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Review of the distribution and abundance of deepwater sharks in New Zealand waters

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Corrections to *New Zealand Fisheries Assessment Report 2003/40*

R. Blackwell & M.L. Stevenson: Review of the distribution and abundance of deepwater sharks in New Zealand waters.

Table 3, Figure 17, and Figure 18 should read

Table 3: Biomass estimates for Owston's dogfish, longnose velvet dogfish, and shovelnose dogfish from trawl survey data; - indicates available data are generally unreliable (either less than 100 t, or where c.v.s exceed 40%). Estimates for longnose velvet dogfish (TAN9303) and Baxter's dogfish (TAN9601 and TAN9701) where c.v.s exceed 40% are included for completeness. The c.v.s for the biomass estimates from the northeast and south Chatham Rise survey series did not exceed 40%.

Trip	Owston's dogfish		Longnose velvet dogfish		Baxter's dogfish		Shovelnose dogfish	
	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)
East coast North Island (750–1500 m): RV *Tangaroa*								
TAN9203	116	17	387	13	138	17	2 336	15
TAN9303	165	24	654	63	593	52	3 259	17
TAN9403	197	23	230	40	238	15	3 501	21
Chatham Rise (600–800 m): RV *Tangaroa*. Data after Livingston (unpublished results), Stevens et al. (2002), NIWA (unpublished data)								
TAN9106	-	-	-	-	-	-	5 090	14
TAN9219	-	-	-	-	-	-	3 810	23
TAN9401	-	-	-	-	-	-	1 884	20
TAN9501	-	-	-	-	-	-	4 189	17
TAN9601	-	-	-	-	3 528	60	3 803	43
TAN9701	-	-	-	-	1 575	66	3 724	38
TAN9801	-	-	-	-	-	-	2 776	27
TAN9901	-	-	-	-	2 078	32	4 121	26
TAN0001	-	-	-	-	857	29	4 420	19
TAN0101	-	-	-	-	854	27	4 190	18
TAN0201	-	-	-	-	2 302	33	5 943	21
Northeast Chatham Rise (750–1500 m): FV *Cordella, Otago Buccaneer*, RV *Tangaroa* Data after Clark et al. (2000)								
BUC8401	250		370		770		1 520	
BUC8501	277		281		347		912	
BUC8601	593		551		493		2 341	
BUC8701	730		588		547		2 782	
COR8801	420		1 976		393		2 949	
COR8901	263		1 121		123		1 383	
COR9002	248		1 739		377		3 146	
TAN9206	705		1 602		331		2 706	
TAN9406	488		1 351		200		1 733	
South Chatham Rise (750–1500 m): RV *Tangaroa*. Data after Livingston (unpublished results)								
TAN9104	-		883		5 626		4 382	
TAN9210	-		1 020		4 752		4 689	
TAN9309	-		950		7 454		6 179	
TAN9511	-		867		10 770		4 820	

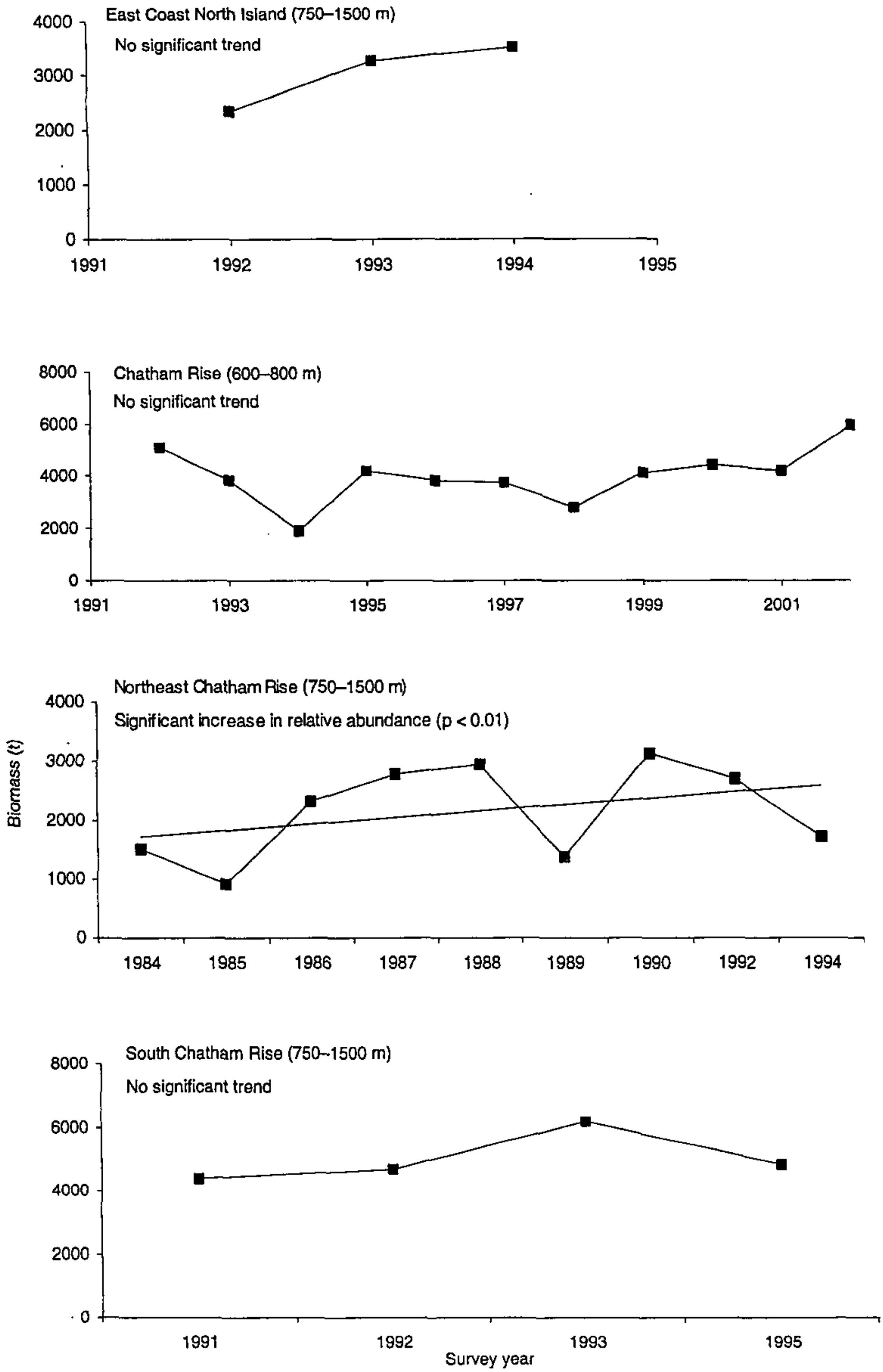

Figure 17: Trends in relative biomass estimates (t) of shovelnose dogfish from trawl surveys, 1984 to 2002. Vessels used and estimates of sampling error are given in Table 3.

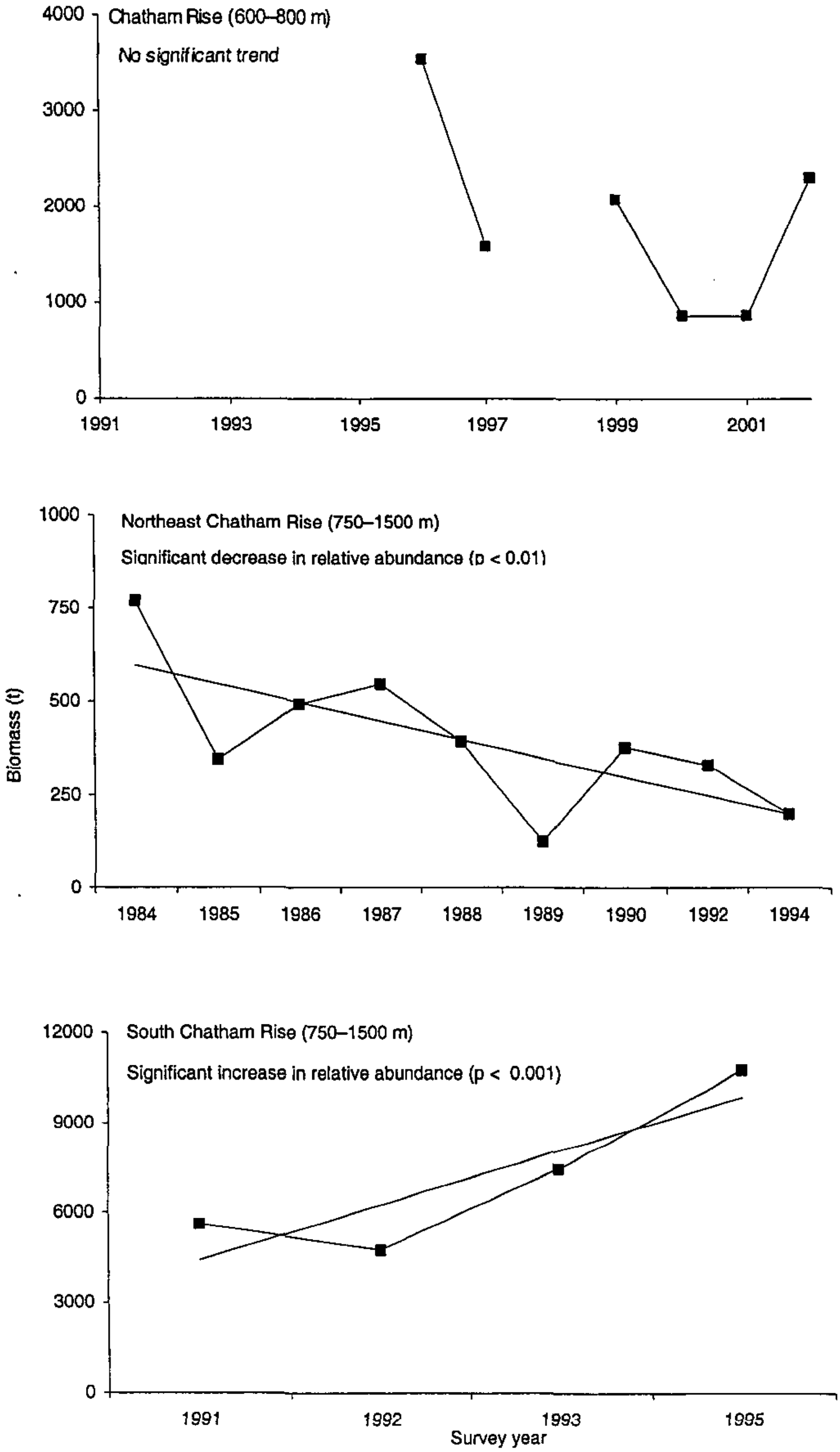

Figure 18: Trends in relative biomass estimates (t) of Baxter's dogfish from trawl surveys, 1984 to 2002. Vessels used and estimates of sampling error are given in Table 3.

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EXECUTIVE SUMMARY

Blackwell, R.G.; Stevenson, M.L. (2003). Review of the distribution and abundance of deepwater sharks in New Zealand waters.

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Six species of squaloid deepwater sharks, shovelnose dogfish (*Deania calcea*), Baxter's dogfish (*Etmopterus baxteri*), Owston's dogfish (*Centroscymnus owstoni*), longnose velvet dogfish (*Centroscymnus crepidater)*, leafscale gulper shark (*Centrophorus squamosus*), and seal shark (*Dalatias licha*) commonly occur on the middle and lower New Zealand continental shelf, mainly in depths greater than 600 m. Baxter's dogfish is endemic to New Zealand, and the other five species have a worldwide distribution, in temperate waters. These sharks are frequently taken as bycatch in the New Zealand middle depths and deepwater fisheries for hoki, orange roughy, and oreos, and are commonly reported from middle depths and deepwater trawl surveys.

Concerns have been raised that these species may be vulnerable to overfishing. The relative abundance of deepwater sharks in New South Wales waters declined between 1970 and 1990, and squaloid sharks are generally considered to have low productivity. There is little information on these sharks in New Zealand waters, and this report reviews trends in distribution, catch composition, and relative biomass using data from fishery observers, commercial catches, and the research *trawl* database.

The reported New Zealand deepwater shark catch has increased from 275 t in 1989–90, to 2347 t in 2000–01. Most were either dumped at sea, or only the fins and livers landed. Catch and landings data are inconsistent between sources, often inaccurate, and appear to under-estimate actual catch. This is largely due to poor species identification and reporting, and the use of conversion factors to determine reported greenweight catch. Data from the Scientific Observer Programme are limited to the major deepwater target fisheries, and provide limited coverage of these species. Few biological data and length frequency data are available.

Deepwater sharks have been routinely reported on the *trawl* database since the early 1970s. However, few relative biomass estimates were available from trawl survey series that provided a minimum of three years of data, and were consistent with respect to vessels, gear, survey stratification, and sample design. These data were confined to the Chatham Rise and to the east coast North Island, and thus provide poor coverage of the known distribution of these species.

The relative abundance of these species has either shown no trend, or increased during the 1980s and 1990s, with the possible exception of Baxter's dogfish, which decreased in abundance between 1984 and 1995 on the northeast Chatham Rise (750–1500 m). Increases in relative abundance were indicated for seal shark and shovelnose dogfish on the northeast Chatham Rise between 1984 and 1994, and also for Baxter's dogfish on the south Chatham Rise (750–1500 m) between 1991 and 1995). No trend was apparent between 1992 and 2002 for shovelnose dogfish on the middle depths (600–800 m) of the Chatham Rise, and for shovelnose dogfish or Owston's dogfish from the east coast North Island between 1992 and 1995. While these data are not consistent with the decline in relative abundance observed for deepwater sharks in New South Wales, the paucity of available data suggests that apparent changes in relative abundance for these species may not be real. Insufficient information currently exists to form definite conclusions on the stock status of these species.

Few length and weight data have been collected from these surveys, and scaled length frequency data cannot always be calculated. Available data suggest successful recruitment for shovelnose dogfish on the Chatham Rise in 2000 and 2002. Unscaled length frequency data support the hypothesis of migration of mature shovelnose dogfish females from the Chatham Rise to nursery and pupping areas on the east coast North Island. The unscaled length frequency data may poorly represent the sampled population, and should be interpreted with caution. Insufficient data are available for other species and areas to determine trends.

These six deepwater sharks represent a medium-sized and widely distributed, but poorly known, deepwater resource that appears to be increasingly exploited. Relative abundance indices (with the exception of Baxter's dogfish) appear to have remained constant, or slightly increased, between 1984 and 1995, but recent estimates are unavailable and these data provide poor coverage of the wide distribution of these species. Given their low productivity, these trends should be interpreted with caution, and further monitoring of relative abundance is recommended. Although commercial fishery statistics provide the only recent data, the usefulness of these data appears to be compromised by inaccurate identification and reporting of catch and landings information.

1. BACKGROUND

The small deepwater sharks of the continental slope represent a potentially important, but poorly known, fisheries resource (Francis 1998) that may be of increasing commercial interest following the recent reductions in orange roughy (ORH) quota. Wetherbee (1999) listed 16 shark species from the Chatham Rise, the most common species in commercial catch and trawl survey data being shovelnose dogfish (*Deania calcea*, SND); Baxter's dogfish (*Etmopterus baxteri*, ETB); Owston's dogfish (*Centroscymnus owstoni*, CYO); longnose velvet dogfish (*Centroscymnus crepidater*, CYP); leafscale gulper shark (*Centrophorus squamosus*, CSQ); and seal shark (*Dalatias licha*, BSH).

Little is known about the distribution, abundance, and productivity of these species, and concerns have been raised about the ability of deepwater sharks to sustain anything other than low levels of fishing mortality. Their productivity is thought to be low as a result of low growth rates and fecundity (Wetherbee 1999). Five of these species have a worldwide distribution, but Baxter's dogfish is endemic to New Zealand (L. Compagno, pers. comm. 2002). All are widespread in the New Zealand Exclusive Economic Zone, and are most abundant in the 500–1300 m depth range (Anderson et al. 1998).

Deepwater sharks are taken mainly as bycatch of trawling for orange roughy (*Hoplostethus atlanticus*), hoki (*Macruronus novaezelandiae*), oreos (*Allocyttus niger*, *Neocyttus rhomboidalis*, *Pseudocyttus maculatus*) and other deepwater species (Clark et al. 2000b) and to a lesser extent by line fishing for ling (*Genypterus blacodes*) and other demersal species (Hurst et al. 2000, Anderson et al. 2001a). Total reported landings from the commercial fishery have historically been around 500 t per year during the last decade (Francis 1998). Little demand exists for fillet products (Francis 1998), and these sharks are either dumped or part-processed at sea for fins (King & Clark 1987), oil (Summers & Wong 1992), and other industrial by-products such as squalene (Summers 1987). The scientific observer database is limited in coverage to the major target fisheries, and data on deepwater sharks may not be representative of the wide distribution of these species.

The Ministry of Fisheries (MFish) is responsible for managing the effects of target fisheries on associated species such as deepwater sharks. Previous research includes a review of the effect of fishing on the sea bottom (Jones 1992), and analysis of trends in discards from deepwater trawl fisheries (Anderson et al. 2001b). The effect of reduction in biomass of major deepwater target fisheries on associated species has been reviewed for the Challenger Plateau orange roughy fisheries (Clark & Tracey 1994), and for the orange roughy, hoki, and oreo trawl fisheries on the Chatham Rise (Wetherbee 1999, Clark et al. 2000a, M.E. Livingston et al. NIWA, unpublished results).

This report summarises data from the MFish scientific observer database, the commercial fishery, and research databases to review trends in relative abundance of six deepwater sharks throughout the EEZ and across all depth ranges. It reviews distribution and catch composition data to provide information on possible stock range, and segregation by size and sex (Yano & Tanaka 1987, Clark & King 1989, Wetherbee 1996). It updates previous estimates of commercial landings (Francis 1998), and updates and extends the reviews of trends in relative abundance for these species from the Chatham Rise (Clark et al. 2000a, Livingston et al., unpublished results).

1.1 Objectives

This report was prepared under MFish Project ENV2001/05 "To assess the productivity and relative abundance of deepwater sharks" and addresses Objective 1 of this programme:

1. To review the relative abundance, distribution and catch composition of the most commonly caught deepwater shark species: shovelnose dogfish (*Deania calcea*), Baxter's dogfish (*Etmopterus baxteri*), Owston's dogfish (*Centroscymnus owstoni*), longnosed velvet dogfish (*Centroscymnus crepidater)*, leafscale gulper shark (*Centrophorus squamosus*), and the seal shark (*Dalatias licha*).

This objective has one key activity.

1. Review and analyse published and unpublished data on the relative abundance, distribution, and catch composition of six deepwater shark species in New Zealand.

2. METHODS

2.1 Review of previous research

Previously published information on these six deepwater sharks in New Zealand has been reviewed to summarise information on the relative abundance, distribution, size and sex composition.

2.2 Review of data from the commercial fishery

Deepwater sharks are taken mainly as bycatch of deepwater trawl fishing (Francis 1998), and to a lesser extent by line fishing (Anderson et al. 2001a). Reported landings data were extracted from the MFish LFRR (Licensed Fish Receiver Return) database, and the catch series for deepwater sharks reported by Francis (1998) was updated.

To review trends in total catch (including discards), landings data were also extracted from the voyage record databases, CELR-landed, from the CELR (Catch Effort Landing Return) database, and CLR (Catch Landing Returns) from the TCEPR (Trawl, Catch, Effort and Processing Return) database. The voyage records report actual landed weights (scaled to greenweight), including discarded catches, but do not provide target species information. To review catches by target species, estimated catch data were also extracted from the MFish TCEPR and CELR databases for deepwater trawl and longline catches. These data provide estimated catches only for the top five species, and may not include discarded catch. Data from the MFish scientific observer databases were also examined to identify the geographical areas and depth ranges from which deepwater sharks are commonly caught.

