

Review of commercial fishery interactions and  
population information for eight New Zealand protected  
fish species

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# Review of commercial fishery interactions and population information for eight New Zealand protected fish species

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## Abstract

Eight fish species are currently protected in New Zealand fisheries waters: spotted black grouper (*Epinephelus daemeli*), white shark (*Carcharodon carcharias*), spinetail devilray (*Mobula japonica*), manta ray (*Manta birostris*), whale shark (*Rhincodon typus*), deepwater nurse shark (*Odontaspis ferox*), giant grouper (*Epinephelus lanceolatus*) and basking shark (*Cetorhinus maximus*). This study documents and describes their interactions with commercial fisheries in New Zealand waters, and locates and describes the available population information relevant to assessing the risk to these species. Information on the catches of protected species was obtained from the literature, commercial catch statistics, and observer records. Data were groomed to remove many records that had been incorrectly assigned protected species codes. For each species, the catch distribution, seasonality, fishing method, and reported totals were described. Population and biological characteristics were reviewed under the categories: stock identification, biological productivity, species overlap with fisheries, and response of the species to exploitation. Whale shark, manta ray and giant grouper are tropical species that are rarely or occasionally seen in northern New Zealand. They are not vulnerable to commercial fisheries in New Zealand and are therefore not regarded as high priority species for research or management. Research and management efforts should focus on basking shark, white shark, deepwater nurse shark, spinetail devilray, and spotted black grouper. These species are present in New Zealand waters in significant numbers for at least part of the year. Basking shark and white shark have the greatest interactions with commercial fisheries, and are potentially the species most impacted by commercial fisheries. Recommendations for reducing bycatch of basking sharks suggested by Francis & Smith (2010) are still appropriate and useful. White sharks are vulnerable to set net, lines and trawl nets throughout much of the country; however hotspots of abundance occur around the Chatham Islands, Stewart Island, and in the large harbours of the northern North Island suggesting that initial mitigation measures should focus on these areas. Furthermore, white sharks are most common in New Zealand during summer–autumn (most emigrate to tropical waters in winter–spring), so mitigation measures should focus on those periods. The deepwater nurse shark stands out as having the lowest or equal lowest information level in all four category groupings, so it rates as high priority for future research. Some information types are most easily obtained by destructive necropsies (e.g. growth and longevity estimated from vertebrae; size at sexual maturity for females, litter size and gestation period estimated by examination of reproductive organs). If destructive sampling for research purposes is unacceptable for protected species, then specimens that are accidentally caught and killed by fishers become extremely valuable for providing crucial biological information. We recommend that efforts are made to increase the availability for

research of specimens of protected fish species by (a) making it legal for fishers to land dead specimens; (b) encouraging and educating fishers about the value of specimens for research; and (c) providing the specimens to a research organisation that can maximise their value by extracting all relevant useful information from each specimen. Other targeted research (e.g. genetic analysis and electronic tagging) should also be implemented urgently as a means of gathering important information in a relatively short time.

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## Introduction

Eight fish species are currently protected in New Zealand fisheries waters under Schedule 7A of the Wildlife Act: spotted black grouper (*Epinephelus daemeli*) was protected in 1996, white shark (*Carcharodon carcharias*) in 2007, and spinetail devilray (*Mobula japonica*), manta ray (*Manta birostris*), whale shark (*Rhincodon typus*), deepwater nurse shark (*Odontaspis ferox*), giant grouper (*Epinephelus lanceolatus*) and basking shark (*Cetorhinus maximus*) in 2010.

All eight species are considered to have low productivity because of their slow growth rates, low fecundity, and small population sizes. They are also actually or potentially caught by fisheries targeting other species in New Zealand and (for migratory species) elsewhere in the Indo-Pacific region. In combination, low productivity and fisheries threats make these species vulnerable to over-exploitation, and possibly even extinction. This risk led to the eight species being declared protected. However, protection does not eliminate fisheries bycatch because these species may be caught unintentionally by various commercial and recreational fishing methods, leading to incidental mortality. It is therefore important to understand the sources and extent of fisheries mortality and the risks these pose for protected species. Armed with such information it may be possible to develop further fisheries management measures or bycatch mitigation techniques for species at significant risk.

Basking shark bycatch during the period 1994–95 to 2007–08 has been the subject of a major recent research project (Francis & Smith 2010), and factors affecting basking shark bycatch have been further investigated recently (Francis & Sutton 2012). A simple bycatch analysis has also been completed for white shark (Francis 2004b), but it is now out of date. Existing commercial and observer data on the bycatch of spinetail devilrays in the skipjack tuna purse seine fishery have also been reviewed recently in order to inform bycatch mitigation measures (Jones & Francis 2012). For the other five species, there have been no detailed analyses of fisheries data, although Duffy (2005) summarised the fisheries interactions for whale shark, deepwater nurse shark, manta ray, spinetail devilray, and giant grouper prior to their protection in 2007.

Population information is largely lacking or sparse for most of the species, mainly because of their rarity and the difficulty of studying large mobile fishes. Some basic biological information (e.g. growth rate, and size and age at maturity) is available for some of the species, though most of the data come from overseas studies. Duffy (2005) summarised relevant population information for whale shark, deepwater nurse shark, manta ray, spinetail devilray, and giant grouper, and provided a rationale for their protection.

This study seeks to document and describe the interactions of eight protected fish species with commercial fisheries in New Zealand waters, and to locate and describe the available population information relevant to assessing the risk to these species. Significant gaps in our knowledge are highlighted, and recommendations are made for further research to fill these gaps. The specific objectives of this study (Department of Conservation project POP2011–03) were:

1. To review existing information to describe the nature and extent of interactions between commercial fishing and basking sharks, nurse sharks, white pointer sharks, whale sharks, manta rays, spinetail devil rays, giant groupers and spotted black groupers.
2. To identify information gaps in the understanding of the nature and extent of interactions between commercial fishing and protected fish species within the New Zealand EEZ, and provide recommendations for further research to address any gaps identified.
3. To review existing information to describe population information relevant to assessing risk from commercial fishing within the New Zealand EEZ to basking sharks, nurse sharks, white pointer sharks, whale sharks, manta rays, spinetail devil rays, giant groupers and spotted black groupers.
4. To identify population information gaps relevant to assessing risk from commercial fishing to protected fish species within the New Zealand EEZ, and provide recommendations for further research to address any gaps identified.

## Methods

Information on the extent of catches of protected species in commercial fishing gear around New Zealand was obtained from three main sources: literature, commercial catch statistics, and observer records.

### Published and unpublished literature

The amount of literature available on commercial fishery interactions was minimal apart from a comprehensive analysis of basking shark trawl bycatch and total reported catches (Francis & Duffy 2002; Francis 2004a; Francis & Smith 2010). A review of reported white shark catches by all fisheries over the period 1989–90 to 2002–03 was presented by Francis (2004b). Captures of spinetail devil rays in purse seine nets have also been reported briefly (Habib et al. 1982; Paulin et al. 1982; Bailey et al. 1996; Baird 2009). The weights of “manta rays” (not identified to species) observed in tuna purse seine fisheries since 2005 have been reported in New Zealand’s “country reports” to the Western Central Pacific Fisheries Commission (WCPFC) (e.g. Anon 2010). Duffy (2005) reported occasional commercial captures of deepwater grey nurse and whale sharks. These sources and other literature found using abstracting databases and search engines were reviewed.

### Commercial catch and effort database (Warehou)

This database is maintained by the Ministry for Primary Industries (MPI). It was searched for all records containing the three-letter species codes for the eight species of interest up to the end of the 2010–11 fishing year (30 September 2011). Fishers began to record protected fish species on “non-fish bycatch” forms from 1 October 2008 onwards, so these were also searched for the eight species. Associated data extracted included date, location, fishing method, fishing gear details, target species, and processed state (if any). For basking sharks, our previous extracts up to 2007–08 (Francis & Smith 2010) were extended to 2010–11.

Most records came from Trawl Catch Effort Processing Returns and Catch Effort Landing Returns (CELR). Unfortunately, location data on CELR forms are usually only available at the resolution of a statistical area. However, in the last few years new catch-effort forms have been introduced for set net, line and trawl vessels over 6 m in length, and those forms require the recording of latitudes and longitudes. Data from these recent forms provided more precise location data for fishing operations that caught protected species from about 2005 onwards. The location data were plotted on maps. Statistical area centroids were used for records with no reported latitude and longitude. Reported catches (in number of records) were summarised by method, region, month and year. Information on the number and weight of fish caught was not consistently available or reliable (for example, non-fish bycatch forms contained no weight estimates but many numerical counts, whereas catch-effort forms usually gave weight estimates but no counts).

## **Central Observer database (COD)**

This database contains data collected by observers on fishing vessels, and is managed by NIWA for MPI. We extracted data up to the end of the 2010–11 fishing year for all eight species. The MPI Observer Programme provided photographs and notes from logbooks completed by observers. These sources were searched for relevant observations and data, particularly date and location of capture, fishing method, and fate (whether alive or dead when caught, and whether discarded whole or killed and processed in some way). We also searched for data and photographs relating to species identification, size and sex in order to characterise the composition of the bycatch and identify the vulnerable species and life history stages. We plotted maps of the location data, and summarised observed catches (in number of records) by method, region, month and year.

## **Data grooming and rationalisation**

Commercial captures of protected fish could potentially be recorded in three separate places: a catch-effort landing form, a non-fish bycatch form, and an observer form. We searched for duplicate records among these sources by comparing vessel key (an anonymous code number given to each vessel), date, location, time, species and (if available) weight. There was little temporal overlap between catch-effort landing forms and non-fish bycatch forms, and no duplicates were found. There was considerable duplication of captures between the observer forms and the other two sources. To avoid double-counting, duplicate records were deleted from the catch-effort landing data or non-fish bycatch data, and retained in the observer data. This means that the number of ‘commercial’ records reported below is underestimated relative to the number of ‘observer’ records. A small number of records with no catch locations or statistical areas were omitted from distribution maps but included in tabulated summaries.

In order to summarise reported commercial catch weights by fishing year, weights were summed by fishing year for all records, including duplicates. Tables of catch weights do not include observer records so there is no double-counting.

All records of “manta ray” (species code RMB) caught in purse seine nets were re-coded as spinetaildevilrays (MJA). Purse seine captures of mobulid rays are overwhelmingly or exclusively the latter; no manta rays have been confirmed caught by purse seiners in New

Zealand waters (Jones & Francis 2012), although that could potentially occur. Until recently, these two species were easily confused because of the lack of a readily available field identification guide. Other species coding errors were apparent in both fisher and observer records. Many of these errors were identified through implausible catch weights. The following records were deleted:

1. Basking shark (BSK) records less than 501 kg, as captures and sightings of basking sharks smaller than that are extremely rare worldwide (Francis & Smith 2010).
2. White shark (WPS) records less than 12 kg, the minimum recorded birth weight (Casey & Pratt 1985).
3. Deepwater nurse shark (ODO) records less than 7 kg, as birth occurs at about 100–110 cm total length (Fergusson et al. 2008).
4. Devilray (MJA) records less than 4 kg as birth occurs at 85–92 cm disk width (Last & Stevens 2009). However some of these records may have been of aborted embryos.
5. All whale shark (WSH) records, as they had catch weights of 3–16 kg.

Other implausible records were also deleted, including:

1. One record of 2000 kg of deepwater nurse shark from cod pots.
2. One record of 10 kg of manta ray (RMB) from an orange roughy trawl in FMA 4.
3. Forty-seven records of white shark (WPS) totalling 9,630 kg reported by one bottom trawler targeting barracouta, ling, arrow squid and silver warehou during a 101-day period (August–December 1990). There were often several records per day. Individual weights were 50–2500 kg. Tagging studies show that most white sharks have left New Zealand waters for tropical areas to the north at this time of year (Duffy et al. 2012).

Genetic analysis of tissue samples and examination of photographs have shown that a small number of observer identifications of basking and white shark were erroneous (Francis & Duffy 2002; Francis & Smith 2010), and these were corrected where possible.

## Results

### Interactions with commercial fisheries

#### Basking shark (BSK, *Cetorhinus maximus*)

Forty-three basking shark records were found to be duplicated between the catch-effort and observer databases, and they have been omitted from the former in subsequent analyses.

Basking sharks are frequently taken as bycatch around southern New Zealand. The main capture locations are the east coast South Island off Banks Peninsula, the west coast South Island between Westport and Hokitika, Puysegur, the shelf edge south and east of Stewart Island and the Snares Islands, and around the Auckland Islands (Figure 1) (Francis & Duffy 2002; Francis & Smith 2010; Francis & Sutton 2012). Basking sharks were mainly caught in FMAs 3, 5, 6 and 7 (Appendix 1). Captures (and sightings) of basking sharks also occurred around North Island but were relatively uncommon (Francis & Duffy 2002; Francis & Smith 2010).

Most basking shark records came from trawl fisheries (Table 1). The sharks were caught mainly by vessels targeting barracouta and hoki off east coast South Island, hoki off west coast South Island, and arrow squid off Southland–Auckland Island (Francis & Duffy 2002; Francis & Smith 2010). Basking sharks are also caught in set nets (Francis & Duffy 2002) but were rarely reported by fishers, and the observer coverage of this fleet is low, so the set net bycatch cannot be quantified. Basking sharks are rarely entangled in surface longlines.

Inter-annual variation in basking shark capture records was large, with peak observer records occurring in 1986–89, 1997–99 and 2002–03 (Appendix 1). Some years had very low or zero observer records. Most additional commercial records came from the early 2000s, but reporting rates appeared to be very low before 2000. Francis & Sutton (2012) found a highly significant association between the numbers of basking sharks caught and vessel nationality in each of the three main fishery areas. This was due to relatively large numbers of sharks being caught by Japanese vessels in the late 1980s and early 1990s. Other operational fleet variables and environmental variables examined were not correlated with shark catch rates. Reasons for the high catch rates by Japanese trawlers are unknown, but may relate to targeting of the sharks for their liver oil, or a high abundance of sharks in the late 1980s and early 1990s (Francis & Sutton 2012).

Most basking shark records were of catches made during spring–summer (October–March) (Table 1). However, the timing of captures varies geographically: a spring–summer peak occurs off the east coast of South Island, a summer peak off Southland, Stewart Island–Snares Shelf, and the Auckland Islands Shelf, and a winter peak off the west coast South Island (Francis & Duffy 2002).

Many of the observer basking shark records consisted of multiple sharks. The 174 observer trawl records comprised 275 individual sharks; most records (140 or 80%) consisted of single captures, and 169 (97%) were of 1–5 sharks, but there were also records of 7, 8, 9, 10 and 14 sharks in individual tows (Francis & Duffy 2002; Francis & Smith 2010; M. Francis unpubl. data). Shark weights were estimated by observers for 173 tows between 1986 and 2011, and they ranged from 250 kg to 57.8 t per tow; total shark weight was 972.8 t (average per tow = 5.6 t; average per shark = 3.6 t [274 sharks]).

Annual catch weights reported by commercial fishers ranged from 3 t to 150 t per year (Table 2). Catch weights before 1999–2000 were undoubtedly under-reported. Low catch weights from 2008–09 onwards do not reflect a shift of reporting from catch-effort forms to non-fish bycatch forms, as there were only nine basking sharks records on the latter, all in the 2010–11 fishing year (which is consistent with protection of this species in 2010).

