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A summary of commercial landings and a validated ageing method for blue warehou, *Seriolella brama* (Centrolophidae), in New Zealand waters, and a stock assessment of the Southern (WAR 3) Fishstock

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1. EXECUTIVE SUMMARY

Reported catches of blue warehou (*Seriolella brama*) have fluctuated considerably since the late 1970's and the Total Allowable Commercial Catch (TACC) has never been exceeded. Catches peaked at 4 387 t in 1983–84 and since then annual landings have fluctuated between about 1 500 and 3 900 t. Blue warehou is both targeted and taken as bycatch, particularly by deepwater vessels fishing for arrow squid (*Nototodarus* spp.), barracouta (*Thyrsites atun*), and to a lesser extent, hoki (*Macruronus novaezelandiae*) and jack mackerel (*Trachurus* spp.).

Catch from vessels filing out inshore reporting forms accounted for 31% of the total catch in 1994–95. Setnet and bottom trawls take nearly all of the inshore catch. The pattern of commercial landings indicate that there is a coastal migration of blue warehou (Annala and Sullivan 1997). Until the mid 1980s, the bulk of landings came from the domestic gill-net fishery which targeted these migrations.

The Southland shelf (Fishstock WAR 3) accounts for most of the New Zealand warehou catch. This is almost exclusively taken by vessels chartered to New Zealand companies. A TACC reduction for WAR 3, from 3 357 to 2 528 t, was approved for the 1990–91 fishing year and in 1991–92 the blue warehou catch (2 514 t) came close to reaching the reduced TACC.

Blue warehou were aged from counts of zones in sectioned otoliths, a technique which was validated by examining the state of otolith margins from fish sampled regularly throughout the year. Von Bertalanffy parameters are presented for blue warehou from the Southland shelf. The fish grow rapidly up to the time of first spawning (about 4–5 years), but growth is negligible after about 10 years. Females grow significantly faster than males. Blue warehou in the commercial catch usually have a fork length (FL) between 40 and 65 cm, but they have been recorded to 75 cm FL.

Blue warehou was one of the key species for the *Tangaroa* Southland trawl surveys conducted in February and March 1993 to 1996. The desired coefficients of variation (under 30%) were not achieved and actual values ranged from 33 to 40%. More importantly, the age structure of the fish caught varied considerably from year to year, with few year classes able to be followed. These factors result in the relative biomass estimates from these surveys being unreliable for monitoring the stock.

A model incorporating catch history, relative abundance indices, and estimates of growth parameters, was used to assess WAR 3 (south of Banks Peninsula). MIAEL estimates of virgin biomass, current biomass, and yield were calculated. Age data from the time series of *Tangaroa* trawl surveys were not incorporated in the model for reasons given above. The base case and sensitivity runs produced minimum and maximum biomass estimates of 14 000 and 51 100 t respectively. The MIAEL estimates of B_0 had zero or low information indices and were not used to

generate MCY or CAY estimates. The MCY range on the base case B_0 range was 1 105–2 256 t. Reliable biomass indices, age class estimates and better definition of stock structure are required to improve yield estimation.

2. INTRODUCTION

2.1 Overview

Blue warehou, also known as common warehou, belong to the family Centrolophidae (raftfishes), represented in New Zealand waters by six genera (McDowall 1982). Of these, four genera (*Tubbia, Schedophilus, Centrolophus* and *Icichthys*) are represented by species not occurring in commercial quantities. The genus *Hyperoglyphe* is represented solely by bluenose, *H. antarctica*, which is commercially important.

Four species make up the genus *Seriolella* (McDowall 1982). Of these, three species are of considerable commercial importance, blue warehou, silver warehou *(S. punctata)* and white warehou *(S. caerulea)*. The remaining species in this genus, *S. labyrinthica,* is taken infrequently in New Zealand.

Blue warehou are widespread in southern New Zealand coastal waters and occurs patchily along the west coast of the North Island and are uncommon or rare on the northeast coast (McDowall 1982). Young fish are often found in small schools in the shallow water of harbours and bays and adult fish are occasionally found in large, surface swimming schools (Ayling & Cox 1982). Migrations have been described as extensive and dependent on water temperature (Gavrilov 1979). Blue warehou are also found in southeastern Australian waters where annual catches of up to 3 000 t have been estimated (Smith 1994).

This document summarises the fishery data for New Zealand's blue warehou. The New Zealand 200 mile Exclusive Economic Zone (EEZ) and places mentioned in the text are given in Figure 1 and blue warehou Fishstocks and Quota Management Areas (QMAs) in Figure 2. The commercial catch data were from the Ministry of Agriculture and Fisheries annual reports and Ministry of Fisheries (MFish) Catch and Effort Database. A stock assessment is presented for the WAR 3 fishstock (south of Banks Peninsula) using the MIAEL estimation technique (Cordue 1993, 1996). Research data relevant to this assessment are also presented and include estimates of growth, natural mortality, maximum age, and recruitment variability. A method to validate and age blue warehou was established and ages of blue warehou from WAR 3 determined.

The estimated primary value (i.e., port price) of New Zealand's blue warehou fishery was about \$1.9 million in 1994 and \$1.7 million in 1995 (NZFIB 1996). In 1994 and 1995 it ranked about 30 in order of importance of all wetfish (excluding tunas) by value and weight.

2.2 Literature review

Key references on the identification of warehou in New Zealand waters are McDowall (1980, 1982). Gavrilov (1976, 1979) and Gavrilov & Markina (1970) gave the first detailed accounts of the biology and distribution of the three commercial warehou species in New Zealand waters. Graham (1956) detailed blue warehou observations and seasonality off Otago.

The first published ageing study of blue warehou was by Tsarev (1971) who counted the check rings on scales from over 3 700 fish, mostly from the east coast of the South Island and Tasman Bay, the fish ranged from 44 to 66 cm FL. He aged fish to 13 years, used back-calculation to derive length at age, and concluded that they grew rapidly for about the first eight years with a growth increment of about 4.7 cm. Gavrilov (1976, reviewed in his 1979 paper) also aged blue warehou mainly by scales, but did use otoliths in an undefined way. He found a rapid growth rate and reported a maximum age of 11 years (although his tables suggest he found some older fish but did not include them in the analyses). Neither author had access to small fish nor reported any attempts to validate their ageing. Jones (1986, unpublished report) examined check rings in whole otoliths and reported a maximum age of 17 years. He calculated length-at-age values similar to those of Tsarev (1971) for ages 5 to 12, but higher values at younger ages. Jones (1994, unpublished results) aged blue warehou and estimated von Bertalanffy parameters from reading whole otoliths.

Graham (1956) provided some direct growth observations of blue warehou under aquarium conditions which support the suggestion of a relatively fast juvenile growth rate. A 3" (7.6 cm) fish grew 1" (2.5 cm) per month, and one specimen grew from 3" to 8" (20.3 cm) in 4 months.

Draft background papers for the fisheries management plans for Central and Challenger Fisheries Management Areas (FMAs) described the fishery and landings in each area to 1983 (Central Fisheries Management Planning Team (1984) and Challenger Plan Development Team (1984)).

Stock assessment information is given in the annual background documents and plenary reports 1985 to 1997, the latest of which is Annala & Sullivan (1997). Hurst (1985) provided the initial yield estimates for blue warehou. Hurst & Jones (1988) and Jones (1988) provided a background to the initial stock assessment, including CPUE analysis of the domestic setnet fishery and target trawl fishery in EEZ area F (*see* Figure 1). There have been few data to update analysis since 1988, but some of the earlier yield estimates were revised in 1996 after a revision of the methodology (Annala & Sullivan, 1996).

Biomass and biological data have been collected from trawl surveys on the continental shelf off central and southern New Zealand. Fenaughty & O'Sullivan (1978) gave catch, distribution, and length data from the Southland area from surveys conducted between 1974 and 1977. Trawl survey reports from *Shinkai Maru* in waters south of New Zealand in February 1981 (Kawahara & Tokusa 1981), March-April 1982, (Van den Broek *et al.* 1984), April 1983 (Uozumi *et al.* 1987) and October-November 1983 (Hatanaka *et al*, 1989) gave biomass and catches of blue warehou. Distribution and length data were given for the two surveys in 1983. Trawl surveys and biomass estimates from around New Zealand (1980 to 1984) were summarised by Hurst & Fenaughty (1985).

Trawl surveys which included blue warehou as a key species were conducted on the Southland shelf by the *Shinkai Maru* in June 1986 (Hurst *et al.* 1990), *Akebono Maru No 3* in November 1986 (Hurst & Bagley 1997a) and *Tangaroa* in February and March from 1993 to 1996 (Hurst & Bagley 1994, Bagley & Hurst 1995, 1996a, 1996b). Results from and comparisons of the four *Tangaroa* surveys and the 1981–1986 *Shinkai Maru* surveys were sumarised by Hurst & Bagley (1997a and 1997b).

There are trawl surveys from inshore and deepwater in most parts of the EEZ which contain various amounts of information on distribution and abundance of blue warehou. They are not detailed here as they are not relevant to the stock assessment of WAR 3.

3. COMMERCIAL FISHERY

3.1 Data sources

For this report, inshore vessels are those vessels filing inshore fishing returns (Fisheries Statistics Unit, FSU) inshore or Quota Management System (QMS) Catch, Effort and Landing Returns, (CELR) forms. Deepwater vessels are the larger New Zealand owned, New Zealand chartered, and foreign licensed vessels filling out FSU deepwater logbooks or QMS Trawl, Catch, Effort and Processing Returns (TCEPR) forms. Historical domestic catch and recent catch and catch limits by QMA are from Annala & Sullivan (1997).

The catch data for blue warehou come from a variety of sources. Before to the introduction of the EEZ on 1 April 1978, the warehou catch was not reported by species the catch by species had to be estimated. Catch data for the three warehou species combined for 1970 to 1977 were from Sato & Sato (1977), Paul & Robertson (1979) and, Paul (1980).

Annual catches from 1978–79 to 1987–88 were from the (FSU) database and summaries. Individual tow (deepwater vessels) or catch by day (inshore vessels) data were also available from the FSU database from 1983–84 to 1987–88.

Catch data for 1988–89 to 1994–95 were from the MFish Catch and Effort Database TCEPR forms which record catches of the top five species (by weight) taken by tow from deepwater vessels and which record the top six species by tow or day for inshore vessels.

There may have been some misreporting of blue warehou as white or silver warehou. The species code WAR may have also been used generically to record any one of the three commercial species of warehou. Reported catches from both the QMS and FSU data in water over 400 m deep on the east coast of the South Island and waters south of New Zealand are likely to be either white or silver warehou. The extent of the mis reporting is unknown. No attempt has been made to error check the data provided by MFish.

3.2 Annual landings

3.2.1 Inshore

Annual landings of blue warehou from inshore vessels from 1936 to 1983 are given in Table 1. Wellington was the major port of landing for blue warehou until the mid 1960s (Jones 1988). With the importation of larger trawlers from 1967, Nelson became the most important port of landing from 1967 to 1982 with 613 t landed in 1978. Large quantities of blue warehou landed into Nelson were taken from, off Tasman Bay, and east and west coasts of the South Island (author's unpublished data). Landings averaged over 100 t for the years 1974 to 1985 in Wellington, Port Chalmers, and Greymouth.

The catch of blue warehou reported on inshore returns (CELR) ranged from 23 to 37% of the total blue warehou catch for the years 1989–90 to 1994–95. Principal fishing methods used were bottom trawl, 68% of the inshore catch and setnet 31% (Table 2). About 72% of the setnet catch was taken when blue warehou is targeted, and 40% was reported targeted by trawl. Small amounts are reported as taken by purse seining and midwater trawling.

Areas where bottom trawl takes most of the inshore blue warehou catch are the west coast South Island, Tasman Bay, Canterbury, and Wellington. Setnet catches most of the fish off New Plymouth and off the east coast of the North Island south of Hawke Bay. Both methods account for about the same quantities of the catch off Kaikoura (Table 3).

3.2.2 Deepwater

Before the establishment of the EEZ, blue warehou landings were combined with silver and white warehou and recorded as 'warehous'. Estimates of blue warehou landings for the years 1970–77 are given in Table 4. The percentage of the Japanese catch estimated to be blue warehou for the following years were: 1970–74 (20%), 1975–76 (16%) and 1977 (17%). The Soviet catch was estimated for 1972–77 (10%) and for 1970–71 the Japanese figures were used to provide an estimate of catch. Korean catches were estimated for 1977 as 20%.

Before and after the introduction of the EEZ various controls were introduced restricting some fishing areas for the larger New Zealand, chartered, and foreign licensed vessels. These included the extension of the 12 mile limit to 20 and 25 miles in some areas, the closure of most of Canterbury Bight from 1 October 1977, and a temporary closure of the Solander Corridor from the 1 October 1977 to 1 January 1978. Catch quotas for individual species and combined species limits by EEZ area were imposed on the foreign licensed fleet from 1 April 1978. Foreign licensed vessels were excluded from EEZ areas G and C from 1 April 1979 and from area B on 1 April 1980. The doubling of the common warehou catch from 1982–83 to 1983–84 may have been partly caused by the introduction of the Deepwater Policy on 1 April 1983 which resulted in more effort on unallocated species such as blue warehou (Hurst 1985). The closure of the Solander Corridor on 1 October 1985 restricted larger vessels from fishing in a blue warehou target area. By the late 1980s foreign licensed vessels trawling in New Zealand were gradually replaced by New Zealand owned and chartered vessels.

From 1978–79 to 1987–88 catches of blue warehou by New Zealand chartered vessels fluctuated from 253 t in 1979–80 to 2 594 t in 1983–84 (Table 6). Most of the chartered vessels catch (71% in 1987–88 to 99% in 1981–82) were reported from southern New Zealand in EEZ areas FE and FW and to a lesser extent in area EA (Table 7). Catches for the fishing year of up to 382 t were taken from the west coast of the South Island (EEZ area G). Only small quantities were reported from other areas. Most of the catch taken in the southern area before to 1 October 1985 was from the Solander Corridor (in area FW). A subsequent decline in catches from FW and corresponding increase in reported landings from area FE occurred from 1985–86 as a result of the closure.

Foreign licensed vessels recorded catches of up to 760 t in 1982–83 (*see* Table 6). These vessels were restricted by various regulations limiting access to areas, and almost all of the blue warehou taken was reported from southern New Zealand in EEZ areas FW, FE, and EA.

The introduction of Individual Transferable Quotas (ITQ's) under the QMS on 1 October 1986 included six blue warehou Fishstocks (*see* Figure 2). Reported catch and TAC for each fishstock are given in Table 5. Deepwater vessels (filing TCEPR returns) from 1988–89 to 1994–95 accounted for about 70 % of the blue warehou catch. It is both targeted (Figure 3) and taken as bycatch of target trawl fisheries on arrow squid, barracouta, jack mackerel and hoki (Figures 4a–4d). Target fishing of blue warehou is reported from the Southland shelf, north and south of Banks Peninsula, the west coast of the South Island, off Tasman Bay, Wellington and east coast of the North Island (*see* Figure 3). The number of target tows and corresponding catch reporting blue warehou as the target species varied considerably from year to year (Figure 5). The percentage of the reported catch from target fishing by deepwater vessels on blue warehou, barracouta, hoki, and squid is given in Figure 6. Small amounts of blue warehou were also recorded from ling (*Genypterus blacodes*), red cod (*Pseudophycis bachus*), gemfish (*Rexea solandri*), silver warehou, spiny dogfish (*Squalus acanthias*), stargazer (*Kathetostoma giganteum*), and tarakihi (*Nemadactylus macropterus*) target fisheries.

Positions of blue warehou target tows by month from 1983–84 to 1994–95 are given in Figure 7. The main areas and months where target fishing was reported are Hawke Bay from May to July, Tasman Bay October to February, north of Banks Peninsula from November to March, the west coast of the South Island in August and September, and Southland September to March. For information on how these relate to known spawning areas, *see* section 4.4.

About 3% of the deepwater blue warehou target catch came from midwater trawling and 97% was taken by bottom trawl. Blue warehou catch was reported from bottom depths between 20 and 600 m for bottom trawls and 70 to 800 m from midwater trawls, with 95% taken from depths less than 300 m. Reported average depth where blue warehou were taken when targeted was 96 m.
Average depths of blue warehou bycatch from target fishing was 121 m for barracouta, 163 m for squid and 168 m for jack mackerel. Higher catchrates occur in the morning (0400–1000 hrs) for bottom trawls (Figure 8). Bycatch of blue warehou from target hoki was reported from an average bottom depth of 412 m for bottom trawl and an average net depth of 411 m for midwater trawl. These catches were primarily from the west coast of the South Island winter fishery. Scientific Observer Programme (SOP) data confirmed that blue warehou were taken from an average depth of 413 m from this fishery.

3.2.3 The southern deepwater fishery (WAR 3)

The catch of blue warehou in (Fishstock) WAR 3 accounted for between 45 and 72% of the total New Zealand blue warehou catch each year from 1988–89 to 1994–95. Most is reported by deepwater vessels fishing in QMA 5 on the Southland shelf from squid and barracouta target fishing (Figure 9). Target fishing for blue warehou is highly variable in this area and ranges from 4 to 611 t for the fishing years 1988–89 to 1994–95 (*see* Figure 5).

