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A summary of biology and commercial landings, and a stock assessment of spiny dogfish (*Squalus acanthias*)

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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1. EXECUTIVE SUMMARY

This paper summarises background information on the biology, landings, stock structure, and distribution and abundance of the spotted or southern spiny dogfish (*Squalus acanthias*).

Aspects of the biology of spiny dogfish, including distribution and abundance, diet, reproduction, age and growth, and potential predators, were studied by Hanchet (1986) and are reviewed here. It has similar population characteristics to the North Atlantic populations of spiny dogfish, and is a slow growing, long lived, low fecundity species.

Historical reported catches are provided for the period 1981–82 to 1994–95 from various catch and catch-effort databases. Reported annual catches have fluctuated between about 2000 and 7000 t. The highest catches have come from Fisheries Management Areas (FMAs) 3, 5, 6, and 7. Although these figures include reported annual discards of 300–1100 t over the past 6 years it is considered likely that the level of discarding is underestimated.

Biomass estimates from all relevant time series of trawl surveys are tabulated. All surveys carried out in 1995 and 1996 recorded the highest estimates in their respective time series. For example, biomass estimates for the Stewart-Snares shelf were about 30 000 t in 1993 and 1994 but increased to 90 000 t in 1995 and 1996. The reason for these large changes in catchability between years is unknown, but this raises concern over the ability of the trawl surveys to monitor changes in spiny dogfish abundance, particularly in the short term.

Analysis of the data on seasonal distribution and abundance, and the reported commercial catch suggests that there may be five stocks of spiny dogfish.

Estimates of MCY based on average catch over various periods for each stock were calculated. Because of non-reported discards in the past these estimates are likely to be conservative. Virgin and current biomass estimates could not be estimated because of the lack of suitable time series of relative abundance estimates and lack of data on the size and age at recruitment to the commercial fishery.

Data on landings and distribution of the northern spiny dogfish (*S. mitsukurii*) are also presented. Annual landings have averaged about 100 t over the past 3 years. An additional 50–100 t.y^{-1} of *S. acanthias* caught in FMA 1 was probably misidentified and should be attributed to *S. mitsukurii*.

2. INTRODUCTION

2.1 Overview

This paper summarises background information on spiny dogfish. Aspects of the biology, stock structure, trawl survey biomass estimates, and commercial catch data are presented. Estimates of MCY for each stock are derived from the catch history.

2.2 Species separation and distribution

There are two species of *Squalus* in New Zealand waters: the spotted or southern spiny dogfish *S. acanthias* (species code, SPD) and the green-eyed or northern spiny dogfish *S. mitsukurii* (species code, NSD). Separation of the two species is usually easy because of the spotted pattern in *S. acanthias*. However, in older individuals of the latter the spots may fade and there is potential for some misidentification. For many years the spiny dogfish catch was not separated by species, and there is still uncertainty over whether fishers currently report them correctly. In this section the distribution and relative abundance of the two species are examined using data from the research trawl database. The proportions caught in the trawl surveys can then be compared to the commercial landings to determine whether there may be discrepancies in the landings data, given that any differences in the market preferences are known.

Plots of all research tows catching *S. acanthias* are shown in Figure 1, and for comparison, all those with zero catch are shown in Figure 2. *S. acanthias* are distributed throughout the southern half of New Zealand, including the Campbell Plateau and Chatham Rise, but are absent from the Bounty Platform. The distribution around the North Island is a little less clear. There have been a number of surveys off the west coast North Island but only one survey (KAH9410) recorded *S. acanthias* in reasonable numbers north of Raglan. These records have been substantiated (N.Bagley, NIWA, pers. comm.) and it appears that spiny dogfish may have moved further north because of colder water temperatures that year. *S. acanthias* have not been recorded from East Northland or the Hauraki Gulf and have only been recorded from one survey in the Bay of Plenty. In this instance the records have not been verified and it is possible that these were *S. mitsukurii* misidentified as *S. acanthias*.

The distribution of *S. mitsukurii* is far more restricted (Figure 3). They are most commonly caught around the North Island and overlap with *S. acanthias* in the central west coast area and around the Chatham Islands. However, even in these areas of overlap *S. acanthias* is by far the more abundant species. The total voyage catch weights of *S. acanthias* substantially exceed those of *S. mitsukurii* in most surveys, and in all areas except FMAs 1 and 9 (Appendix 1). In the areas of overlap *S. acanthias* is more abundant in depths less than 200 m, but beyond 200 m *S. mitsukurii* is the species more commonly caught (Figure 4).

In the remainder of this report spiny dogfish refers only to *S. acanthias.*

2.3 Description of fishery

Spiny dogfish have probably always been commonly taken by commercial trawlers, set netters, and longliners in New Zealand waters. However, apart from a small fishery for their livers which developed in the 1940s, they had little commercial value until the early 1980s. Since then an increasing amount of spiny dogfish has been processed and landed by both domestic and chartered vessels. Most spiny dogfish are caught by factory trawlers as a bycatch in the jack mackerel, barracouta, hoki, red cod, and arrow squid fisheries.

Spiny dogfish are also taken as bycatch by inshore trawlers, set netters, and longliners targeting flatfish, snapper, tarakihi, and gurnard. Because of processing problems due to their spines, sandpaper-like skin, and short shelf life, and their low economic value most fishermen are not interested in processing and landing them. Furthermore, because of their sheer abundance they can at times severely hamper fishing operations for other commercial species and they are regarded by many fishers as a major nuisance. For example, Hanchet (1986) noted that trawlers working off Otago during the summer months often reduced towing times and headline heights, and at times left the area altogether to avoid having to spend hours pulling hundreds of meshed dogfish out of trawl nets. Set netters and longliners from off the Otago coast and in Tasman Bay and the south Taranaki Bight have also complained about spiny dogfish taking longline baits, attacking commercial fish caught in the nets or lines, and rolling up nets (K. Drummond, Ministry of Fisheries, pers.comm.). However, reports of a spiny dogfish on every hook of a longline or every mesh of a set net are not confined to New Zealand waters (*see* Compagno 1984, Ketchen 1986). In North America and Europe spiny dogfish have become more commercially desirable as other more preferred species have been overfished. The continuing trend of increasing catches by domestic inshore vessels is a sign that this trend is also occurring now in New Zealand.

2.3 Literature Review

Bryant (1980) reviewed aspects of the commercial utilisation of spiny dogfish in New Zealand. Hanchet (1986) studied aspects of the biology and ecology of spiny dogfish in New Zealand waters and overseas and Palmer (1994) examined the market potential of various spiny dogfish and deepwater dogfish in New Zealand waters.

2.3.1 Distribution and abundance

Compagno (1984) stated that *S. acanthias* is perhaps the most abundant living shark, and the only one capable of supporting fisheries of a size rivalling those of the more commercially important teleosts. Standing stocks of 300 000–500 000 t of marketable sized fish have been estimated for the northeast Pacific (Wood *et al.* 1979) and a minimum of 160 000 t for the northwest Atlantic (Nammack *et al.* 1985).

Large-scale fisheries for *S. acanthias* exist in the northeast Pacific, the northwest Atlantic, and the northeast Atlantic. In the northeast Pacific, a fishery for the liver developed in the late 1930s and catches peaked at 54 000 t in 1944 (Ketchen 1986). CPUE analysis showed that the stock had declined by over 60%, and with the advent of synthetic vitamins the fishery reduced to a very low level. Wood *et al.* (1979) considered that the stock had rebuilt by the mid 1970s, when a second era of fishing began. Landings were initially low, about 5 000–10 000 t per year up to 1982, but have increased to supply markets in Europe. In 1994 landings in the northwest Atlantic exceeded 22 000 t with a further estimated 25 000 t discarded: 95% of the landings are of mature females and it is believed that they are overexploited (McRuer & Hurlbut 1996). Current mortality rates are considered to be in excess of reproductive rates. The stocks in the northeast Atlantic have supported annual landings averaging about 30 000 t since the 1950s (Fahy & Gleeson 1990).

Studies have shown that spiny dogfish undergo marked changes in their distribution which are related to water temperature. They prefer a range with a minimum of 7-8°C and a maximum of 12-15°C, and make latitudinal and depth migrations to stay within this preferred range (Compagno 1984). Tagging studies have shown that large numbers of spiny dogfish seasonally migrate up to 1000 km on both coasts of North America. However, studies in the Canadian northeast Pacific have also shown that quite localised stocks may also occur which remain resident in the area throughout the year. Individual fish have been recaptured after making transAtlantic and transPacific migrations of 1600 km and 6500 km respectively.

Hanchet (1986) carried out a regular sampling programme off the Otago coast in the early 1980s and also analysed historical trawl survey data from the east coast South Island (ECSI). He found strong evidence for a north-south movement along the east coast. During the winter months, fish were more abundant in the Canterbury Bight. As the water temperatures in the Bight increased some fish migrated offshore, but the most appeared to migrate south towards Nugget Point. Hanchet (1986) was unable to discern the full latitudinal extent of the migration because at the time there were few data on spiny dogfish distribution and abundance from the Stewart Island-Snares region. However, he concluded that it was unlikely that spiny dogfish in New Zealand undertook such extensive migrations as those reported overseas.

2.3.2 Diet

Hanchet (1991) examined over 7000 spiny dogfish stomachs: 97 different prey species were recorded. The prey items ranged from pelagic and mesopelagic to demersal and benthic; encompassing a range in size from invertebrate larvae (less than five mm long) to paddle crabs (*Ovalipes catharus*) measuring 100 mm across the carapace. The major dietary components based on occurrence were 60% crustacea, 15% fish, 8% salps, and 7% molluscs. The principal food items were the post larval phase of the squat lobster (*Munida* *gregaria*) (30%) and the euphausiid *Nyctiphanes australis* (20%). Other taxonomic groups commonly taken included polychaetes, squid, ctenophores, crabs, and mantis shrimps.

The main species of fish eaten by spiny dogfish were sprat (*Sprattus* spp.), ahuru (*Auchenoceros punctatus*), juvenile spiny dogfish, lanternfish (Myctophidae), and opalfish (*Hemerocoetes* spp.). The identification of 35 juvenile spiny dogfish (18–26 cm long) in the stomachs of spiny dogfish was of particular interest as cannibalism has only rarely been reported in spiny dogfish and this has implications for assumptions about compensatory changes in natural mortality. A number of fish were identified from only partial remains (e.g., heads, tails, guts, or vertebrae), indicating that these species may have been scavenged from fishing boats or nets. Commercial fish species contributed to less than 5% of the diet.

Diet varied with dogfish sex and size, and with season. The smaller dogfish fed mainly on planktonic invertebrates, and the diet of larger dogfish included a greater proportion of fish, squid, and benthic prey items. The diet was more varied, and generally more benthic, during the winter months.

2.3.3. Reproduction

Aspects of the reproduction of spiny dogfish on the ECSI were published by Hanchet (1988). Spiny dogfish produce live young that are nourished exclusively by yolk contained in the egg (aplacental viviparity). He found a wide variation in size at sexual maturity. The length at which 50% of the females matured was 71.5 cm: the shortest mature female was 65 cm and the longest immature female was 81 cm. The equivalent lengths for males were 57.5, 53, and 63 cm. There was an increase in size at maturity of females with decreasing latitude; fish collected from ECSI south of Timaru matured at 71.5 cm, fish from north of Timaru matured at 74 cm, and fish in Tasman Bay matured at 76.5 cm.

Hanchet (1988) demonstrated that the female gestation period lasted 2 years, and that there was a well defined behaviour pattern during their reproductive cycle. Females with newly ovulated eggs in the uteri were found in 200–300 m depth during winter. These females remained in that depth until the embryos had reached about 2 cm, after which they moved inshore (50 m depth). They spent the following 9 months in shallow water by which time the embryos had reached an average length of 11 cm. During winter and spring these females moved back offshore and by the following summer they were found mainly in deeper water. Parturition occurred during late autumn followed by mating and ovulation. Both the distribution of mature males, and the timing of spermatogenesis, were consistent with these findings.

Hanchet (1988) showed that there were positive linear relationships between embryo length at birth and parent length, and between fecundity and parent length. Length at birth varied between 18 and 30 cm with a mean of 24 cm at a parent length of 85 cm. Fecundity ranged from 1 to 16 embryos per female with a mean of 6 embryos at a parent length of 85 cm. The fecundity-parent length relationship was:

$$F = 0.22\,L - 12.7 \quad \text{(where F = fecundity, and L = total length in cm)}$$

Hanchet (1988) found that reproductive abnormalities were high compared to the northern hemisphere populations, and comprised addled eggs (eggs being resorbed), females resting between pregnancies, and non-developing uterine eggs.

2.3.4 Weight-length relationship

The weight-length relationship for spiny dogfish collected from throughout the year from ECSI was described by Hanchet (1986) and is shown below. Parameters and sample sizes (n) for males and females for the equation $W = aL^b$ (where W is in g, L is in cm) are:

	b	a	n
Males	3.05	0.00275	542
Females	3.25	0.00139	742

2.3.5 Age and growth

Hanchet (1986) carried out an ageing study of spiny dogfish caught mainly from the Otago coast using posterior (second) dorsal fin spines, length frequency data, eye lens weight frequency data, and reproductive data. He validated the ages of the young fish (less than 4 years old) using modal class analysis of eye lens weight frequency data and length frequency data. These ages were used to establish criteria for interpreting the rings found on the spines of the young fish. A total of 938 fish collected over a 4 month period were aged using spines and growth curves for males and females were derived separately. The calculated von Bertalanffy growth parameters, sample size and maximum age are:

	L_∞	K	t_0	n	Max age
Males	89.5	0.116	-2.88	441	21
Females	120.1	0.069	-3.45	497	26

Males matured at age 6 and had a maximum recorded age of 21 years and females matured at age 10 and had a maximum recorded age of 26 years.

Although the ages of older fish (greater than 4 years) were not validated, Hanchet (1986) considered that the ages were reasonably reliable for the following reasons.

- The different methods of ageing gave similar estimates of growth rates.