The life status and destination (fate) of basking sharks were not recorded on the observer database. However, observer logbooks often recorded the life status of sharks, and these data have been summarised (M. Francis, unpubl. data): of 39 sharks whose life status was recorded, 29 (74%) were alive when landed on deck. But a number of these sharks were damaged while being dragged off the deck and discarded into the sea (tails were sometimes ripped off or gills damaged by strops placed around the head), and prior to their protection, many basking sharks were finned and the carcasses dumped. Thus few sharks were returned to the sea alive, and even fewer were likely to have survived their release.

Francis & Duffy (2002) reviewed other miscellaneous basking shark capture records. Notable among these was a report of 32 basking sharks caught by commercial trawlers off Hawke Bay between October and December 1997; this event was remarkable because of the paucity of basking shark captures in the region previously or subsequently.

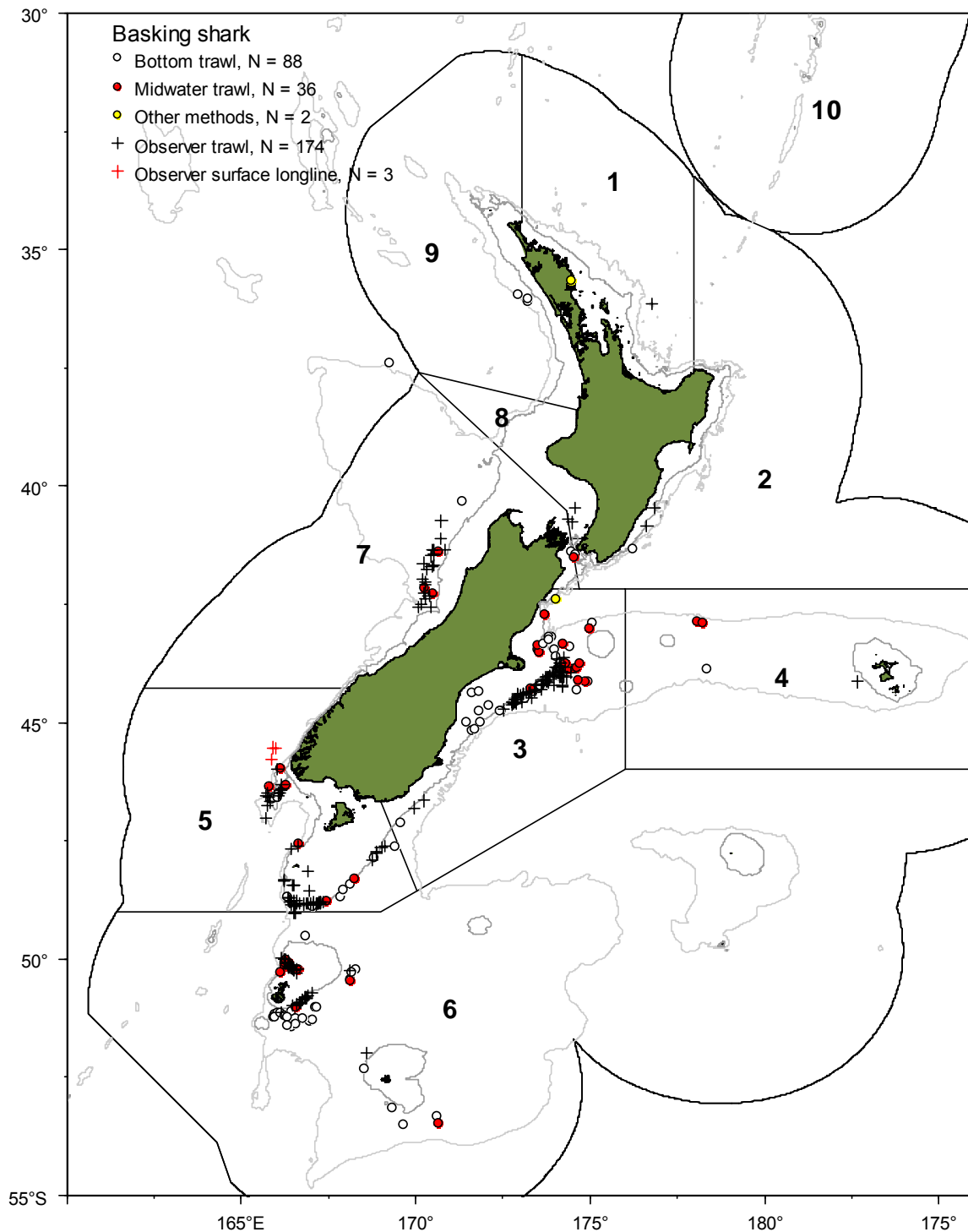


Figure 1: Reported capture locations of basking sharks in commercial (circles) and observer (crosses) data records. Some points represent multiple captures. Commercial records that duplicate observer records are not shown. The Exclusive Economic Zone and Fisheries Management Areas are shown as black lines. The dark and light grey lines indicate the 250 m and 1,000 m isobaths respectively.

Table 1: Commercial fisher and observer (Obs) records of protected fish species classified by fishing method and month. Commercial records that duplicate observer records are not shown. Species: BSK, basking shark; WPS, white shark; ODO, deepwater nurse shark; MJA, spinetaildevilray; SBG, spotted black grouper; GGP, giant grouper. Methods: TWL, bottom and midwater trawl; PS, purse seine; SN, set net; SLL, surface longline; BLL, bottom longline.

Species	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
BSK	TWL	20	11	10	5	4	5	3	1	4	8	12	43	126
	PS	1												1
	SN		1											1
	TWL (Obs)	33	23	20	9	2	6	11	5	6	15	17	27	174
	SLL (Obs)				2	1								3
	Sum	54	35	30	16	7	11	14	6	10	23	29	70	305
WPS	TWL		1	3				2		1			2	9
	SN		1	3	3		2	1			1	2	2	15
	SLL				1									1
	BLL	1			1			1						3
	TWL (Obs)	1	6	10	2			4	9	1		2	1	36
	SN (Obs)		2											2
	SLL (Obs)				2	1			1					4
	BLL (Obs)		1								1			2
Sum	2	11	16	9	1	2	8	10	2	2	4	5	72	
ODO	TWL	1											1	2
	SN					1						1	1	3
	TWL (Obs)	15	23	14	8			10		21	2	1	1	95
	BLL (Obs)										6			6
	Sum	16	23	14	8	1		10		21	8	2	3	106
MJA	PS	23	17	1									2	43
	SLL			1	1							1		3
	PS (Obs)	27	27	5										59
	SLL (Obs)	2		1										3
	Sum	52	44	8	1								1	2
SBG	SN		1	1			2				1			5
	TWL (Obs)							1						1
	Sum		1	1			2	1			1			6
GGP	SLL				1									1
	TWL (Obs)							1						1
	Sum				1			1						2



Table 2. Annual basking shark capture weights reported on commercial fishing returns. All commercial records are **included** in this table, including those that duplicate observer records. Year 1990 = Fishing year 1989–90.

Year	Weight (t)
1990	33.6
1991	70.0
1994	46.5
1995	9.0
1996	18.0
1997	12.0
1998	29.0
1999	15.5
2000	117.3
2001	134.9
2002	75.9
2003	150.1
2004	140.7
2005	72.0
2006	19.0
2007	21.9
2008	25.0
2009	3.4
2010	5.0
2011	5.5
Total	1004.2

### **White shark (white pointer shark, WPS, *Carcharodon carcharias*)**

Only one white shark record was found to be duplicated between the catch-effort and observer databases, and it has been omitted from the former in subsequent analyses.

White shark captures were reported from throughout mainland New Zealand and as far south as the Auckland Islands, but not from around the other outlying islands (Figure 2). Regions with multiple captures included the west coast South Island off Hokitika, the southern edge of the Stewart–Snares Shelf, and the Auckland Islands Shelf. White sharks were mainly caught in FMAs 1, 5, 6 and 7 (Appendix 1).

Most white shark records came from trawl and set net fisheries with few captures reported from surface and bottom longline (Table 1). Observer coverage of the set net and bottom longline fleet has been low, so the bycatch in these fisheries is likely to have been underestimated. White shark catches were reported throughout the year, with small peaks in February–April and July–August (Table 1).

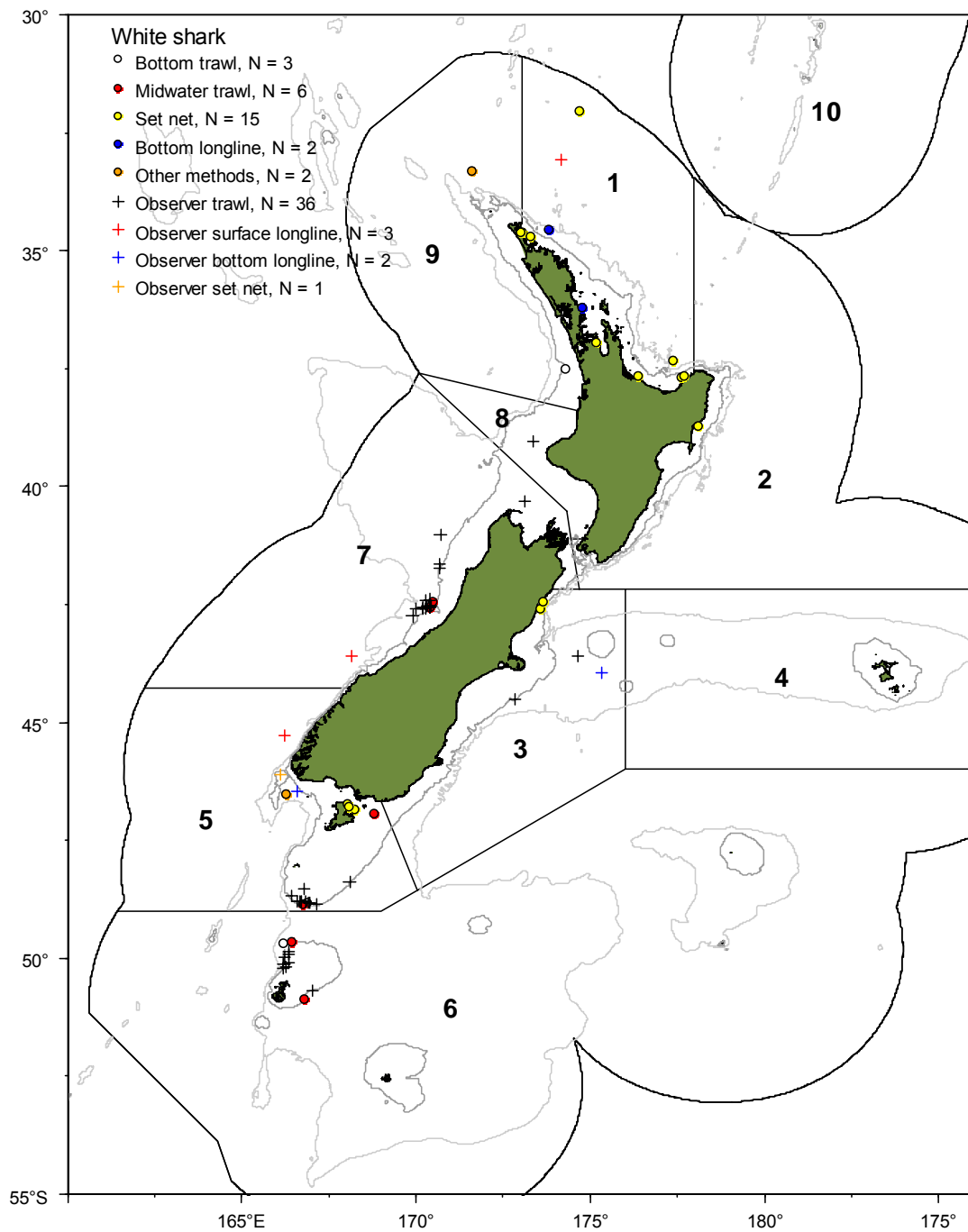


Figure 2: Reported capture locations of white sharks in commercial (circles) and observer (crosses) data records. Some points represent multiple captures. Commercial records that duplicate observer records are not shown. The Exclusive Economic Zone and Fisheries Management Areas are shown as black lines. The dark and light grey lines indicate the 250 m and 1,000 m isobaths respectively.

The three white sharks observed on surface longlines were recorded as struck off the line or lost, implying that they were released alive. One dead white shark observed caught in a set net in 2009 was retained, whereas another live shark was released alive. The life status of sharks observed caught on bottom longlines and in trawls was never recorded.

Annual catch weights reported by commercial fishers are shown in Table 3. A maximum of 6.3 t was reported in 1990, but catches reported in other years have been low (and often zero).

Further records of white sharks caught in fishing gear in New Zealand waters have been compiled by C. Duffy (Department of Conservation, pers. comm.) from a number of sources, including newspaper reports and personal communications with fishers. These records are being analysed by Duffy for his Ph. D. degree and are not included in the present study. Biological information, particularly, size, sex and maturity, was collected from some of the specimens brought in by commercial fishers over more than a decade (C. Duffy & M. Francis, unpubl. data). The numbers of white sharks being reported directly to scientists by fishers has dropped to negligible levels since the sharks were protected in 2007.

Table 3. Annual white shark capture weights reported on commercial fishing returns. All commercial records are **included** in this table, including those that duplicate observer records. Year 1990 = Fishing year 1989–90.

Year	Weight (t)
1990	6.3
1991	3.3
1996	0.2
1997	0.3
1999	0.0
2000	0.2
2002	0.7
2003	0.0
2004	3.6
2006	2.3
2007	0.2
Total	17.1

### **Whale shark (WSH, *Rhincodontypus*)**

No captures of whale sharks have been reported by fishers or observers in New Zealand waters. However, a single individual was caught by a coastal trawler off South Canterbury in the late 1970s (Duffy 2005).

### **Deepwater nurse shark (smalltoothsandtiger shark, ODO, *Odontaspis ferox*)**

Four deepwater grey nurse shark records were found to be duplicated between the catch-effort and observer databases, and they have been omitted from the former in subsequent analyses.

Deepwater nurse sharks have been reported frequently from along the edge of the continental shelf between Otago Peninsula and south of the Snares Islands (Figure 3). Clusters of records are also available from the Chatham Islands, and off Banks Peninsula and Farewell Spit. However, the southern limit of the known distribution of deepwater nurse sharks in New Zealand is a line from Cape Kidnappers in Hawke Bay to Cape Egmont (Duffy 2005; Fergusson et al. 2008; A. Stewart, Museum of New Zealand, pers. comm.). Given that most of the records in Figure 3 are from south of that range, and that many other ODO records were omitted because they were implausibly small, we believe that most records of this species are erroneous. Almost three-quarters (72%) of the ODO records came from observers in FMAs 3–5 during 1999–2000 and 2000–01 (Appendix 1). Discussions with the Observer Programme suggested that the species code ODO may have been incorrectly applied to other small shark species, perhaps school shark or rig (as they are sometimes called “sand sharks” which might be confused with “sandtiger sharks”) or deepwater dogfish (the code ODO may have been used thinking it applied to “other dogfish”).

We conclude that the only plausible commercial and observer database records of deepwater nurse shark captures are three from FMA 2 and one from the Louisville Seamount Chain (Figure 3). The only verified observer photograph we have seen of a deepwater nurse shark was of a ca 800 kg female caught in an orange roughy trawl tow at 883–928 m on the Louisville Seamount Chain in 2003–04 (Fergusson et al. 2008); ironically this shark was misidentified by the observer as a white shark. The two Hawke Bay observer records came from scampi and gemfish trawl tows at 340–359 m in 1996–97, and at 200–284 m in 1999–2000, respectively. The single commercial record from the Wairarapa coast came from a scampi trawl tow in 2002–03. No information was provided on life status or destination, so they were probably discarded.

