New Zealand Fisheries Assessment Research Document 99/39

Analysis of commercial catch and effort data and age determination and catch-at-age of barracouta in BAR 5

S. J. Harley, P. L. Horn, R. J. Hurst, & N. W. Bagley

NIWA
PO Box 14 901
Wellington

October 1999

Ministry of Fisheries, Wellington

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New Zealand Fisheries Assessment Research Document 99/39. **39 p.**

1. EXECUTIVE SUMMARY

Barracouta form a moderate sized commercial fishery in New Zealand. Catches in BAR 5 declined to 28% of the TACC during the early 1990s leading to concerns over the status of the BAR 5 stock. Subsequently the Ministry of Fisheries requested a descriptive catch and effort analysis, and determination of catch-at-age of the BAR 5 fishery. This document describes these two pieces of work.

The BAR 5 fishery comprises a target trawl fishery and substantial bycatch components from the squid trawl fisheries, and more recently the jack mackerel trawl fishery. Catches declined during the mid 1990s but increased to 6167 t (66% TACC) in 1997–98 with increases in target barracouta catches and a large bycatch from the jack mackerel target fishery.

TCEPR data were used to estimate unstandardised and standardised catch rates from the different fisheries. Unstandardised mean and median catch rates of barracouta are highly variable between years and fisheries. A preliminary standardised CPUE analysis was performed, both including and excluding zero barracouta target catches. Estimated year effects declined by about 40–50% since 1989–90.

Barracouta otoliths from trawl surveys and observer collections were aged using whole otoliths viewed in water against a dark background with illumination from reflected light. Estimated ages for juvenile barracouta were consistent with observed modes in trawl survey length frequency data.

Von Bertalanffy growth parameters were determined for each sex using age data from the four Southland trawl surveys (1993–96). L_∞ was higher for females than males (89.3 cm versus 81.1 cm) and there is evidence to suggest that females also have a longer life expectancy. There were some significant differences in mean length at age between years for the younger age classes in both sexes providing some evidence of inter-annual variability in growth rates. This variability indicates that it would not be valid to apply an age length key to a year other than the one from which it was constructed.

Recruitment success in BAR 5 varies considerably between years, with length frequency data indicating relatively strong recruitment during the 1980s. Since 1987, only two strong newly recruiting year classes have been observed; 1989 and 1995. The 1989 year class dominated research survey and commercial landings from 1993 to 1996. The 1995 year class first appeared in the commercial fishery in 1997. This recruitment pattern is consistent with the drop in catch and CPUE observed during the mid 1990s.

2. Commercial catch and effort for BAR 5 1989–90 to 1997–98

2.1 Introduction

Barracouta form a moderate sized commercial fishery in New Zealand, with average annual landings over 25 000 t since the introduction of the Quota Management System (QMS) in 1986–87. They are widespread around the New Zealand coastline to depths of about 450 m (Anderson *et al.* 1998). BAR 5 (Figure 1) covers a wide area including Southland, Puysegur, the Stewart-Snares shelf (Fishery Management Area (FMA) 5), and the Sub-Antarctic and Bounty Plateau (FMA 6), but most catches are taken on the Stewart Snares shelf. Landings in this area have fluctuated from 1000 to 12 500 t since the introduction of the 200 mile Exclusive Economic Zone (EEZ) in 1978 (originally EEZ areas E(A) & F), with the peak occurring before the introduction of the QMS (Table 1). BAR 5 is made up of a target fishery and large bycatch component from the squid and jack mackerel target trawl fisheries.

Commercial catches declined to about 28% of the TACC from 1993–94 to 1996–97 but increased to 66% of the TACC in 1997–98 (*see* Table 1). Hurst & Bagley (1997b) analysed trends in biomass estimates in BAR 5 and suggested that recruitment may have been relatively low in the years after 1989 and that biomass may have declined between surveys by *Shinkai Maru* (1981 and 1986) and *Tangaroa* (annually from 1993 to 1996). The scale of the decline appeared to be greater than could be explained by the different catching efficiency of the two vessels.

Preliminary analysis of the proportion of barracouta bycatch in the squid fishery also suggested that abundance may have declined in the early to mid 1990s (T. Chatterton, MFish, pers. comm.).

This section reports on characterisation of the BAR 5 fishery. The following steps were taken:

1. Extract BAR 5 data for 1985–86 to 1987–98.
2. Construct a database and carry out gross error checks.
3. Analyse and summarise seasonality, distribution, and associated target species for the BAR 5 fishery.

First the data used will be described, then commercial catch and effort data will be summarised to describe patterns in the BAR 5 fishery. Finally, the results are summarised and conclusions made about the fishery.

2.2 Data

Data were obtained from the Ministry of Fisheries from a number of sources

- FSU data from 1985–86 to 1988–89
- CELR data from 1988–89 to 1997–98
- TCEPR data from 1988–89 to 1997–98

where the following criteria for fishing activity were met:

- FMA 5 and 6
- Bottom depth less than 400 m or not recorded

- Trawl methods and method not recorded

Examination of the different data sources led to the use of only the TCEPR tow by tow records. All tows in the TCEPR data that meet the selection criteria were loaded into a relational database.

The estimated catches by fishing year from the TCEPR data ranged from 88 to 107% of QMS totals, so it was felt that the data were representative of the fishery (Table 2). Records for 1988–89 were incomplete, especially for barracouta bycatch from the squid trawl fishery, so the 1988–89 data was excluded from the analysis.

Most annual barracouta catches were taken from the barracouta target fishery, and the squid and jack mackerel trawl fisheries. Due to the annual differences in distribution of the squid fisheries, squid tows were separated into those from FMA 5 and those from FMA 6 (hereafter referred to as SQU 5 and SQU 6). The target barracouta fishery and the three bycatch fisheries were examined in detail.

2.3 Summary of commercial catch and effort data

Catch

BAR 5 catches were highest in the late 1980s and early 1990s, peaking at 8817 t in 1990–91. Catches more than halved from 1993–94 to 1996–97, but increased again in 1997–98. The breakdown of barracouta catch by target fishery has changed throughout the 1990s (Table 3); SQU 5 produced the greatest barracouta landings up to 1994–95; SQU 5, SQU 6, and barracouta target landings were equal contributors in 1995–96; and SQU 5, jack mackerel, and barracouta target fisheries almost equally contributed in 1997–98 (Figure 2).

The reduction in catches during the mid 1990s appears to be due to both the decline in barracouta target catch and the large reduction in bycatch from the SQU 5 fishery. The increase in 1997–98 is associated with the emergence of the jack mackerel target fishery and an increase of target barracouta catches.

Ratio of barracouta bycatch to target species catch was examined for the three bycatch fisheries. With the exception of 1995–96, the bycatch ratio was higher in the early 1990s for the two squid fisheries. In 1995–96 the ratios are much higher than other years in the mid to late 1990s. In SQU 5 this is associated with a very low squid target catch which may indicate either increased barracouta abundance or incorrect target specification. In SQU 6 the ratio is considerably higher than any of the years for which large target catches occurred. As the target squid catch is not low, it is possible that environmental conditions may have resulted in increased barracouta abundance around the Auckland Islands.

Effort

Effort was examined in terms of number of tows and hours fished. Effort in the barracouta target fishery was variable, ranging from 209 tows in 1993–94 to 677 in 1994–95 (*see* Table 3). There is only a weak relationship between the total number of hours fished and catch, but both hours towed and catch increased in 1997–98 (Figure 3). The proportion of zero barracouta target tows ranged from 2 to 20% with a decline from 20% to 7% from 1995–96 to 1997–98. Mean tow duration has increased from 3.4 to 4.8 hours.

Effort in the SQU 5 fishery was also variable between years, ranging from 6192 tows in 1990–91 to 1801 in 1995–96. There is evidence of a relationship between hours fished and subsequent barracouta bycatch from 1989–90 to 1993–94, and both hours fished and barracouta bycatch increased in 1997–98 (*see* Figure 3). The proportion of tows where barracouta was not reported is variable, ranging from 0.31 in 1990–91 to 0.72 in 1994–95. The year with the highest proportion of zeros is the year where only 28% of the TACC was landed. Mean tow duration has increased from 3.3 to 4 hours.

The SQU 6 fishery had variable fishing effort with only 549 tows reported in 1992–93 (*see* Table 3). Barracouta bycatch was low in all years except 1995–96 when barracouta was recorded in 44% of all squid target tows. Aside from 1992–93, this was the only year when the proportion of zero tows fell below 0.86.

Effort in the jack mackerel fishery was low up until 1995–96 when 667 tows were reported and this increased in 1997–98 to 1247 tows (*see* Table 3). There is a strong relationship between levels of barracouta bycatch and hours fished (*see* Figure 3) but little relationship with the proportion of zeros.

Spatial distribution of the fisheries

The barracouta target fishery is concentrated in three main areas, along the edge of the Snares shelf, south of the Snares Islands on the 12 n.mile limit, and east of Stewart Island on the 12 n.mile limit (Figure 4). There is some evidence of less fishing effort around the Snares Islands in recent years compared to that in the early 1990s.

The squid target fishery is concentrated in two areas, north and east of the Auckland Islands, and along the southern edge of the Snares shelf (Figure 5). These two areas were separated into SQU 6 and SQU 5 respectively. In 1995–96, when the barracouta bycatch from the SQU 6 was 1591 t, there is no evidence that the fleet were catching barracouta in areas different to where they had caught them in other years.

The jack mackerel target fishery has been concentrated in two main areas since the increase in barracouta bycatch in 1995–96, east of Stewart Island on the 12 n.mile line, and along the southern edge of the Snares shelf (Figure 6). Bycatch from the jack mackerel fishery forms a relatively new component of the barracouta catch but its distribution is similar to part of the FMA 5 barracouta target fishery (i.e., to the south and east).

Seasonal distribution of the fisheries

The barracouta target fishery operates throughout the year, but most of the catch and effort occurs between October and May (Figure 7). In 1997–98 there were two main periods of catches in October to December and March to May. In the early 1990s considerable catches were also taken during January and February. Target catches in October to December are probably on spawning fish known to occur off Stewart Island (Hurst & Bagley 1997b).

All catches in the SQU 5 fishery are taken between December and July, but most of the catch is taken over a three month period from February to April (Figure 8). The seasonal pattern in the SQU 6 target fishery is similar (Figure 9).

The catch in the jack mackerel fishery in 1997–98 was mostly in March and April (Figure 10).

Catch rates

Mean and median catch rates (estimated as tonnes per nautical mile towed) were estimated for each year and fishery (*see* Table 3). The median catch rate was estimated as a robust measure due to the minimal data grooming of the data. Estimates of catch rates from the bycatch fisheries are based only on tows where barracouta was reported. Catch rates standardised to a value of 1 in 1989–90 are presented in Figure 11.

Mean and median catch rates were variable in all of the fisheries, with the lowest median catch rates for all fisheries observed in 1994–95. Catch rates appear to have increased slightly since then for all fisheries. An overall mean catch rate across all of the fisheries was calculated and is discussed in the section below.

Standardised CPUE analysis

As a further exploratory tool, a log-normal linear model (*after* Vignaux 1992) was used to model catch rates (tonnes per nautical mile towed) for tows where barracouta was either caught or targeted. CPUE was calculated by dividing the estimated catch by speed times duration. Tows were excluded where speed was either zero or greater than 5 knots, and where duration was zero. As log(CPUE) was used, a small constant (0.1) was added to all CPUE observations. A total of 22 013 observations were left: 563 represented barracouta target tows with zero catch. The variables used are given in Table 4. As over 150 vessels were represented in the data and only vessel ID was available, no vessel information was included in the analysis due to the excessive memory demands of using vessel as a categorical variable. The model had low explanatory power with the reduction in residual deviance 13% of the null deviance (Table 5). *Fishing year*, *month*, *statistical area*, and *gear* type were the variables selected by the model. *Target species* and *tow speed* were not selected by the model. The indices declined by at least 50% since 1989–90 (Table 6). Residual plots indicated problems due to the observations to which the small constant was added.

As the model included zero catches from barracouta target tows only, it was felt that it was inappropriate to use target tows and tows where barracouta was caught in an analysis for such a mixed fishery. The zero catches were then removed and the model refitted with an increase in the explanatory of the model to 20% (Table 7). *Target species* was selected by the model as the most important variable in addition to those selected in the first model (Table 8). This is consistent with the differences in catch rates between fisheries (*see* Table 3). The trend in the resulting indices was the same, but all indices were 15–45% higher. The 1997–98 year effect was 0.55. The model diagnostics plots were acceptable with no evidence of non-normality in the residuals.

Unstandardised CPUE was calculated across the entire fishery and is presented with the estimated year effects in Figure 12. All three series show the same trend, but the decline is much shallow for the unstandardised CPUE. The increase in 1995–96 appears to be due to the increased catch rates in the squid bycatch fisheries in that year (*see* Table 3 and Figure 11), and the increase in 1997–98 is driven mainly by the small increase in target barracouta catch rates and the large increase in catch rates observed in the jack mackerel fishery (*see* Table 3 and Figure 11).

2.4 Discussion

The BAR 5 fishery is complex with both target and bycatch components. Catches were closely related to fishing effort in the early 1990s, but during the mid to late 1990s, when catches were lowest, there was little correlation between effort and catch and catch rates were generally lower. Catches increased in 1997–98 to levels not reached since 1992–93. This appears to be driven by both increased effort in the barracouta target, SQU 5 bycatch, and jack mackerel fisheries, and increased catch rates in the jack mackerel fishery (*see* Table 3 and Figure 11). Increased CPUE in 1997–98 appears to be driven by increased catch rates in both the target barracouta fishery and jack mackerel fishery.

To better understand this fishery it is recommended that a full standardised CPUE analysis be undertaken. The analysis should include vessel characteristics and all tows from the four fisheries (including tows for the other target fisheries where barracouta was not recorded), and be performed using a gamma log-link model or similar to incorporate the many zero tows.

3. Age determination and catch-at-age for BAR 5

3.1 Introduction

No growth parameters for barracouta (*Thyrsites atun*) in New Zealand waters are listed in the most recent Fishery Assessment Plenary report (Annala *et al.* 1999). Hurst & Bagley (1987) presented mean length at age data for barracouta from around the Chatham Islands in December 1984, based on counts of assumed annual zones in whole otoliths. They found a maximum age of 10 years, but concluded that this could be an underestimate because a high proportion of otoliths from large fish was classified as unreadable. (Hurst & Bagley (1992) noted that the 1982 year class, which was absent as age 2 fish in the 1984 survey, was also weak as age 3 in the 1985 survey length frequencies. This, suggested that the presence of strong and weak year classes could be used to validate age classes, at least in younger fish.

Grant *et al.* (1978) presented age and growth data for barracouta from three areas off southeastern Australia, based on an examination of whole otoliths in 50% ethanol against a dark background. They found no differences in growth between sexes up to age 6, and presented mean length at age data for the three areas. Von Bertalanffy parameters were fitted to only one of the data sets; the authors concluded that the von Bertalanffy model did not fit the data from the other two areas.