Squid fishing accounted for 53.2% of the blue warehou catch on the Southland shelf for 1988–89 to 1994–95 and vessels targeting barracouta fishing took 24%. Target fishing directed on blue warehou took 15.7 %, with a number of other target species accounting for small amounts (Table 8).

The southern New Zealand squid fishery runs from summer to autumn on the Southland shelf and Auckland Islands shelf with catches varying between these two areas. Analysis of the squid to blue warehou relationship was looked at in more detail to see if it explained why blue warehou catches fluctuate so widely year to year in the southern area and sometimes approach the TACC. The proportion of the southern squid catch by fishing year reported from the Southland shelf ranges from 30% to 94%. In 1990–91 the total blue warehou catch increased substantially in WAR 3 and remained at high levels (in excess of 2 000 t) for three years. Blue warehou bycatch taken during January to June as a percentage of the squid catch from the Southland shelf for the same months is given in Table 9. Although the ratios vary considerably, the highest catches of blue warehou bycatch were recorded in 1985–86 and 1990–91 to 1992–93, when squid catches on the Southland shelf exceeded 15 000 t.

3.3 Non commercial fisheries

The 1987 National Marine Recreational Fisheries Survey and the 1991–92 Marine Recreational Fishing Catch and Effort Survey (South region) showed that blue warehou are not commonly caught by recreational fishers. A survey in the Ministry of Fisheries Central Region in 1992–93 estimated that 10 t was caught in WAR 2 (*c.v.* 59%.). A Northern Region survey in 1993–94 indicated that blue warehou were not caught in substantial quantities (Annala & Sullivan 1997). There is no quantitative information on the past or current level of Maori customary take.

3.4 Illegal catch

The species code WAR may have been used generically to represent other warehou species and the extent of this is unknown.

4. RESEARCH DATA FOR THE ASSESSMENT OF WAR 3

4.1 Data sources and (biological) model input parameters

This section summarises biomass and biological data from research surveys and the Scientific Observer Programme (SOP) required for the stock assessment of WAR 3.

Data, required for modelling WAR 3, were extracted from the MFish trawl survey and SOP databases. Otoliths collected from a number of research voyages and areas since 1970 were used for age validation. Biomass, length frequencies, age frequencies, length-weight, and a maturity ogive were derived from data collected on all four of the *Tangaroa* Southland time series 1993 to 1996.

4.2 Biomass estimates and size frequencies

Two times series of relative abundance indices were incorporated into the model: January-March (1981), March-May (1982), April (1983), and June (1986) *Shinkai Maru* trawl surveys, and February to March *Tangaroa* trawl surveys (1993–96) (Table 10). The coefficients of variation (c.v.s) applied in the model were 60% for the *Shinkai Maru* and 40% for the *Tangaroa* series. Biomass indices were calculated for adult fish above 50 cm, the size at which blue warehou are fully recruited to the fishery. This size was determined from length frequency data from the *Tangaroa* Southland time series 1993–1996 (Figure 10) and the SOP data (Figure 11).

4.3 Age and age validation

A validated ageing method using baked and sectioned otoliths from the closely related silver warehou gave a maximum age of 23 years (Horn & Sutton 1996). Gavrilov (1979) used scales to conclude a maximum age of "10 years or more" for the same species. Horn & Sutton (1996) concluded that reading whole otoliths of larger fish sometimes produced an under-estimate of age because the otolith growth zones produced when the fish is increasing only slightly in length resulted in a thicker, rather than wider, otolith, and so were not readily visible. The later growth zones on scales are also likely to be very narrow and lacking in clarity if they are related to an increment in fish length. Hence, it was concluded that an examination of sectioned otoliths was probably the best method to investigate the growth of blue warehou.

Otoliths (sagittae) of blue warehou have been collected sporadically from research and commercial landings since about 1970. Large samples of otoliths were also available from blue warehou caught during research surveys of the Southland shelf conducted annually in February–March 1993–1996. Fork length (FL, rounded to the nearest centimetre below actual length) and sex were recorded for all fish from which otoliths were taken.

4.3.1 Methods

Otoliths for a validation study would ideally be collected regularly over a 12-month period from fish known to come from a single stock. This was not possible for blue warehou because of the sporadic nature of the otolith collection. Hence, otolith samples were compiled for each month from archived material collected from 1970 to 1997 (Table 11). Wherever possible, otoliths were selected to obtain at least 35 per month from a wide range of ages, and from fish sampled in the postulated northern stock area (i.e., North Island and northern South Island waters). This was achieved in general, although the August and September samples were small and had to be combined, the November, February, and part of the March samples were from the southern stock area (Southland shelf), and no December samples were available from any area.

Otoliths were examined in cross-section following preparation by baking whole in an oven until amber coloured, embedding in clear epoxy resin (Araldite K142), and cutting along the dorso-ventral axis through the nucleus using a rotary diamond edged saw. The prepared cross-section was coated in paraffin oil, illuminated by reflected light with an incident angle of about 30°, and examined under a binocular microscope (x40). A pattern of dark brown (translucent) and light brown (opaque) zones was apparent. Subsequently in this paper, 'zone' refers to the paired structure of one opaque band inside one translucent band. The number of complete zones (i.e., zones with at least some opaque material outside them) was counted. Fish length and sex were unknown to the one otolith reader.

To convert zone counts to estimates of age, it was necessary to validate the ageing method by determining when and how frequently the zones were laid down. To examine changes in otolith margin characteristics throughout the year, margins of otoliths from the validation samples in Table 11 were classified as either translucent or opaque, and the number of complete zones was counted. Less than 2% of otoliths examined had a marginal state too indistinct to classify confidently, and all of these were from fish older than 10 years. The month of collection was unknown to the otolith reader.

Von Bertalanffy growth curves were fitted to the age-length data of blue warehou from the Southland shelf using a non-linear least-squares regression procedure (Ralston & Jennrich 1978). Separate equations were derived for each sex.

4.3.2 Results

Otolith interpretation

Estimating the age of blue warehou less than about 8 years was straightforward because of the relative clarity of the zones. Split zones (true annual zones that comprised of two translucent and two opaque bands) were sometimes apparent, but they were identified because of the regularly decreasing distances between true annual zones with increasing age. Some otoliths had a clear double banding pattern (commonly adjacent to the sulcus) in older zones, but again the true interpretation was clear because of the regular overall zonation pattern.

It was generally possible to determine whether an otolith margin was translucent or opaque (particularly for fish up to 4 years old), although some interpretations for older fish were difficult because of the narrowness of the margin. Percentages of otoliths with translucent margins, for each sample separated into three groups of age classes (0–4, 5–9, ≥ 10+), are shown in Figure 12. Translucent material is initially laid down about April–May, most otoliths have a translucent margin in winter, and most fish are laying down opaque material by November. There is an indication that marginal changes occur about a month earlier in younger fish. These data support the hypothesis that one opaque and one translucent band (i.e., one complete zone) are laid down annually in the otoliths.

Blue warehou spawn off Southland in November (Hurst 1985), so a 'birthday' of 1 December was chosen. As the translucent part of a zone appears to be complete by late spring (October–November), fish are about 1 year old on completion of the first translucent band. Hence, the number of complete zones, plus a correction for the time elapsed between 1 December and the date of the sample, was taken as the age of the fish.

Growth parameters

Von Bertalanffy growth curve parameters calculated from the otolith readings of fish from the Southland shelf are given in Table 12. Time of sampling, and hence, part-year growth, is incorporated in this analysis. These samples provide data from virtually the full life span of the species, i.e., 2 to 22 years.

The calculated curves and raw data (corrected for part-year growth) are plotted in Figure 13. The calculated curves fit the observed data well. Female blue warehou grow significantly faster and reach a larger size than males (Table 12). Male blue warehou had a maximum age of 22 years, and females were aged to 21 years. There does not appear to be any difference in longevity between sexes; in the combined Southland samples, proportions of fish aged 16 years or more were 92 and 91% for males and females respectively. The minimum age reached by the oldest 1% of the sampled fish was 19 years for both sexes.

4.3.3 Discussion

Baked, sectioned otoliths of blue warehou exhibit a pattern of zones each comprising one opaque and one translucent band, and the fish were aged from counts of the number of complete zones. Validation of this ageing method was achieved by showing that, for various age groups of fish and for all fish combined, one translucent band was formed annually. It was not possible to validate the method for every year class individually because of inadequate sample sizes. It was also unfortunate that samples from various different years had to be combined to complete this study as different climatic conditions between years could influence the time of formation of the otolith growth zones. The samples could also come from fish from two different biological stocks if the current stock hypothesis is correct. Thus, it is pleasing that, despite these possible complications, the annual cycle of change at the otolith margin is clear (particularly for the relatively wide zones of young fish) and consistent over all age classes.

Like many teleosts, female blue warehou are larger than males at corresponding ages after sexual maturity, and they have a significantly larger L_∞ value (*see* Table 12). Fish of both sexes have a relatively fast growth rate up to the time of first spawning (4–5 years). Growth then slows and is negligible after about 10 years. Similar growth characteristics have been shown for silver warehou (Horn & Sutton 1996).

Previous studies of blue warehou also indicated that the species was relatively fast growing, but put the maximum age as about 13 years (Tsarev 1971, Gavrilov 1976, and Jones 1986). The current study showed many fish aged older than 13 years, up to a maximum of 22 years. Differences in ageing methods between studies are the most likely cause of the different estimates of maximum age. The very narrow zones visible near the margin of sectioned otoliths from large, old fish are likely to be very difficult to distinguish on the scales examined by Tsarev (1971) and Gavrilov (1976). Jones (1994, unpublished data) examined whole otoliths and reported a maximum age of 17 years. Again, he is likely to have missed seeing all the zones on old otoliths because when a fish stops growing significantly in length its otolith tends to get thicker rather than wider. The problem of underestimating true age when counting zones on whole otoliths was demonstrated for silver warehou by Horn & Sutton (1996).

The numbers at age for female and male blue warehou taken from the Southland *Tangaroa* surveys from 1993 to 1996 are given in Figure 14. There were no clear patterns of strong or weak year classes from the data suggesting the trawl surveys did not sample the population well. This may be due to the fish not being sampled well by bottom trawl or the fish not always being within the survey area.

The sampled fish from the Southland shelf cover a wide range of ages (2–22 years) and so the fitted von Bertalanffy parameters are considered to be good descriptors of growth for this population. The minimum age reached by the oldest 1% of the population (19 years) implies an estimate of instantaneous natural mortality (*M*) of about 0.24. However, these samples are not from virgin populations, so *M* may be not well estimated.

4.4 Stock assumptions for WAR 3

Blue warehou have been treated as one stock for stock assessment purposes as no definite stock boundaries are known (Annala & Sullivan, 1997). Hurst (1985) suggested there were probably at least two stocks, a central and a southern stock, based on spawning grounds. Known spawning grounds include the west coast of the South Island in August to September (authors' unpublished data), Kaikoura in March, April, and May (Fenaughty & Bagley 1981), Southland in November (Hurst & Bagley 1997a) and Hawke Bay in August (authors' unpublished data).

Seasonal landings (*see* Figure 7, section 3.2.2) and known spawning locations suggest four possible stocks.

i). A southern population, mainly off Southland but perhaps extending into the Canterbury Bight. The main spawning time is November in inshore waters east and west of Stewart Island.

ii). A central eastern population, located on the northeast coast of the South Island and Southeast coast of the North Island (including Wellington), spawning mainly in the northern area in winter-early spring and also in autumn off Kaikoura.

iii). A south-western population which spawns on the west coast of the South Island in winter.

iv). A north-western population which may spawn off New Plymouth in winter-spring.

The stock structure is very tentative and there may be overlap between them. The age and length frequency data are insufficient to compare by area and tagging studies have been minimal (about 150 fish tagged) with no returns.

For modelling WAR 3, the area on the east coast of the South Island south of Banks Peninsula including Southland was assumed to be a separate stock. Movement between the west coast of the South Island and Southland is possible but there was no evidence for this from seasonal trawl surveys and the existence of two spawning periods in August to September off the west coast of the South Island and November to December in Southland (Hurst *et al.* 1990, Hurst & Bagley 1997a).

5. STOCK ASSESSMENT OF WAR 3

The TAC levels for each fish stock were set originally at the 1983 catch levels except for southern areas (Fishstock WAR 3), where the highest biomass estimate from trawl surveys from 1981–83 was included. A TACC reduction for WAR 3, from 3357 to 2528 t, was approved for the 1990–91 fishing year based on declining catches and a re-interpretation of relevant trawl survey data from 1981 to 1986 (reported in Annala & Sullivan 1996).

There have been few data since 1988 to update yield estimates, but some of the earlier yield estimates were revised in 1996 after a revision of methodology. This revision made Maximum Constant Yield (MCY) estimates based on trawl survey results obsolete (Annala & Sullivan 1997). All yield estimates now rely on commercial landings data (Annala & Sullivan 1996).

This section reports a new stock reduction analysis for the southern blue warehou stock, which contains most of WAR 3. Estimates of virgin biomass B_0, biomass in mid-1997 as a percentage of virgin biomass(B_{mid97}), biomass at the start of 1998 (B_{beg98}), MCY, and Maximum Annual Yield (MAY) are presented using the MIAEL estimation technique of Cordue (1993). The bounds on virgin biomass used by the MIAEL technique were derived using the model based approach of Cordue (1996).

5.1 Estimation of fishery parameters and abundance

The catch history used in the model for WAR 3 is given in Table 13. The method to estimate the catch of blue warehou from 'all warehous' recorded by deepwater vessels from 1970 to 1977 was given in section 3.2.2. Half the estimated blue warehou catch from 1970 to 1977 was used to represent the catch from WAR 3, and assumed the catch was taken in equal proportions from the west coast of New Zealand and the east coast of the South Island including Southland. For 1970 and 1971 Only Japanese data were available which was doubled to take in to account the Soviet catch of blue warehou, as the Soviet fleet was known to take blue warehou during this time (Gavrilov 1979). The catch for the Southland spawning period (October to December) was estimated to be 25% of the east coast and Southland catch, and 75% for non-spawning (January to September). Figures have been rounded up to the nearest 10 t.

For the years 1978–79 to 1983–83 (excluding the fishing year 1980–81) FSU estimated catch data for EEZ areas EA, FE, FW, C- and CM were used. Tow by tow data available from October 1983 were used for all subsequent years. No deepwater statistics are available for blue warehou for the fishing year 1980–81 and an average for the years 1979–80 and 1981–82 was used. TCEPR data determined catches in WAR 3 from 1988–89 to 1995–96. The catch from 1997 was assumed as equal to the 1996 catch.

Catch by port of landing was used to determine the inshore domestic catch in WAR 3, south of Banks Peninsula, from 1970 to 1983. Catch by statistical area 022 to 030 (south of Banks Peninsula) was used from 1983–84 to 1995–96.

Two time series of relative abundance indices were incorporated into the model (Hurst *et al.* 1990, *see* section 4.2). The c.v.s applied in the model were 60% for the *Shinkai Maru* and 40% for the *Tangaroa* series. Biomass indices were calculated for adult fish above 50 cm for both these time series *see* section 4.2, (*see* Table 10).

The model developed using the biological input parameters given in Table 14 was a two sex population model. Length weight data from the four *Tangaroa* Southland trawl surveys are given in Figure 15. Model input parameters used in base case assessments and parameters used in sensitivity tests are given in Tables 15 and 16.

M was estimated using the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Preliminary ageing work suggested 22 years for the maximum age from the four *Tangaroa* Southland trawl surveys, which indicated an *M* of about 0.21 (Note that the final estimate of M from the ageing work was 0.24, but this was not available at the time of the modelling). A sensitivity test using an *M* of 0.31 was carried out. The effect of fishing on age structure before the ageing work outlined above is unknown.

Steepness was set at 0.75, as recommended by Francis (1992) when there is no other information available. Recruitment variability of blue warehou is thought to be similar to hoki and therefore a value of 1.0 was used. A sensitivity test of 0.6 was carried out. The maximum exploitation rate (r_{max}), which is the maximum proportion of the beginning of season biomass that could have been caught by the fleet was set at 0.5, with a sensitivity test of 0.8. The minimum level of exploitation when the catch was the largest (r_{mmx}) was set at 0.05 with a sensitivity test of 0.10.

The proportion spawning was determined as 1.0, from spawning condition data collected on the November 1986 trawl survey in Southland (Hurst & Bagley 1997a). Initial estimates of the proportion of fish available to the deepwater fleet were 0.10 and 0.05, but these values were increased to allow for inshore vessel catch. The proportions available to the fleet used in the model were 0.25 for the spawning season from 1970 to 1985, and 0.20 from 1986, the closure of the Solander Corridor in 1985 accounted for the different value from 1986. A sensitivity test of 100% of the fish available was done, as the base case proportion was calculated from one survey.

