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Southern blue whiting (*Micromesistius australis*) stock assessment for the 1995–96 fishing year

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SOUTHERN BLUE WHITING (*Micromesistius australis)* STOCK ASSESSMENT FOR THE 1995–96 FISHING YEAR

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1. EXECUTIVE SUMMARY

This paper reviews the stock assessment of southern blue whiting (SBW) resources in New Zealand waters. A summary of the 1995 fishing season is presented and the results of research carried out over the past year are outlined.

The results of a standardised catch per unit effort (CPUE) analysis for the Campbell Island fishery for the period 1986 to 1995 are presented. The 1995 index was the highest since 1986. The 1995 catch was dominated by the strong 1991 year class which formed over 80% by number. Catch-at-age data, CPUE data, and acoustic estimates of adult biomass for the Campbell Island stock were fitted using the separable Sequential Population Analysis used in previous assessments. Two base case runs were considered which covered the likely range of parameters as input to the model. Run 1 treated the acoustic estimates as relative abundance indices, and gave a higher weighting to the catch-at-age data. Run 2 treated the acoustic estimates as absolute, and effectively downweighted the catch-at-age data. Estimates of mid-season spawning stock biomass declined steadily from 1979 to 1993 but increased sharply in 1994 and 1995 due to the recruitment of the very strong 1991 year class to the fishery. The two estimates of current biomass, 110 000 t and 147 000 t from runs 1 and 2 respectively, are both well above B_{MAY}. The estimates of CAY for 1995–96 from the two runs are 21 800 t and 29 700 t and are similar for 1996–97. The CAY estimates are very sensitive to the size of the 1991 year class, which is not yet well known.

Virgin and current biomass for the Bounty Platform and Pukaki Rise stocks were estimated for the first time by fitting the absolute acoustic estimates using stock reduction analyses. For both stocks current biomass is not well known, but is thought to be above B_{MAY}. Estimates of CAY for 1995–96 on Bounty Platform were slightly below the current catch limit but well above recent levels of catch. A strong year class is predicted to recruit to the fishery in 1996–97. Estimates of CAY for 1995–96 and 1996–97 on the Pukaki Rise are above current catch limits and recent levels of catch.

2. INTRODUCTION

2.1 Overview

This paper reviews the stock assessment of southern blue whiting (SBW) resources in New Zealand waters. Length-frequency and reproductive data for the commercial fishery are presented. The results of a standardised catch per unit effort (CPUE) analysis for the Campbell Island fishery for the period 1986 to 1995 are presented. These CPUE data, together with catch-at-age data for Campbell Island Rise for the period 1979 to 1995 and estimates of biomass from acoustic surveys from 1993 to 1995 (Ingerson & Hanchet unpubl. results), were used in a separable Sequential Population Analysis (sSPA) to estimate historic and current biomass for the Campbell Island stock. Estimates of virgin and current biomass for the Bounty Platform and Pukaki Rise stocks were derived from stock reduction analyses fitted to the acoustic estimates. Estimates of Current Annual Yields for 1995–96 and 1996–97 are provided for all three stocks.

2.2 Description of fishery

In this paper the word "season" refers to August and September, the months of intense fishing at the end of the fishing year (i.e., the 1995 season is part of the 1994–95 fishing year).

The SBW fishery was developed by Soviet vessels during the early 1970s, with landings of over 40 000 t in 1973 and 1974 (Table 1). It was known that SBW spawned in most years on the Bounty Platform (Shpak 1978) and in some years on the Campbell Plateau (Shpak & Kuchina 1983), and that feeding aggregations could be caught on the Pukaki Rise, southeast of the Campbell Island Rise, and the Auckland Islands Shelf (Shpak 1978). Some fishing probably took place on each of the grounds, but the proportion of catch from each ground cannot be determined.

From 1978 to 1984, fishing was carried out on the entire Campbell Plateau throughout the year, but highest catches were usually made whilst fish were spawning in September on the Pukaki Rise and the northern Campbell Island Rise (Figure 1). In some seasons (notably 1979, 1982, and 1983) vessels also targeted spawning fish on the Bounty Platform in August and September.

As a result of the increase in hoki quota in 1985 and 1986, the Japanese surimi fleet increased its presence in New Zealand waters and some vessels stayed on after the hoki fishery to fish for SBW. Since then many of the Soviet and Japanese vessels which fish for hoki on the west coast of the South Island during July and August move in mid to late August to the SBW spawning grounds. Between 1986 and 1989, fishing was confined to the spawning grounds on the northern Campbell Island Rise.

From 1990 onwards, vessels started fishing spawning aggregations on Bounty Platform, Pukaki Rise, and Campbell Island Rise. Fishing effort increased quite markedly between 1990 and 1992, culminating in the record catch in 1992 of over 75 000 t. The increased catch came predominantly from the Bounty Platform where catches increased from zero to almost 60 000 t in only 3 years. There was concern that the large 1992 catch was not sustainable so a catch limit of 32 000 t was introduced for the first time in the 1992–93 fishing year, and has been retained since then. This catch limit has not been reached in the 3 years since it was introduced.

2.3 Recent papers

Results of the first two acoustic surveys of spawning SBW stocks on Bounty Platform, Pukaki Rise, and Campbell Island Rise in August and September 1993 and 1994 were presented by Hanchet *et al.* (1994) and Hanchet & Ingerson (1996). Standardised analyses of CPUE data have been carried out by Ingerson & Hanchet (1995) and Chatterton (1996). Recent stock assessments were made by Hanchet (1991, 1992, 1993), Hanchet & Haist (1994), Punt (1994), and Hanchet & Ingerson (1995). In the most recent stock assessment of the Campbell Island Rise stock, CPUE data from 1986 to 1994, together with catch-at-age data for the period 1979 to 1994, and acoustic data from 1993 and 1994 were modelled using an sSPA (Hanchet & Ingerson 1995). Catch projection models were run to examine the effect of future catches on stock size and fishing mortality.

3. REVIEW OF THE FISHERY

3.1 TACs, catch, landings, and effort data

3.1.1 Total Allowable Catch

Catch quotas, allocated to individual operators, were introduced for the first time in the 1992–93 fishing year. The total catch limit of 32 000 t was divided as follows: 15 000 t from the Bounty Platform, 11 000 t from south of a line drawn at 50° 30' S, and the remaining 6000 t to be caught north of 50° 30' S (but west of Bounty Platform) (*see* Figure 1). This line separates the Campbell Island fishery from the Pukaki Rise fishery, but divides into two a smaller spawning ground on the Auckland Islands Shelf where some vessels have fished in the past 3 years.

3.1.2 Landings

Estimates of the annual landings of SBW are given in Tables 1 and 2. There are some discrepancies between figures on the Licensed Fish Receiver Returns (LFRRs) and the catches from vessel logbooks. This is partly because the main fishing season for SBW is September, but catches are often not reported on the LFRRs until October, which is after the start of the new fishing year. A more accurate estimate of the season's landings was therefore obtained by combining landings for all months from each calendar year (*see* Table 2). Before 1990–91, when the conversion factors were changed, landings from LFRRs were further corrected by multiplying the surimi catch by 1.16 to account for the lower conversion factors used by the Quota Monitoring System. There is reasonably good agreement between the totals from the vessel logbooks (*see* Table 1) and the estimated calendar year total from the LFRRs (*see* Table 2) for most years. The values given in Table 1 are used for modelling purposes.

The estimated total catch for 1994–95 was about 18 000 t with the catch limit being undercaught on each fishing ground. The catch limits have been undercaught on most grounds in most years since their introduction. This appears to reflect the low economic value of the fish and difficulties experienced by operators in this fishery, rather than low stock sizes. In particular, the effort on the Bounty Platform depends largely on the success of the hoki fishery. If there is a poor hoki season, then the vessels remain longer on the hoki grounds and miss the peak fishing season on the Bounty Platform. On the Pukaki Rise, operators have a smaller allocation and have also found it difficult to locate large aggregations of fish. On the Campbell Island Rise the catch limit has usually been reached (in the last season the outstanding 1250 t were caught in October 1995).

3.1.3 The 1995 season

The 1995 season was similar to the 1994 season. Six vessels fished on Bounty Platform during the peak of the spawning season from 19 to 27 August, and caught about 6500 t. Several more vessels arrived later in the season but caught only small amounts of fish and were unable to fill their quota.

About five vessels fished the Pukaki Rise at various times during September. Vessels were unable to find large aggregations of fish and only poor catches were made, mostly along the south of the Rise. The total catch was 1300 t.

A maximum of 11 vessels fished the Campbell Island Rise during September. Vessels caught about 8000 t on the northern grounds and about 2000 t on the southern grounds. The catch in both areas was dominated by 4 year olds of the 1991 year class (*see* Section 3.2.3). A further 1250 t were caught in October 1995.

Four vessels fished on the Auckland Islands Shelf from 19 to 24 September. They located aggregations of spawning fish and caught about 500 t.

3.1.4 CPUE analysis

Campbell Island Rise

A multivariate standardised approach to the CPUE analysis was made for the 1986 to 1993 period by Chatterton (1996). The same approach was used in the 1995 assessment, although two new variables were included in the analysis (Ingerson & Hanchet 1995). Since then, other variables that could have been included in the modelling were investigated. For a CPUE analysis, variables that describe skipper/fishing master experience and/or search time would be highly desirable. However, it was found that there were insufficient data to adequately fit these variables in the model.

There are a large number of zero tows in the data set in some years, so last year the data were analysed using two models: a gamma distribution model with a log-link function (GLL), and a combined model (previously referred to as a delta-lognormal (DLN) model). The results from the two models were very similar, so only the less complex GLL model has been used this year.

There were only 170 tows carried out in the Campbell Island Rise fishery during the 1995 season. Only four of these tows (2.4%) were recorded as having caught no SBW and this is the lowest percentage of zero tows seen since 1986 (Table 3). This was probably because in 1995 the fleet found a large aggregation of fish to the northeast of Campbell Island which remained in the same place for most of the season, and this reduced the need for exploratory tows.

The significant variables for the GLL model were the same as last year, and entered the model in a similar order. In order of importance the variables were: year, vessel length, time/depth, tow position, season, end time, and headline height. The CPUE indices show a very similar trend to the analysis carried out last year, with a general decline from 1986 to 1992, followed by an increase in 1993 which was sustained in 1994. The 1995 index rose to a level close to the 1986 index (*see* Table 3). The large error bars around the 1995 index are probably due to the relatively small number of tows carried out during the 1995 season.

The CPUE indices were converted to annual indices of relative fishing effort by dividing the total catch for each year by the CPUE index for that year (*see* Table 3). The effort data were used in the sSPA model.

There are concerns that because of the highly aggregated nature of the fishery, and the associated difficulty in finding and maintaining contact with the highly mobile schools in some years, the CPUE series may not be monitoring abundance accurately. There is also concern that there is not a direct relationship between CPUE and abundance. A decline in biomass may not necessarily lead to a decline in CPUE because the fleet may still be able to target dense aggregations and maintain high catch rates. Similarily an increase in biomass may not lead to a proportional increase in CPUE.

3.2 Other information

3.2.1 Size composition of the commercial catch

Length frequency data were collected by scientific observers from the commercial catch from each fishing ground during 1995. The length frequency data were scaled up to the total catch for each strata and each fishing ground.

The size distribution of the catch on the northern and southern Campbell Island grounds in 1995 is shown in Figure 2. The strong 1991 year class dominated the catch for each sex, on both grounds, with males being slightly outnumbered by females. The size distribution of the catch on the Campbell Island Rise since 1979 is shown in Figure 3. A number of strong year classes have dominated the fishery throughout this period. The modal length at age of the 1991 year class continues to be much smaller than that of previous year classes.

The size distribution of the catch on the Bounty Platform since 1990 is shown in Figure 4. The catches during this period have largely comprised the 1986 and 1988 year classes. In the past 2 years the slow growing 1991 year class has recruited to the fishery, but it has not dominated the catch on this ground to the same extent that it has dominated the catch on the Campbell Island grounds.

The size distribution of the catch on the Pukaki Rise since 1989 is shown in Figure 5. The catch in most years has been dominated by the strong 1986 year class. In the past 2 years the size distribution of the catch has been strongly trimodal, with the 1986, 1990, and 1991 year classes being equally abundant in the catch. The 1991 year class continues to be very small for its age but has now started spawning.

Only a few length frequency samples have been collected from the Auckland Islands Shelf grounds, but they have been consistent between years (Figure 6). The otoliths have not been read but, assuming fish have similar growth rates to those on the Pukaki Rise and Campbell Island Rise, the catch appears to be dominated by the 1986, 1988, and 1991 year classes.

3.2.2 Age composition of the commercial catch

A further 563 otoliths from the Campbell Island Rise collected in 1995 were read for use as an age-length key. Catch-at-age was estimated by combining the scaled length frequency data with the age-length key (*see* Hanchet & Ingerson 1995). The *c.v.*s incorporate the variance from both the length-frequency data and the age-length key. Catch-at-age data are tabulated in Table 6 and illustrated in Figure 7. They show the strong dominance of the 1991 year class in 1994 and 1995 that was seen in the length frequency data.

3.2.3 Timing of spawning

The spawning cycle of SBW was described by Hanchet (1993). Table 4 summarises the 1995 reproductive data collected by observers.