- Marginal increment analysis showed that rings were generally deposited in winter and spring, which corresponded with a winter check in growth.
- There was good agreement between the predicted L_∞ and the largest fish observed.
- Changes in growth rates and markings on the spine could be correlated with changes occurring during the life cycle of the fish.
- Results of spine ageing gave similar maximum ages, ages at maturity and von Bertalanffy growth parameters to north Atlantic populations where annual ring deposition has been at least partially validated using tetracycline.
- Growth rates in the present study and in overseas studies agree with those derived from tagging studies and captive rearing.

Hanchet (1986) concluded that the New Zealand population had similar growth characteristics to the North Atlantic populations, but was faster growing and shorter lived than the North Pacific populations.

2.3.6 Natural mortality

An estimate of M was obtained by Hanchet (1986) using the survivorship table approach (*after* Holden 1977). At an instantaneous mortality rate of about 0.2 year^{-1}, an initial population of 1000 females would replace themselves over their lifespan (given their length at age, length at maturity and fecundity-parent length relationship).

2.3.7 Predators

Hanchet (1986) recorded stomach contents of several potential predators of spiny dogfish collected off the Otago coast (mainly at shark fishing tournaments). He examined 30 blue sharks (*Prionace glauca*), of which 15 had at least 1 spiny dogfish (2 of them each had 6 spiny dogfish). The spiny dogfish ranged from 20 to 80 cm but were mainly 0+ or 1+ fish. He also recorded spiny dogfish from the stomachs of school shark (*Galeorhinus australis*), mako (*Isurus oxyrinchus*), porbeagle (*Lamna nasus*), the great white shark (*Carcharias carcharadon*), and adult spiny dogfish (*see* Section 2.3.2). He concluded that the major predators of juvenile (0+ and 1+) fish would be adult spiny dogfish and blue sharks, and the main predators of adults would be the larger sharks.

3. REVIEW OF THE FISHERY

3.1 TACs, catch, landings, and effort data

3.1.1 Total allowable catch

Competitive quotas of 4075 t for FMA 3, and of 3600 t for FMAs 5 and 6, were introduced for the first time in the 1992–93 fishing year. The basis for setting these yields has not been formally documented and so is briefly outlined below.

The yields were based on the equation:

MCY = $0.25 * M * B_0$ (Annala & Sullivan 1996)

M was estimated to be 0.2 from a survivorship table analysis (Hanchet 1986).

Estimates of B_0 were taken directly from trawl surveys carried out in the early to mid 1980s when the stocks were assumed to be unexploited. For the east coast South Island (FMA 3) nine trawl surveys aimed at barracouta were carried out using *James Cook* between 1980 and 1982 (Hurst & Fenaughty 1985). The average of the wingspread and doorspread estimates of spiny dogfish biomass for the Canterbury Bight area ranged from 6500 t to 106 500 t. The biomass from the September 1982 survey (81 500 t) was chosen because it had the lowest *c.v.* (25%) and was the only one conducted in winter, when spiny dogfish are found in the shallow waters of the Bight. For the Stewart-Snares shelf here (FMA 5) only one survey using the *Shinkai Maru* had covered the entire area in winter (Hurst *et al.* 1990). The biomass estimate from this survey was 76 700 t (*c.v.* 10%). The biomass of spiny dogfish in FMA 6 was assumed to be negligible.

Substituting the above estimates of biomass and M into the equation gave MCY estimates of 4075 t for FMA 3, and 3600 t for FMAs 5 and 6. This method of estimating biomass from trawl surveys is no longer considered appropriate by the Ministry of Fisheries. Furthermore, Francis & Francis (1992) showed that the estimate of MCY derived from the above equation always produced levels of harvesting which were unsustainable for rig stocks. The case will almost certainly be the same for spiny dogfish because of its slower growth rates and lower fecundity (*see* also Section 5).

3.1.2 Landings

Estimated landings from all the available databases are summarised in Table 1. Before 1980–81 landings of rig and both *Squalus* species were included together, and catches of the latter were probably small. In the early years of the fishery the records came from the Fisheries Statistics Unit (FSU) inshore and deepwater logbooks. The FSU logbooks were discontinued in 1987–88 and replaced by the Licensed Fish Receiver Returns (LFRR), the inshore Catch Effort Landing Returns (CELR), and the deepwater Trawl Catch Effort

Processing Returns (TCEPR) and Catch Landing Returns (CLR). Both the CLR and CELR include a destination category which allows fishers to record the fate of the fish. As a large amount of spiny dogfish may be caught but discarded it is important to include the discarded fish as part of the total catch history.

The close agreement between the CLR, the processed TCEPR, and the estimated TCEPR totals suggests the factory trawler data may be reasonably reliable (see Table 1). The reliability of the inshore data is questionable because the estimated CELR totals are substantially higher than the landed CELR totals. By comparing the sum of the CLR and CELR totals (both estimated and landed) with the LFRR totals it appears that the estimated CELR totals are too high. It has not been possible to determine the reason for the high estimated CELR totals, but may be a problem with the extract procedure rather than the forms or database themselves.

The best estimate of reported catch from the fishery is shown in the final column in Table 1. For the period up to 1986–87 this is the sum of the FSU data. For the period 1987–88 to 1994–95 this is the sum of the LFRR and the discards from the CELR and CLR. It has been assumed here that all the fish which have been caught and discarded will die, and that all the discarded fish have been recorded. Although neither assumption is likely to be true, and the biases they produce will at least partially cancel each other out, it is likely that the true level of discards is considerably higher. However, these figures are currently the best estimates of total removals from the fishery.

The fishery developed in the early 1980s and since then the reported catch has fluctuated between about 3000 and 7000 t. The reported catch by the deepwater fleet has remained fairly constant during most of the period, averaging 2000–4000 t, with a slight decrease in recent years. Reported catch by the inshore fleet has shown a steady increase throughout the period and is now at a similar level to the catch from the deepwater fleet.

Catch by area

The catch by area from the FSU, CELR, and CLR databases is shown in Table 2. The catch has been summed for each of the FMAs and pro-rated by a small amount to the best estimate of total catch given in Table 1.

The highest catches have been recorded in FMAs 3, 5, 6, and 7. FMAs 5 and 6 were most important in the early 1980s, with catches of 1000–2000 t taken by the deepwater fleet. In more recent years FMA 3 and to a lesser extent FMA 7 have become more important. The catch in both these areas is taken equally by the deepwater and inshore fleets.

The catch in FMA 1 is unlikely to be *S. acanthias* which is considered to be virtually absent from the area (*see* Section 2.2), and so these catches should probably be attributed to *S. mitsukurii*.

The catches by proposed Fishstock (*see* Section 4.1 for definitions of Fishstocks) are given in Table 3.

Tow-by-tow data

It had been intended to extract and analyse more detailed (daily or tow-by-tow) data from the CELR database, if this was appropriate. However, because of delays in obtaining the summarised data there was insufficient time to extract and examine the inshore data in any detail. Therefore data on catch of spiny dogfish by method and season from the inshore fleet are unknown.

An examination of the more detailed FSU and TCEPR tow-by-tow data showed that spiny dogfish are mainly taken as a bycatch of other trawl fisheries for barracouta, arrow squid, hoki, and jack mackerel (Table 4). Most of the catch in FMA 3 is taken in the barracouta, squid, and hoki bottom trawl fishery operating on the edge of the continental shelf (Figure 5). In FMAs 5 and 6 spiny dogfish are caught as a bycatch of the squid and barracouta fisheries on the Stewart-Snares shelf and Auckland Island shelf. Most of the catch in FMAs 7, 8, and 9 is from the jack mackerel trawl fishery in the North and South Taranaki Bights.

Landings of the northern spiny dogfish (*Squalus mitsukurii*)

Reported catches of *S. mitsukurii* are shown by FMA in Table 5. They are small compared to those for *S. acanthias*, but have been steadily increasing over the past few years. There were no reported catches before 1985–86 and there have been no reported catches from factory vessels. Most of the catch is from FMAs 1, 7, and 8. The proportion of *S. mitsukurii* and *S. acanthias* in the catch is shown by FMA in Table 6. As stated above, it appears likely that most of the catch of *S. acanthias* in FMA 1 should be attributed to *S. mitsukurii*. The proportions of the two species in FMAs 2 and 7 are within the range reported in trawl surveys (*see* Section 2.2). The highest proportion of *S. mitsukurii* was reported from FMA 8 and is well outside the range of catch ratios from the trawl surveys and implies either preferential targeting or reporting of this species in this area. It is unknown why there has been no catch reported from FMA 9.

Recreational catch

Spiny dogfish are caught by recreational fishers throughout their geographical range in New Zealand. They are mainly taken as bycatch when targeting other more valued species using rod and line and set net. In many parts of New Zealand spiny dogfish are regarded by recreational anglers as a pest (K. Drummond, Ministry of Fisheries, pers.comm.), often clogging nets and taking baits from hooks. Estimates of recreational landings obtained from diary surveys from 1991–92 to 1993–94 are given in Table 7. Recreational landings make up a small proportion (less than 10 %) of the total spiny dogfish catch.

Traditional catch

Maori fishers traditionally caught large numbers of "dogfish" during the last century and this included rig, school shark, and spiny dogfish.

4. RESEARCH

4.1 Stock structure

No specific research on the stock structure of spiny dogfish has been carried out. There has been only very limited tagging, so the only data come from seasonal trawl surveys (Section 4.2) and fisheries landings data (Section 3.1).

The analysis of *W.J. Scott* and *James Cook* surveys carried out from 1978 to 1983 clearly showed seasonal migrations of spiny dogfish along ECSI (Hanchet 1986). Spiny dogfish were most abundant in the south of the survey area from October to April and more abundant to the north in May to September. It is presently unclear whether these fish migrate south as far as the Stewart-Snares shelf. The results of a series of *W.J. Scott* surveys of the Stewart-Snares shelf during the late 1970s showed a large increase in catch rates of spiny dogfish from October-December through to January-April (Fenaughty & O'Sullivan 1978). Hurst & Bagley (in press) reported a three fold drop in biomass between two trawl surveys carried out by different sized vessels in June and November 1986. Although the seasonal effect was probably confounded by differences in fishing power between the two vessels, they concluded that the fish had moved out of the area. The pattern is therefore quite confusing. It is clear there are quite large changes in abundance both between seasons and between years on both the ECSI and the Stewart–Snares shelf. However, the timing of the peak abundance of fish in each of the areas is not consistent with a clear seasonal migration of fish between the two areas. Until more data become available it may be more prudent to treat fish from the two areas as separate stocks.

Seasonal trawl surveys were also carried out on west coast South Island (WCSI) between June 1981 and April 1983 using the *W.J. Scott* (Hurst & Fenaughty 1985). The catches showed a strong seasonal component, being highest in summer and autumn and lowest in winter and spring. It is likely that some fish migrate north in winter, perhaps to the North and South Taranaki Bights, and Tasman Bay and Golden Bay. However, it is also clear from summer trawl surveys of the areas that there is a resident part of the population of spiny dogfish in the Taranaki Bights over the summer months. It may therefore be appropriate to treat fish from FMA 7 and FMA 8 as a single stock.

There is little commercial catch in FMAs 1, 2, 4, and 9, and little data on movement in or between the areas. Until more data have been obtained it would seem appropriate to manage spiny dogfish with the following five fish stocks:

SPD1: FMA 1 & 2
SPD3: FMA 3
SPD4: FMA 4
SPD5: FMA 5 & 6
SPD7: FMA 7, 8, & 9

4.2 Trawl surveys

4.2.1 Catch rates and relative biomass estimates

Relative biomass estimates from all relevant bottom trawl surveys have been collated and tabulated in Tables 8–15, and catch rates are shown in Figures 6–12. Because of potentially large differences in fishing power between vessels, only those more recent surveys carried out using *Tangaroa* or *Kaharoa* can be regarded as time series of relative abundance. However, the earlier surveys have been reported where relevant as they often provide data on seasonal distribution and relative abundance and may sometimes reflect an estimate of the biomass before exploitation. Most early survey reports presented only wingspread biomass estimates and these have all been converted to doorspread estimates using the WS : DS ratios presented in those reports, or if none were available a value of 4.0 was used.

East coast North Island

A time series of surveys to monitor groundfish abundance on the east coast North Island was begun in 1993. Biomass estimates for spiny dogfish have generally been low with high *c.v.*s (Table 8). Much of the biomass in each of the surveys has come from a "hot spot" in stratum 1, in the extreme south of the survey area (Figure 6).

East coast South Island

A series of surveys of the east coast South Island was carried out using *W.J. Scott* from 1978 to 1980 (Fenaughty & Bagley 1981). Although trawls were not random (and so biomass could not be estimated), the results provided useful data on the seasonal distribution and abundance of spiny dogfish on ECSI (Figure 7). The catch rates were significantly higher south of Timaru in the summer and significantly higher north of Timaru in the winter (Hanchet 1986).

A series of transect surveys aimed at determining the distribution and abundance of barracouta in the Canterbury Bight was carried out between 1980 and 1982 using *James Cook*. Biomass estimates generally had high *c.v.*s and varied from 3 700 t to 37 800 t (Hurst & Fenaughty 1985). The results were analysed by Hanchet (1986). Catch rates during the winter were significantly higher than during the summer. The data also clearly showed a movement of spiny dogfish away from shallow waters during the summer.

A time series of random bottom trawl surveys to monitor red cod abundance on ECSI was begun by *Kaharoa* in 1991 (Table 9). Biomass estimates of spiny dogfish have had reasonably low *c.v.*s and were very consistent between 1991 and 1994, but showed a significant increase in 1996. The increase was seen in most strata throughout the survey area (Figure 8).

Chatham Rise

A number of surveys have been carried out on the Chatham Rise, but before 1986 they only covered part of the complete depth range and area (Table 10). In 1986, *Shinkai Maru* surveyed inside the 12 n. mile zone and into 50 m depth throughout the Chatham Rise (Livingston *et al.* 1991).