The maturity ogive was based on commercial and Southland trawl survey length frequency data, which suggest fish of both sexes start to recruit to the fishery at age 2 (FL length about 30 cm) and are fully recruited at age 6 (average FL about 50 cm).

The age data from the *Tangaroa* Southland trawl surveys, 1993–1996 (*see* Figure 14) were not incorporated into the model as there were no clear patterns of strong or weak year classes from the data. This may be due significant variations in vertical and areal availability.

5.2 Biomass estimates

Estimates and ranges of mid-season virgin biomass (B_0), current biomass (B_{mid97}), and estimates of 1998 beginning of year biomass (B_{beg98}) were obtained for WAR 3 using the MIAEL method of estimating B_0 (Cordue 1993, 1996).

The MIAEL estimate of B_0 for the base case scenario was 32 400 t, and the MIAEL estimates of B_{beg98} was 27 300 t (Table 17). The MIAEL estimate of B_{mid97} was 66% of B_0 (range 54–82%) (Figure 16). The information index for these MIAEL estimates are all 0% indicating that they estimates are not well estimated within the range of positive values.

For the sensitivity runs, the MIAEL estimates of B_0 were generally lower for runs 2, 3, 4, and 6 (*see* Table 17, Figure 16), but in all runs the information indices were close to 0%. Sensitivity runs 3 and 4, with the proportion of fish available at 1.00, gave the lowest values of B_0 and B_{beg98}, and low information indices (4–11%). Recruitment variability (run 7) gave very similar results to the base case.

5.3 Estimation of Maximum Constant Yield (MCY)

The method used to estimate MCY was MCY = pB_0, where p is determined for each stock using the method of Francis (1992) such that the biomass does not go below 20% B_0 more than 10% of the time. B_0 is estimated by the MIAEL method of Cordue (1993).

MCY estimates are given in Table 18. Using the base case values for recruitment variability (1.0), growth rate, recruitment ogive, and steepness parameter, MCY was calculated as 5% of B_0. Sensitivity runs did not change this value (*see* Table 17), although B_{MCY} was lower for a lower rsd (recruitment variability) value (run 7). The range of estimates of MCY for the base case were 1105 to 2256 t.

5.4 Estimation of Maximum Annual Yield (MAY)

Under a CAY harvest strategy the mean mid-season biomass (B_{MAY}) was estimated to be 37% of B_0. B_{MAY} is defined as the average stock size maintained by a maximum constant harvest rate policy which is conditioned by the requirement that the stock be allowed to decrease below 0.2 B_0 only 10% of the time. Sensitivity runs did not change this value much (*see* Table 18), although B_{MAY} was much lower for a lower rsd value.

Current Annual Yield (CAY) was not estimated because the information indices on biomass estimates were close to 0.

5.5 Other factors

Mis-reporting of silver or white warehou as blue warehou may have occurred and might have inflated the catches. The use of one trawl survey in 1986 to determine the proportion available to the fleet during the spawning season may not be an accurate indicator of the proportion of fish inside and outside the 12 mile limit, including the Solander Corridor, in all years. The effect of this in the model is considerable and has increased the spawning biomass as a percentage of B_0 in the base case analysis.

The estimates of catch from 1970 to 1977 are derived from a number of assumptions and there is considerable uncertainty about these estimates. It is likely that blue warehou were taken by deepwater vessels before 1970 as Hurst (1988) recorded catches of barracouta from 1967. No data are available to enable an estimate of blue warehou catch before to 1970. For the fishing years 1983–84, 1984–85 and 1985–86 the totals from FSU catch summaries exceeded the figures given in the plenary reports for all of WAR 3. The reasons for this are not known.

6. STATUS OF THE WAR 3 STOCK (SOUTH OF BANKS PENINUSLA)

Problems with stock structure, estimation of year class strengths, and insufficient information make the assessment of WAR 3 (south of Banks Peninsula) very uncertain. The estimation of the catch history of blue warehou from all 'warehous' before 1978 and the likelihood of catches of blue warehou by the deepwater fleet before to 1970 cast some doubt on the accuracy of the early catch histories used in the model. The stock structure and stock relationships for blue warehou are not well understood and more work is required to better understand stock boundaries.

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Table 1: Reported inshore* landings (t) by New Zealand vessels of blue warehou from 1936 to 1983

Year	Landings	Year	Landings	Year	Landings
1936	80	1952	20	1968	370
1937	150	1953	40	1969	170
1938	90	1954	70	1970	370
1939	30	1955	40	1971	440
1940	50	1956	60	1972	430
1941	80	1957	125	1973	720
1942	70	1958	110	1974	840
1943	70	1959	140	1975	530
1944	50	1960	70	1976	990
1945	10	1961	70	1977	1 090
1946	20	1962	110	1978	1 680
1947	30	1963	110	1979	1 820
1948	20	1964	140	1980	1 870
1949	20	1965	80	1981	2 900
1950	50	1966	40	1982	2 300
1951	30	1967	330	1983	2 340

* see section 3.1 (data sources) for definition of inshore vessels.

Table 2: Catch by method (t) for fishing years (1 October– 30 September) 1983–84 to 1994–95 for all vessels

Fishing year	Bottom trawl	Setnet	Other	Total catch
1983–84	3 972	407	8	4 387
1984–85	1 845	319	1	2 165
1985–86	2 613	166	3	2 782
1986–87	2 283	90	1	2 347
1987–88	1 802	105	8	1 915
1988–89	1 378	51	37	1 466
1989–90	1 522	158	16	1 696
1990–91	3 027	195	10	3 232
1991–92	3 658	241	6	3 905
1992–93	2 977	236	2	3 215
1993–94	1 176	323	1	1 500
1994–95	1 834	220	20	2 074

Table 3: Estimated percentage of the blue warehou catch by bottom trawl and setnet for inshore vessels by area for the fishing years 1988–89 to 1994–95. Note small quantities are reported taken by other methods

Area	Bottom trawl (%)	Setnet (%)
Wairarapa	36	61
Wellington	86	14
Kaikoura	55	45
Canterbury	98	2
West coast South Island	96	1
Nelson	100	<0.1
New Plymouth	<0.1	100

Table 4: Estimated deepwater catch (t) of blue warehou by year 1970–77#

Year	1970	1971	1972	1973	1974	1975	1976	1977
Estimated catch	68	100	1094	1493	1208	1474	2869	3323

See Bagley and Hurst (1997a) for method used.

Table 5: Reported landings (t) of blue warehou by Fishstock from 1983–84 to 1995–96 and TACs (t) from 1986–87 to 1995–96

Fishstock	WAR 1		WAR 2		WAR 3		WAR 7	
QMA (s)	1 & 9		2		3, 4, 5 & 6		7	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*[1]	13	–	346	–	3 222	–	702	–
1984–85*	5	–	278	–	1 313	–	478	–
1985–86*	15	–	185	–	1 584	–	955	–
1986–87†	7	30	190	480	1 330	3 210	780	910
1987–88†	7	41	204	560	976	3 223	685	962
1988–89†	12	41	177	563	672	3 348	561	969
1989–90†	17	41	201	570	814	3 357	607	1 047
1990–91†	14	41	250	570	2 097	2 528	758	1 117
1991–92†	25	41	235	570	2 514	2 528	1 001	1 117
1992–93†	15	41	199	578	2 310	2 530	539	1 120
1993–94†	16	41	233	578	688	2 530	436	1 120
1994–95†	15	41	203	578	1 274	2 530	468	1 120
1995–96†	32	41	367	578	1 573	2 530	756	1 120

Fishstock	WAR 8		WAR 10			
QMA (s)	8		10		Total	
	Landings	TAC	Landings	TAC	Landings‡	TAC
1983–84*	104	–	0	–	4 387	–
1984–85*	91	–	0	–	2 165	–
1985–86*	43	–	0	–	2 782	–
1986–87†	40	210	0	10	2 347	4 850
1987–88†	43	218	0	10	1 915	5 014
1988–89†	44	231	0	10	1 466	5 162
1989–90†	57	233	0	10	1 696	5 459
1990–91†	113	233	0	10	3 232	4 499
1991–92†	132	233	0	10	3 905	4 499
1992–93†	152	233	0	10	3 215	4 512
1993–94†	126	233	0	10	1 500	4 512
1994–95†	114	233	0	10	2 074	4 512
1995–96†	186	233	0	10	2 913	4 512

* FSU data.
† QMS data.
‡ Includes landings from unknown areas before 1986–87.
[1] Fishing year from 1 October to 30 September.

Table 6: Reported deepwater catch (t) of blue warehou by nation, 1978–79 to 1987–88

	N. Z.	Foreign licensed			
Fishing year	Chartered	Japanese	USSR	Korean	Total
1978–79[1]	6	140	37	24	207
1979–80	253	176	208	105	742
1980–81	–	–	–	–	–
1981–82	1 434	62	1	111	1 608
1982–83	982	284	11	465	1 742
1983–83*	80	35	15	103	233
1983–84#	2 594	293	6	374	3 267
1984–85	622	13	23	686	1 344
1985–86	1 751	151	1	72	1 975
1986–87	1 080	58	8	73	1 219
1987–88	626	43	1	22	692

Fisheries statistics data.
– No data available for the 1980–81 fishing year.
[1] Fishing year from 1978–79 to 1982–83 April to March.
* Six month fishing period April to September 1983.
# Fishing year from October to September.

Table 7: Reported deepwater catch (t) of blue warehou by EEZ area 1978–79 to 1987–88

NZ chartered and foreign licensed vessels combined.

	EEZ area									
Fishing year	CM	C-	D	All (E)	EA	FE	FW	G	H	Total
1978–79[1]	1	16	1	3	44	39	78	24	2	207
1979–80	12	2	11	+	66	409	231	4	5	742
1980–81	–	–	–	–	–	–	–	–	–	–
1981–82	1	+	12	-	94	126	1 357	3	12	1 608
1982–83	1	1	3	2	574	474	669	12	4	1 742
1983–83*	3	11	6	-	148	21	17	16	10	233
1983–84#	88	7	9	8	293	319	2 498	42	3	3 267
1984–85	2	1	1	1	638	261	375	27	4	1 344
1985–86	+	1	11	21	17	1 196	337	382	10	1 975
1986–87	6	9	53	5	6	738	262	134	5	1 219
1987–88	+	24	1	+	1	359	151	130	23	692

Fisheries statistics data.
[1] Fishing year from 1978–79 to 1982–83 April to March.
– No data available for the 1980–81 fishing year.
* Six month fishing period April to September 1983.
# Fishing year from October to September.
Differences between the total landings and area totals in 1984–85 is from catches with no area specified.
Minor differences are due to the rounding of figures

Table 8: The percentage of the Southland shelf blue warehou catch reported from target fisheries, 1988–89 to 1994–95

Target fishery	Blue warehou catch (%)
Squid	53.2
Barracouta	24.0
Blue warehou	15.7
Jack mackerel	3.1
Silver warehou	2.3
Hoki	1.1
Ling	0.1
Red cod	0.1
Gemfish	0.1
Spiny dogfish	0.1
Stargazer	0.1
Tarakihi	0.1

Table 9: Squid and blue warehou (WAR) catch (t) from deepwater vessels on the Southland shelf 1983–84 to 1994–95

Fishing year	Squid (t)	WAR (t)	WAR catch Target fishing (t)	WAR bycatch as a percentage of the squid catch Jan to Jun (t)	%
1983–84[1]	14 788	3 115	162	813	5.5
1984–85	19 810	1 279	21	298	1.5
1985–86	16 486	1 577	239	1 084	6.6
1986–87	22 314	1 019	9	262	1.2
1987–88	18 155	534	11	354	2.0
1988–89	20 427	165	0	40	0.2
1989–90	8 869	443	3	355	4.0
1990–91	16 354	1 550	3	1 344	8.2
1991–92	27 830	2 060	28	1 484	5.3
1992–93	24 926	1 869	52	1 761	7.1
1993–94	13 833	336	18	112	0.8
1994–95	25 569	1 083	10	19	>0.1

[1] Fishing year from 1 October to 30 September.

Table 10: Trawl survey biomass indices (t) and coefficients of variation (*c.v.*) for recruited blue warehou over 50 cm

Fishstock	Area	Vessel	Voyage	Date	Biomass	c.v. (%)
WAR 3	Southland	*Shinkai Maru*	SHI8101	Jan-Mar 81	2 100	43
			SHI8201	Mar-May 82	800	62
			SHI8302	Apr 83	4 700	72
			SHI8601	Jun 86	2 000	59
WAR 3	Southland	*Tangaroa*	TAN9301	Feb-Mar 93	2 297	36
			TAN9402	Feb-Mar 94	1 629	38
			TAN9502	Feb-Mar 95	1 103	38
			TAN9604	Feb-Mar 96	1 615	40

Table 11: Details of otolith samples examined to determine marginal state (Samples 1–10 and 13), and to provide data to calculate growth parameters (Samples 10–13). Only subsets of Samples 10 and 13 were used in the marginal state analysis (*n* = 79 and 59, respectively), *n*, sample size

Sample	Area	*n*	Collection date
1	Golden Bay	18	27 Jan 1983
	Pegasus Bay	15	27 Jan 1980
2	Pegasus Bay	19	26 Mar 1983
3	Tasman Bay	30	4–6 Apr 1997
	Wairarapa	59	Apr 1978
4	Cook Strait	47	24–25 May 1987
5	Wairarapa	57	6–24 Jun 1984
6	Tasman Bay	15	5–10 Jul 1996
	Cape Egmont	50	17 Jul 1987
7	Tasman Bay	12	6–12 Aug 1984
	Palliser Bay	5	21 Sep 1984
	Cape Kidnappers	10	25 Sep 1984
	Tasman Bay	9	28 Sep 1974
8	Wellington Harbour	9	5 Oct 1984
	Cape Campbell	19	11 Oct 1979
	Tasman Bay	9	19–23 Oct 1970
9	Southland shelf	49	9–21 Nov 1986
10	Southland shelf	256	9 Feb–5 Mar 1993
11	Southland shelf	206	13 Feb–5 Mar 1994
12	Southland shelf	187	14 Feb–8 Mar 1995
13	Southland shelf	240	25 Feb–22 Mar 1996

Table 12: Von Bertalanffy parameters (with 95% confidence intervals) for blue warehou from the Southland shelf

Sex	n	L_∞		k		t_0	
Male	428	63.8	(63.2–64.4)	0.241	(0.226–0.256)	–0.46	(–0.70 to –0.21)
Female	461	66.3	(65.6–67.0)	0.209	(0.195–0.223)	–0.79	(–1.06 to –0.52)

Table 13: Catch history (t) for the years 1970 to 1997 used in the WAR 3 model

Year total	Non spawning Jan - Sep	Spawning Oct - Dec	Total catch
1970	40	20	60
1971	50	20	70
1972	490	150	640
1973	600	200	800
1974	480	170	650
1975	580	200	780
1976	1 290	390	1 680
1977	1 380	420	1 800
1978	38	58	96
1979	225	581	806
1980	508	1 000	1 508
1981	600	1 752	2 352
1982	699	1 061	1 760
1983	963	2 159	3 122
1984	1 440	864	2 304
1985	715	273	988
1986	1 553	556	2 109
1987	722	232	954
1988	618	162	780
1989	294	90	394
1990	506	20	656
1991	1 707	620	2 582
1992	1 674	67	2 097
1993	1 950	162	2 222
1994	365	1 054	1 197
1995	66	795	861
1996	425	467	892
1997	425	467	892

Table 14: Biological parameters for the WAR 3 model

Natural mortality (*M*):

Males	Females
0.21	0.21

Weight = a (length)^b: (Weight in g, length in cm total length)

Males:	a = 0.0015	b = 3.09
Females:	a = 0.0016	b = 3.07

von Bertalanffy growth parameters:

	K	t_0	L_∞
Males	0.241	-0.46	63.8
Females	0.209	-0.79	66.3

Table 15: Model input parameters for the WAR 3 model

Parameters	Estimate	Sensitivity tested
M	0.21	0.31
Steepness (SRR)	0.75	-
Recruitment variability (rsd)	1.00	0.6
Maximum exploitation (rmax) spawning	0.5	0.8
non-spawning	0.5	0.8
Minimum exploitation when largest catch (rmmx)	0.05	0.10
Proportion spawning	1.00	-
Proportion available	0.20 (1970–85)	1.00
	0.25 (1986–97)	1.00

Plus group: 17 years and older

Maturity ogive

Age	Male	Female
2	0.10	0.10
3	0.25	0.25
4	0.50	0.50
5	0.75	0.75
6	1.00	1.00

Table 16: Base case and sensitivity analyses

Run	Base case	Sensitivity
1	Base case	-
2	$r_{max} = 0.5$	$r_{max} = 0.8$
3	pout = 0.25, 0.20	pout = 1
4	$r_{max} = 0.5$, pout=0.20, 0.25	$r_{max} = 0.8$, pout = 1.00
5	M = 0.21	M = 0.31
6	$r_{mmx} = 0.05$	$r_{mmx} = 0.1$
7	rsd = 1	rsd = 0.6