A large collection of otoliths was obtained during four comparable research trawl surveys of the Southland shelf (BAR 5) in February-March 1993–96. Analyses of the data indicated that recruitment of barracouta may have been poor in recent years (Hurst & Bagley 1997b), so it is possible that, with strongly variable recruitment, the population may comprise a few clearly discernible year classes. Collections of Ministry of Fisheries Scientific Observer Programme (observer) length-frequency data were also available from BAR 5 from 1987 to 1998, as a result of sampling bycatch species in the Snares squid target trawl fishery.

This section reports on a project with the following aims.

1. To age barracouta from Southland trawl surveys in 1993–96 and produce von Bertalanffy growth parameters, by examining the progression of modes in length-frequency data, and counting zones in otoliths.
2. To develop age-length keys for male and female barracouta from BAR 5 in summer-autumn, 1993–96.
3. To summarise observer length frequencies in BAR 5, 1987–98.
4. To develop a time series of age-frequencies from the commercial catch of barracouta from observer data in BAR 5, 1993–96.

3.2 Methods

Age determination

The structure of barracouta and gemfish (*Rexea solandri*) otoliths appears similar, so barracouta otoliths were read in the same way that gemfish are (i.e., whole, untreated otoliths were examined in water against a dark background, with illumination from reflected light). A similar method was used by Grant *et al.* (1978) for barracouta, and in a study to validate the age and growth of gemfish (Horn & Hurst 1999).

Otoliths were available from four trawl surveys of the Southland shelf (Table 9). Otoliths from the first four peaks in the length-frequency distribution from survey TAN9301 were examined (Figure 13). It was considered likely that these peaks represented age classes 0+, 1+, 2+, and 3+. The number of complete translucent (dark) zones in the otoliths was counted, and the distance from the nucleus to the outer margin of each translucent zone (along the longitudinal axis to the posterior edge) was measured on several otoliths. This information enabled the interpretation of patterns of juvenile growth in otoliths.

Samples of 250–300 otoliths were then selected for reading from each of the four trawl surveys. Otoliths were selected so that each sample distribution approximated the shape of the survey length-frequency distribution, and all possible 1 cm length classes were represented.

Von Bertalanffy growth curves were fitted to the age-length data from the four Southland trawl surveys combined using a non-linear least-squares regression procedure (SAS Institute 1988). Separate equations were derived for each sex. Time elapsed between the 'birthday' for barracouta (taken as 1 October) and date of sample (taken as 1 March) was accounted for by adding 0.5 years to all estimates of age.

Mean lengths at age, for both sexes, were calculated from each survey and compared to see whether there were any significant differences in growth rates between years.

Age-frequency distributions

Catch-at-age distributions were calculated separately by sex for each trawl survey sample using the total scaled length-frequency and the otoliths read, in the following manner:

$$A_t = \Sigma_x(L_x\, p_{tx})$$

where A_t is the estimated proportion of fish of age t in the population, L_x is the proportion of fish of length x in the length-frequency sample, and p_{tx} is the proportion of fish of length x which were age t. A single age-length key, using the data from the four surveys combined, was also calculated.

Commercial length-frequency data are available from 1987 (*see* Table 9). However, in 1987 and 1988, most of the measured fish were unsexed, so a combined-sex length-frequency distribution was calculated for these years. In 1989, 1990, and 1992 less than 150 fish were measured, precluding the calculation of useful length-frequency distributions.

Catch-at-age distributions for the commercial catch of barracouta in BAR 5 from 1993 to 1996 were calculated in a manner similar to those for the trawl surveys, except that the total scaled length-frequency was derived from observer data collected during the period January–May each year. In each of the four years, the actual age data from the relevant trawl survey was applied to the length-frequency data to produce a catch-at-age distribution. To examine the applicability of using all the available age data to calculate a catch-at-age distribution in years where there were sufficient length-frequency data, but no trawl survey age data, the age-length key derived from all surveys combined was used to produce catch-at-age distributions for the 1991 and 1997 commercial catches.

3.3 Results

Otolith interpretation

Otoliths in the first four modes of the TAN9301 length-frequency distribution were found to have 0, 1, 2, and 3 complete translucent zones, respectively. Measurements of the first three zones are presented in Table 10. In general, these zones were quite clear, although multiple banding within individual zones was sometimes apparent. The width, and thus the visibility, of the first translucent zone could also vary considerably between (and sometimes within) year classes. This characteristic sometimes aided age determinations. For example, the 1+ year class in 1995 had quite a faint and thin first translucent zone, but this characteristic helped distinguish between 1+ and 2+ fish in 1996. In 1994, the 1+ year class exhibited quite a broad and bimodal distribution (*see* Figure 13). The smaller fish generally had a faint first zone, but in larger ones it was usually very distinct. This broad length range continued in 1995 when the fish were 2+. A degree of bimodality is still apparent in the female distribution, and the visibility difference in the first zone in otoliths of small and large fish from this year class was still apparent.

Zone counts were made, wherever possible, at various places on each otolith. Zone width could be very narrow after age 4, particularly on the dorsal and ventral margins, but was often quite clear even at these sites. The posterior margin and, particularly, the anterior rostrum exhibited broader zones. Maximum ages of 12 years for females and 10 years for males were obtained.

Growth parameters

Von Bertalanffy growth parameters by sex, with 95% confidence intervals, were calculated using all the age data from the four trawl surveys (Table 11). Data points for unsexed fish (the 0+ age class) were included in the calculations for both sexes. Female fish have a significantly larger L_∞ than males, and females may also have a slightly greater life expectancy (Figure 14).

Estimates of mean length at age are listed in Table 12. For both sexes, there were some statistically significant between-year differences at ages 0, 2, and 3 ($p < 0.05$), but no differences between years for age classes 1 and 4 to 10.

All age data were recorded on the *age* database administered by NIWA for the Ministry of Fisheries.

Trawl survey age-frequency distributions

Age-frequency distributions, by sex, for the four Southland trawl surveys are presented in Figure 15. Distributions by sex from individual surveys exhibit generally similar shapes. The progression of a strong year class (spawned in late 1989 and aged 3+ in 1993) is apparent throughout the entire series of distributions. Recruitment in the years immediately following 1989 appears to have been relatively poor, though there is an indication that in 1992 recruitment may have been moderately successful. Fish aged 0+ occur in only the first and last surveys of the series, representing the 1992 and 1995 year classes (*see* Table 12).

The progression of a single, strong year class which, by 1996, comprises a major proportion of the adult population, is supported by an apparent progression of the adult mode in the scaled length-frequency distributions from the survey series (*see* Figure 13).

An age-length key, based on data from the four surveys combined, is presented in Table 13.

Commercial catch age-frequency distributions

Scaled length-frequency distributions from the commercial fishery in BAR 5 from January to May are presented in Figure 16 (some years in the series are missing owing to insufficient data). In 1987, most of the measured fish were probably aged 1+ to 4+ years (from Table 12); the catch contained relatively few fish larger than 67 cm. The 1988 distribution contained a high proportion of fish with a likely age range of 2–5 years. From 1993 to 1997, mean fish size appears to have steadily increased, and small fish were virtually absent from the commercial catch. In 1998, mean fish size decreased, and there was a clear mode of fish at about 53 cm probably aged 2+ (also apparent in the 1997 distribution at about 38 cm). There was also a reasonable number of fish with lengths 62–72 cm (and a likely age range of 4–5 years).

Calculated age-frequency distributions are shown in Figure 17. (Note that the 1991 and 1997 distributions are based on an age-length key from the four intermediate years combined.) The 1989 year class is abundant in the commercial catch from 1993 to 1997, and occurs in small numbers in the 1991 distribution as 1+ fish. There appears to have been a relatively strong year class spawned in late 1995, apparent as 1+ fish in 1997 and 2+ in 1998.

The commercial fishery length-frequency distributions from 1991 to 1997 show a trend similar to the trawl survey series of an adult population increasing in mean size during a period of apparently poor recruitment.

3.4 Discussion

It appears possible to age barracouta by counting translucent zones in whole, untreated otoliths. The number of zones in otoliths from fish in juvenile length-frequency modes increased by one in each consecutive mode. Counts of zones in otoliths collected from 1993 to 1996 identified a strong year class spawned in 1989 (also supported by the progression of length-frequency modes), indicating that one translucent zone is formed each year in otoliths. Although this study does not constitute a complete validation of the ageing method (fish age at the formation of the first translucent zone has not been determined), it is strongly indicative that otoliths can be used successfully for ageing this species.

Mean lengths at age calculated from all the Southland survey data combined (Table 14) are similar to values calculated for Chatham Islands barracouta by Hurst & Bagley (1987). Estimates for Australian barracouta are slightly higher than for New Zealand fish (Table 14).

Differences in growth rates between years are apparent, particularly for juvenile fish, which have relatively large annual growth increments. For this reason, juvenile year classes cannot always be reliably aged from the position of their mode in a length-frequency distribution. For example, the modal length of 2+ fish in 1995 is about half way between the modes of 2+ and 3+ fish in 1993. There is also a likelihood of extended or multiple spawning in some years; the distribution of 1+ fish in 1994 is clearly bimodal (*see* Figure 13). Although the main Southland barracouta spawning season is known to be spring-summer, trawl surveys in February-March consistently produced some actively spawning fish (e.g., Hurst & Bagley 1994).

The relative strengths of year classes in age distributions for 1993 to 1996 trawl surveys and the commercial fishery are quite similar for all years for fish aged above age 5. However, the trawl survey distributions have a higher proportion of fish aged 5 and below. This is probably because the surveys sample the entire shelf from depths of 30–600 m, whereas the commercial data are mostly from outside the 12 n.mile limit in waters deeper than 100 m. Thus, although the commercial age distributions can be used to estimate catch at age of the adult population, trawl survey data would provide more reliable estimates of year class strength because more observations of each year class can be made. Trawl survey age frequencies would be essential if predictions of recruitment to the fishery were required.

Recruitment success has clearly varied considerably in BAR 5, at least since the early 1980s. The length-frequency distributions from 1987 and 1988 indicate relatively strong recruitment for at least some of the years from 1982 to 1985 (and possibly poor recruitment for some years prior to 1982). The 1989 year class comprised a major proportion of the commercial catch from 1994 to 1997. The 1995 year class was recorded in the 1996 trawl survey as 0+ fish (although in numbers too small to be apparent on Figure 15), and was the first year class to be recorded in reasonable numbers as 1+ and 2+ fish in commercial landings since 1991. Reliable information on recruitment success since 1995 is not yet available.

There is also evidence of a similar pattern of relative year class strengths of barracouta through the early 1990s from a time series of surveys off the east coast of the South Island (Beentjes & Stevenson, in press). Surveys from 1991 to 1996 indicated weak year classes were spawned from 1991 to 1994, with 1995 being relatively strong. These surveys also show a strong year class in 1989 but, unlike the Southland data, there was also a strong year class in 1990.

The catch-at-age distributions for 1991 and 1997 demonstrate the problems of constructing age distributions using data from other years. The 1991 length-frequency distribution has a clear mode of fish between lengths of about 46 and 56 cm that probably comprise a single year class of either 2+ or 3+ fish. However, the age-length key has allocated these fish almost equally to age classes 2 and 3. In the 1997 catch-at-age distribution, the estimated number of 7 year old fish (known to be the dominant year class) is only slightly higher than estimated numbers of fish aged 6 and 8 years. A sample of otoliths from 1997 would almost certainly show a greater proportion of aged 7 barracouta. It is concluded, therefore, that the age-length key given in Table 13 is likely to provide misleading age distributions if applied to any set of length data from BAR 5.

It would also not be advisable to use the age-length key developed for BAR 5 for any of the other South Island fisheries. Tagging work (Hurst & Bagley 1989) suggested that barracouta in FMA 3 are probably part of a separate stock (BAR 1) and although there may be some movement of BAR 5 fish into FMA 7 to spawn (*see* Hurst & Bagley 1997a), there is also likely to be a resident population in FMA 7 as well.

4 GENERAL CONCLUSIONS

- The Southland barracouta catch is taken by both target and non-target trawling: most of the non-target fishing is directed at squid and, more recently, jack mackerel. There is no direct relationship between target species catch and barracouta bycatch in FMA 5, except for jack mackerel.

- There has been a decline in barracouta catch from the peak of about 12 500 t in 1984–85 to less than 3000 t during the mid 1990s. The decline since 1990–91 is associated with a decline in CPUE by at least 40–50%.

- The increase in catch in 1997–98 was caused mainly by about 1750 t of bycatch in the developing jack mackerel target fishery.

- Barracouta age frequencies from 1993 to 1996 (research survey and commercial catch samples) indicate that the recruited (age 3 years and older) population contained about five main year classes in 1993. From 1994 to 1996, the recruited population became more dominated by one year class spawned in 1989. There does not appear to have been another relatively strong year class spawned until 1995, which started recruiting to the commercial fishery in 1997 and 1998.

- The apparent lack of strong recruitment during the mid 1990s suggests that the declining trend in catch and CPUE over this period is reflecting a general decline in abundance.

- Continued monitoring of this fishery would require analysis of catch and CPUE in both target and non-target fisheries, as well as determination of age frequencies. Data are being collected on catch and effort, but age frequencies cannot be determined without otoliths being read annually from either commercial or research sampling.

- The data presented in this report address concerns about the barracouta fishery during the 1990s. Any attempt to use these data in a population model would require inclusion of catch data from the start of the fishery (mid 1970s) and should ideally include catch and effort data for the full period, as well as age frequencies from trawl surveys carried out in the 1980s, where appropriate.

5 ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries (code MOF801a). We would like to thank Stuart Hanchet for a constructive review of an earlier draft which greatly improved the final manuscript.

6 REFERENCES

Anderson, O.F., Bagley, N.W., Hurst, R.J., Francis, M.P., Clark, M.R., & McMillan, P.J. 1998: Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report* 42. 303 p.

Annala J.H., Sullivan, K.J., & O'Brien, C.J., (Comps.) 1999: Report from the Fishery Assessment Plenary, April 1999: stock assessments and yield estimates. 430 p. (Unpublished report held in NIWA library, Wellington).

Beentjes, M., Stevenson, M. (in press): Review of southeast South Island winter trawl survey time series (1991–96). *NIWA Technical Report* xx. xx p.

Grant, C.J., Cowper, T.R., & Reid, D.D. 1978: Age and growth of snoek, *Leionura atun* (Euphrasen) in South-eastern Australian waters. *Australian Journal of Marine and Freshwater Research 29*: 435–444.

Horn, P.L. & Hurst, R.J. 1999: Age and stock structure of gemfish (*Rexea solandri*) in New Zealand waters. *Marine and Freshwater Research 50*: 103–115.

Hurst, R.J. 1988: The barracouta, *Thyrsites atun*, fishery around New Zealand, historical trends to 1984. *N.Z. Fisheries Technical Report No. 5.* 43 p.

Hurst, R.J. & Bagley, N.W. 1987: Results of a trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1984. *N.Z. Fisheries Technical Report No. 3.* 44 p.

Hurst, R.J. & Bagley, N.W. 1989. Movements and possible stock relationships of the New Zealand barracouta, *Thyrsites atun,* from tag returns. *New Zealand Journal of Marine and Freshwater Research 23:* 105–111.