A new time series of surveys to monitor hoki and other middle depth species abundance in January on the Chatham Rise was begun by *Tangaroa* in 1992. Although the survey only covers depths greater than 200 m, the area shallower than this is small. An estimate of the proportion of the spiny dogfish biomass shallower and deeper than 200 m can be made from the July 1986 *Shinkai Maru* survey. The biomass in the 50–200 m strata on that survey was about 15% of the total for the Rise. It therefore appears that, at least from the depth perspective, the current *Tangaroa* time series of surveys is adequate for monitoring spiny dogfish abundance on the Chatham Rise. The biomass estimates from the series of surveys were similar for the first 4 years but showed a large increase in 1996 (Table 10).

Stewart-Snares Shelf

Although there were a number of surveys of the area before 1986, the early ones did not survey inside the 12 n. mile restriction zone and so would have missed much of the spiny dogfish biomass. The only winter-summer comparisons carried out in the area were made in June and November 1986 using *Shinkai Maru* (94.9 m, 3393 GRT), and *Akebono Maru No. 3* (57 m, 1100 GRT) respectively (Table 11). Hurst & Bagley (in press) considered that the three fold drop in biomass in the November survey was unlikely to be due just to differences in fishing power between the two vessels, and suggested that the fish had moved out of the area. Fenaughty & O'Sullivan (1978) also reported lower catch rates of spiny dogfish in October-December compared with January-April, during a series of *W.J. Scott* surveys during the late 1970s.

A new time series of surveys of the Stewart–Snares shelf has been carried out since 1993 using *Tangaroa.* Despite standardisation of area, gear, and timing, the biomass estimates of spiny dogfish increased threefold between the first two and last two surveys (Table 11).

In the first two surveys, catch rates were highest to the west of Stewart Island, but in the last two surveys they were highest to the east of Stewart Island (Figure 9). It is not known whether this has resulted from a movement of fish into the area (perhaps from the east coast?) or whether it is due to a change in its vertical availability.

Sub-Antarctic

Biomass estimates for all trawl surveys of the subantarctic since 1981 are included in Table 12. Estimates have ranged from 270 t to 6200 t, averaging about 1000 t. Low numbers of spiny dogfish are caught throughout the Campbell Plateau and Auckland Islands shelf and catch rates are much lower than on the Stewart–Snares shelf.

West coast South Island

A series of surveys was carried out on the west coast South Island between June 1981 and April 1983 by *W.J. Scott* (Hurst & Fenaughty 1985). The catches showed a strong seasonal component, being highest in summer and autumn and lowest in winter and spring (Figure 10), and this is reflected in the biomass estimates (Hurst & Fenaughty 1985). It is likely that during winter the fish migrate north to the North and South Taranaki Bights.

A time series of surveys to monitor groundfish abundance on the west coast South Island, and Tasman Bay/Golden Bay was begun using *Kaharoa* in autumn 1992 (Table 13). Biomass estimates for spiny dogfish have been very precise. The biomass more than doubled between 1992 and 1995. Catch rates have been slightly higher in the south of the survey area (Figure 11).

Central west coast

Three surveys of the Central west coast area targeting jack mackerel were carried out in 1980, 1981, and 1990 by three different vessels (Table 14). The surveys covered the northern part of FMA7 and all of FMA 8, but the first two excluded the 12 n. mile territorial sea, where spiny dogfish are found. Spiny dogfish were spread throughout the survey area, favouring depths of 50–150 m.

West coast North Island

A time series of surveys to monitor groundfish abundance on the west coast North Island was begun using *Kaharoa* in 1991, but only the last two covered comparable areas. Biomass estimates for spiny dogfish have generally been low with high *c.v.*s (Table 15). In both surveys the highest catch rates of spiny dogfish were in the North Taranaki Bight.

However, in the 1994 survey spiny dogfish were caught as far north as Ninety Mile Beach (Figure 12).

4.22 Length-frequency data

Apart from the ECSI survey most inshore trawl surveys have not measured spiny dogfish.

On the east coast South Island all sizes of the population have been represented, but the surveys have been dominated by mature males (Figure 13). The large increase in biomass in 1996 was the result of a large increase in the numbers of adult males and immature fish (less than 55 cm) of both sexes. It is unlikely that this was due to a period of good recruitment because otherwise juvenile modes would have been present in the 1993 and 1994 surveys.

On the Stewart–Snares shelf the size distribution is dominated by fish greater than 55 cm of both sexes (Figure 14). The large increase in biomass in 1995 and 1996 was due to a large increase in the abundance of mature males; the number of females has remained reasonably constant throughout.

On the Chatham Rise the size distribution is dominated by fish greater than 55 cm, comprising mature males, and sub-adult and mature females (Horn 1994a, 1994b, Schofield & Horn 1994, Schofield & Livingston 1995, 1996). Females have outnumbered males on each survey with sex ratios ranging from 8 : 1 in 1994 to 3 : 1 in 1996. This distribution is not surprising as Hanchet (1986) found that immature fish and adult males tended to be more abundant in shallower waters (less than 200 m).

4.2.3 Estimating relative abundance from trawl surveys

It is not known if time series of bottom trawl surveys will be adequate for measuring the relative abundance of spiny dogfish in New Zealand waters. Although spiny dogfish are caught in large numbers in bottom trawls throughout the EEZ, they also inhabit mid water. Hanchet (1986) recorded the capture of spiny dogfish from dahn lines during the day at the surface, over 40 m depth, and reported a diver's observations of huge schools of spiny dogfish in mid water. Livingston (1990) reported schools of spiny dogfish in Cook Strait feeding on recently spawned hoki eggs in 100–300 m depth over a bottom depth of 400–500 m. They have also often been seen around boats on the surface at night, perhaps one of the most notable being on the Chatham Rise over 1500 m depth of water (A. Hart, NIWA, pers. comm.).

From a consideration of the length-frequency data and a knowledge of the biology of this species, the spate of high biomass estimates for spiny dogfish reported in 1995 and 1996 on most *Tangaroa* and *Kaharoa* surveys is unlikely to be due to a real increase in population abundance. It is more likely to be due to changes in their areal or vertical availability to the trawl gear, perhaps due to changes in environmental conditions. This raises some doubts over the ability of trawl surveys to monitor changes in spiny dogfish abundance, particularly in the short term. However, although the biomass estimates from the surveys are highly variable it is possible that they will pick up any longer term changes in stock size.

4.3 Other studies

Natural mortality

Natural mortality has been estimated in the present study using the formula:

$$M = -\log_e(p) / A$$

where p is the proportion of the population that reaches age A (or older) in an unexploited stock (Annala & Sullivan 1996). p was set to 0.01, and A, the maximum age observed in the ageing study, was set to 26 (*see* Section 2.3.5), and the resulting estimate of M equalled 0.18. This value agrees closely with the M of 0.2 calculated by Hanchet (1986) using the survivorship table approach (*see* also Section 2.3.6). The value has been rounded up to 0.2 to reflect the imprecision with which this value is known.

This estimate is higher than that estimated for *Squalus acanthias* in the northern hemisphere which ranged from 0.1 to 0.16 in the eastern North Atlantic and from 0.03 to 0.094 in the eastern North Pacific (Fahy 1989). However, the current estimate is based on two methods and is considered to be the best available for the New Zealand population.

4.4 Estimation of biomass

Because of the lack of suitable time series of relative abundance and lack of knowledge on certain biological parameters, virgin and current biomass cannot be estimated for spiny dogfish. Time series of relative abundance from trawl surveys in all areas show no evidence of decline in biomass for any stocks. There are a number of fisheries where spiny dogfish are caught as a bycatch which might be appropriate for a standardised CPUE analysis.

Estimates of most biological parameters are available to carry out the modelling work. However, there are no data on the size or age at recruitment to the commercial fishery. This is especially important for modelling shark populations because many shark fisheries initially target the larger, more valuable mature females. This impacts severely on the recruitment potential of the stock. Modelling the population without knowledge of current targeting practices could result in quite unrealistic estimates of biomass and yields.

4.5 Estimation of Maximum Constant Yield (MCY)

Because no estimates of biomass are available the only way to estimate MCY is:

$MCY = cY_{av}$ (Annala & Sullivan 1996) where c is the estimate of recruitment variability and Y_{av} is the average catch over a period where catch and effort have been reasonably constant.

There are some reservations about applying this method to a fishery, such as this one, where there is a strong stock-recruit relationship. Although landings have been reasonably stable over the past 15 years there are no data on what effort has been applied to the fishery during this time. Catches could have been maintained high through targeting, although in such a low value fishery this seems unlikely, and any reduction in recruitment may not have appeared yet in the parent stock. However, given that the biomass estimates from the trawl surveys have shown no sign of decline (in fact most show an increase), and that the true level of discards is probably much higher than has been reported, it seems likely that estimates of MCY derived from this method will be sustainable and possibly conservative.

Annala & Sullivan (1996) specified a natural variability value of 0.8 for a species where M equals 0.2. However, the true natural variability is probably very low for this species and so c has been set at 0.9. The periods chosen for the analysis and the corresponding estimates of MCY are shown in Table 16.

5. MANAGEMENT IMPLICATIONS

It is likely that spiny dogfish are a single genetic stock within New Zealand with smaller sub-populations or units which undergo a small amount of mixing. It is likely that there are locally resident fish as well as larger groups which undergo seasonal inshore-offshore and alongshore migrations. For the purposes of stock assessment it is considered that the fishery is best assessed as five Fishstocks.

The ability to withstand harvesting depends on the strength of a number of compensatory mechanisms. For example, under exploitation individuals may grow faster, show increased fecundity, or suffer reduced natural mortality. In teleosts it is widely believed that this compensation comes from the large numbers of eggs produced per individual fish, so that even when the stock has been depleted to low levels there are still enough eggs to ensure good recruitment should the environmental conditions be right. However, in elasmobranchs the number of young born is related directly to the number of adult females, and, because of the large size and hence good survival of the young at birth, it is presumed that there is a strong stock recruit relationship for these species (Anderson 1990, Francis & Francis 1992).

Several methods of estimating MCY given in Annala & Sullivan (1996) involve the multiplication of a harvest level by an estimate of B_0 or B_{av}. Francis & Francis (1992) used Monte Carlo simulation to estimate harvest levels for calculating MCY for a rig stock. No stock-recruitment data were available for elasmobranchs at the time and so they used values for the Beverton & Holt steepness parameter ranging from 0.35 to 0.50, and recruitment variability of 0.4. These values were all at the low end of values used for teleost species and which they considered appropriate for rig. The results of their simulation studies showed that the estimates of MCY obtained using the harvest levels given in the equations in Annala & Sullivan (1996) were overly optimistic for rig.

The only published analyses of the stock-recruit relationship for spiny dogfish (and in fact for any elasmobranch population) have been carried out by da Silva (1993) and Myers *et al.* (1995). They found evidence of a strong stock-recruit relationship. However, they did not provide estimates of B_0 and so the actual steepness value cannot be calculated. Given that spiny dogfish has a slower growth rate and is less fecund than rig, it seems reasonable to assume that those harvest levels given for estimating MCY in Annala & Sullivan (1996) are also unsuitable for spiny dogfish. Without knowledge of the size and age at recruitment to the fishery, Monte Carlo simulation modelling cannot be carried out for spiny dogfish.

A summary of the MCY, catch limit and 1994–95 catch for each proposed Fishstock is given in Table 17. These catch limits are based on yields derived from trawl surveys using a method which is now considered obsolete, and harvest levels which are now considered unreliable.

No estimates of current or reference biomass are available. Reported catches of spiny dogfish over the past 15 years have been reasonably stable but with an upward trend. Biomass estimates from trawl surveys have been erratic, but have either shown no change or an increase in recent years. Based on the results of the trawl surveys recent catch levels in all stocks are thought to be sustainable and are probably at levels which would allow the stocks to move towards a size that will support the MSY. It is unknown whether the catch limits which are greater than recent catch levels, are sustainable or whether they are at levels which would allow the stock to move towards a size that will support the MSY.

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Table 1: Reported catches of spiny dogfish (t) by fishing year. FSU (Fisheries Statistics Unit), CELR (Catch Effort Landing Return), CLR (Catch Landing Return), TCEPR (Trawl Catch Effort Processing Return), LFRR (Licensed Fish Receiver Return. Numbers in brackets are probably underestimates. -, no data

	FSU		CELR			CLR		TCEPR		CELR	LFRR	Total	Best
	Inshore	Deepwater	Landed only	Estimated	Discards	Landed only	Discards	Process	Estimated	+ CLR		discards	estimate
1980–81	-	(196)	-	-	-	-	-	-	-	-	-	0	196
1981–82	-	1881	-	-	-	-	-	-	-	-	-	0	1881
1982–83	(107)	2568	-	-	-	-	-	-	-	-	-	0	2675
1983–84	309	2949	-	-	-	-	-	-	-	-	-	0	3258
1984–85	303	3266	-	-	-	-	-	-	-	-	-	0	3569
1985–86	311	2802	-	-	-	-	-	-	-	-	-	0	3113
1986–87	870	2277	-	-	-	-	-	-	-	-	2608	0	3147
1987–88	834	3877	-	-	-	-	-	-	-	-	4823	0	4823
1988–89	(351)	(500)	(235)	(473)	(6)	(391)	(10)	(39)	(856)	(626)	3573	16	3589
1989–90	(14)	(0)	1213	2020	158	1341	163	1749	1803	2554	2952	321	3273
1990–91	-	-	1800	3017	203	3554	130	4049	3792	5354	5983	333	6316
1991–92	-	-	1434	2386	322	1706	199	1509	1519	3140	3274	521	3795
1992–93	-	-	1938	3481	211	2097	405	1914	1867	4035	4157	616	4773
1993–94	-	-	2699	4425	540	2977	523	2869	2733	5676	6150	1063	7213
1994–95	-	-	1904	2993	232	1814	396	1719	2029	3718	4793	628	5421

Table 2a: Reported catches of spiny dogfish by FMA from FSU and CELR inshore databases