2.3 Review of trawl survey data

Deepwater sharks are commonly recorded in low numbers from middle depth and deepwater trawl surveys in the New Zealand EEZ, but are not generally included in the top 20 species for which distribution and abundance data are published. Distribution data from bottom and midwater trawl surveys were summarised by Anderson et al. (1998) and Hurst et al. (2000) respectively, and the distribution of juveniles from trawl surveys has been summarised by O'Driscoll et al. (2003). These data (included in the literature review, Section 3.1) indicate known distribution, but are biased towards areas that have been surveyed frequently and may not describe the full distribution range.

Data for relative biomass estimation were restricted to time series of trawl surveys where at least three years of data were available, and where the series was consistent in survey design, stratification, vessel, and sampling gear (D. Gilbert, NIWA, pers. comm. 2002). Transect based surveys, such as the 1985–86 FV *Wanaka* survey series of Clark & King (1989) were not used for biomass estimation.

Relative biomass estimates were derived using the *TrawlSurvey Analysis* program (Vignaux 1994) where data had not previously been analysed, and linear regression was used to identify any temporal trends in relative abundance. Statistical significance was assessed using a standard t-test of the regression slope. These methods were used by Clark et al. (2000a) for the northeast Chatham Rise orange roughy surveys, and Livingston et al.(unpublished results) for the south Chatham Rise oreo surveys.

Because trawl survey series have been designed to optimally sample their target species, they may not necessarily provide a reasonable sample design for other species. Trawl survey series were not included in this review where a significant proportion of the biomass estimates were less than 100 t, or where the coefficient of variation (c.v.) of the estimates was greater than 40%. Such surveys were considered to poorly sample deepwater sharks (M. Francis, pers. comm. 2002).

Previous research on shovelnose dogfish (Clark & King 1989), Baxter's dogfish (Wetherbee 1996), and Owston's dogfish (Yano & Tanaka 1987) indicates these species may be segregated by size and sex. To investigate trends in size and sex composition with depth and region, scaled length-frequency distributions were derived for surveys in which at least 100 fish were measured. Individual fish weight data are necessary to scale the raw length frequencies to the catch. Where weight data were not available, but at least 100 fish were measured, raw (unscaled) length frequency data were plotted. Unscaled length frequency data may represent a biased estimate of the population length frequency distribution, and should be interpreted with caution.

3. RESULTS

3.1 Previous research

Between the 1970s and 1990s, large declines in catch rates of nearly all species of deepwater sharks were observed off the New South Wales shelf (Andrew et al. 1997, Graham et al. in press). Large declines in relative biomass have not been observed for deepwater shark species in New Zealand waters, with the exception of Baxter's dogfish in depths between 750 and 1500 m on the northeast Chatham Rise (Wetherbee 1999, Clark et al. 2000a, Livingston et al. unpublished results). Similar analyses have not been carried out for other areas of New Zealand.

Wetherbee (1999) reviewed deepwater shark distribution and species composition on the northwest and northeast Chatham Rise, and found densities declined with depth between 700 and 1200 m (Figure 1). Species composition varied with depth, with shovelnose dogfish and leafscale gulper shark dominating catches between 700 and 800 m, shovelnose dogfish and longnose velvet dogfish most dominant between 800 and 1000 m, and Baxter's dogfish dominant in depths greater than 1000 m. Densities of all deepwater sharks were low in depths greater than 1000 m (Anderson et al. 1998).

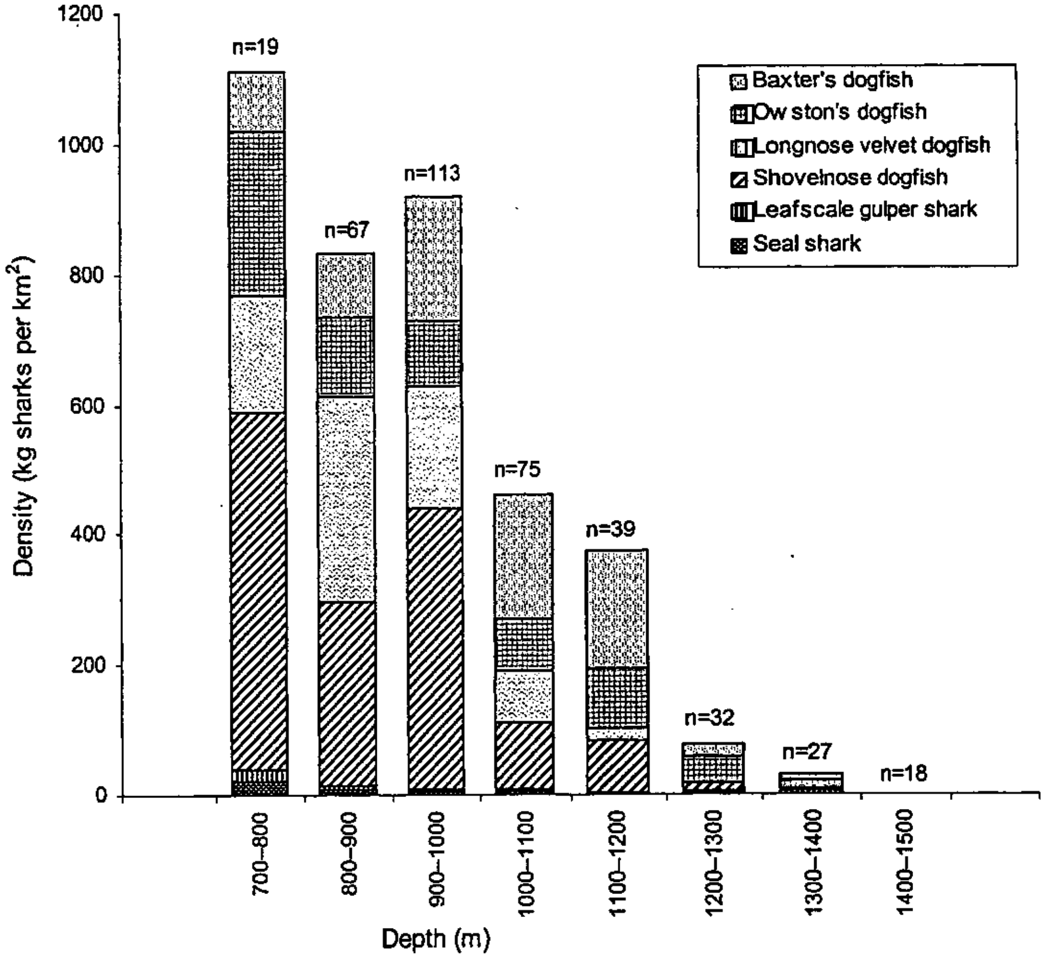


Figure 1: Densities (kg/m²) of deepwater sharks collected at all locations on the Chatham Rise by depth interval, from the 1990 (n = 281 stations) and 1993 (n = 109 stations) orange roughy trawl surveys. n = number of stations in each depth interval. After Wetherbee (1999), used with permission.

3.1.1 Shovelnose dogfish (SND)

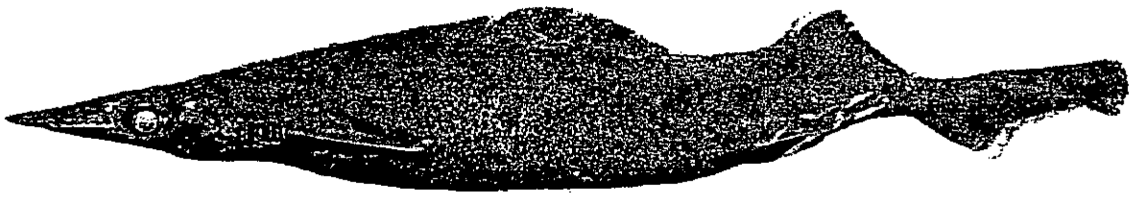


Figure 2: Shovelnose dogfish. Photograph by NIWA staff.

This medium-large (to 122 cm) demersal dogfish (Figure 2) is widely distributed in temperate waters between latitudes 70° N and 45° S, in the Eastern Atlantic (from Iceland to South Africa); the Eastern Pacific (Chile), and the Western Pacific (Japan, Australia, and New Zealand). It occurs over the continental slope in depths of 70–1450 m (Last & Stevens 1994, Anderson et al. 1998). It varies in colour from light grey to brown, and is characterised by an elongate snout, a long, low first dorsal fin, and both dorsal fins with prominent spines (Last & Stevens 1994, Tracey et al. 2002). Males vary in length from 72 to 102 cm (TL), and females from 98 to 120 cm (TL) (King & Clark 1987). Adults generally occur north of the Subtropical Convergence, often in large schools, in depths of 600–1500 m, and were reported from 5003 research stations (Figure 3). Francis et al. (2002) found shovelnose dogfish to be most common in deep waters (median depth 720 m, 90% range 400–1050 m) and low latitudes

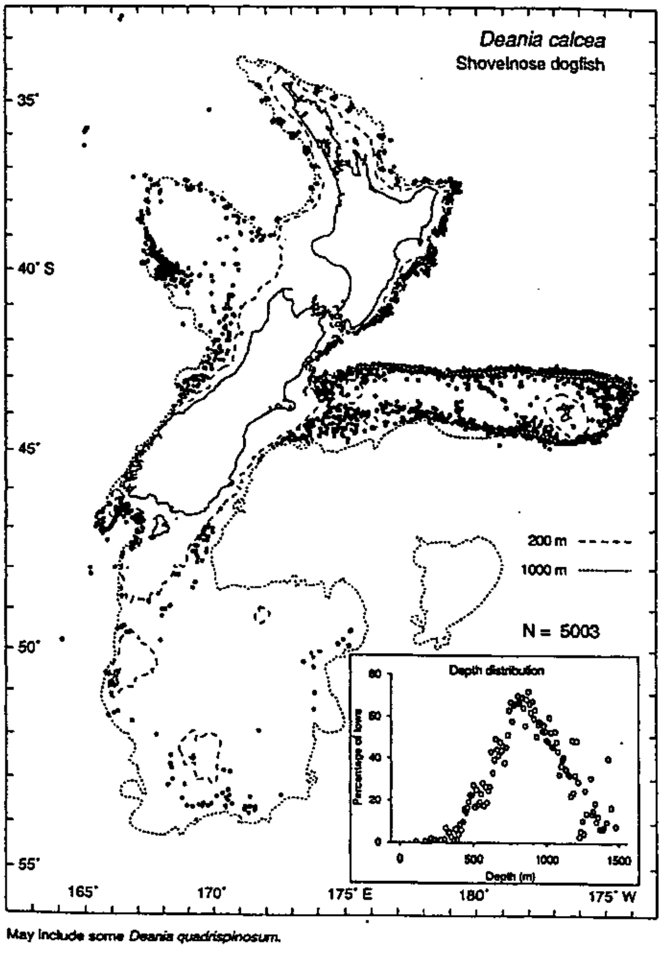


Figure 3: Distribution of shovelnose dogfish from trawl surveys (after Anderson et al. 1998).

(median 42.7° S, 90% range 36°–54° S). Shovelnose dogfish is taken by bottom trawling and occasionally by midwater trawling (King & Clark 1987, Hurst et al. 2000). Shovelnose dogfish was the most common dogfish species reported in the 1985 and 1986 *Wanaka* trawl surveys from northern and northeast New Zealand. Diet consists mainly (78%) of fish (including orange roughy, lookdown dory, ribaldo, cardinalfish, and alfonsino) and squid (20%) (King & Clark 1987, Wetherbee 1999).

Shovelnose dogfish forms a single stock off the North Island, but this stock is strongly segregated by size, sex, and reproductive state among depth strata and areas (K. King & M. Clark, NIWA, unpublished results). To explain this, King & Clark (unpublished results) suggest that migration occurs between areas. Shovelnose dogfish are ovoviviparous, and sexual maturity occurs at 76–100 cm (King & Clark unpublished results). Mature females migrate to pup in a nursery area off the east coast of the North Island in 600–800 m. Birth length varies between 29 and 34 cm (King & Clark 1987), and litters average 6–12 pups (Last & Stevens 1994). Early stage juveniles initially remain in the nursery area, while mature females return to deeper water (600–1000 m) off the west coast North Island, the Chatham Rise, or Puysegur Bank. Late stage juveniles migrate to deeper water where they mature and mate, and these have been recorded from trawl survey stations in 500–1100 m depths in areas where adults are generally abundant (O'Driscoll et al. 2003). Pregnant females then return to the nursery areas to spawn. Similar movements have been reported for *Deania* and *Centrophorus* spp. from Japan (Yano & Tanaka 1984).

3.1.2 Baxter's dogfish (ETB)

Figure 4: Baxter's dogfish. Photograph by NIWA staff.

This medium sized (to 80 cm) deepwater dogfish (Figure 4) is also known as the southern, or New Zealand, lantern shark. It is uniform brownish black, with a short caudal peduncle and prominent dorsal spines (Last & Stevens 1994). Although initially synonymised with *Etmopterus granulosus* (Tachikawa et al. 1989), recent examination of type material shows that the two are distinct and Baxter's dogfish can be considered endemic to New Zealand (L. Campagno, South African Museum, pers. comm. 2002).

Baxter's dogfish commonly occurs over the shelf and lower slope between 600 and 1400 m (Figure 5). It occurs off the east coast South Island, the Chatham Rise, and the Southland, sub-Antarctic and Campbell Plateau, but is relatively uncommon in northern New Zealand. Adults were reported from 5729 tows, which represented more than 30% of all research tows, up to 1997 (Anderson et al. 1998). It was the most abundant deepwater shark recorded from the FV *Wanaka* surveys of east-central New

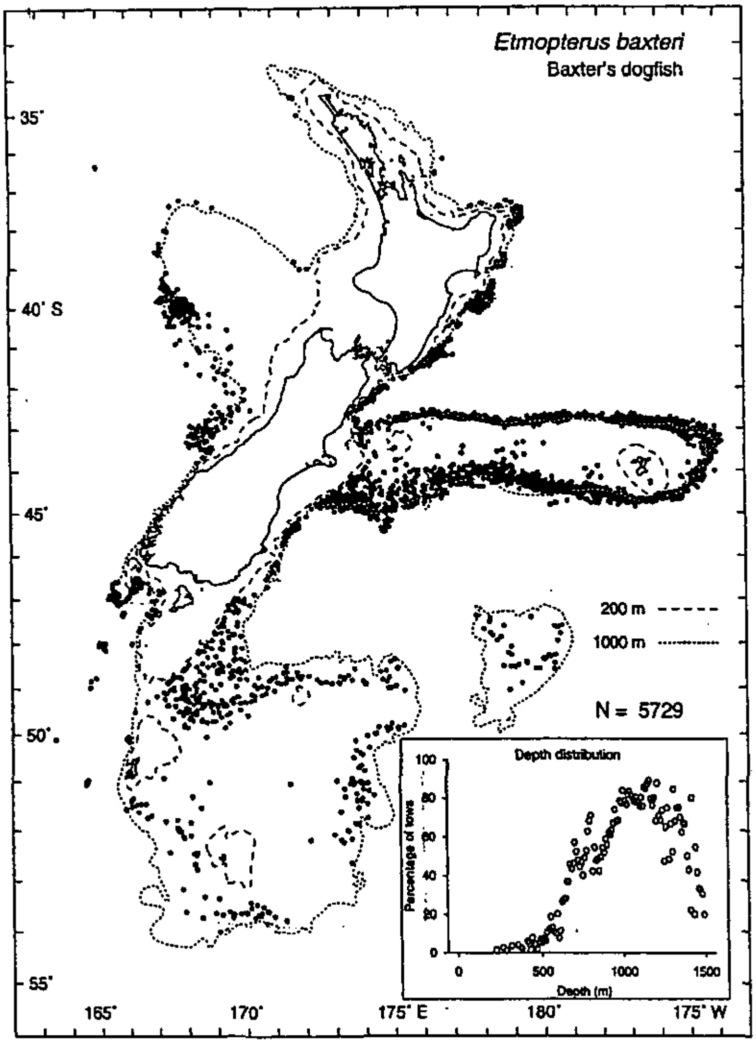


Figure 5: Distribution of Baxter's dogfish from trawl surveys (after Anderson et al. 1998).

Zealand (Clark & King 1989), and the most abundant deepwater shark reported from the south Chatham Rise (Wetherbee 1999). Francis et al. (2002) found Baxter's dogfish to be most common in deep water (median 1500 m, 90% range 600–1400 m), and low latitudes (median 45.9° S, 90% range 37°–53°). Diet consists mainly of fish (79%) and squid (21%) (King & Clark 1987).

Mature males range from 56 to 73 cm, and females from 64 to 79 cm in length (King & Clark 1987). Baxter's dogfish is ovoviviparous, and sexual maturity occurs at 55–58 cm for males and 64–69 cm for females. Litter sizes are 7–30 pups (Wetherbee 1996), and birth length varies between 17 and 20 cm (King & Clark 1987). Juvenile Baxter's dogfish were mainly reported from the Chatham Rise, with occasional specimens reported from the north and east of the North Island (O'Driscoll et al. 2003). Wetherbee (1999) found few mature females on the deepwater Chatham Rise surveys in 1990 and 1993 and suggested that adults may be segregated by sex and size.

3.1.3 Owston's dogfish (CYO)

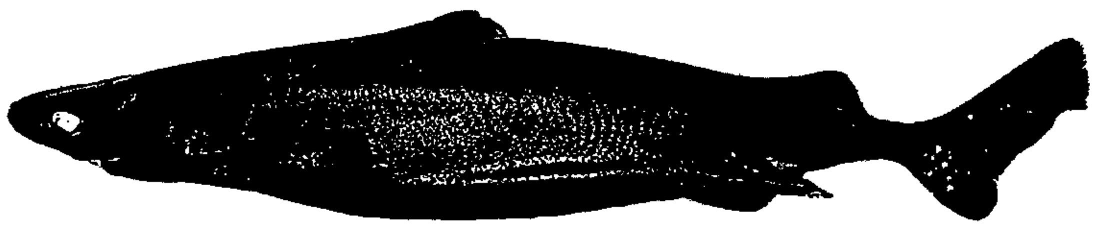


Figure 6: Owston's dogfish. Photograph by NIWA staff.

This medium-large (70–120 cm) deepwater dogfish (Figure 6) is widely distributed in temperate waters between latitudes 40° N and 45° S, and reported from the western North Atlantic and the western Pacific, including Japan, Australia, and New Zealand. It commonly occurs on the upper continental slope in depths from 500 to 1400 m (Last & Stevens 1994, Anderson et al. 1998). It is dark brown or black, with a short snout, and its small denticles give the skin a smooth sheen. The second dorsal fin is larger than the first dorsal fin, the fin spines are very small, and a prominent belly ridge is present on the side of the

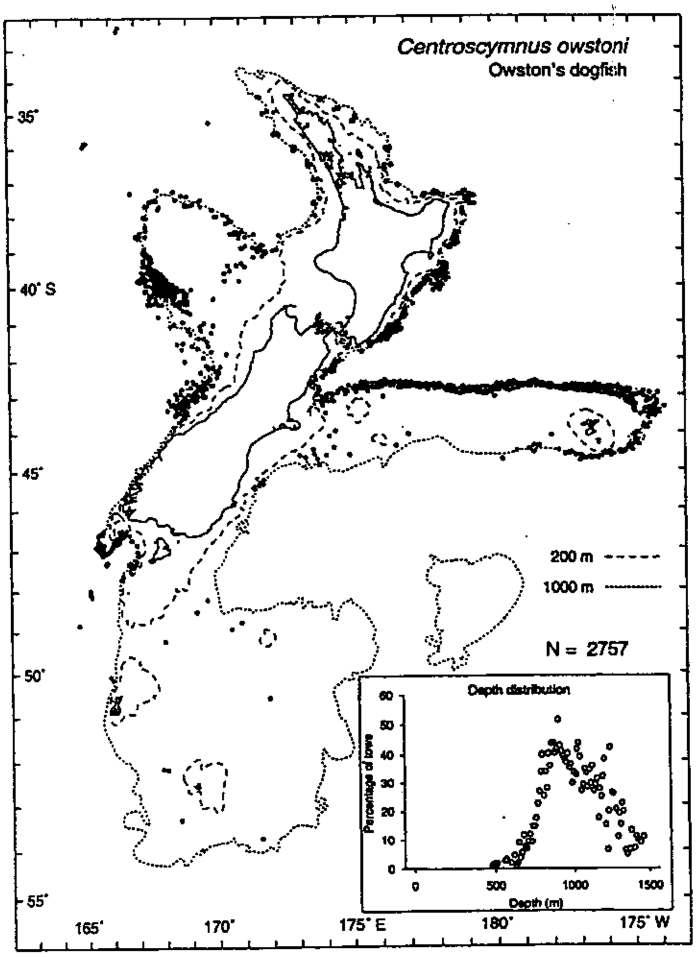


Figure 7: Distribution of Owston's dogfish from trawl surveys (after Anderson et al. 1998).

body (Last & Stevens 1994, Tracey et al. 2002). In New Zealand, Owston's dogfish is commonly recorded north of the Subtropical Convergence in depths from 600 to 1500 m, from northern and east coasts of the North Island, the north and southeast Chatham Rise, the west coast of the South Island, the Challenger Plateau, and Puysegur Bank (Figure 7). It was recorded from 2757 research trawl stations (Anderson et al. 1998). From Francis et al (2002), Owston's dogfish was found in deep water (median 980 m, 90% range 700–1300), and high latitudes (median 40.0° S., 90% range 35°–48° S). Diet consists mainly of squid (64%) and fish (34%) (King & Clark 1987).