Hurst, R.J. & Bagley, N.W. 1992: Trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1985. *N.Z. Fisheries Technical Report No. 30.* 36 p.

Hurst, R.J. & Bagley, N.W. 1994: Trawl survey of inshore and middle depth species off Southland, February-March 1993 (TAN9301). *N.Z. Fisheries Data Report No. 52.* 58 p.

Hurst, R.J. & Bagley, N.W. 1997a: Trawl survey of shelf and upper slope species off southern New Zealand, November 1986. *N.Z. Fisheries Technical Report No. 47.* 38 p.

Hurst, R.J. & Bagley, N.W. 1997b: Trends in Southland trawl surveys of inshore and middle depth species, 1993–96. *N.Z. Fisheries Technical Report No. 50.* 67 p.

SAS Institute 1988: SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc. 1028 p.

Vignaux, M. 1992: Catch per unit effort (CPUE) analysis of the hoki fishery. *New Zealand Fisheries Assessment Research Document 92/14.* 31 p.

Table 1: **Reported landings (t) for barracouta in EEZ Areas E(A) and F (to 1983–83) and BAR 5 (from 1983–84), and TAC for BAR5 from 1986–87. Catches before 1983–84 are minimum estimates and do not include landings by domestic inshore vessels, or foreign vessels other than Japanese vessels before 1978–79 (*see* Hurst 1988, table 5). Catches from 1983–84 are from Annala *et al.* (1999)**

Year*	Landings	Year	Landings	TAC
1975–76	770	1986–87	7 653	9 010
1976–77	440	1987–88	6 457	9 010
1977–78	1 590	1988–89	5 323	9 010
1978–79	1 080	1989–90	5 960	9 282
1979–80	7 190	1990–91	8 817	9 282
1980–81	4 560	1991–92	6 897	9 282
1981–82	7 780	1992–93	7 019	9 281
1982–83	5 690	1993–94	3 410	9 282
1983–83	880	1994–95	2 645	9 282
1983–84	11 291	1995–96	4 255	9 282
1984–85	12 487	1996–97	2 839	9 282
1985–86	6 380	1997–98	6 167	9 282

* Years before 1983 are 1 Apr-31 Mar; 1983, 1 Apr-30 Sep; from 1983–84, 1 Oct-30 Sep.

Table 2: **Estimated BAR 5 catches (t) from TCEPR data, QMS totals, and TCEPR as a % of QMS for 1989–90 to 1997–98**

	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98
TCEPR	5 498	8 566	6 426	7 490	3 011	2 466	4 115	2 499	5 373
QMS	5 960	8 817	6 897	7 019	3 410	2 645	4 255	2 839	6 167
% QMS	0.92	0.97	0.93	1.07	0.88	0.93	0.97	0.88	0.87

Table 3: **BAR 5 catch and effort data for the barracouta, squid, and jack mackerel target fisheries in FMA 5 and 6 for 1989–90 to 1997–98 (mean and median catch rates are in tonnes per nautical mile towed)**

	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98
BAR									
Catch BAR (t)	2 928	1 287	1 499	1 686	1 192	978	1 009	991	1 839
Catch target (t)	2 928	1 287	1 499	1 686	1 192	978	1 009	991	1 839
By catch / target	1	1	1	1	1	1	1	1	1
Total tows	635	435	565	406	209	677	612	335	518
Tows catching	620	358	454	373	168	554	489	287	481
Prop zeros	0.02	0.18	0.20	0.08	0.20	0.18	0.20	0.14	0.07
Mean tow (hours)	3.4	3.6	4.1	3.7	4.1	4.2	4.3	4.6	4.8
Mean catch rate	0.35	0.23	0.18	0.38	0.44	0.09	0.12	0.20	0.22
Median catch rate	0.24	0.09	0.07	0.14	0.08	0.04	0.03	0.06	0.07
SQU 5									
Catch BAR (t)	1 977	6 969	4 723	5 479	1 626	1 268	1 145	1 147	1 643
Catch target (t)	8 456	15 933	26 704	23 931	13 036	22 865	4 093	14 343	17 584
By catch / target	0.23	0.44	0.18	0.23	0.12	0.06	0.28	0.08	0.09
Total tows	1 702	6 192	3 953	5 255	2 055	4 201	1 801	3 582	3 972
Tows catching	894	4 360	1 637	3 453	797	1 170	885	1 263	1 437
Prop zeros	0.47	0.30	0.59	0.34	0.61	0.72	0.51	0.65	0.64
Mean tow (hours)	3.3	3.5	3.3	3.4	3.5	3.7	3.8	3.8	4.0
Mean catch rate	0.19	0.15	0.23	0.13	0.19	0.09	0.12	0.08	0.08
Median catch rate	0.07	0.06	0.08	0.06	0.06	0.02	0.03	0.02	0.03
SQU 6									
Catch BAR (t)	307	262	80	193	119	69	1 591	64	12
Catch target (t)	20 654	10 535	10 532	1 438	32 373	29 162	14 513	19 463	7 056
By catch / target	0.01	0.02	0.01	0.13	0.00	0.00	0.11	0.00	0.00
Total tows	4 974	2 889	1 969	549	4 508	3 732	4 044	3 513	1 354
Tows catching	556	399	75	201	219	131	1 781	411	26
Prop zeros	0.89	0.86	0.96	0.63	0.95	0.96	0.56	0.88	0.98
Mean tow (hours)	3.5	3.4	3.9	3.3	4.1	4.3	3.7	4.1	3.0
Mean catch rate	0.04	0.06	0.09	0.09	0.04	0.04	0.07	0.01	0.05
Median catch rate	0.01	0.02	0.03	0.04	0.01	0.00	0.03	0.01	0.03
JMA									
Catch BAR (t)	92	5	53	62	49	52	274	240	1 748
Catch target (t)	178	87	469	432	321	944	4 286	3 371	8 193
By catch / target	0.52	0.06	0.11	0.14	0.15	0.06	0.06	0.07	0.21
Total tows	44	40	142	112	59	154	667	447	1 247
Tows catching	41	16	74	59	25	48	269	195	727
Prop zeros	0.07	0.73	0.55	0.49	0.63	0.74	0.64	0.58	0.44
Mean tow (hours)	4.0	2.9	3.1	2.3	2.5	3.2	3.3	2.9	3.1
Mean catch rate	0.16	0.03	0.06	0.11	0.20	0.14	0.11	0.11	0.21
Median catch rate	0.13	0.02	0.03	0.07	0.07	0.04	0.04	0.07	0.12

Table 4: **Variables used in the standardised CPUE analysis**

Variable	No. levels	Description
Fishing year	9	Fishing years 1989–90 to 1997–98
Month	12	Month of year
Statistical area	19	Statistical area reported for tow
Target species	4	Target species of tow: BAR, JMA, SQU 5 & SQU 6
Speed	continuous	Tow speed reported for the tow
Gear	2	Gear type: bottom or midwater trawl

Table 5: **Variables selected and model deviance from the LNL model using all tows**

Step	Variable	Cumulative % deviance
1	Fishing year	5.1
2	Month	8.6
3	Statistical area	12.5
4	Gear	13.1

Table 6: **Estimated year effects from the LNL model using all tows**

Year	Index	SE
1989–90	1.000	0.000
1990–91	0.674	0.033
1991–92	0.579	0.034
1992–93	0.575	0.030
1993–94	0.537	0.035
1994–95	0.264	0.015
1995–96	0.438	0.023
1996–97	0.265	0.015
1997–98	0.473	0.026

Table 7: **Variables selected and model deviance from the LNL model excluding zero target tows**

Step	Variable	Cumulative % deviance
1	Year	5.7
2	Target species	14.3
3	Month	18.0
4	Gear	19.4
5	Statistical area	20.3

Table 8: **Estimated year effects from the LNL model excluding zero target tows**

Year	Index	SE
1989–90	1.000	0.000
1990–91	0.879	0.036
1991–92	0.818	0.040
1992–93	0.695	0.031
1993–94	0.783	0.043
1994–95	0.327	0.016
1995–96	0.627	0.028
1996–97	0.326	0.015
1997–98	0.546	0.026

Table 9: **Details of length-frequency and otolith samples examined in this analysis, and derived from trawl surveys and Scientific Observer Programme sampling in the vicinity of the Southland shelf. *N*, length-frequency sample size; *n*, number of aged fish**

		Trawl survey		Observer
Year	Trip code	*N*	*n*	*N*
1987	–			2 913
1988	–			2 912
1989	–			102
1990	–			0
1991	–			2 202
1992	–			150
1993	TAN9301	5 909	283	3 620
1994	TAN9402	3 602	287	5 420
1995	TAN9502	3 501	277	1 969
1996	TAN9604	4 161	255	2 271
1997	–			948
1998	–			1 583

Table 10: **Mean radial measurements (mm, with standard deviations) from the nucleus to the outer portion of the first, second, and third complete translucent zones in barracouta otoliths. Measurements were taken along the longitudinal axis posterior to the nucleus**

Zone	Radius length	s.d.	*n*
1	2.02	0.15	40
2	3.14	0.17	30
3	3.84	0.21	24

Table 11: **Von Bertalanffy parameters (with 95% confidence intervals), by sex, for barracouta from the Southland shelf. Parameters reported for eastern Tasmanian barracouta by Grant *et al.* (1978), fitted using ages from fish aged 2 to 9 years and with t_0 constrained to equal –0.25, are also listed**

Group	*n*	L_∞		*k*		t_0	
Male	534	81.1	(80.0–82.2)	0.336	(0.314–0.357)	–0.35	(–0.46 to –0.24)
Female	577	89.3	(87.6–91.0)	0.259	(0.240–0.278)	–0.60	(–0.74 to –0.46)
Tasmania	838	91.0		0.420		–0.25	

Table 12: **Mean length at age (cm, with standard deviation) for barracouta from the four Southland trawl surveys, by sex, where $n \geq 3$. True ages are about 0.5 years greater than the value listed in the 'Age' column**

Age	1993		1994		1995		1996	
	Mean	s.d.	Mean	s.d	Mean	s.d.	Mean	s.d.
Unsexed								
0	17.8	1.8	–		–		12.5	1.9
Male								
1	37.9	3.5	39.6	4.0	34.4	5.9	39.5	3.5
2	48.0	3.0	55.6	1.8	52.6	3.2	48.6	3.2
3	57.4	2.3	58.6	1.8	62.7	1.8	61.5	2.5
4	63.4	2.0	63.7	2.6	64.9	1.5	64.5	2.7
5	68.4	2.8	69.1	2.2	69.0	2.9	67.8	2.6
6	69.7	3.0	72.8	3.5	72.2	2.6	70.9	2.5
7	74.5	3.3	74.6	4.3	74.6	3.3	74.0	4.3
8	78.7	3.0	78.5	4.0	80.2	4.7	78.6	3.8
9	80.6	4.0	77.6	5.7	79.3	4.3	79.6	3.0
10	–		80.7	5.1	80.5	3.5	–	
Female								
1	38.7	3.4	38.8	3.3	35.4	5.0	39.2	3.0
2	48.6	2.2	56.0	1.8	53.5	3.8	48.6	3.2
3	57.4	2.4	58.3	2.0	64.1	2.0	62.5	2.4
4	65.0	2.5	65.4	2.4	65.7	2.0	66.1	1.3
5	68.1	3.1	69.1	2.2	69.8	2.5	69.7	1.8
6	72.0	3.3	73.3	2.4	72.6	2.6	73.3	2.8
7	78.1	2.8	77.0	3.8	76.6	3.7	77.2	4.7
8	83.1	5.8	80.5	4.1	80.9	4.4	83.8	3.9
9	84.8	5.4	86.1	5.9	83.2	3.7	87.0	5.4
10	86.9	5.4	86.7	4.4	87.8	6.0	82.5	3.4
11	–		–		92.2	3.1	–	

Table 13: **Age-length key, by sex, for barracouta based on age data from trawl surveys of the Southland shelf, and applicable to fish caught in summer-autumn. Values show percentages of each specified length class occurring in each age class**

	Age class												
Length	0	1	2	3	4	5	6	7	8	9	10	11	12
Male													
11–25	100												
26–42		100											
43–45		55	45										
46–52			100										
53–54			75	25									
55–56			65	35									
57–58			33	67									
59–60				62	38								
61–62				42	52	6							
63–64				20	68	6	6						
65–66				6	50	29	12	3					
67–68					16	49	32	3					
69–70					2	40	33	21	2	2			
71–72						24	43	29	2	2			
73–74						3	32	34	18	13			
75–76						3	16	34	31	13	3		
77–78							7	27	36	23	7		
79–80								24	48	20	8		
81–82								19	38	38	5		
83–84									47	33	20		
>84									50	37	13		
Female													
11–25	100												
26–42		100											
43–45		44	56										
46–52			100										
53–54			62	38									
55–56			54	46									
57–58			47	53									
59–60				81	19								
61–62				46	46	8							
63–64				32	52	12	4						
65–66				17	50	23	7	3					
67–68					43	48	9						
69–70					5	53	40	3					
71–72						22	54	19	5				
73–74						7	58	28	7				
75–76						3	37	36	16	8			
77–78							16	38	32	11	3		
79–80							3	41	41	9	6		
81–82								35	42	11	4	8	
83–84								19	38	31	12		
85–86									43	47	5	5	
87–88									64	18	18		
89–90									15	47	23	15	
>90									18	27	27	18	10

***Table 14*: Mean length at age (cm) for barracouta, by sex where available and where $n \geq 4$, from the Southland shelf (BAR 5) from the current study, the Chatham Islands (BAR 4) from Hurst & Bagley (1987), and from off the Australian coasts of Victoria and eastern Tasmania from Grant *et al.* (1978).**

	BAR 5		BAR 4		Victoria	Tasmania
Age	Male	Female	Male	Female	All fish	All fish
1	38.1	37.8	29.6	31.4	–	–
2	51.8	52.1	–	–	59.3	62.5
3	60.1	59.9	58.3	57.5	63.8	72.4
4	63.9	65.4	65.7	67.2	68.7	80.3
5	68.7	69.2	68.0	71.8	75.1	82.1
6	71.1	72.8	72.9	75.8	80.7	85.1
7	74.5	77.3	75.9	78.5	84.3	87.9
8	79.0	81.8	–	80.3	87.3	89.2
9	79.4	84.6	–	81.5	88.2	91.7
10	81.3	86.3	–	–	–	–
11	–	88.0	–	–	–	–