The main spawning on the Bounty Platform occurred from 24 to 28 August, slightly later than usual. No samples were taken after 31 August so the timing of the second spawning could not be determined. The timing of spawning on the Pukaki Rise could not be determined, but would have started after 18 September. On the Auckland Islands Shelf, spawning probably started on around 14–15 September.

The timing of spawning on the Campbell Island Rise was slightly earlier than in the last 2 years. On the northern ground, the main spawning was from 13 to 16 September. On the southern grounds, spawning would probably have been from about 16 to 20 September because spawning and spent fish were caught on 19 September when the first vessels with observers arrived.

3.3 Recreational, traditional, and Maori fisheries

There is no record of recreational, traditional, or Maori fisheries for SBW, which are usually found in subantarctic waters at depths greater than 300 m.

4. RESEARCH

4.1 Stock structure

No genetic studies have been carried out and, given their close proximity, it is unlikely that there would be genetic differences between the fish in the different areas of the sub-Antarctic. However, there do appear to be consistent differences between fish from the main fishing grounds on Bounty Platform, Pukaki Rise, and Campbell Island Rise based on morphometric and biological data (*see* Hanchet & Ingerson 1995).

For the purposes of stock assessment the stock has been split into three substocks assuming fidelity within substocks. The stocks are: the Bounty Platform, the Pukaki Rise (including Pukaki Rise and Auckland Islands Shelf), and the Campbell Island Rise (including both spawning grounds on the Campbell Island Rise).

4.2 Resource surveys

4.2.1 Trawl surveys

No new trawl surveys have been carried out in the sub-Antarctic (*see* Hanchet & Haist 1994 for a list of previous surveys).

4.2.2 Acoustic surveys

An acoustic survey of southern blue whiting on the Bounty Platform, Pukaki Rise, Campbell Island Rise, and Auckland Island Shelf was carried out by *Tangaroa* in August and September 1995. The objectives of the survey, the methodology, and the treatment of the results are given by Ingerson & Hanchet (unpubl. results), and were essentially the same as in previous years. Two snapshots were completed on each of the grounds. In addition, high density strata were surveyed on the Bounty and Campbell grounds. Southern blue whiting marks were assigned as adults, immatures (mainly 2 year olds), or juveniles (1 year olds).

The mean area backscattering results were converted into estimates of absolute biomass using the target strength-fork length relationship used for blue whiting in the Northern Hemisphere (Monstad *et al.* 1992). *In situ* target strength work carried out during the 1994 survey on small fish with mean lengths of 27 cm and 31 cm produced results which were consistent with that relationship (G. Macaulay, NIWA, unpubl. data).

Results

Mean estimates of mid-season biomass (and *c.v.*s) for each category of southern blue whiting are shown for 1993, 1994, and 1995 in Table 5.

Two complete acoustic snapshots of the main Campbell Island Rise fishing grounds were made each year. Only one adult aggregation of 18 500 t was found on the northern ground in 1993, but about 89 600 t of pre-recruits (2 year olds) were found in shallow waters around the eastern Campbell Island Rise. In 1994, adult aggregations totalling 161 400 t were found on the Rise with about 85% coming from the southern ground. In addition, 22 400 t of pre-recruits were found in shallow water around the Rise. In 1995, 121 100 t of adults were estimated from the Rise with about 60% coming from the northern ground. An additional 20 000 t of pre-recruits were found in shallow water.

At least two complete snapshots of the main Bounty Platform fishing grounds were made each year. In each year, large spawning aggregations were surveyed on the main spawning grounds as they were being fished by the fleet. There is some concern that fish in 1993 and 1994 may have been double-counted and the biomass overestimated (Hanchet & Ingerson 1996), and that in 1995 some of the fish were not surveyed and the biomass underestimated (Ingerson & Hanchet unpubl. results). Smaller aggregations of 1 and 2 year old fish were found in shallower waters and to the east of the Platform.

At least two complete snapshots of the Pukaki Rise fishing grounds were carried out each year before spawning had begun. Several small dense aggregations of adults were found in 1993 and 1994. However, the 1995 spawning season appeared to be much later than usual and no dense aggregations were seen during the survey.

The Auckland Island Shelf was surveyed for the first time in September 1995. The first snapshot in early September did not cover the entire depth range of the fish and so underestimated the biomass. The second snapshot in mid September found a small spawning aggregation being fished by the fleet, and should be a reasonable estimate of the stock size there.

4.4 Biomass estimates

(i) Campbell Island stock

The data were again analysed using the sSPA used in last year's assessment (Hanchet & Ingerson 1995). The sSPA model uses a maximum likelihood method to find the set of parameter values which minimises the following objective function:

$$- \sum_y W_{Sy} \sum_a \ln p_{ya} + \sum_y W_{Cy} (\ln C_y - \ln \hat{C}_y)^2 + \sum_y W_{Ey} (\ln E_y - \ln \hat{E}_y)^2$$

$$+ \sum_y W_{By} (\ln B_y - \ln \hat{B}_y)^2$$

where

W_{Sy} = sample size for catch-at-age data for year y
p_{ya} = predicted proportions-at-age a in year y
W_{Cy} = penalty weight in year y on estimated annual catch
C_y = observed catch in year y
$\hat{C}_y$ = predicted catch
W_{Ey} = penalty weight in year y on annual effort data
E_y = observed effort in year y
$\hat{E}_y$ = predicted effort in year y
W_{By} = penalty weight in year y on annual acoustic biomass data
B_y = observed mid-season spawning stock biomass in year y, from acoustic surveys
$\hat{B}_y$ = predicted mid-season spawning stock biomass in year y, from acoustic surveys

Note that for the current assessment the weights for catch, effort, and biomass are equal for each year.

The model was fitted using catch-at-age data from 1979 to 1995, CPUE indices from 1986 to 1995, and acoustic estimates from 1993 to 1995. The catch-at-age data covered ages 2 to 10 with a plus group at age 11. The model assumes that the selectivity after age 4 is 1.0, estimates a single selectivity for age 4, and allows the option of estimating annual selectivities for both ages 2 and 3 or just for age 2. Natural mortality was assumed to be 0.2, and mean weight at age was calculated from the weight-length regression and von Bertalanffy growth parameters given in Hanchet (1993).

Weightings

In the 1995 assessment a penalty weight of 5 was used for the CPUE data, which approximated a *c.v.* of 30% (Hanchet & Ingerson 1995). Because of the highly aggregated nature of the fishery, and the associated difficulty in finding and maintaining contact with the highly mobile schools in some years, the CPUE series may not be monitoring abundance accurately. Therefore, in the current assessment the penalty weight for the CPUE series has been changed to an arbitrary value of 2, which is equivalent to a *c.v.* of 50%.

In previous assessments, the catch-at-age data were assumed to come from a multinomial distribution with a sample size of 300, and this value was used for each year as a weighting in the fitting procedure. However, the earlier data (pre-1986) are much less reliable than more recent data because only one vessel was sampled each year, and there were fewer length-frequencies taken and otoliths collected and read. There was also concern that the catch-at-age data may have too much weight compared to the acoustic data. Cordue (1993) outlined a methodology for calculating a sample size for each year which was consistent with the standard errors of the proportion at age. He then calculated the median of these and weighted it between years using the number of tows sampled per year.

Essentially the same procedure was adopted here. For a given sex and year, sample sizes were calculated for each age i using the numbers at age and the associated *c.v.*s using the following equation:

$$n_i = Y_i(1-Y_i) / S_i^2$$

where n_i = sample size, Y_i = observed proportion of fish in the catch, S_i^2 = variance of Y_i.

The median of these sample sizes was then calculated for each year and sex. The median of these medians was 325. However, the Working Group was concerned that a sample size of 300 gave too much weight to the catch-at-age data. Therefore, a range of median sample sizes was chosen arbitrarily from 10 to 325 for sensitivity analyses.

The median sample sizes were weighted between years by the proportion of tows made in that year compared to the median number of tows in the series:

$$n_y = n_{med} (t_y / t_{med})$$

where, n_y is the sample size in year y, n_{med} is the median sample size, t_y is the number of tows sampled in year y, and t_{med} is the median number of tows in any year in the series.

Although there were considerable length frequency data, no otoliths were available for 1987 so the weighting for that year was assigned the median for the series.

A penalty weight of 5 (equivalent to a *c.v.* of 30%) was used for each acoustic point which is consistent with the *c.v.*s calculated for the surveys. A penalty weight equivalent to a *c.v.* of about 5% was given to each year's estimated annual catch.

Model runs and sensitivities

In previous assessments the acoustic estimates have been fitted as absolute indices of abundance. Because of uncertainty in target strength, bottom definition, and species identification it was considered appropriate to also fit them as relative indices of abundance.

This year two base case runs were considered which cover the range of likely input parameters to the sSPA model (Table 7). Base case 1 treats the acoustic indices as relative, gives a higher weighting to the catch-at-age data, and allows the selectivity of the 3 year olds by the fishery to vary annually (i.e., assumes that unusually high or low proportions of 3 year olds in the catch are due to changes in selectivity rather than errors in the catch-at-age data). Base case 2 gives more weighting to the acoustic data by treating them as absolute, downweights the catch at age data, and assumes a constant selectivity for 3 year olds.

The data were bootstrapped to obtain 90% confidence limits for the estimates. Four sources of uncertainty were included in the procedure (*see* Hanchet & Ingerson 1995). The length at age data within individual years were bootstrapped (with replacement) and then scaled up to catch at age using the weighted length frequency of the catch for that year. Uncertainty in the CPUE data, acoustics data, and annual catch was captured by assuming the data were log-normally distributed with *c.v.*s of 50%, 30%, and 5% respectively. For each of the 500 bootstrap runs, data were randomly selected from each distribution.

Results

The stock size trajectories from the two base case runs are plotted in Figure 8, and the results summarised in Table 8. The trajectories are very similar and show a steady decline from the early 1980s until 1993 followed by a large increase in 1994 and 1995. In base case 1, the catchability coefficient for the acoustic survey (q) was estimated to be 0.88 and $B_{1994-95}$ equalled 110 200 t. In base case 2, which appears to fit the average of the 1994 and 1995 acoustic data points, $B_{1994-95}$ equals 147 400 t. The bootstrap results are shown in Table 8 and the trajectories in Figure 9. The confidence intervals for base case 2 are much tighter than for base case 1. This is because q is fixed at a value of 1 in base case 2, but is being estimated in base case 1 and so a much wider range of biomass estimates is possible.

Sensitivity analysis showed that the main reason for the difference between the two base cases was the selectivity assumption (Table 9). When the selectivity for 3 year old fish for 1994 was freed up it was estimated to be 0.85, whereas when it was set equal to the mean of all years it was assigned a value of 0.5. This had the effect of increasing the size of the 1991 year class by about 30% and increased $B_{1994-95}$ by a similar amount. Why the model estimates the selectivity for the 3 year olds so high is unclear, but appears to be related to the lower than expected proportion of this year class as 2 and 4 year olds in the catch at age matrix.

The selectivity of the 1991 year class as 3 year olds by the fishery was considered in some detail in last years assessment (Hanchet & Ingerson 1995). They considered that there was no evidence that the fleet targeted this particular year class: all the evidence suggested that the fleet actively avoided it by concentrating on the northern ground. Further support for a large 1991 year class comes from the 1993 acoustic estimate of prerecruits. The 90 000 t biomass estimate equated to about 600 million fish, which is at the upper end of the range of 400–600 million fish estimated by the model. The 1991 year class is estimated to be 3–5 times larger than the previous highest recruitment, but this is within the expected range of variability for this species.

Current biomass was also moderately sensitive to whether the acoustic estimates were treated as relative or absolute, and to the penalty weight used for the effort data.

Retrospective analysis showed that historical biomass estimates were insensitive to the removal of the more recent years (*see* Table 9). However, the size of the 1991 year class and hence current and future biomasses were all quite sensitive to the removal of recent years because of the selectivity assumptions outlined above.

Estimation of recruitment for projections

As stated in the previous section the number of 3 year olds in the terminal year (1995) is estimated by the model assuming that the selectivity of that age class by the fishery is fixed at the geometric mean of the selectivity of that age class omitting the last 2 years. In forward projections, the number of 2 year olds entering the fishery is assumed to be the geometric mean of the number of 2 year olds over the years 1979 to 1992. These years were chosen as recruitment is estimated fairly precisely by the model over this period.

Estimation of virgin biomass

An estimate of virgin biomass (B_0) was obtained from the product of the spawning stock biomass per recruit (age 2) in an unfished stock (2.17 kg per recruit) (Hanchet & Ingerson 1995) and the arithmetic mean of the recruitment of 2 year olds from the period 1979 to 1992 calculated from the sSPA. Using mean recruitments of 55.3 and 57.1 million fish gave virgin biomass estimates of 120 000 t and 124 000 t.

(ii) Bounty Platform stock

The acoustic estimates were modelled, both as relative and as absolute indices of abundance, using stock reduction analysis with deterministic recruitment. The stock was assumed to be in a virgin state in 1979 although catches had been taken before this. Growth rates, the maturity ogive, the weight-length relationship, and other input parameters were assumed to be the same as for the Campbell Island stock (Table 10).

