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Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform and Pukaki Rise for 1998 and 1999

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

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1. EXECUTIVE SUMMARY

This paper reviews the stock assessment of southern blue whiting resources in New Zealand waters.

For the Bounty Platform stock the catch-at-age data and acoustic estimates of vulnerable (age 3 years or over) biomass were fitted using separable Sequential Population Analysis. The biomass declined from 1991 to 1993, largely as a result of the 60 000 t catch taken in 1992, but has since recovered towards 1990 levels. A strong year class is predicted to recruit to the fishery in 1998. Estimates of Current Annual Yield (CAY) for 1998 and 1999 are about 15 000 t and 12 000 t respectively and are well above recent levels of catch.

For the Pukaki Rise stock the catch-at-age data were estimated for the first time. The catch-at-age data and acoustic estimates of recruited biomass were fitted using separable Sequential Population Analysis. Under the base case assumptions the model was unable to track the series of acoustic estimates, and essentially fitted a flat trajectory through their mean. Estimates of CAY for 1998 and 1999 are about 5500 t and 4800 t respectively and are well above recent levels of catch.

The 1997 assessment for the Campbell Island Rise stock has not been updated. The 1997 catch was dominated by the strong 1991 year class. Unstandardised CPUE has dropped slightly since 1996 but is still above the 1986 level. The estimate of CAY for 1998 is 25 000 t.

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 an unstandardised catch per unit effort (CPUE) analysis for the Campbell Island fishery for the period 1986 to 1997 are presented. Catch-at-age data for the Pukaki Rise stock are provided for the first time, and are updated for the Bounty Platform stock. The catch-at-age data and estimates of adult and pre-recruit biomass from acoustic surveys from 1993 to 1995, and 1997 were used in a separable Sequential Population Analysis (sSPA) to estimate historic and current biomass for the Bounty Platform and Pukaki Rise stocks. The 1997 assessment for the Campbell Island Rise stock has not been updated. Estimates of Current Annual Yield (CAY) are provided for all three stocks for 1998 and for the Bounty Platform and Pukaki Rise stocks for 1999.

2.2 Description of fishery

In this paper the word fishing "season" refers to August and September, the months of intense fishing at the end of the fishing year (i.e., the 1998 season is part of the 1997–98 fishing year).

The SBW fishery was developed by Soviet vessels during the early 1970s, with landings exceeding 40 000 t in 1973 and 1974 (Table 1). It was recorded 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 on 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, the entire Campbell Plateau was fished throughout the year, but highest catches were usually made while 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 (Table 2).

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 each year 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 also started fishing spawning aggregations on the Bounty Platform and the Pukaki Rise. Fishing effort increased quite markedly between 1990 and 1992, culminating in a catch of over 75 000 t in 1992. The increased catch came predominantly from the Bounty Platform where catches increased to almost 60 000 t in only 3 years. In 1993, a fishery developed for the first time on the Auckland Islands spawning grounds and fishing has continued at a low level since then. 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 retained for the next 3 years (*see* Table 2). The area sub-limits were revised for the 1995–96 fishing year, and the total catch limit increased to 58 800 t for the 1996–97 fishing year.

2.3 Recent papers

Various designs for acoustic surveys of SBW were investigated using simulation studies by Dunn & Hanchet (1998). Results of the 1997 acoustic survey of the SBW spawning grounds on the Bounty Platform and Pukaki Rise are given in Grimes & Hanchet (in prep.). Stock structure was reviewed by Hanchet (1998). He concluded that SBW should be assessed as four stocks. A detailed account of the 1996 assessment of the Campbell Island stock and documentation of the sSPA model was provided by Hanchet *et al.* (in press). Other recent developments to the sSPA model, and a comparison with other models, are given by Hanchet (in press). In the most recent stock assessment of the Campbell and Bounty stocks, catch-at-age and acoustic data were modelled using an sSPA, and the Pukaki stock was modelled using a stock reduction analysis (Hanchet 1997). Catch projections 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 catch limit of 32 000 t, with area sub-limits, was retained for the next 3 years (*see* Table 2). The area sub-limits were revised for the 1995–96 fishing year, and the total catch limit increased to 58 800 t for the 1996–97 fishing year. A single combined catch limit was set for the Pukaki Rise and Auckland Islands fisheries, but in 1996–97 the industry agreed to a 3000 t limit for the Auckland Islands fishery.

3.1.2 Landings

Estimates of the annual landings of SBW are given in Tables 1 and 2. Catches during the fishing season (August to October) are used in the stock assessment for modelling purposes.

The estimated total catch for 1996–97 was about 21 000 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 small allocation and have found it difficult to locate large aggregations of fish, which makes it uneconomic to fish there. On the Campbell Island Rise a greater proportion of the catch limit has been taken each year.