Sexual maturity occurs at about 70 cm. It is ovoviviparous, with sexual maturity occurring at about 70 cm. Mature females contain 11 eggs on average, but some have up to 34 eggs and the ovary makes up almost one-quarter of the body weight (Last & Stevens 1994). Yano & Tanaka (1984) noted that sharks are segregated by sex and maturity, with females occurring in deeper waters than males. Birth length varies between 27 and 30 cm TL (King & Clark 1987). Immature Owston's dogfish were reported from the Chatham Rise, the northern North Island, and from the north and southeast Challenger Plateau (O'Driscoll et al. 2003).

3.1.4 Longnose velvet dogfish (CYP)

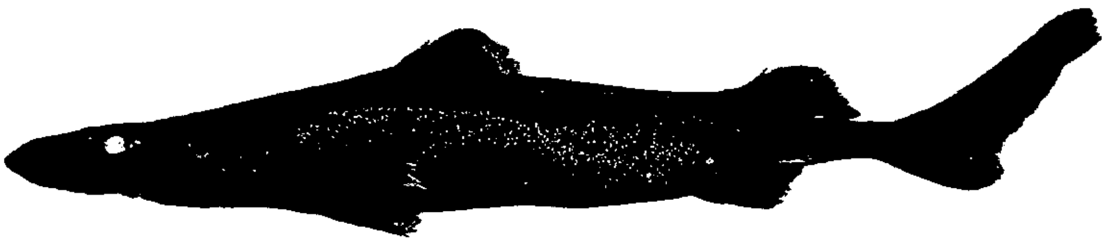


Figure 8: Longnose velvet dogfish. Photograph by NIWA staff.

This medium-large (to 110 cm) slender shark (Figure 8) is widely distributed on the continental slope in the eastern Atlantic Ocean, from Iceland to South Africa; the Indian Ocean; the western Pacific Ocean, from Australia and New Zealand; and Chile in the eastern Pacific Ocean (Last & Stevens 1994). It is dark brown to black, and is superficially similar to Owston's dogfish, but has a longer nose and a much longer first dorsal fin (Last & Stevens 1994). It has short dorsal fin spines, with only the tips protruding through the skin. The small skin denticles produce a velvet sheen.

In New Zealand it commonly occurs around the northern and eastern North Island, the Chatham Rise, Puysegur Bank, the west coast South Island including the Hokitika Trench, and the Challenger Plateau, but is rare on the Campbell Plateau (Figure 9).

Longnose velvet dogfish were recorded from 4191 research survey stations (Anderson et al. 1998), and has a similar latitude range to shovelnose dogfish (median 42.7° S, 90% range 36°– 54° S), but inhabits deeper water (median 930 m, 90% range 650–1300 m) (Francis et al. 2002). Diet consists mainly of fish (65%) and squid (20%) (King & Clark 1987).

It is ovoviviparous, with sexual maturity occurring at about 60 cm for males and 80 cm for females, and females appear to breed throughout the year (Last & Stevens 1994). The litter size is small (4–8 pups) with a birth length from 28 to 35 cm (King & Clark 1987). Immature longnose velvet dogfish were reported from the Chatham Rise and Memoo Bank, northwest North Island, and from the north and southeast Challenger Plateau (O'Driscoll et al. 2003).

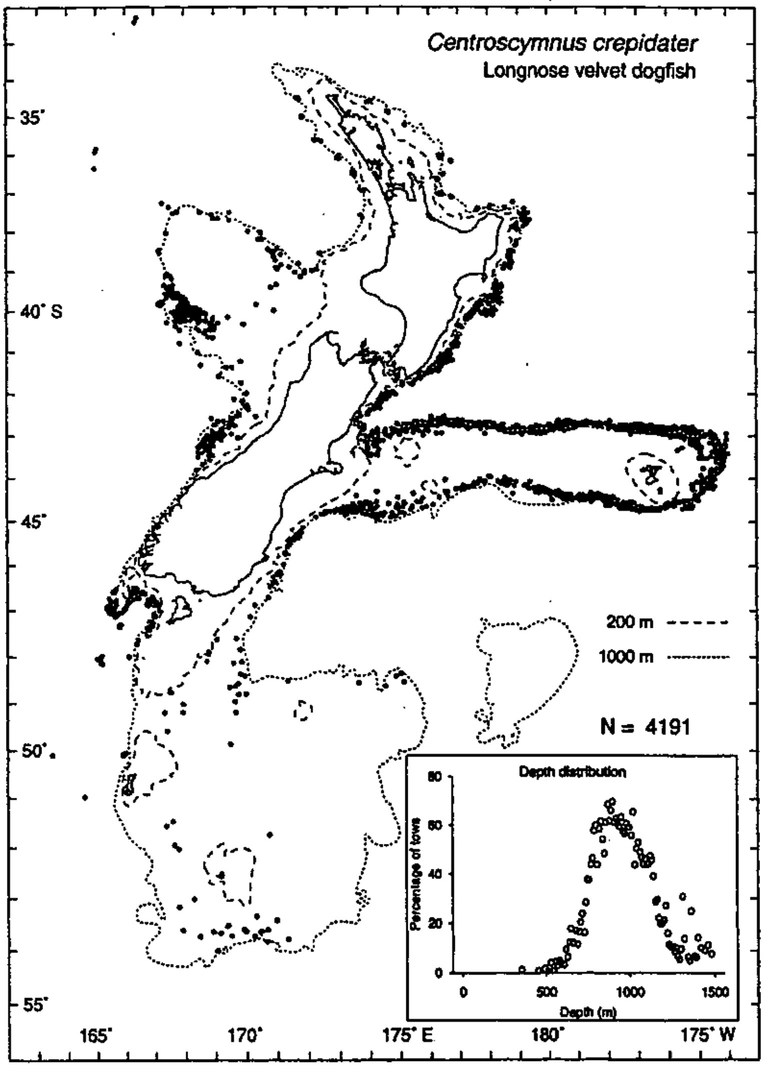


Figure 9: Distribution of longnose velvet dogfish from trawl surveys (after Anderson et al. 1998).

3.1.5 Leafscale gulper shark (CSQ)

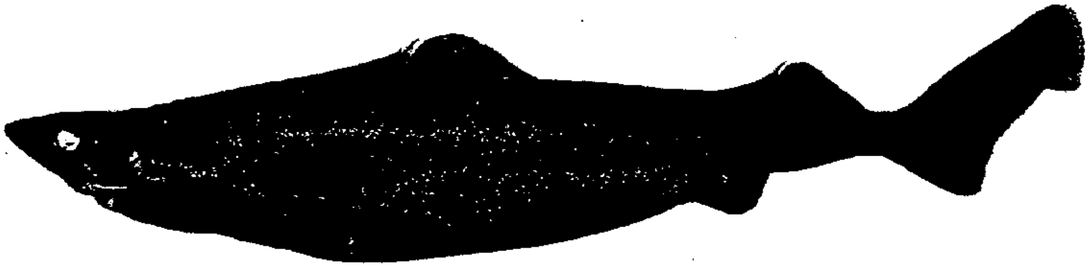


Figure 10: Leafscale gulper shark. Photograph by NIWA staff.

This medium-large (to 150 cm) deepwater shark (Figure 10) occurs widely in temperate waters from Iceland to South Africa in the eastern Atlantic Ocean; from South Africa to Aldabra in the Indian Ocean; and from Japan, the Philippines, Australia, and New Zealand in the western Pacific Ocean (Last & Stevens 1994, Anderson et al. 1998). It is found on the continental slope in 230–2400 m, but also occurs in the upper 1250 m of deep oceanic waters (Last & Stevens 1994). It is light greyish brown to dark grey, with a short, blunt snout. The fine skin denticles have a characteristic leaf shape. Dorsal fin spines are large and prominent, and the caudal fin has a pronounced ventral lobe (Last & Stevens 1994, Tracey et al. 2002).

In New Zealand, it ranges from the Three Kings Islands to the Campbell Plateau (Figure 11), and was recorded from 1066 research trawl stations (Anderson et al. 1998). Francis et al. (2002) found leafscale gulper shark occupies medium depths (median 820 m, 90% range 550–1390 m), and latitudes (median 46.2° S., 90% range 35°–53° S). Diet consists of fish (76%) and squid (24%) (King & Clark 1987).

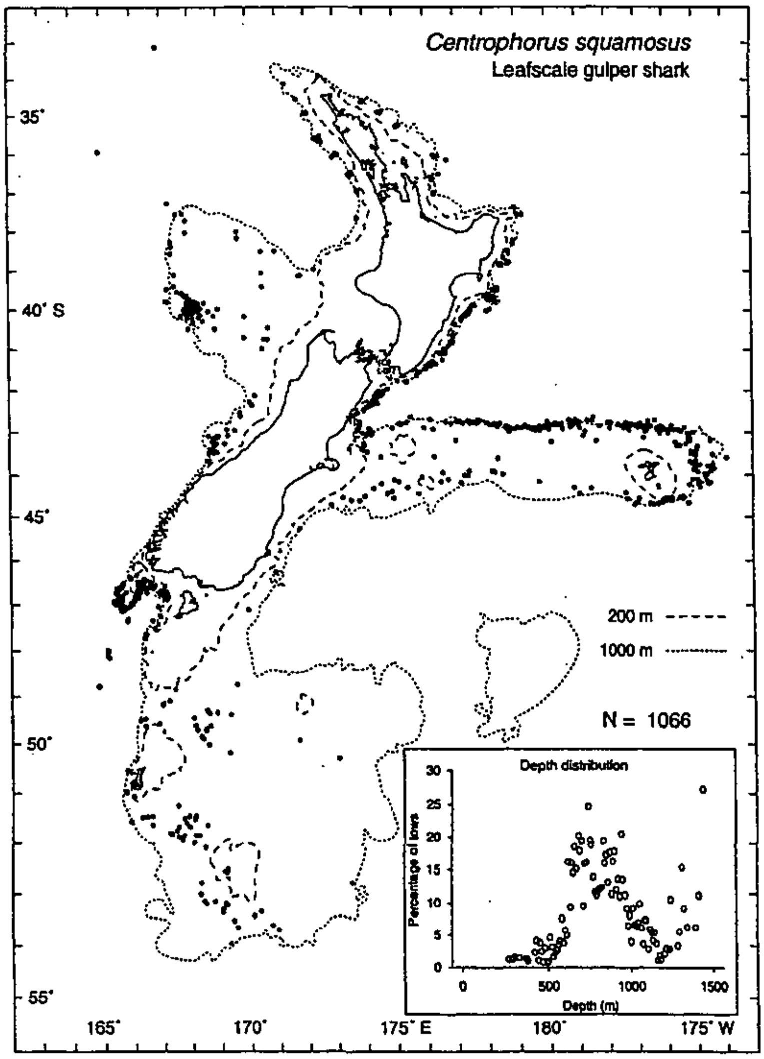


Figure 11: Distribution of leafscale gulper shark from trawl surveys (after Anderson et al. 1998).

Leafscale gulper shark may undergo depth segregation in relation to sex and maturity stage in northern hemisphere waters (Clarke et al. 2001), although insufficient data are available to determine trends in New Zealand. It is ovoviviparous, and sexual maturity occurs at about 100 cm for males and 110 cm for females (Last & Stevens 1994). Litter size is 5 to 9 pups, and birth length varies between

42 and 43 cm (King & Clark 1987, Last & Stevens 1994). No data are available on juvenile distribution.

3.1.6 Seal shark (BSH)

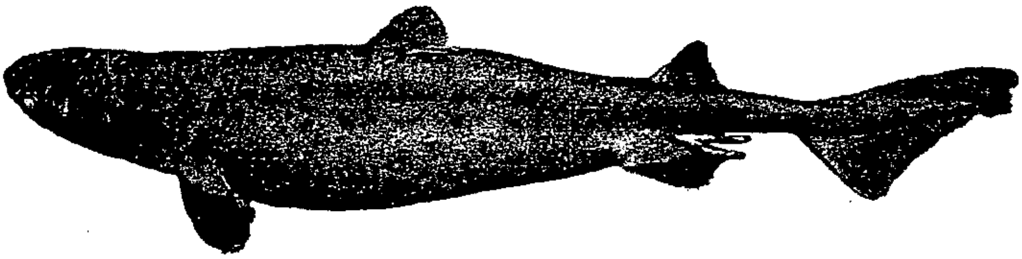


Figure 12: Seal shark. Photograph by NIWA staff.

This large (to 182 cm) deepwater dogfish (Figure 12) occurs widely on the continental shelf and slope from Iceland to South Africa in the western Atlantic, to Chile in the eastern Pacific, and from Japan from to south Australia and New Zealand in the western Pacific. It is found in a wide depth range from 400 to 1450 m (Last & Stevens 1994, Anderson et al. 1998). Coloration varies m dark brown to black. Seal sharks have a short rounded snout, with pronounced rounded and spineless dorsal fins (King & Clark 1987, Tracey et al. 2002). Seal shark occurs over most of the New Zealand EEZ (Figure 13),

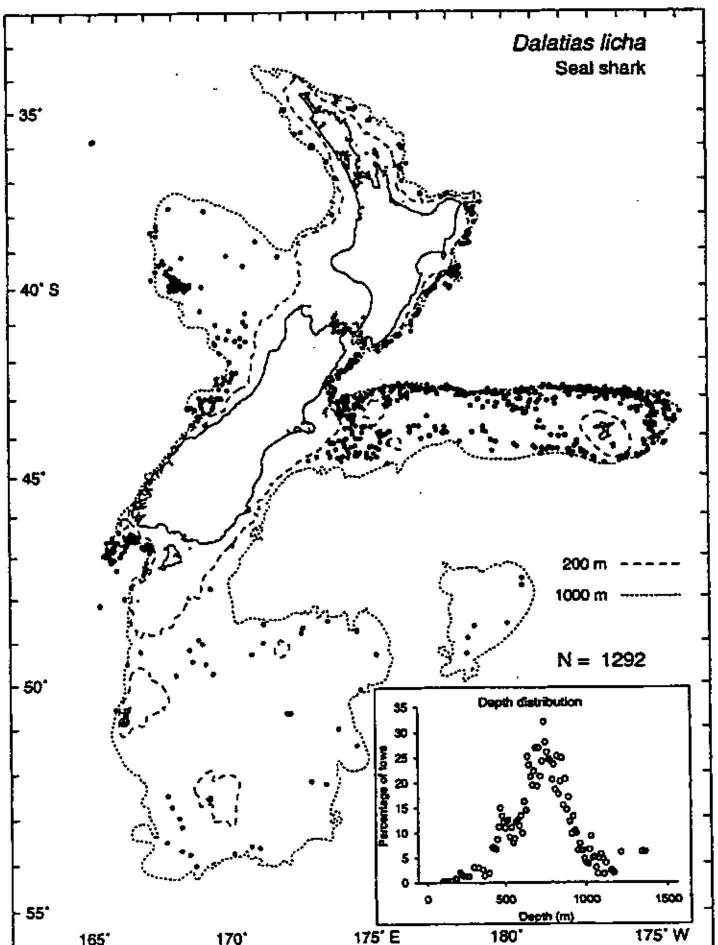


Figure 13: Distribution of seal shark from trawl surveys. (after Anderson et al. 1998).

and commonly occurs off the east coast North Island, Challenger Plateau, Puysegur Bank, west coast South Island, and the Chatham Rise (King & Clark 1987). It was recorded from 1292 research survey stations (Anderson et al. 1998). Francis et al. (2002) found seal shark occurred in medium depths (median 720 m, 90% range 400–1050 m), and latitudes (median 43.1° S., 90% range 35°– 50° S). Last & Stevens (1994) found seal sharks feed mainly (94%) on bony fish and elasmobranchs, and cephalopods (6%).

Males are sexually mature at about 100 cm and females at 120 cm. Seal sharks are ovoviviparous, with an average litter size of 12 pups (King & Clark 1987). Birth length varies between 40 and 42 cm (Marques 1988). No data are available on the distribution of juveniles.

3.2 Commercial fishery data

3.2.1 LFRR data

Total landings data for deepwater sharks recorded on the LFRR database (Table 1) decreased from 637 t in 1986–87 to 364 t in 1991–92, then increased to peak at 1257 t in 1988–99. Subsequent landings have remained at about 1000 t. These data update previous estimates by Francis (1998). Little or no landings data were reported for longnose velvet dogfish, Owston's dogfish, or Baxter's dogfish. An unknown amount of deepwater dogfish landings may be reported against the generic code "other sharks and dogfish" (OSD), which could also include inshore and pelagic shark species. These shortcomings precluded further analysis of these data.

3.2.2 CLR and CELR-landed data

Total reported landings increased from 275 t in 1989–90, to 2529 t in 1999–00 (Figure 14), although these data are influenced by the landings of "other sharks and dogfish (unspecified)", which may include shallow water non-target shark species, such as northern spiny dogfish (*Squalus mitsukurii*) or southern spiny dogfish (*Squalus acanthias*), and pelagic shark species, such as blue shark (*Prionace glauca*) or bronze whaler (*Carcharhinus brachyurus*). Landings of seal shark, shovelnose dogfish, and deepwater dogfish increased between 1989–90 and 2000–01, while reported landings of leafscale gulper shark and Baxter's dogfish remained low during this period. Seal shark catch probably includes other black sharks, such as lucifer dogfish, and may be an over-estimate of actual landings. The reported landings differ between data sources (Table 1), and from the estimated catch data (Appendix 1), although the latter may not include discards.

Table 1: Landings and discards (t) of seal shark, leafscale gulper shark, shovelnose dogfish, Baxter's dogfish and other sharks and dogfish (unspecified), that total less than 1 t, from the CLR and CELR-landed databases, and reported landings from the LFRR database 1986–87 to 2000–01. L=landed, D=discarded, T= total (excluding minor destination codes). Other sharks and dogfish (unspecified) may also include shallow water and pelagic sharks. Reported landings do not include landings of Owston's dogfish or longnose velvet dogfish. The table also provides an estimate of Scientific Observer coverage (%) of deepwater shark landings.