NB: pout = proportion of fish available to the spawning season fishing fleet

Table 17: MIAEL estimates of B_0 (t), B_{cur} (t), and B_{mid97}, (Ind, Information index)

Run	B_0 range (t)	B_0 (t)	Ind. (%)	B_{cur} range (t)	B_{beg98} (t)	Ind. (%)	B_{mid97} Range (%)	B_{mid97} (%)	Ind. (%)
1	22.1–51.1	32.4	0	16.1–53.0	27.3	0	54–82	66	0
2	16.0–51.1	26.2	2	6.7–53.0	15.3	1	28–82	44	0
3	14.4–51.1	24.1	5	2.8–53.0	8.3	6	11–82	24	4
4	14.0–51.1	23.6	5	1.1–53.0	4.2	11	3–82	10	7
5	20.5–49.5	30.9	0	20.2–62.7	33.3	0	67–88	76	0
6	22.1–29.6	25.4	0	16.1–25.9	20.2	0	54–67	60	0
7	22.1–51.1	32.3	0	16.0–53.0	27.1	0	54–82	65	0

Table 18: Estimates of MAY, B_{MAY}, MCY, and B_{MCY} (as a percentage of B_0)

Run	MAY (% B_0)	B_{MAY} (% B_0)	MCY (%B_0)	B_{MCY} (%B_0)	MCY range for B_{min}	B_{max}
1	7	37	5	54	1 105	2 256
2	7	36	5	59	800	2 256
3	7	37	5	59	720	2 256
4	7	37	5	59	700	2 256
5	10	39	7	58	1 435	3 465
6	7	37	5	58	1 105	1 480
7	7	28	7	40	1 547	3 577

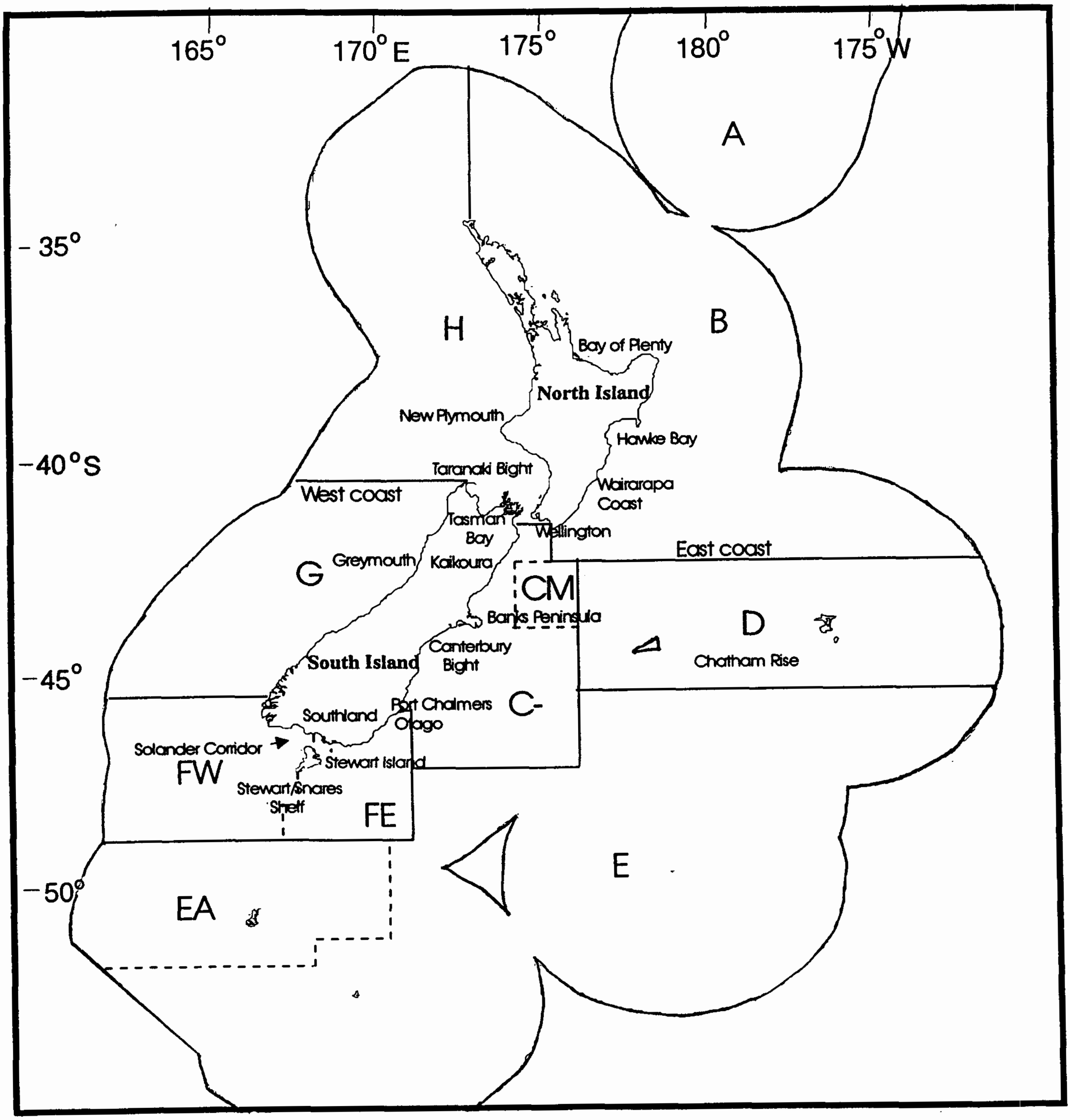


Figure 1: map of the 200 n.mile Exclusive Economic Zone (EEZ), place names mentioned in the text and EEZ areas (denoted by large capital letters).

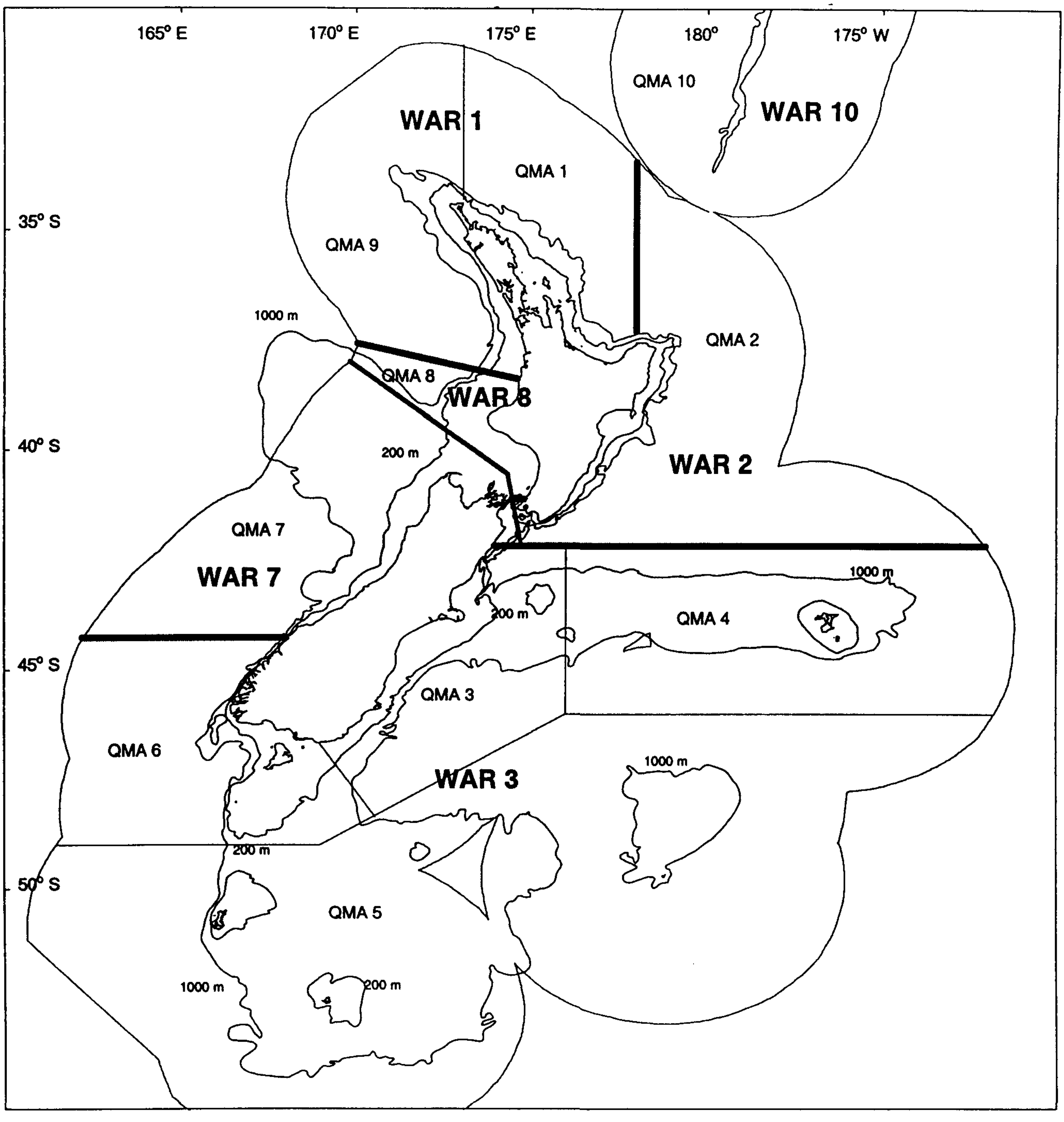


Figure 2: Quota management areas (QMA) and blue warehou Fishstock areas.

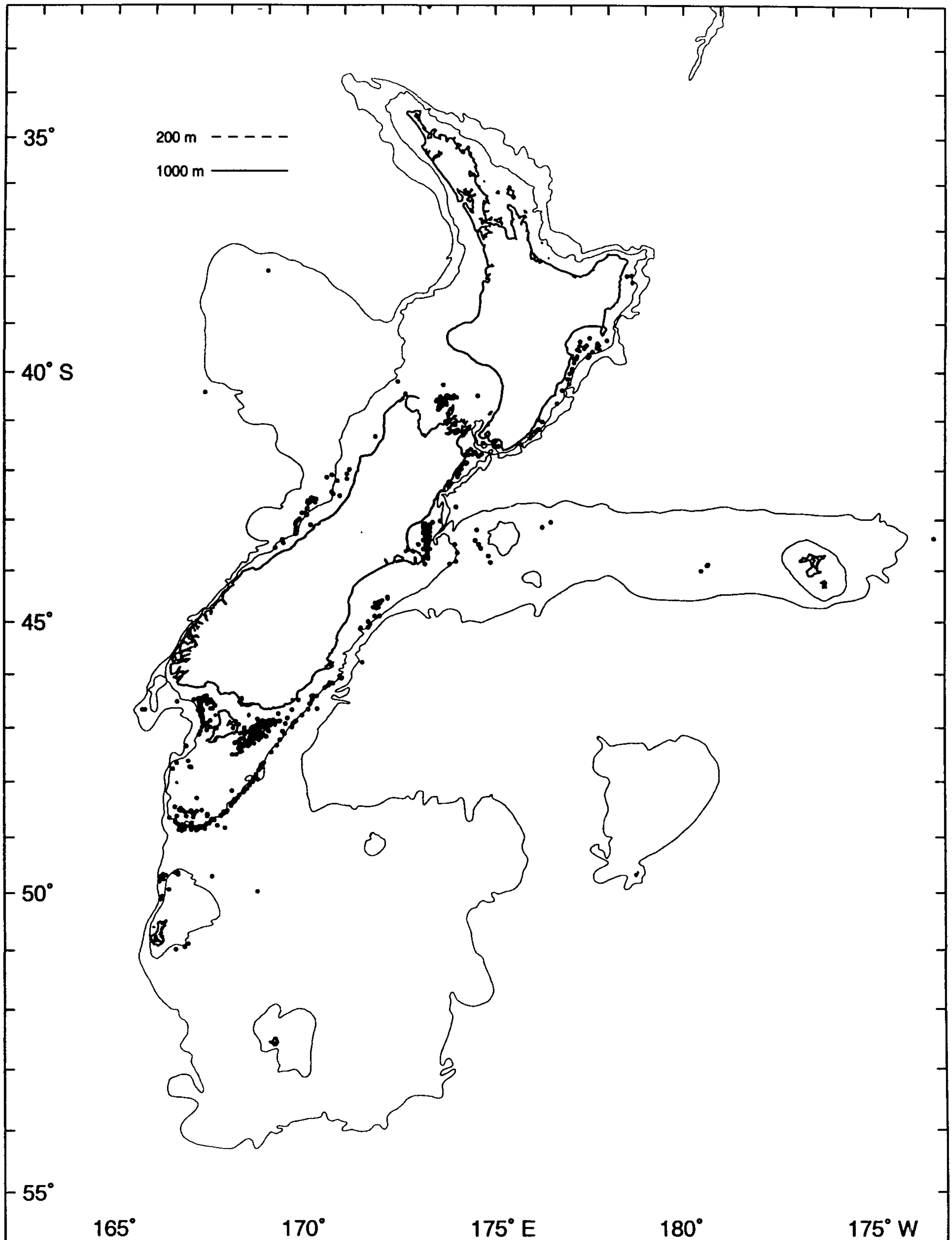


Figure 3: Blue warehou target trawl positions from deepwater vessels, 1983–84 to 1994–95.

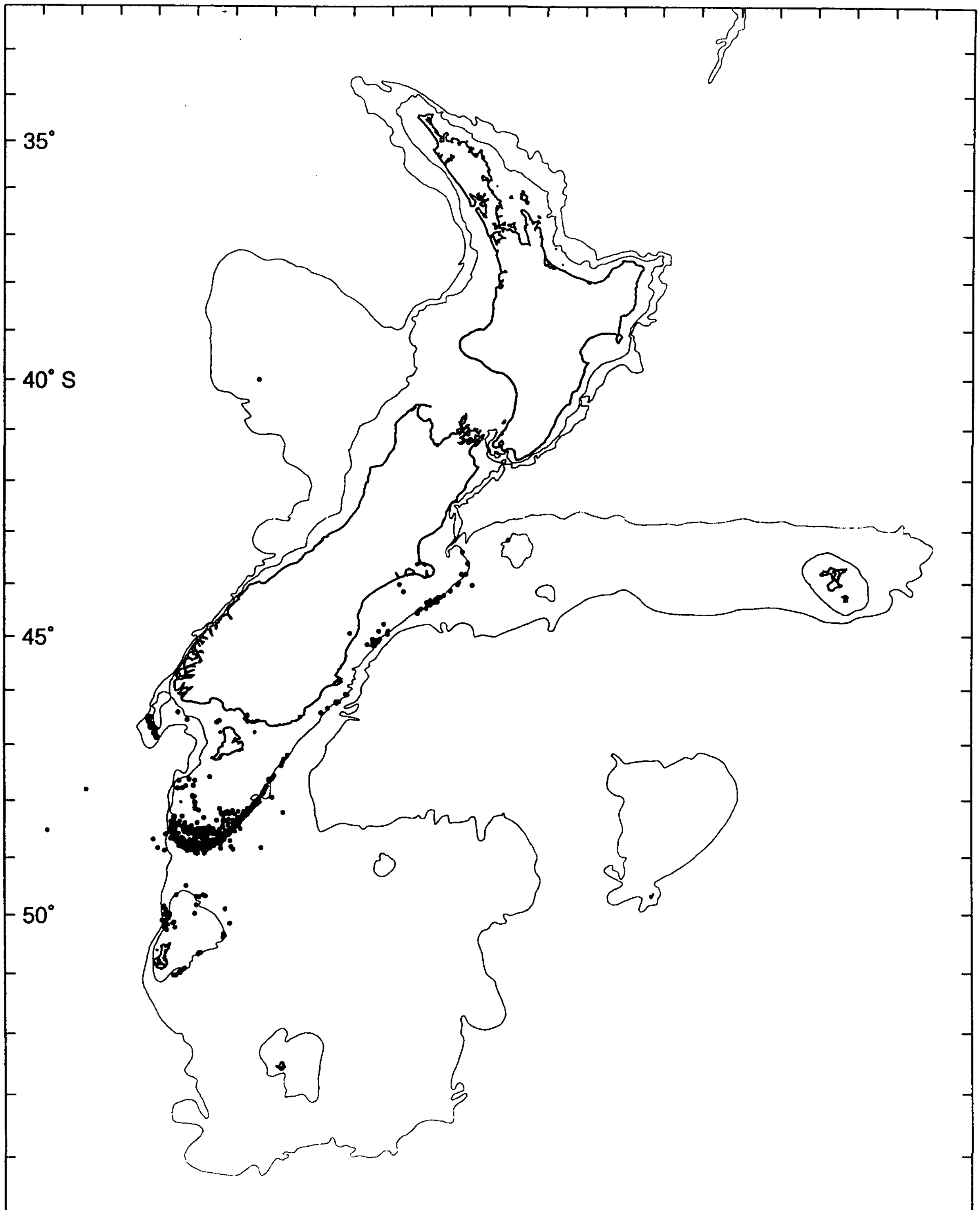


Figure 4a: Blue warehou bycatch trawl positions from deepwater vessels target fishing for arrow squid, 1983–84 to 1994–95.