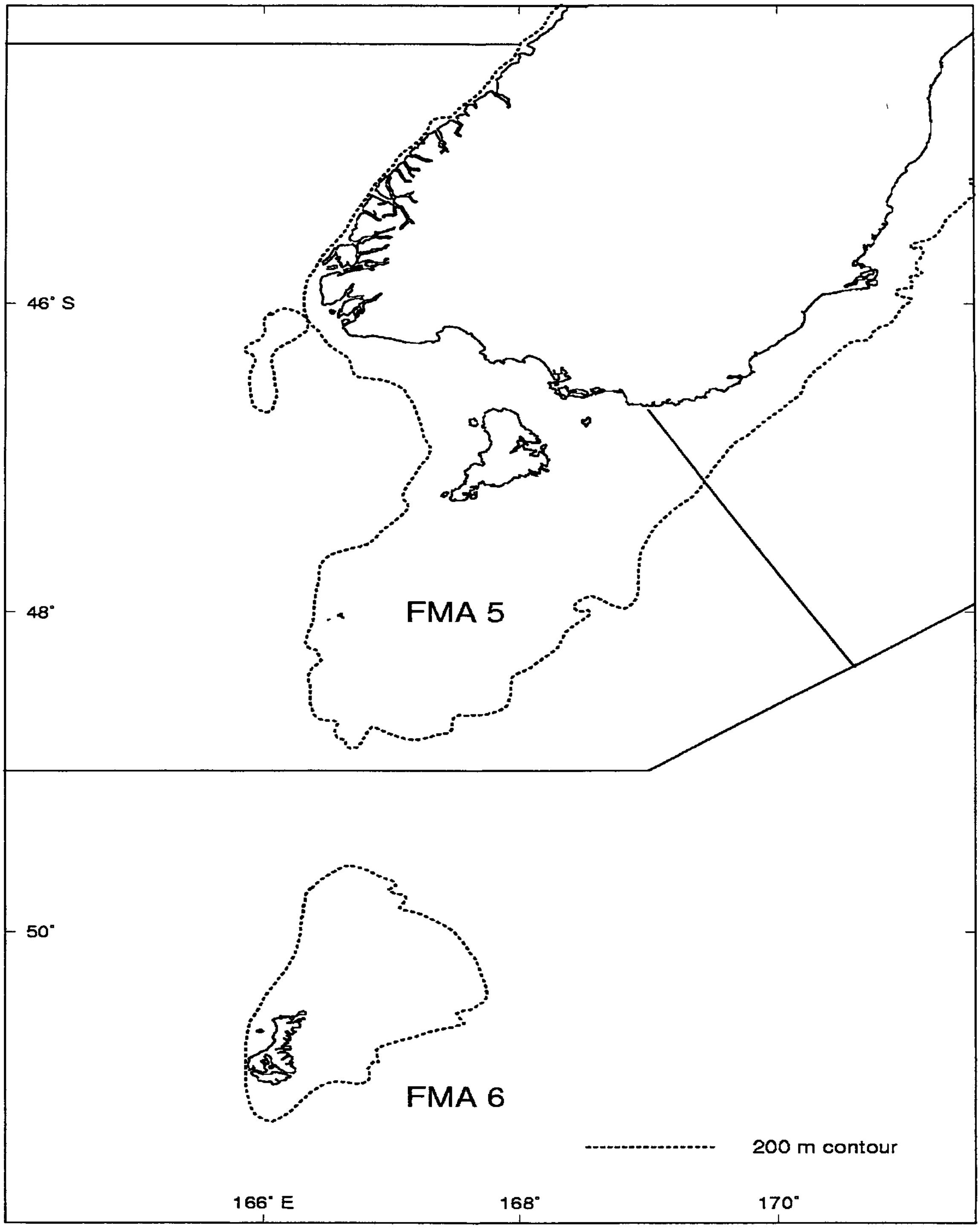

Figure 1: Areas of FMA 5 and 6 .

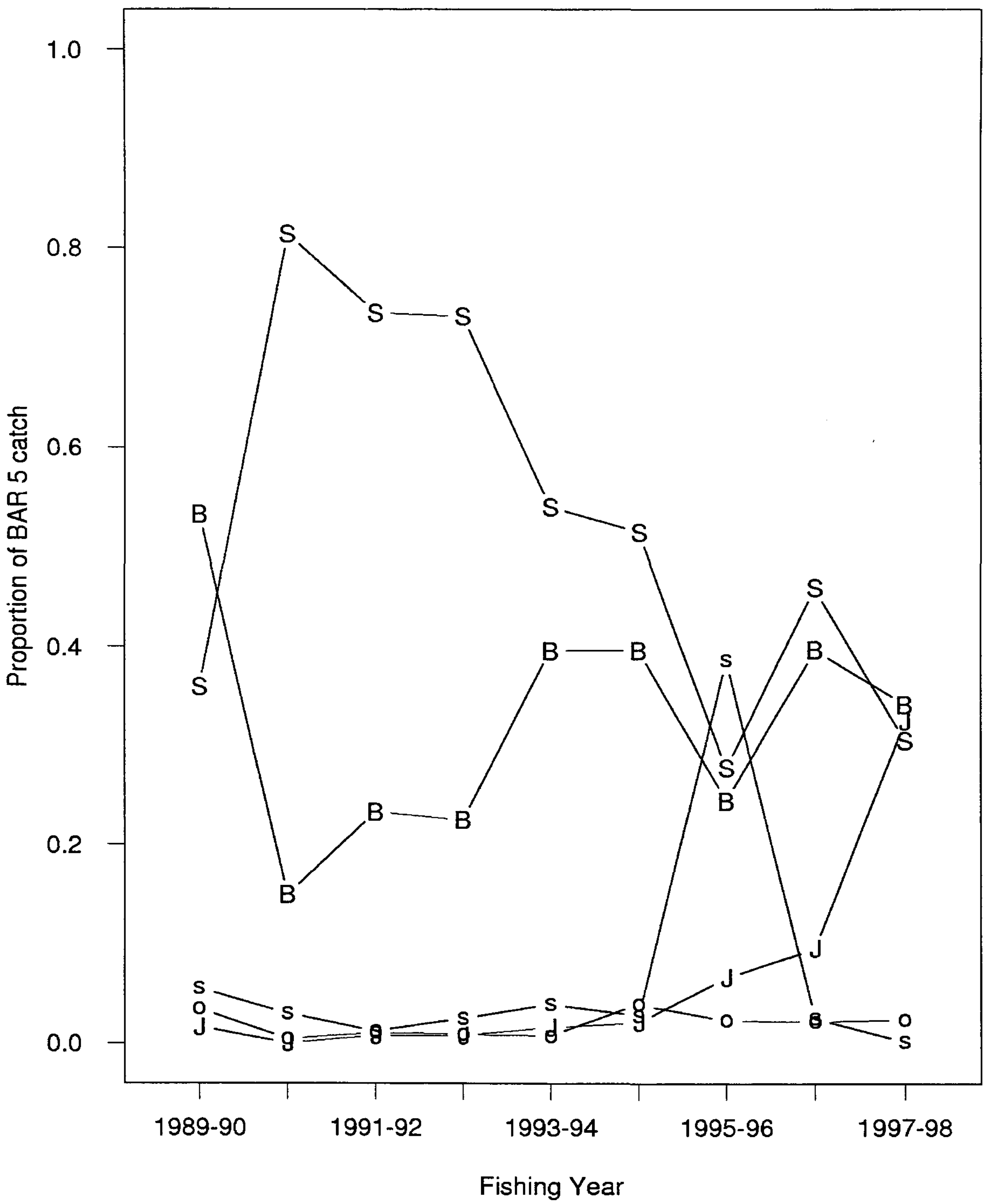

***Figure 2*: Proportion of BAR 5 catch by target fishery for 1989–90 to 1997–98 (B = BAR, S = SQU 5, s = SQU 6, J = JMA, o = other).**

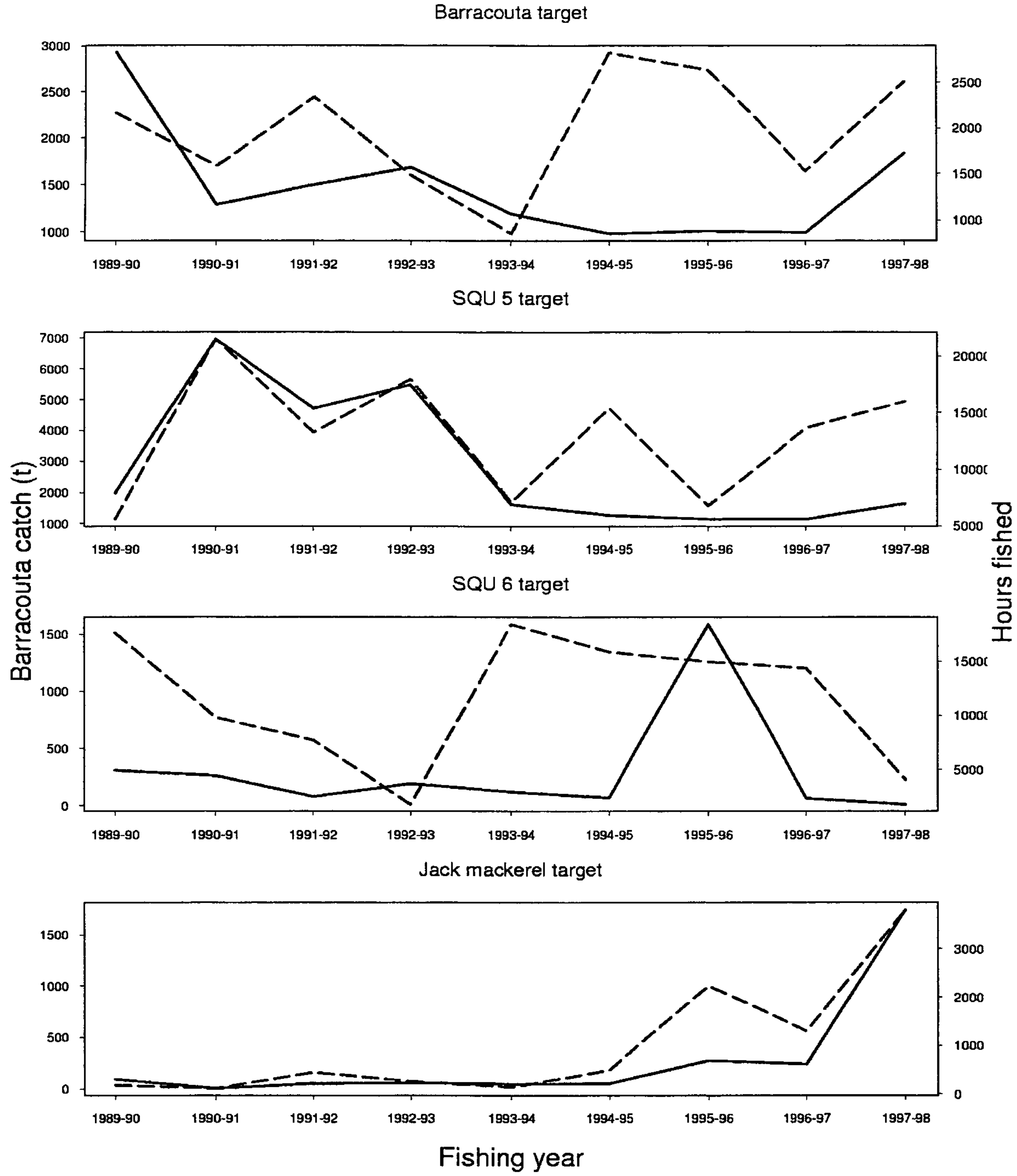

Figure 3: **BAR 5 catch (solid line) and hours fished (dashed line) by target fishery for 1989–90 to 1997–98 (B = BAR, S = SQU 5, s = SQU 6, J = JMA, o = other).**

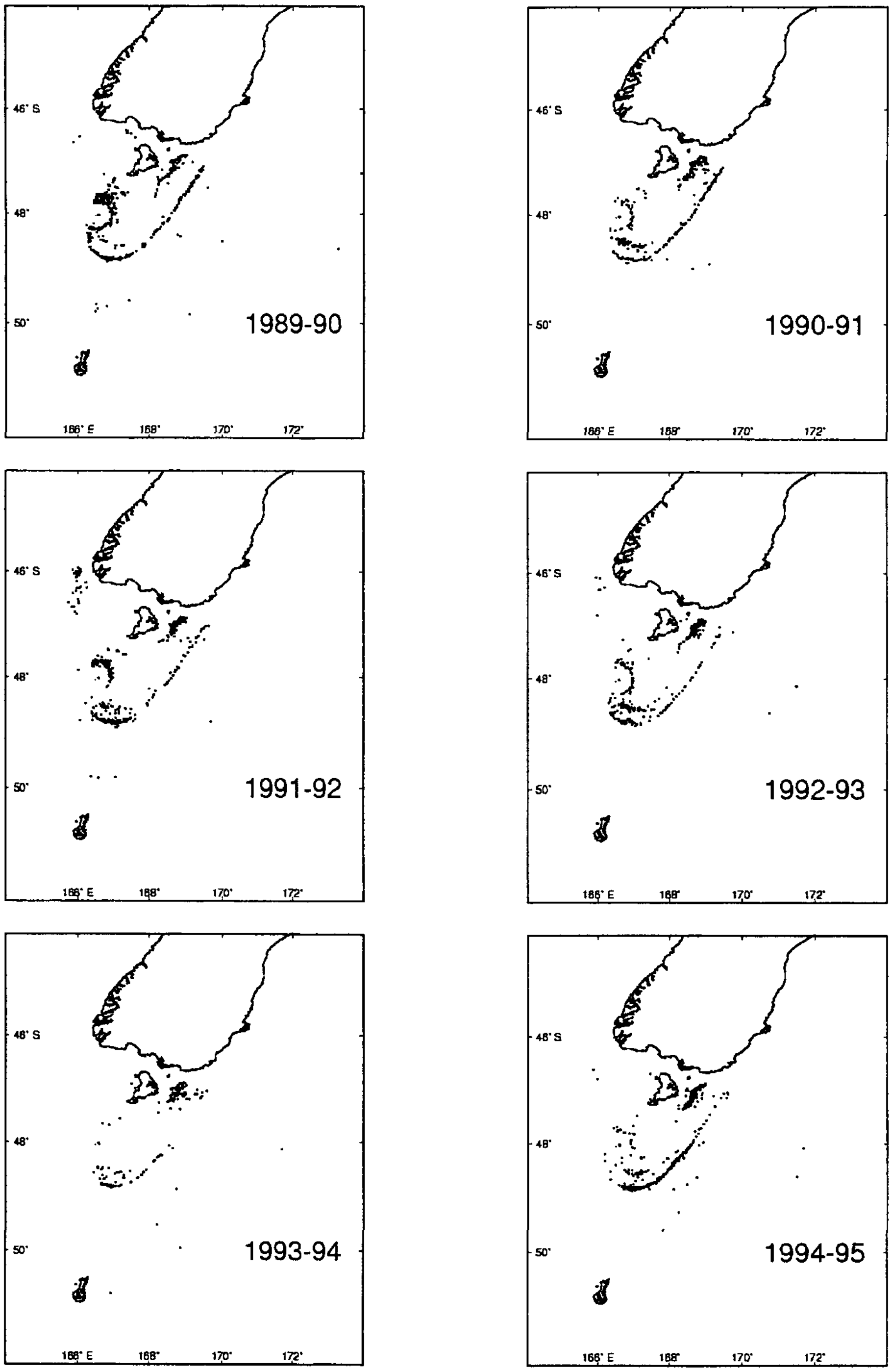

Figure 4: **Distribution of tows for the barracouta target fishery for 1989–90 to 1997–98.**