Fishing year	Seal shark				Leafscale gulper shark				Shovelnose dogfish				Baxter's dogfish				Other sharks and dogfish				Total		
Species	L	D	T	LFRR	L	D	T	LFRR	L	D	T	LFRR	L	D	T	LFRR	L	D	T	LFRR	L	D	T
1986–87	0	0	0	190	0	0	0	0	0	0	0	164	0	0	0	0	0	0	0	283	0	0	0
1987–88	0	0	0	379	0	0	0	0	0	0	0	167	0	0	0	0	0	0	0	69	0	0	0
1988–89	0	0	0	203	0	0	0	0	0	0	0	101	0	0	0	0	0	0	0	69	0	0	0
1989-90	15	1	16	104	0	0	0	0	164	5	169	199	0	0	0	0	73	17	90	97	252	23	275
1990-91	96	1	97	141	0	0	0	0	2	2	4	0	0	0	0	0	64	79	143	234	162	82	244
1991-92	123	2	125	183	0	0	0	0	3	5	8	1	0	0	0	0	431	44	475	180	557	51	608
1992-93	185	3	188	231	0	0	0	0	3	2	5	6	0	0	0	0	191	19	210	274	379	24	403
1993-94	254	2	256	304	0	0	0	0	4	2	6	5	0	0	0	0	183	27	210	256	441	31	472
1994-95	323	8	331	372	0	0	0	0	25	7	32	21	0	0	0	0	191	45	236	467	539	60	599
1995-96	332	47	379	282	13	0	13	12	50	3	53	44	0	0	0	0	263	178	441	506	658	228	886
1996-97	275	184	459	327	13	0	13	11	28	0	28	21	0	0	0	0	390	280	670	629	706	464	1170
1997-98	333	23	356	419	6	0	6	5	34	2	36	36	0	5	5	0	1388	376	1764	540	1761	406	2167
1998-99	377	144	521	356	1	0	1	1	16	65	81	16	29	0	29	0	349	649	998	884	772	858	1630
1999-00	301	470	771	319	0	0	0	0	27	111	138	28	26	0	26	0	691	903	1594	573	1045	1484	2529
2000-01	293	468	761	406	1	0	1	0	37	305	342	57	21	0	21	2	206	1016	1222	672	558	1789	2347

Estimated scientific observer coverage of deepwater fisheries

Total landings

Fishing year	LFRR Landings (t)	Observer Landings (t)	Estimated coverage (%)
1986–87	637	0	0
1987–88	615	152	25
1988–89	373	183	49
1989-90	400	54	14
1990-91	375	125	33
1991-92	364	81	22
1992-93	511	69	14
1993-94	565	85	15
1994-95	860	58	7
1995-96	844	17	2
1996-97	988	50	5
1997-98	1000	87	9
1998-99	1257	127	10
1999-00	920	162	18
2000-01	1137	133	12

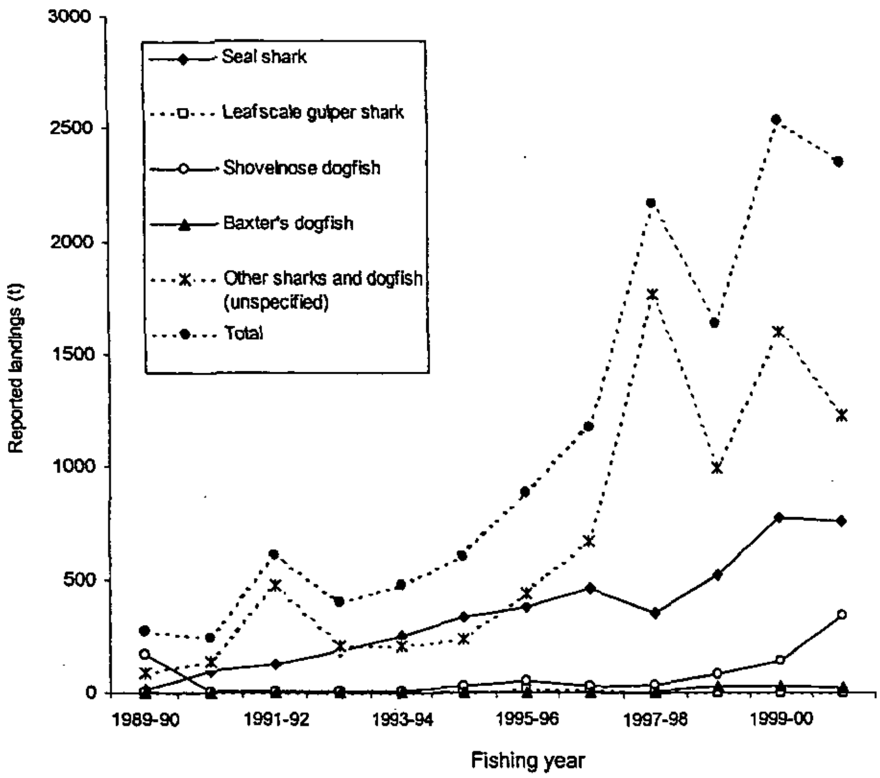


Figure 14: Total catch (t), including discards of seal shark, leafscale gulper shark, Baxter's dogfish, and shovelnose dogfish) reported from the CLR and CELR-landed databases, 1989–90 to 2000–01. Note: the landings of other sharks and dogfish (unspecified) may also include other shallow water and pelagic sharks. No data are reported for longnose velvet dogfish or Owston's dogfish. Data from MFish extract January 2003.

Reported discards increased for all species (Table 1), particularly after 1995–96, possibly reflecting more accurate data reporting, although these data are usually determined by an estimate (Francis 1998). Discards represented 61% of the seal shark catch, 89% of the shovelnose dogfish catch, and 83% of the "other sharks and dogfish (unspecified)" catch respectively in 2000–01, and indicate that reported landings underestimate actual catches. Because deepwater sharks are often part-processed at sea to trunks, fins, and livers only, greenweight is determined from the processed catch weight by applying an appropriate conversion factor. Species identification and subsequent reporting is suspect, and an unknown amount of catch is reported to generic codes such as "deepwater dogfish", or "other sharks and dogfish (unspecified)". These data should be interpreted with caution, and were not considered sufficiently accurate to justify further analysis.

3.2.3 Estimated catch data

Estimated catch data summarised by target species for fishing years 1989–90 to 2000–01 (Appendix 1) vary widely among fishing years. No landings are separately reported for longnose velvet dogfish or Owston's dogfish, although these species may constitute most of the reported deepwater dogfish (DWD) landings (Livingston et al. unpublished results). Seal shark and shovelnose dogfish landings are generally associated with hoki, ling, and orange roughy target fishing, and deepwater dogfish are mainly associated with the orange roughy and oreo fisheries. Few data are reported for leafscale gulper shark or Baxter's dogfish. These data are inaccurate due to poor species identification and subsequent misreporting, the use of generic codes, and inconsistent reporting of dumped fish. Reported landings under-estimate actual catch as dumped catch is inconsistently reported, and no further analysis has been completed on these data.

3.3 Scientific observer data

The Scientific Observer Programme (SOP) database was considered to represent the most accurate data from the commercial fishery in terms of species identification. As the focus of the SOP has varied among fishing years, grounds, and target fisheries, estimated observer coverage of deepwater shark catches (Table 1) has also varied. These estimates are probably inflated, because observers may have recorded catch that was subsequently discarded, and consequently would not appear in the LFRR records. Species composition data have been summarised by depth stratum and major target fishery only. Length/sex data were available from only 50 Baxter's dogfish, and no other deepwater sharks were measured. These data are therefore unlikely to be representative of the commercial catch.

3.3.1 Species composition by depth

If it is assumed that the observed landings represent a random sample of the target species catch, then changes in the species composition of deepwater sharks with depth can be estimated. Most observed tows occurred within the depth range 400–1200 m, with only 225 tows deeper than 1200 m (Table 2). Deepwater sharks represented 1% of reported catch in depths less than 600 m (Figure 15) 4% in 600 to 800 m, and 6–7% between 800 and 1200 m. Species composition varied among depth strata (Figure 15). Shovelnose dogfish and seal shark occurred in all depth strata, but shovelnose dogfish was

Table 2: Depth distribution of the numbers of observed tows where deepwater sharks were reported on the scientific observer database, 1985–86 to 2001–02, by 200 m depth zone and target species. (Source: MFish extract August 2002).

Target						Depth range (m)		Total observed
species	200–399	400–599	600–799	800–999	1000–1199	1200–1399	1400+	tows
Arrow squid	26	11	6					43
Barracouta	10	3						13
Black oreo	1		63	144	7		2	217
Alfonsino	5	15	21	1	2			44
Cardinalfish		5	58	15	27			105
Frost fish								0
Hake	4	103	158					265
Hoki	309	5 654	3 479	301	28	5		9 776
Jack mackerel	13							13
Ling	21	126	67					214
Oreo		2	29	266	101	1	1	400
Orange roughy	3	98	1 151	4 120	1 598	197	18	7 185
Prawns			6	6	4			16
Southern ble whitin	3	78	2					83
Scampi	217	208						425
Gemfish	17	11	1					29
Spiny dogfish	3	1						4
Squid	21	2						23
Smooth oreo		2	66	471	165		1	705
Silver warehou	31	137	1					169
White warehou	15	10	1					26
Unspecified		1	1					2
Total	699	6 467	5 110	5324	1932	203	22	19 757

most common between 600 and 1200 m. Seal shark was most abundant between 600 and 1400 m, and dominated catches in depths greater than 1400 m. Baxter's dogfish occurred in depths greater than 600 m, while longnose velvet dogfish, Owston's dogfish, and leafscale gulper shark were rarely recorded in depths less than 600 m.

3.3.2 Species composition by target fishery

The target fisheries for hoki, orange roughy, and oreos represent over 90% of the total observed tows for which deepwater sharks were reported (Table 2). The proportion of deepwater sharks in the total catch and the relative proportion of each species in the deepwater shark catch from 1985–86 to 2000–01 are shown for each of these three target fisheries in Figure 16. For the target hoki fishery, deepwater sharks represented only 1.5% of total catch. The deepwater shark catch was dominated by shovelnose dogfish (65%) and seal shark (21%), with the other deepwater sharks representing less than 15% of this catch. For the oreo fishery, deepwater sharks comprised 3% of the total catch. Baxter's dogfish and seal shark comprised 45% and 39% of the deepwater shark catch respectively and other sharks represented 15% of this catch. For the orange roughy fishery, deepwater sharks represented 7% of the catch. Deepwater shark catch was dominated by seal shark (62%), and shovelnose dogfish (21%).

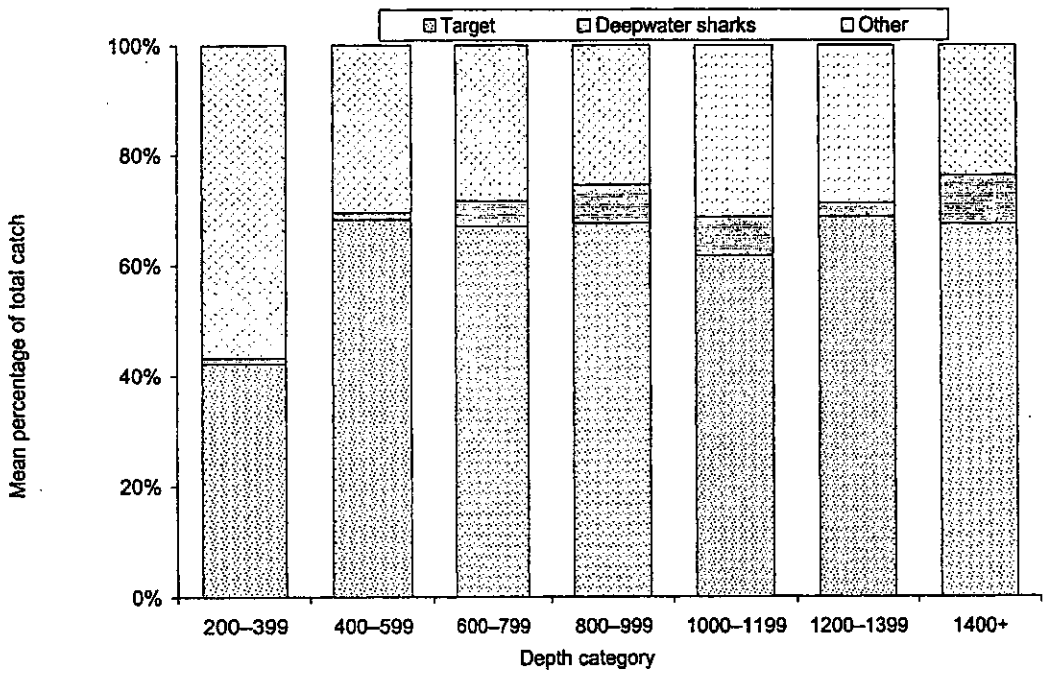
4. REVIEW OF RESEARCH SURVEY DATA

4.1 Survey data

Deepwater sharks are commonly reported from middle-depth (600–800 m) and deepwater (750–1500 m) trawl surveys (see Appendix 2), but few of these surveys provide sufficient data to derive scaled length frequency distributions and accurate estimates of relative biomass.

This review has focused on random trawl surveys completed by RV *Tangaroa*. Although the deepwater northeast Chatham Rise series between 1984 and 1994 (which used FV *Otago Buccaneer* and *Cordella*, and RV *Tangaroa*) has been included, it is not clear whether these surveys provide a valid time series for relative biomass estimation of deepwater sharks, as estimates varied substantially between vessels. Survey series were excluded where derived biomass estimates were less than 100 t, or where sampling variability was high (c.v. greater than 40%), as these surveys were assumed to have poorly sampled the deepwater shark population (M. Francis, pers. comm. 2003). Other survey series were excluded due to inconsistent stratification. Deepwater sharks generally occur in the deeper (800–1500 m) strata of trawl surveys where the catch rates of the target species may not be optimal. These deeper strata were not consistently sampled in many survey series. Surveys that focused on particular target species aggregations, or on specific undersea structures, were also excluded because they were unlikely to have adequately sampled widely distributed species such as deepwater sharks (M. Clark, NIWA, pers. comm. 2002).

Deepwater trawl surveys have often been replaced by acoustic sampling programmes since the mid 1990s, and recent (2001 and 2002) trawl survey data are available only for the Chatham Rise. Because trawl tows completed as part of acoustic survey programmes are used for detailed examination of a particular echo trace, these data are inappropriate for use in relative biomass estimation (S. Hanchet, NIWA, pers. comm. 2002).



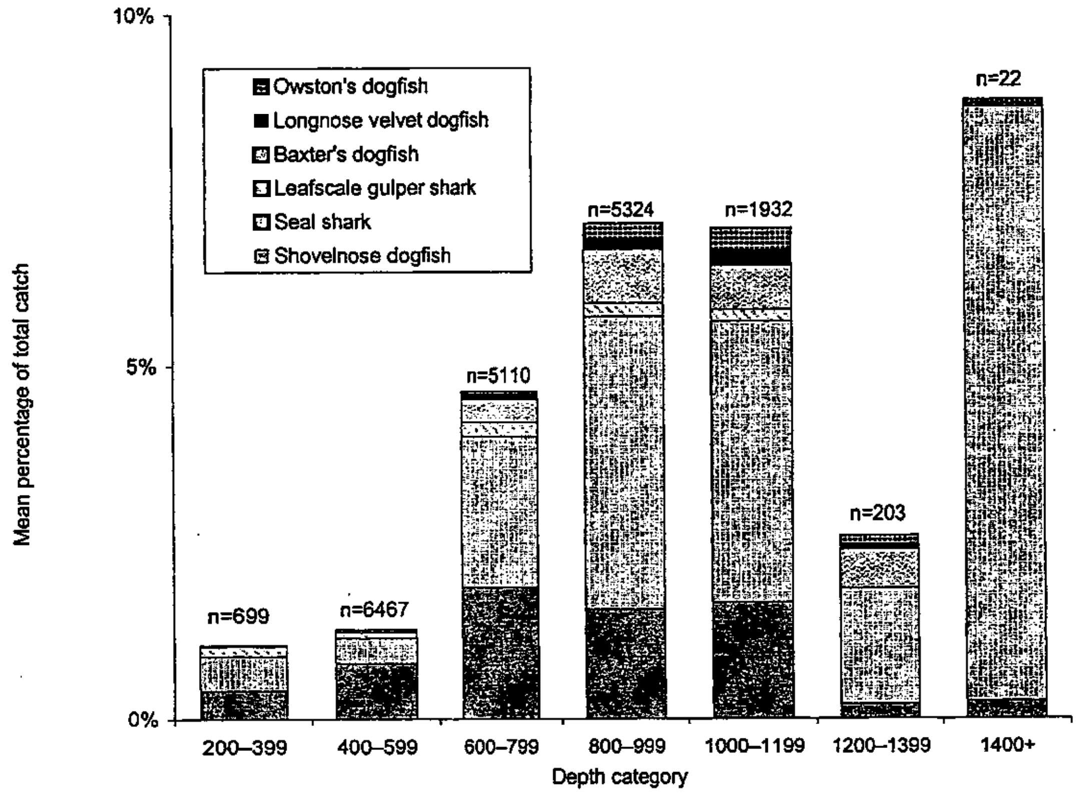
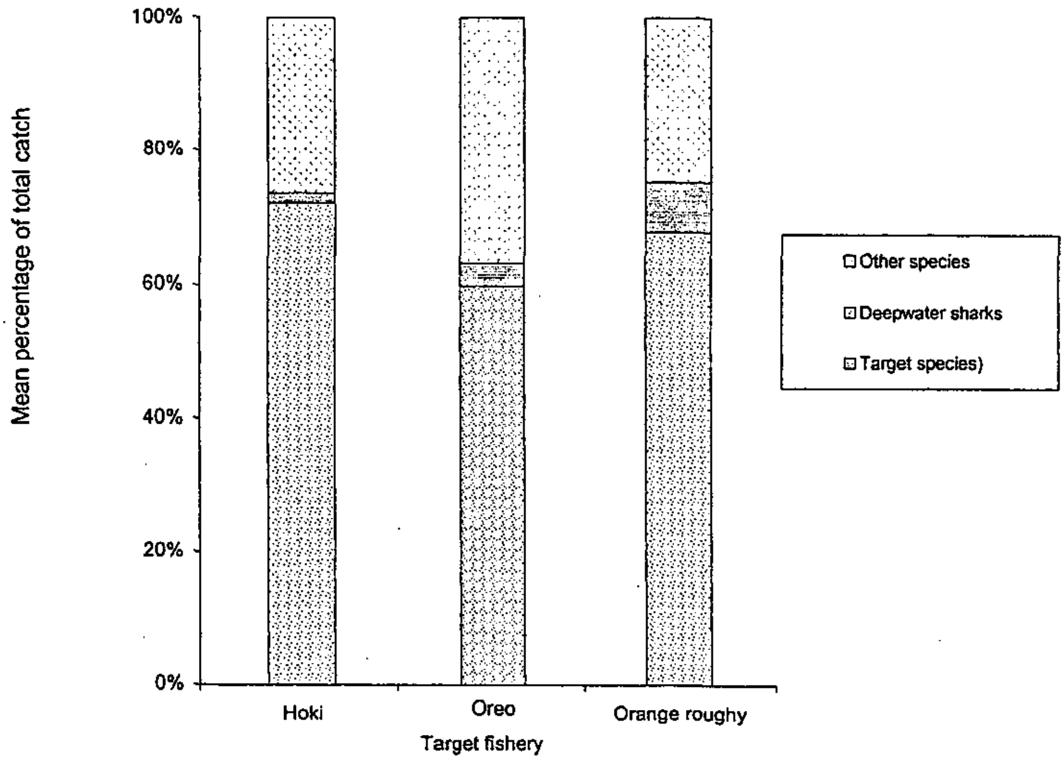


Figure 15: Catch composition of deepwater sharks reported from the Scientific Observer Database, by depth category, 1985–86 to 2000–01, giving numbers of observations. Data from MFish extract September 2002.