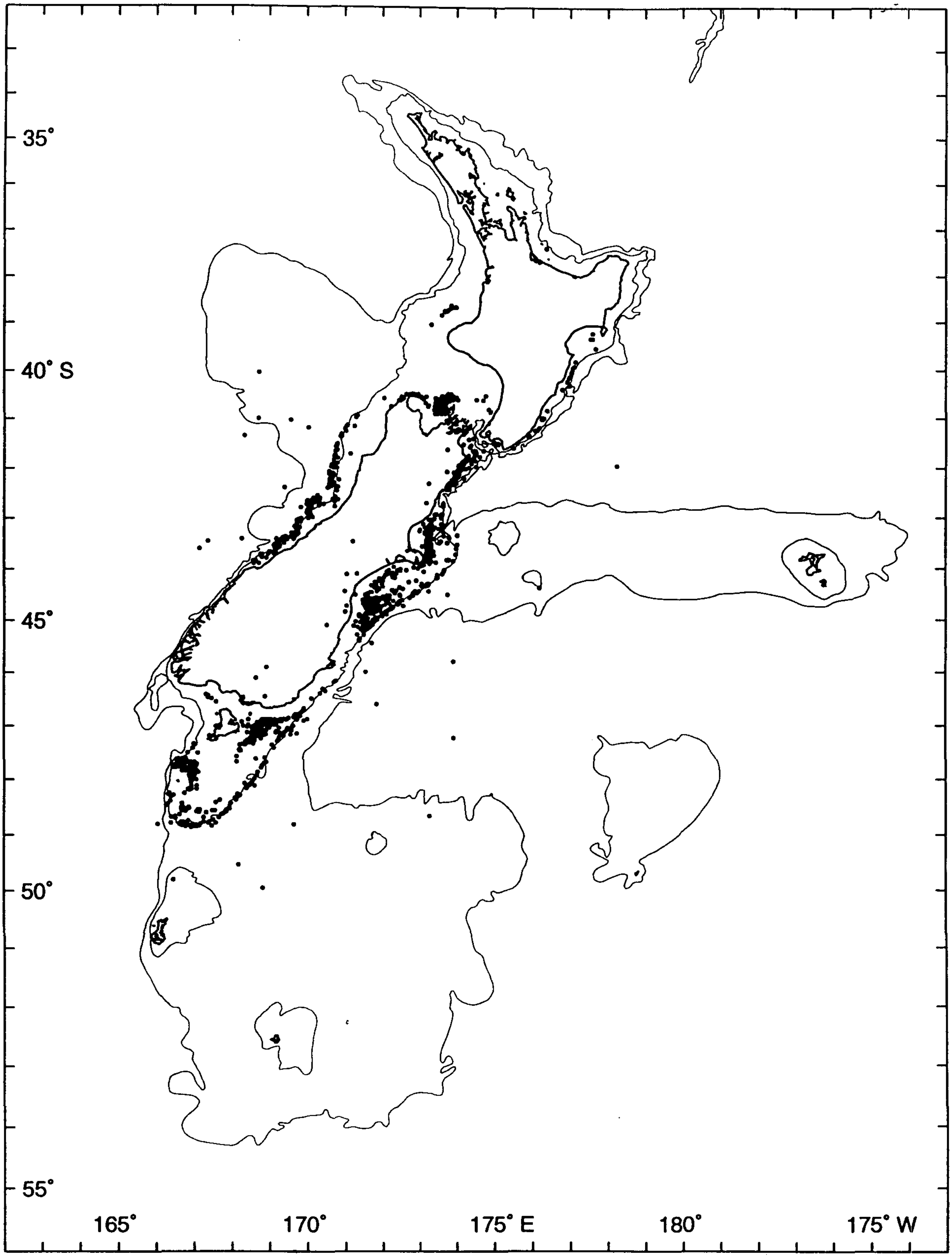


Figure 4b: Blue warehou bycatch trawl positions from deepwater vessels target fishing for barracouta, 1983–84 to 1994–95.

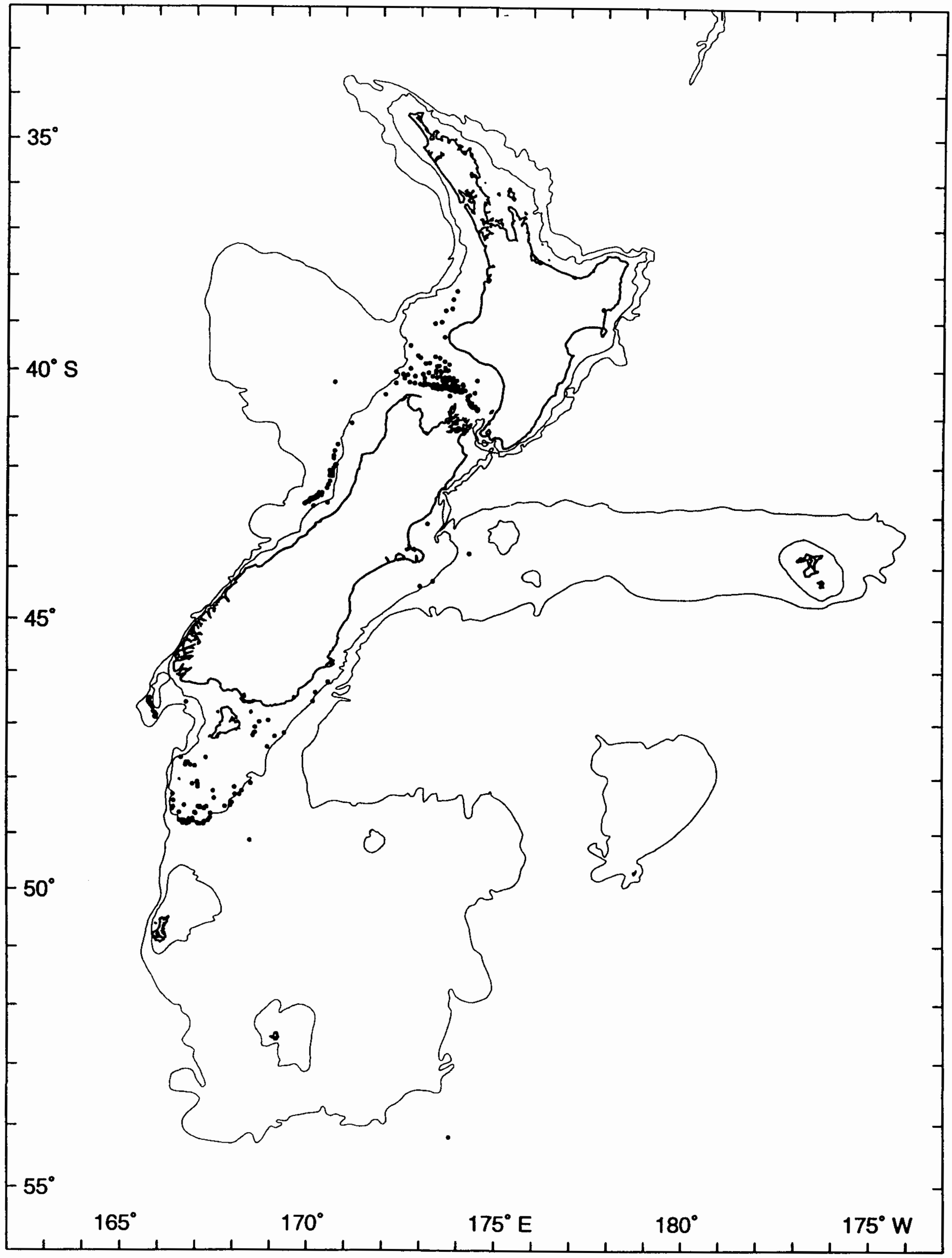


Figure 4c Blue warehou bycatch trawl positions from deepwater vessels target fishing for jack mackerel, 1983–84 to 1994–95.

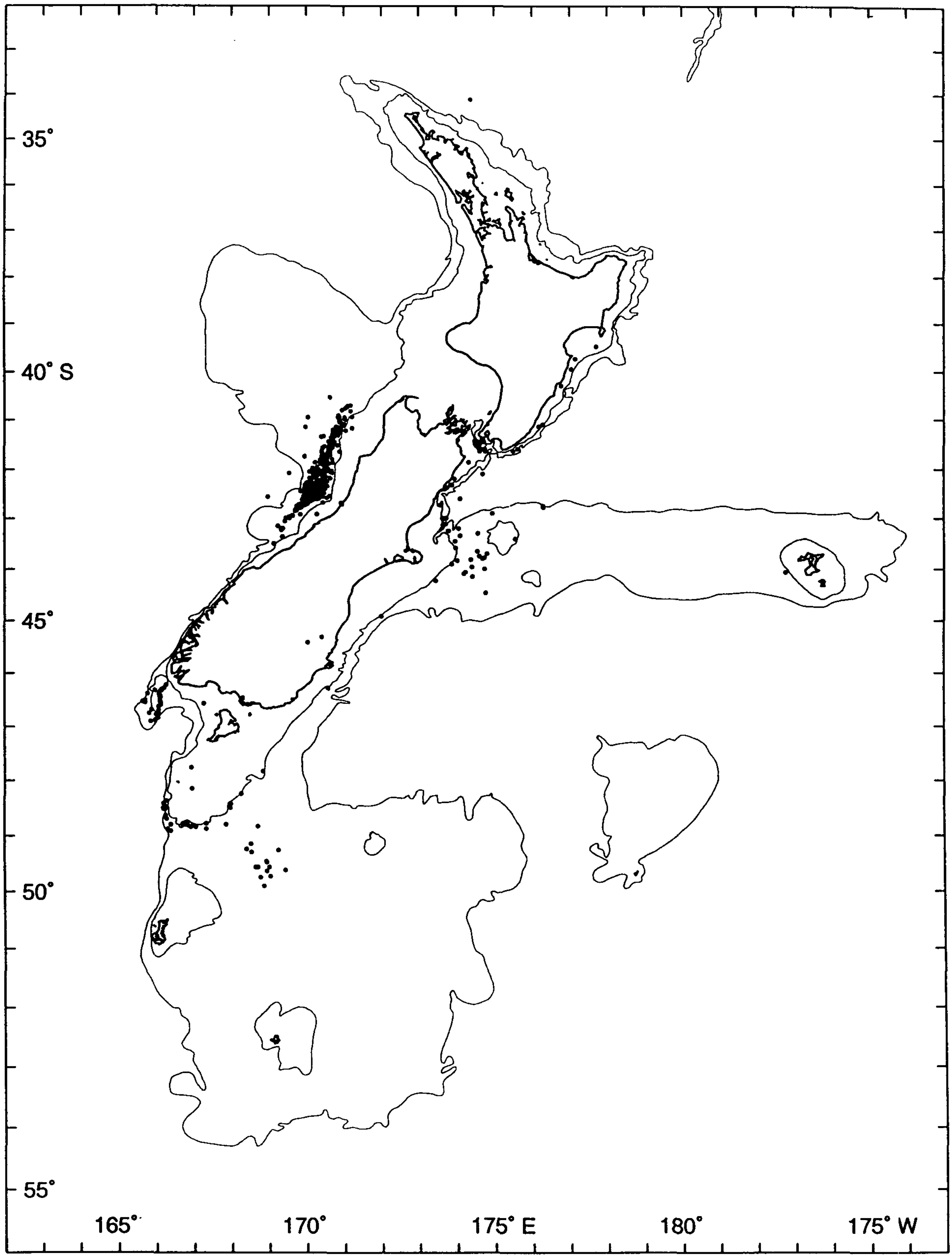


Figure 4d: Blue warehou bycatch trawl positions from deepwater vessels target fishing for hoki, 1983–84 to 1994–95.

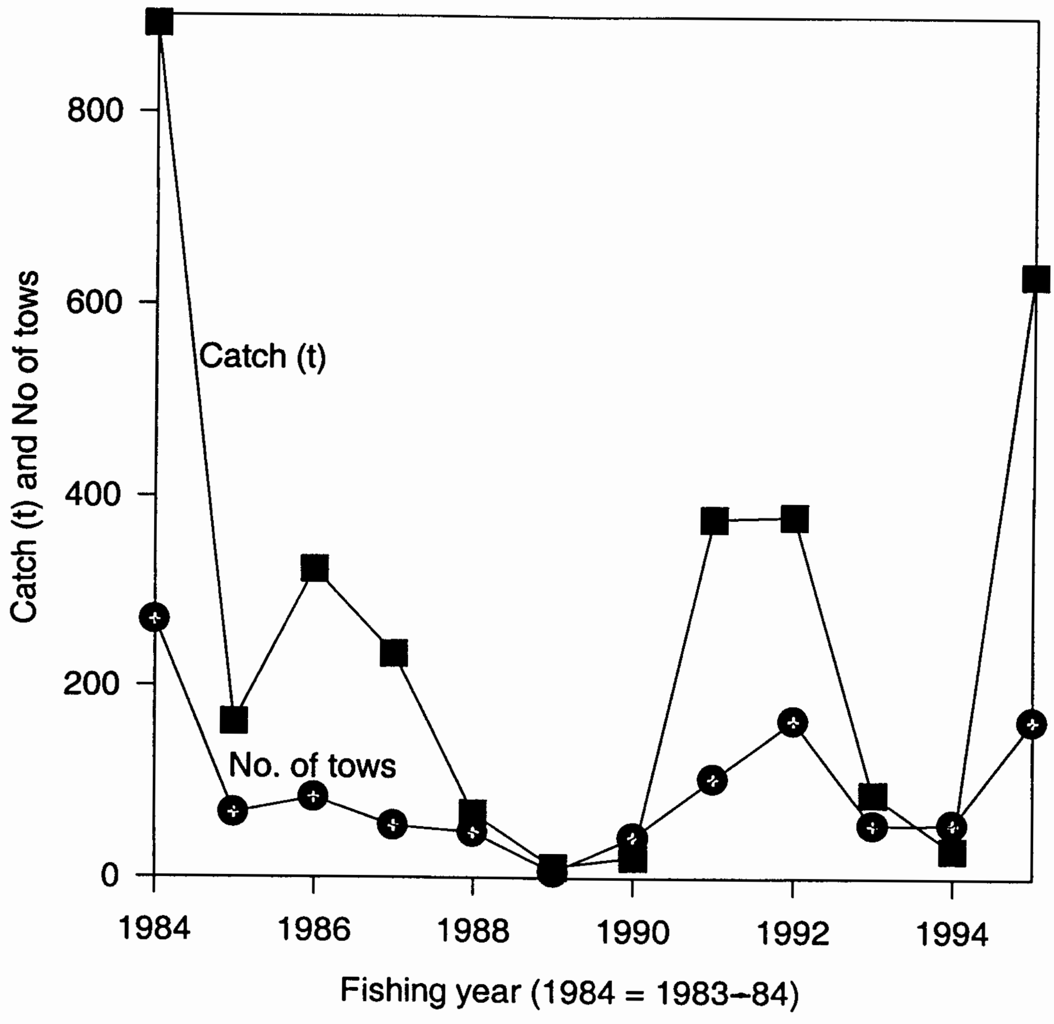


Figure 5: The number of blue warehou target trawls and catch from deepwater vessels, 1983–84 to 1994–95.