The best fits to the relative indices were at B_{min} and the q was estimated to be about 6, which was considered unrealistic when compared to the q of 0.88 estimated for the Campbell stock. When the acoustic estimates were fitted as absolute, B_0 was estimated to be 125 000 t, and $B_{1994-95}$ was estimated to be 59 700 t (Table 11).

The population trajectory does not fit the acoustic indices very well (Figure 10). However, it is suspected that the 1993 biomass was overestimated whilst the 1995 biomass was underestimated (*see* Section 4.2.2). The 1994 estimate is probably the most reliable because it has the lowest *c.v.*, and a further snapshot in that year provided a very similar estimate of the biomass (Hanchet & Ingerson 1995). The trajectory hits the 1994 acoustic point, so current biomass may be reasonably well estimated. There are also problems with the assumption of deterministic recruitment. Experience with the Campbell Island stock has shown recruitment to be extremely variable (up to two orders of magnitude) and it is clear from the length frequency data that the large catch in 1992 comprised mainly young fish from the strong 1986 and 1988 year classes. The trajectory is therefore likely to change considerably once the data are fitted to a full catch-at-age model.

Consideration should also be given to the highest exploitation rate estimated by the analysis. The catch to pre-season biomass ratio for the year with the biggest catch (1992) was 0.54. This is consistent with the highest exploitation rate estimated for the Campbell Island fishery. It can be concluded that whilst there is a great deal of uncertainty with this assessment the current biomass is probably somewhere in the range 40 000–80 000 t.

(iii) Pukaki Rise stock

The acoustic estimates were modelled, both as relative and as absolute indices of abundance, using stock reduction analysis with deterministic recruitment. The stock was assumed to be in a virgin state in 1979, although catches had been taken before this. Growth rates, the maturity ogive, the weight-length relationship, and other input parameters were assumed to be the same as for the Campbell Island stock (*see* Table 10).

The catch history was applied back to 1978–79 and includes fish caught on both the Pukaki Rise and Auckland Island Shelf. The best fits to the relative indices were at B_{min} and the q was estimated to be about 10, which was considered unrealistic when compared to the q of 0.88 estimated for the Campbell stock. When the acoustic estimates were fitted as absolute, B_0 was estimated to be 51 000 t, and $B_{1994-95}$ was estimated to be 33 300 t (Table 11). The population trajectory and fit to the acoustic points are shown in Figure 11.

The population trajectory does not fit the acoustic indices very well (Figure 11). The 1995 acoustic biomass is almost certainly underestimated as the survey was carried out well before the spawning season started. The 1993 and 1994 surveys were carried out just before spawning started, but the acoustic biomass estimates appear to be too high because they are not consistent with the catches that have been taken from the fishery and the difficulty fishers experience in catching fish in this area. Furthermore, the large numbers of prerecruits (2 year olds) found in 1993 do not appear to have recruited to the Pukaki Rise fishery in the numbers expected.

Although there is considerable uncertainty over the estimates of current biomass it probably lies somewhere in the range 20 000–50 000 t.

(b) <u>Estimation of Maximum Constant Yield (MCY)</u>

The simulation method of Francis (1992) was used to determine the MCY reference harvest rate. This harvest rate is the highest constant catch policy (as a percentage of B_0) which allows the stock to go below $0.2B_0$ only 10% of the time. Using the input parameters shown in Table 10, MCY was calculated as 5.1% of B_0.

(i) Campbell Island stock

MCY was estimated by multiplying the harvest level by the estimates of B_0 from base case 1 and 2.

$$MCY = 0.051 * 120\,000 \text{ t} = 6\,100 \text{ t}$$
$$MCY = 0.051 * 124\,000 \text{ t} = 6\,300 \text{ t}$$

(ii) Bounty Platform stock

MCY was estimated by multiplying the harvest level by the estimate of B_0.

$$MCY = 0.051 * 125\,000 \text{ t} = 6\,400 \text{ t}$$

(iii) Pukaki Rise stock

MCY was estimated by multiplying the harvest level by the estimate of B_0.

$$MCY = 0.051 * 51\,000 \text{ t} = 2\,600 \text{ t}$$

(c) Estimation of Current Annual Yield (CAY)

The simulation method of Francis (1992) was also used to determine u_{CAY}, the ratio of catch to pre-season biomass. Using the input parameters shown in Table 10, u_{CAY} equalled 0.21. This harvest rate is the highest constant F policy (as a percentage of B_0) which allows the stock to go below $0.2B_0$ only 10% of the time. Under a CAY harvest strategy the mean biomass (B_{MAY}) was estimated to be $0.38B_0$.

CAYs for 1995–96 and 1996–97 were calculated for each stock and their 90% confidence intervals calculated for the Campbell Island stock.

(i) Campbell Island stock

CAY was estimated by multiplying the harvest rate by pre-season biomass in 1995–96 and 1996–97. Pre-season biomass in 1995–96 was calculated by projecting forward the 1995–96 beginning - of - year numbers for ages 4 through to 11+ for each of the base runs, assuming all natural mortality occurred before the fishing season started. Recruitment of 2 year olds in 1994–95 and 1995–96 was assumed to be the geometric mean of recruitment over the period 1978–79 to 1991–92. The projection was carried forward to 1996–97 by making the same assumptions about recruitment, and assuming the 1995–96 catch equalled either $CAY_{1995-96}$ or the current catch limit (11 000 t). The resulting CAY estimates and 90% confidence intervals are shown in Table 8.

The sensitivity of the yield estimates to various input parameters is shown in Table 12. CAY was most sensitive to the selectivity assumptions. The size of the 1991 year class, on which yields are highly dependent, is still unknown. The size of the 1993 year class was estimated by the acoustic survey to be over 100 million fish. There was only a slight increase in yields when this value was used in the projections.

(ii) Bounty Platform stock

Biomass estimates from 1995 were projected forwards in two ways. In the first, recruitment was assumed to be deterministic and the biomass projected forwards accounting for natural mortality, growth, and recruitment. In the second, the biomass was projected forwards assuming recruitment was equal to the estimates from the 1995 acoustic survey and assuming natural mortality equalled growth. The projections were carried forward to 1996 making the same assumptions about M, recruitment, and growth, and assuming the 1995–96 catch equalled 15 000 t (the current catch limit). CAY was calculated by multiplying the pre-season biomass by the harvest rate, 0.21. CAY estimates are shown in Table 11. The large difference in $CAY_{1996-97}$ between the two methods is due to the large number of 1 year olds recorded in the acoustic survey.

(iii) Pukaki Rise stock

Biomass estimates from 1995 were projected forwards in two ways. In the first, recruitment was assumed to be deterministic and the biomass projected forwards accounting for natural mortality, growth, and recruitment. In the second, the biomass was projected forwards assuming recruitment was equal to the estimates from the 1995 acoustic survey and assuming natural mortality equalled growth. The projections were carried forward to 1996 making the same assumptions about M, recruitment, and growth, and assuming the 1995–96 catch equalled 6000 t (the current catch limit). CAY was calculated by multiplying the pre-season biomass by the harvest rate, 0.21. CAY estimates are shown in Table 11.

5. STATUS OF THE STOCKS

For all stocks, CAY estimates for 1995–96 and 1996–97 are greater than recent catch levels and for most cases greater than current catch limits (Table 13). In general, estimates for 1995–96 are much better known than estimates for 1996–97, and there is more confidence in the estimates for the Campbell Island stock than for the Bounty Platform and Pukaki Rise stocks.

(i) Campbell Island stock

Estimates of current and reference biomass are available. The stock appears to be well above B_{MAY}.

There is some uncertainty over the estimate of current biomass and yields for this stock.

Current biomass depends to a large extent on the size of the recently recruited 1991 year class. All the available evidence from catch-at-age, acoustic, and CPUE data suggest that this year class is extremely large.

Yields are largely dependent on the size of the 1991 year class. CAY estimates for both 1995–96 and 1996–97 are considerably greater than recent catch levels and current catch limits. The 1993 year class which will recruit into the Campbell Island Rise fishery for the first time in 1995–96 was also estimated to be well above average by the 1995 acoustic survey.

(ii) Bounty Platform stock

Estimates of current and reference biomass are available. The model estimates the stock size is above B_{MAY}.

There is considerable uncertainty over the estimate of current biomass and yields for this stock. The main underlying assumption of the assessment is that the acoustic surveys provide realistic estimates of absolute abundance (i.e., $q = 1$). Modelling from the Campbell stock estimated an acoustic q of 0.88, which suggests that this is a reasonable assumption.

Yield estimates are uncertain because of uncertainty over current biomass and future recruitments. The CAY estimate for 1995–96 is slightly below the current catch limit of 15 000 t, but above recent catch levels. The CAY estimate for 1996–97 is considerably higher because the strong 1994 year class is expected to recruit to the fishery in 1996–97.

(iii) Pukaki Rise stock

Estimates of current and reference biomass are available. The model estimates the stock size is above B_{MAY}.

There is considerable uncertainty over the estimate of current biomass and yields for this stock. The main underlying assumption of the assessment is that the acoustic surveys provide realistic estimates of absolute abundance (i.e., $q = 1$). Modelling from the Campbell stock estimated an acoustic q of 0.88, which suggests that this is a reasonable assumption.

Yield estimates are uncertain because of uncertainty over current biomass and future recruitments. CAY estimates for both 1995–96 and 1996–97 are above recent catch levels and either above or close to the current catch limit. These yield estimates are at the same level as the highest historical landings from this fishery.

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We thank Chris Francis for estimating harvest rates for the various fishing policies, and Kevin Sullivan and Patrick Cordue for help with modelling and for useful discussions about the assessment. Thanks to Marianne Vignaux, Kevin Sullivan, and John Annala for comments on an earlier draft of the manuscript.

7. REFERENCES

Chatterton, T.D. 1996: Catch per unit effort (CPUE) analysis of the Campbell Island Rise southern blue whiting (*Micromesistius australis*) trawl fishery from 1986 to 1993. N.Z. Fisheries Assessment Research Document 96/1. 26 p.

Cordue, P.L. 1993: MIAEL estimation of biomass and fishery indicators for the 1993 hoki stock assessment. N.Z. Fisheries Assessment Research Document 93/15. 33 p.

Francis, R.I.C.C. 1992: Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). N.Z. Fisheries Assessment Research Document 92/8. 27 p.

Hanchet, S.M. 1991: Southern blue whiting fishery assessment for the 1991–92 fishing year. N.Z. Fisheries Assessment Research Document 91/7. 48 p.

Hanchet, S.M. 1992: Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1992–93 fishing year. N.Z. Fisheries Assessment Research Document 92/19. 42 p.

Hanchet, S.M. 1993: Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1993–94 fishing year. N.Z. Fisheries Assessment Research Document 93/17. 56 p.

Hanchet, S.M., & Haist, V. 1994: Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1994–95 fishing year. N.Z. Fisheries Assessment Research Document 94/22. 41 p.

Hanchet, S.M., Chatterton, T.D., & Cordue P.L. 1994: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, Pukaki Rise, and Campbell Island Rise, August-September 1993. N.Z. Fisheries Assessment Research Document 94/23. 38 p.

Hanchet, S.M., & Ingerson, J.K.V. 1995: Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1995–96 fishing year. N.Z. Fisheries Assessment Research Document 95/20. 37 p.

Hanchet, S.M. & Ingerson, J.K.V. 1996: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, Pukaki Rise, and Campbell Island Rise, August-September 1994. N.Z. Fisheries Assessment Research Document 96/3. 28 p.

Ingerson, J.K.V. & Hanchet, S.M. 1995: Catch per unit effort (CPUE) analysis of the Campbell Island Rise southern blue whiting (*Micromesistius australis*) fishery from 1986 to 1994. N.Z. Fisheries Assessment Research Document 95/21. 15 p.

Monstad, T., Borkin, I., & Ermolchev, V. 1992: Report of the joint Norwegian-Russian acoustic survey on blue whiting, spring 1992. *ICES C.M. 1992/H:6*. 26 p.

Punt, A.E. 1994: Assessments of the stock of southern blue whiting (*Micromesistius australis*) from the Campbell Island Rise. N.Z. Fisheries Assessment Research Document 94/12. 30 p.

Shpak, V.M. 1978: The results of biological investigations of the southern putassu *Micromesistius australis* (Norman, 1937) on the New Zealand plateau and perspectives of its fishery. Unpublished TINRO manuscript. (Translation held in NIWA library, Wellington.)

Shpak, V.M. & Kuchina, V.V. 1983: Dynamics of abundance of southern putassu. *Biologiya Morya, 2:* 35–39. (Translation held in NIWA library, Wellington.)