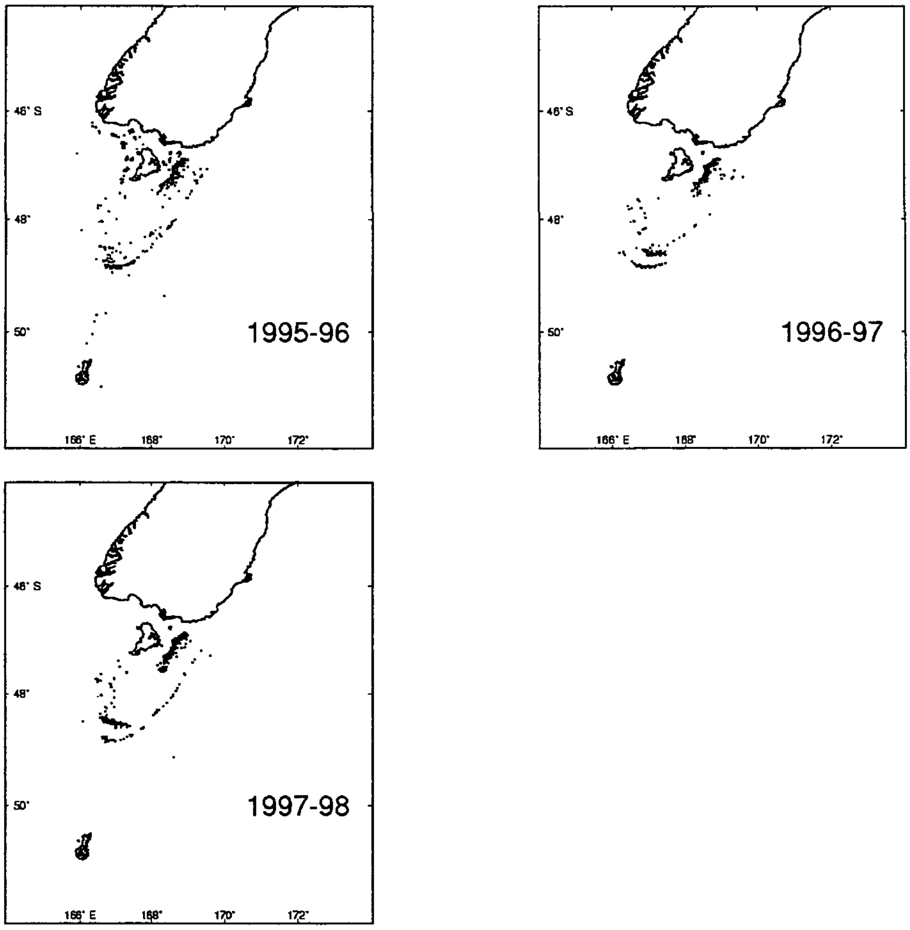

Figure 4: **Continued.**

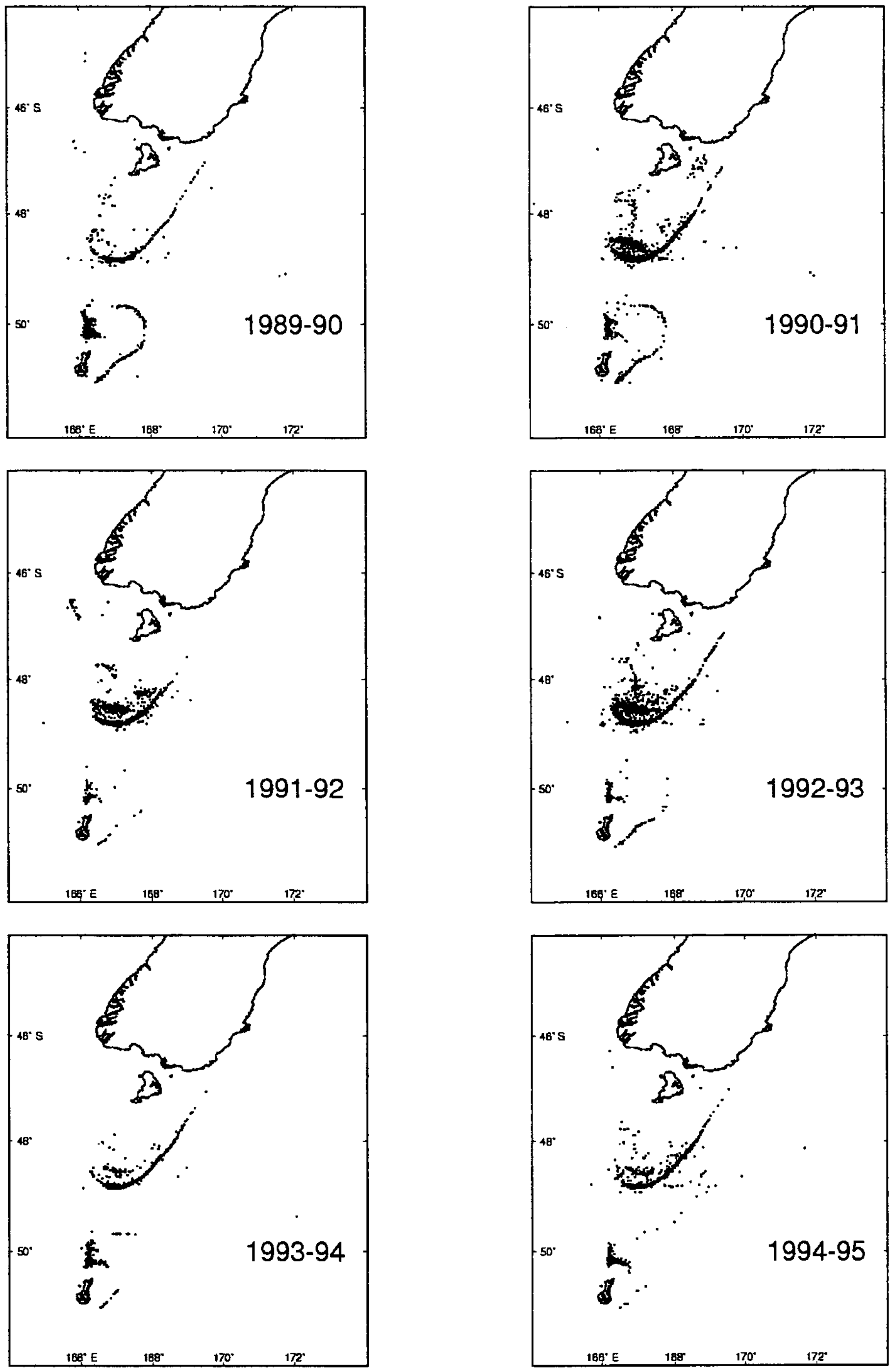

Figure 5**: Distribution of tows catching barracouta from the squid target fishery for 1989–90 to 1997–98.**

