as *T. novaezelandiae* was so abundant.

No important conclusions can be made about the interaction of *Delphinus delphis* or *Stenella coeruleoalba* with NSW fisheries because the sample size is too small. Amalgamation of the data from other such studies may provide a better indicator of the overall diet of *Delphinus delphis* and *Stenella coeruleoalba.*

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References

Barros, N.B., D.K. Odell. 1990. Food Habits of Bottlenose dolphins in the Southeastern United States. *The bottlenose dolphin*, Academic Press Inc. p 309-328.

Bompar, J.M., F. Dhermain, F. Poitevin, M. Cheylan.1991. Les dauphins mediterranées victimes d'un virus mortel. *La Recherche* 231 : 506-508.

Carwardine, M., E. Hoyt, R.E. Fordyce, P. Gill. 1998. *Whales, dolphins and porpoises*. Reader's Digest, Australia.

Cebrian, D. 1995. The striped dolphin *Stenella coeruleoalba* epizootic in Greece, 1991-1992. *Biological Conservation* 74: 143-145.

Das, K., G. Lepoint, V. Loizeau, V. Debacker, P. Dauby, J.M. Bouquegneau. 2000. Tuna and Dolphin Associations in the North-East Atlantic: Evidence of different ecological niches from stable isotope and heavy metal measurements. *Marine Pollution Bulletin* 40(2): 102-109.

Evans, P.G. 1987. *The natural history of whales and dolphins*. Croom Helm, Bromley.

Fea, N., R. Harcourt. 1997. Assessing the use of faecal and regurgitate analysis as a means of determining the diet of New Zealand fur seals. *Marine mammal research in the Southern Hemisphere: Status, Ecology and Medicine.* M. Hindell, C. Kemper (eds) Surrey Beatty and Sons Ltd. Chipping Norton, p143-150.

Fea, N., R. Harcourt, C. Lalas. 1999. Seasonal variation in the diet of New Zealand fur seals (*Arctocephalus forsteri*) at Otago Peninsula, New Zealand. *Wildlife Research* 26:147-160.

Hoelzel, A.R. (ed) 2002. *Marine Mammal Biology: An evolutionary approach.* Blackwell Science. UK.

Law, R.J, R.J. Morris, C.R. Allchin, B.R. Jones, M.D. Nicholson. 2003. Metals and organochlorins in

small cetaceans stranded on the coast of Australia. *Marine Pollution Bulletin* 46:1200-1211.

Lu, C.C., R. Ickeringill. 2002. Cephalopod beak identification and biomass estimation techniques: tools for dietary studies of Southern Australian finfishes. *Museum Victoria Science Reports* 6:1-65.

Morison, A.K., K.R. Rowling. 2001. Age, growth and mortality of redfish *Centroberyx affinis*. *Marine and Freshwater Research* 52:637-649.

Silva, M.A. 1999. Diet of common dolphins, *Delphinus delphis*, off the Portugese continental coast. *Journal of the Marine Biological Association of the United Kingdom* 79:531-540.

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No. 66 Heasman, M., Diggles, B.K., Hurwood, D., Mather, P., Pirozzi, I. and Dworjanyn, S., 2004. Paving the way for continued rapid development of the flat (angasi) oyster (*Ostrea angasi*) farming in New South Wales. Final Report to the Department of Transport & Regional Services. Project No. NT002/0195. 40pp.

ISSN 1449-9967 (NSW Department of Primary Industries - Fisheries Final Report Series)

No. 67 Kroon, F.J., Bruce, A.M., Housefield, G.P. and Creese, R.G., 2004. Coastal floodplain management in eastern Australia: barriers to fish and invertebrate recruitment in acid sulphate soil catchments. Final Report to Fisheries Research and Development Corporation. Project No. 1998/215. 212pp.

No. 68 Walsh, S., Copeland, C. and Westlake, M., 2004. Major fish kills in the northern rivers of NSW in 2001: Causes, Impacts & Responses. NSW Department of Primary Industries - Fisheries Final Report. 55pp.

No. 69 Pease, B.C. (Ed), 2004. Description of the biology and an assessment of the fishery for adult longfinned eels in NSW. Final Report to Fisheries Research and Development Corporation. Project No. 1998/127. 168pp.

No. 70 West, G., Williams, R.J. and Laird, R., 2004. Distribution of estuarine vegetation in the Parramatta River and Sydney Harbour, 2000. Final Report to NSW Maritime and the Australian Maritime Safety Authority. 37pp.

No. 71 Broadhurst, M.K., Macbeth, W.G. and Wooden, M.E.L., 2005. Reducing the discarding of small prawns in NSW's commercial and recreational prawn fisheries. Final Report to the Fisheries

Research & Development Corporation. Project No. 2001/031. NSW Department of Primary Industries - Fisheries Final Report Series No. 71. 202pp.

No. 72. Graham, K.J., Lowry, M.B. and Walford, T.R., 2005. Carp in NSW: Assessment of distribution, fishery and fishing methods. NSW Department of Primary Industries - Fisheries Final Report Series No. 72. 88pp.

No. 73 Stewart, J., Hughes, J.M., Gray, C.A. and Walsh, C., 2005. Life history, reproductive biology, habitat use and fishery status of eastern sea garfish (*Hyporhamphus australis*) and river garfish (*H. regularis ardelio*) in NSW waters. Final report on the Fisheries Research & Development Corporation Project No. 2001/027. 180pp.

No. 74 Growns, I. and Gehrke, P., 2005. Integrated Monitoring of Environmental Flows: Assessment of predictive modelling for river flows and fish. NSW Department of Primary Industries - Fisheries Final Report Series No. 74. 33pp.

No. 75 Gilligan, D., 2005. Fish communities of the Murrumbidgee catchment: Status and trends. Final report to the Murrumbidgee Catchment Management Authority. Project No. BG4_03. 138pp.

No. 76 Ferrell, D.J., 2005. Biological information for appropriate management of endemic fish species at Lord Howe Island. NSW Department of Primary Industries - Fisheries Final Report Series No. 76. 18 pp.

No. 77 Gilligan, D., Gehrke, P. and Schiller, C., 2005. Testing methods and ecological consequences of large-scale removal of common carp. Final report to the Water Management Fund - Programs MFW6 and MUR5. 46pp.

No. 78 Boys, C.A., Esslemont, G.and Thoms, M.C., 2005. Fish habitat and protection in the Barwon-Darling and Paroo Rivers. Final report to the Department of Agriculture, Fisheries and Forestry – Australia (AFFA). 118pp.

No. 79 Steffe, A.S., Murphy, J.J., Chapman, D.J. and Gray, C.C., 2005. An assessment of changes in the daytime recreational fishery of Lake Macquarie following the establishment of a 'Recreational Fishing Haven'. NSW Department of Primary Industries - Fisheries Final Report Series No. 79. 103pp.

No. 80 Gannassin, C. and Gibbs, P., 2005. Broad-Scale Interactions Between Fishing and Mammals, Reptiles and Birds in NSW Marine Waters. Final Report for a project undertaken for the NSW Biodiversity Strategy. 172pp.