A 188 cm total length (TL) immature female and a 164 cm female (presumably also immature) were caught in set nets off New Plymouth (Stewart 1997; Fergusson et al. 2008) and one of these is deposited in the Museum of New Zealand. Other specimens of deepwater nurse shark have been taken by trawl in Hawke Bay and by the NIWA research trawl vessel Tangaroa on the Norfolk Ridge (Garrick 1974; Stewart 1997; Fergusson et al. 2008), confirming that the species is occasionally caught by trawlers in northern waters. Two of the Hawke Bay sharks reported by Garrick (1974) were a 213 cm male and a 231 cm female respectively. Males mature at about 200–250 cm TL and females at 300–350 cm TL, indicating that these animals were probably immature. The 800 kg female caught on the Louisville Seamount Chain would likely have been mature.

Duffy (2005) cited anecdotal information that deepwater nurse sharks were “not uncommon” bycatch in a set net fishery operating around White Island and Volkner Rocks in the eastern Bay of Plenty, but noted that this fishery had ceased. Duffy (2005) and Fergusson et al. (2008) also reported the capture of deepwater nurse sharks from the same location for

display at Kelly Tarlton's Sealife Aquarium from the mid 1980s to the early 2000s, but all of the sharks died and the practice was discontinued.

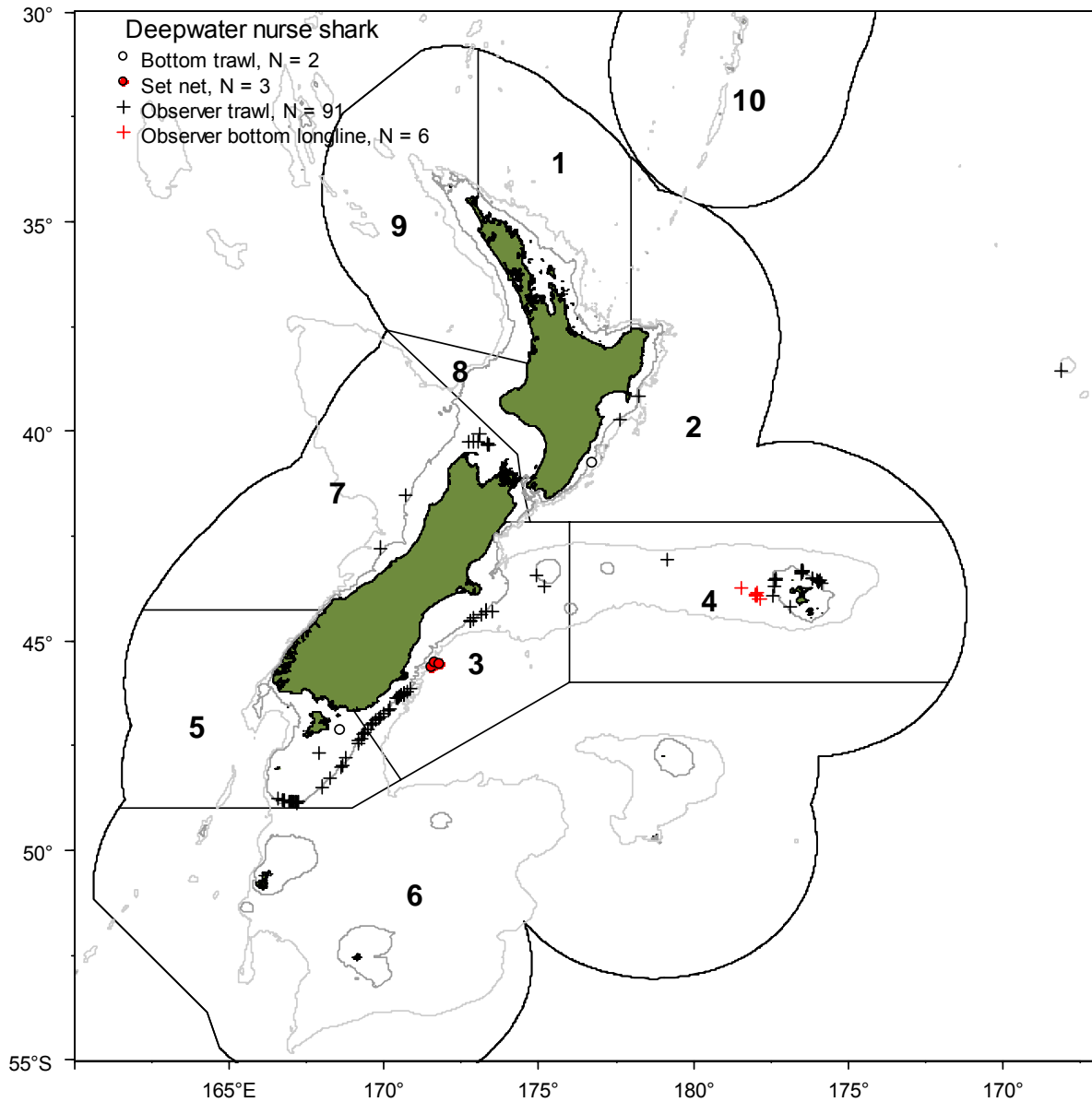


Figure 3: Reported capture locations of deepwater nurse sharks in commercial (circles) and observer (crosses) data records. Some points represent multiple captures. Commercial records that duplicate observer records are not shown. The Exclusive Economic Zone and Fisheries Management Areas are shown as black lines. The dark and light grey lines indicate the 250 m and 1,000 m isobaths respectively.

## **Spinetail devilray and manta ray (MJA, MNT, RMB, *Mobulajapanica*, *Manta birostris*)**

Most if not all mobulid rays reported caught in commercial fisheries are likely to have been spinetail devilrays (Paulin et al. 1982); no manta rays have been confirmed caught in New Zealand waters (Duffy 2005; Jones & Francis 2012). However, positive identification of mobulids has been hampered until recently by the unavailability of suitable field identification guides. It is possible that manta rays are occasionally caught in purse seines along the north-east coast of North Island.

Twenty-one devilray records were found to be duplicated between the catch-effort and observer databases, and they have been omitted from the former in subsequent analyses.

All commercial and observer records of mobulid rays, assumed here to be mostly if not exclusively spinetail devilrays, were from the northern North Island in FMAs 1 and 9 (Figure 4, Appendix 1). Most records came from purse seine vessels (Table 1). Most observer records were from the edge of the continental shelf between the Bay of Islands and Great Barrier Island; this concentration of ray catches is not an artifact of the distribution of observer or purse seine fishing effort, which were both much more widely spread along the north-east and north-west coasts of North Island (Jones & Francis 2012). Two clusters of commercial purse seine points at about 35.5 °S (open circles) in Figure 4 represent jittered records plotted at the centroids of statistical areas 3 and 4; actual capture locations were more likely to have been near the 250 m depth contour in the line of observer records (crosses). Commercial purse seine records are available from the eastern Bay of Plenty, and there are a few commercial and observer records from the North Taranaki Bight. Most devilrays have been caught over seabed depths of 150–350 m (Jones & Francis 2012). Three devilrays have been reported on surface longlines, mainly near the 1,000 m depth contour. It is not known whether these rays were hooked or were tangled in the backbone or float line of the gear; mobulid rays are planktivorous, but they are known to attack and become hooked on trolled lures (Duffy 2005).

Most mobulid rays were recorded in summer (January–March) (Table 1). Observer and commercial records were not available before 2001–02 (Appendix 1) (Baird 2009), although devilray bycatch in purse seine catches was documented between 1975 and 1981 by Paulin et al. (1982). All observed devilrays were discarded by fishers. The three rays caught on surface longlines were alive when retrieved, but the life status of rays caught in purse seines was not recorded.

Annual catch weights have only been reported by commercial fishers since 2003–04, and were less than 5 t per year (Table 4).

Table 4. Annual devilray capture weights reported on commercial fishing returns. All commercial records are **included** in this table, including those that duplicate observer records. Year 2004 = Fishing year 2003–04.

Year	Weight (t)
2004	1.5
2005	1.0
2006	0.1
2007	3.6
2008	3.3
2009	4.7
2010	0.8
Total	15.0

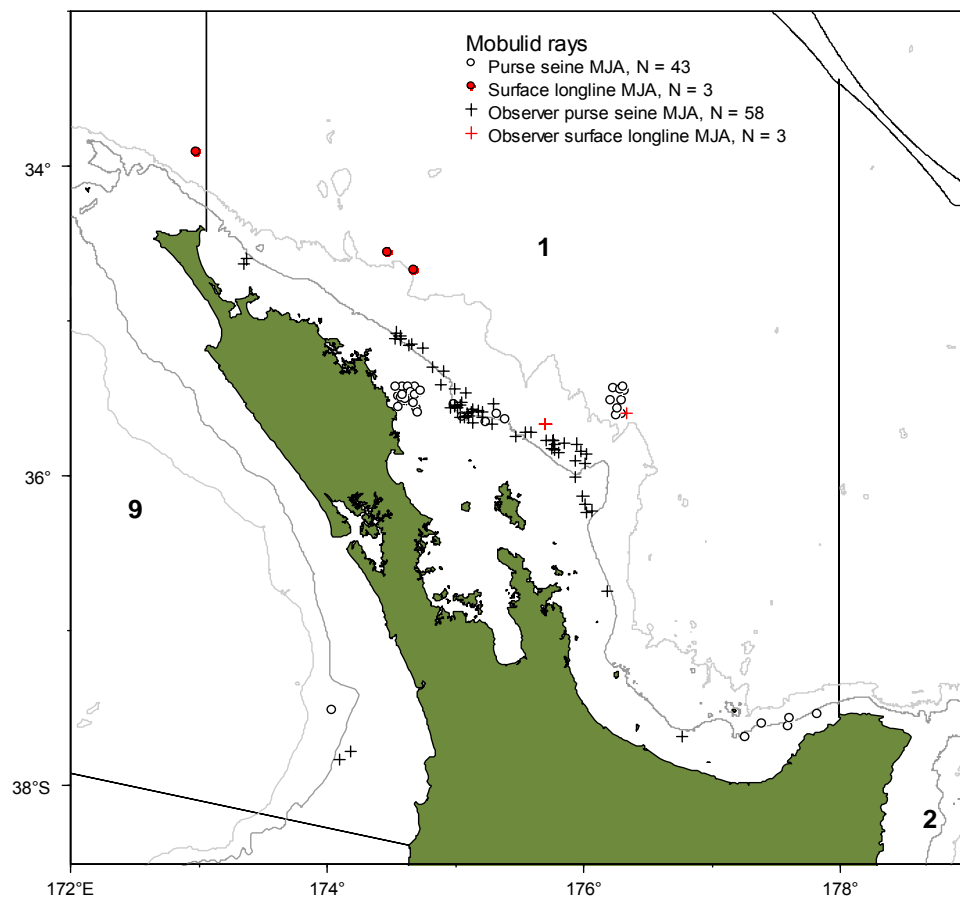


Figure 4: Reported capture locations of spinytail devilray in commercial (circles) and observer (crosses) data records. Some points represent multiple captures. Two clusters of commercial purse seine points at about 35.5 °S (open circles) represent jittered records plotted at the centroids of statistical areas 3 and 4; actual capture locations were more likely to have been along the 250 m depth contour near the line of observer records (crosses). Commercial records that duplicate observer records are not shown. The Exclusive Economic Zone and Fisheries Management Areas are shown as black lines. The dark and light grey lines indicate the 250 m and 1,000 m isobaths respectively.

Observers operating during 1975–81 reported devilrays as bycatch in the purse seine fishery, but these data are not available in the observer database (COD). The species caught was often called “manta ray” but specimen identification indicates that most if not all were spinetail devilrays (*Mobula japonica*). Habib et al. (1982) noted the capture of “manta ray”, but provided no details in their data tabulation. These data may have been purposely omitted in favour of their inclusion in a paper reporting spinetail devilray from New Zealand for the first time (Paulin et al. 1982). Paulin et al. (1982) reported data for 235 specimens of spinetail devilray caught by purse seiners between 1975 and 1981. The rays were caught at (presumably surface) temperatures of 17.2–22.5 °C over seabed depths of 110–434 m. 128 specimens were measured, which ranged between 100 and 310 cm disk width (DW). Five foetuses measured 58–85 cm DW. Bailey et al. (1996) analysed New Zealand Ministry of Agriculture and Fisheries observer data for 904 sets in the purse seine fishery between 1976 and 1982. They found that 74 sets (8.2%) contained “manta ray (*Mobula japonica*)” with an average number of 2.2 rays per occurrence, suggesting a total of about 163 rays caught in 904 sets (0.18 per set) (Jones & Francis 2012).

Two spinetail devilrays were reported caught by a purse seine vessel in the northern Bay of Plenty in 2002 and deposited in the Museum of New Zealand; they were a 252 cm DW adult male and a 56 cm DW unsexed newborn juvenile (Stewart 2002). Calendar year bycatch of mobulid rays in purse seine fisheries since the mid 2000s (the same period covered by our database extract and analyses above) has been reported in New Zealand’s “Country reports” to the Western Central Pacific Fisheries Commission (WCPFC) (Anon 2010). Comparisons of the data in the Country Reports with those in Table 4 above are impossible because the former are for calendar years and are sometimes aggregated across two years (see Jones & Francis 2012).

### **Spotted black grouper (SBG, *Epinephelus daemeli*)**

Only six commercial and observer records of spotted black grouper were found (Figure 5, Table 1, Appendix 1). Five records were from the far north in FMAs 1 and 9, consisting of four set net records from east Northland and one observer trawl record from the West Norfolk Ridge. The four set net records came from sets targeting trevally, but no weight or destination information was provided. The identification of the observer trawl record is dubious because it was a 1 kg fish caught in an orange roughy trawl at 1186–1390 m depth; spotted black grouper typically inhabit rocky reefs at depths less than 50 m, and small juveniles are particularly tied to reef habitat with caves, large boulders and overhangs for shelter (Francis 2001). The sixth record was caught in a set net near Wellington in the south of FMA 2; that fish was kept alive at the Island Bay Marine Education Centre for just over one month before it died. Necropsy determined that the fish was an immature female measuring 590 mm standard length (about 69 cm TL) and weighing 6.1 kg (A. Stewart, Museum of New Zealand, pers. comm.).