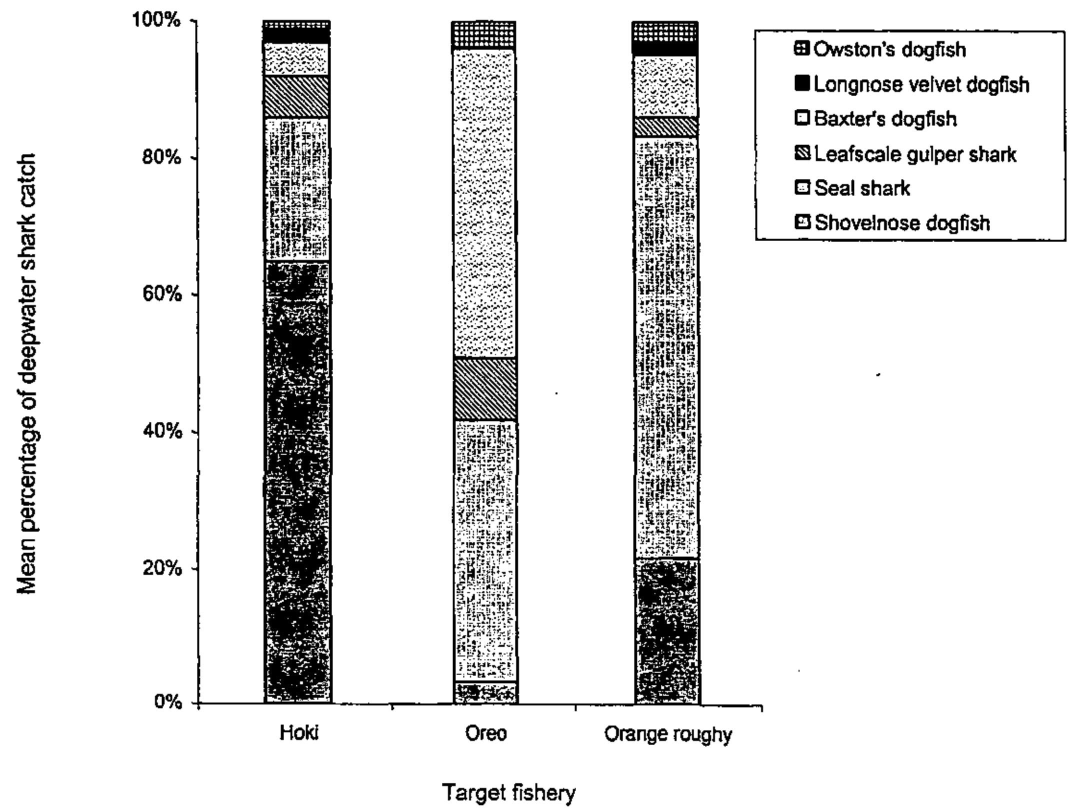


Figure 16: Catch composition of deepwater sharks reported from the Scientific Observer Database, by target fishery, 1985–86 to 2000–01. Data from MFish extract September 2002.

4.2 Relative biomass estimates

Four data series provide relative biomass estimates for deepwater sharks; three from the Chatham Rise and one from the east coast North Island. Biomass estimates and c.v.s are given in Table 3.

Length frequency and relative biomass estimates were derived for the middle depths (600–800 m) strata of the 1992–2000 Chatham Rise RV *Tangaroa* hoki survey series (Livingston et al. unpublished results) which covered depths between 200 and 800 m. This series was updated for 2001 (Stevens et al. 2002), and 2002 (Stevens et al. 2003), and will be referred to as the Chatham Rise middle depths series.

The second data series was the 1984–94 northeast slope (750–1500 m) Chatham Rise orange roughy survey series (Clark et al.2000a), which used FV *Otago Buccaneer*, FV *Cordella*, and RV *Tangaroa*. This series will be referred to as the northeast Chatham Rise series. The third data series was the 1991–95 RV *Tangaroa* oreo survey series on the south slope (750–1500 m) of the Chatham Rise (Livingston et al. unpublished results), here referred to as the south Chatham Rise series.

Outside the Chatham Rise, relevant biomass estimates are available only from the east coast North Island deepwater (750–1500 m) orange roughy trawl surveys. This excludes TAN9306 as doorspread values are unavailable for this survey. This series will be referred to as the east coast North Island series.

4.2.1 Shovelnose dogfish

Relative biomass (Figure 17) increased on the northeast Chatham Rise between 1984 and 1994, but no trend was determined for the Chatham Rise middle depths between 1992 and 2002. No trend was determined from the south Chatham Rise between 1991 and 2002, or from the east coast North Island between 1992 and 1994.

4.2.2 Baxter's dogfish

Relative biomass decreased on the northeast Chatham Rise between 1984 and 1994 (Figure 18), but increased on the south Chatham Rise between 1991 and 1995. Baxter's dogfish was inconsistently reported from the Chatham Rise middle depths (Table 3) between 1991 and 2002, but these data indicate no trend in relative abundance.

4.2.3 Owston's dogfish

No trend in relative biomass was determined from the northeast Chatham Rise between 1984 and 1994, or from the east coast North Island between 1992 and 1994 (Figure 19).

4.2.4 Longnose velvet dogfish.

Relative biomass increased on the northeast Chatham Rise between 1984 and 1994 (Figure 20), but no change in relative biomass occurred on the south Chatham Rise between 1991 and 1995.

Table 3: Biomass estimates for deepwater sharks from trawl survey data, - indicates estimate is unreliable (either less than 100 t, or where c.v. exceeds 40%).

Trip	Seal shark		leafscale gulper shark		Owston's dogfish		longnose velvet dogfish		Baxter's dogfish		Shovelnose dogfish	
	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)
East coast North Island (750–1500 m): RV *Tangaroa*												
TAN9203	-	-	-	-	116	17	387	13	138	17	2 336	15
TAN9303	-	-	-	-	165	24	654	63	593	52	3 259	17
TAN9403	-	-	-	-	197	23	230	40	238	15	3 501	21
Chatham Rise (600–800m): RV *Tangaroa*. Data after Livingston et al. (2002), Stevens et al. (2002), NIWA (unpublished data)												
TAN9201	-	-	-	-	-	-	-	-	-	-	5 100	23
TAN9301	-	-	-	-	-	-	-	-	-	-	3 800	13
TAN9401	-	-	-	-	-	-	-	-	-	-	1 900	7
TAN9501	-	-	-	-	-	-	-	-	-	-	4 200	23
TAN9501	-	-	-	-	-	-	-	-	-	-	3 800	14
TAN9601	-	-	-	-	-	-	-	-	3 528	60	3 700	15
TAN9701	-	-	-	-	-	-	-	-	1 575	66	2 800	15
TAN9801	-	-	-	-	-	-	-	-	-	-	4 100	18
TAN9901	-	-	-	-	-	-	-	-	2 708	32	4 400	23
TAN0001	-	-	-	-	-	-	-	-	800	27	4 200	20
TAN0101	289	44	683	45	353	56	634	37	854	27	4 190	18
TAN0201	103	31	336	24	731	49	1 493	44	2 302	33	5 943	21
Northwest Chatham Rise (750–1500 m): FV *Cordella, Otago Buccaneer*, RV *Tangaroa* Data after Clark et al. (2000), c.v.'s < 40%												
BUC8401	-	-	-	-	250		370		770		1 520	
BUC8501	-	-	-	-	275		281		347		0 912	
BUC8601	-	-	-	-	593		373		493		2 341	
BUC8701	-	-	-	-	730		398		547		2 782	
COR8801	-	-	-	-	420		1 335		393		2 949	
COR8901	-	-	-	-	263		758		123		1 383	
COR9002	-	-	-	-	248		1 175		377		31 464	
TAN9206	-	-	-	-	705		1 083		331		2 706	
TAN9406	-	-	-	-	488		913		200		1 733	
***South Chatham Rise (750–1500 m): RV Tangaroa* Data after Livingston (unpublished results)**												
TAN9104	-	-	-	-	-	-	-	-	-	-	4 382	16
TAN9210	-	-	-	-	-	-	-	-	-	-	4 676	22
TAN9309	-	-	-	-	-	-	-	-	-	-	6 146	16
TAN9511	-	-	-	-	-	-	-	-	-	-	4 803	10

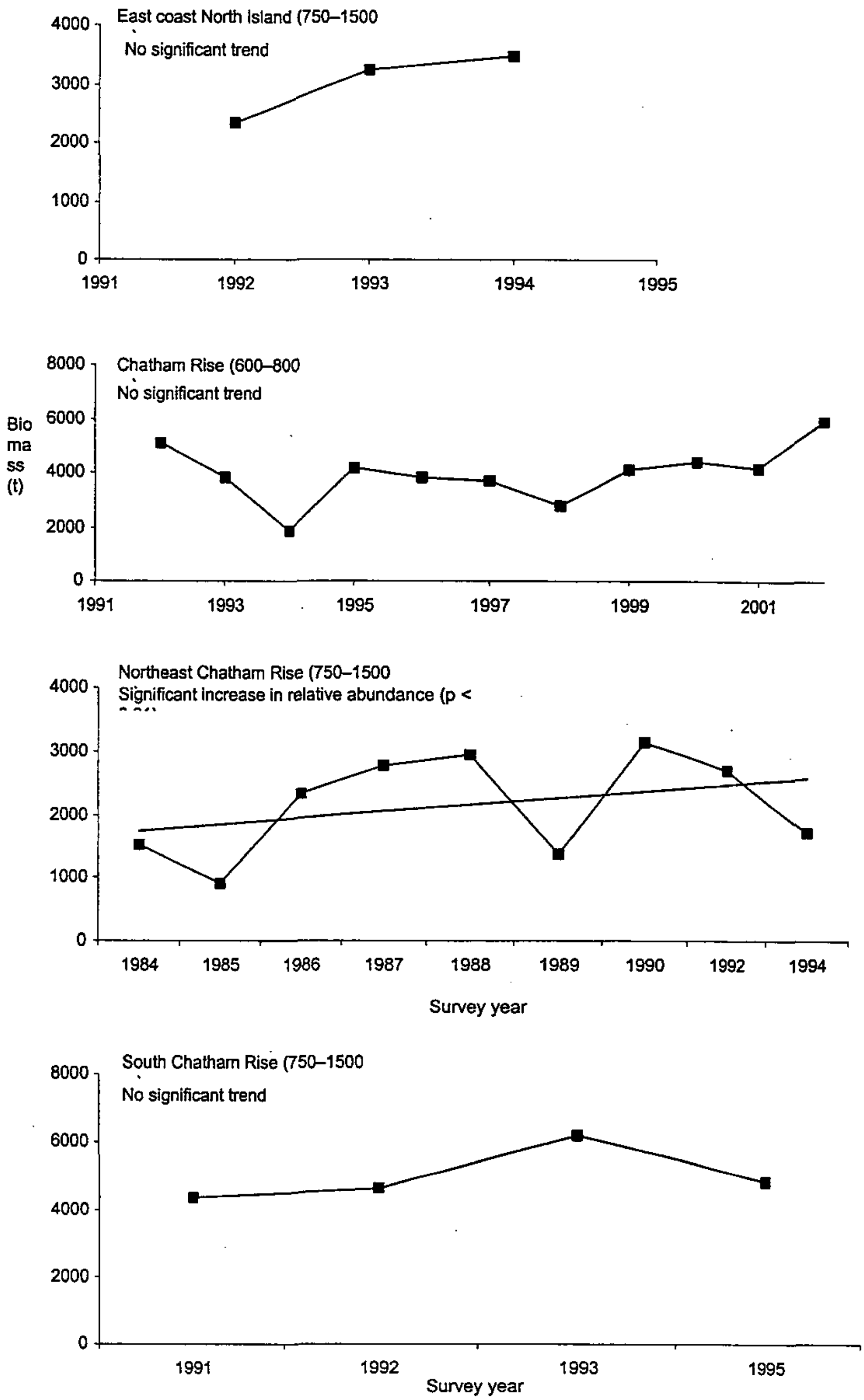


Figure 17: Trends in relative biomass estimates (t) of shovelnose dogfish from trawl surveys, 1984 to 2002. Vessels used and estimates of sampling error are given in Table 3.

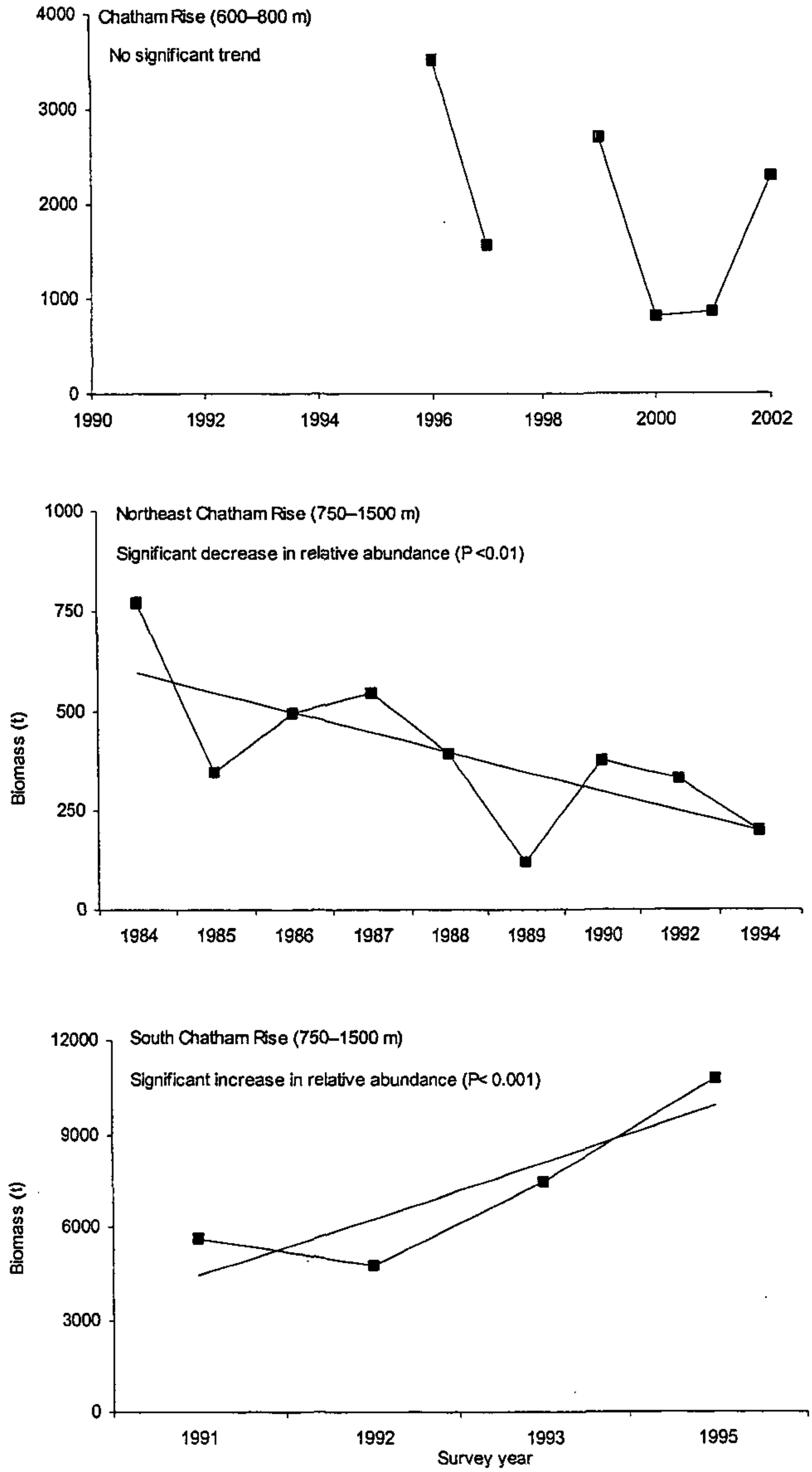


***Figure 18:* Trends in relative biomass estimates of Baxter's dogfish from trawl surveys, 1984 to 2002. Vessels used and estimates of sampling error are given in Table 3.**

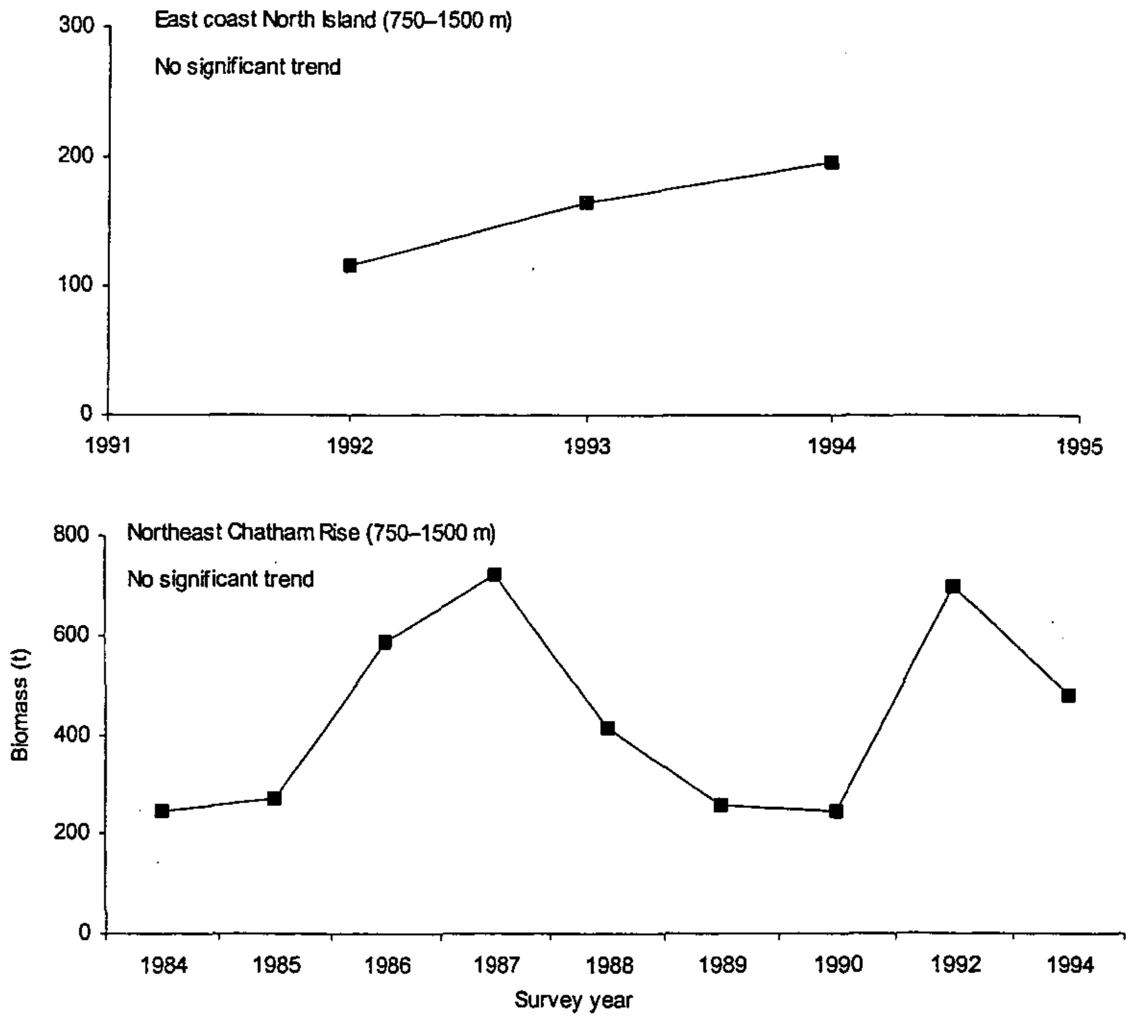


Figure 19: Trends in relative biomass estimates of Owston's dogfish from trawl surveys, 1984 to 2002. Vessels used and estimates of sampling error are given in Table 3.