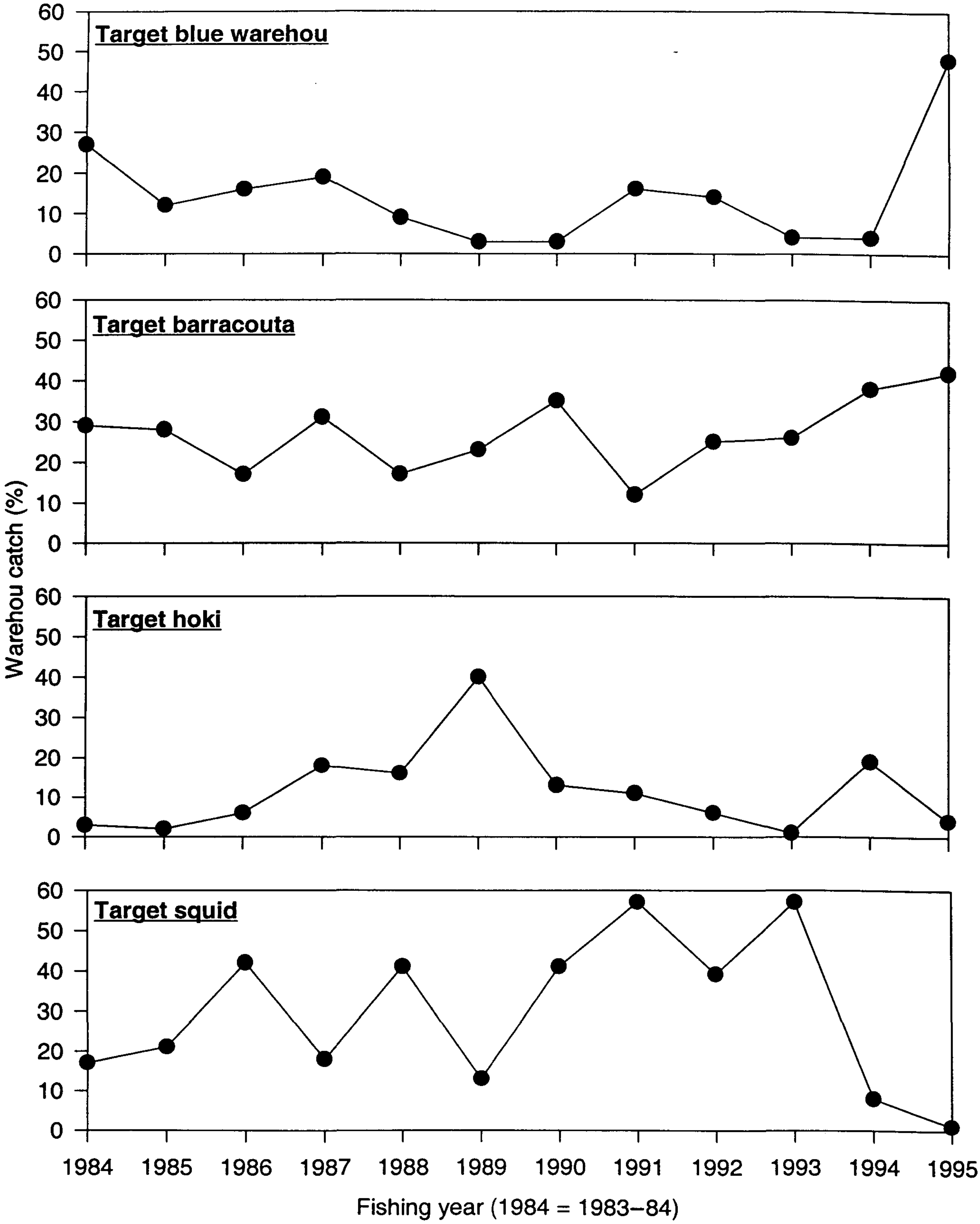


Figure 6: The percentage of blue warehou catch taken in deepwater target blue warehou, barracouta, hoki, and squid fisheries, 1983–84 to 1994–95.

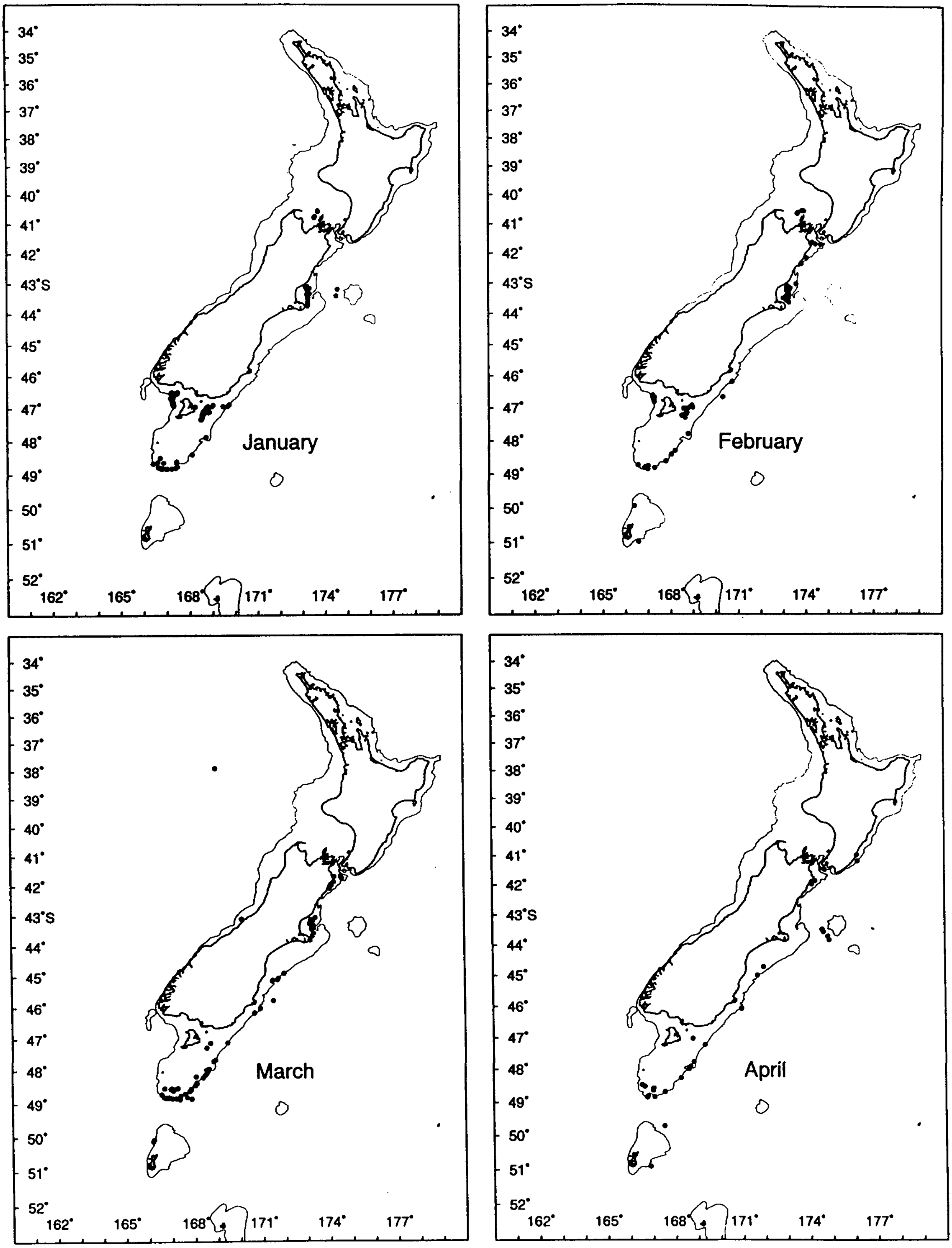


Figure 7: Blue warehou target trawl positions for deepwater vessels by month, 1983–84 to 1994–95.

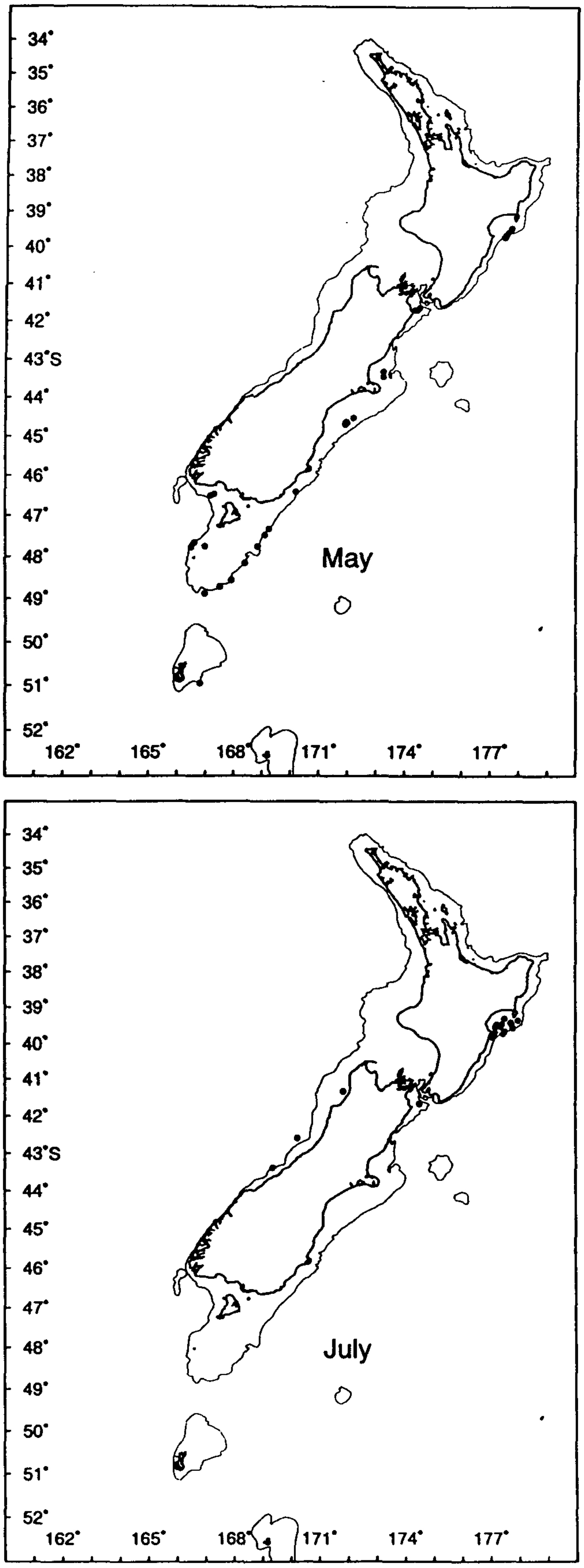


Figure 7: continued.

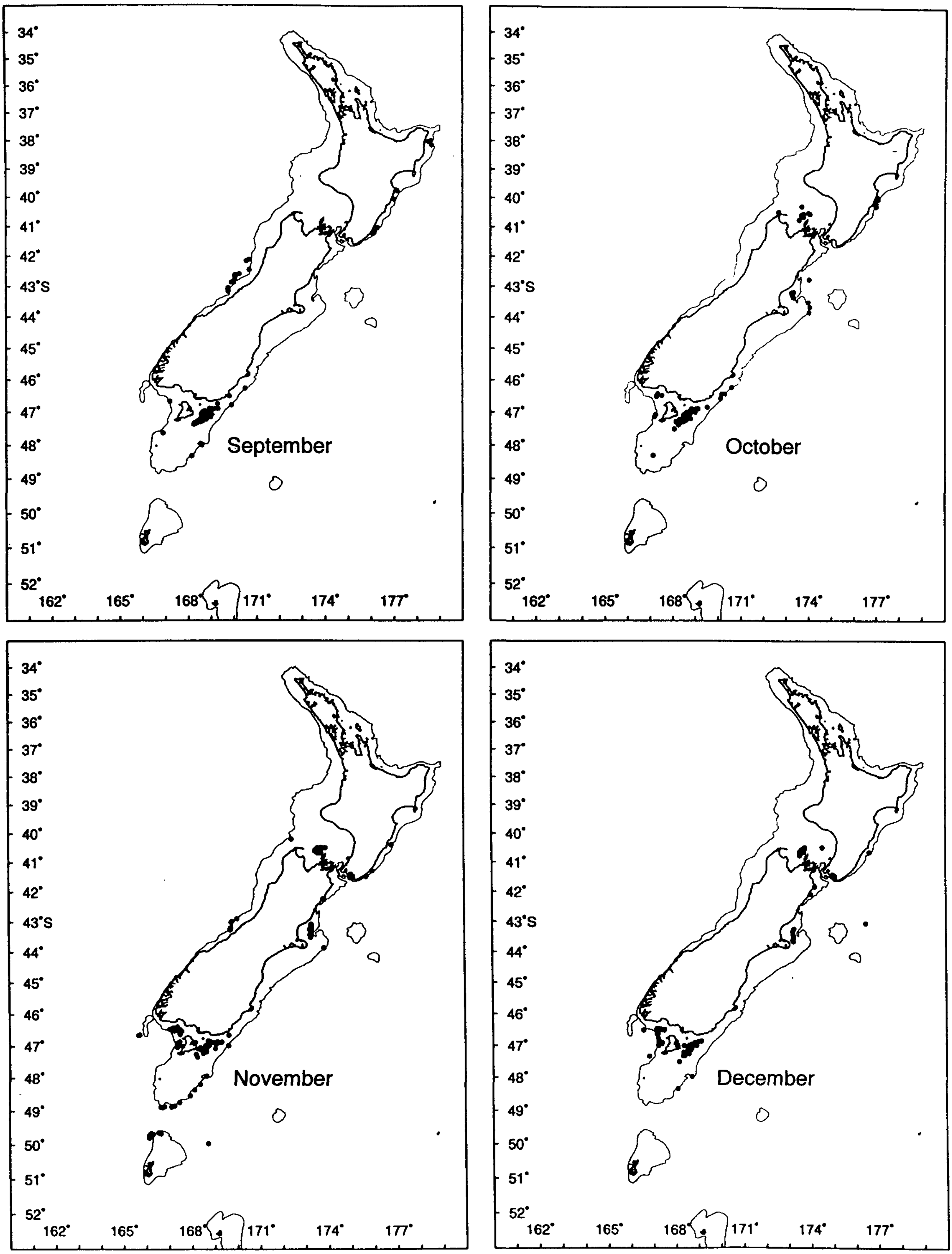


Figure 7: continued.

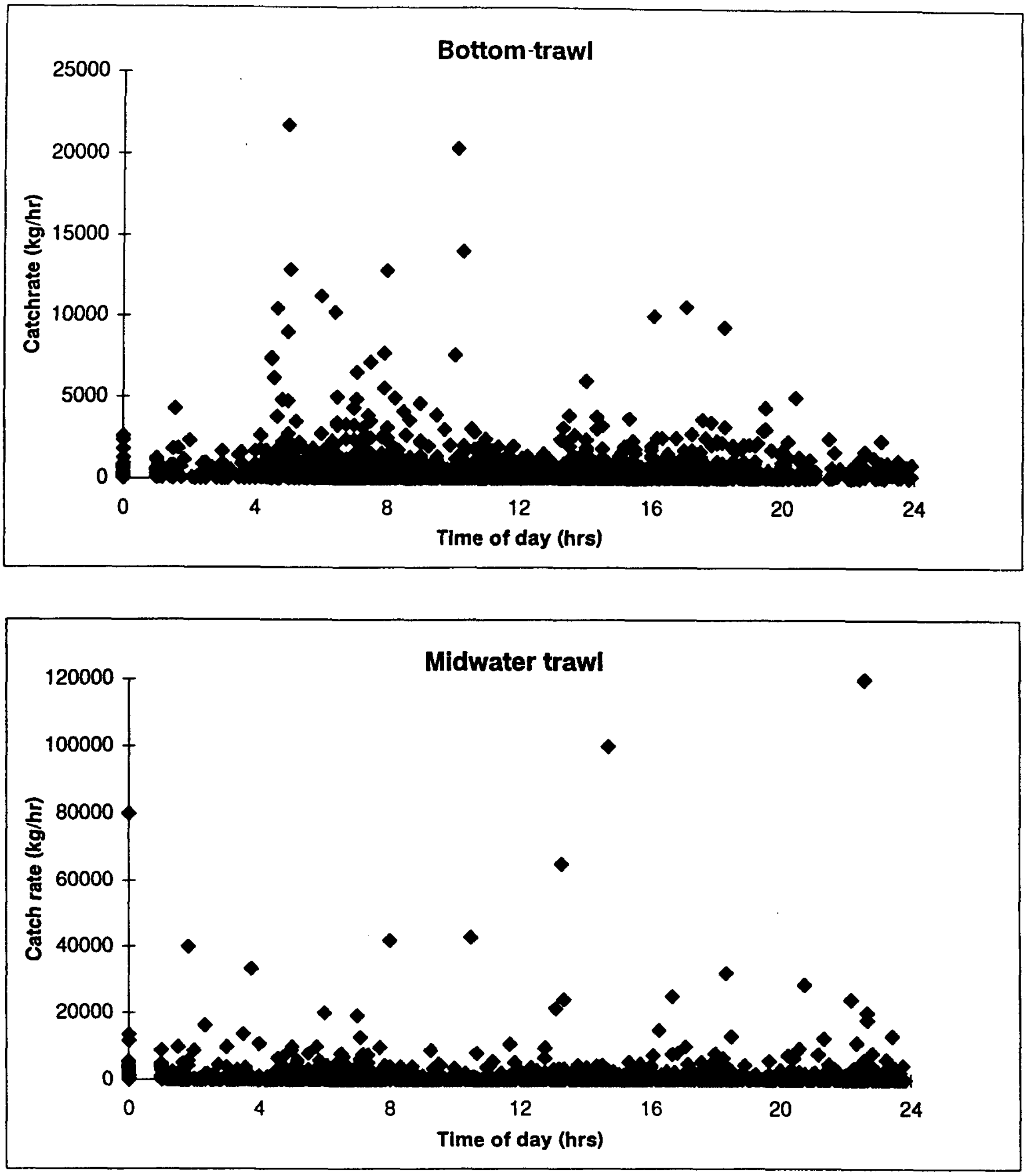
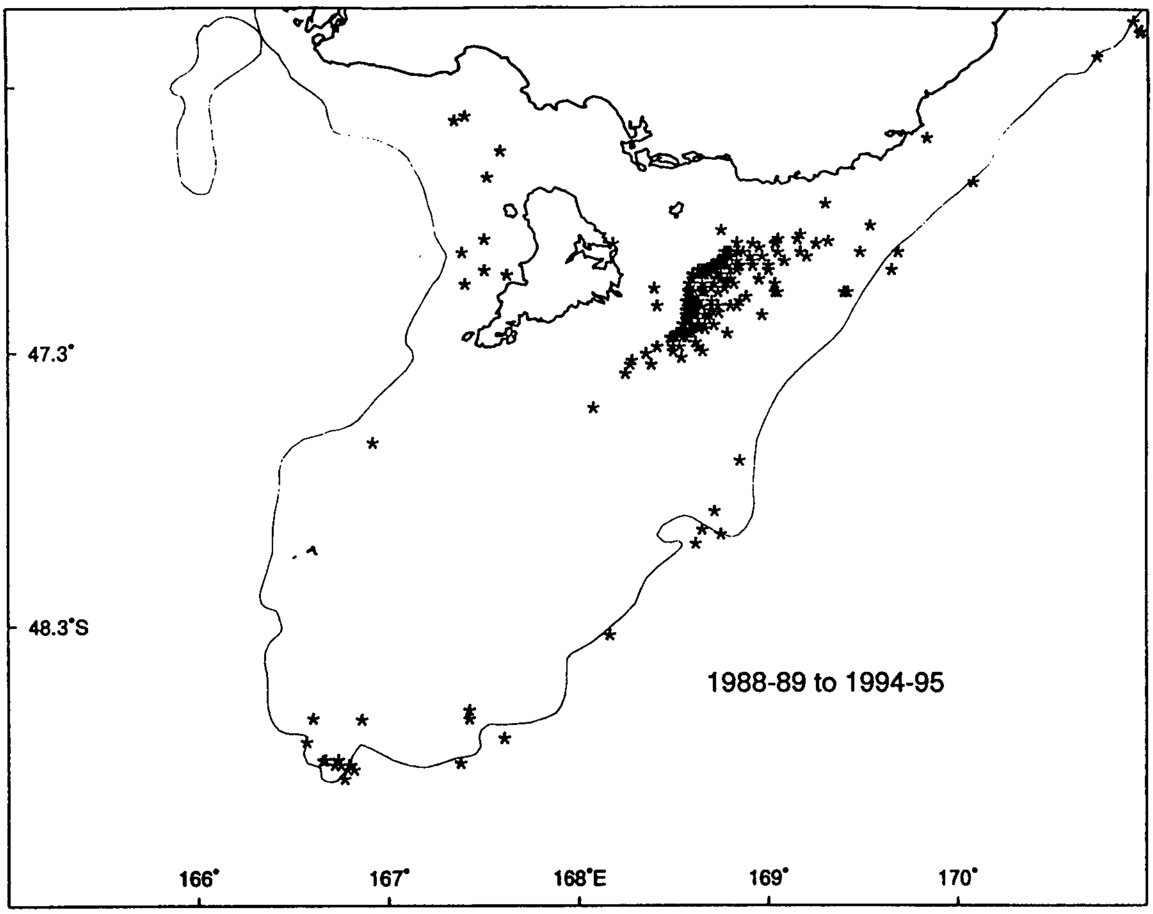