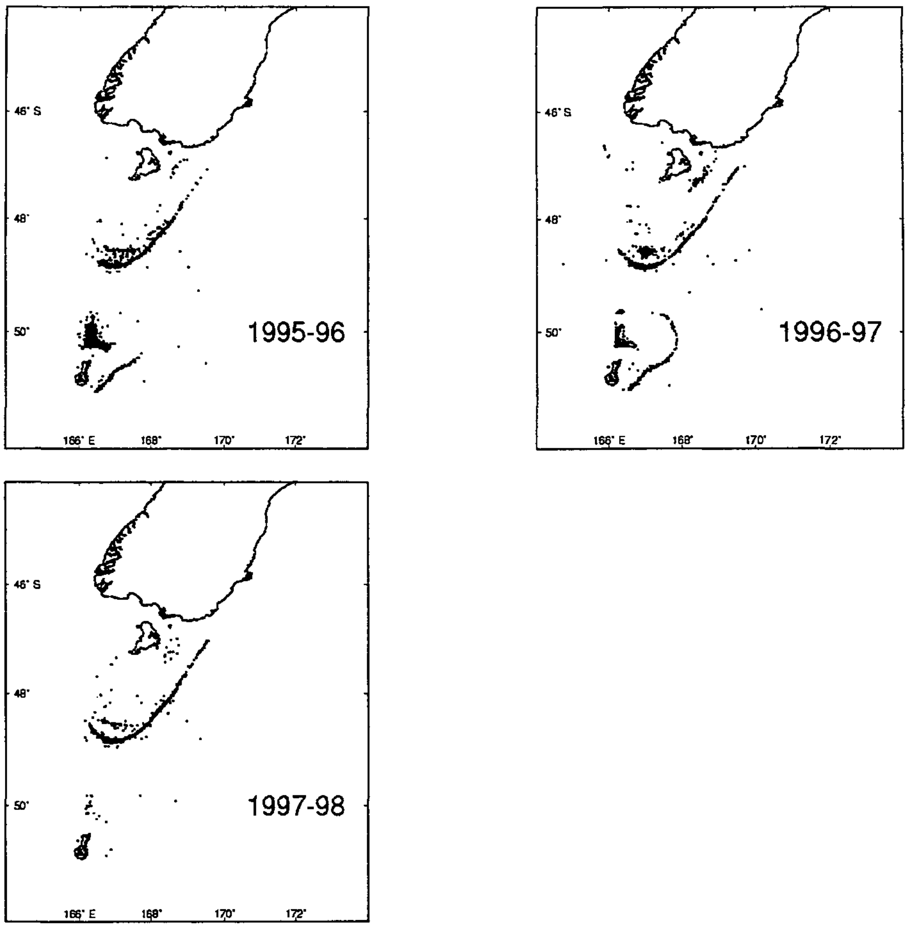

Figure 5: **Continued.**

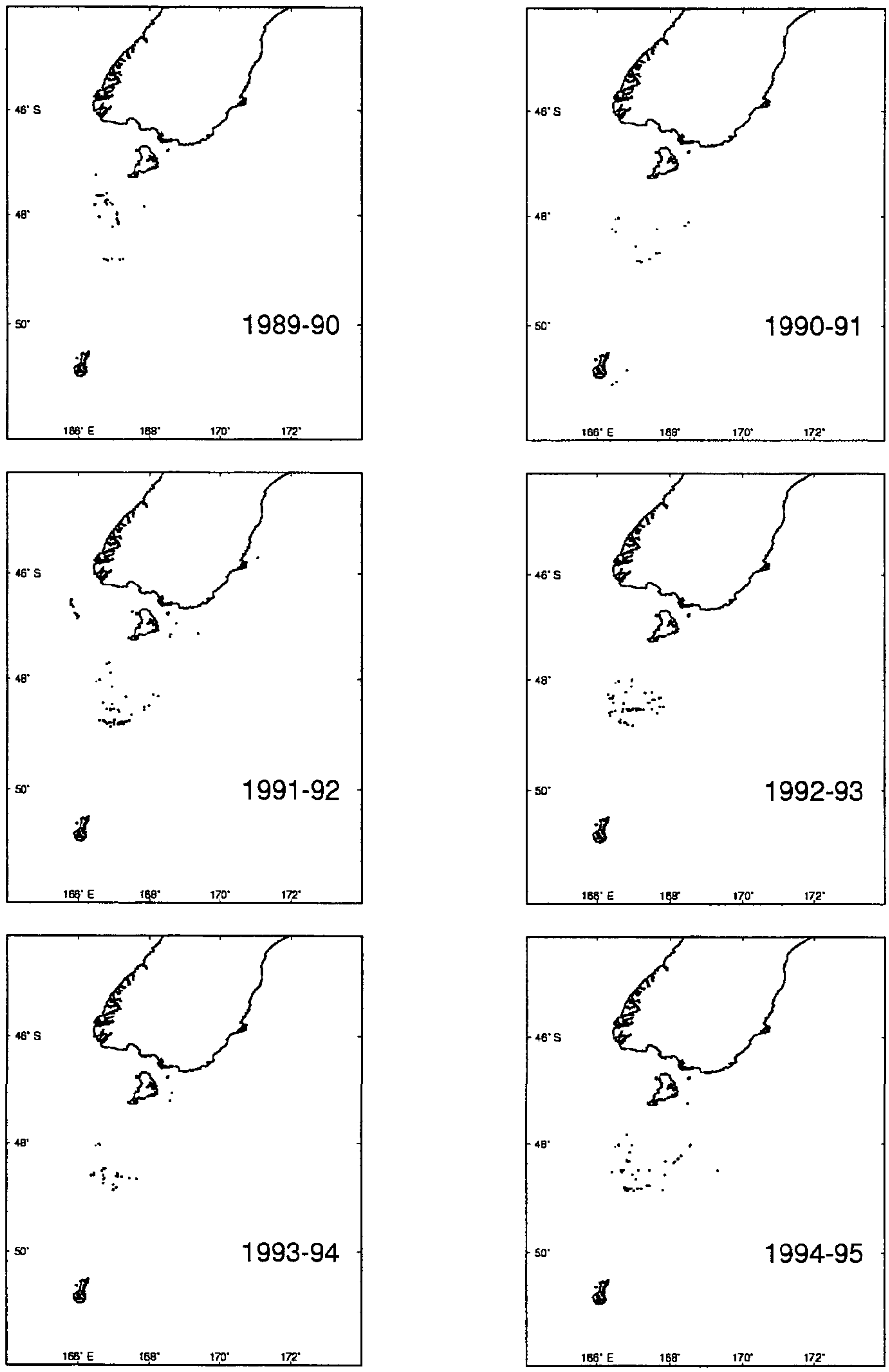

***Figure 6*: Distribution of tows catching barracouta from the jack mackerel target fishery for 1989–90 to 1997–98.**

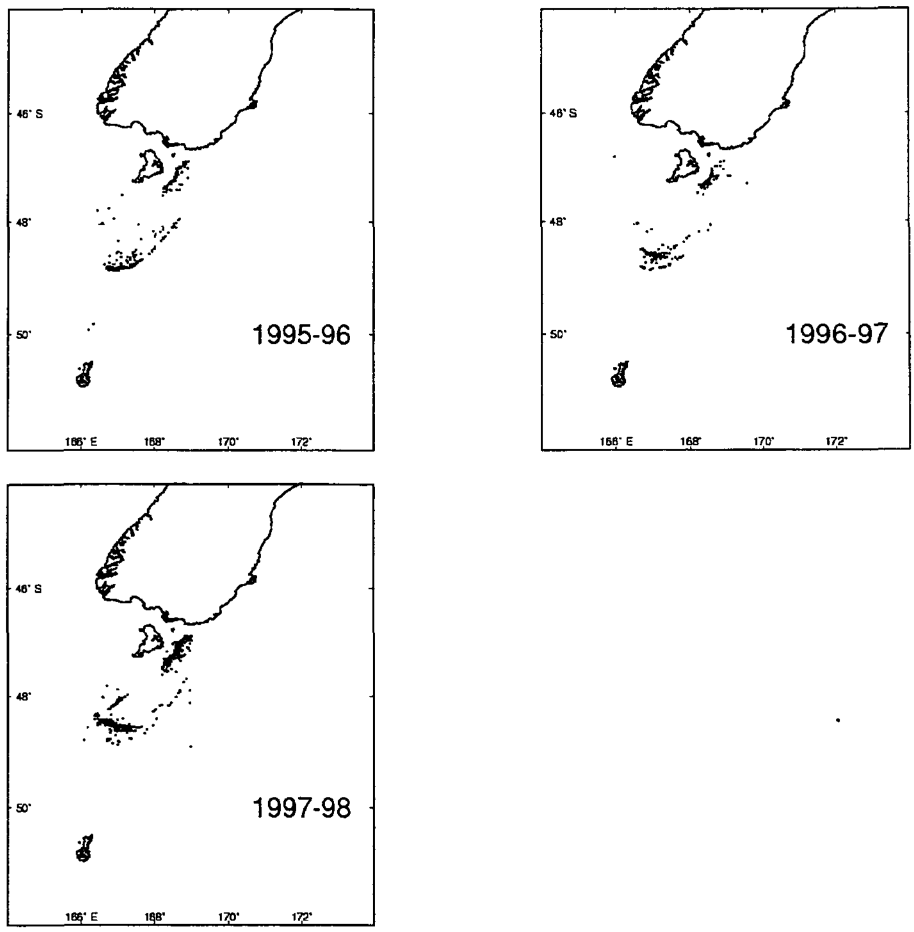

***Figure 6*: Continued.**

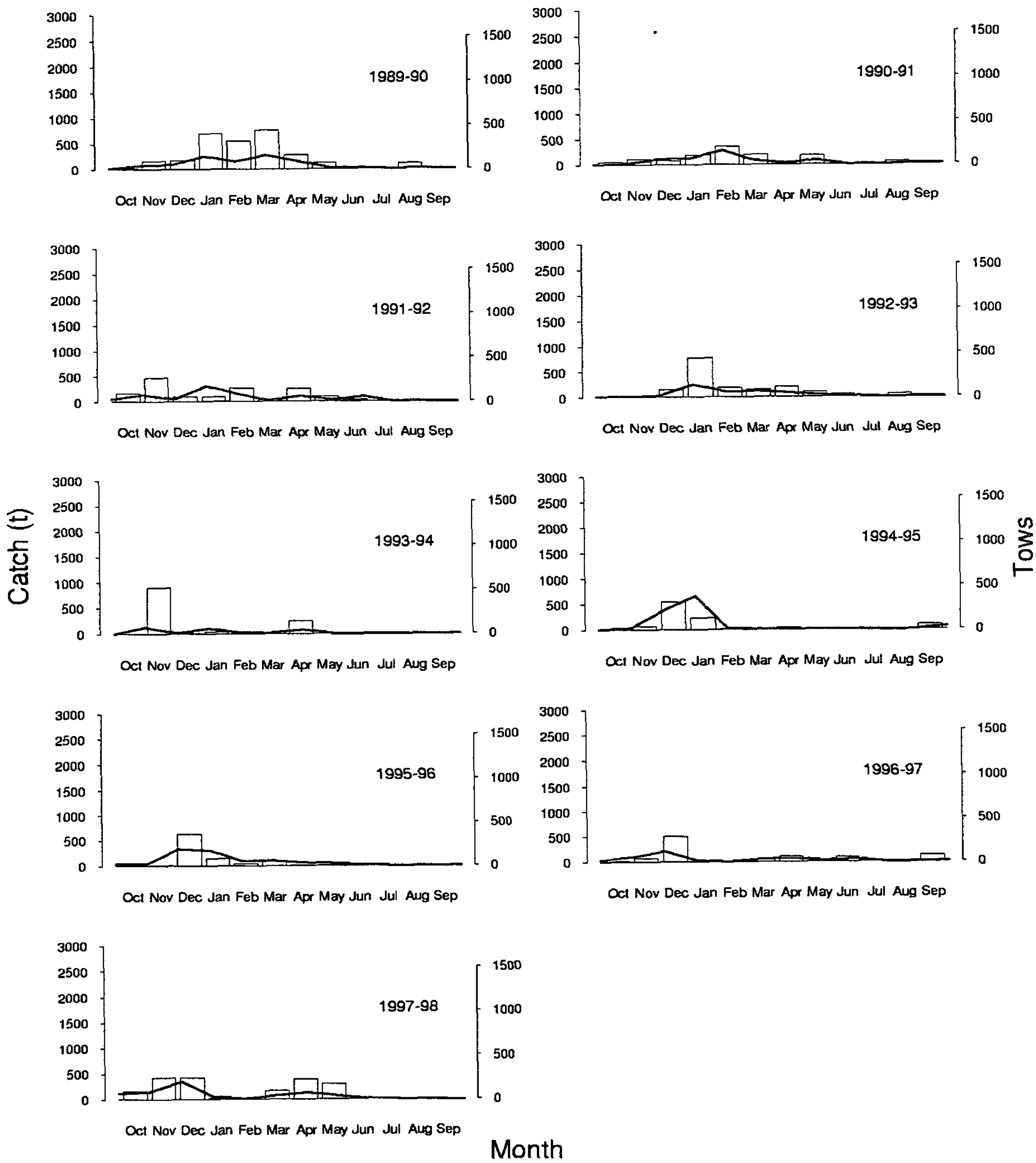

Figure 7: **Catch (bars) and number of tows targeting barracouta by month and year in FMA 5 and 6 for 1989–90 to 1997–98.**

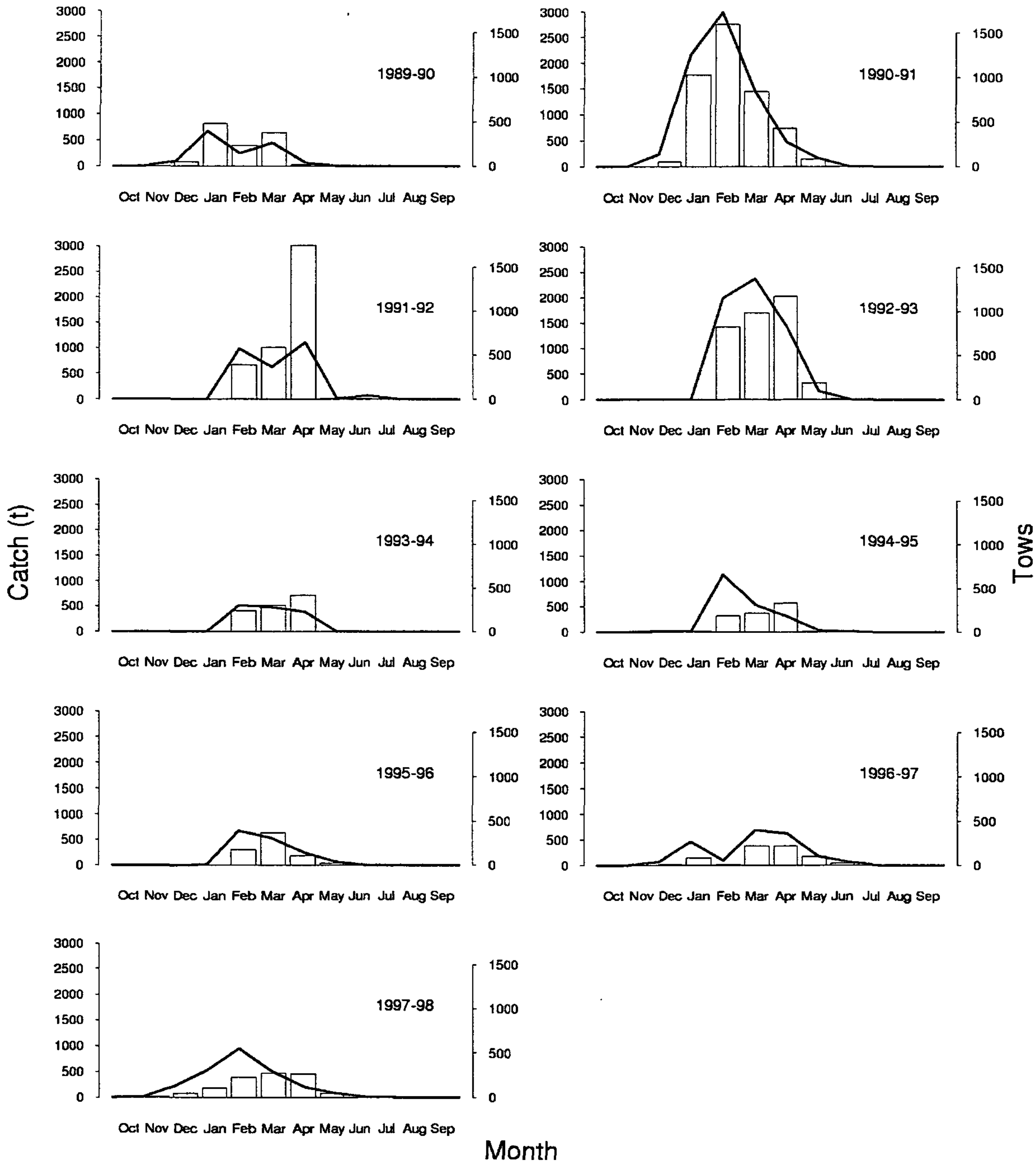

Figure 8: **Catch of barracouta (bars) and number of tows catching barracouta by month and year for the SQU 5 target fishery for 1989–90 to 1997–98.**

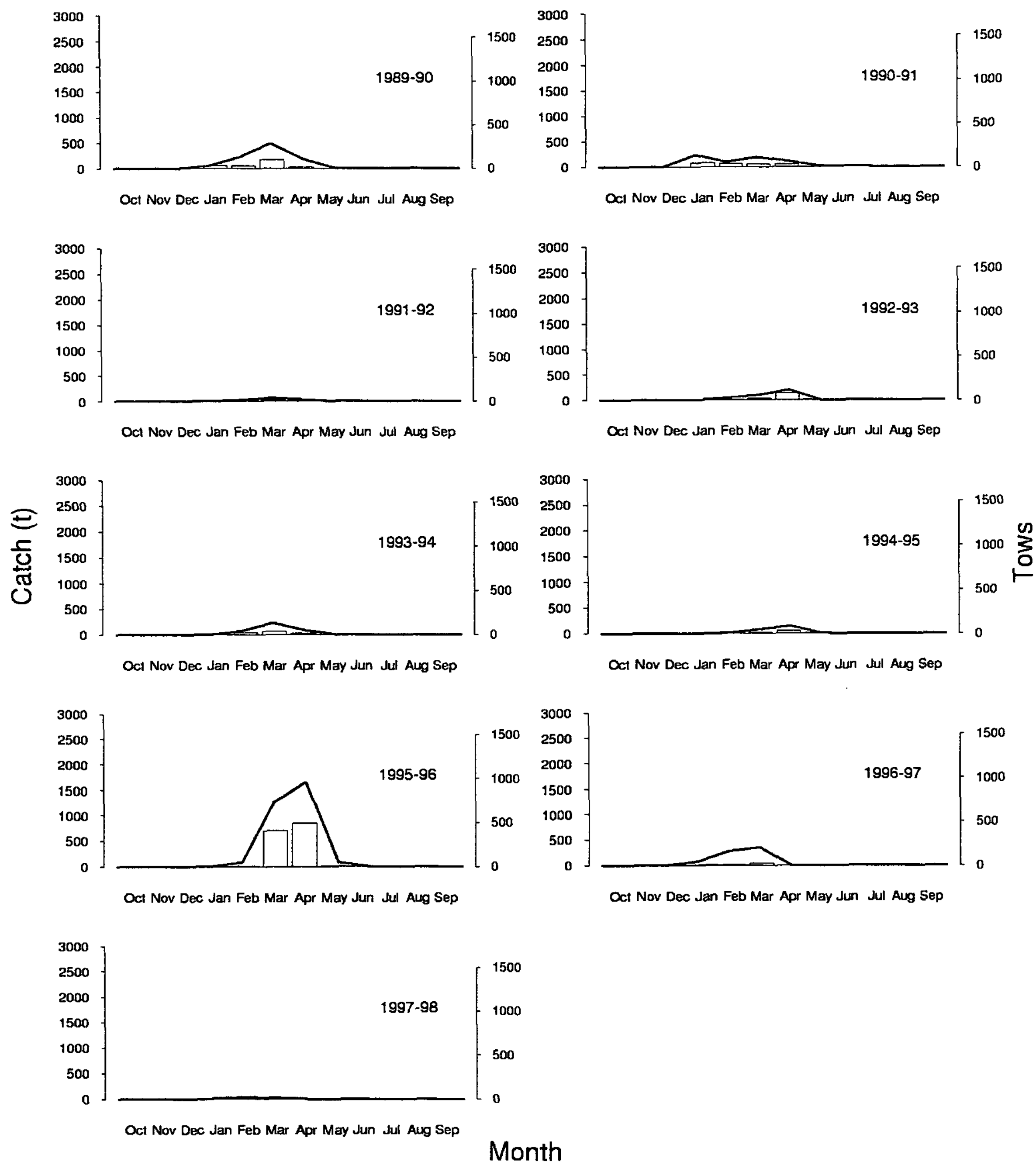

Figure 9: **Catch of barracouta (bars) and number of tows catching barracouta by month and year for the SQU 6 target fishery for 1989–90 to 1997–98.**