Year	1	2	3	4	5	6	7	8	9	FMA unspec.	Total
1982–83	3	0	43	0	9	0	22	20	5	6	108
1983–84	22	18	190	2	6	0	12	38	14	7	309
1984–85	21	12	183	4	12	0	30	14	10	17	303
1985–86	13	11	165	3	2	0	28	26	13	50	311
1986–87	62	17	372	2	87	0	114	76	24	116	870
1987–88	48	9	502	2	75	0	62	22	24	90	834
1988–89	114	6	301	2	63	0	26	5	4	70	591
1989–90	30	12	930	4	56	0	233	28	0	78	1371
1990–91	100	6	1215	3	79	0	587	13	0	0	2003
1991–92	51	20	1126	13	36	21	463	26	0	0	1756
1992–93	44	8	1242	39	32	7	745	32	0	0	2149
1993–94	43	18	1772	240	94	3	1000	69	0	0	3239
1994–95	66	1	1290	216	67	25	453	18	0	0	2136

Table 2b: Reported catches of spiny dogfish by FMA from FSU and CLR deepwater databases

Year	1	2	3	4	5	6	7	8	9	FMA unspec.	Total
1982–83	0	0	69	97	1541	60	86	29	0	0	1883
1983–84	0	0	218	344	558	1696	106	25	2	0	2949
1984–85	0	0	371	474	437	1890	59	34	0	1	3266
1985–86	0	0	713	401	526	1001	90	64	6	0	2802
1986–87	0	0	637	154	878	28	369	209	2	0	2277
1987–88	0	0	1092	162	540	16	1281	784	2	0	3877
1988–89	19	0	288	63	238	3	221	46	0	21	901
1989–90	1	0	985	112	150	2	212	40	0	0	1502
1990–91	16	7	1474	459	1458	13	208	47	0	0	3682
1991–92	1	2	611	51	483	11	532	214	0	0	1905
1992–93	5	1	832	173	764	14	388	325	0	2	2504
1993–94	4	14	1173	93	983	17	1058	130	0	29	3501
1994–95	1	37	1022	75	419	5	513	139	0	0	2211

Table 3: Reported catches of spiny dogfish by proposed Fishstock. Proportions by area have been taken from CELR and CLR and pro-rated to the best estimate from Table 1. Competitive quotas of 4075 t for FMA 3, and of 3600 t for FMAs 5 and 6, were introduced for the first time in the 1992–93 fishing year

Fishstock	SPD1	SPD3	SPD4	SPD5	SPD7	
FMA	1, 2	3	4	5, 6	7, 8, 9	Total
1982–83	4	151	131	2172	218	2675
1983–84	40	408	346	2274	196	3258
1984–85	33	554	478	2372	147	3569
1985–86	24	878	404	1629	227	3113
1986–87	82	1049	162	1031	824	3147
1987–88	60	1664	171	658	2271	4823
1988–89	145	1342	313	481	1308	3589
1989–90	49	2182	132	237	673	3273
1990–91	143	2987	513	1722	950	6316
1991–92	77	1801	66	571	1280	3795
1992–93	59	2127	217	838	1530	4773
1993–94	85	3152	356	1174	2446	7213
1994–95	131	2883	363	643	1401	5421

Table 4: Catches of spiny dogfish by target species from the FSU and TCEPR databases. Frequency, number of tows catching SPD; Catch, catch of SPD

Target species	FSU Frequency	FSU Catch	TCEPR Frequency	TCEPR Catch	Totals Frequency	Totals Catch
Barracouta	2929	1634	3549	4709	6478	6343
Spiny dogfish	1992	4983	632	892	2624	5875
Squid	4138	1982	4861	3056	8999	5038
Jack mackerel	4254	1836	2932	1734	7186	3570
Hoki	4368	887	2896	2426	7264	3313
Red cod	181	81	1382	1554	1563	1635
Silver warehou	1440	398	1394	1054	2834	1452
Warehou	299	115	172	229	471	344
Ling	367	45	279	178	646	223
Tarakihi	142	66	83	44	225	110

Table 5: Reported catches (t) of Squalus mitsukurii for each FMA by fishing year. Source: FSU, CELR, LFRR

FMA	1	2	3	7	8	Unspec.	Total	LFRR
1984–85	0	0	0	0	0	0	0	-
1985–86	0	0	0	5	2	0	7	-
1986–87	0	0	0	40	0	4	44	0
1987–88	0	0	0	22	1	2	25	102
1988–89	0	0	0	3	2	1	6	144
1989–90	1	0	0	14	10	0	25	81
1990–91	0	0	3	10	12	0	25	44
1991–92	3	0	0	14	29	0	46	53
1992–93	18	0	1	22	63	10	114	106
1993–94	23	0	0	23	44	0	90	103
1994–95	32	4	0	40	55	0	131	131

Table 6: Comparison of catches (t) of *Squalus acanthias* and *Squalus mitsukurii* by FMA for the period 1989–90 to 1994–95 (Source: CELR)

FMA	1	2	7	8
SPD	334	65	3481	186
NSD	76	4	123	213
%NSD	19	6	3	53

Table 7: Estimated catch (t) of spiny dogfish harvested by recreational fishers by proposed Fishstock and survey. Surveys were carried out in different years in the Ministry of Fisheries regions: South in 1991-92, Central in 1992-93, and North in 1993-94. The estimated Fishstock harvest is indicative and was made by combining the estimates from the different years

FMA	Survey	Catch	*c*.v. (%)
1, 9	North	<10	-
2	Central	133	42
3	South	120	23
5	South	2	-
7	South	11	92
7	Central	46	35
8	Central	143	45

Table 8: Doorspread biomass estimates (t) of spiny dogfish for the east coast North Island (FMA 2) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1

Voyage code	Year	Month	Depth range (m)	Biomass (t)	*c.v.* (%)	Source
KAH9402	1994	Feb/Mar	20-400	1 200	46	Stevenson & Kirk 1996
KAH9502	1995	Feb/Mar	20-400	660	25	Unpubl. Data
KAH9602	1996	Feb/Mar	20-400	3 800	74	Unpubl.data

Table 9: Doorspread biomass estimates (t) of spiny dogfish for the east coast South Island (FMA 3) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1

Voyage code	Year	Month	Depth range (m)	Biomass (t)	*c.v.* (%)	Source
KAH9105	1991	May/Jun	30-400	14 100	21	Beentjes & Wass 1994
KAH9205	1992	May/Jun	30-400	12 500	22	Beentjes 1995a
KAH9306	1993	May/Jun	30-400	16 100	17	Beentjes 1995b
KAH9406	1994	May/Jun	30-400	16 900	10	Unpubl. data
KAH9606	1996	May/Jun	30-400	35 700	15	Unpubl. data

Table 10: Doorspread biomass estimates (t) of spiny dogfish for the Chatham Rise (FMA 4) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1

Voyage code	Year	Month	Depth range (m)	Biomass (t)	*c.v.* (%)	Source
AKE8401#	1984	Dec	50-400	970	64	Hurst & Bagley 1987
AKE8501#	1985	Dec	50-400	1 400	21	Hurst & Bagley 1992
SHI8602	1986	Jul	50-800	6 208	14	Livingston *et al.* 1991
AEX8903	1989	Nov/Dec	200-800	1 458	19	Livingston & Schofield 1995
TAN9106	1992	Jan	200-800	2 400	14	Horn 1994a
TAN9212	1993	Jan	200-800	2 200	11	Horn 1994b
TAN9401	1994	Jan	200-800	3 400	13	Schofield & Horn 1994
TAN9501	1995	Jan	200-800	2 800	21	Schofield & Livingston 1995
TAN9601	1996	Jan	200-800	5 000	11	Schofield & Livingston 1996

Only Chatham Islands area

Table 11: Doorspread biomass estimates (t) of spiny dogfish for the Stewart-Snares Shelf (FMA 5) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1

Voyage code	Year	Month	Depth range (m)	Biomass (t)	*c.v.* (%)	Source
SHI8601	1986	Jun	50-600	28 500	10	Hurst *et al.* 1990
AKE8601	1986	Nov	50-600	10 700	19	Hurst & Bagley in press.
TAN9301	1993	Feb/Mar	30-600	36 000	13	Hurst & Bagley 1994
TAN9402	1994	Feb/Mar	30-600	36 300	17	Bagley & Hurst 1995
TAN9502	1995	Feb/Mar	30-600	91 400	29	Bagley & Hurst 1996a
TAN9604	1996	Feb/Mar	30-600	89 800	29	Bagley & Hurst 1996b

Table 12: Doorspread biomass estimates (t) of spiny dogfish for the subantarctic (FMA 6) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1. These estimates have been calculated by summing the appropriate strata from the various reports and so *c.v.*s are not available

Voyage code	Year	Month	Depth range (m)	Biomass (t)	Source
SHI8201	1982	Mar/Apr	100–600	1 050	van den Broek *et al.* 1984
SHI8303	1983	Oct/Nov	100–600	640	Hatanaka *et al.* 1989
AEX8902	1989	Oct/Nov	300–800	739	Livingston & Schofield 1993
AEX9001	1990	Jul/Aug	300–800	713	Hurst & Schofield 1995
AEX9002	1990	Nov/Dec	300–1000	497	Hurst & Schofield 1995
TAN9105	1991	Nov/Dec	300–1000	6 189	Chatterton & Hanchet 1994
TAN9209	1992	Sep	300–800	266	Schofield & Livingston 1994
TAN9211	1992	Nov/Dec	300–1000	1 071	Ingerson *et al.* 1995
TAN9310	1993	Nov/Dec	300–1000	1 015	Ingerson & Hanchet 1995

Table 13: Doorspread biomass estimates (t) of spiny dogfish for the west coast South Island (FMA 7) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1

Voyage code	Year	Month	Depth range (m)	Biomass (t)	*c.v.* (%)	Source
KAH9204	1992	Mar/Apr	20-400	3 900	15	Drummond & Stevenson 1996
KAH9404	1994	Mar/Apr	20-400	7 100	7	Drummond & Stevenson 1996
KAH9504	1995	Mar/Apr	20-400	8 400	10	Drummond & Stevenson 1996

Table 14: Doorspread biomass estimates (t) of spiny dogfish for the Central west coast (FMA 7, 8) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1

Voyage code	Year	Month	Depth range (m)	Biomass (t)	*c.v.* (%)	Source
TOM8001	1980/1	Dec/Feb	25-300	*2 500	-	Robertson *et al.* 1989
SHI8102	1981	Oct/Nov	25-300	14 700	20	Robertson *et al.* 1989
COR9001	1990	Feb/Mar	25-300	6 900	15	Horn 1991

* Assuming WS:DS = 4.

Table 15: Doorspread biomass estimates (t) of spiny dogfish for the west coast North Island (FMA 8, 9) from the results of trawl surveys assuming vulnerability, areal availability and vertical availability equal 1

Voyage code	Year	Month	Depth range (m)	Biomass (t)	*c.v.* (%)	Source
KAH9111	1991	Oct	10-200	1 100	45	Drury & Hartill 1993
KAH9410	1994	Oct	10-200	940	20	Langley 1995

Table 16: The period chosen for the estimation of average catch (t) for spiny dogfish and estimates of MCY (t) for each proposed Fishstock. *, an unknown proportion of this catch should probably be attributed to the northern spiny dogfish

Fishstock	Period	Mean catch (t)	MCY
SPD1	1986–87 to 94–95	92*	83
SPD3	1986–87 to 94–95	2130	1920
SPD4	1982–83 to 94–95	255	230
SPD5	1982–83 to 94–95	1210	1090
SPD7	1986–87 to 94–95	1410	1270

Table 17: Estimates (t) of 1994–95 reported catch, catch limits and MCY by proposed Fishstock. *, an unknown proportion of this catch should probably be attributed to the northern spiny dogfish

Fishstock	QMA	MCY	Catch limit	1994–95 catch
SPD1	1,2	83	-	131*
SPD3	3	1920	4075	2880
SPD4	4	230	-	360
SPD5	5,6	1090	3600	640
SPD7	7,8,9	1270	-	1400

Appendix 1. Voyage catch weights of northern (NSD) and southern (SPD) spiny dogfish by FMA.