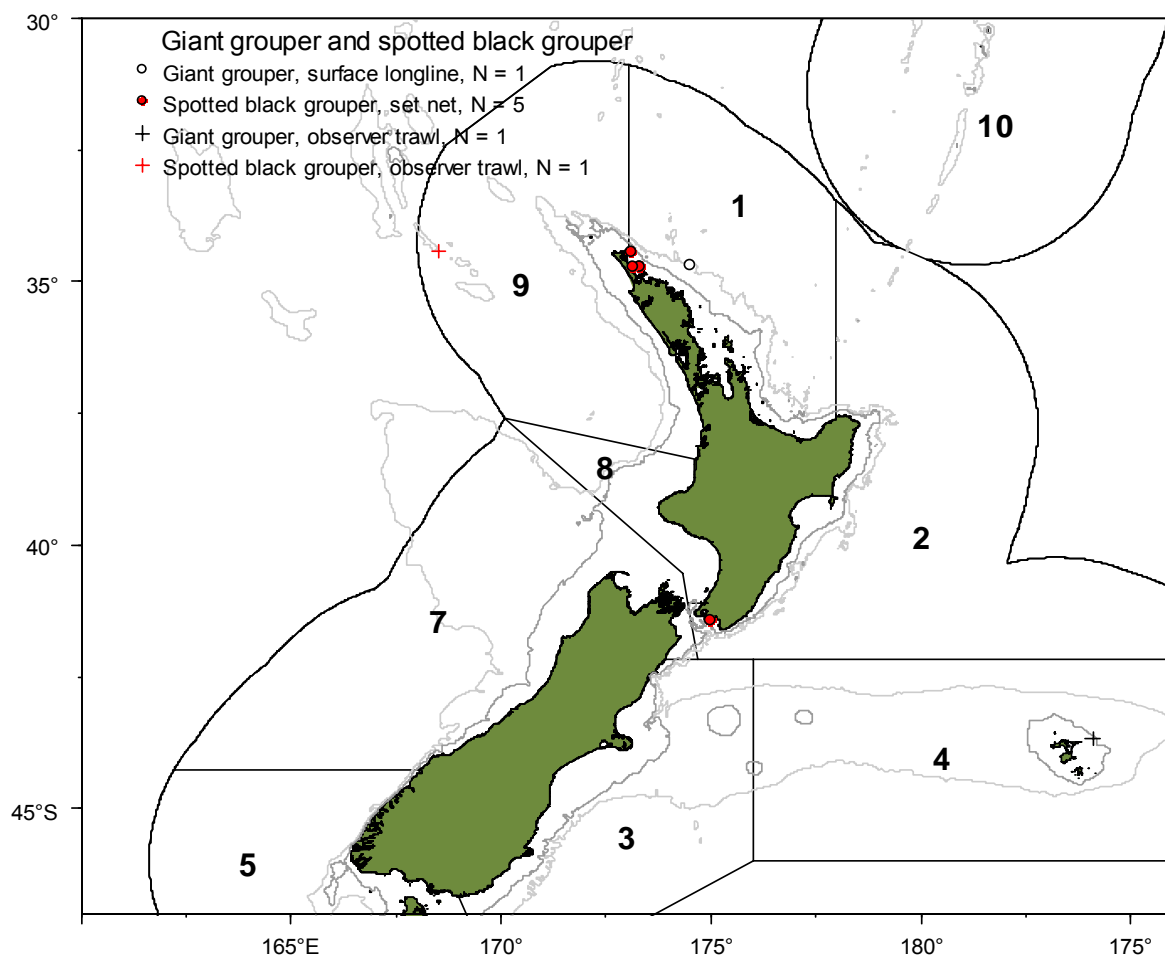


Figure 5: Reported capture locations of giant and spotted black grouper in commercial (circles) and observer (crosses) data records. Some points represent multiple captures. Commercial records that duplicate observer records are not shown. The Exclusive Economic Zone and Fisheries Management Areas are shown as black lines. The dark and light grey lines indicate the 250 m and 1,000 m isobaths respectively.

### **Giant grouper (GGP, *Epinephelus lanceolatus*)**

Only two records of giant grouper are known. One commercial record came from a surface longline targeting bigeye tuna off east Northland (Figure 5, Appendix 1); the fish was recorded as “Green” suggesting it was landed whole. One observer record came from a trawl tow off the Chatham Islands. It was caught in a barracouta tow in 217–235 m of water in 2007–08, and the grouper was estimated to weigh 30 kg; no other information was recorded. The identification of this observer record remains unconfirmed because no other records of the species are known from south of East Cape.

## Information gaps and recommendations

There are three major deficiencies in the analyses of interactions of protected fishes with commercial fisheries that are presented above:

1. Identification of protected species by both observers and fishers has historically been poor.
2. Many captures of protected species are not reported by commercial fishers.
3. Observer coverage of many commercial fisheries has been low or non-existent.

The eight fish species protected in New Zealand waters are only occasionally encountered by commercial fishers, and most of them can be confused with other similar species. Hence it is not surprising that fishers and observers often misidentify these species when caught. In this study we discovered many records of non-protected fishes that were identified as protected species (presumably these were mainly a result of applying an incorrect species code). The converse, where protected species are incorrectly identified as non-protected species, cannot easily be detected from the data, and may be a much more significant issue. Recently, NIWA produced three fish identification guides for the Ministry for Primary Industries (McMillan et al. 2011a; 2011b; 2011c). All eight protected species are included in the guides, so if the guides are distributed widely among fishers and observers, identification of these species should improve in future. Efforts should be made to ensure that the guides are available to all New Zealand fishers.

Fishers are inherently wary about reporting the capture of protected species, even though this is a legal requirement. Fishers may not realise that it is not an offence to catch protected fishes, as long as the capture was incidental to legal fishing operations. Alternatively, they may wish to hide the extent of fishing mortality on protected species to avoid the possible implementation of fishing restrictions designed to reduce such mortality. Under-reporting of protected species introduces a major bias into estimates of fishery interactions. Measures that might increase the reporting rate of protected species captures should be explored.

Observer coverage has been reasonably good over the last decade or more in some large valuable fisheries (e.g. trawl fisheries for hoki and orange roughy (Anderson 2011)), and on chartered foreign fishing vessels (e.g. in the tuna longline fishery (Griggs et al. 2008)). Trawl fisheries around southern New Zealand and tuna purse seine fisheries in northern New Zealand, receive reasonable coverage, providing good information on captures of basking sharks, white sharks and spinytail devilrays. But observer coverage has not always been representative of the spatial and temporal distribution of these fisheries. Furthermore, other fisheries, notably inshore set net, bottom longline, and trawl fisheries, have received only sparse observer coverage. Those fisheries may have a significant, cryptic mortality of some protected species, especially basking shark, white shark, deepwater nurse shark, and spotted black grouper. Bycatch of whale shark and giant grouper is probably negligible in New Zealand waters. Attempts by MPI to increase observer coverage in some inshore fisheries, and in the domestic tuna longline fishery, have been hindered by the practical difficulties of deploying observers on small fishing vessels. Video technology may offer a

solution in such situations, as all of our protected fish species grow to a large size, and can be readily identified to at least genus level from a distance of several metres.

Addressing these three deficiencies will not be simple, and may require increased resources as well as greater focussing and prioritisation of existing resources. But even incremental progress in these areas would greatly enhance our knowledge of the interactions between protected species and fishing gear.

## **Population information**

### **Basking shark**

#### Genetic stock structure

Hoelzel et al. (2006) found little genetic variation in the basking shark mitochondrial DNA control region among samples from the western North Atlantic, eastern North Atlantic, Mediterranean Sea, Indian Ocean and western Pacific (including 33 samples from New Zealand). They also found no genetic differentiation among the ocean basins. By contrast, Noble et al. (2006) found higher levels of mitochondrial DNA variation that clearly distinguished Atlantic and Pacific populations (the latter including a specimen from New Zealand). Furthermore, they found variation in microsatellite DNA that distinguished northern and southern hemisphere basking sharks. Noble et al. (2006) noted that larger sample sizes and samples from more geographic areas were required to adequately assess basking shark stock structure.

#### Evidence of the scale of movement and migration from tagging studies

Relatively little tagging has been conducted on basking sharks, but there is clear evidence that they are capable of moving large distances. Sharks tagged in the Isle of Man, United Kingdom, have travelled 1800 km to Scotland and 9600 km across the Atlantic to near Newfoundland, Canada (Gore et al. 2008). Sharks tagged off Massachusetts in the northwest Atlantic have migrated as much as 6500 km (five sharks moved more than 2400 km) southwards along the eastern USA into the Caribbean and as far south as Brazil (Skomal et al. 2004; 2009).

#### World distribution and any barriers to movement

Basking sharks are known to occur in the Atlantic and Pacific oceans, but not the Indian Ocean. Until recently they were thought to be limited to temperate and subantarctic water masses in the northern and southern hemispheres (Last & Stevens 2009), but electronic tagging has shown that they can traverse tropical regions by submerging into deeper colder water (Skomal et al. 2009). Thus their distribution should be considered to range from subantarctic to tropical waters in the Atlantic and Pacific oceans.

#### Habitat requirements and constraints

Basking sharks are mainly observed in shallow coastal waters in highly productive areas during spring–summer where they feed on plankton blooms (Sims 2008). However tagging and capture records have shown they can dive as deep as 1264 m and there are many

records from 600–1000 m (Francis & Duffy 2002; Sims et al. 2003; Gore et al. 2008; Skomal et al. 2009). Basking sharks have also been recorded in brackish Lake Ellesmere (Francis & Duffy 2002).

#### Growth rate

Basking shark vertebrae contain growth bands but these vary in number along the length of the vertebral column, and about seven bands are already present at birth; this indicates that basking sharks cannot be aged from their vertebrae (Natanson et al. 2008). Other estimates of growth were well summarised by Sims (2008). Various estimates have been made using length-frequency distributions, and observation of growth in a tagged shark, but they are very speculative, being based on untested assumptions, or imprecise: a range of 0.4–0.8 m per year has been suggested.

#### Longevity

Longevity is unknown but has been suggested to be more than 50 years (Pauly 2002). Maximum length for a measured shark appears to be 10.43 m for a New Zealand shark (Cheeseman 1891; Francis & Duffy 2002).

#### Length and age at maturity

Male basking sharks mature at about 7.5 m TL and females possibly at about the same size (Matthews 1950; Matthews & Parker 1950; Francis & Duffy 2002). Given the inability to age basking sharks, estimates of age at maturity are currently impossible.

#### Fecundity and reproductive rate

Little is known about reproduction in basking sharks, except that they are viviparous (live-bearing), and probably oophagous (the embryos are nourished by eggs produced by the mother). There are only three accounts of basking shark embryos; all were second-hand reports, and all gave only cursory details. Pennant (1769) recorded 'a young one about a foot [30 cm] in length being found in the belly' of a basking shark. Sund (1943) reported six embryos about 1.5–2.0 m long being born after their mother was harpooned in Norway. And Matthews (1950) cited an unconfirmed report of a pregnant female having a six-foot [1.8 m] long embryo. Given the large size of embryos at birth, and by analogy with other oophagous sharks such as shortfin mako and porbeagle sharks, the gestation period is likely to be lengthy (one year or more), the reproductive cycle extended (there may be a resting period between pregnancies), and fecundity low (almost certainly less than 10 per year).

#### Natural mortality rate

Pauly (2002) estimated the natural mortality rate  $M$  as 0.068, but as this was based on questionable growth parameters, its accuracy is dubious.

#### Spatial and temporal distribution of species

Basking sharks occur throughout New Zealand, but most records are from south of Cook Strait (Francis & Duffy 2002).

## Distribution of relevant fisheries

The interaction between trawl fisheries and basking sharks has been intensively studied (Francis & Duffy 2002; Francis & Smith 2010; Francis & Sutton 2012). However, basking sharks are also caught in set net fisheries, but the extent and location of captures are not well known.

## Vulnerable components of population (size and sex composition)

Basking sharks of both sexes and lengths between 4 m and 10 m are caught in New Zealand trawl fisheries (Francis & Duffy 2002; Francis & Smith 2010). Small sharks are rarely seen worldwide and their habitat is unknown, although a 2.9 m TL shark was reported caught in a driftnet in the South Pacific (Yatsu 1995).

## Trends in catches and population biomass

No information is available on basking shark population biomass trends in New Zealand waters. However, trends in catches have been analysed in detail (Francis & Smith 2010; Francis & Sutton 2012). Elsewhere, basking sharks populations have shown substantial decline in areas subject to target fisheries and eradication programmes, although it appears that spatial changes in the abundance of their planktonic food may have contributed to some of these trends (reviewed by Sims 2008).

## Trends in size composition

No information is available on trends in basking shark size composition.

# **White shark**

## Genetic stock structure

Several distinct genetic stocks have been identified worldwide. Pardini et al. (2001) showed that sharks from South Africa were genetically distinct from those in Australia and New Zealand, and this has been confirmed in more recent studies (Jorgensen et al. 2010; Tanaka et al. 2011). Northeast Pacific Ocean (Jorgensen et al. 2010) and northwest Pacific Ocean (Tanaka et al. 2011) white sharks are genetically distinct from those in the South Pacific. Finer scale spatial population structuring has also been demonstrated. Genetically distinct populations of white sharks have been identified in eastern and western Australia waters, albeit with a low level of migration between regions (Blower et al. 2012). Tagging of white sharks in New Zealand waters has shown no direct migration between major centres of abundance at Stewart Island and the Chatham Islands (although sharks from these areas do mingle in tropical waters) (Duffy et al. 2012), suggesting that New Zealand may have two or more different populations.

## Evidence of the scale of movement and migration from tagging studies

White sharks tagged at Stewart Island and the Chatham Islands nearly all migrate to tropical and subtropical waters north of New Zealand (in an arc between the Great Barrier Reef of Australia and Tonga) during winter and spring (Bonfil et al. 2010; Duffy et al. 2012). A small number of sharks also migrate southwards along the New South Wales coast. Many, probably most, of these sharks return to their New Zealand tagging sites during the following

summer–autumn (M. P. Francis & C. Duffy, unpubl. data), indicating that they undergo an annual return migration. Several white sharks tagged in Australia have also been recorded in New Zealand (Bruce et al. 2006; Bruce & Bradford 2012). Thus New Zealand white sharks spend a considerable part of the year (half or more) outside the EEZ in waters of the south-west Pacific.

#### World distribution and any barriers to movement

White sharks occur throughout the world in tropical, temperate and subantarctic waters, but are uncommon in equatorial regions (Last & Stevens 2009). Genetic and tagging information indicate that white sharks may migrate large distances (see above) but that they rarely if ever cross the equator, and they form regionally distinct stocks in each hemisphere.

#### Habitat requirements and constraints

White sharks range from depths of less than 1 m in shallow harbours to at least 1200 m in oceanic basins (Francis et al. 2012). In New Zealand, juvenile white sharks less than about 2 m TL are most common in shallow coastal waters and large harbours around the northern North Island (C. Duffy, unpubl. data). Larger animals are found throughout New Zealand and undertake large-scale migrations between cold temperate and tropical habitats, ranging from rocky reefs, through open ocean to coral reefs. During summer–autumn they tend to aggregate in areas inhabited by large concentrations of marine mammals (particularly fur seals) and inhabit depths of less than 50 m; during winter and spring they cross open oceans, diving to depths greater than 800 m (although spending most time at the surface) (Francis et al. 2012). In tropical waters, white sharks prefer depths shallower than 75 m, but spend significant amounts of time diving to depths of 300–400 m adjacent to coral reefs, seamounts and ridges (Francis et al. 2012).

#### Growth rate

Estimates of growth in white sharks are inadequate, being based on either small samples, or samples lacking large animals (Bruce 2008). Furthermore, there is some doubt whether vertebral bands are formed annually in all animals at all times and further validation is required (Kerr et al. 2006). Nevertheless, the four studies that have been done (Cailliet et al. 1985; Wintner & Cliff 1999; Malcolm et al. 2001; Tanaka et al. 2011) suggest that growth rates vary among populations, with growth being fastest in Japan, intermediate in California and South Africa and slowest in Australia. Australian sharks were estimated to reach lengths of 2 m in 3 years, 3 m in 6 years, 4 m in 11 years and 5 m in 18 years (using “low” band counts) (Malcolm et al. 2001).

#### Longevity

Longevity is unknown. The oldest aged animals have been in the range 21–25 years (Francis 1996c; Bruce 2008). Age estimates are not available from sharks over 6 m, and vertebral counts may underestimate age in large sharks (Francis et al. 2007), so longevity is likely greater than this, probably in the order of 30–40 years and possibly higher (Bruce 2008).

#### Length and age at maturity

White sharks mature at lengths of about 3.6–3.8 m TL for males and 4.5–5.0 m TL for females (Francis 1996c; Pratt 1996; Bruce 2008). These lengths correspond with ages of

about 9–10 years and 14–18 years respectively based on Australian growth curves (Malcolm et al. 2001).