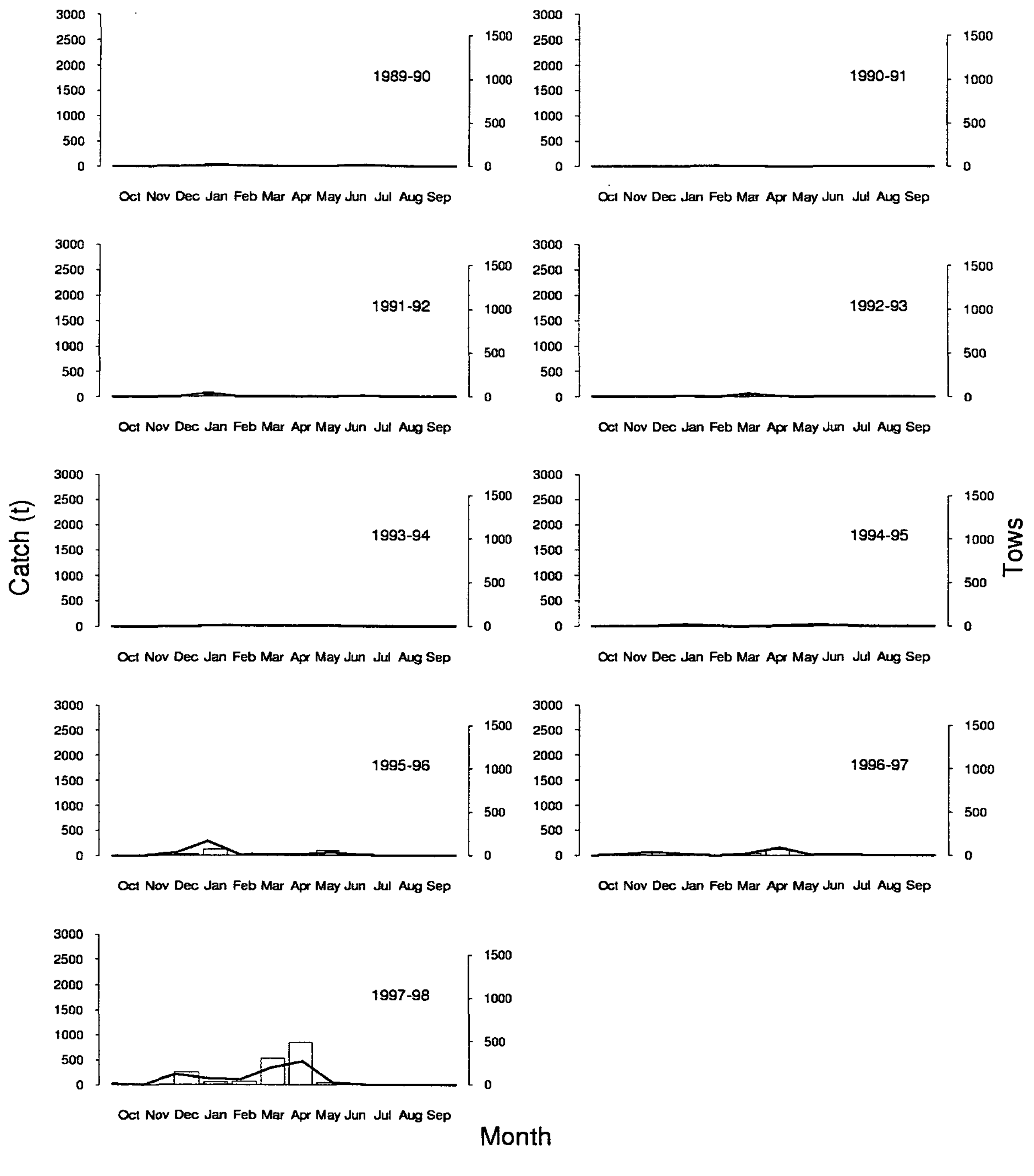

Figure 10: **Catch (bars) and number of tows (lines) catching barracouta by month and year for the jack mackerel target fishery for 1989–90 to 1997–98.**

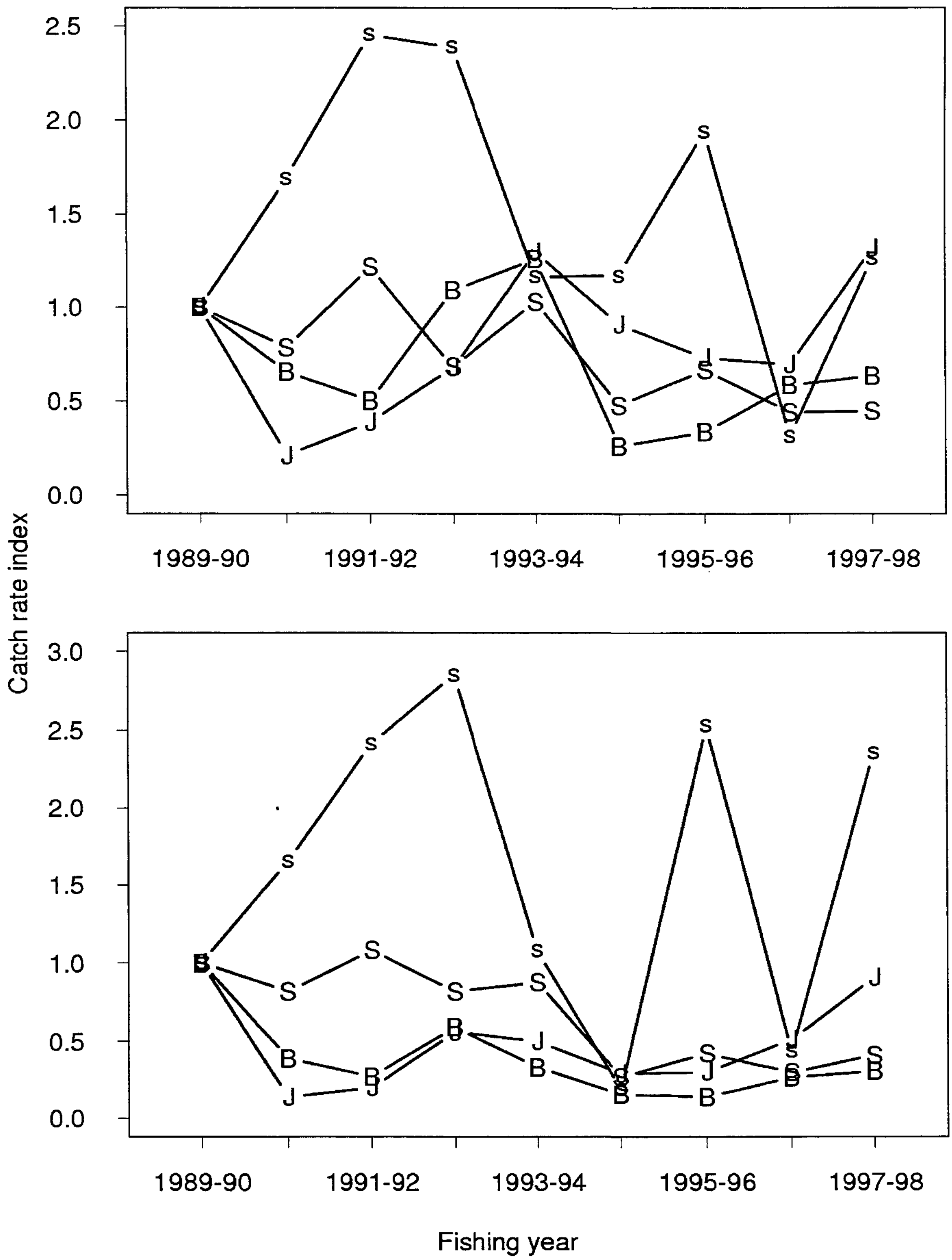

Figure 11: **Mean (top) and median (bottom) catch rates of barracouta by target fishery for 1989–90 to 1997–98 (B = BAR, S = SQU 5, s = SQU 6, J = JMA).**

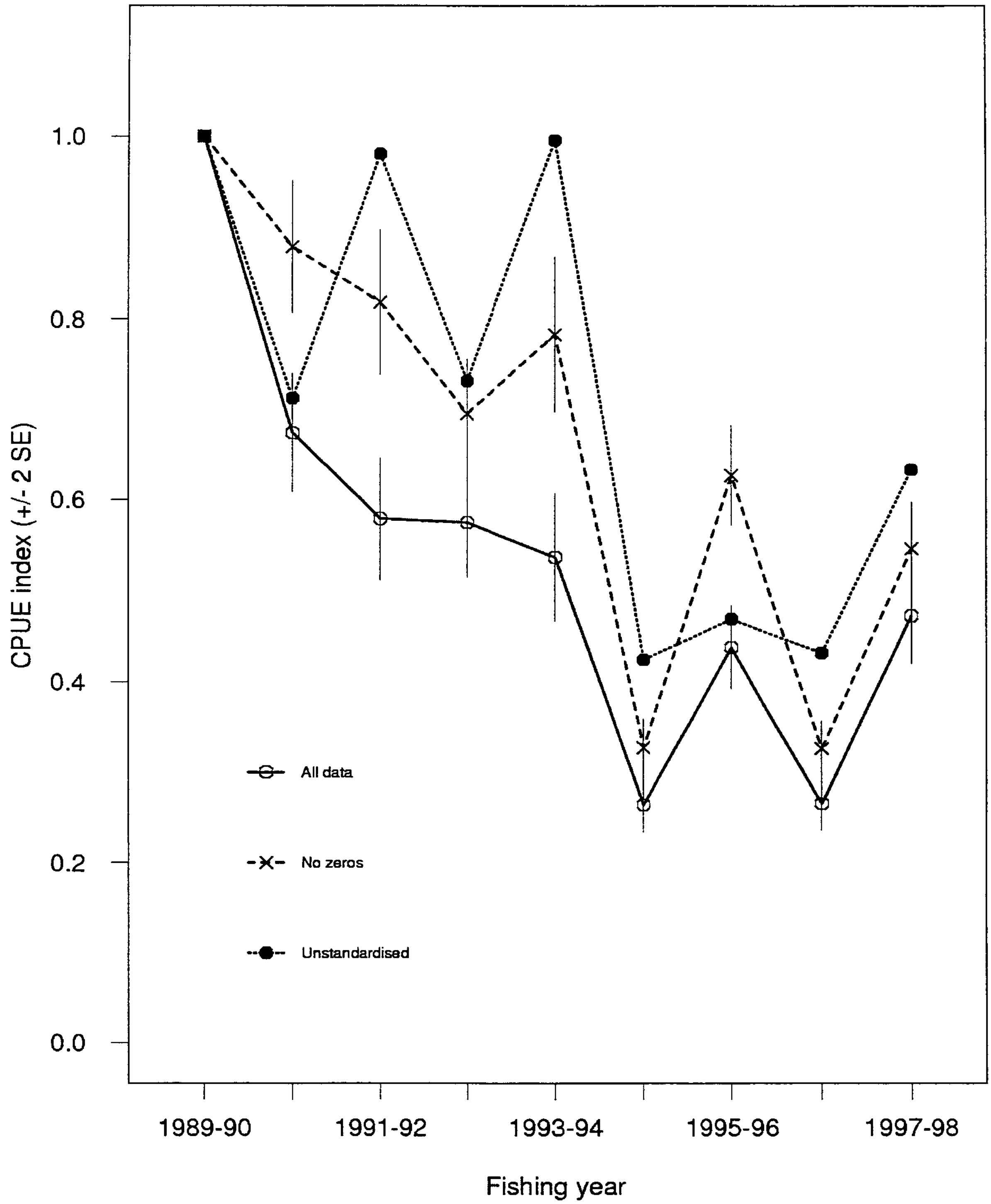

***Figure 12*: Estimated year effect from the LNL models with standard errors.**

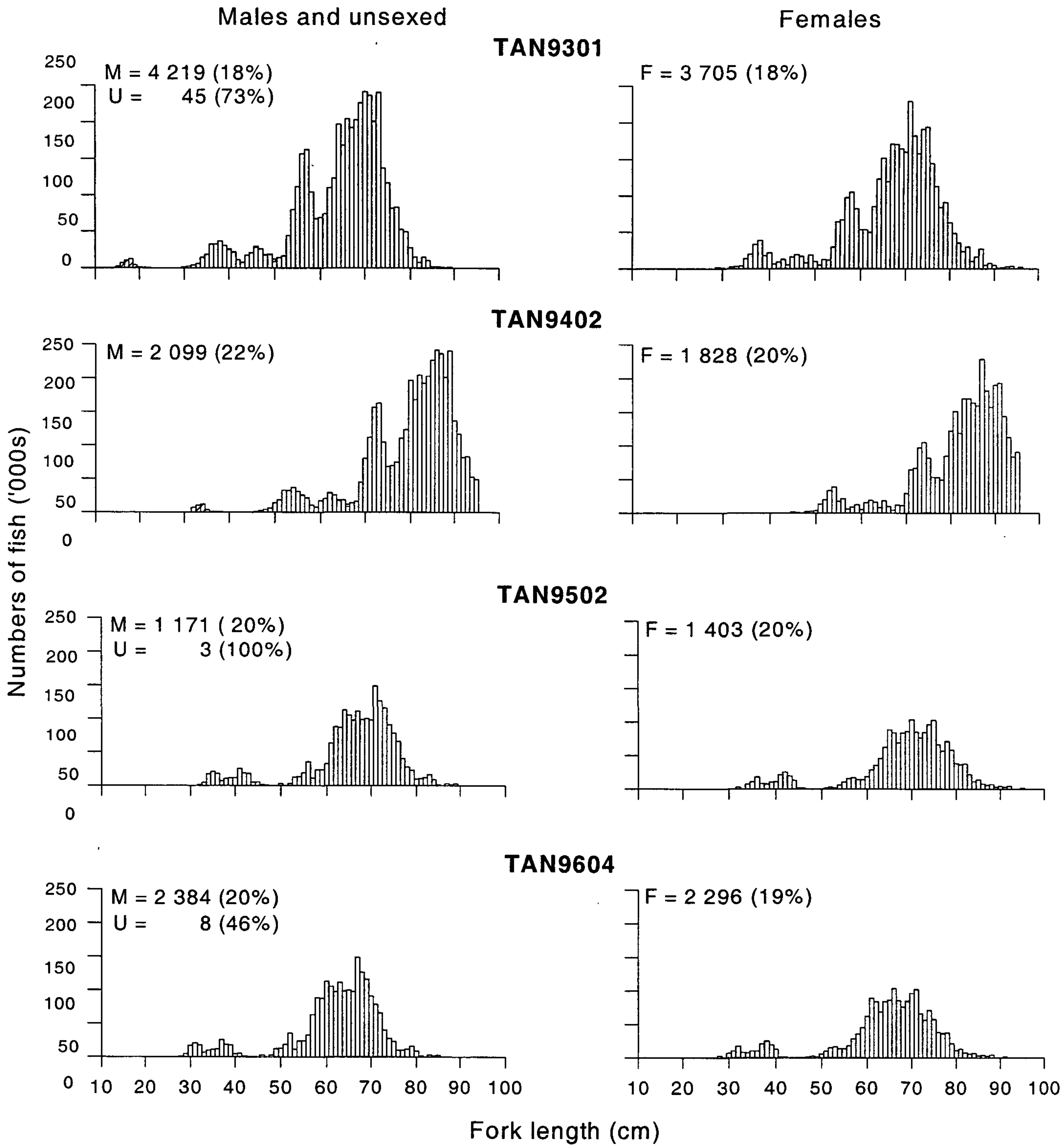

Figure 13: **Scaled length-frequency distributions of barracouta from trawl surveys of the Southland shelf, 1993–96, with the estimated total number of fish in the population and percentage coefficient of variation (from Hurst & Bagley 1997b). M, number of males; F, number of females; U, number of unsexed fish.**