Table 1: Estimated catches (t) of southern blue whiting by area for the 1 October to 30 September fishing years for the period 1971 to 1994–95. Source – vessel logbooks. For the purposes of this table Bounty Platform is > 176°E; Campbell Island Rise is > 50°30'S and > 168°30'E; and Pukaki Rise is the remaining area (Figure 1). –, no data. 1994–95 estimates are preliminary

Fishing year	Bounty Platform	Campbell Island Rise	Pukaki Rise	Total
1971~	–	–	–	10 400
1972~	–	–	–	25 800
1973~	–	–	–	48 500
1974~	–	–	–	42 200
1975~	–	–	–	2 378
1976~	–	–	–	17 080
1977~	–	–	–	26 435
1978*	0	6 403	94	6 497
1978–79+	1 211	25 305	1 620	28 136
1979–80+	16	12 828	5 789	18 633
1980–81+	8	5 989	2 469	8 466
1981–82+	8 325	7 915	1 355	17 595
1982–83+	3 864	12 803	7 572	24 239
1983–84+	348	10 777	2 249	13 374
1984–85+	0	7 490	1 845	9 335
1985–86+	0	15 252	567	15 819
1986–87+	0	12 804	906	13 710
1987–88+	18	17 422	161	17 601
1988–89+	8	26 611	1 220	27 839
1989–90+	4 430	16 542	1 393	22 365
1990–91+	10 897	21 314	4 659	36 870
1991–92+	58 928	14 208	3 119	76 255
1992–93+	11 908	9 316	6 484	27 708
1993–94+	3 877	11 668	3 015	18 560
1994–95+	6 500	9 750	1 750	18 000

~ Calendar year
* 1 April – 30 September
\+ 1 October – 30 September

Table 2: Reported landings (t) of southern blue whiting by fishing year from 1986–87 to 1994–95 and by calendar year for 1987 to 1995. Source — Licensed Fish Receiver Returns. 1994–95 estimates are preliminary

Fishing year	Catch	Calendar year	Catch
1986–87	3 468	1987	10 696
1987–88	13 720	1988	16 374
1988–89	30 692	1989	28 556
1989–90	24 514	1990	22 127
1990–91	35 593	1991	42 025
1991–92	83 427	1992	78 592
1992–93	29 184	1993	27 382
1993–94	13 300	1994	14 670
1994–95	19 200	1995	19 500

Table 3: Results of standardised CPUE analysis for the Campbell Island Rise, showing the number of tows, percentage of zero tows, relative year effect, catch, and relative effort for each year

Year	Number of tows	Percentage zero tows	Relative year effect	Catch (t)	Relative effort
1986	893	4.6	1.00	15 252	15 252
1987	637	5.3	0.68	12 804	18 829
1988	843	7.1	0.52	17 422	33 504
1989	1008	4.7	0.53	26 611	50 209
1990	994	7.8	0.46	16 652	35 883
1991	1057	3.7	0.35	21 314	61 072
1992	1091	18.7	0.23	14 208	62 044
1993	411	10.7	0.61	9 316	15 272
1994	384	6.8	0.53	11 290	21 302
1995	170	2.4	0.88	9 750	11 080

Table 4: Dates associated with presence of certain gonad stages in 1995 in each of the three areas, and percentage spent and reverted in the last sample (–, could not be determined)

Gonad stage	Bounty	Pukaki	Campbell
1st sample	19/8	3/9	5/9
>10% ripe	22/8	16/9	11/9
>10% running ripe	24/8	–	13/9
Main spawning	24–28/8	–	13–20/9
>10% spent	-	–	16/9
>10% reverted	28/8	–	16/9
>50% spent	–	–	–
2nd spawning	–	–	–
Last sample	31/8	17/9	28/9
% spent	1	0	20
% reverted	70	0	45

Table 5: Summary of biomass estimates (t x 10^3) (and *c.v.*s) for each area, and category of SBW for the 1993, 1994, and 1995 acoustic surveys

	Adult (mature)			Immature (mostly 2)			Juvenile (age 1)		
Area	1993	1994	1995	1993	1994	1995	1993	1994	1995
Campbell Island	18.5	161.4	121.1	89.6	22.4	20.0	0	0	0
	(21)	(36)	(30)	(23)	(38)	(25)			
Bounty Platform	94.6	55.0	35.2	5.9	15.8	0	7.2	0.2	93.3
	(46)	(22)	(24)	(43)	(87)		(46)	(80)	(37)
Pukaki Rise	49.8	39.0*	12.8	26.3	0	0	0	0	0
	(24)	(45)	(18)	(20)					
Auckland Is.	-	-	7.8	-	-	0	-	-	0
			(20)						

* Includes some immature 3 yr old fish.

Table 6: Catch-at-age (years) matrix for the Campbell Island Rise (in '000s)

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
2	389	43	1 508	1 940	934	45	296	813	689	2 617	192	838	150	2 558	577	1 363	124
3	979	247	91	7 599	10 626	1 113	130	2 975	4 342	5 238	10 340	4 649	30 548	506	6 616	33 854	2 872
4	9 497	584	205	1 153	7 713	5 262	1 604	1 381	4 563	5 226	6 093	14 870	6 983	13 262	761	2 671	22 231
5	3 036	1 367	177	479	330	6 188	3 739	1 642	589	4 118	5 078	2 630	6 353	3 997	5 327	176	1 185
6	711	183	565	256	428	780	3 037	6 035	1 218	118	5 027	1 934	1 709	3 936	1 336	1 496	61
7	418	612	248	1 231	336	554	186	5 887	4 293	1 596	391	1 779	1 132	440	1 866	277	858
8	3 241	460	116	197	1 154	471	103	775	3 454	6 059	2 224	278	556	485	260	632	136
9	391	721	434	169	268	1 143	181	438	390	3 012	6 446	527	244	338	219	57	432
10	949	91	403	401	0	365	395	635	299	187	4 316	1 383	432	59	131	30	31
11	1 969	680	120	513	596	106	195	676	287	436	1 333	1 188	704	202	58	15	25
12	3 582	1 366	363	224	429	149	108	215	388	174	239	248	440	133	36	0	14
13	3 577	1 408	606	134	0	557	498	337	157	440	564	51	200	155	172	1	4
14	5 770	2 459	643	274	136	210	361	354	262	172	321	243	92	97	54	59	5
15	7 422	4 188	996	422	472	263	283	479	275	357	350	229	58	0	19	14	49
16	2 008	2 436	1 085	206	448	198	132	284	224	435	56	32	95	0	6	9	5
17	538	2 039	1 146	1 126	572	191	267	314	144	232	370	0	34	45	5	5	0
18	0	748	723	1 228	1 808	267	24	200	112	57	291	145	64	28	20	0	0
19	0	0	133	450	710	687	192	687	77	26	0	64	55	0	0	0	0
20+	0	0	83	177	454	1 068	548	1 682	994	426	129	127	19	0	39	0	10

Table 7: Values for the input parameters to the separable Sequential Population Analysis for the two base-case assessments and sensitivity tests for the Campbell Island stock

Parameter	Base case 1	Base case 2	Sensitivity
M	0.2	0.2	0.15, 0.25
Acoustic index	relative	absolute	
Acoustic penalty weights	5	5	
Catch-at-age sample sizes	100	50	325, 10
Effort penalty weights	2	2	1
Ages for which selectivity allowed to vary annually	2 + 3	2	2 or 2 + 3
Years	79–95	79–95	79–94 and 79–93

Table 8: Estimates of mid-season spawning stock biomass (*t*), from the two base case runs, for the Campbell Island stock in 1980, 1988, 1994, and 1995, fully selected F in 1995, $GMR_{1979-92}$, geometric mean of the recruitment (number of 2 year olds in thousands) over the period 1979 to 1992, $CAY_{1995-96}$, and $CAY_{1996-97}$ assuming 1995–96 catch equals (i) $CAY_{1995-96}$, or (ii) 11 000 t. Also shown are the bootstrap means, medians, and percentile 90% confidence intervals. –, not estimated

Base case 1

Parameter	Estimate	Bootstrap mean	Bootstrap median	Bootstrap 90% confidence interval	
B_{1980}	105 300	104 600	104 500	96 900	112 600
B_{1988}	54 600	54 100	53 800	50 100	59 200
B_{1994}	96 500	106 100	94 200	43 200	216 400
B_{1995}	110 200	125 900	109 900	45 600	265 800
F_{1995}	0.120	-	-	-	-
$GMR_{1979-92}$	35 500	35 500	34 900	31 500	41 600
$CAY_{1995-96}$	21 800	25 800	22 500	9 300	54 200
$CAY_{1996-97}$ (i)	18 800	21 900	19 300	8 900	44 300
$CAY_{1996-97}$ (ii)	21 200	24 500	21 500	9 900	49 600

Base case 2

Parameter	Estimate	Bootstrap mean	Bootstrap median	Bootstrap 90% confidence interval	
B_{1980}	108 900	109 100	108 600	101 000	117 000
B_{1988}	55 300	54 700	54 900	51 200	58 500
B_{1994}	95 900	95 700	94 000	64 100	138 900
B_{1995}	147 400	148 000	145 400	94 800	220 000
F_{1995}	0.090	-	-	-	-
$GMR_{1979-92}$	36 000	35 700	35 400	33 000	38 700
$CAY_{1995-96}$	29 700	30 400	29 800	18 900	45 900
$CAY_{1996-97}$ (i)	25 200	25 600	25 100	16 500	37 700
$CAY_{1996-97}$ (ii)	28 300	29 400	28 900	18 900	43 500

Table 9: Relative changes (expressed as percentages) of selected parameter estimates as a result of alternative model assumptions for the Campbell Island stock. Note the value T refers to the last year in the analysis, and is 1995 except for the last lines (e.g., for yrs = 79–94 the 1994 biomass is 6.5% lower than the 1994 base case 1 biomass). B, mid-season spawning stock biomass; F, fishing mortality rate; R_{1991}, size of the 1991 year class; GMR, geometric mean of the recruitment of 2 year olds omitting the last three years. samp size, sample size from a multinomial distribution; selages, number of ages for which selectivity allowed to vary annually; effpen, effort penalty weight; acoust, acoustic biomass estimate - whether fitted as relative or absolute

Base case 1

Model	B_{1980}	B_{1988}	B_T	F_T	R_{1991}	GMR
samp size = 325	0.0	0.1	2.0	-1.9	1.6	0.1
samp size = 50	-0.1	-0.1	-1.8	1.8	-1.3	-0.2
selages = 2	3.4	0.8	**29.5**	**-23.0**	**32.9**	1.0
effpen = 1	0.1	0.5	9.1	-8.3	7.3	1.1
acoust = abs	0.3	0.9	11.8	-10.4	9.5	1.7
M = 0.15	**-24.7**	-9.2	-9.1	10.1	**-20.0**	**-22.6**
M = 0.25	**37.3**	11.3	11.2	-10.1	**26.4**	**31.5**
yrs = 79-94	-0.2	-0.4	6.5	-6.1	**82.2**	-1.7

Base case 2

Model	B_{1980}	B_{1988}	B_T	F_T	R_{1991}	GMR
samp size = 100	0.1	0.0	1.7	-1.8	1.1	0.2
samp size = 10	-0.1	0.3	-5.0	5.7	-1.1	-0.4
selages = 2,3	-3.0	-0.1	-16.1	**21.8**	**-21.2**	0.0
effpen = 1	-0.1	-0.2	3.3	-3.4	3.3	-0.2
acoust = rel	-0.3	-0.8	-8.1	8.7	-6.9	-1.2
M = 0.15	**-24.5**	-9.3	0.8	-0.6	13.2	**-21.6**
M = 0.25	**36.6**	9.9	-0.7	0.0	15.4	**29.2**
yrs = 79-94	0.0	-0.4	**23.0**	-19.5	**31.2**	-2.4
yrs = 79-93	-0.5	-2.0	-6.5	5.9	**-97.1**	13.8

Table 10: Input parameters for stock reduction analysis.

Parameter	Males	Females
Natural mortality (M)	0.21	0.21
Age of recruitment (years)	3	3
Gradual recruitment (years)	1	1
Age at maturity (years)	3	3
Gradual maturity (years)	1	1
L_∞ cm	47.6	51.5
k year^{-1}	0.35	0.32
t_0 year	– 0.93	– 1.03
a) From weight-length relationship	0.0052	0.0041
b)	3.09	3.15
Recruitment variability	1.0	1.0
Recruitment "steepness"	0.95	0.95

Table 11: Mid-season biomass (B), pre–season biomass (PB) and CAY estimates for the Bounty Platform and Pukaki Rise stocks. R, projection assuming (a) acoustic recruitment indices or (b) deterministic recruitment. $PB_{1996-97}$ and $CAY_{1996-97}$ were estimated assuming a catch in 1995–96 equal to the current quota in 1995–96 (i.e., 6000 t on Pukaki Rise and 15 000 t on Bounty Platform). All values in t x 10^3

				1995–96		1996–97	
	B_0	$B_{1994-95}$	R	PB	CAY	PB	CAY
Bounty Platform	125	59.7	(a)	60	12.5	138	29.0
			(b)	67	14.0	62	12.9
Pukaki Rise	51	33.3	(a)	33	6.8	27	5.6
			(b)	35	7.4	32	6.7

Table 12: Sensitivity of yield estimates (t) for the Campbell Island stock. $CAY_{1996-97}$ was estimated assuming the 1995–96 catch equals $CAY_{1995-96}$. R_{1993}, size of 1993 year class. For a definition of the base cases *see* Table 7. R_{1993} equals the geometric mean of recruitment for 1979–92 (*see* Table 8)

	$CAY_{1995-96}$	$CAY_{1996-97}$	MCY
Base case 1	21 800	18 800	6 200
effpen = 1	23 700	20 400	6 200
selages = 2	28 700	24 400	6 200
R_{1993} = 100 million	23 500	21 600	6 200

	$CAY_{1995-96}$	$CAY_{1996-97}$	MCY
Base case 2	29 700	25 200	6 300
effpen = 1	30 700	25 900	6 300
selages = 2,3	24 000	20 600	6 200
R_{1993} = 100 million	31 400	27 900	6 300

Table 13: Summary of yields, catch levels, and reported landings. $CAY_{1996-97}$ was estimated assuming the 1995–96 catch equals (i) $CAY_{1995-96}$, or (ii) the 1995–96 catch limit. All values are t x 10_3. – not estimated

Area	$CAY_{1995-96}$	$CAY_{1996-97}$ (i)	$CAY_{1996-97}$ (ii)	1995–96 Catch limit	1994–95 Landings
Campbell Island†	21.8–29.7	18.8–25.2	21.2–28.3	11.0	9.8
Bounty Platform§	12.5–14.0	–	12.9–29.0	15.0	6.5
Pukaki Rise§	6.8–7.4	–	5.6–6.7	6.0	1.8
Total	41.1–50.6		38.7–67.0	32.0	18.1

† Range of estimates is based on projections from two base case runs.
§ Range of estimates is based on two projections with different recruitment assumptions.