### Fecundity and reproductive rate

Few pregnant females have been studied, so information on the reproductive cycle is sparse. Litter size ranges from two to 10, though the lower values may represent incomplete litters; larger reported values (up to 17) are probably erroneous (Francis 1996c; Cliff et al. 2000; Bruce 2008). The length of the gestation period and the reproductive cycle are uncertain, but a variety of indirect evidence suggests gestation may be of the order of one year and the reproductive cycle may be 2–3 years (Francis 1996c; Mollet et al. 2000; Bruce 2008). Male and smaller female white sharks are usually absent from coastal aggregation sites in California and Mexico for one year, compared with two years for large and presumably mature females (Anderson & Pyle 2003; Domeier & Nasby-Lucas 2012; Nasby-Lucas & Domeier 2012). This suggests that mature females may inhabit offshore waters during a reproductive cycle that lasts two years.

### Natural mortality rate

The natural mortality rate of white sharks is unknown. A longevity of 30–40 years suggests a value of  $M$  of about 0.11–0.15 (Hoenig 1983).

### Spatial and temporal distribution of species

White sharks occur throughout New Zealand waters, from the Kermadec Islands to Campbell Island and at the Chatham Islands. Most subadults and adults emigrate to subtropical and tropical waters during winter–spring, but some of them, and small juveniles, occur in coastal waters year-round (Duffy et al. 2012).

### Distribution of relevant fisheries

White sharks have been reported or observed caught in commercial fisheries throughout their New Zealand range, except at the Kermadec Islands and Campbell Island (Figure 2; M. Francis & C. Duffy unpubl. data). Trawl, set net and line fisheries all catch white sharks but are probably not well reported. New Zealand white sharks are probably also caught outside the EEZ by fisheries and beach-protection programmes (using set nets or droplines) in the islands of the tropical southwest Pacific and off Queensland and New South Wales.

### Vulnerable components of population (size and sex composition)

All size classes and both sexes are vulnerable to commercial fisheries, although very large females are rarely caught.

### Trends in catches and population biomass

There are no time series of catches or estimates of population biomass for New Zealand white sharks. Elsewhere, such information is very limited because of the difficulty of obtaining data. In South Africa, there was no trend in catch rate data from beach-meshing programmes between 1978 and 2003 (Dudley & Simpfendorfer 2006). The catch rate of white sharks in New South Wales' beach-meshing programme declined by about two-thirds between 1950 and 2010, and there was a significant reduction in the proportion of larger (longer than 2.5 m TL) sharks (Reid et al. 2011). A report of a 79% decline in the abundance of white sharks in



the northwest Atlantic (Baum et al. 2003) is erroneous. It was based on a misinterpretation of fishery logbooks: whitetip sharks were mistakenly interpreted as white sharks.

#### Trends in size composition

There is no information on trends in size composition of New Zealand white sharks. In South Africa, the median size of male and female white sharks caught in nets in beach-meshing programmes during 1978–2003 showed no trend, and neither did the mean size of males; however the mean size of females declined initially and then stabilised (Dudley & Simpfendorfer 2006).

### **Whale shark**

#### Genetic stock structure

Castro et al. (2007) analysed the mitochondrial control region of DNA from 70 whale sharks from six areas around the world. They identified 51 polymorphic sites in 44 haplotypes, but found no evidence of geographical clustering (Rowat & Brooks 2012). Microsatellite analysis of whale sharks sampled primarily at feeding aggregations around the world showed little genetic differentiation (Schmidt et al. 2009). The Pacific and Indian Ocean populations were very similar, but there was subtle differentiation between Caribbean and Indian Ocean whale sharks. Despite this, the data show that there has been significant gene flow between geographically disparate populations. Individual-based analyses indicate no clear genetic clusters of whale sharks based on sampling location (Schmidt et al. 2009).

#### Evidence of the scale of movement and migration from tagging studies

Recent satellite tagging of whale sharks has demonstrated that they undertake multi-annual, long-distance migrations. These include a 2,000 km, two month migration from the Mindanao Sea, inner Philippines, to south of Vietnam (Eckert et al. 2002), and a 13,000 km migration over 37 months from the Gulf of California, Mexico, to near Tonga (Eckert & Stewart 2001; Norman 2005). Whale sharks travel thousands of kilometres across ocean basins and through multiple political jurisdictions (Eckert & Stewart 2001; Eckert et al. 2002; Wilson et al. 2006; Brunnschweiler et al. 2009). New Zealand almost certainly shares its whale shark population with a number of other regional states, including the islands of the south-west Pacific Ocean, Australia, Indonesia and the Philippines (Duffy 2005). Despite these large movements, tagging and photo-identification studies have shown whale sharks to be philopatric, returning to the same seasonal feeding grounds in successive years (Taylor 1994; Compagno 2001; Duffy 2005).

#### World distribution and any barriers to movement

Whale sharks are circumglobal in all tropical and warm temperate seas from 30° N to 30° S (Compagno 2001). They were thought to be absent in the Mediterranean Sea, but recent sightings have confirmed their presence there (Jaffa & Taher 2007). They have also been recorded off South Africa between 30 and 35° S and off New Zealand between 34 and 38° S (Duffy 2002; Compagno et al. 2005). There are also occasional sightings in latitudes with far cooler temperatures, as far as 41° N off the Scotian and northern Californian coasts (Coad 1995; Ebert et al. 2004) and at 44° N in the Bay of Fundy, Canada (Turnbull & Randell

2006). This increased range into higher latitudes may be enabled by localised areas of warm water due to oceanic currents (Rowat & Brooks 2012).

#### Habitat requirements and constraints

Whale sharks are epipelagic and are found in both oceanic and coastal waters, forming fairly predictable seasonal aggregations at some sites (Colman 1997; Compagno 2001; Rowat & Brooks 2012). Whale sharks have been recorded diving to depths well into the mesopelagic and bathypelagic zones (1286 m) in a bathymetrically non-constraining habitat. The water temperature range recorded during this shark's movement was 3.4–29.9° C (Brunnschweiler et al. 2009).

#### Growth rate

Only 19 whale sharks less than 1.5 m long have been reported, most of which have been captured in fishing gear. One embryo from India was 94 cm TL (Manojkumar 2003), and a free-swimming neonate from the Philippines was 46 cm (Aca & Schmidt 2011). These findings suggest that whale sharks vary considerably in size at birth (Rowat & Brooks 2012).

The only growth study of a wild population is that of Wintner (2000) from South Africa. Based on X-radiography of 15 whale shark vertebrae (418–770 cm pre-caudal length; PCL) she found a linear relationship between length and the number of growth rings. The maximum number of growth bands observed was 31 (770 cm PCL). A 670 cm male had 20 growth bands, and a 445 cm female had 22 bands (Stevens 2007). The study was limited by the lack of very large animals. However the growth rate estimates were similar to those of captive animals, and one captive animal has been shown to form annual growth bands on its vertebrae (Wintner 2000).

Uchida et al. (2000) recorded mean annual growth rates of 22–30 cm for one female and two males between 365–450 cm TL while housed at the Okinawa Aquarium during a 1.3 to 2.8 year period (Stevens 2007).

#### Longevity

Maximum age is unknown for this species. Pauly (2002) tentatively suggested they have a slow growth rate and longevity of 60 to more than 100 years (see also Norman 2005).

The largest whale shark so far reported was a female caught in Taiwan in 1987 that was an estimated 20 m in length and 34 tonnes in weight (Chen et al. 1997; Chen & Phipps 2002). The next largest was 18.8 m from India (Borrell et al. 2011; Rowat & Brooks 2012).

#### Length and age at maturity

Estimation of the size at first maturity has been limited by poor access to specimens. In stranded specimens from South Africa, three males of 9.03–9.45 m TL were classed as mature, while three other males of 8.66–9.10 m TL were immature (Wintner 2000). Another seven stranded South African females of 4.8–8.7 m TL were immature (Beckley et al. 1997). Between 1995 and 1997, 360 observations of whale sharks at Ningaloo Reef, Australia revealed that all males shorter than 7 m TL were immature and only 36.6% of males between 8 and 9 m TL were mature. All but one whale shark longer than 9 m was mature (Norman &

Stevens 2007). Overall, it appears that males mature at about 9 m TL and females at a similar or larger size (Rowat & Brooks 2012).

### Fecundity and reproductive rate

A pregnant 10.6 m TL whale shark was landed at a Taiwan fish market and had 304 embryos in her two uteri (Joung et al. 1996). Many embryos were still in their egg cases with external yolk sacs, but many had hatched and had no yolk sacs. This proved conclusively that whale sharks are aplacental viviparous. Recent genetic analysis of 29 pups of various sizes from that litter found that all had been sired by the same father (Schmidt et al. 2009).

### Natural mortality rate

Pauly(2002) reanalysed published whale shark length-frequency data and suggested a low natural mortality rate of 0.05–0.07. Predation rates are probably low because of the large size of whale sharks. There are two reports of juvenile whale sharks being killed by other animals; one was a blue marlin (A. Goorah, pers. comm.) and the other was a blue shark (Kukuyev 1996). Two orcas have been filmed attacking, killing and consuming an 8 m whale shark (Norman 2005).

### Spatial and temporal distribution of species

Whale sharks migrate annually during summer to northeast New Zealand, with sightings usually associated with the East Auckland Current (Duffy 2002, unpubl. data). Rarely, they may range south to Fiordland and South Canterbury in extraordinarily warm years (Duffy 2002, unpubl. data). Sightings occur from November to March but are most common during February. Whale shark size in New Zealand waters ranges from 4 to 15 m TL, with 73% of sightings being 6–9 m (Duffy 2002; Duffy 2005), suggesting that most animals are immature. Whale sharks in New Zealand waters are part of a more-widely distributed population that may range through a large part of the Pacific Ocean and possibly also the Indian Ocean.

### Distribution of relevant fisheries

No fisheries impact whale sharks in New Zealand waters, with only a single individual of about 12 m TL known to have been caught accidentally by a small trawler off South Canterbury in the late 1970s(Duffy 2005). Whale sharks occurring in New Zealand waters may be caught by fisheries operating elsewhere along their migratory path, but without information on population distribution and movements, this is impossible to ascertain.

### Vulnerable components of population (size and sex composition)

Whale sharks are not vulnerable in New Zealand waters, and the effects of fishing on this population elsewhere are unknown.

### Trends in catches and population biomass

No information is available on whale shark population biomass in New Zealand waters. Biomass may vary inter-annually as a result of oceanographic factors that affect the number of animals that migrate here from tropical areas. Duffy (2005) summarised trends in catches from other countries with target fisheries as follows:

“Commercial catches from Taiwan are estimated to have declined between 30-90% from the 1960s to 1980s, 50-80% from the mid 1980s to the 1990s, and about 70% from 1997 to 2001 (CITES prop. 12.35). ... In the Philippines whale shark catches declined by an average of

27% per year during the 1990s before the fishery was closed. In Gujarat, the centre of whale shark fishing in India, the catch declined by 40% in 1999-2000 and the fishery was closed (CITES prop. 12.35).”

Relative abundance measured from ecotourism sightings at Ningaloo Reef, Western Australia fell by approximately 40% over the last decade. As this species is protected in Australia but is highly migratory, the rapid change over a decade suggests an effect of fishing in other parts of their range (Bradshaw et al. 2008).

#### Trends in size composition

There is no information on trends in size composition of whale sharks in New Zealand, as there are few records and few of them have accurate lengths. In Taiwan, there was a decline in the average size of whale sharks from 10–20 m TL up until the late 1990s to 4.6 m TL between 2000 and 2003 (Duffy 2005). A long-term continuous record of whale sharks from 1995–2004 at Ningaloo Reef, Western Australia showed that mean shark length declined by nearly 2.0 m (Bradshaw et al. 2008).

### **Deepwater nurse shark**

Genetic stock structure.

Nothing is known about genetic stock structure.

Evidence of the scale of movement and migration from tagging studies

Fergusson et al. (2008) suspected that deepwater nurse sharks might move over large oceanic distances by following submarine ridges and ‘hopping’ between islands and seamounts. However no tagging studies have been conducted to assess the degree of movement.

World distribution and any barriers to movement

Although previously considered to be an uncommon or rare species (Compagno 1984, 2001), the deepwater nurse shark is widely distributed in warmtemperate and tropical seas of continental and insular shelves and upper slopes (Fergusson et al. 2008). Its latitudinal range is between 46°N in the Bay of Biscay to around 39°S in the Indian and Pacific oceans. The species has been recorded from the northeast Atlantic Ocean, the Indian Ocean, and the western, central and northeast Pacific Ocean (Pollard et al. 2009). It has a patchy distribution, and although essentially demersal, it has also been caught pelagically in mid-ocean and observed in very shallow water. The species often occurs inshore at steeply shelving coastal and insular locations (Fergusson et al. 2008).

Habitat requirements and constraints

Although mature-sized sharks have been caught across a wide depth range (15–880 m), all juveniles smaller than 150 cm TL came from depths greater than 200 m, suggesting that parturition occurs in relatively deep water (Fergusson et al. 2008). Deepwater nurse sharks prefer swimming near the bottom and appear to aggregate on or near reefs; however, they have also been caught or seen as individuals or small groups over soft sediments (Garrick 1974; Duffy 2005; Fergusson et al. 2008).

### Growth rate

Size at birth is probably around 100–105 cm TL, as the smallest free-living specimens known were 107–110 cm TL (Duffy 2005; Fergusson et al. 2008). Females reach about 450 cm TL and males 344 cm TL (Duffy 2005; Fergusson et al. 2008). Age and growth rate are unknown.

### Longevity

Longevity is unknown.

### Length and age at maturity

Length at maturity is not well determined, but is about 200–250 cm TL for males and 300–350 cm TL for females (Fergusson et al. 2008). Age at maturity is unknown.

### Fecundity and reproductive rate

Reproduction is presumably the same as in the closely-related grey nurse shark (*Carchariastaurus*) which has a litter size of two, and a gestation period of 8–9 months (Duffy 2005).

### Natural mortality rate

Natural mortality rate has not been estimated.

### Spatial and temporal distribution of species

The known distribution of deepwater nurse sharks in New Zealand is patchy, with most records from the east coast of North Island and none from South Island (see discussion of apparently erroneous observer and commercial records in “Interaction with commercial fisheries” above). The only west coast North Island reports are of two juvenile females caught by set nets in about 40 m depth south of New Plymouth. The remaining New Zealand records are from Norfolk Ridge, Louisville Ridge Seamount Chain, Kermadec Islands, Volkner Islets and White Island, Gisborne, Mahia Peninsula and Lachlan Banks (Garrick 1974; Duffy 2005; Fergusson et al. 2008). There is no information to suggest that deepwater nurse sharks undergo seasonal migrations.

### Distribution of relevant fisheries

Worldwide, most recorded specimens have been caught in depths less than 300 m on steep, rocky terrain by bottom-set nets, longlines, and vertical lines; deeper captures were all by trawl (Fergusson et al. 2008). In New Zealand, there are few reliable records from commercial fisheries (see above), but species identification suggest that under-reporting is likely. This makes it difficult to determine which fisheries interact with the species, but it appears that set nets and longlines deployed near rocky reefs around North Island may catch the species. Commercial captures are known from White Island and Volkner Islets, Hawke Bay and Taranaki, but the fishery around White Island has largely ceased (Duffy 2005). Trawl fisheries probably catch the species in small numbers across a wide depth range around the northern North Island and at offshore seamounts, plateaux and ridges. Sharks at

the Kermadec Islands are protected by a marine reserve. Recreational catch in New Zealand is probably very low.