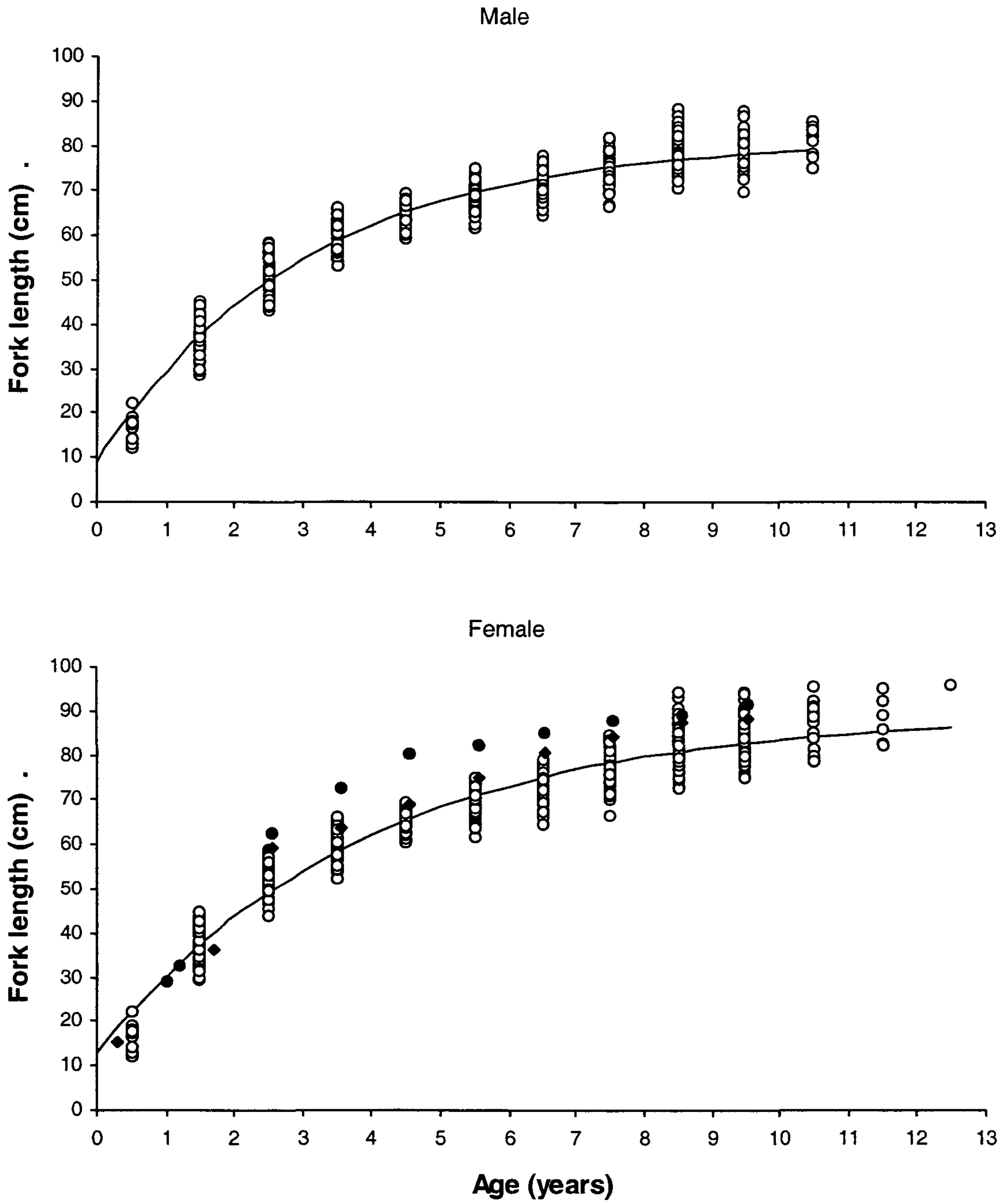

***Figure 14*: Raw age-length data (O) and calculated Von Bertalanffy growth curves, by sex, for barracouta from the Southland shelf. Values of mean length at age for barracouta from off the Australian coasts of Victoria (◆) and eastern Tasmania (●) are also plotted (from Grant *et al.* 1978).**

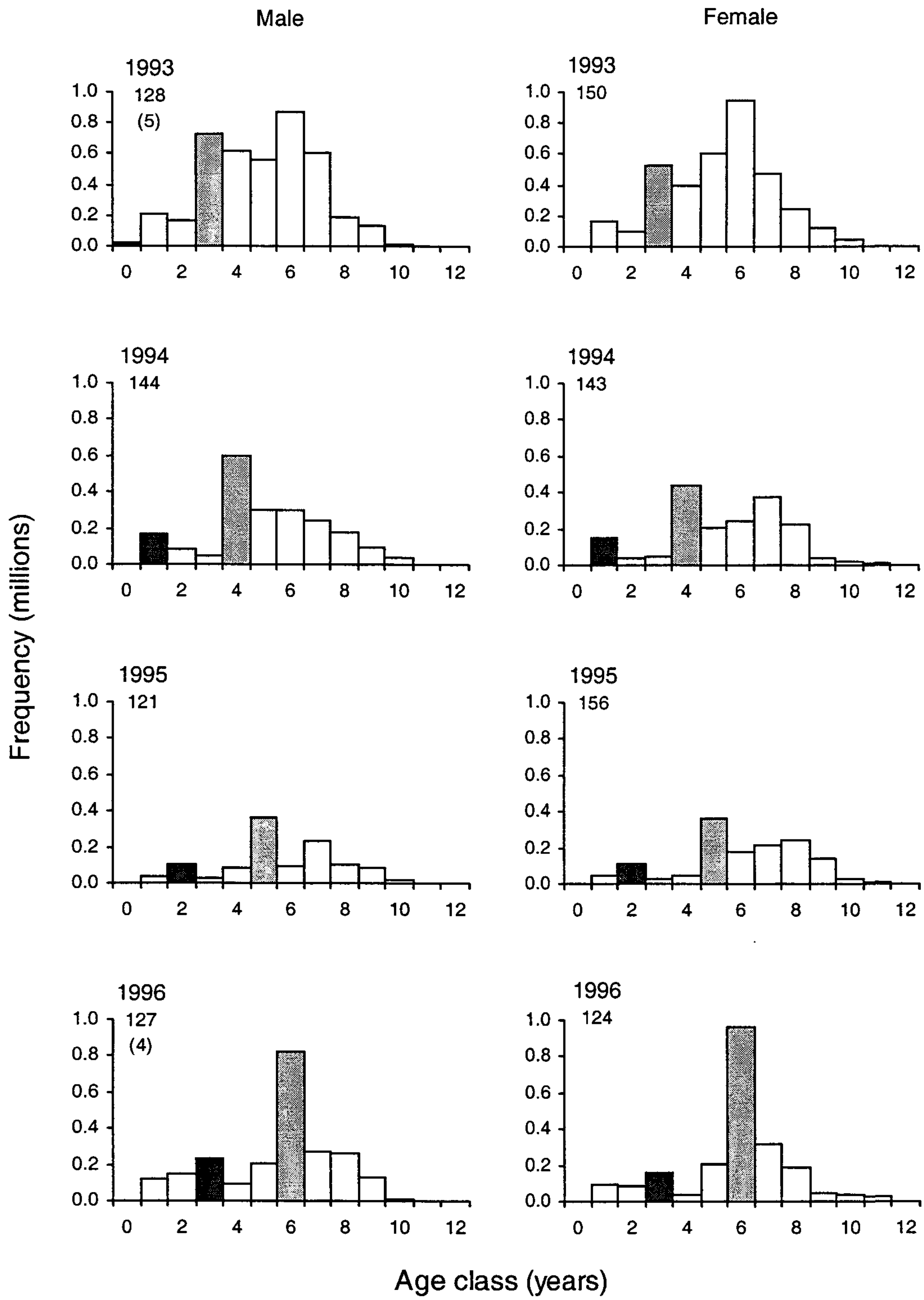

Figure 15: **Age-frequency distributions, by sex, for barracouta caught in comparable trawl surveys of the Southland shelf conducted in February–March 1993 to 1996. Similarly shaded bars represent individual strong year classes. Age class 0 fish were all unsexed, but are plotted on the male distribution. Sample sizes (numbers of fish aged) are shown by sex, with numbers of unsexed fish in parentheses.**

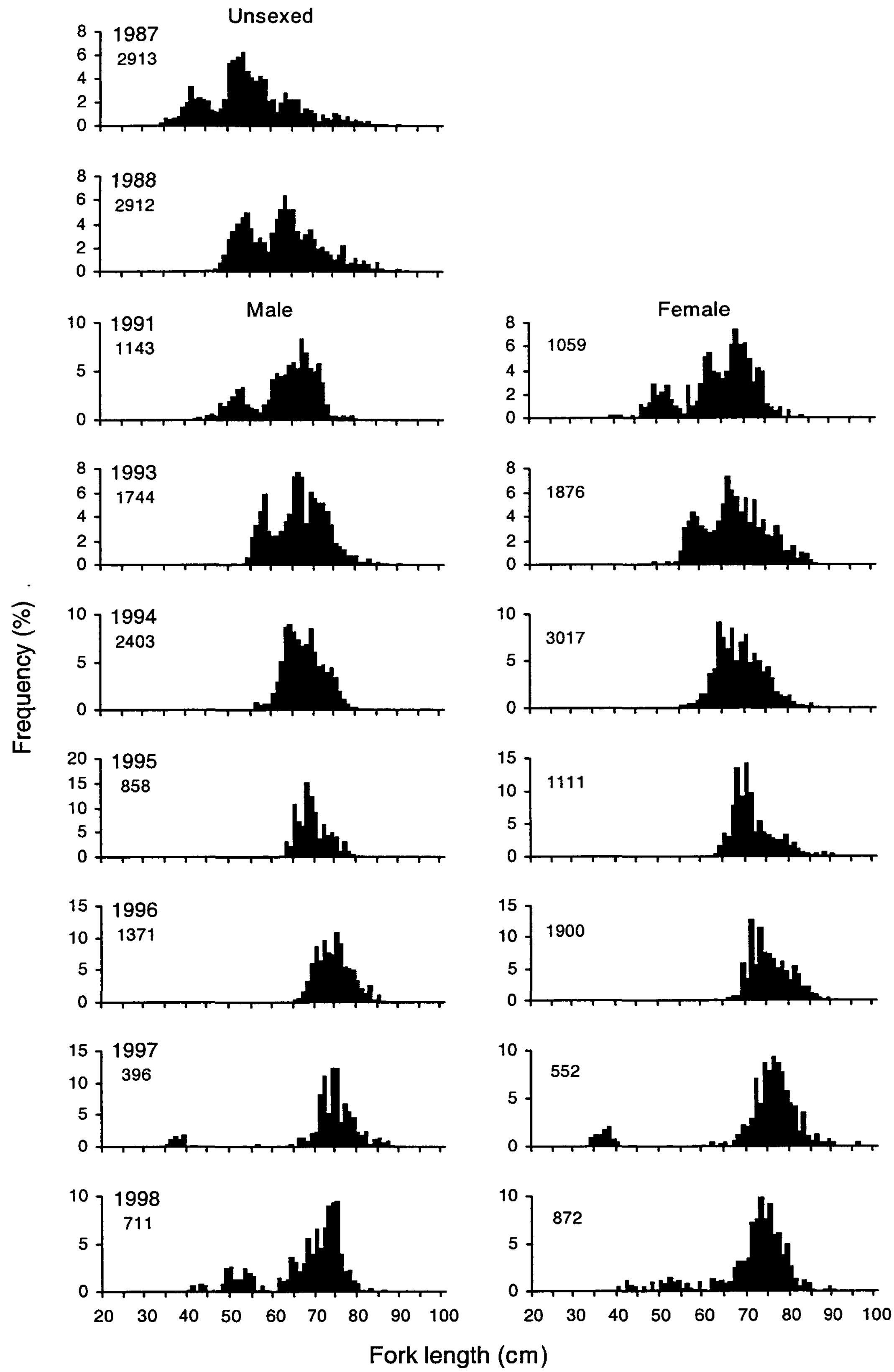

Figure 16: **Length-frequency distributions (and sample sizes), by year and sex where data were available, of the commercial catch of barracouta from BAR 5, as sampled by observers.**

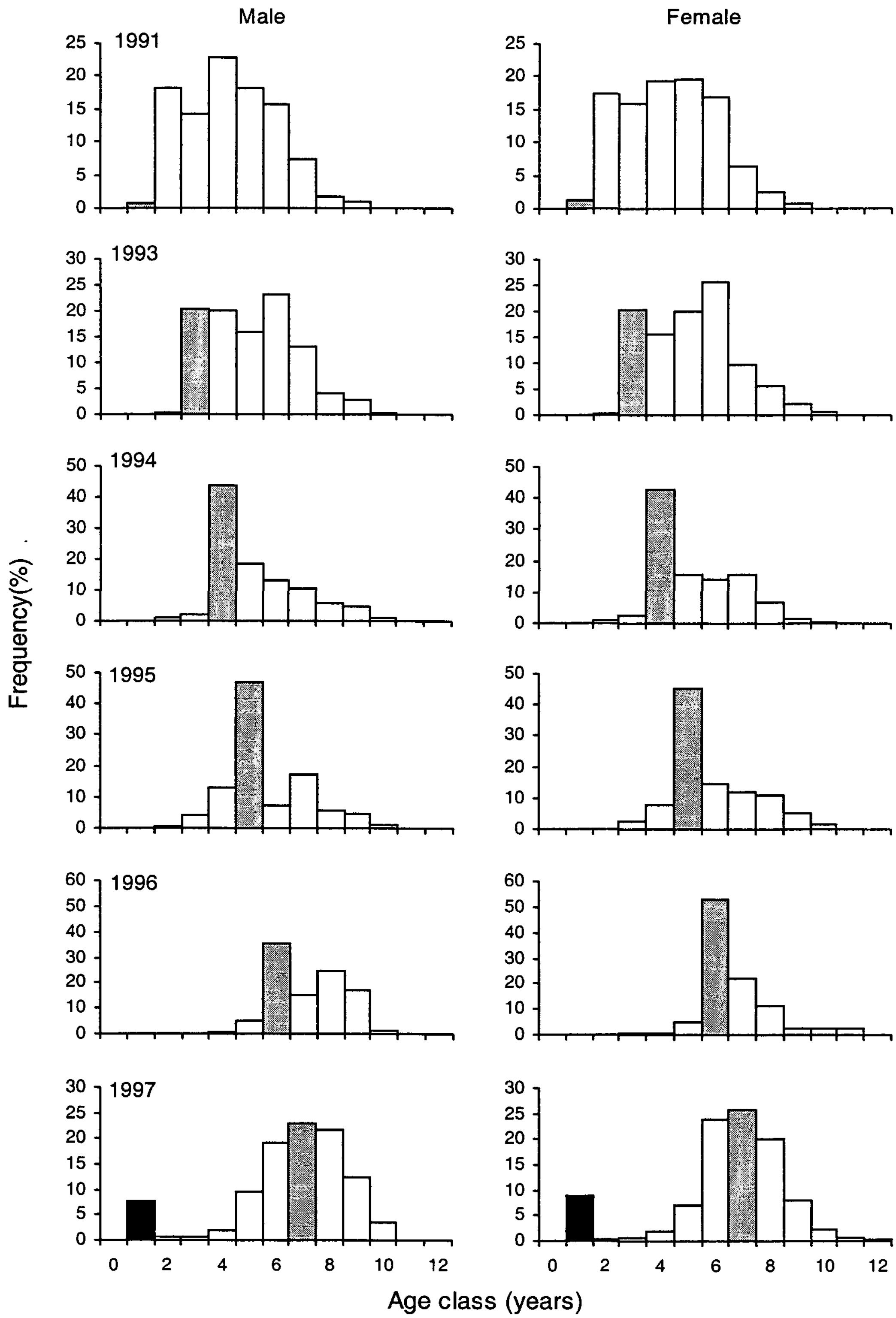

Figure 17: **Age-frequency distributions, by sex, for barracouta caught in the commercial fishery in BAR 5, during the period January–May each year. Similarly shaded bars represent individual strong year classes.**