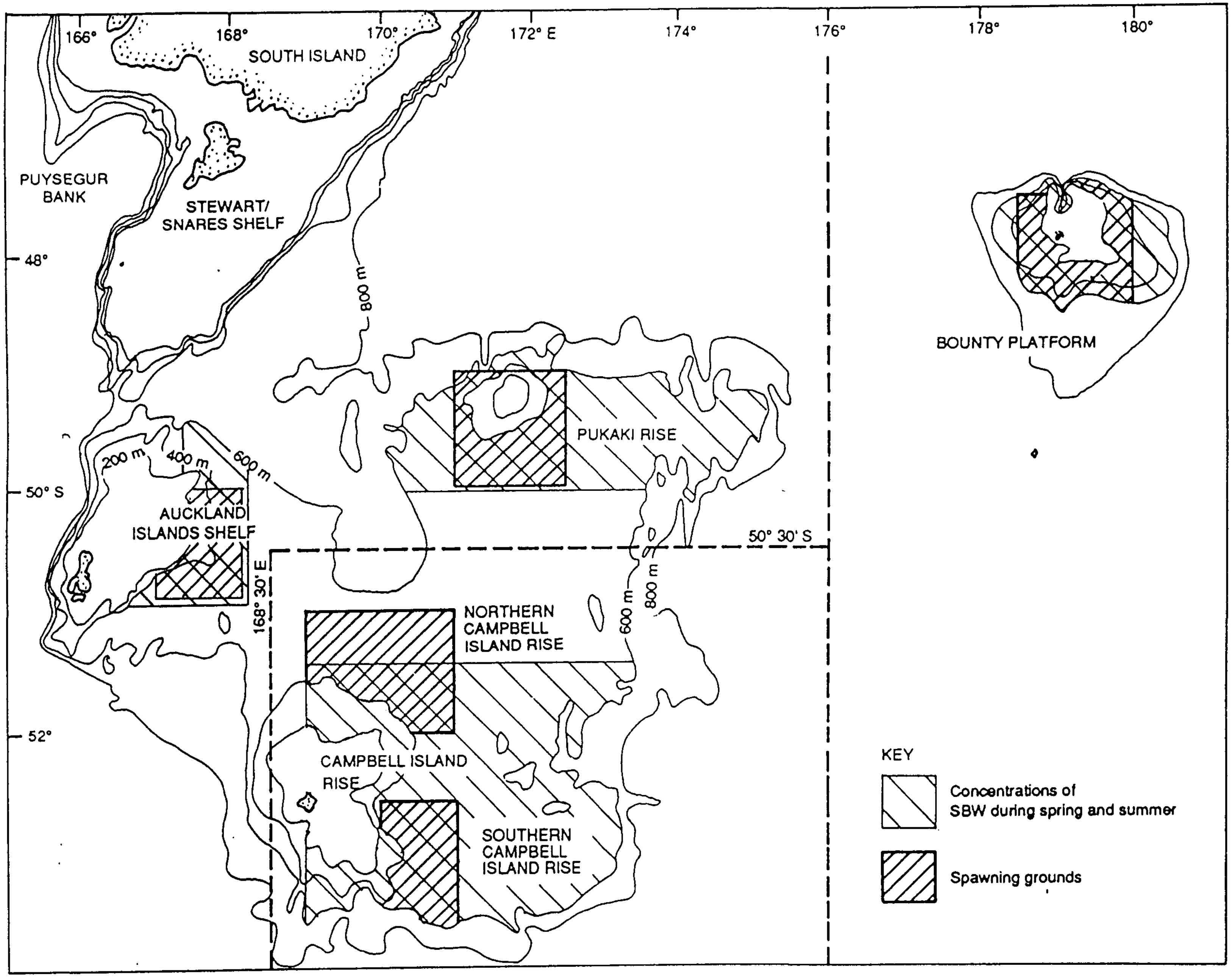

Figure 1. Main feeding grounds and spawning grounds of southern blue whiting, showing proposed stock boundaries.

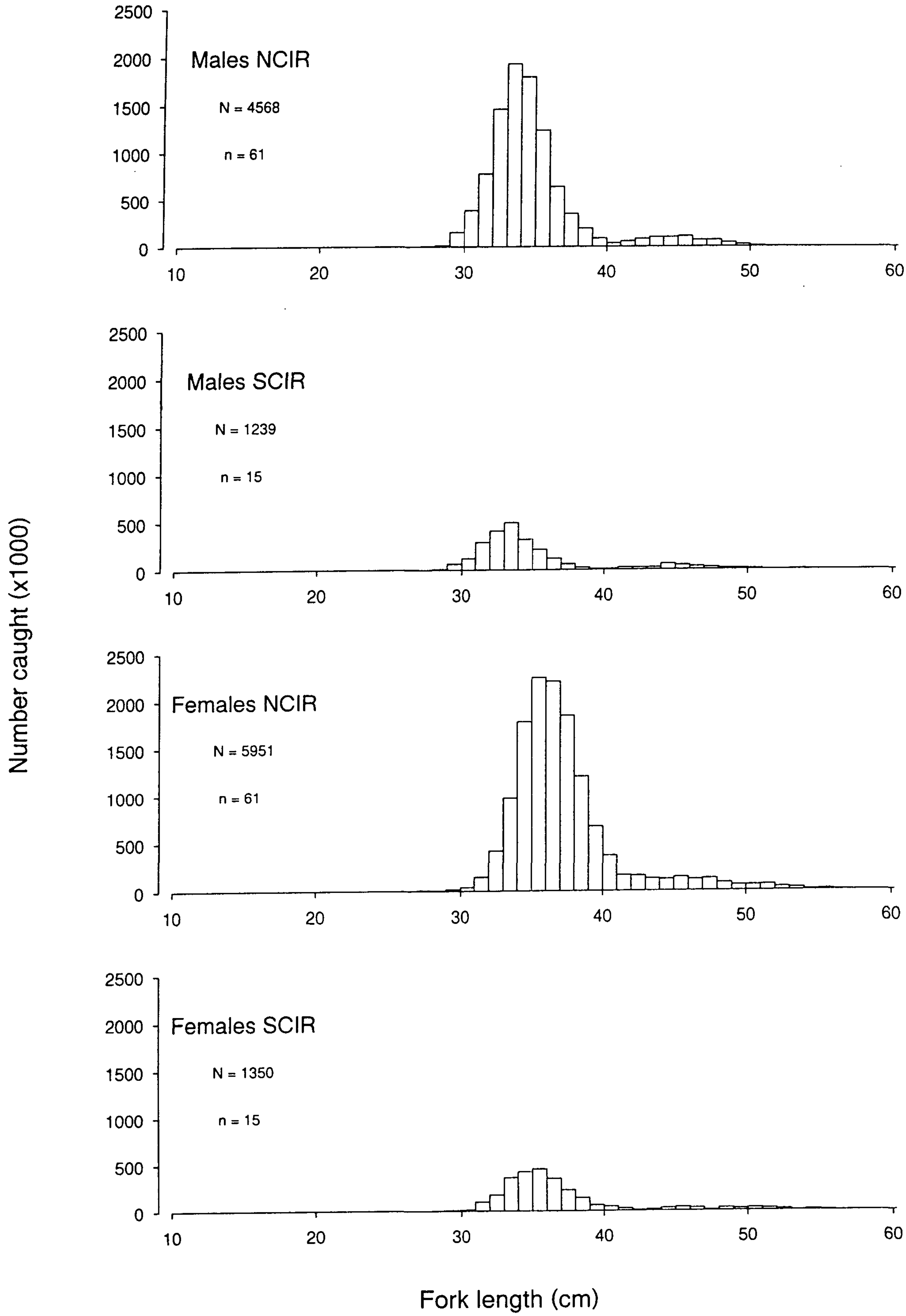

Figure 2. Weighted length frequency distribution of males and females in the 1995 catch on the northern (NCIR) and southern (SCIR) Campbell Island Rise spawning grounds. (N, number of fish measured, n, number of samples).

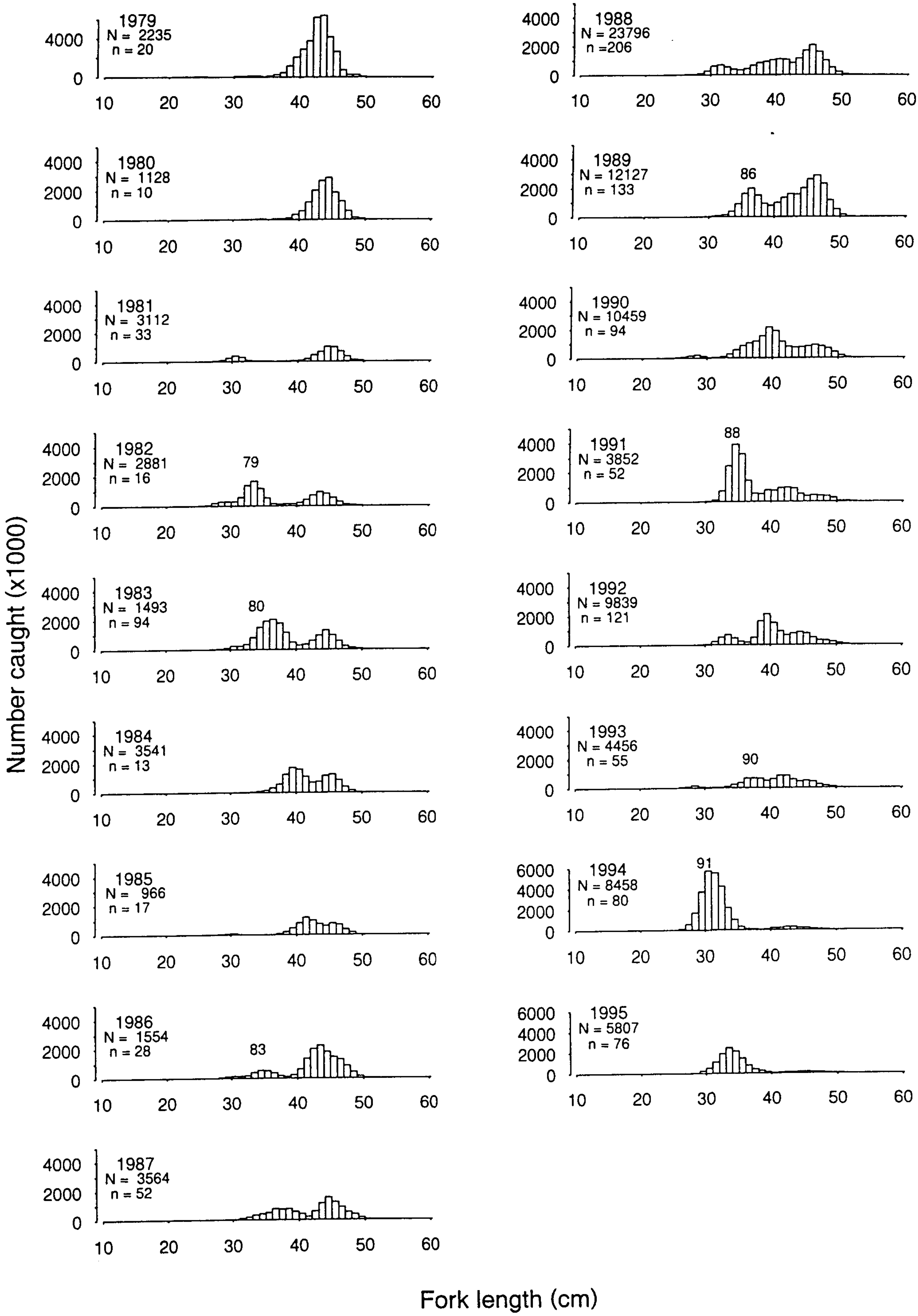

Figure 3a. Weighted length frequency distribution of males in the catch from the Campbell Island Rise. (N, number of fish measured, n, number of samples). Modal lengths of 3 year old fish from strong year classes are shown.