Figure 8: Blue warehou catch by time of day for bottom trawls (top) and midwater trawls (bottom) 1983–84 to 1994–95.



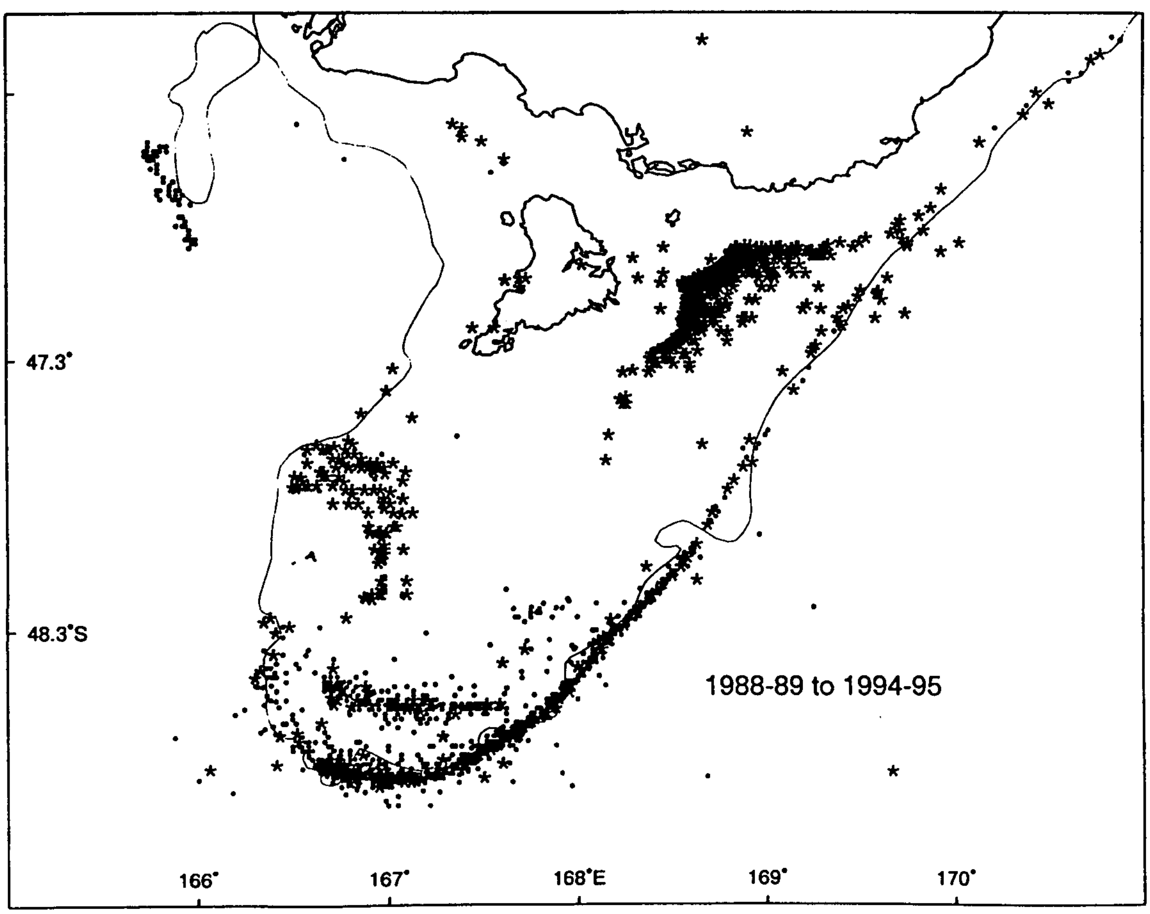


Figure 9: Positions on the Southland shelf for target blue warehou (top) and blue warehou bycatch (bottom) from arrow squid (.) and barracouta (*) trawls.

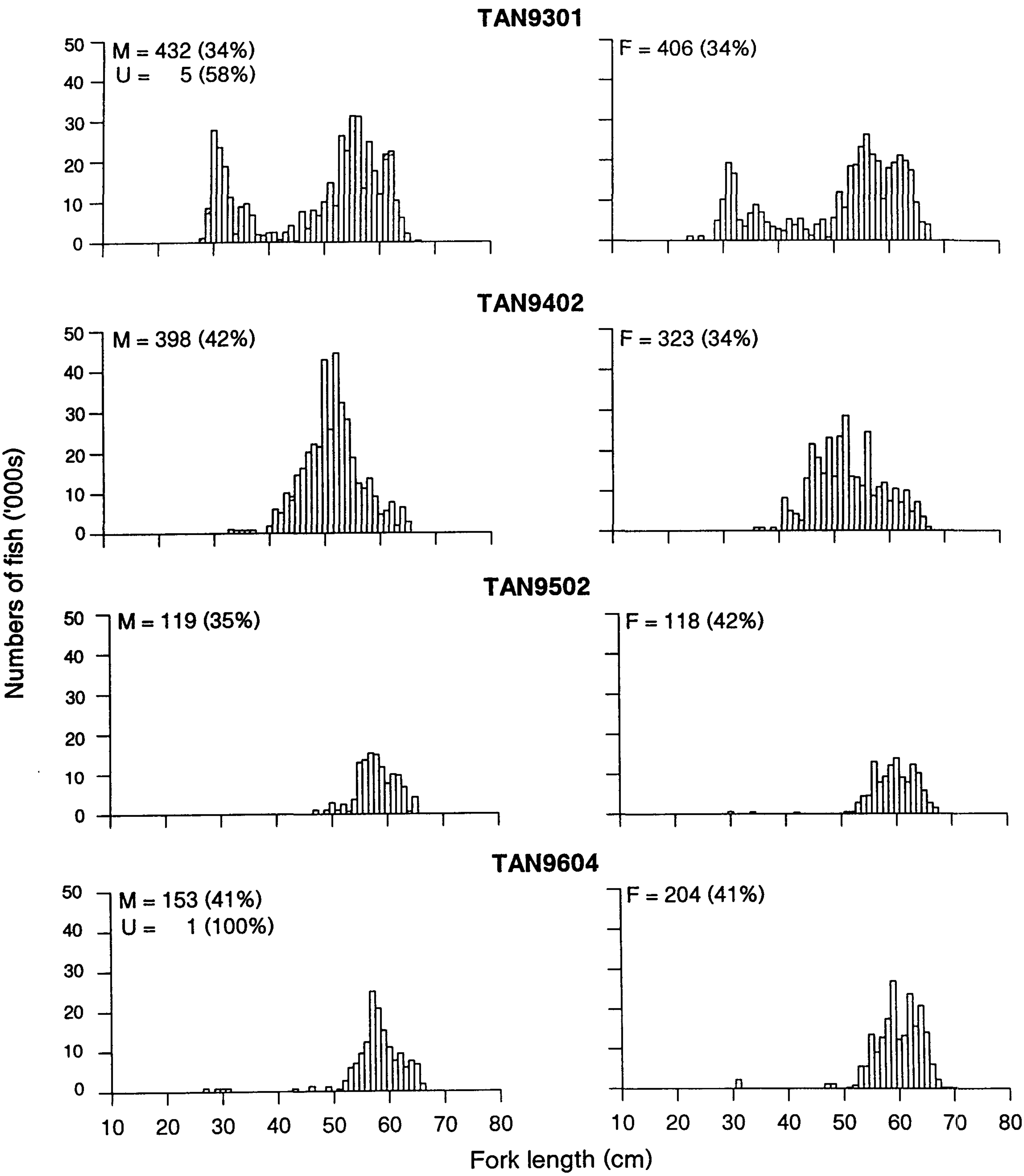


Figure 10: Scaled length-frequency distributions of blue warehou from Southland trawl surveys by the *Tangaroa*, 1993–96. (M, number of males; F, number of females; U, number of unsexed fish; (%), coefficent of variation.

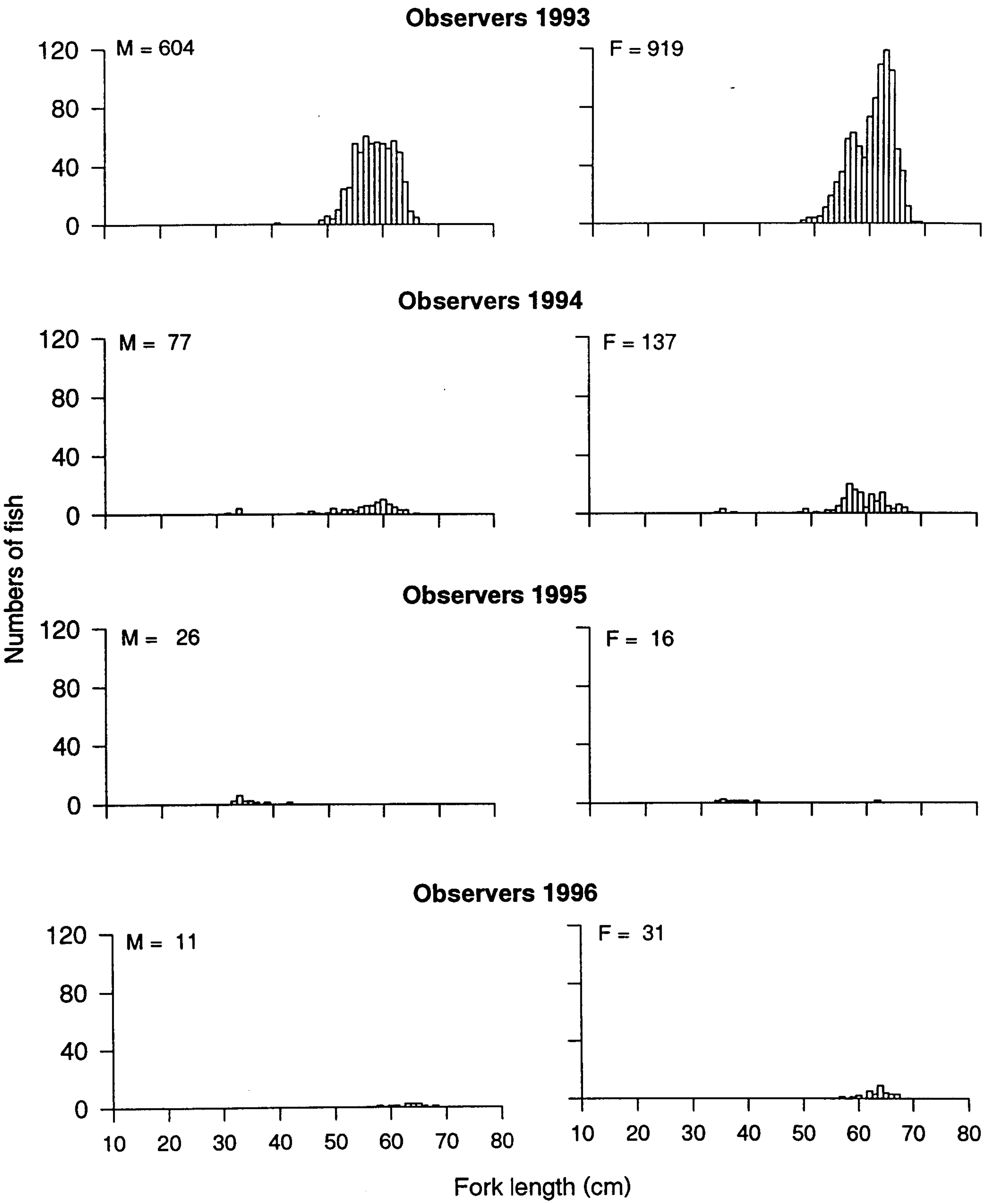


Figure 11: Length-frequency distributions of blue warehou from the Scientific Observer Programme in Southland, 1993–96 (M, number of males; F, number of females).

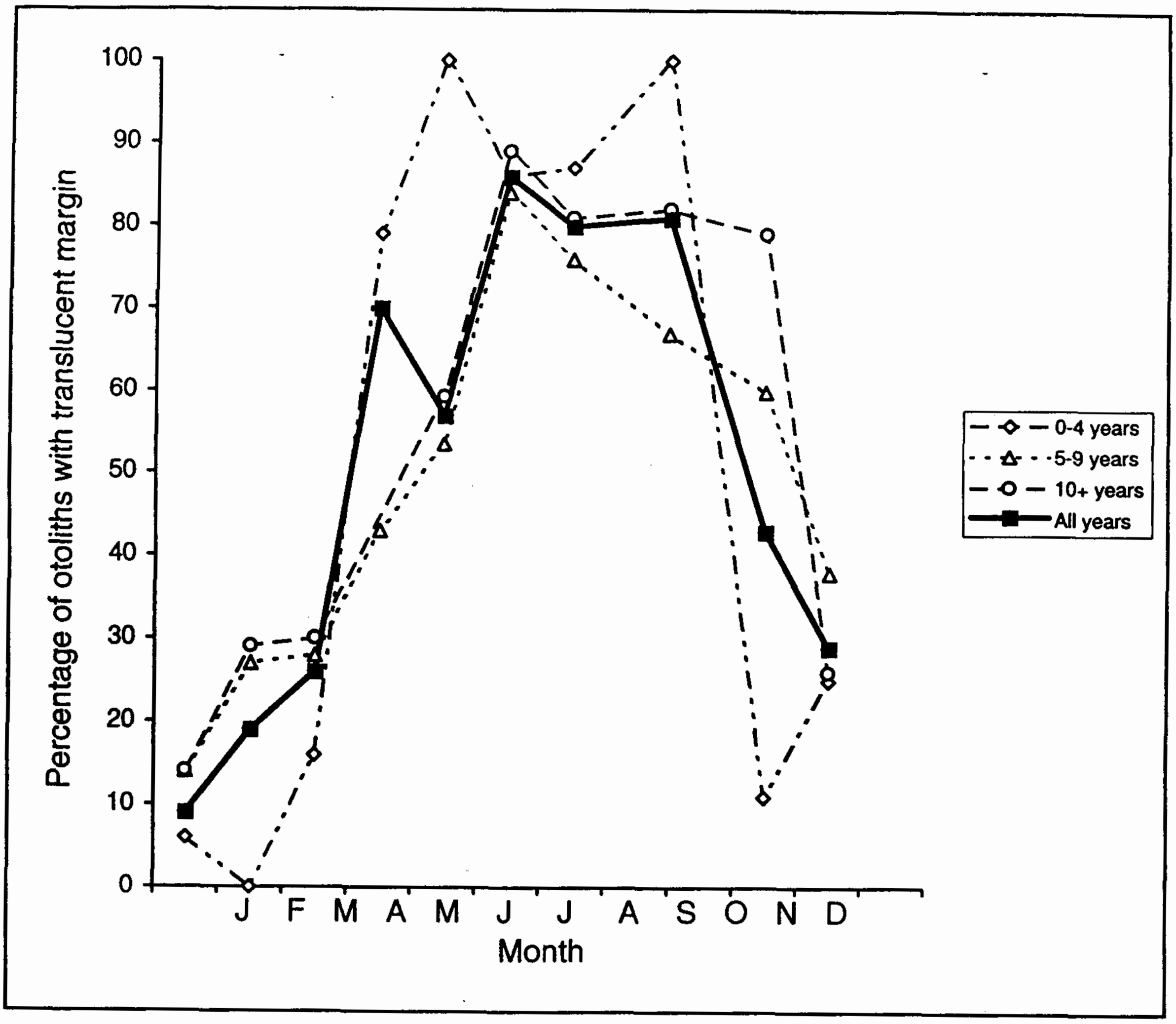


Figure 12: Seasonal change in the percentage of otoliths with a translucent margin. Data are presented for three groups of ages, and all fish combined.