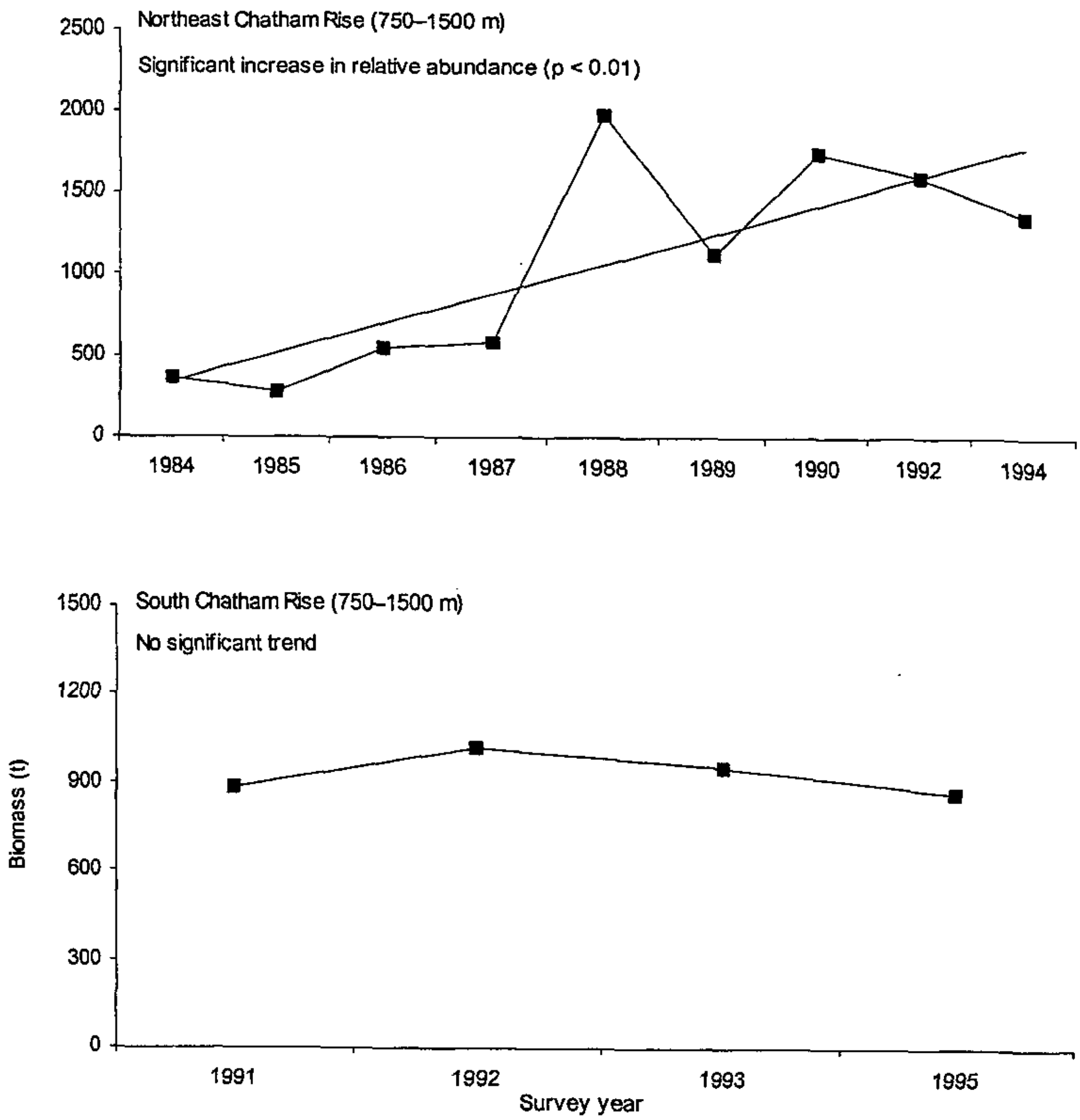


Figure 20: Trends in relative biomass estimates of longnose velvet dogfish from trawl surveys, 1984 to 2002. Vessels used and estimates of sampling error are given in Table 3.

4.3 Length frequency data from trawl surveys

Scaled length frequencies were derived where more than 100 fish were measured, and where weight data are available. Unscaled (raw) length frequencies are given where no weight data are available but more than 100 sharks of each species were measured.

4.3.1 Shovelnose dogfish

Scaled length frequencies from the Chatham Rise are generally similar between 1998 and 2002 (Figure 21), but the high numbers of juveniles (under 60 cm in length) present in 2000 and 2002 suggest successful recruitment. High numbers of smaller juveniles (under 40 cm) also occur in the unscaled length frequency data from the east coast North Island in 1985 and 1986 (Figure 22), but this size class was present on the Chatham Rise only in 2000. These data are consistent with the presence of a nursery ground on the east coast North Island, and possible age and sex related migration to the Chatham Rise.

4.3.2 Baxter's dogfish

Insufficient scaled length frequency data are available from the Chatham Rise to determine trends (Figure 23). From the unscaled length frequency data (Figure 24), the high numbers of juveniles (under 30 cm in length) present on the Chatham Rise in 1998 may suggest possible recruitment.

4.3.3 Longnose velvet dogfish

Scaled length frequencies from the Chatham Rise in 1999 and 2002 (Figure 25) differ markedly in sex ratio and size composition. In 1999, the sex ratio (males to females) was 5:1, where the data were dominated by large (60–80 cm) males. In 2002, the sex ratio was 0.77:1 and the presence of several modal peaks in the data is suggestive of successful recruitment. The high numbers of unsexed fish reported in 1998 precludes the identification of trends in the unscaled length frequency data (Figure 26).

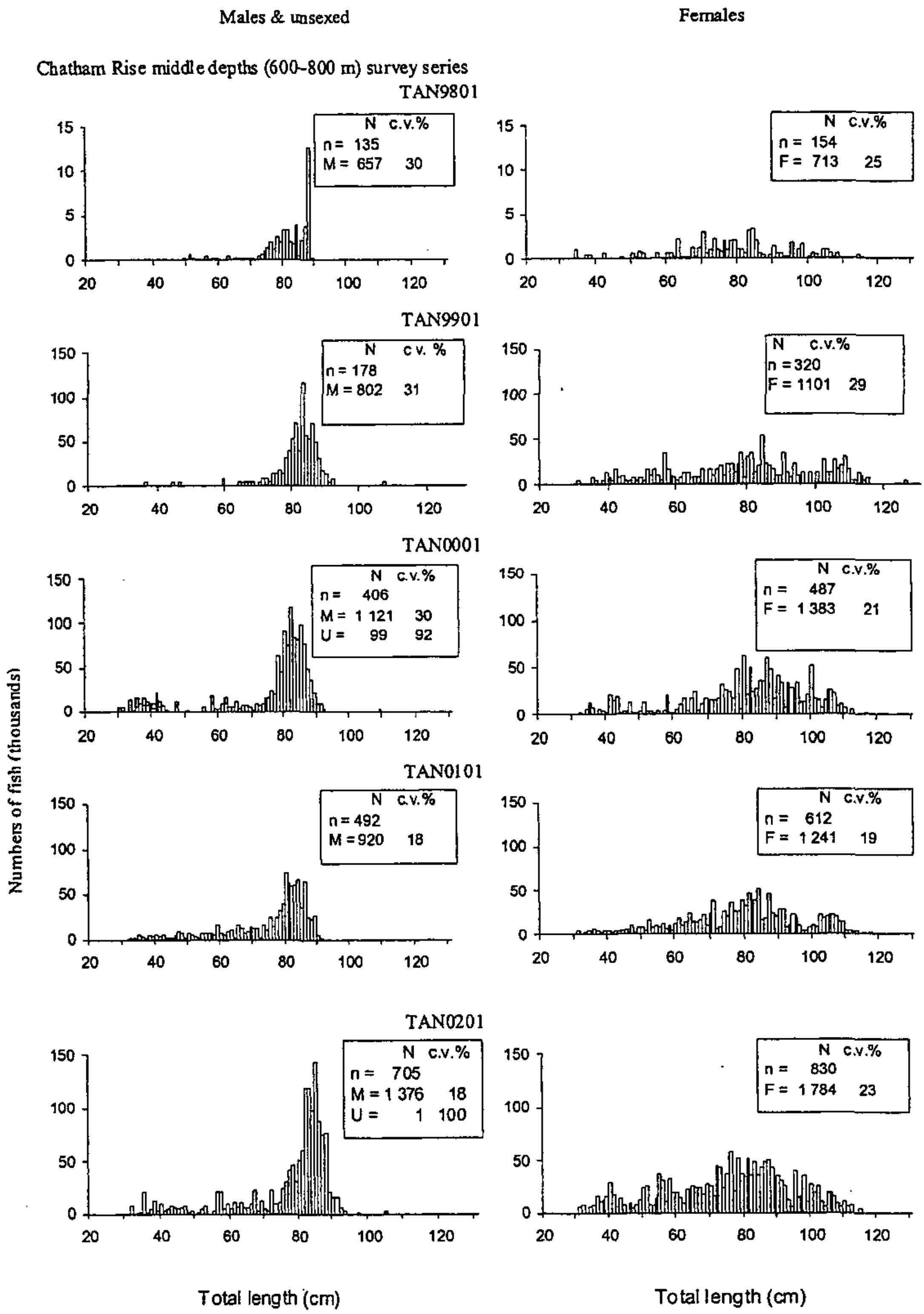


Figure 21: Scaled length frequencies for shovelnose dogfish from trawl surveys where more than 100 fish were measured. n. no. of fish measured; N, scaled number of fish (thousands); M, no. of males; F, no. of females; U (shaded), unsexed. Areas and survey series are given in Appendix 2.

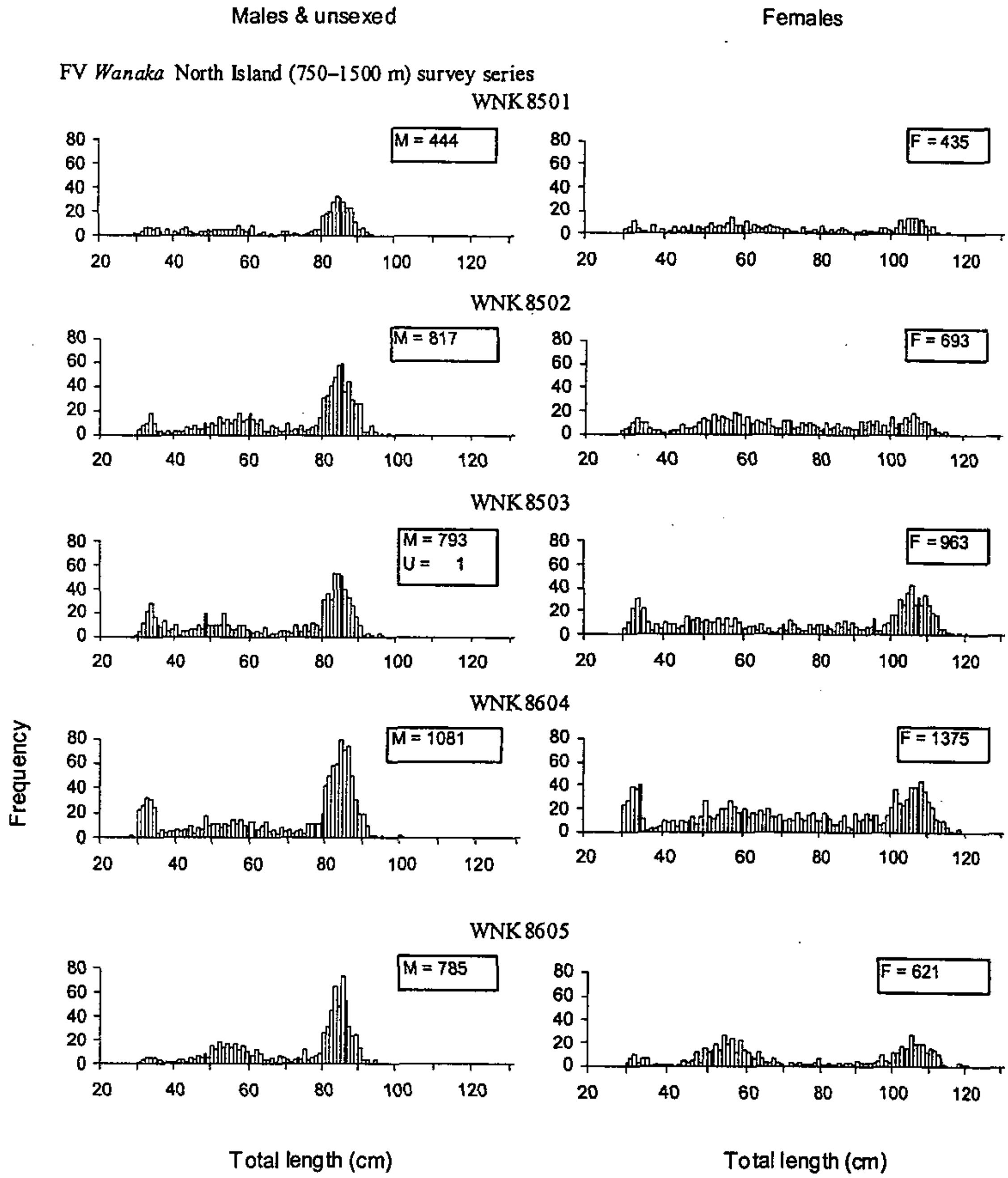


Figure 22: Length frequencies (unscaled) for shovelnose dogfish from trawl surveys where more than 100 fish were measured, and scaled length frequency data are unavailable. M, no. of males; F, no. of females; U (shaded), no. of unsexed fish. Areas and survey series are given in Appendix 2.

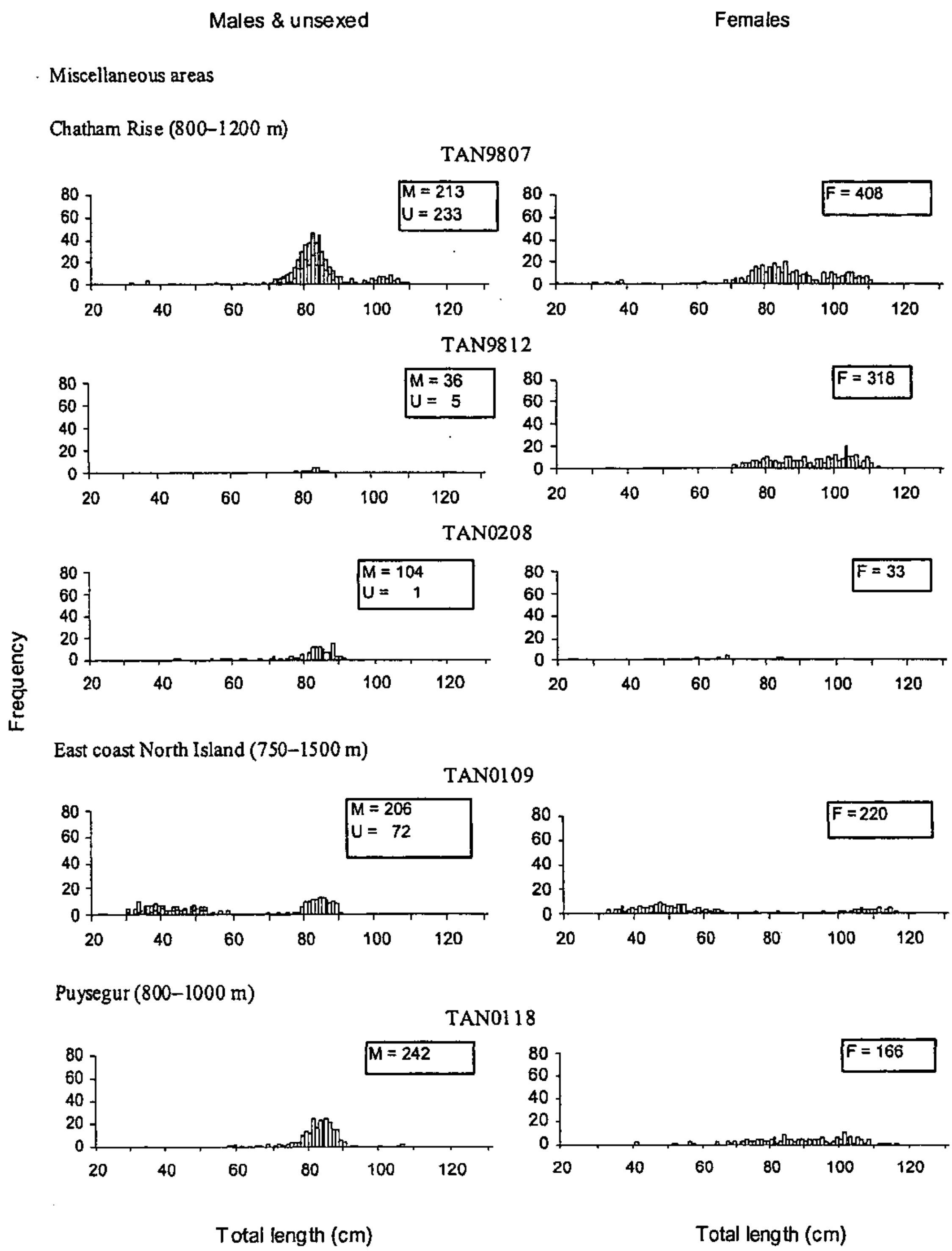


Figure 22:–continued

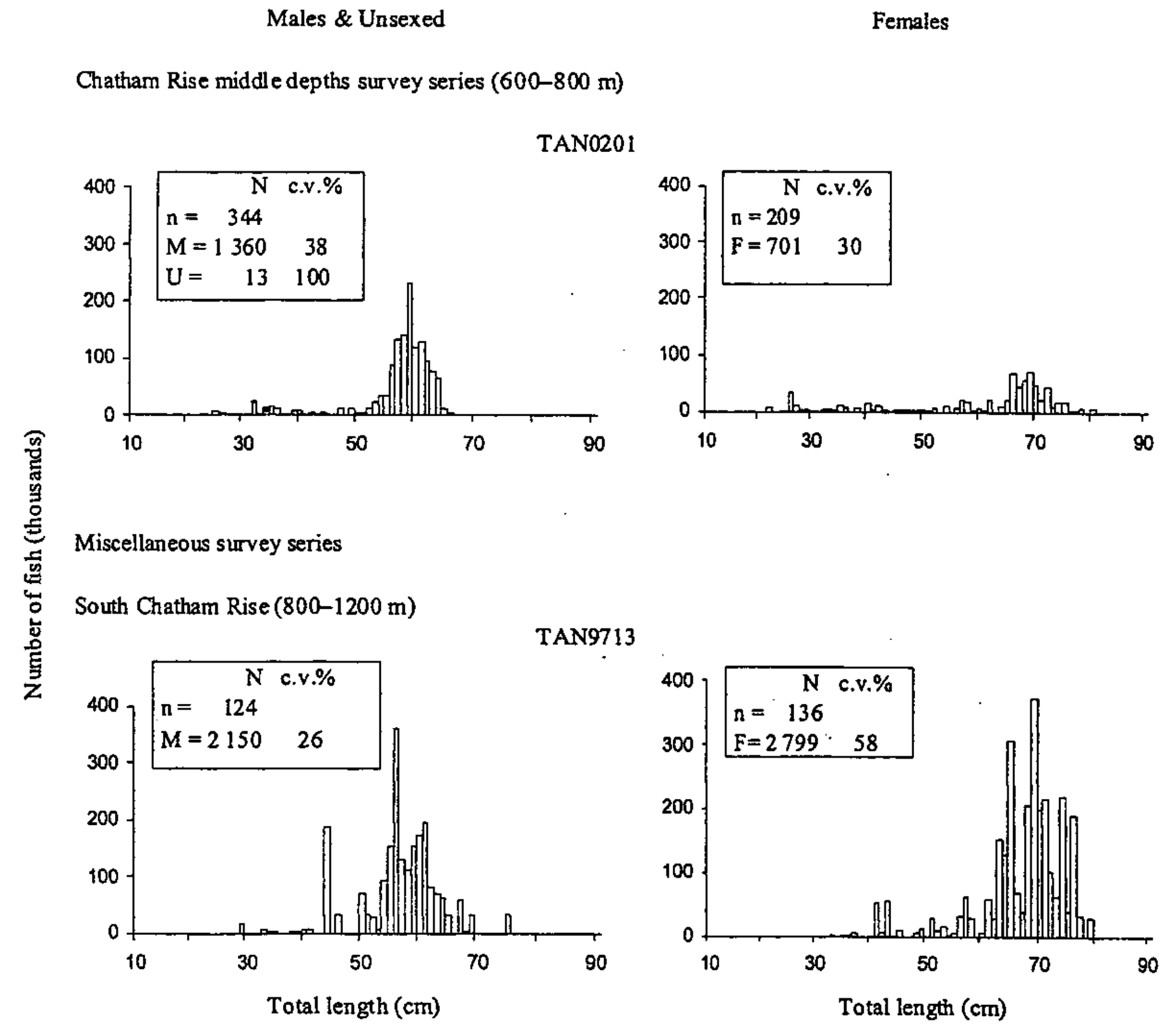


Figure 23: Scaled length frequencies for Baxter's dogfish from trawl surveys where more than 100 fish were measured. n, no. of fish measured; N, scaled number of fish (thousands); M, males, F, females, U, unsexed (shaded). Areas and survey series are given in Appendix 2.