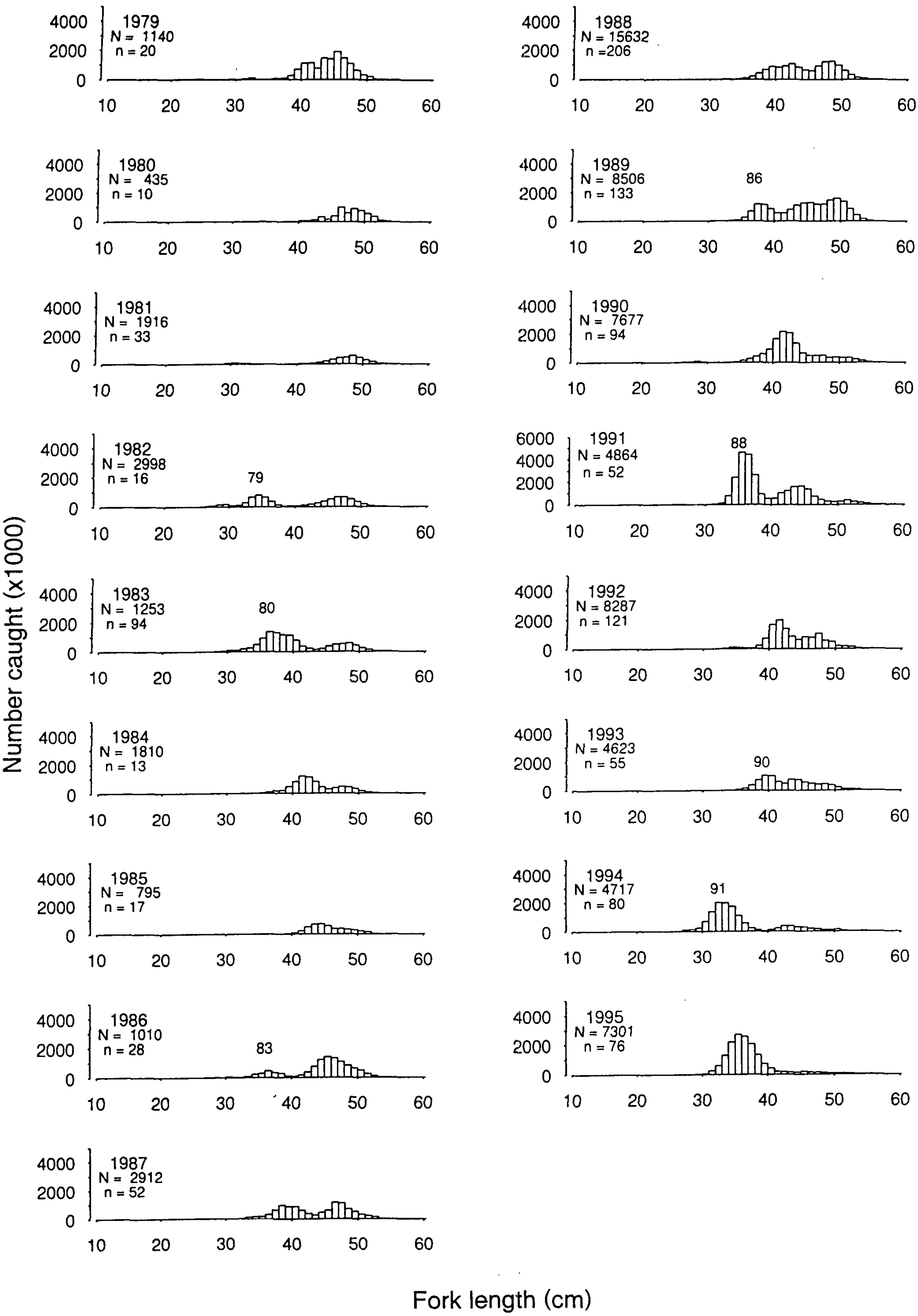

Figure 3b. Weighted length frequency distribution of females in the catch from the Campbell Island Rise. (N, number of fish measured, n, number of samples). Modal lengths of 3 year old fish from strong year classes are shown.

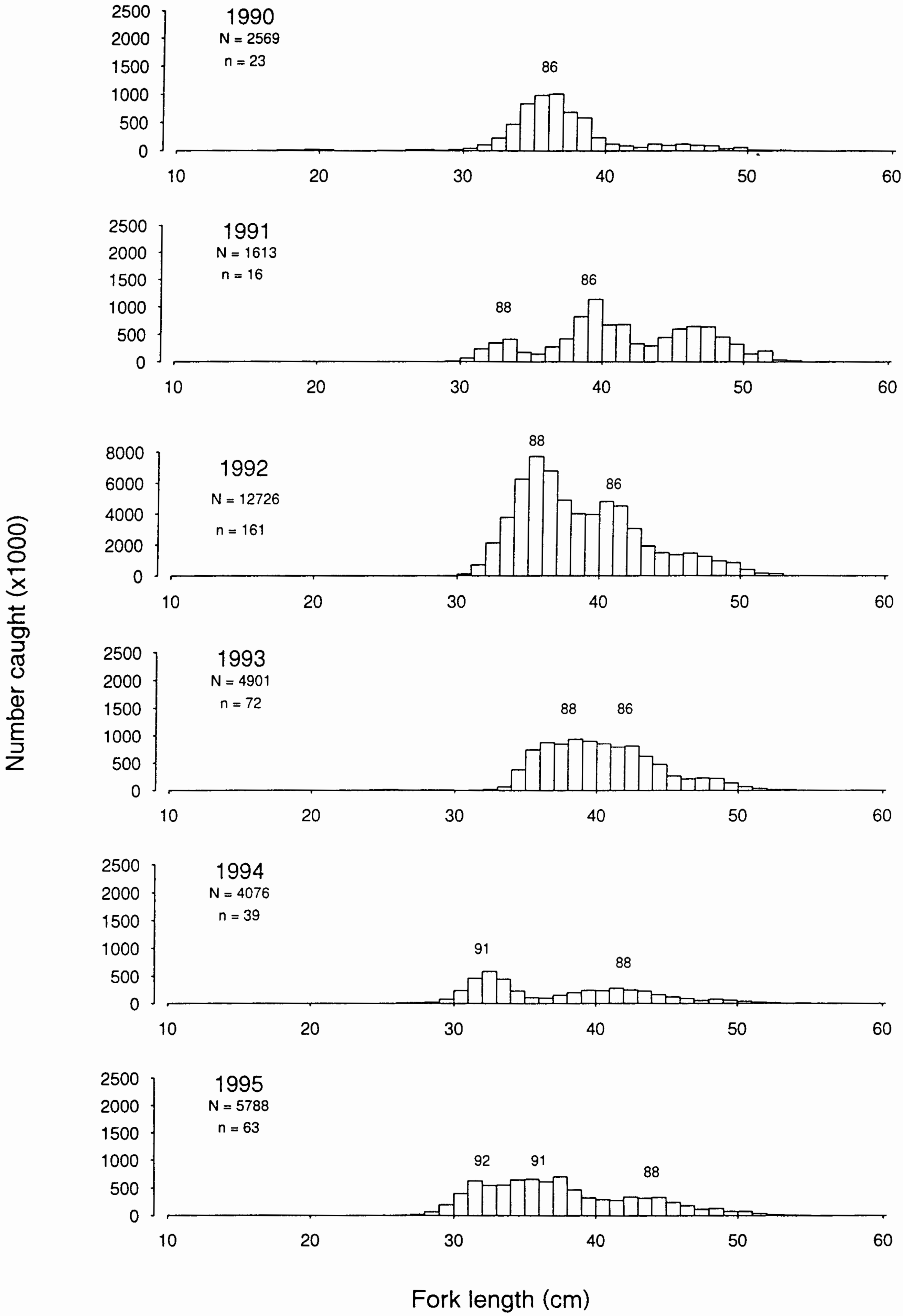

Figure 4a. Weighted length frequency distribution of males in the catch from the Bounty Platform. (N, number of fish measured, n, number of samples). Modal lengths of strong year classes are shown.

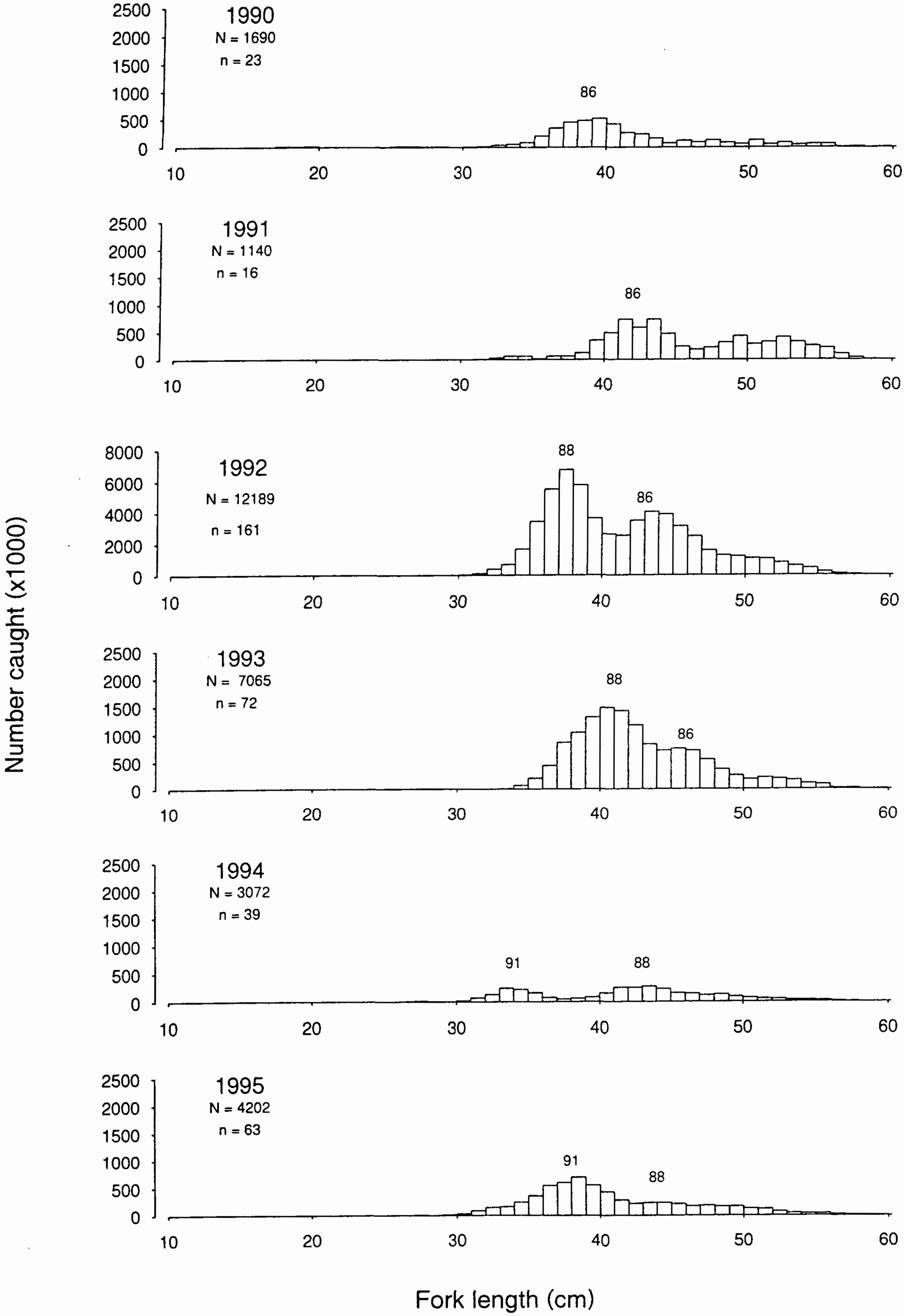

Figure 4b. Weighted length frequency distribution of females in the catch from the Bounty Platform. (N, number of fish measured, n, number of samples). Modal lengths of strong year classes are shown.