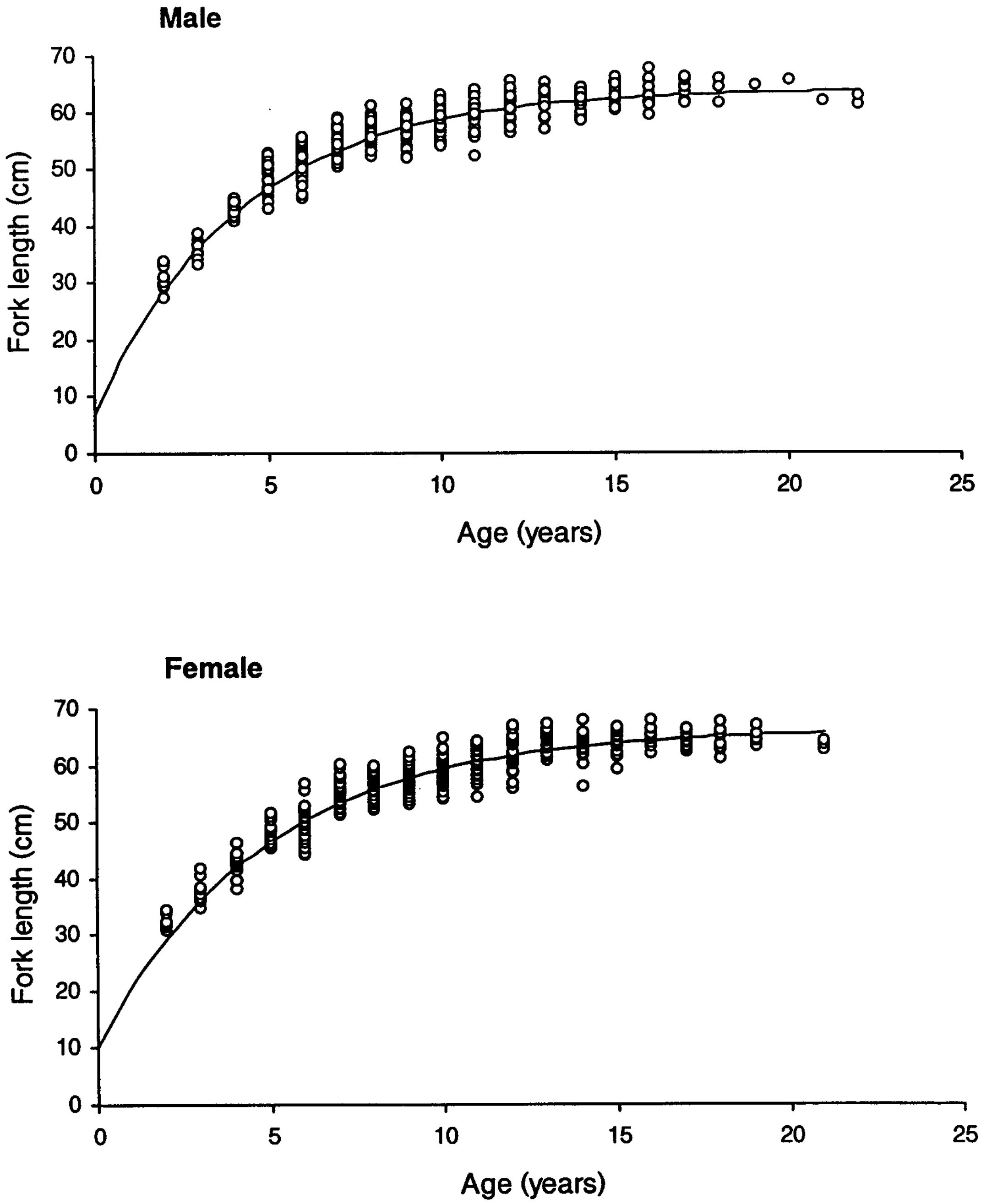


Figure 13: Raw age-length data and calculated von Bertalanffy growth curves, by sex, for blue warehou from the Southland shelf.

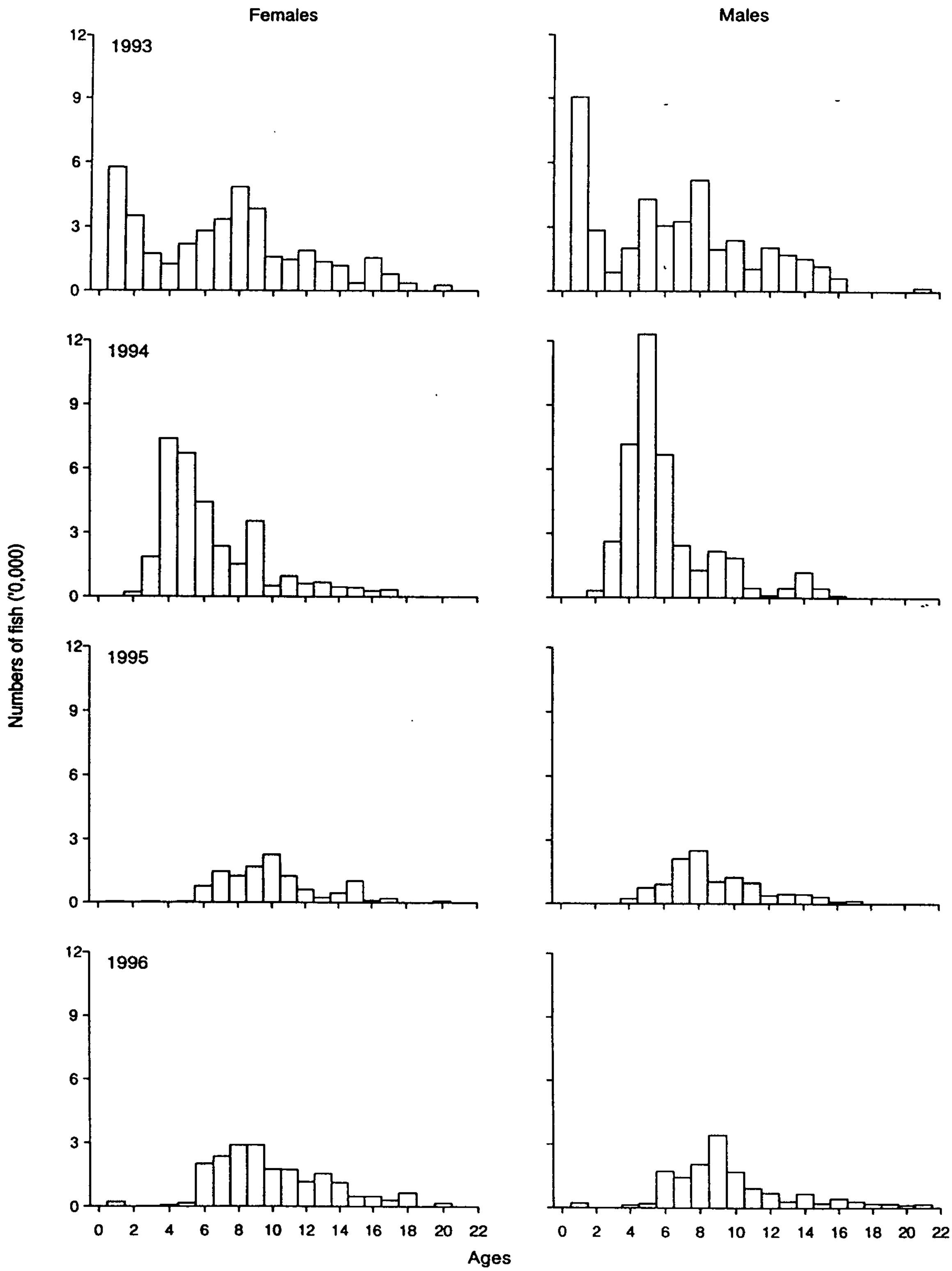


Figure 14: Numbers at age for female and male blue warehou taken from the Southland shelf *Tangaroa* surveys, 1993–96.

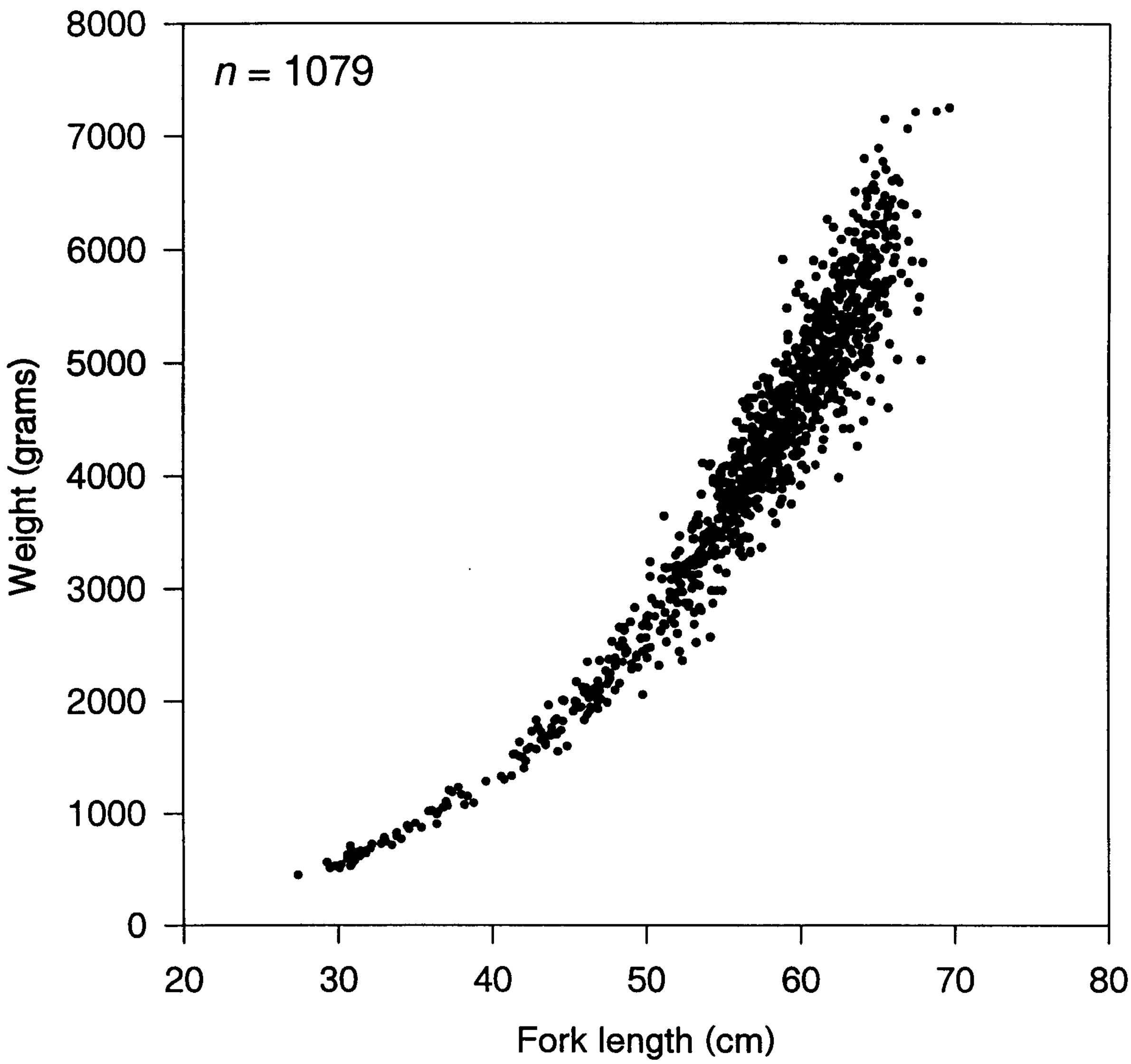


Figure 15: Blue warehou length-weight relationship.

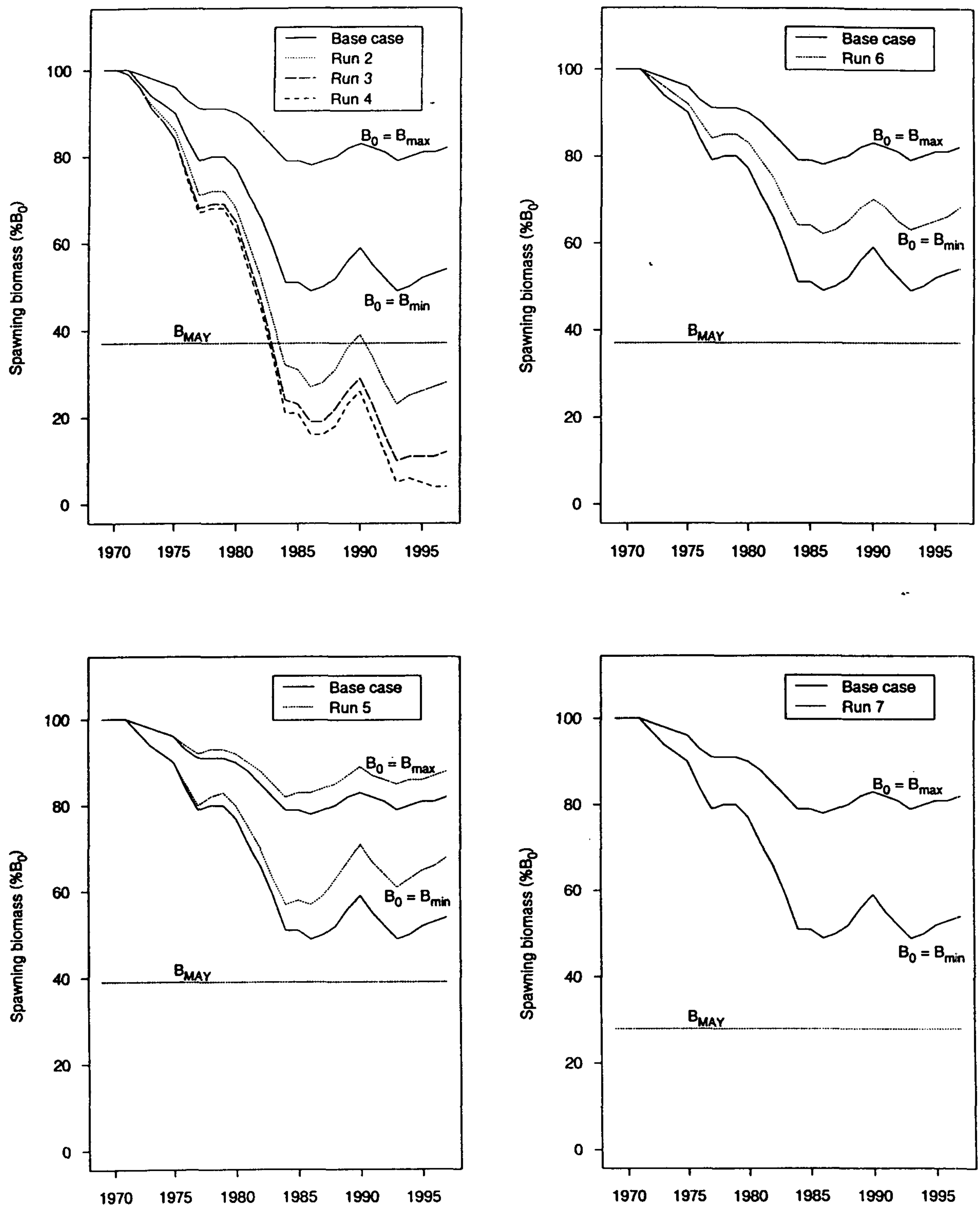


Figure 16: Trajectories from minimum and maximum estimates of virgin biomass for the base case, and sensitivity analyses, for the blue warehou stock WAR 3. Note: Run 7 gave the same trajectory as the base case.