Voyage	FMA	NSD	SPD	% NSD	Comments
KAH8203	1	9.2		100.0	)
KAH8716	1	0.8		100.0	)Hauraki Gulf SNA survey
KAH9212	1	1.5		100.0	)
KAH9017	1	10.7		100.0	)E. Northland trawl survey series
KAH9302	1	1.9		100.0	)
KAH8506	1	2		100.0	Bay of Plenty SNA survey
KAH9301	1	25.8	171.5	13.1	)
KAH9401	1	224.1	2.1	99.1	)BOP Scampi survey
KAH9501	1	220.9	7.1	96.9	)
KAH9511	1	158.7		100.0	)
KAH9301	2	3	30.5	9.0	)
KAH9401	2	7.2		100.0	) Scampi trawl survey
KAH9501	2	32.9		100.0	)
KAH9304	2	28.9	2882.5	1.0	)
KAH9402	2	28.8	8539.4	0.3	)ECNI trawl survey series
KAH9502	2	5.7	1963.2	0.3	)
KAH9602	2	35.5	16078.9	0.2	)
KAH9008	3		6086.8	0.0	)
KAH9105	3		16181.5	0.0	)
KAH9205	3		17514.9	0.0	) ECSI trawl survey series
KAH9306	3		21605.4	0.0	)
KAH9406	3		35805.4	0.0	)
KAH9510	3		1093	0.0	)
WJScott	3		289626	0.0	All *W.J. Scott* surveys combined
AKE8401	4	44	7565	0.6	Chatham Islands survey
AKE8501	4	94	11038	0.8	Chatham Islands survey
SHI8602	4	218.2	3323.5	6.2	Hoki Chatham Rise survey
TAN9106	4	51.6	1579.7	3.2	)
TAN9212	4	20.4	2402.7	0.8	)
TAN9401	4	15.3	1668.5	0.9	) Chatham Rise trawl survey series
TAN9501	4	7.6	1368.1	0.6	)
TAN9601	4	29.2	1735	1.7	)
Tangaroa	5,6		242876.3	0.0	All *Tangaroa* surveys
KAH9204	7	270.9	7919.8	3.3	)

KAH9404	7	267.6	16932	1.6	) WCSI trawl survey series
KAH9504	7	128	17938.4	0.7	)
SHI8102	7	1651	6865	19.4	Jack mackerel survey
COR9001	7	157.3	6803.4	2.3	Jack mackerel survey
WJScott	7	3444	29216.5	10.5	All *W.J. Scott* surveys combined
KAH9111	8		299.7	0.0	) WCNI trawl survey series
KAH9410	8		327.5	0.0	)
SHI8102	8	1814	16479	9.9	Jack mackerel survey
COR9001	8	131	3537.1	3.6	Jack mackerel survey
KAH8612	9		24	0.0	)
KAH8715	9		10	0.0	) Juvenile SNA surveys (<100m)
KAH8918	9		11.8	0.0	)
KAH9017	9	10.5		100.0	SNA Northland survey (<200 m)
KAH9111	9	44.8	44.5	50.2	) WCNI trawl survey series
KAH9410	9	7.8	186.2	4.0	)
SHI8102	9	296	1881	13.6	JMA survey (southern edge only)
COR9001	9	19.3	171.7	10.1	JMA survey (southern edge only)
WNK8501	9	11.6		100.0	)
WNK8502	9	29.3		100.0	) All surveys > 400 m
WNK8503	9	63.4		100.0	)
WNK8604	9	35.1		100.0	)

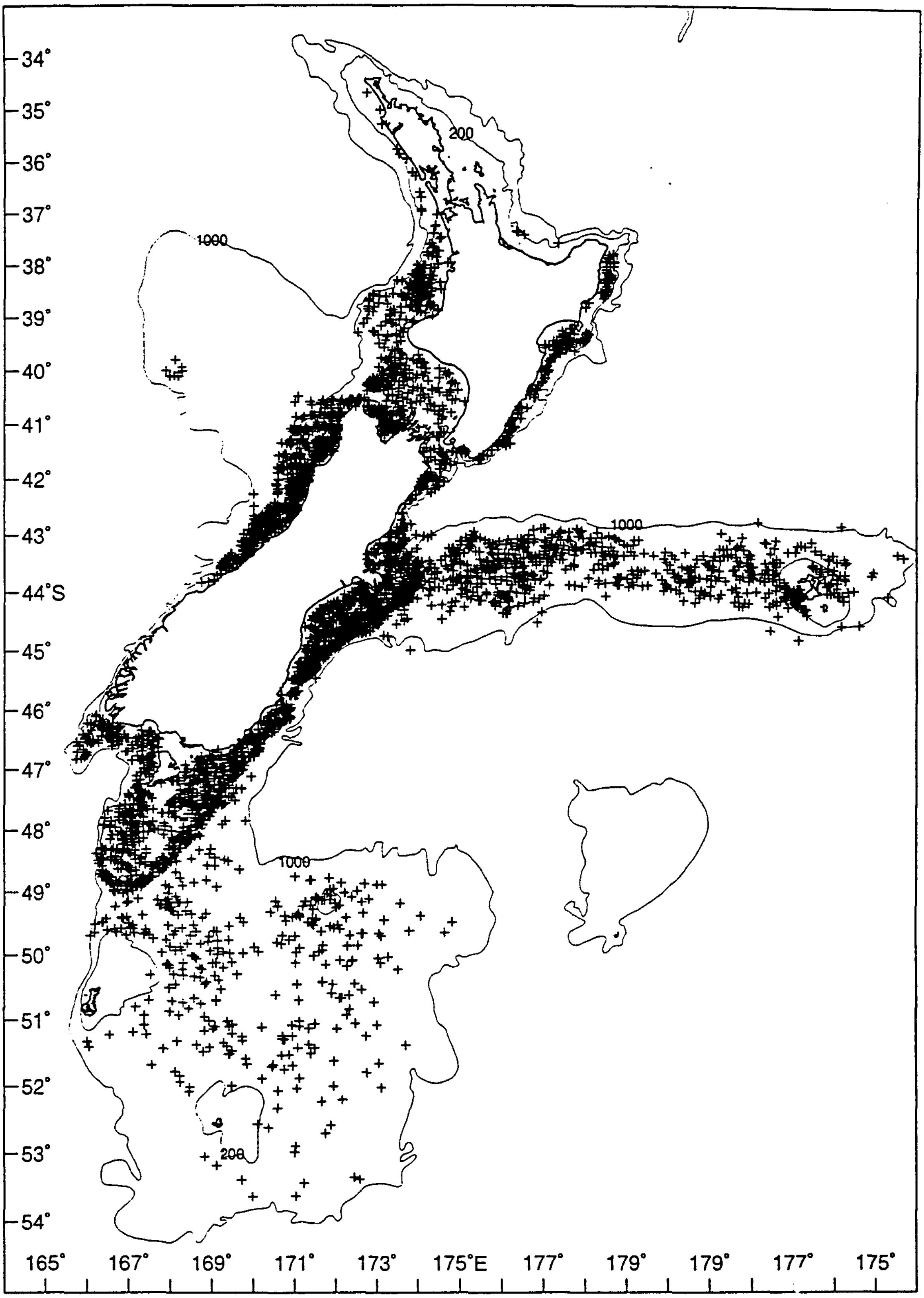

Figure 1: Position of all research tows catching southern spiny dogfish (*Squalus acanthias*).

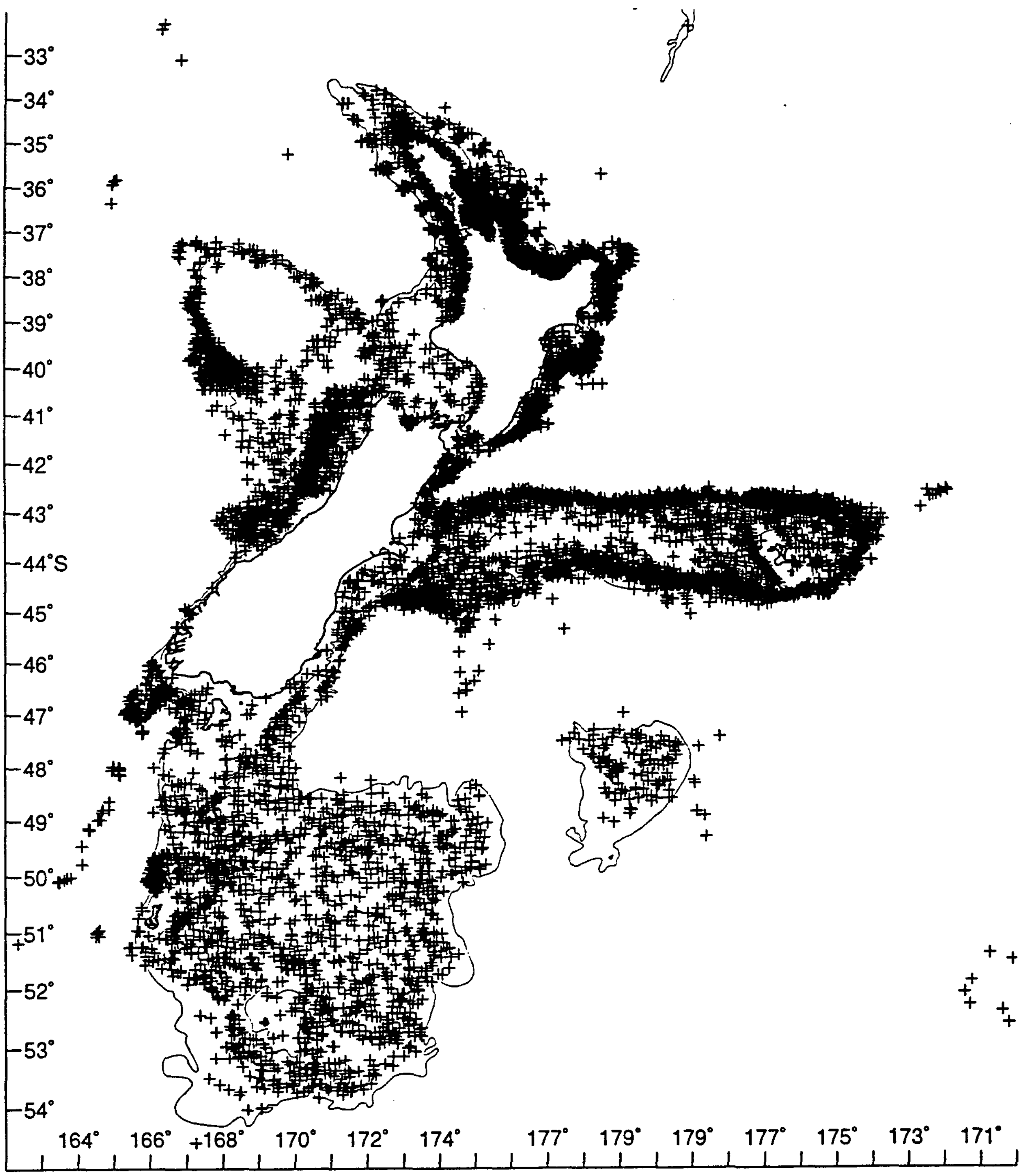

Figure 2: Position of all research tows not catching southern spiny dogfish (*Squalus acanthias*).

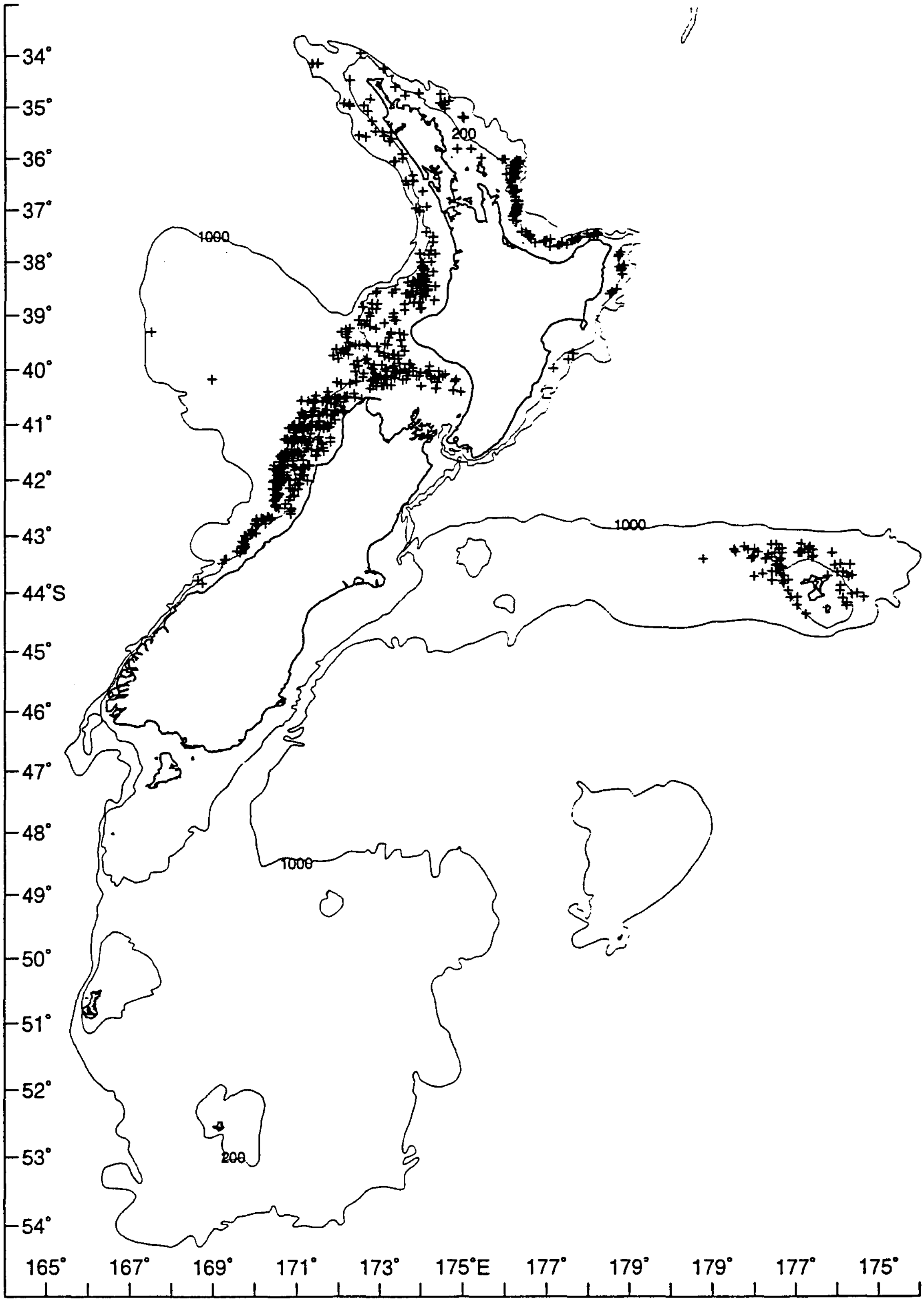

Figure 3: Position of all research tows catching northern spiny dogfish (*Squalus mitsukurii*).