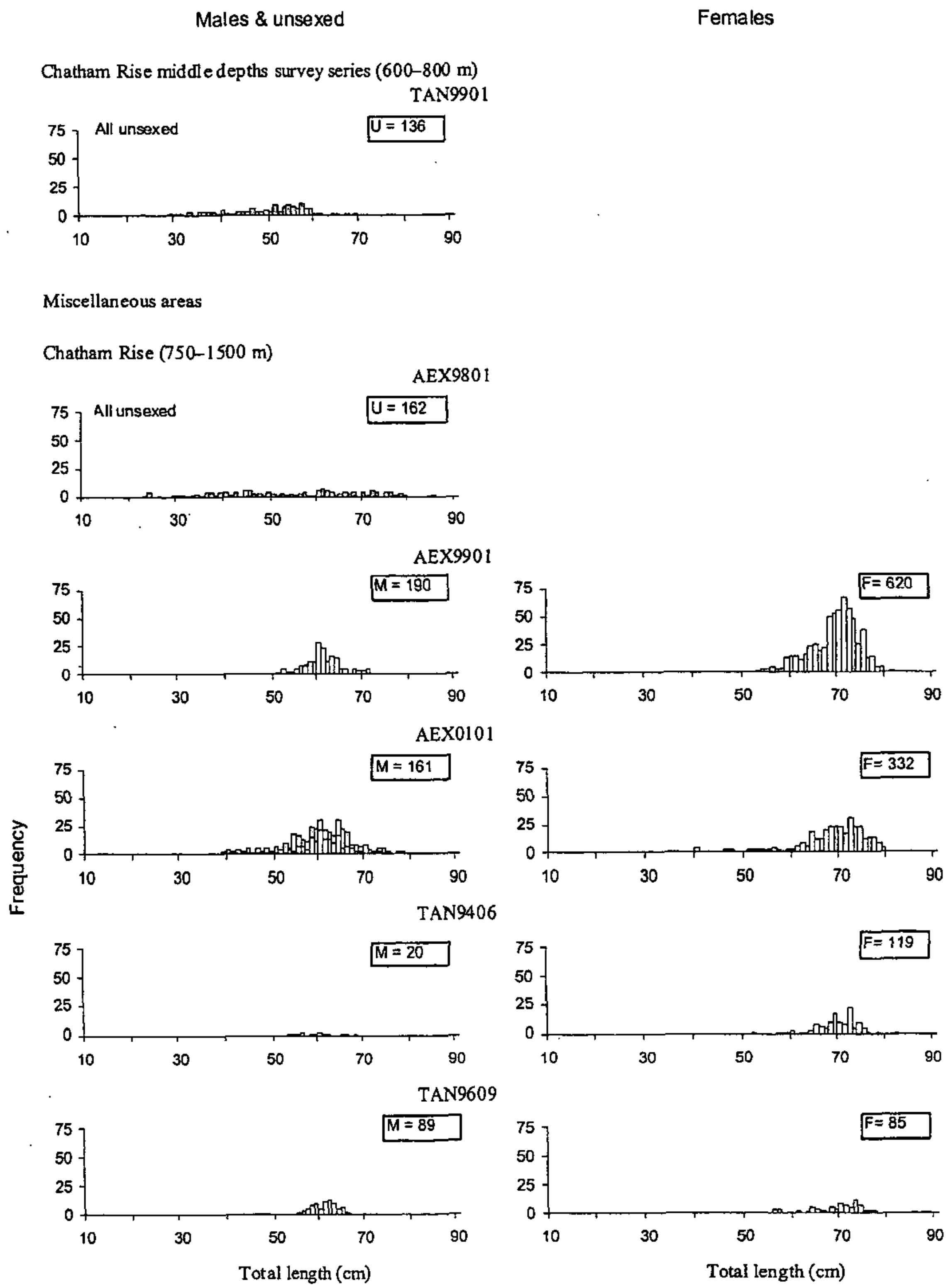


Figure 24: Length frequencies (unscaled) for Baxter's dogfish where more than 100 fish were measured. M, no. of males; F, no. of females; U (shaded), no. of unsexed fish. Areas and survey series are given in Appendix 2.

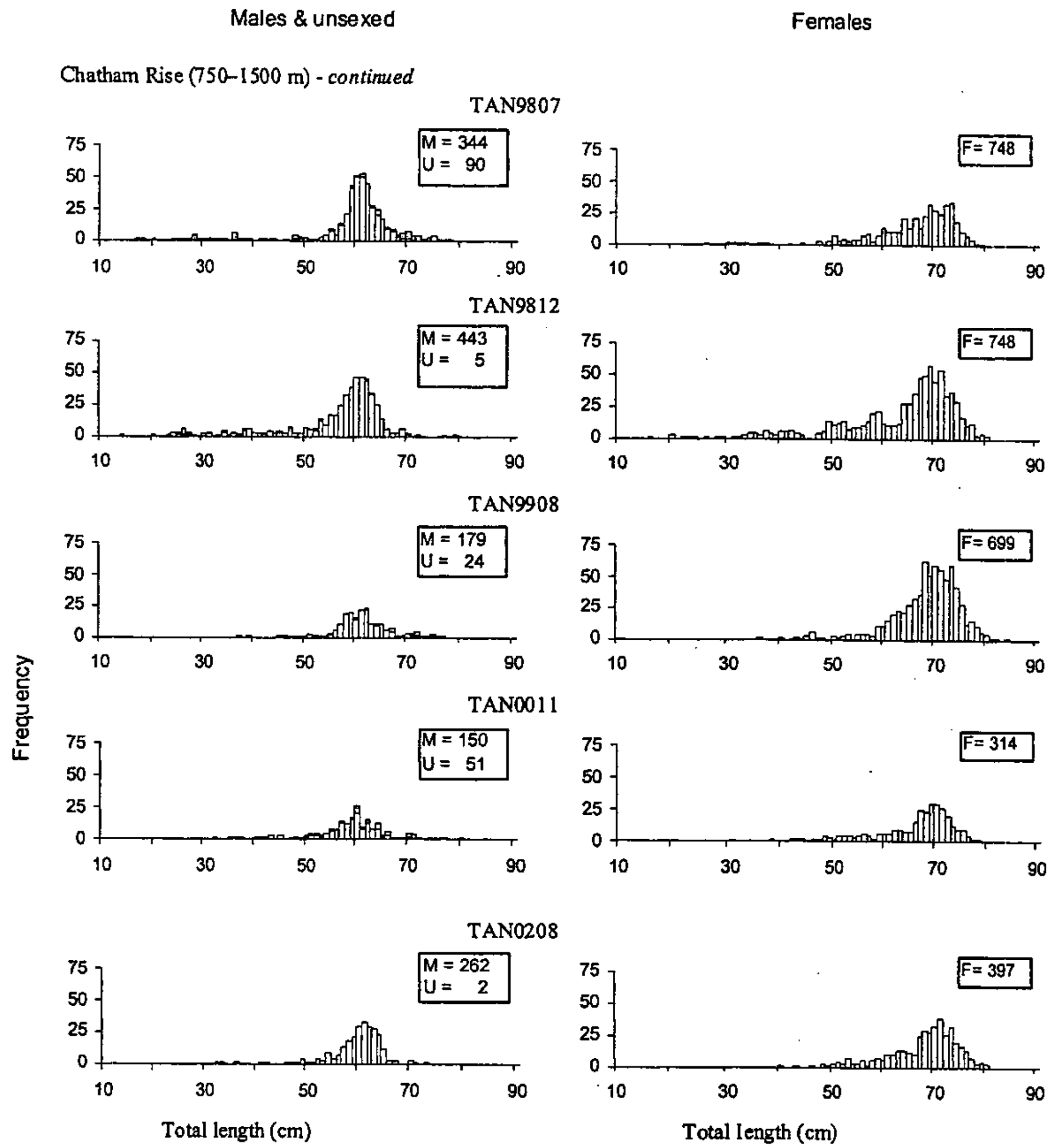


Figure 24: – continued

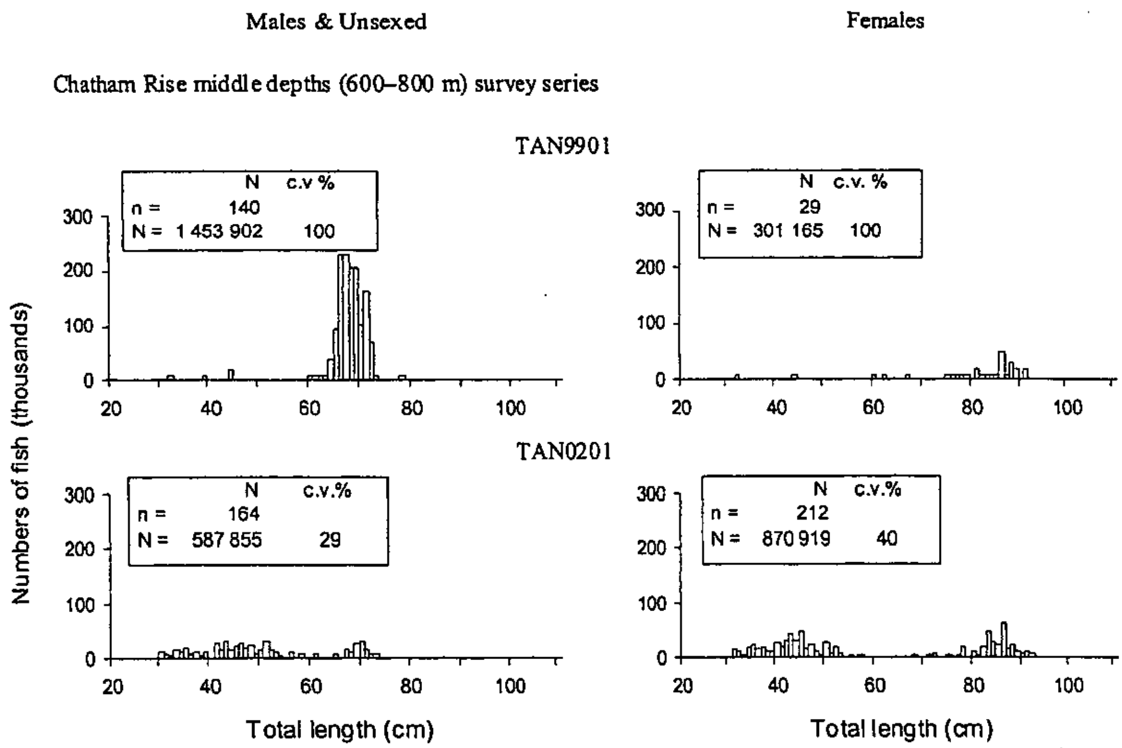


Figure 25: Scaled length frequencies for longnose velvet dogfish from trawl surveys where more than 100 fish were measured. n, no. of fish measured; N, number of fish (thousands); M, males; F, females. Areas and survey series are given in Appendix 2.

Miscellaneous areas

Chatham Rise (750–1200 m)

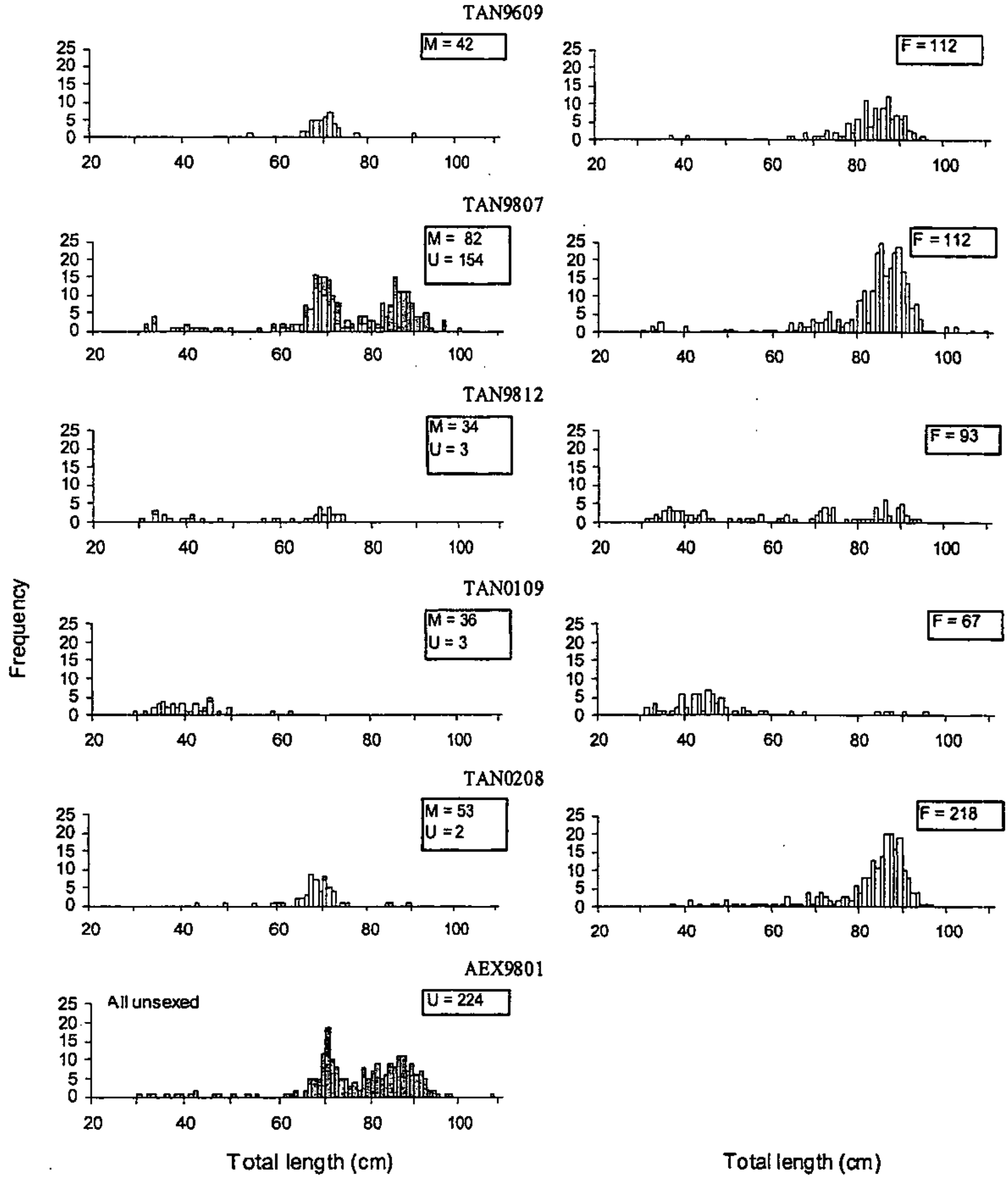


Figure 26: Length frequencies (unscaled) for longnose velvet dogfish where more than 100 fish were measured. M, no. of males; F, no. of females; U (shaded), no. of unsexed fish. Areas and survey series are given in Appendix 2.

Table 4: Summary of trends for deepwater dogfish from the Chatham Rise 1984 to 2000 as described by Livingston et al. (unpublished data). (↑ rising trend, ↓ declining trend, nil no trend, – no data).

(a) Trends in trawl survey relative biomass estimates.

Area	Chatham Rise middle	Chatham Rise deepwater		
		Northwest	Northeast	South
Depth range	(600–800 m)	(>800m)	(750–1500 m)	(750–1500 m)
Survey series	RV *Tangaroa* 1992–02	–	*FV Cordella* *FV Otago Buccaneer* RV Tangaroa 1984–94	RV *Tangaroa* *1991–95*
Species				
Baxter's dogfish	–	–	↓	↑
Leafscale gulper shark	–	–	nil	–
Longnose velvet dogfish	–	–	↑	nil
Owston's dogfish	–	–	nil	–
Seal shark	–	–	nil	–
Shovelnose dogfish	nil	–	↑	nil

(b) Overall trends in relative abundance of deepwater dogfish from (trawl surveys (1984 to 2000) and CPUE (1989–90 to 1998–99) interpreted together, as described by Livingston et al. (unpublished results). Deepwater dogfish is assumed to mainly comprise Owston's dogfish and longnose velvet dogfish. (↑ rising trend, ↓ declining trend, ? slight trend, nil no trend, – no data).

Area	Chatham Rise middle	Chatham Rise deepwater		
		Northwest	Northeast	South
Depth range	(600–800 m)	(>800m)	(750–1500 m)	(750–1500 m)
Species				
Baxter's dogfish	–	nil	?↓	?↑
Leafscale gulper shark	–	–	–	–
Deepwater dogfish	–	↑	?↑	?↑
Seal shark	–	?↑	↑	↑
Shovelnose dogfish	↓	–	–	

5. DISCUSSION

Deepwater sharks are commonly reported from most middle depth and deepwater trawl surveys in New Zealand waters. Baxter's dogfish is endemic to New Zealand, and seal shark, longnose velvet dogfish, Owston's dogfish, shovelnose dogfish and leafscale gulper shark are widely distributed in most temperate waters (Last & Stevens 1994). Little is known about the abundance of these deepwater sharks in New Zealand.

The catch rates of deepwater shark species declined off New South Wales between the 1970s and the 1990s (Andrew et al. 1997, Graham et al. in press). Trends in relative biomass do not indicate a similar decline in relative abundance for deepwater sharks in New Zealand waters during this period, other than for Baxter's dogfish. As available data are largely confined to the Chatham Rise, they may not adequately describe population trends in such widely distributed species, and should be interpreted with caution.

Livingston et al. (unpublished results) found shovelnose dogfish and longnose velvet dogfish increased in relative abundance on the northeast Chatham Rise between 1984 and 1994, while little change occurred for leafscale gulper shark, Owston's dogfish, or seal shark during this period (Table 4). The decline in Baxter's dogfish between 1984 and 1994 from this area contrasts with the increase in relative abundance noted on the south Chatham Rise between 1991 and 1995 (Livingston et al. unpublished results). The lack of trend determined for shovelnose dogfish from the Chatham Rise middle depths in 2001 (Stevens et al. 2002) and 2002 (NIWA, unpublished data) is consistent with the results of Livingston et al. (unpublished results) for 1992–2000 (Table 4). Outside of the Chatham Rise, data from the east coast North Island indicate no change in relative abundance for shovelnose dogfish, or Owston's dogfish between 1992 and 1994.