Vulnerable components of population (size and sex composition)

All size classes and both sexes of deepwater nurse shark are probably vulnerable to commercial fishing.

Trends in catches and population biomass

No trends in catches or biomass have been identified in New Zealand waters. Surveys off New South Wales, Australia, over 25 years strongly suggested declining abundance, and vulnerability of the species to both accidental and directed fishing pressure (Fergusson et al. 2008; Pollard et al. 2009).

Trends in size composition

No time series of size composition data are available.

### **Spinetail devilray**

Identification of devilrays (*Mobula* spp.) has proven problematic because of the resemblance of many species, and this has led to taxonomic problems. Although only one species (*M. japanica*) has so far been recorded from New Zealand waters, the overseas literature relating to that species may be based on other species, or a combination of species. Furthermore, other species of *Mobula* may also occur in New Zealand (Duffy 2005). Caution is therefore required in the interpretation of the literature summarised below.

Genetic stock structure

Several population genetics studies on the Mobulidae are underway (Poortvliet et al. 2011), but no results have been published (Couturier et al. 2012).

Evidence of the scale of movement and migration from tagging studies

Movement patterns and swimming capacities of most mobulid species are poorly understood. All mobulids are believed to undertake relatively large-scale movements, travelling from one productive area to another, and some species aggregate at specific locations (Notarbartolo-di-Sciara 1988; Celona 2004; Couturier et al. 2012). Acoustic telemetry in the southern Gulf of California has shown that the spinetail devilray moves relatively fast, travelling up to 50 km in 24 hours at speeds of up to 8.3 km.h<sup>-1</sup> (Freund et al. 2000). Tagged animals spent most of their time at depths shallower than 50 m, with occasional deeper excursions to a maximum of 445 m (Freund et al. 2000; Croll et al. 2012). Pop-up tags have shown that most individuals tagged in the southern Gulf of California moved to the Pacific coast of Baja California Sur (about 500 km) over a period of four months (Croll et al. 2012), indicating considerable mobility. Spinetail devilrays are seen in New Zealand waters for only a few months in summer, suggesting that they migrate between New Zealand and tropical waters to the north.

World distribution and any barriers to movement

The spinetail devilray has a worldwide distribution in tropical waters, and also penetrates into some subtropical and warm temperate areas (Last & Stevens 1994; White et al. 2006a).

#### Habitat requirements and constraints

Spinetail devilrays are an oceanic pelagic species, but they also occur in inshore waters (White et al. 2006a). Spinetail devilrays in the Baja California region are usually found near the surface, rarely descending deeper than 50 m, where they experience temperatures of 20–30 °C (Croll et al. 2012). They feed on planktonic crustaceans such as euphausiids and their migrations may track movements or changes in abundance of their prey (Croll et al. 2012).

#### Growth rate

Growth rates have not been estimated. Specimens from Mexico have been aged from bands on their caudal vertebrae, with a maximum of 14 band pairs found in a female of 230 cm disc width (Cuevas-Zimbrón 2007; Cuevas-Zimbrón et al. 2008; Couturier et al. 2012). Disc width at birth is 85–92 cm (Paulin et al. 1982; White et al. 2006b; Last & Stevens 2009). Maximum disc width is 310 cm (Notarbartolo-di-Sciara 1987).

#### Longevity

Longevity is not known but is probably greater than 14 years (see above).

#### Length and age at maturity

Disc width at maturity is 198–205 cm for males and greater than 236 cm for females (Notarbartolo-di-Sciara 1987; Couturier et al. 2012). Age at maturity is unknown.

#### Fecundity and reproductive rate

Mobulids are aplacental viviparous. The gestation period of most species is unknown, but the reproductive cycle is likely to last for about one year, possibly longer if females have resting periods between pregnancies (Couturier et al. 2012). All mobulid species normally give birth to a single pup, but may occasionally produce twins. A new born juvenile spinetail devilray and a number of adults containing term embryos have been collected in New Zealand indicating that this species gives birth here (Paulin et al. 1982; Stewart 2002).

#### Natural mortality rate

The natural mortality rate of devilrays is unknown but is assumed to be low. Natural predation is probably low and opportunistic, with sharks probably the most common cause. Non-fatal shark-inflicted injuries are occasionally observed on mobulids (A. Marshall, unpubl. obs., in Couturier et al. 2012).

#### Spatial and temporal distribution of species

Spinetail devilrays are common or abundant in north-eastern North Island waters near the shelf break to about 36 °S during most New Zealand summers, but they also extend as far south as East Cape and Cape Egmont (Figure 4).



## Distribution of relevant fisheries

The skipjack tuna purse-seine fishery overlaps in time and space with the distribution of spinetail devilrays in New Zealand waters, particularly between the Bay of Islands and Great Barrier Island (Jones & Francis 2012). Purse-seine fisheries for small pelagic fish in northern North Island waters (e.g. jack mackerels, blue mackerel, trevally) could potentially catch devilrays, but this has not been recorded. These fisheries tend to occur further inshore and outside the summer peak of devilray abundance.

## Vulnerable components of population (size and sex composition)

All sizes classes of spinetail devilray are caught in skipjack purse-seine fisheries but the sex composition of the catch is unknown.

## Trends in catches and population biomass

No information is available on spinetail devilray population biomass in New Zealand waters. Biomass may vary inter-annually as a result of oceanographic factors that affect the number of animals that migrate here from tropical areas. Elsewhere in the world, *Mobula* species are caught by target and bycatch fisheries in many countries, but little information is available on population biomass. Catches have declined in a number of regions suggesting that there have been population declines in areas with target or large bycatch fisheries (see review by Couturier et al. 2012).

## Trends in size composition

No information is available on trends in size composition.

## **Manta ray**

Until recently, it was believed there was only one species of manta ray worldwide – *Manta birostris*. In 2009, a second species, *M. alfredi*, was confirmed as valid (Marshall et al. 2009). Both species have worldwide distributions. Only *M. birostris* has been recorded from New Zealand (Duffy & Abbott 2003) but *M. alfredi* may also visit here as it occurs in tropical waters to the north of New Zealand and in Queensland (Marshall et al. 2009). Manta literature pre-dating 2009 may refer to one or both species, making it difficult to review biological and population information, and caution is required in its interpretation. The failure to differentiate the two *Manta* species prior to 2009 has resulted in confusion concerning almost all the biological information available (Couturier et al. 2012).

## Genetic stock structure

Manta ray DNA sequence analysis has shown significant population structure between the eastern and western Pacific Ocean but no structure within either region (Clark 2001).

## Evidence of the scale of movement and migration from tagging studies

*Manta birostris* is a larger, more oceanic and probably more migratory species than *M. alfredi*, with individuals regularly sighted around offshore islands, oceanic seamounts and submarine ridge systems (Yano et al. 1999; Marshall et al. 2009; Kashiwagi et al. 2011). In addition, rare or seasonal sightings of *M. birostris* at locations such as northern New Zealand (Duffy & Abbott 2003), southern Brazil, the Azores and the Similan Islands, and the eastern

coast of the U.S.A. suggest that this species undergoes extensive migrations (Couturier et al. 2012). Preliminary pop-off satellite tag studies have recorded broad-scale movements of more than 1000 km (A. Marshall, J. Holmerg, J. M. Brunnschweiler & S. J. Pierce, unpubl. data). Together with international photo-identification projects, these data have so far revealed little interchange between regional populations, and whether *M. birostris* crosses ocean basins is still unknown (Couturier et al. 2012). The fact that manta rays are seen in New Zealand waters for only a few months in summer (January–April) (Duffy & Abbott 2003) suggests that they migrate between New Zealand and tropical waters to the north.

#### World distribution and any barriers to movement

*Manta birostris* occurs worldwide in tropical and subtropical waters although it is not currently known from most islands of the South Pacific Ocean (Marshall et al. 2009).

#### Habitat requirements and constraints

*Manta birostris* inhabits productive coastlines with regular upwelling, oceanic island groups and particularly offshore pinnacles and seamounts (Marshall et al. 2009). It has a more oceanic distribution than *M. alfredi*.

#### Growth rate

Growth rates are unknown for either *Manta* species, but they are presumed to be slow-growing. Manta rays are born at 120–150 cm disc width and reach a maximum disc width of at least 700 cm and possibly up to 910 cm (Last & Stevens 2009; Couturier et al. 2012).

#### Longevity

Longevity is unknown but at least 20 years (A. Marshall, J. Holmerg, J. M. Brunnschweiler & S. J. Pierce, unpubl. data). Photo-identification surveys have resulted in re-sighting of individuals up to 20 years after their initial identification (Marshall et al. 2011). As the age at first identification of these animals was unknown, actual longevity is likely to be considerably greater than 20 years (Couturier et al. 2012).

#### Length and age at maturity

Disc width at maturity is about 370–380 cm for males and 380–415 cm for females (White et al. 2006b; Last & Stevens 2009). Age at maturity is unknown.

#### Fecundity and reproductive rate

Mobulids are aplacental viviparous. All species normally give birth to a single pup, but may rarely produce twins (Notarbartolo-di-Sciara 1987; White et al. 2006b; Couturier et al. 2012) (Marshall & Bennett 2010b). The gestation period of *M. birostris* is unknown, but *M. alfredi* has a gestation period of 12–13 months and mobulids in general may have resting periods between pregnancies, suggesting that the reproductive cycle may be longer than one year (Notarbartolo-di-Sciara 1987; Marshall & Bennett 2010b; Couturier et al. 2012).

#### Natural mortality rate

The natural mortality rate of mantas is unknown but is assumed to be low. Natural predation is probably low and opportunistic, with sharks probably the most common cause. Non-fatal

shark-inflicted injuries are regularly observed on manta rays (Homma et al. 1999; Marshall & Bennett 2010a; Deakos et al. 2011; Couturier et al. 2012).

#### Spatial and temporal distribution of species

*Manta birostris* is an uncommon migrant to New Zealand and verifiable sightings of this species have been of individuals and occasionally pairs (Duffy & Abbott 2003). Most sightings have been made over the shelf along the north-east North Island, including the Poor Knights Islands, the outer Hauraki Gulf, and the Aldermen Islands (Duffy & Abbott 2003; Duffy 2005; C. Duffy & S. Cook unpubl. data).

#### Distribution of relevant fisheries

Manta rays are not known to have been caught in New Zealand commercial fisheries (Duffy 2005; Jones & Francis 2012), although they are possibly taken as rare bycatch by skipjack purse seine vessels. Mobulid rays are occasionally caught on trolled lures by recreational fishers (Duffy 2005). Manta rays occurring in New Zealand waters may be caught by fisheries operating elsewhere along their migratory path, but without information on population distribution and movements, this is impossible to ascertain.

#### Vulnerable components of population (size and sex composition)

Manta rays do not appear to be vulnerable to commercial fisheries in New Zealand, and the effects of fishing on this population elsewhere are unknown.

#### Trends in catches and population biomass

No information is available on *Manta birostris* population biomass in New Zealand waters. Biomass may vary inter-annually as a result of oceanographic factors that affect the number of animals that migrate here from tropical areas. Elsewhere in the world, *Manta* species are caught by target fisheries in many countries, but little information is available on population biomass. Catches have declined in a number of regions suggesting that there have been population declines in areas with target fisheries (see review by Couturier et al. 2012).

#### Trends in size composition

No information is available on trends in size composition.

### **Spotted black grouper**

#### Genetic stock structure

Preliminary research based on small sample sizes found little genetic differentiation between the Elizabeth–Middleton reefs and New South Wales spotted black grouper populations, but more samples were required to confirm this (Appleyard & Ward 2007; Van Herwerden et al. 2009; Marsh 2011). Given its geographic proximity to Elizabeth and Middleton reefs, spotted black grouper at Lord Howe Island are likely to form part of the same stock. The stock relationships of spotted black grouper at Norfolk and Kermadec islands, and northern New Zealand, are unknown.

#### Evidence of the scale of movement and migration from tagging studies

No tagging studies have been undertaken.

## World distribution and any barriers to movement

Temperate and subtropical waters of the southwestern Pacific: Australia, Lord Howe Island, Norfolk Island, Elizabeth and Middleton reefs, Kermadec Islands, and northern New Zealand. The Australian range extends from southern Queensland to Kangaroo Island off South Australia; reported from Bass Strait, but not known from the coast of Tasmania (Heemstra & Randall 1993; Pogonoski et al. 2002; Harasti et al. 2004; Hobbs & Feary 2007; Malcolm & Harasti 2010; Harasti et al. 2011). In New Zealand, spotted black grouper are mainly found in the northern North Island and at the Three Kings Islands. They have been recorded as far south as Cook Strait and Westport, but are rare south of Cape Brett (Paulin & Roberts 1992; Francis 1996b; 2001; C. Worthington, pers. comm.). Breeding is not known to occur in New Zealand waters (apart from at the Kermadec Islands), and individuals occurring here are probably vagrants from upstream sources such as Norfolk and Lord Howe islands.

## Habitat requirements and constraints

Spotted black grouper generally inhabit near-shore rocky and offshore coral reefs at depths down to 50 m, but they prefer depths shallower than 25 m (Francis 2001). However, they are occasionally recorded from deeper water (Harasti et al. 2004; Marsh 2011; New South Wales Department of Primary Industries 2012). A large 1.8 m fish was caught in a depth of 300 m at Lord Howe Island, and others have been reported from there in depths greater than 100 m (K Galloway pers. comm. in Harasti et al. 2011; Malcolm 2011). A 70 kg fish was reported from 110 m by an observer on a boat carrying out exploratory fishing north-west of Macauley Island at the Kermadec Islands in September 1992 (MPI data sheet; data sheets from some observer trips on exploratory fishing expeditions to the Kermadecs, including this trip, were not entered into COD).

In coastal waters, adult spotted black grouper are found in or near rock caves, rock gutters, overhangs, boulders, corals and also on open reefs (Francis 2001; Malcolm & Harasti 2010); they are uncommon in areas exposed to heavy wave action (Choat et al. 2006). Overhangs and caves are important for this territorial species (Pogonoski et al. 2002), individuals of which may occupy a particular cave for decades (Heemstra & Randall 1993; New South Wales Department of Primary Industries 2012). When conducting underwater visual censuses it is essential for divers to actively look under ledges and in caves, as one-third of the fish may be hiding out of immediate view (Choat et al. 2006; Harasti 2011; Harasti et al. 2011).

Very small juveniles (less than 10 cm long) may be found in very shallow water under boulders, in caves and crevices, and in rock pools (Paulin & Roberts 1992; Malcolm & Harasti 2010; M. Francis, pers. obs., C. Worthington, pers. comm.). The best habitat for small juvenile spotted black grouper (10–15 cm) is in crevices and under boulders, often in large gutters with good water flow (C. Worthington, pers. comm.). The greatest numbers of 40–60 cm long juveniles in mainland New Zealand occur from Cape Reinga to Cape Karikari. They are found right through Parengarenga Harbour, with excellent juvenile habitat in the broken sandstone foreshore along Paua and TeHapua foreshores. Larger fish are found on the harbour's rocky points and TeKao channel. Whangatupere on Karikari Peninsula is also a stronghold for juveniles. The coast between Cape Reinga and North Cape and the broken sandstone foreshore of Houhora Harbour also provide nursery habitat. Fish abundance drops

slightly between Cape Karikari and Cape Brett, but there are good numbers in areas that have good oceanic water flows but are not too exposed to easterly storms, for example Stephenson's Island, Cavalli Islands, inner Bay of Islands, and more sheltered shores at Cape Brett. The largest Bay of Islands populations occur between Tapeka Point and Paroa Bay along the shore closest to Russell township, and in Oke Bay to Deepwater Cove. The juvenile spotted black grouper population decreases further south, with only a few seen around Whangarei and Tutukaka (C. Worthington, pers. comm.).