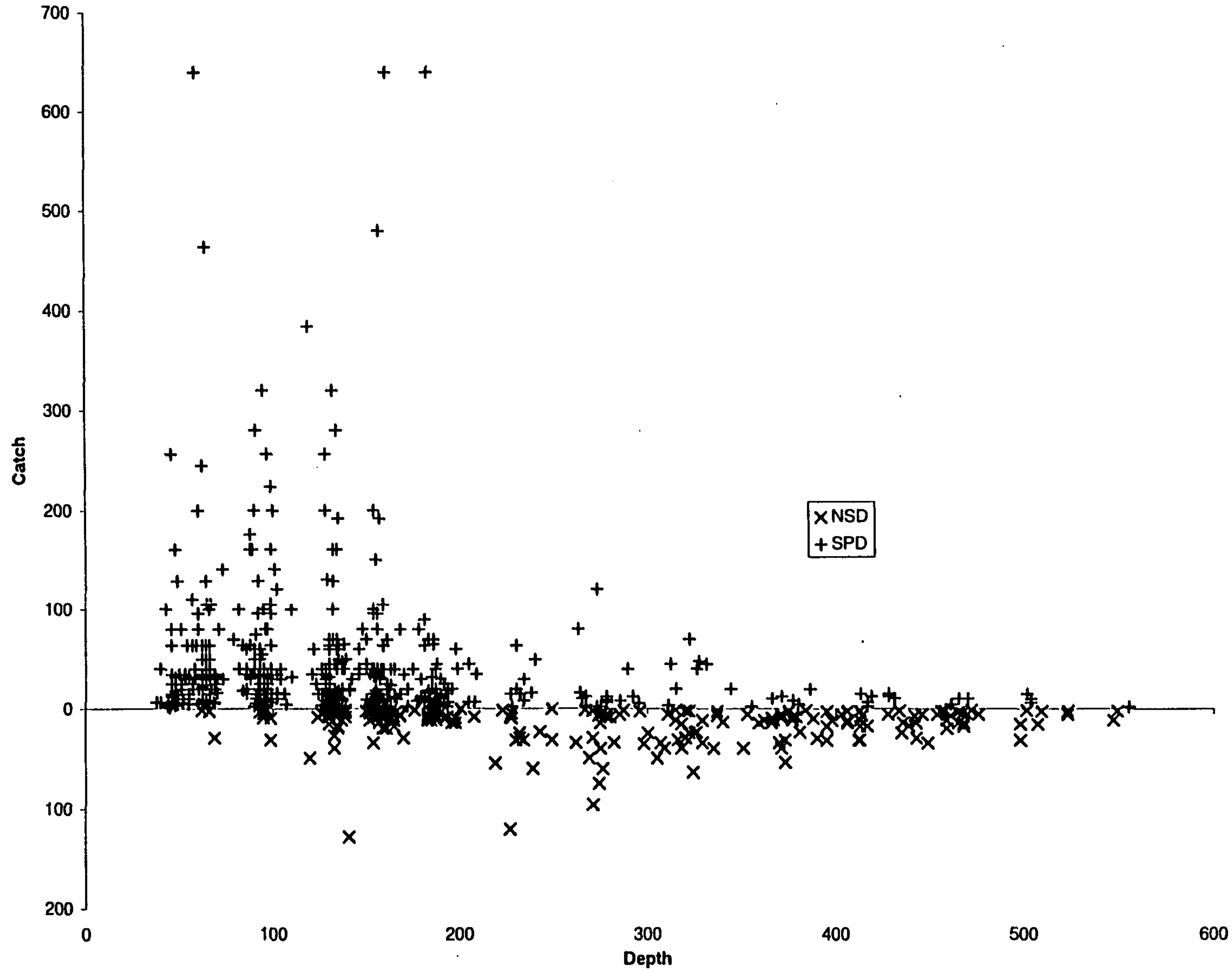

Figure 4: Catch rates (kg per tow) of southern spiny dogfish (SPD)and northern spiny dogfish (NSD) by depth from *W.J. Scott* surveys carried out on the west coast South Island between 1979 and 1981.

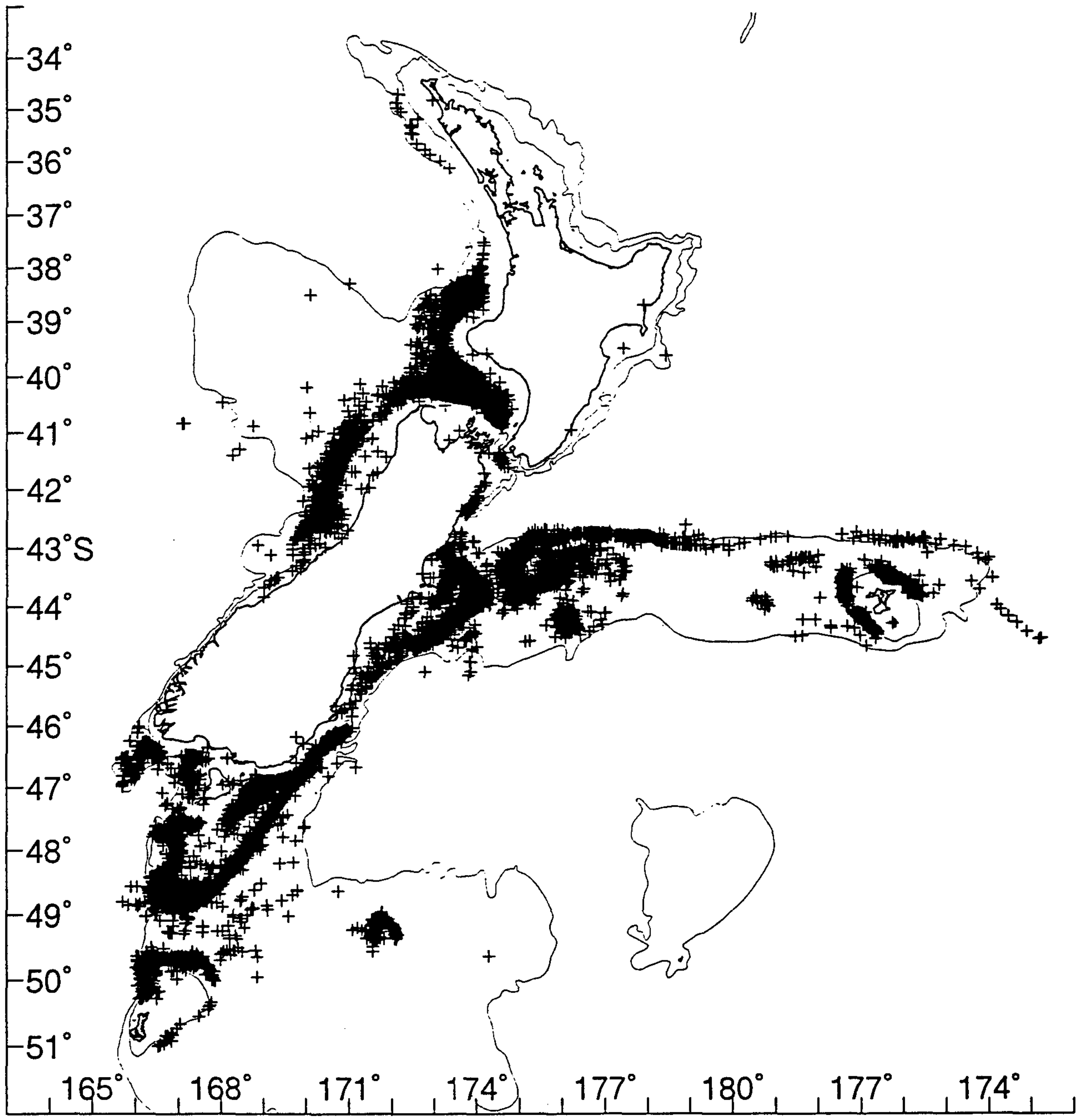

Figure 5: Position of all commercial tows catching greater than 100 kg spiny dogfish from the FSU and TCEPR deepwater trawl databases. (Note the data have not been checked for errors.)

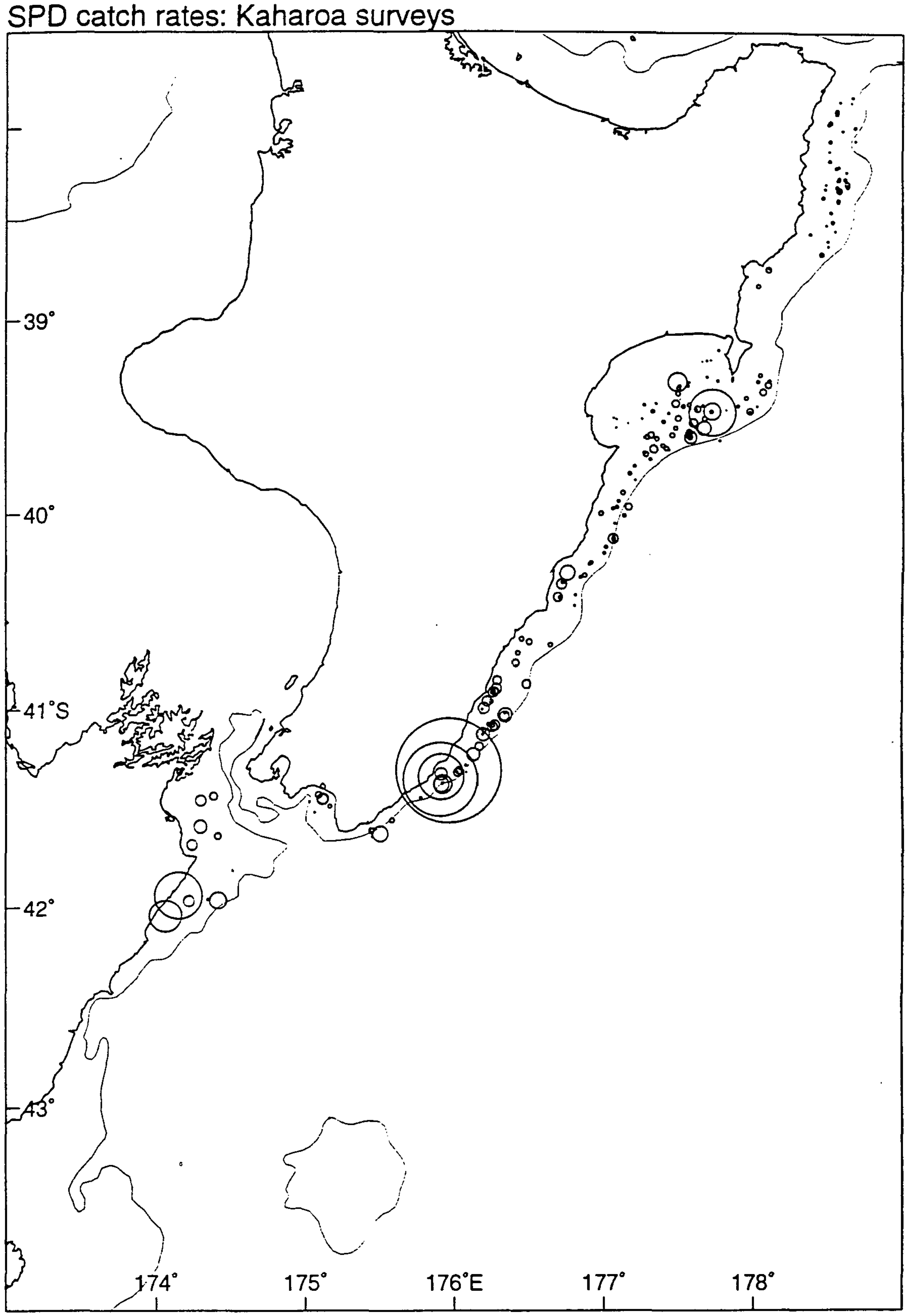

Figure 6: Catch rates (kg per tow) from all tows carried out during the east coast North Island *Kaharoa* trawl survey series, 1993–96. Note since 1994 the survey has only covered the east coast North Island. Maximum circle size 12 t per tow.

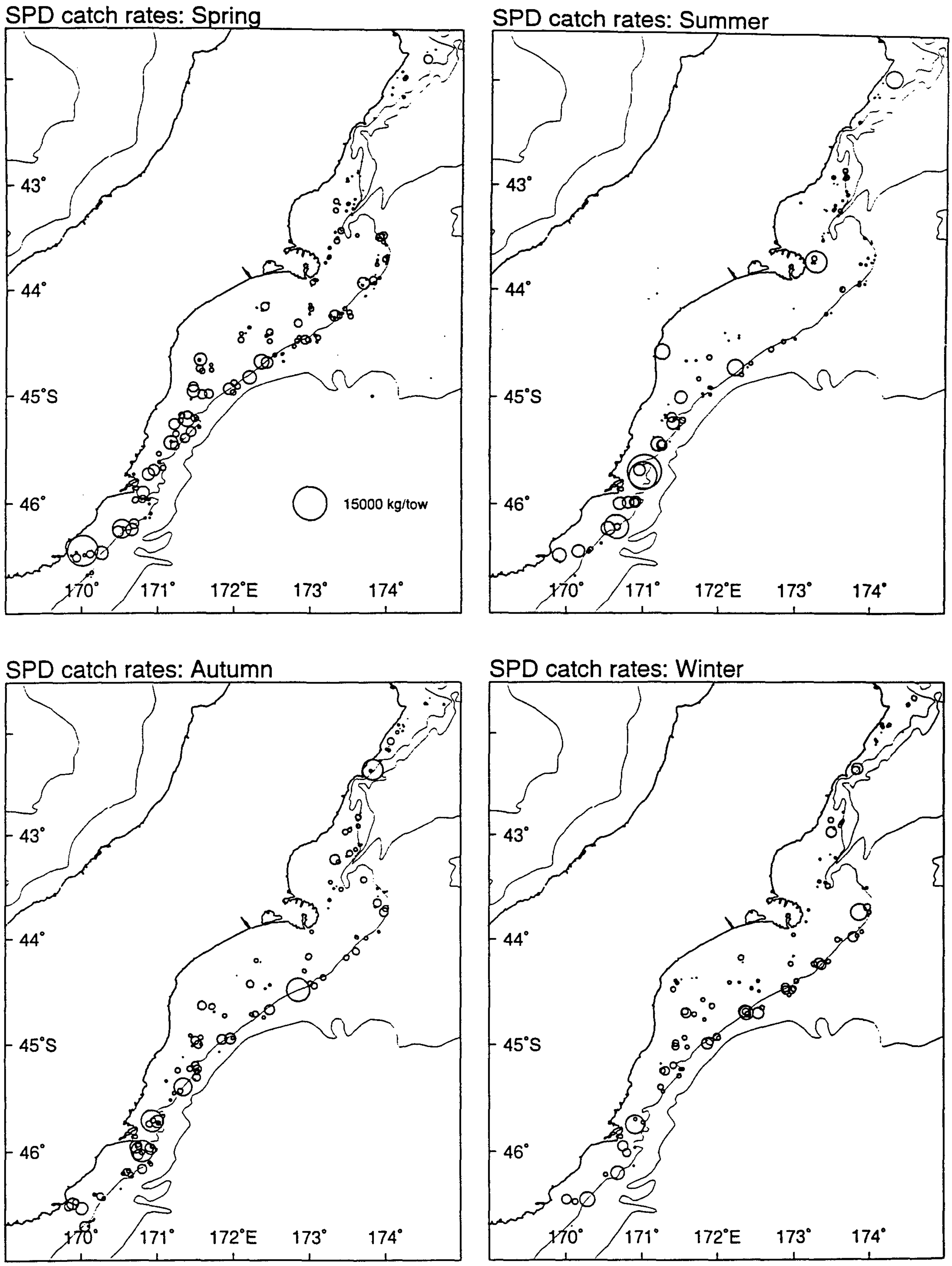

Figure 7: Seasonal catch rates (kg per tow) from all tows carried out during the east coast South Island *W.J.Scott* seasonal trawl surveys in 1979. Maximum circle size 15 t per tow.