3.1.3 The 1997 season

Because of the late hoki season vessels did not arrive on the Bounty Platform until 28 August. Only four vessels fished the Bounty Platform from 27 August to 1 September, making a total of about 20 tows. Spawning was later than usual that year, starting on 29 August (Section 3.2.3). Although several catches exceeding 100 t were made the total catch was only 830 t, the lowest since 1989. Most of the fishing was carried out where the large aggregation had been seen during the acoustic survey.

Five vessels fished the Pukaki Rise at various times during September, making about 35 tows. The vessels located spawning fish from 2 to 6 September, which was consistent with the results of trawling carried out on board *Tangaroa* (Section 3.2.3). The total catch was 800 t on the Pukaki Rise.

Four vessels fished on the Auckland Islands Shelf from 7 to 9 September. Again, observer data indicated that these fish were spawning (Section 3.2.3). A total of 540 t was caught in about 10 tows.

Vessels started fishing on the Campbell Island Rise on 8 September and immediately located spawning fish to the north of Campbell Island (Section 3.2.3). Vessels moved east and then south as the season progressed. A second spawning event started on 28 September, and fishing continued until mid October. A total of 17 vessels took part in the Campbell Island fishery that year catching 22 000 t, of which about 4000 t was caught in October.

3.1.4 CPUE analysis

Campbell Island Rise

A multivariate standardised approach to the CPUE analysis has been used in recent assessments of the Campbell Island stock (Hanchet 1997). Because the Campbell Island assessment was not being updated, only an unstandardised analysis was carried out this year. The raw and standardised CPUE indices show similar trends for the period 1986 to 1996 (Table 3). The raw index showed a slight drop in 1997, but was still above the 1986 level.

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 1997. The length frequency data were scaled up to the total catch for each strata and each fishing ground (Figure 2). The strong 1991 year class continued to dominate the catch on the northern and southern Campbell Island Rise. The mode of 2 year old fish at about 25 cm suggests that the 1995 year class may also be strong.

The catch on the Bounty Platform was dominated by the 1992 year class, with little sign of the 1994 year class (*see* Figure 2). The size distribution of the catch since 1990 shows that the 1992 year class has dominated the catch since 1995 (Figure 3). The 1986 and 1988 year classes which dominated the catch during the early 1990s have been largely fished out.

The catch on the Pukaki Rise was dominated by the 1990, 1991, and 1992 year classes. The size distribution of the catch since 1989 shows that this is the continuation of a trend since 1993 (Figure 4). The strong 1986 year class which dominated the catch during the early 1990s appears to have been fished out.

The size distribution of the fish on the Auckland Islands Shelf is shown in Figure 2. The fish have not been aged but the modes probably represent the 1986, 1991, and 1992 year classes.

3.2.2 Age composition of the commercial catch

A total of 446 otoliths from the Bounty Platform collected in 1997 were read and used to derive 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. The number of otoliths and length measurements used each year to derive the catch at age data are given in Table 4, and the resulting catch-at-age data are illustrated in Figure 5.

Catch-at-age data were derived for the Pukaki Rise stock for the first time. Catch-at-age was estimated by combining the scaled length frequency data with the age-length key for that year (*see* Hanchet & Ingerson 1995). The *c.v.*s incorporate the variance from both the length-frequency data and the age-length key. The number of otoliths and length measurements used each year to derive the catch-at-age data are given in Table 4, and the resulting catch-at-age data are illustrated in Figure 6. Very little fishing was carried out on the Pukaki Rise in 1996, and no catch at age data are available for that year.

3.2.3 Timing of spawning

The reproductive data collected by observers are shown in Table 5. Spawning on the Bounty Platform was later than usual in 1997, whereas spawning on the other three grounds was earlier than usual (*see* also Hanchet 1998). Spawning on the Bounty Platform started on 29 August. Samples collected during the *Tangaroa* acoustic survey from 17 to 24 August confirmed that fish had not spawned earlier. Spawning was occurring from 2 to 6 September on the Pukaki Rise, 7 to 9 September on the Auckland Islands Shelf, and 8 to10 September on the Campbell Island Rise. Second spawning events were taking place on 25 September on the Pukaki Rise, and from 28 September to 9 October on the Campbell Island Rise.

3.3 Recreational, Maori customary fisheries, illegal catches, and other sources of mortality

(i) Recreational fisheries

There is no recreational fishery for southern blue whiting.

(ii) Maori customary fisheries

There is no customary fishery for southern blue whiting.

(iii) Illegal catches

There is no known illegal catch of southern blue whiting.

(iv) Other sources of mortality

Scientific observers have reported discards of undersized fish and accidental loss from torn or burst codends. There is no quantitative estimate of this mortality.

4. RESEARCH

4.1 Stock structure

Stock structure of SBW was reviewed by Hanchet (1998). He examined data on distribution and abundance, reproduction, growth, and morphometrics. There appear to be four main spawning grounds: Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise. There are also consistent differences in the size and age distributions of fish, in the recruitment strength, and in the timing of spawning between these four areas. Multiple discriminant analysis of data collected in October 1989 and 1990 showed that fish from Bounty Platform, Pukaki Rise, and Campbell Island Rise could be distinguished on the basis of their morphometric measurements. This constitutes strong evidence that fish in these areas return to spawn on the grounds to which they first recruit. No genetic studies have been carried out, but given the close proximity of the areas, it is unlikely that there would be detectable genetic differences in the fish between these four areas.