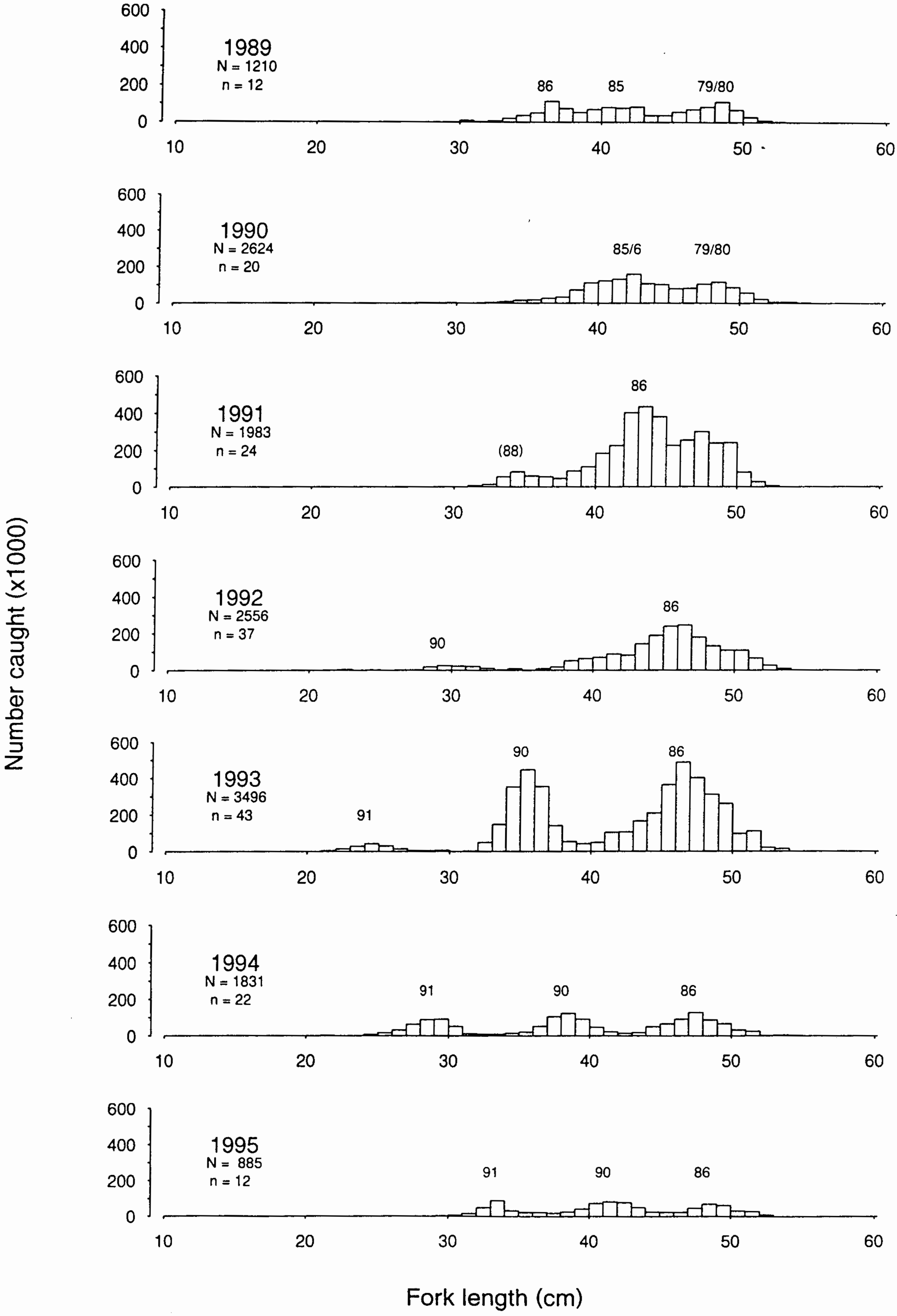

Figure 5a. Weighted length frequency distribution of males in the catch from the Pukaki Rise. (N, number of fish measured, n, number of samples). Modal lengths of strong year classes are shown.

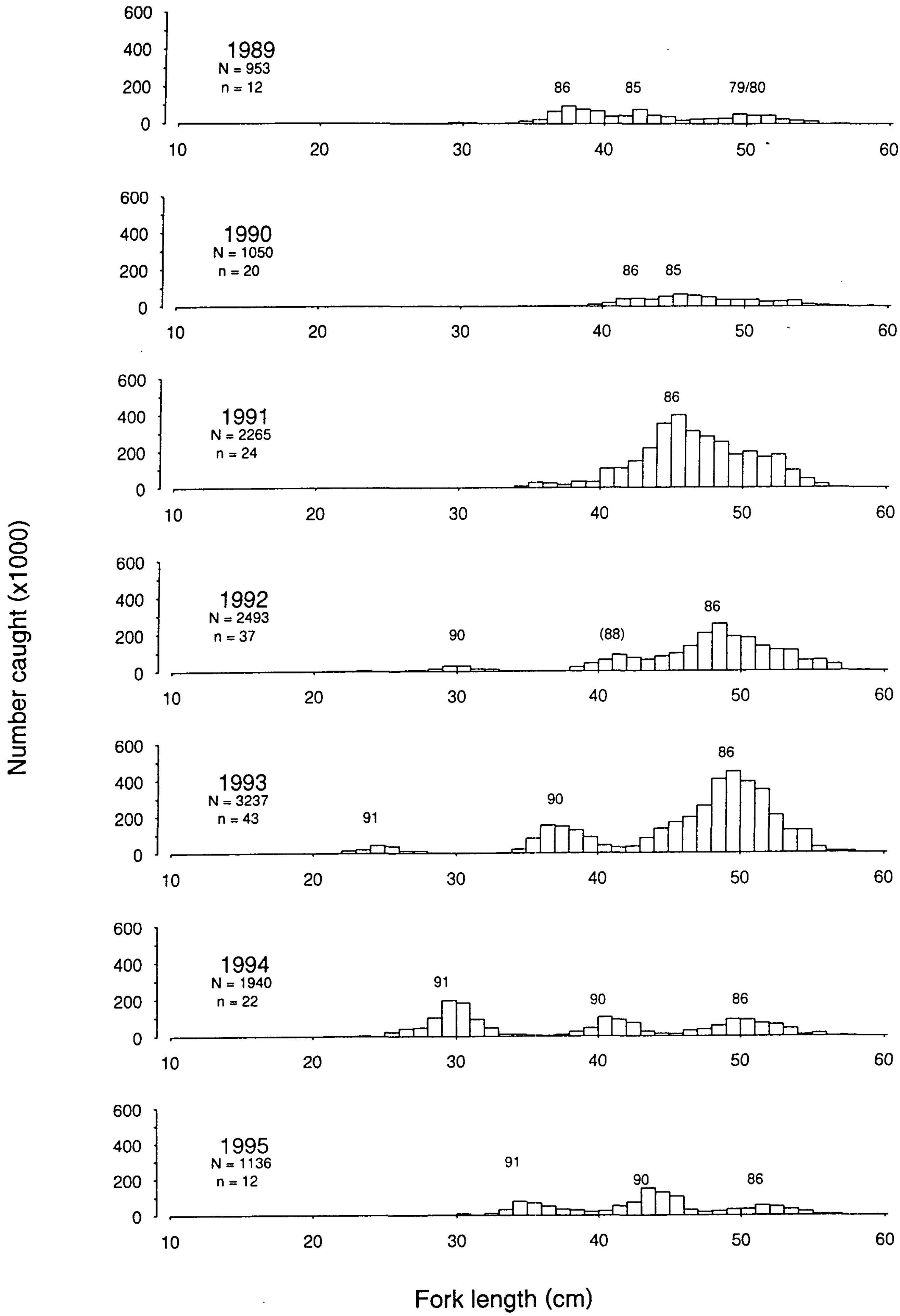

Figure 5b. Weighted length frequency distribution of females in the catch from the Pukaki Rise. (N, number of fish measured, n, number of samples). Modal lengths of strong year classes are shown.

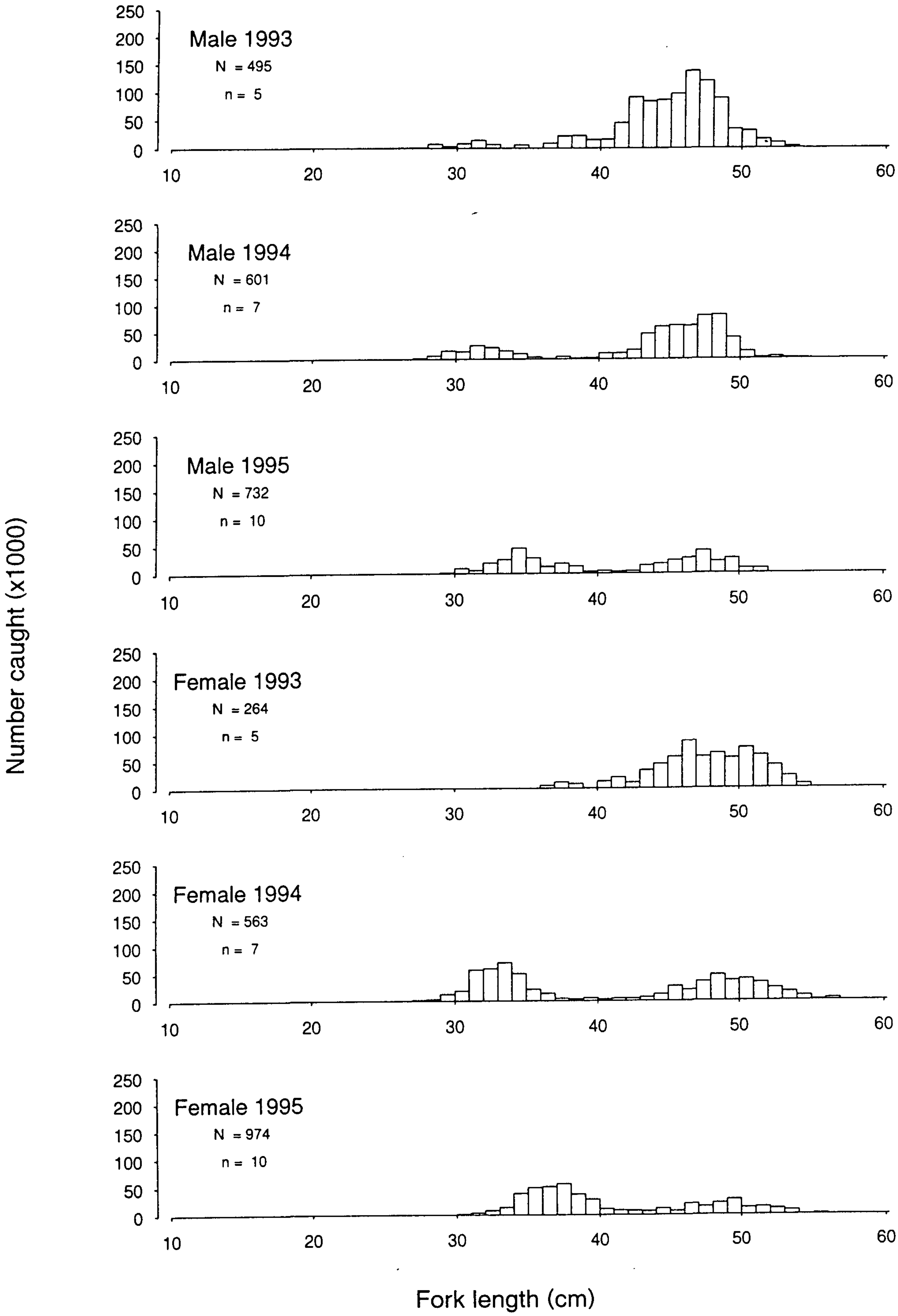

Figure 6. Weighted length frequency distribution of males and females in the catch from the Auckland Island Shelf. (N, number of fish measured, n, number of samples).

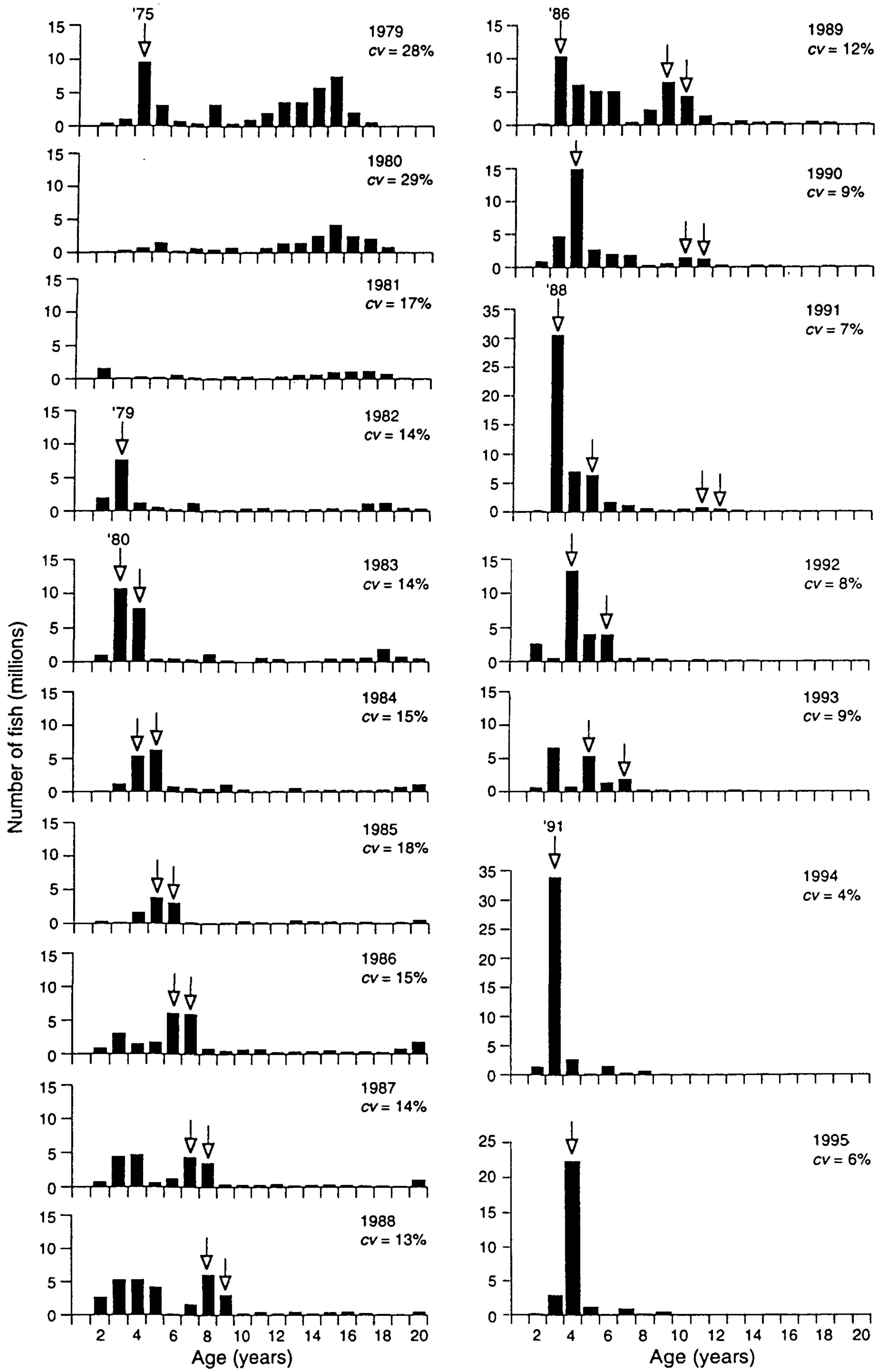

Figure 7. Age composition of the catch on the Campbell Island Rise from 1979 to 1995. Arrows denote strong year classes and the year they were spawned. Mean weighted *c.v.* given for each year.