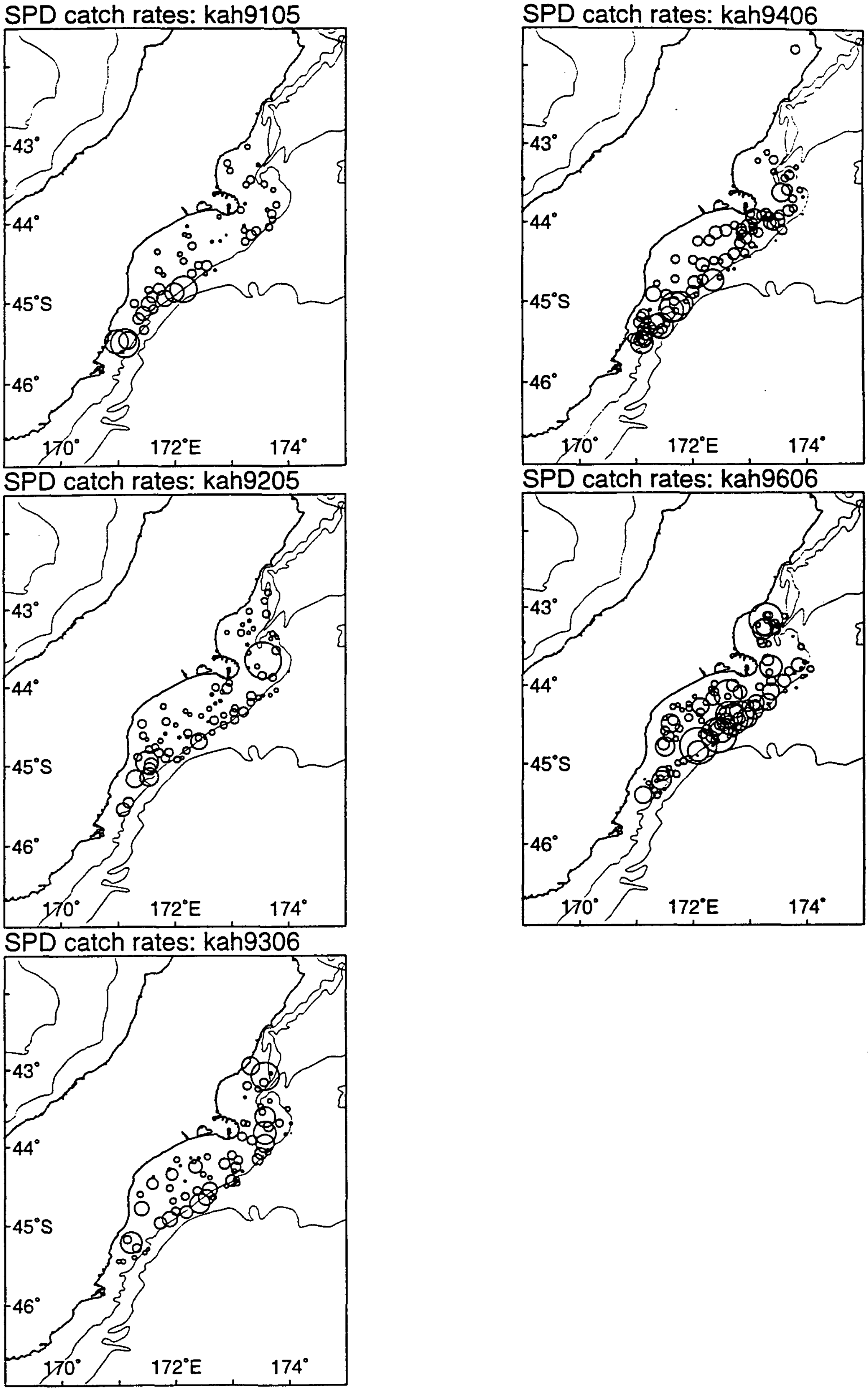

Figure 8: Catch rates (kg per tow) from each of the east coast South Island Kaharoa trawl survey series, 1991-1996. Maximum circle size 6.4 t per tow.

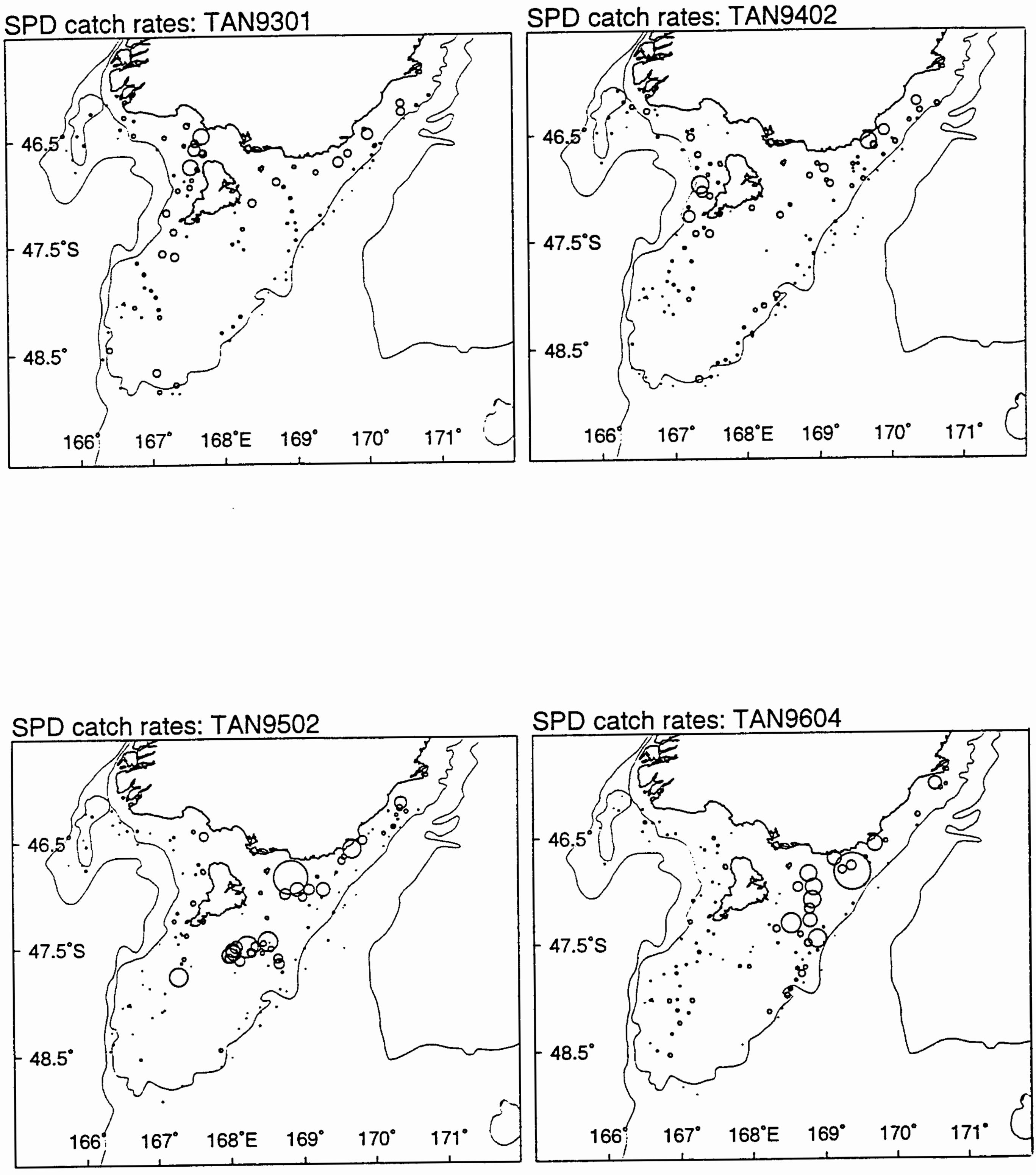

Figure 9: Catch rates (kg per tow) from each of the Stewart–Snares shelf *Tangaroa* trawl survey series, 1993-1996. Maximum circle size 30 t per tow.

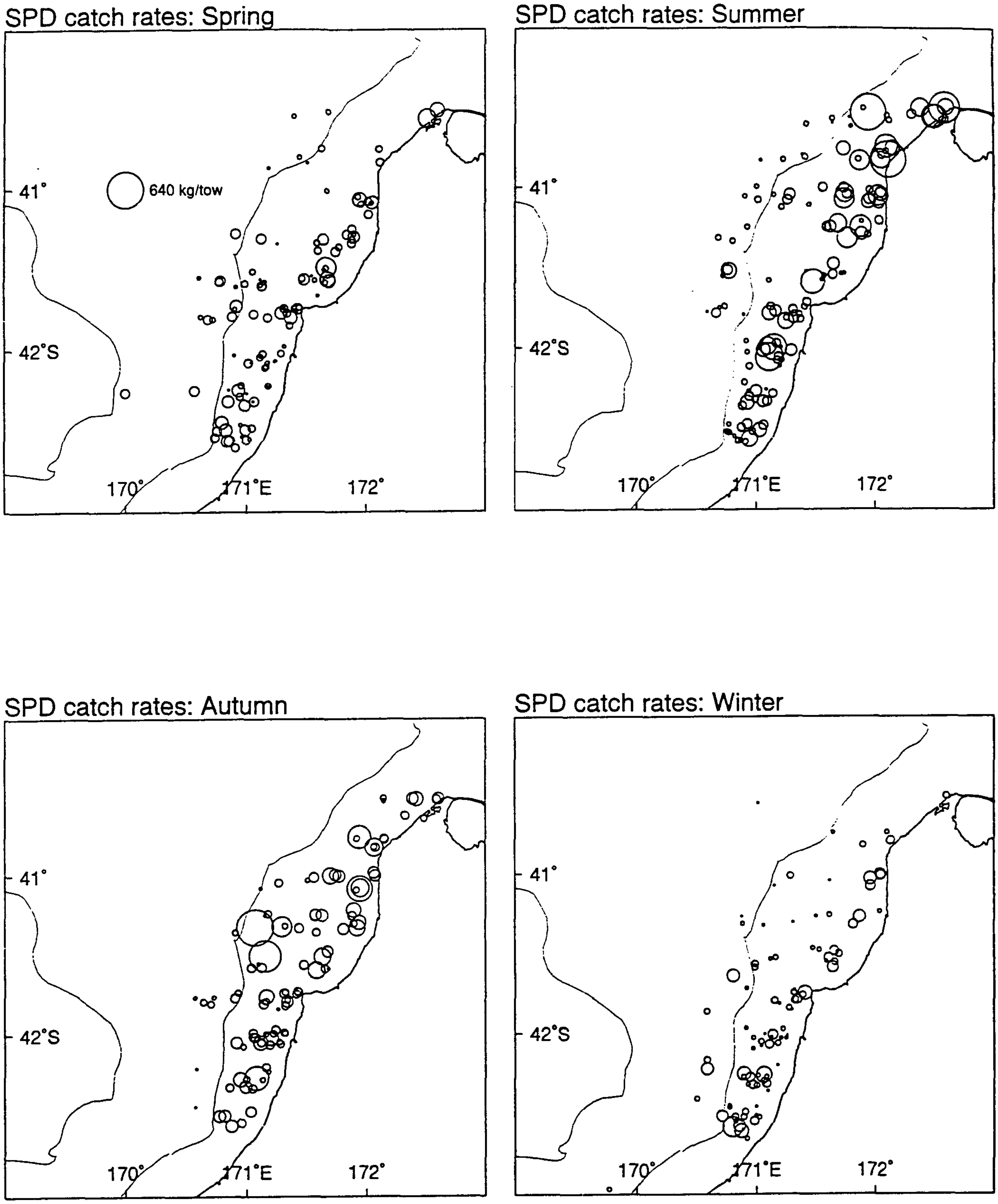

Figure 10: Seasonal catch rates (kg per tow) from all tows carried out during the west coast South Island *W.J. Scott* seasonal trawl surveys between 1979 and 1981. Maximum circle size 0.64 t per tow.