In Australia, recently settled juveniles are often found in rock pools and intertidal areas dominated by boulders and overhangs, indicating a preference for structural features that provide plenty of cover, while slightly older juveniles often occur in estuary systems (Hutchins & Swainston 1986; Pogonoski et al. 2002; Harasti et al. 2004; Harasti & Gallen 2012).

At the Kermadec Islands, spotted black grouper are occasional or common throughout the island chain (Francis et al. 1987), with many over 1 m in length observed under ledges and near boulders in shallow water (3 m depth) (Schiel et al. 1986).

#### Growth rate

No studies have been published on the growth rate or longevity of spotted black grouper, but it has been widely assumed to be a slow-growing species, as is typical of groupers of its size (Harasti et al. 2004). Data from several small aged samples of spotted black grouper are reported below because they are the only age information available on the species.

Ten spotted black grouper collected at the Kermadec Islands in 1985 and 1987 were aged using burnt half-otoliths (M. P. Francis, unpublished data). Unvalidated otolith age estimates ranged from 31 to 65 years (Table 5). Only the head was available for the oldest animal, so it could not be measured or sexed. However, the head measured 38 cm from the snout to the severed end of the backbone (assumed to be near the back of the skull), and 45 cm from the snout to the cut edge on the ventral side (assumed to be the isthmus). Total length was estimated from these measurements using body proportions measured on a side-on underwater photograph of a spotted black grouper; the estimates were 154 cm for the backbone measurement, and 156 and 168 cm for the isthmus measurement (for two possible extreme locations where the cut was made). A third total length estimate, based on the fisher's estimate of "three and a half feet" for the length of the trunk (= 107 cm), was 157 cm. After discarding the larger of the two isthmus estimates, the mean of the three remaining length estimates was 156 cm. The estimated weight of this fish (30 kg) seems to be too low for a fish of this size. This fish was assumed to be a male because of its large size. The only female in the Kermadec Islands samples was 106 cm; all longer fish were males (Table 5). An otolith from a 119 cm male with an estimated age of 56 years is shown in Figure 6.

In a letter written in 1981 by D. D. Francois, Director of New South Wales State Fisheries in Australia, based on unpublished data compiled by D. A. Pollard et al., spotted black grouper of 490–515 mm standard length were reported to be aged 5–6 years based on scale ring counts. Standard length is about 85% of total length (estimated from underwater photographs of five different fish), suggesting these fish would have been about 58–61 cm TL. All of these fish were females.

An unmeasured 70 kg spotted black grouper from Norfolk Island was reportedly about 58 years old based on otolith band counts (Clifton 2001; Harasti et al. 2004). Two other fish from Lord Howe Island and New South Wales have also been aged from otoliths (Harasti et al. 2011; Malcolm 2011).

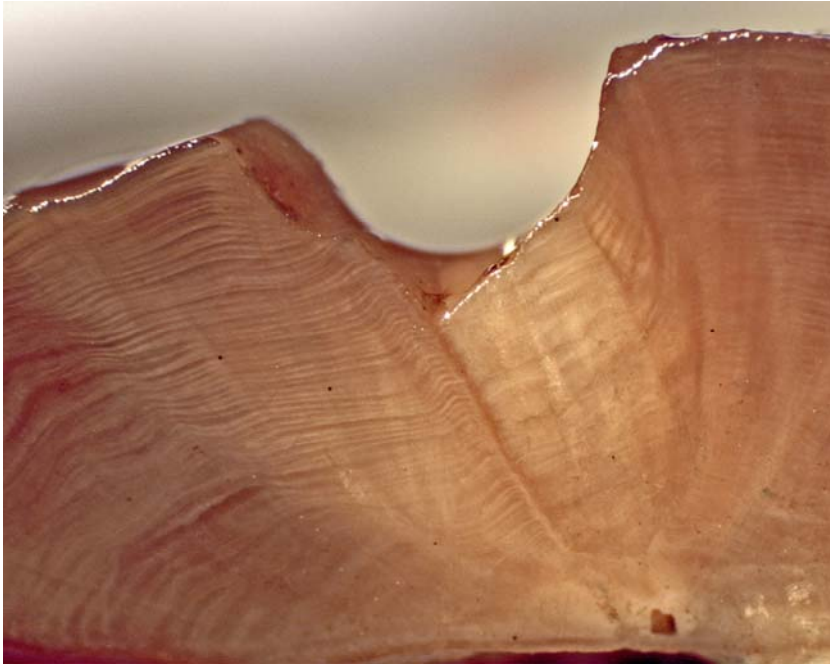


Figure 6. Half-otolith from a 119 cm male spotted black grouper showing growth bands. Estimated age was 56 years.

Table 5. Ages estimates, length and sex for spotted black grouper (see text for data sources).

Date	Age estimate (years)	Total length (cm)	Sex	Location	Source
1975-76	5.5	59.5	F	NSW, multiple specimens	D. Francois (in lit.)
April 2011	17	80.5	F	Fish Rock, SW Rocks, NSW	Malcolm (2011)
18 August 1985	31	106	F	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
18 August 1985	32		M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
18 August 1985	32	112	M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
May 2011	42	127		Lord Howe Island	Harasti et al. (2011)
18 August 1985	43	115	M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
18 August 1985	44	115	M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
18 August 1985	46	121	M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
18 August 1985	49	122	M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
18 August 1985	54	117	M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
19 August 1985	56	119	M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)
12 October 1987	65	ca 156	?M	Raoul Island, Kermadec Islands	M. Francis (unpubl. data)

The available length-at-age data are plotted in Figure 7. No growth curve was fitted to the data because of the small number of data points, and because the uncertain length of the oldest fish would have a strong influence on a fitted curve. The data suggest that growth is rapid initially, but then slows considerably from a length of about 110 cm and an age of 30 years (possibly earlier).

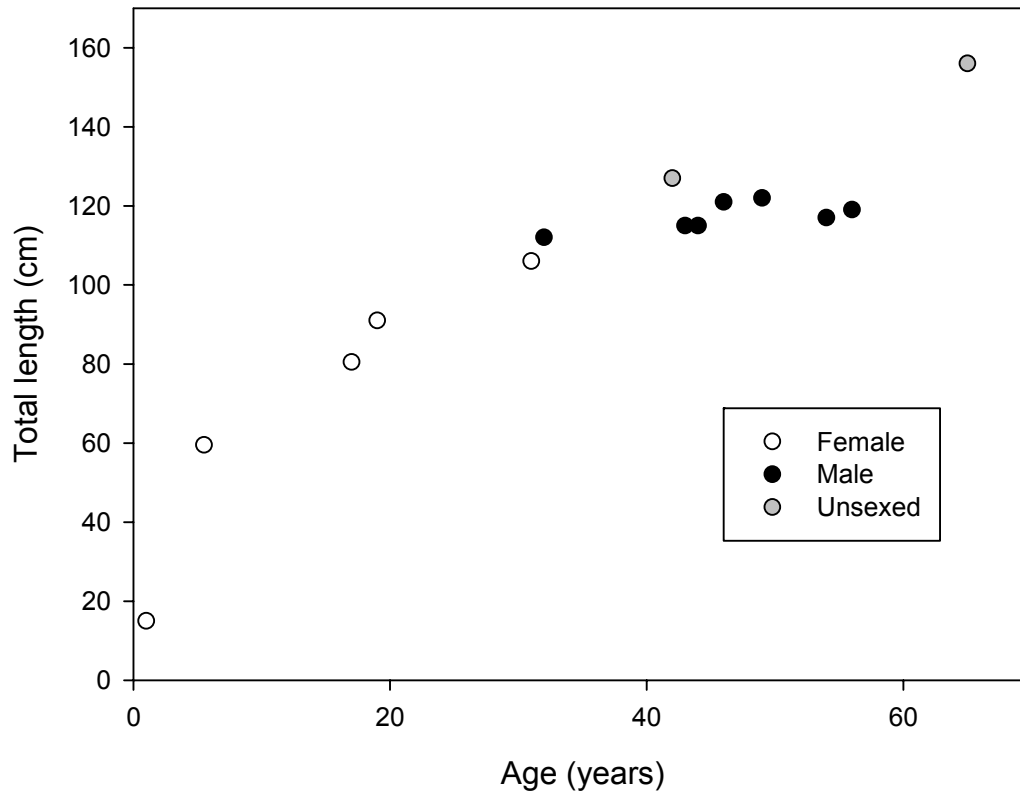


Figure 7. Length-at-age data for spotted black grouper from Kermadec Islands, New South Wales and Lord Howe Island. The oldest fish (65 years) was not measured and is plotted at an estimated length of 156 cm (see text for details). Data sources are as shown in Table 5, plus two additional unpublished records from New South Wales (D. Harasti, pers. comm.).

The maximum length of spotted black grouper is unclear, as few large fish have been measured. Francis (1988; 1996a) stated that Kermadec Islands fish reach 200 cm TL, and this has been widely reported as the maximum length of the species. While very large fish do occur at the Kermadecs, and a length of 200 cm is plausible, this has not been verified from actual measurements. Paulin & Roberts (1992) reported the maximum length in New Zealand as 180 cm. At Lord Howe Island, the species is reputed to reach at least 180 cm TL and weigh over 100 kg (K. Galloway pers. comm., in Harasti et al. 2011). In mainland Australia, spotted black grouper reach 155 cm TL and 81.6 kg weight (Hutchins & Swainston 1986; Malcolm & Harasti 2010).

#### Longevity

Based on the data in Table 5, the greatest known age is about 65 years. However, very large fish have yet to be measured and aged, so longevity may be greater than this.



### Length and age at maturity

Length at maturity is not known for either sex. Seventeen fish examined from Sydney spearfishing competitions in the mid 1970s were immature at standard lengths of 30–50 cm (about 35–60 cm TL) (D. A. Pollard et al. unpubl. data; in a 1981 letter by D. D. Francois, Director of New South Wales State Fisheries). A single ca 69 cm TL fish caught near Wellington (see above) was an immature female. Given the estimated length at sex reversal (see section 8 below), females must mature at a length smaller than about 100 cm and males at a length greater than 100 cm. Thus female maturity probably occurs in the range 70–100 cm TL. Males are presumably mature and reproductively competent soon after they make the transition from females. The female age at maturity is therefore less than about 25–28 years, and male age at maturity is around 25–33 years (Figure 7).

### Length and age at sex reversal

Members of the family Serranidae (groupers) are protogynous sex-changers: they begin life as females and change into males later (Heemstra & Randall 1993). The largest known female spotted black grouper was 106 cm and the smallest male was 112 cm (Table 5). The sample size is inadequate for accurate estimation of the length at sex reversal, but these data were used by Francis (1988) to estimate that reversal occurs in the range 100–110 cm. More recent publications have repeated this estimate without adding any further data (Paulin & Roberts 1992; Heemstra & Randall 1993; Francis 1996a; Francis 2001). Sex reversal probably occurs at around 25–33 years of age.

### Fecundity and reproductive rate

Fecundity and reproductive rate are not known in spotted black grouper. They have been reported to form large spawning aggregations in Australia (Malcolm & Harasti 2010). Epinephelus species produce pelagic eggs in a number of spawning bouts, and their pelagic larval stage lasts up to 60 days (Heemstra & Randall 1993; Richardson & Gold 1997), during which time larvae may drift long distances in ocean currents.

### Natural mortality rate

The natural mortality rate has not been reported for spotted black grouper. However, based on a maximum age of 65 years, the instantaneous mortality rate  $M$  would be about 0.07 using the Hoenig method (Hoenig 1983; Ministry for Primary Industries 2012).

### Spatial and temporal distribution of species

In New Zealand waters, spotted black grouper are most abundant at the Kermadec Islands. They are also found along the north-eastern coast of North Island (Cape Reinga to East Cape) and at the Three Kings Islands. Occasional stragglers occur as far south as Westport.

### Distribution of relevant fisheries

The Kermadec Islands population of spotted black grouper is protected within the 12-nautical mile marine reserve “bubbles” that surround the four island groups. This population is not considered vulnerable to fishing, other than to any illegal fishing that may occur within the reserve. At the Three Kings Islands and along the north-east coast of North Island, spotted black grouper are vulnerable to line and set net fisheries. Recreational fishers often catch

them when bottom lining for other species, so it is likely that there is also bycatch in commercial fisheries operating in the same areas.

Vulnerable components of population (size and sex composition)

Fish of all sizes are potentially vulnerable to line and set net fisheries operating in rocky reef habitats. Few fish larger than 100 cm are seen around mainland New Zealand (though they do occur at the Three Kings Islands), so the vulnerable population components are mainly juveniles and females.

Trends in catches and population biomass

There is no information on trends in catches or population size in New Zealand waters. In Australia, it is now unusual to find large spotted black grouper (known there as black cod) in areas where they were once common. There is abundant evidence of population decline in New South Wales as a result of fishing (Pogonoski et al. 2002; Marsh 2011; New South Wales Department of Primary Industries 2012). Declines in numbers were already noticed near coastal cities as far back as the early 20th century (Roughley 1916). Localised depletions in New South Wales waters over the last 20 years have been reported by recreational divers including further local extinctions within this period of time (DEH, unpublished expert comment, 2004, in Marsh 2011). Population declines have also been reported from Lord Howe Island (Harasti et al. 2011). The species is absent from many NSW locations where it used to be abundant (Marsh 2011). At Elizabeth and Middleton reefs, densities of spotted black grouper declined significantly at four out of eight sites surveyed in both 2006 and 2011 (Pratchett et al. 2011).

Trends in size composition

There is no information on trends in size composition in New Zealand waters. However, large spotted black grouper are clearly vulnerable to fishing, because large fish are rarely recorded today except in reserves like the Kermadec Islands where they have never been intensively fished and have been protected since 1991, and Elizabeth and Middleton reefs where fishing is limited. As large fish over 1 m were preferentially targeted by spear-fishers in New South Wales, the mean size of the population there declined dramatically. Most “large” individuals sighted in Australia in recent years are 40–90 cm in length (Harasti 2011). However, some larger individuals (100–135 cm length) have been measured at the outer Solitary Islands in recent years (H. Malcolm, NSW Department of Primary Industries, pers. comm.).

## **Giant grouper**

Genetic stock structure

There does not seem to have been any research on stock structure. Recent genetic work has focussed on the ability to differentiate wild giant grouper from commercially farmed fish (Chiu et al. 2012).

Evidence of the scale of movement and migration from tagging studies

Nil.

#### World distribution and any barriers to movement

Giant grouper is the most widely distributed grouper in the world (Heemstra & Randall 1993). It is widespread throughout the Indo-west Pacific Ocean. Most reports of this species in New Zealand are one-off observations of large solitary adults from the northern North Island. Individuals seem capable of oceanic migrations, perhaps as adults as well as larvae and juveniles.

#### Habitat requirements and constraints

Adults are solitary and inhabit shallow rocky reefs to 30 m depth in New Zealand (Duffy 2005). Globally, giant grouper uses a wide range of inshore habitats including rocky areas, caves, wrecks, harbours and estuaries with brackish water. It is more common in shallow waters but has been found down to depths of 100 m (Pogonoski et al. 2002; Shuk Man & Ng 2006).