Changes in relative biomass indices from the Chatham Rise are generally consistent with the changes in scaled catch and effort indices for these species from the Chatham Rise between 1989–90 and 1998–99. These data (summarised in Table 4) were scaled to changes in the Chatham Rise hoki fishery by Livingston et al. (unpublished results). They indicate an increase in abundance for longnose velvet dogfish, Owston's dogfish, and seal shark on the northwest Chatham Rise where no survey data are available. These data also indicate a decline in CPUE for shovelnose dogfish from the Chatham Rise middle depths, and an increase in seal shark on the northeast Chatham Rise that are not apparent from the trawl survey relative biomass data. Livingston et al. (unpublished results) suggest that deepwater sharks (other than Baxter's dogfish) have been more resilient than most teleost bycatch species to the high levels of fishing effort associated with the target hoki and orange roughy fisheries on the Chatham Rise.

Review of commercial catch data for deepwater dogfish, particularly outside the major deepwater fisheries of the Chatham Rise, suggests the catch and landings data are inaccurate, inconsistent among data sources, and underestimate actual catch. This is largely due to poor species identification and subsequent data reporting, inaccurate estimation of dumped catch, the use of conversion factors to determine greenweight catch, and the inclusion of an unknown amount of deepwater shark catch in generic reporting codes (Francis 1998).

Relative abundance data derived from the SOP are confounded by between-year variability in observer coverage of the target hoki, orange roughy, and oreo fisheries, especially outside yhe Chatham Rise. These data are derived from tows targeted at high concentrations of the target fisheries, instead of from randomly allocated stations, and may provide biased estimates of bycatch and relative abundance of deepwater sharks. Trends that are not supported by data derived from random trawl surveys should be interpreted with caution.

Few data are available on the biology of these deepwater shark species, although distribution is determined by depth and latitude preferences (McClatchie et al. 1997, Wetherbee 1999, Bull et al. 2001, Francis et al. 2002). Shovelnose dogfish and seal shark are found over a wide depth range (600–1200 m), while longnose velvet dogfish, Owston's dogfish, and leafscale gulper shark are uncommon in deeper waters (over 600 m), and Baxter's dogfish is rarely reported in depths less than 600 m. These depth preferences largely determine the relative occurrence of deepwater sharks in middle-depths and deepwater target trawl fisheries on the Chatham Rise. Shovelnose dogfish was the dominant shark caught in the middle depths (300–800 m) hoki trawl fishery (Wetherbee 1999, Bull et al. 2001, Livingston, unpublished results). Seal shark was the dominant shark in the deeper water (750–1500 m) orange roughy fishery between 1985–86 and 2000–01, and Baxter's dogfish was the dominant shark in the deepwater (750–1500 m) oreo fishery during this period.

Available scaled length frequency data for shovelnose dogfish are consistent with the patterns of schooling of fish by sex and size proposed by Wetherbee (1999) for the Chatham Rise, and the migratory patterns of pregnant females to the east coast North Island pupping and nursery grounds proposed by Clark & King (1989). Other than the *Wanaka* surveys of the northern North Island in 1985 and 1986 (King & Clark 1987, Clark & King 1989), available unscaled length frequency data for deepwater sharks are based on small sample sizes. Unscaled length frequencies may be biased and poorly represent the deepwater shark population. These data should be interpreted with caution.

Relative biomass indices and distribution data from trawl surveys indicate that deepwater sharks represent a modest sized, but widely distributed, resource. Trawl fishing in the deep waters of the New Zealand coastal shelf and slope is known to influence the structure of demersal communities (Clark et al. 2000a, Anderson et al. 2001b). These deepwater sharks are considered to have low productivity and fecundity (Wetherbee 1999), and thus are possibly vulnerable to overfishing. Other than Baxter's dogfish, they appear to be relatively resilient to the high fishing pressure associated with deepwater fisheries on the Chatham Rise (Livingston, unpublished results). Such trends may be influenced by these fisheries which are targeted, rather than widespread, and the bycatch of deepwater sharks may be low in spawning aggregations.

Trawl survey relative abundance indices and data from the Scientific Observer Programme cover only a part of the wide distribution of these species. The cessation of many trawl survey programmes in favour of more cost-effective acoustic survey methods has also reduced the amount of recent data available for analysis, and data from 2001 and 2002 are available only from the Chatham Rise middle depths survey series. Continued monitoring of deepwater shark relative abundance appears necessary, and alternatives to trawl survey indices are limited to commercial catch, effort and scientific observer data. Before these data can be properly used, accurate identification and recording of catch and effort is necessary. As a first step, an identification guide to deepwater sharks has been produced (Tracey et al. 2002).

6. ACKNOWLEDGMENTS

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Appendix 1: Summary of estimated catch (t) of deepwater sharks from TCEPR and CELR reports combined by nominated target species, where catch > 5 t. BSH = seal shark *Dalatias licha*, CSQ = leafscale gulper shark, *Centrophorus squamosus*, ETB = Baxter's dogfish *Etmopterus baxteri*, SND = shovelnose dogfish *Deania calcea*, DWD = deepwater dogfish (unspecified), OSD = other sharks and dogfish (unspecified). Data from MFish extract, August 2002. Note: No landings reported for Owston's dogfish *Centroscymnus owstoni* (CYO), or longnose velvet dogfish *Centroscymnus crepidater* (CYP).

Fishing year		1989–90						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Hoki	HOK	1	0	0	119	2	151	273
Orange roughy	ORH	69	0	0	4	11	68	152
Other		19	0	0	7	0	67	93
Ling	LIN	47	0	0	1	0	3	51
Oreo (all)	BOE, OEO.SSO	12	0	0	0	0	11	23
Squid	SQU	0	0	0	0	0	13	13
Groper	HAP	4	0	0	0	0	2	6
Total		152	0	0	131	13	315	611

Fishing year		1990–91						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Other		21	0	0	1	0	85	107
Hoki	HOK	1	0	0	1	6	79	86
Orange roughy	ORH	38	0	0	13	0	29	80
Ling	LIN	69	0	0	0	0	8	77
Oreo (all)	BOE, OEO,SSO	15	0	0	3	0	0	18
Squid	SQU	0	0	0	0	0	13	13
Bluenose	BNS	4	0	0	0	0	1	5
Total		148	0	0	18	6	215	386

Fishing year		1991–92						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Ling	LIN	75	0	0	0	0	22	97
Other		38	3	0	0	0	56	97
Squid	SQU	0	0	0	0	0	84	84
Orange roughy	ORH	0	0	0	0	0	60	60
Hoki	HOK	2	0	0	0	0	30	32
Total		115	3	0	0	0	252	370

Fishing year		1992–93						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Ling	LIN	100	0	0	1	1	39	141
Hoki	HOK	1	0	0	1	0	118	120
Other		73	0	0	0	1	46	120
Orange roughy	ORH	1	0	0	0	1	58	60
Seal shark	BSH	19	0	0	0	1	0	20
Bluenose	BNS	5	0	0	1	0	2	8
Groper	HPB	4	0	0	0	0	3	7
Total		203	0	0	3	4	266	476

Fishing year		1993–94						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Ling	LIN	127	0	0	1	0	71	199
Other		95	0	0	1	0	49	145
Hoki	HOK	1	0	0	0	1	89	91
Orange roughy	ORH	2	0	0	0	2	36	40
Seal shark	BSH	7	0	0	0	0	0	7
Total		232	0	0	2	3	245	482

Fishing year		1994–95						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Ling	LIN	147	0	0	2	0	70	219
Hoki	HOK	0	0	0	0	1	117	118
Orange roughy	ORH	70	0	0	0	5	34	109
Other		30	0	0	10	1	41	82
Bluenose	BNS	6	0	0	0	0	9	15
Groper	HPB	5	0	0	0	0	4	9
Oreo (all)	BOE, OEO, SSO	3	0	0	0	0	5	8
Sth blue whiting	SBW	0	0	0	0	0	0	0
TCEPR subtotal		261	0	0	12	7	280	560

Appendix 1: – continued

Fishing year		1995–96						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Ling	LIN	108	7	0	3	1	73	192
Other		66	1	0	21	3	66	157
Hoki	HOK	1	0	0	1	4	130	136
Orange roughy	ORH	1	0	0	0	3	21	25
Bluenose	BNS	7	0	0	0	0	3	10
Groper	HPB	5	0	0	0	0	5	10
Total		188	8	0	25	11	298	530

Fishing year		1996–97						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Ling	LIN	151	10	0	10	0	104	275
Hoki	HOK	11	0	0	0	13	127	151
Other		38	0	0	14	0	41	93
Orange roughy	ORH	11	0	0	0	0	39	50
Groper	HPB	15	0	0	0	0	4	19
Oreo (all)	BOE, OEO, SSO	9	0	0	0	9	0	18
Squid	SQU	0	0	0	0	0	5	5
Total		235	10	0	24	22	320	610

Fishing year		1997–98						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Hoki	HOK	22	0	2	<1	3	259	286
Ling	LIN	157	5	0	24	1	39	226
Orange roughy	ORH	23	0	3	<1	3	55	83
Oreo (all)	BOE, OEO, SSO	7	0	0	0	11	51	69
Other		22	0	0	1	0	43	66
Bluenose	BNS	9	0	0	0	0	0	9
Total		240	5	5	25	18	447	740

Fishing year		1998–99						
Target species	Species code	BSH	CSQ	ETB	SND	DWD	OSD	Total
Hoki	HOK	142	0	0	24	18	428	612
Ling	LIN	135	1	0	8	0	73	217
Orange roughy	ORH	46	0	4	2	21	44	117
Other		19	0	0	2	1	53	75
Oreo (all)	BOE, OEO, SSO	12	0	15	0	8	14	49
Bluenose	BNS	6	0	0	0	0	6	12
Groper	HPB	8	0	0	0	0	4	12
Hake	HAK	0	0	0	0	0	9	9
Total		368	1	19	36	48	631	1103

Fishing year		1999–00						
Target species		BSH	CSQ	ETB	SND	DWD	OSD	Total
Hoki	HOK	199	0	0	49	4	440	692
Orange roughy	ORH	58	0	0	0	31	59	148
Ling	LIN	92	0	0	8	0	41	141
Other	SQU	39	0	0	6	2	60	107
Oreo (all)	BOE, OEO, SSO	38	0	4	0	22	41	105
Bluenose	BNS	7	0	0	2	0	5	14
Groper	HPB	8	0	0	0	0	4	12
		441	0	4	65	59	650	1219

Fishing year		2000–01						
Target species		BSH	CSQ	ETB	SND	DWD	OSD	Total
Hoki	HOK	209	0	0	119	18	491	836
Ling	LIN	160	0	0	3	0	63	226
Orange roughy	ORH	34	0	7	4	97	21	163
Oreo	OEO	14	0	32	0	73	11	130
Other		26	0	1	0	0	40	67
Bluenose	BNS	12	0	0	0	0	1	13
Squid	SQU	0	0	0	0	0	11	11
Groper	HPB	6	0	0	0	0	4	10
Hake	HAK	1	0	0	0	0	7	8
Total		462	0	40	126	188	648	1463

Appendix 2: Records of deepwater sharks from trawl surveys, to 2002, where areas are as defined on the *Trawl* database.

Trip code	Areas	Number of stations where reported	Number of length frequencies recorded: Males	Females	Total
Shovelnose dogfish *(Deania calcea)*					
AEX0101	Chatham Rise	6	2	9	11
AEX8701	Challenger Plateau	8	29	47	76
AEX9801	Chatham Rise	20	0	0	117
AEX9901	Northwest Chatham Rise	4	29	60	89
ARR8401	Challenger Plateau	1	6	1	7
GAL8603	East coast North Island	1	42	100	142
JCO7903	East coast North Island	2	32	34	64
JCO8405	Challenger Plateau	31	52	77	129
JCO8702	Challenger Plateau	5	17	7	24
JCO8902	Challenger Plateau	2	27	16	43
KAH0209	Cook Strait	3	4	2	6
KAH9604	Bay of Plenty	1	0	0	3
TAN0001	Chatham Rise	32	406	487	911
TAN0007	West coast South Island	36	41	134	176
TAN0011	Chatham Rise	22	0	47	50
TAN0012	East coast North Island	11	71	22	93
TAN0101	Chatham Rise	33	492	612	1104
TAN0109	East coast North Island	27	206	220	498
TAN0111	Cook Strait	1	0	8	8
TAN0118	Southland-Puysegur Bank	16	242	166	48
TAN0201	Chatham Rise	48	705	830	1536
TAN0208	Chatham Rise	44	104	33	138
TAN9708	East coast North Island	3	7	13	20
TAN9713	Southwest Chatham Rise	4	3	5	8
TAN9801	Chatham Rise	15	135	174	309
TAN9807	Northwest Chatham Rise	36	213	408	914
TAN9812	Southeast Chatham Rise	46	36	318	359
TAN9901	Chatham Rise	17	178	320	500
TAN9908	Northwest Chatham Rise	2	7	0	10
TVI0101	Northern Bay of Plenty	7	17	18	44
WNK8501	Northern and Central North Island	27	444	435	879
WNK8502	Northern and Central North Island	30	817	693	1510
WNK8503	Northern and Central North Island	31	793	963	1757
WNK8604	Northern and Central North Island	30	1081	1375	2456
WNK8605	Northern and Central North Island	26	785	621	1406
Baxter's dogfish (*Etmopterus baxteri*)					
AEX0101	Snares. Auckland Island	22	161	332	721
AEX8902	Snares. Auckland Island	2	43	25	68
AEX9801	Chatham Rise	24	0	0	162
AEX9901	Northwest Chatham Rise	16	190	620	810
JCO7903	East coast North Island	1	5	6	11
JCO8405	Challenger Plateau	8	5	6	11
TAN0011	Chatham Rise	43	150	314	515
TAN0109	East coast North Island	11	22	37	61
TAN0118	Southland-Puysegur Bank	4	3	11	14
TAN0201	Chatham Rise	13	344	209	562
TAN0208	Chatham Rise	80	262	397	661
TAN9406	Chatham Rise	3	20	119	139
TAN9608	Chatham Rise	1	1	1	2
TAN9609	Chatham Rise	20	89	85	174
TAN9705	East coast North Island	8	120	93	213
TAN9708	East coast North Island	7	41	73	114
TAN9713	East coast North Island, Chatham Rise	17	124	136	260

Appendix 2: – continued.

Trip code	Areas	Number of stations where reported	Number of length frequencies recorded Males	Females	Total
TAN9807	Chatham Rise	44	344	395	829
TAN9812	Chatham Rise	84	443	748	1222
TAN9901	Chatham Rise	9	0	0	136
TAN9908	Chatham Rise	22	179	699	902
WES7902	Southland-Puysegur Bank	1	7	7	14
WNK8504	Northern and Central North Island	2	49	31	80
Owston's dogfish (*Centroscymnus owstoni*)					
TAN0118	Southland-Puysegur Bank	2	2	1	1
AEX9801	Chatham Rise	3	0	0	3
TAN9708	East North Island, Chatham Rise	3	0	7	7
TAN9812	Southeast Chatham Rise	6	1	6	7
JCO7903	East coast North Island	1	5	3	8
JCO8106	East coast North Island	2	6	2	8
JCO8702	Challenger Plateau	1	6	4	10
TAN9908	Northwest Chatham Rise	4	0	7	13
WNK8502	Northern and Central North Island	1	8	9	17
TAN0109	East coast North Island	14	11	9	21
AEX9901	Northwest Chatham Rise	5	12	20	32
TAN0201	Chatham Rise	4	24	12	36
WNK8605	Northern and Central North Island	1	37	14	51
JCO8304	Challenger Plateau	20	34	21	55
TAN9807	Chatham Rise	26	37	23	72
JCO8405	Challenger Plateau	30	36	41	78
TAN0208	Chatham Rise	37	52	31	83
Longnose velvet dogfish (*Centroscymnus crepidater*)					
AEX0101	Chatham Rise	9	4	28	32
AEX8901	Chatham Rise	23	0	0	224
AEX9901	Chatham Rise	5	9	20	29
JCO7903	East coast North Island	2	34	18	52
JCO8106	East coast North Island	2	11	8	19
JCO8304	Challenger Plateau	15	16	22	38
JCO8405	Challenger Plateau	26	19	25	45
KAH0107	Cook Strait	1	0	1	1
KAH0209	Cook Strait	3	3	8	11
KAH9911	North Island	1	0	1	1
TAN0011	Chatham Rise	22	12	52	66
TAN0109	Chatham Rise	23	36	67	106
TAN0111	Cook Strait	6	1	17	19
TAN0118	Southland-Puysegur Bank	2	0	4	4
TAN0201	Chatham Rise	7	164	212	376
TAN0208	Chatham Rise	59	53	218	273
TAN9609	Chatham Rise	19	42	112	154
TAN9708	East coast North Island	4	4	16	20
TAN9713	Chatham Rise	5	4	7	11
TAN9807	Chatham Rise	40	82	283	519
TAN9812	Chatham Rise	40	34	93	130
TAN9901	Chatham Rise	1	140	29	169
TAN9908	Chatham Rise	10	2	8	14
TVI0101	Northern Bay of Plenty	2	0	1	3
WNK8502	Northern and Central North Island	1	10	4	14

Appendix 2: – continued.

Trip code	Areas	Number of stations where reported	Number of length frequencies recorded Males	Females	Total
Leafscale gulper shark *(Centrophorus squamosus)*					
AEX0101	Chatham Rise	1	5	7	12
AEX8902	Snares, Auckland Islands	5	4	24	29
AEX8901	Chatham Rise	1	0	0	1
AEX9901	Northwest Chatham Rise	1	0	2	2
JCO8106	East coast North Island	1	0	1	1
JCO8405	Challenger Plateau	1	0	1	1
KAH9911	Cook Strait	2	3	1	4
KAH0107	Cook Strait	1	0	1	1
KAH0209	Cook Strait	3	6	7	13
TAN0007	West coast South Island	19	7	37	44
TAN0109	East coast North Island	2	1	1	2
TAN0111	Cook Strait	7	1	20	28
TAN0118	Southland-Puysegur Bank	3	0	4	4
TAN0201	Chatham Rise	2	0	4	4
TAN9609	Chatham Rise	1	1	0	1
TAN0208	Chatham Rise	33	15	42	57
TAN9705	Northern and Central North Island	1	0	3	3
TAN9708	Chatham Rise	2	0	3	3
TAN9807	Chatham Rise	12	5	28	34
TAN9812	Chatham Rise	5	1	4	5
TAN9908	Northwest Chatham Rise	4	1	5	8
TVI0101	Northern Bay of Plenty	1	0	0	1
WNK8502	Northern and Central North Island	1	0	7	7
WNK8605	Northern and Central North Island	1	2	4	6
Seal shark *(Dalatias licha)*					
AEX8902	Snares, Auckland Islands	1	0	1	1
AEX9801	Chatham Rise	3	0	0	4
JCO7903	East coast North Island	2	5	5	10
JCO8106	East coast North Island	4	11	4	15
JCO8201	East coast South Island	1	0	0	1
JCO8405	Challenger Plateau	10	4	8	13
KAH0209	Cook Strait	3	2	6	8
KAH9304	East coast North Island	1	3	0	3
KAH9911	Cook Strait	3	2	2	4
TAN0007	West coast South Island	22	10	22	33
TAN0011	Cook Strait	2	0	2	2
TAN0012	North Island	1	2	1	3
TAN0109	East coast North Island	3	3	0	3
TAN0111	Cook Strait	4	0	2	8
TAN0118	Southland-Puysegur Bank	3	2	2	4
TAN0208	Chatham Rise	2	0	2	2
TAN9807	Chatham Rise	9	3	9	12
TAN9812	Chatham Rise	6	1	4	7
TAN9901	Chatham Rise	3	0	0	3
TAN9908	Chatham Rise	3	1	1	3
WES7902	Chatham Rise	2	3	4	9
WNK8501	Northern and Central North Island	1	19	2	21