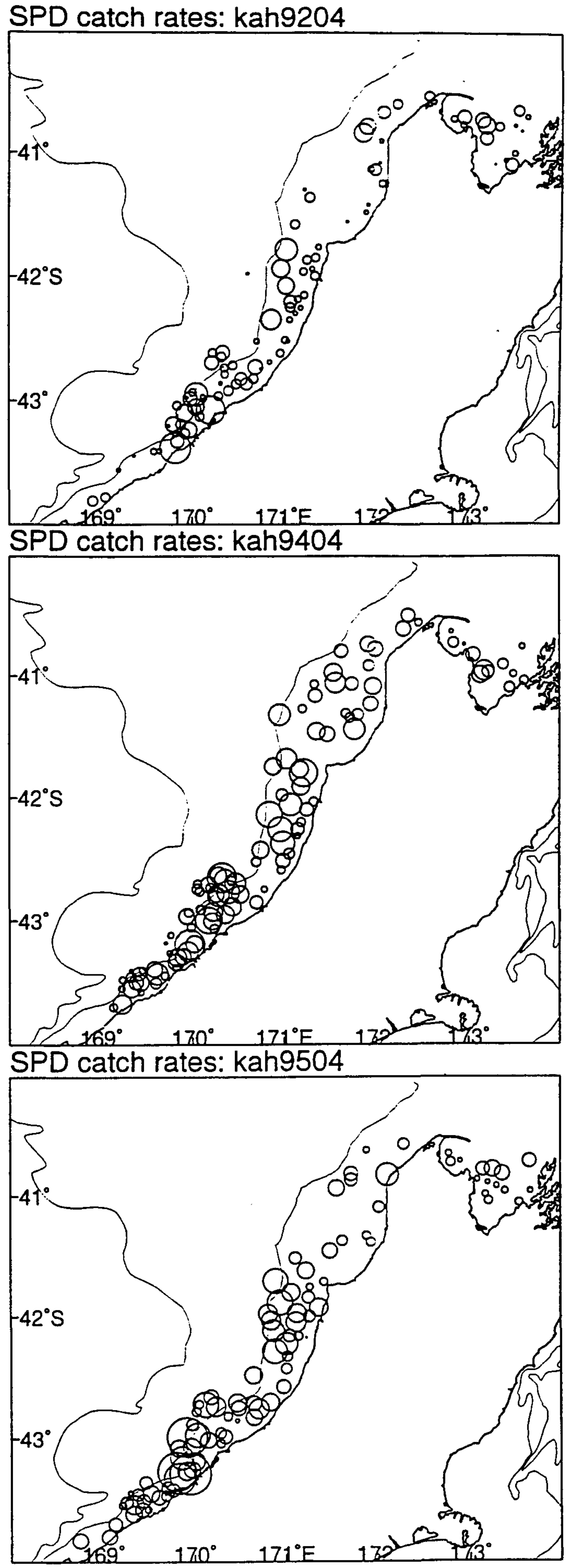

Figure 11: Catch rates (kg per tow) from each of the west coast South Island Kaharoa trawl survey series, 1992-1995. Maximum circle size 1.2 t per tow.

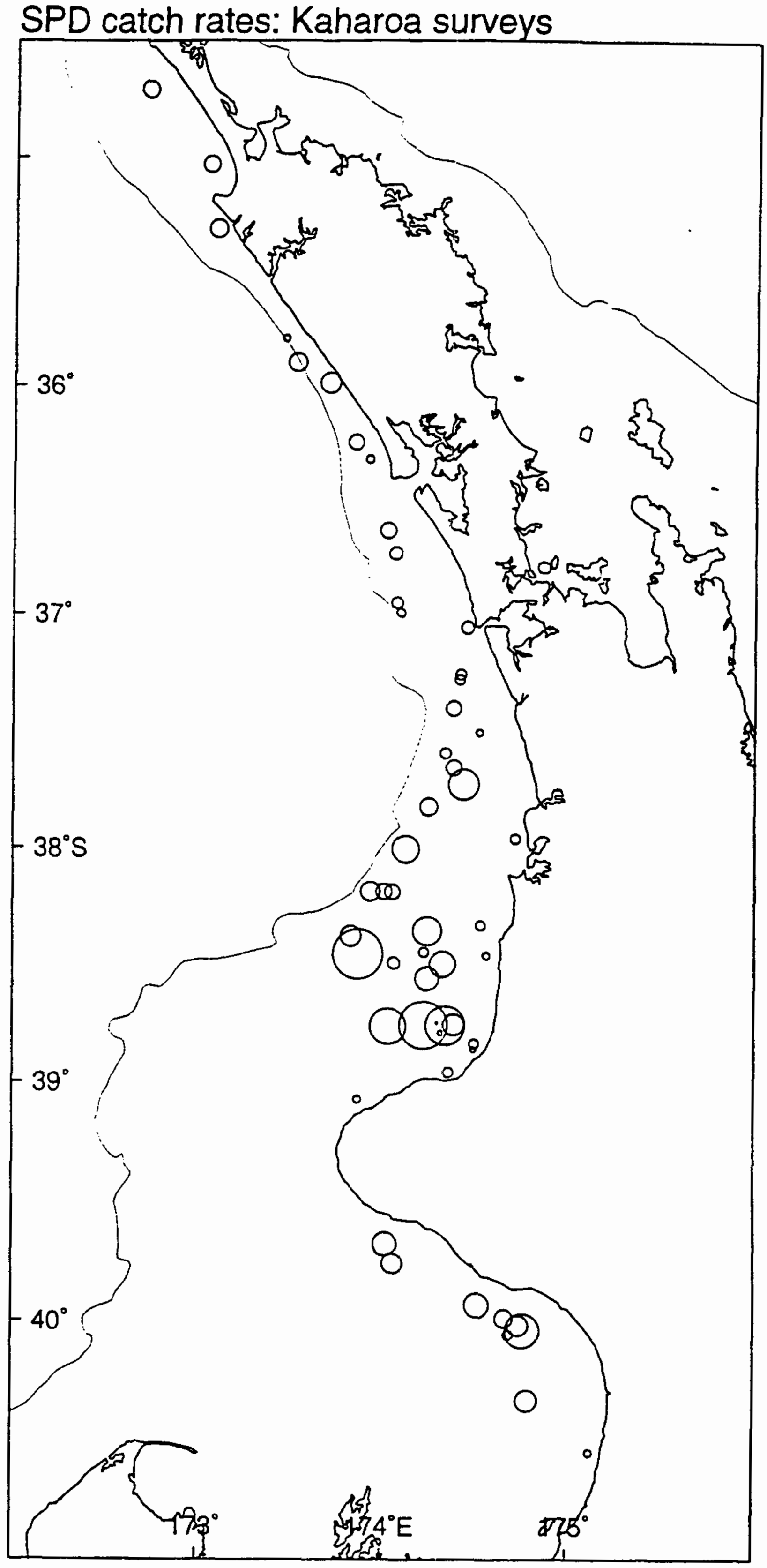

Figure 12: Catch rates (kg per tow) from all tows carried out during the west coast North Island *Kaharoa* trawl survey series, 1991 and 1994. Maximum circle size 0.1 t per tow.

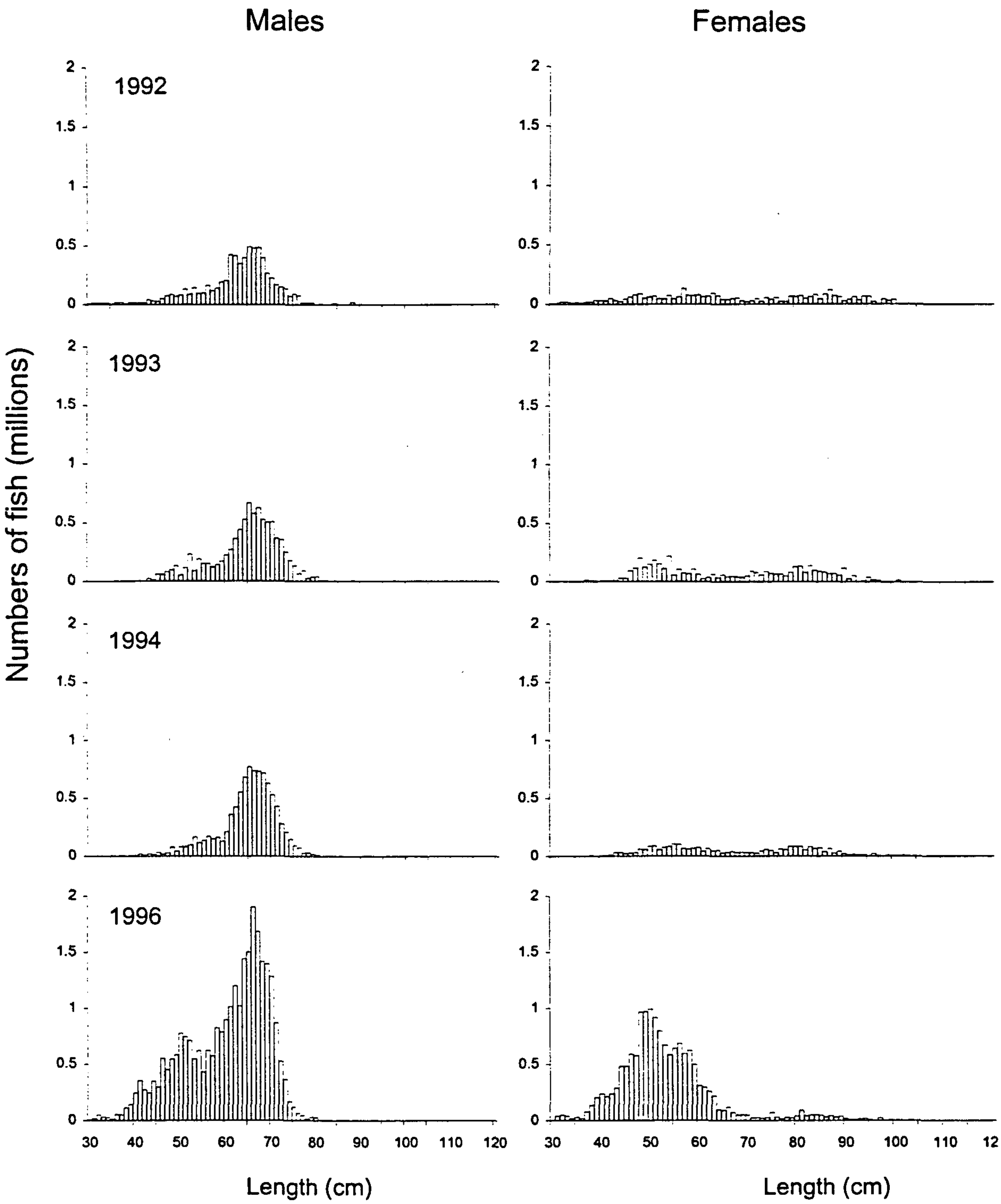

Figure 13: Weighted length frequency distributions of spiny dogfish for the east coast of the South Island from trawl surveys carried out using *Kaharoa* from 1992 to 1996.

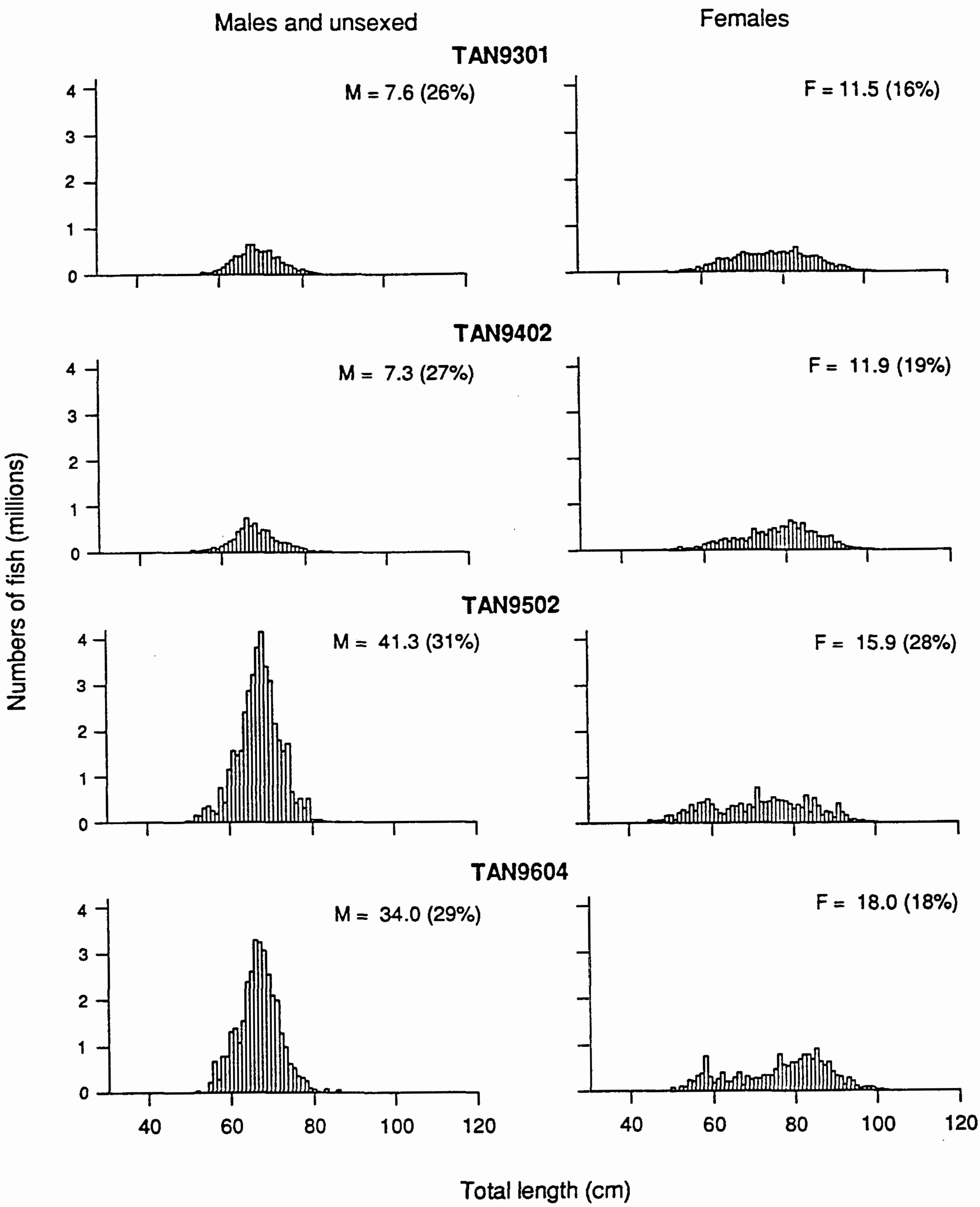

Figure 14: Weighted length frequency distributions of spiny dogfish for the Stewart-Snares Shelf from trawl surveys carried out using *Tangaroa* from 1993 to 1996.