#### Growth rate

No growth rate data are available. Giant grouper can grow to about 3 m in length and weigh up to 600 kg (Fourmanoir & Laboute 1976; Heemstra & Randall 1993; Pogonoski et al. 2002; Gomon et al. 2008). One recognisable individual has been observed in Vanuatu for more than 20 years (Duffy 2005). A 220 cm long fish caught in New South Wales, Australia was aged at 37 years from otolith bands (New South Wales Department of Industry and Investment 2008).

#### Longevity

Longevity is unknown, but giant grouper is the largest species of grouper in the world and is probably long-lived.

#### Length and age at maturity

Length at maturity for males is about 129 cm (Lau & Li 2000; Pogonoski et al. 2002). Age at maturity is unknown.

#### Length and age at sex reversal

Unknown.

#### Fecundity and reproductive rate

In Indonesia, increased catch rates by local fishers suggest fish aggregate during a spawning season of December–February (Shuk Man & Ng 2006).

#### Natural mortality rate

Unknown.

#### Spatial and temporal distribution of species

Most observations of giant grouper in New Zealand have been of large solitary fish around the northeast of North Island (Francis & Evans 1993; Francis et al. 1999; Anderson 2004;

Duffy 2005). The infrequency of sightings by divers suggests that the New Zealand population is very small, probably less than a few hundred adults (Duffy 2005) and perhaps much less than that. The capture of a 50 cm juvenile at the Three Kings Islands suggests larval or juvenile recruitment to New Zealand waters does occur (Duffy 2005), probably intermittently during warm summers, as is the case for the many other subtropical and tropical species that appear sporadically in northeast New Zealand (Francis 1996b; Francis et al. 1999).

#### Distribution of relevant fisheries

Giant grouper are rarely caught by commercial fishers in New Zealand, although they have been caught by rod and reel and by spearfishing (Duffy 2005).

#### Vulnerable components of population (size and sex composition)

The exceptional size of giant grouper and its shallow water habitat makes it a target for sport fishers, particularly spearfishers seeking record or trophy catches. However, the spearing of one in Northland during 2001 was widely condemned by the wider diving community (Duffy 2005), leading to their protection. There is a global demand for giant grouper in the live fish trade in Hong Kong where it is highly valued at US\$100/kg for juveniles, and up to US\$10,000 for large fish. The market prefers juvenile fish of 45–90 cm in length (Pogonoski et al. 2002). Given their very low occurrence in commercial catches, giant grouper are not considered vulnerable to commercial fisheries in New Zealand.

#### Trends in catches and population biomass

There is no information on trends in catches or population size in New Zealand waters. Giant grouper is the largest reef-dwelling fish in the world and was much sought after by line- and spear-fishers in Australia prior to being listed as a protected species in NSW in the early 1980s. The IUCN Red List concludes that giant grouper has a decreasing population size, and recognises its vulnerability to exploitation, listing it as “Vulnerable A2d” (Shuk Man & Ng 2006). Being such a large predator, it is rare even in areas that have not been exploited by fishing (Randall & Heemstra 1991), and it has been nearly extirpated from heavily fished areas (Lieske & Myers 1994). Giant grouper are now part of a growing aquaculture industry and can be successfully hatchery reared, especially in Taiwan. If hatchery production constitutes a significant proportion of the market and replaces wild-caught fish, then the threat to the wild population may be alleviated (Shuk Man & Ng 2006). The species may be vulnerable to disease, as 93 giant grouper were found dead in Queensland, Australia, from 2007 to 2011; most dead fish occurred in northern Queensland, with a peak of mortalities in Cairns in June 2008 (Bowater et al. 2012).

#### Trends in size composition

There is no information on trends in size composition in New Zealand waters. Only small (immature) giant grouper are commercially targeted for the live fish trade in Asia and no trends in size composition are available from this catch.

## Information gaps and recommendations

The quality and quantity of population information available for each of the eight protected fish species is summarised in Table 6. Each information category was scored on a 5-point scale for each species. Only two cells rated a score of 'excellent': they were for information on the distribution of spotted black grouper (which is confined to New Zealand, Australia and the Tasman Sea), and the distribution of the fisheries catching whale sharks (there is negligible catch in New Zealand). 'Good' scores were restricted to information on world and New Zealand distribution, genetic stock structure, movement, habitat and fishery distribution. Cells with 'none' or 'poor' information were concentrated in the categories of genetic stock structure, movement, all of the biological categories, and the response of the species to exploitation in New Zealand waters. Overall, these categories were poorly understood for all eight species. Future research clearly needs to focus on understanding stock structure, geographic range, and the scale, direction and timing of movements (all best addressed by genetic studies and electronic tagging); biological characteristics that affect the productivity of the species (especially growth, longevity, length and age at maturity, reproduction and natural mortality); and measures of population size and status (such as relative abundance and biomass estimates, and trends in size composition).

Table 6. Summary of the level of population information available for each of eight protected species. Species and their score sums which are coloured purple have a moderate–high proportion of their population in New Zealand waters for at least part of the year.

Species	Proportion of stock in NZ	Stock identification - population unit				Sum	Biological information - species productivity					Sum
		Genetic stock structure	Movement	World distribution	Habitat		Growth	Longevity	Maturity	Reproduction	Natural mortality	
Basking shark	High	1	2	3	2	8	1	1	1	1	1	5
White shark	High	3	3	3	3	12	2	1	2	1	1	7
Whale shark	Low	2	2	3	3	10	1	1	1	1	1	5
Deepwater nurse shark	High?	0	0	2	1	3	0	0	1	1	0	2
Spinetail devilray	Moderate	0	1	3	3	7	1	1	2	2	0	6
Manta ray	Low?	1	1	3	2	7	0	1	2	2	0	5
Spotted black grouper	High	1	0	4	3	8	2	2	1	1	2	8
Giant grouper	Low	0	0	3	3	6	0	0	1	0	0	1
Sum		8	9	24	20		7	7	11	9	5	
		Species and fishery distribution - extent of overlap in NZ				Response to exploitation in NZ						
Species	Proportion of stock in NZ	Stock distribution	Fishery distribution	Vulnerable components in commercial fisheries	Sum	Catches and biomass	Size composition	Sum	Information level			
Basking shark	High	3	2	> 4 m	5	2	0	2	0 = none			
White shark	High	3	2	All	5	0	0	0	1 = poor			
Whale shark	Low	3	4	Not vuln.	7	NA	NA		2 = moderate			
Deepwater nurse shark	High?	1	1	All	2	0	0	0	3 = good			
Spinetail devilray	Moderate	3	3	All	6	0	0	0	4 = excellent			
Manta ray	Low?	2	3	Not vuln.	5	NA	NA		NA = not applicable			
Spotted black grouper	High	3	3	All	6	0	0	0				
Giant grouper	Low	3	2	Not vuln.	5	NA	NA					
Sum		21	20			2	0					

Three of the eight protected species (whale shark, manta ray and giant grouper) are tropical species that are rarely or occasionally seen in northern New Zealand, and even more rarely straggle further south. They are not vulnerable to commercial fisheries in New Zealand (though giant grouper may be caught by recreational fishers) and are therefore not regarded as high priority species for research or management in New Zealand; nevertheless, New Zealand as a range state should participate in regional international efforts to study and manage these species.

Research and management efforts should focus on basking shark, white shark, deepwater nurse shark, spinetail devilray, and spotted black grouper. These species are present in New Zealand waters in significant numbers for at least part of the year. Of these, basking shark and white shark have the greatest interactions with commercial fisheries, and are potentially

the species most impacted by commercial bycatch. Recommendations for reducing bycatch of basking sharks suggested by Francis & Smith (2010) are still appropriate and useful, although the low incidence rate of this (and other protected) species means that it is difficult to identify and implement measures to avoid it, other than to reduce fishing effort in the times and/or places where they occur. The same applies to white sharks which are vulnerable to set net, lines and trawl nets throughout much of the country; however hotspots of abundance occur around the Chatham Islands, Stewart Island, and in the large harbours of the northern North Island (M. Francis and C. Duffy, unpubl. data) suggesting that initial mitigation measures should be focused in these areas. Furthermore, white sharks are most common in New Zealand waters during summer–autumn (most emigrate to tropical waters in winter–spring), so mitigation measures should focus on those periods.

The deepwater nurse shark stands out in Table 6 as having the lowest or equal lowest category score sums in all four category groupings. Information levels were scored as ‘none’ or ‘poor’ in nearly all categories, so this species rates as high priority for future research.

Some information types are most easily obtained by destructive necropsies (e.g. growth and longevity estimated from vertebrae; size at sexual maturity for females, litter size and gestation period estimated by examination of reproductive organs). However, new non-destructive techniques are being developed for estimating some of these parameters (e.g. shark reproductive and maturity status can be estimated, following suitable validation on specimens, from blood hormone levels). If destructive sampling for research purposes is unacceptable for protected species, then specimens that are accidentally caught and killed by fishers become extremely valuable for providing crucial biological information.

Since the protection of the eight fish species was implemented, the number of specimens available from fishery bycatch sources has dwindled to almost zero. Fishers discard protected species at sea (as required by law) and often do not report them (also required by law). Some fishers undoubtedly fear the legal or management consequences of reporting the death of protected species. As a result, the availability of dead specimens for biological research has essentially dried up. Specimens that are brought in have often been sent to the Museum of New Zealand which makes it difficult to obtain all the useful data that would otherwise be available. Recently, a specimen of spotted black grouper was sent to the museum, who provided length and sex information for the above review; however, it was not possible to obtain the otoliths from this specimen for ageing purposes because of the damage it would have done to the specimen. Unless the Museum of New Zealand has very few specimens of a species, in which case there is a good case for depositing a fish specimen with them, the specimens would be more valuable if they were made available for destructive sampling. For some species, notably deepwater nurse shark and spotted black grouper, there is no other way to obtain the required information, apart from targeted fishing. If sufficient samples are not forthcoming over a reasonable time period, the latter may become necessary.

We recommend that efforts are made to increase the availability for research of specimens of protected fish species by (a) making it legal for fishers to land dead specimens; (b) encouraging and educating fishers about the value of specimens for research; and (c) providing the specimens to a research organisation that can maximise their value by extracting all relevant useful information from each specimen. Other targeted research mentioned above (e.g. genetic analysis and electronic tagging) should also be implemented urgently as a means of gathering important information in a relatively short time.

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## Appendix 1: Commercial fisher and observer records of basking shark by fishing year and FMA.

Year 1986 = Fishing year 1985–86. ET, outside the New Zealand Exclusive Economic Zone; Unk = Unknown. Duplicate records were omitted from the Commercial records.

BSK	Year	Commercial records											Observer records											Total			
		FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET		Unk	Sum	
	1986											0												1	1	1	
	1987											0			4		2	3	1							10	10
	1988											0			15	1	1	1	2	1						21	21
	1989											0			2		21		6							29	29
	1990			3								3						5		1						6	9
	1991				1			1				2			6				1							7	9
	1992											0			5											5	5
	1993											0														0	0
	1994			4			1					5			3			1		1						5	10
	1995			1								1							2							2	3
	1996			3		2						5														0	5
	1997											0			1				1							2	2
	1998			1				1				2			1	11			2							14	16
	1999			1								1			1	5		2	2	1						11	12
	2000			15			2					17		1			1	5	1							8	25
	2001		1	1		2	16					20			4		2	1								7	27
	2002			4	2		4				1	2	13				2	1								3	16
	2003			5		2	14	1		2		24			3		7	4	1							15	39
	2004			6		2	2	1				11			1		6	2								9	20
	2005			1		1	1					3					1	1	1							3	6
	2006			1		2						3														0	3
	2007						1	1		2		4						6								6	10
	2008			4		2						6					2	1								3	9
	2009	1										1						1								1	2
	2010		1									1					2	1								3	4
	2011			2		3		1				6				6										6	12
	Sum	1	2	52	3	16	41	6		4	1	2	128	1	2	60	1	55	35	20	3				177	305	

**Appendix 1 (cont.): Commercial fisher and observer records of white shark by fishing year and FMA.**

Year 1986 = Fishing year 1985–86. ET, outside the New Zealand Exclusive Economic Zone; Unk = Unknown. Duplicate records were omitted from the Commercial records.

WPS	Year	Commercial records											Observer records											Total	
		FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET		Unk
	1986											0											0	0	
	1987											0			1		3		12					16	16
	1988											0											0	0	
	1989											0			1								1	1	
	1990											0				1		1					2	2	
	1991											0	1										1	1	
	1992											0											0	0	
	1993											0											0	0	
	1994											0				1							1	1	
	1995											0			1								1	1	
	1996											1											0	1	
	1997					1						2		1									0	2	
	1998											0											0	0	
	1999											0											0	0	
	2000											1											0	1	
	2001											0						1					1	1	
	2002					1						1				1	1						2	3	
	2003	1										1											0	1	
	2004	2										3				5	2					1	8	11	
	2005											0					2	2					4	4	
	2006	2				1						3					2						2	5	
	2007	2										2				1			1				2	4	
	2008											0					1						1	1	
	2009	2	1									5										1	1	6	
	2010	1		1		3						5				1							1	6	
	2011	1		1		1						4											0	4	
	Sum	11	1	2		7	3	2				28			1	3	13	8	16	1			2	44	72

**Appendix 1 (cont.): Commercial fisher and observer records of deepwater nurse shark by fishing year and FMA.**

Year 1992 = Fishing year 1991–92. ET, outside the New Zealand Exclusive Economic Zone; Unk = Unknown. Duplicate records were omitted from the Commercial records. There were no records before 1991–92.

ODO	Year	Commercial records											Observer records											Total		
		FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET		Unk	Sum
	1992											0												8	8	8
	1993											0													0	0
	1994											0													0	0
	1995											0													0	0
	1996			1								1													0	1
	1997			2								2		1											1	3
	1998											0			1										1	1
	1999											0			1					1					2	2
	2000											0		1		21									22	22
	2001											0			28	1	20								49	49
	2002											0													0	0
	2003		1									1													0	1
	2004											0									1				1	1
	2005					1						1			1		6								7	8
	2006											0													0	0
	2007											0													0	0
	2008											0				6									6	6
	2009											0													0	0
	2010											0													0	0
	2011											0													0	0
	Sum		1	3		1						5		2	31	28	26			9			1		97	102



**Appendix 1 (cont.): Commercial fisher and observer records of spinetaildevilray (MJA), spotted black grouper (SBG), and giant grouper (GGP) by fishing year and FMA.**

Year 2002 = Fishing year 2001–02. ET, outside the New Zealand Exclusive Economic Zone; Unk = Unknown. Duplicate records were omitted from the Commercial records. There were no records before the first year in each table.

		Commercial records											Observer records													
MJA	Year	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	Total
	2002											0		2										2	2	
	2003											0												0	0	
	2004	1								1		2												0	2	
	2005											0		3										3	3	
	2006	1										1		2										2	3	
	2007	2										2		21										21	23	
	2008	15										15		2								2		4	19	
	2009	13										13		15										15	28	
	2010	1								1		2		4										4	6	
	2011	11										4		11										11	26	
	Sum	44								2		4		60								2		62	112	
		Commercial records											Observer records													
SBG	Year	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	Total
	2007											0											1		1	1
	2008											0												0	0	
	2009	3										3												0	3	
	2010	1										1												0	1	
	2011		1									1												0	1	
	Sum	4	1									5											1		1	6
		Commercial records											Observer records													
GGP	Year	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	ET	Unk	Sum	Total
	2006	1										1												0	1	
	2007											0												0	0	
	2008											0				1								1	1	
	2009											0												0	0	
	2010											0												0	0	
	2011											0												0	0	
	Sum	1										1				1								1	2	