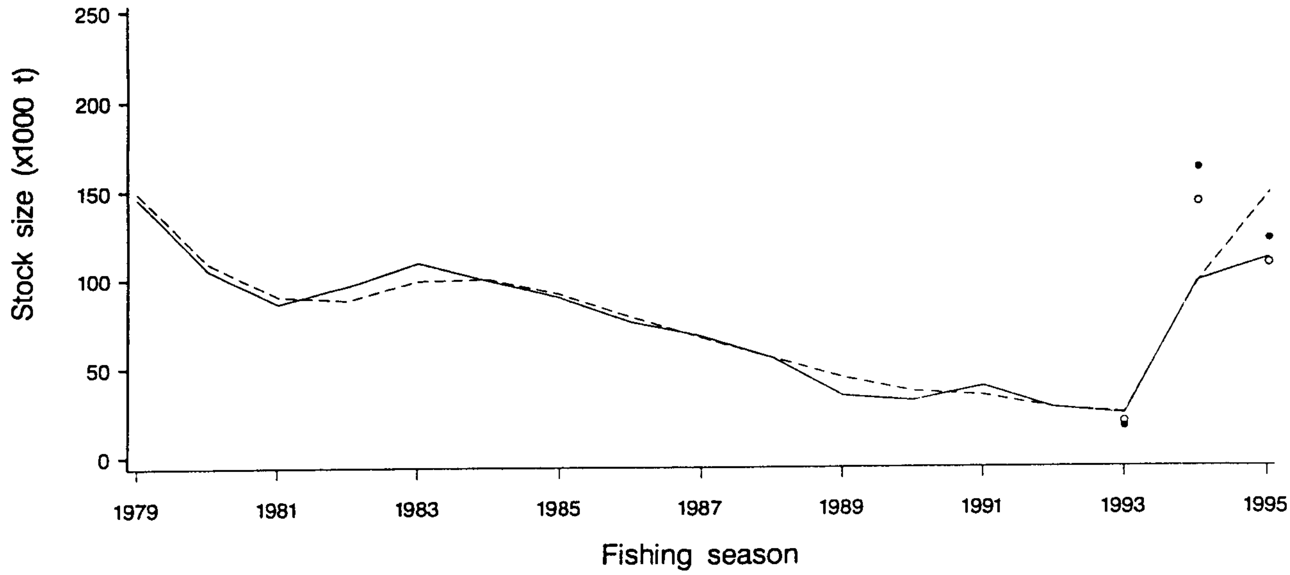

Figure 8. Mid-season spawning stock biomass (t) for the Campbell Island Rise from the two base cases, showing the fit to the acoustic estimates. ○ base case 1, ● base case 2.

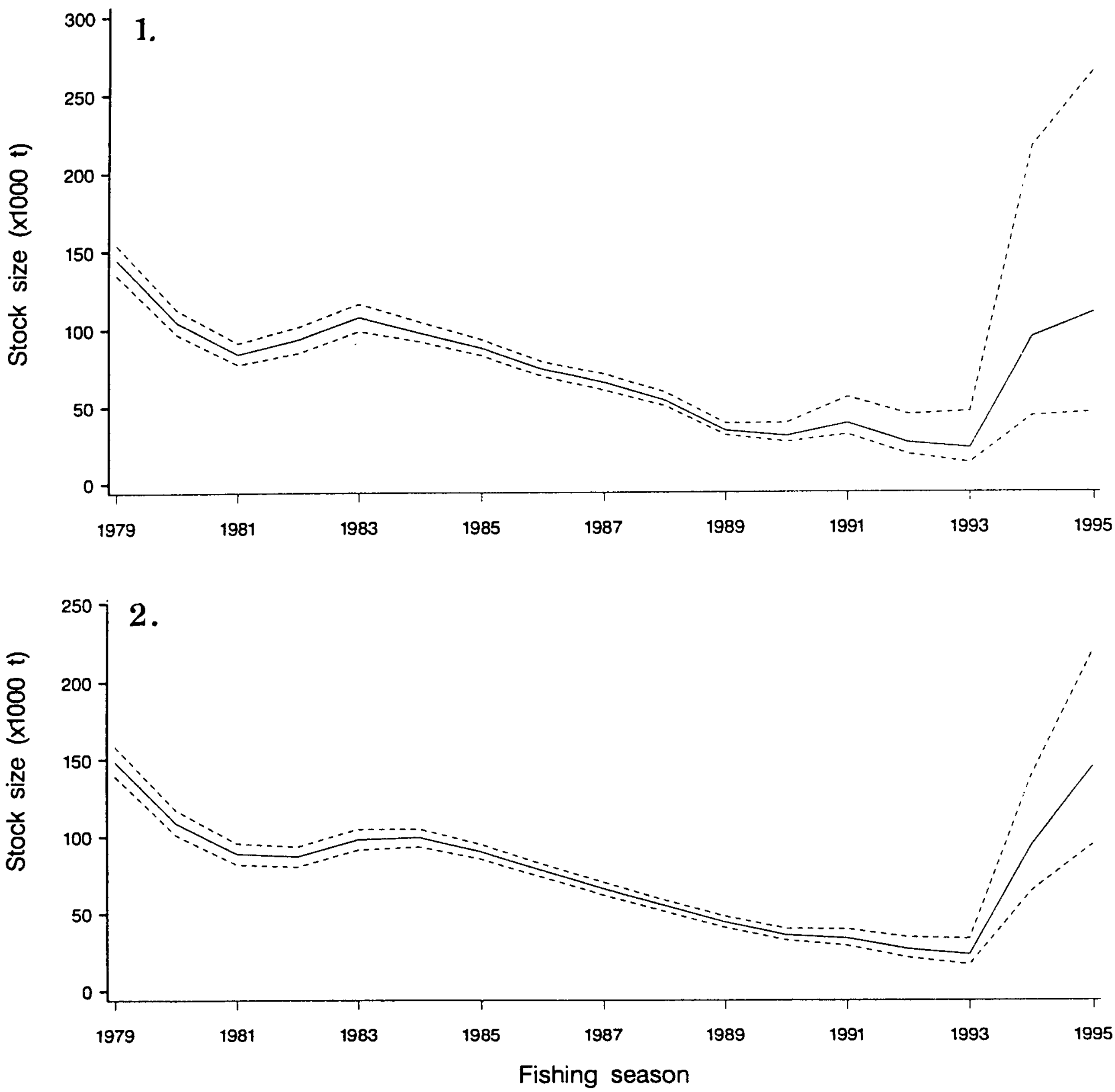

Figure 9. Mid-season spawning stock biomass (t) for the Campbell Island Rise with 90% confidence intervals for the two base cases.

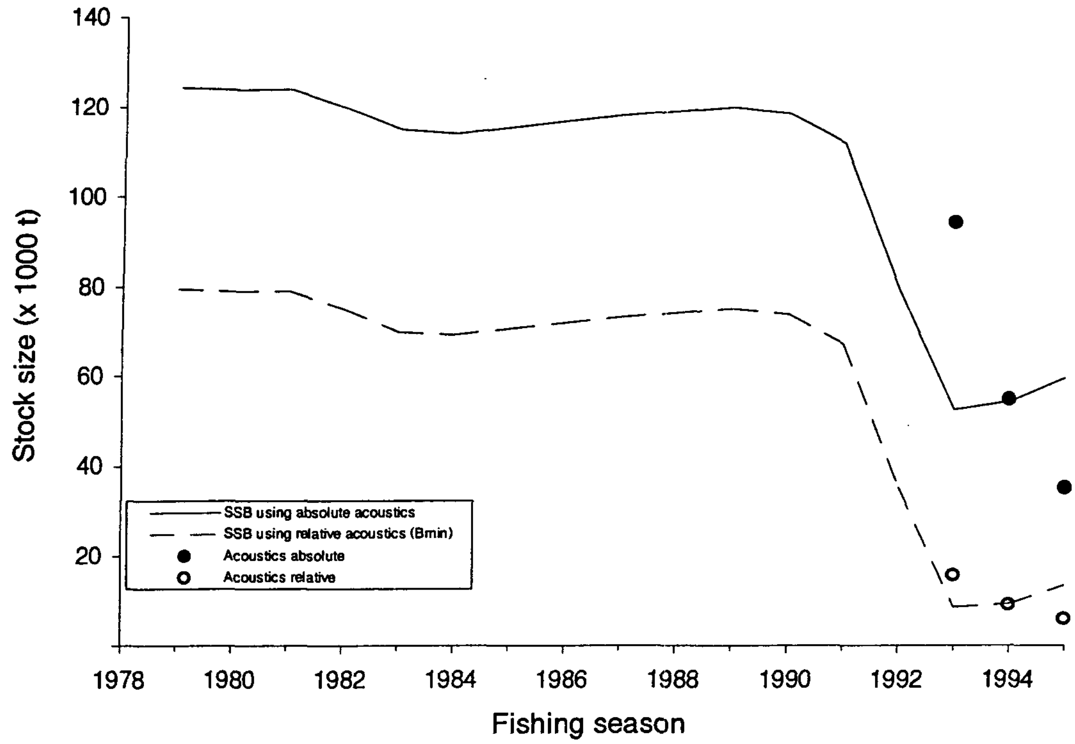

Figure 10. Population trajectory for the Bounty Platform stock using stock reduction analysis showing the fit to the acoustic estimates.

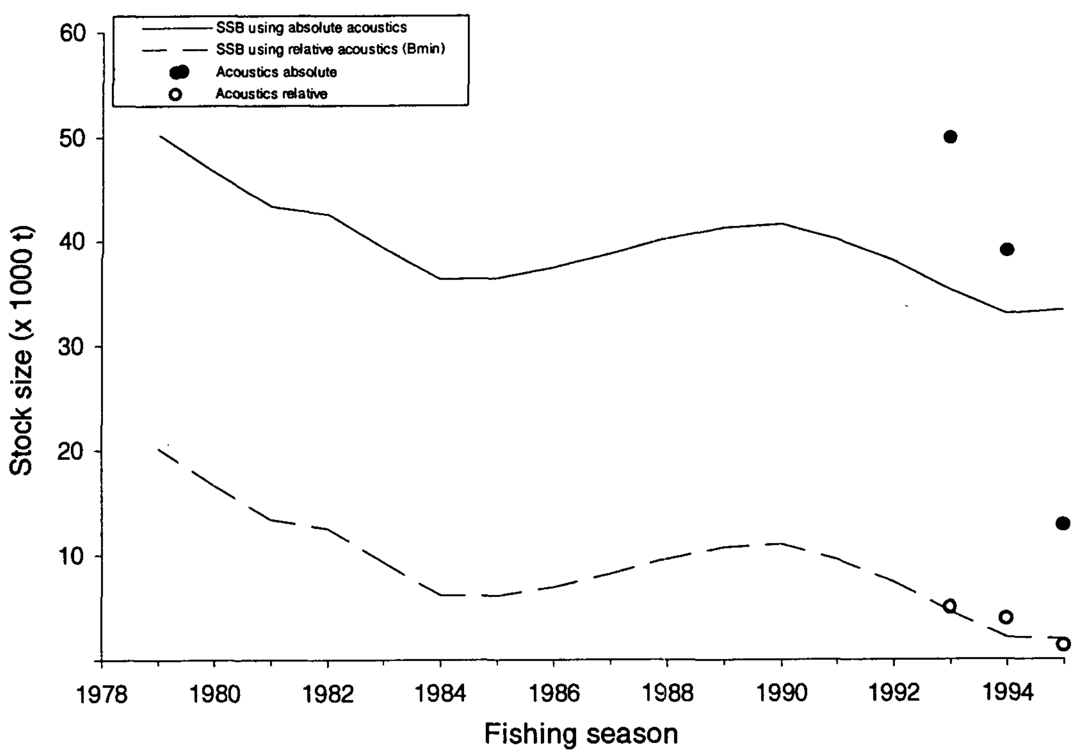

Figure 11. Population trajectory for the Pukaki Rise stock using stock reduction analysis showing the fit to the acoustic estimates.