For stock assessment it is assumed that there are four stocks of southern blue whiting with fidelity within stocks: the Bounty Platform stock, the Pukaki Rise stock, the Auckland Islands stock, and the Campbell Island stock.

4.2 Resource surveys

4.2.1 Acoustic survey

Results of the acoustic surveys of the SBW spawning grounds carried out in August and September 1993, 1994, 1995, and 1997 were presented by Hanchet *et al.* (1994), Hanchet & Ingerson (1996,) Ingerson & Hanchet (1996), and Grimes & Hanchet (in prep.). The abundance indices were turned into absolute estimates by using the target strength – fish length relationship derived for blue whiting in the Northern Hemisphere (Monstad *et al.* 1992). *In situ* target strength work during the 1994 survey and theoretical modelling studies have produced results which are consistent with that relationship (McClatchie *et al.* 1998).

Concern has been expressed in earlier reports (e.g., Hanchet 1997, Grimes & Hanchet in prep.) that some of the earlier acoustic surveys may have under-estimated or over-estimated spawning stock biomass on the Bounty and Pukaki grounds. In particular, there was some uncertainty over target identification of spawning and pre-recruit fish. The results of these surveys were therefore reviewed to determine the appropriate *c.v.* which should be applied to the biomass estimates from these surveys for modelling.

Bounty Platform (Table 6)

In 1993, there was strong evidence that the fish were migrating around the Platform during the survey. During snapshot 1 the fleet (and fish) appeared to be moving in an anti-clockwise direction around the Platform ahead of the vessel as the survey was in progress. During snapshot 2 about 45 000 t was detected on the west of the Platform, where very little had been detected on the first snapshot, and the following night a further 45 000 t was surveyed in a spawning aggregation 15 n.miles to the south-east. It is suspected that the fish were double counted.

In 1994, snapshots 1 and 2 were completed before the fish had aggregated, and snapshot 5 after they had started to disperse. Biomass estimates from snapshots 3 and 4 were similar, although snapshot 4 did not survey the entire area, so snapshot 3 was taken as the best estimate.

In 1995, snapshot 2 surveyed only the main spawning aggregation and therefore may have underestimated total biomass. However, the estimate was higher than during snapshot 1, so the biomass from the two snapshots were averaged.

In 1997, there were no obvious biases in estimates from either snapshot, so the biomass from the two snapshots were averaged.

The resulting biomass estimates and *c.v.*s for all surveys and areas are given in Table 8. However, these estimates were unsatisfactory because:
(i) the adult (recruited) biomass estimates in 1994 and 1997 included immature 3 year old fish, which would not have recruited to the fishery;
(ii) the immature category (ostensibly of mainly 2 year old fish) in 1994 and 1997 included a large proportion of immature 3 year olds;
(iii) the abundance of 3 year olds was not being indexed effectively.

The acoustic survey covered the entire Bounty Platform area, and so fish of all ages should be fully available to the acoustic gear. Therefore, to make fuller use of the data the adult biomass on the Bounty Platform was redefined to include all fish greater than or equal to 3 years old. The Bounty Platform acoustic estimates have therefore been revised so that all 3 year old fish are now included with the adults to make an index of 3 year old fish and greater (Table 9).

Pukaki Rise (Table 7)

The 1993 survey was carried out immediately before spawning but there was considerable uncertainty over target identification. The main uncertainty was in distinguishing immature (2 year old) SBW from adults, but there may also have been a problem with other species. Therefore, biomass estimates from the two snapshots were averaged.

The 1994 survey was carried out immediately before spawning, and there was still some uncertainty over target identification. The main uncertainty was in distinguishing immature 3 year old SBW from adults, so biomass estimates from the two snapshots were averaged.

The 1995 survey was carried out at least 2 weeks before spawning started, and it is unlikely that all the fish were on the grounds. Biomass estimates from the two snapshots were averaged.

The 1997 survey was carried out while fish were spawning and there were no obvious biases in estimates from either snapshot, so biomass estimates from the two snapshots were averaged. It is believed that the 1997 estimate is the most reliable estimate to date because it is the first time that the Pukaki Rise has been surveyed whilst spawning has been in progress, and the first where there has been virtually no problem of inclusion of immature SBW or other species in the adult biomass.

The resulting biomass estimates and *c.v.*s for all surveys and areas are given in Table 8. On the Pukaki Rise, problems with immature 3 year old fish have occurred in some of the earlier surveys (Hanchet *et al.* 1994, Hanchet & Ingerson 1996), but no attempt was made to correct for these in the current assessment.

4.3 Biomass estimates

In this section estimates of biomass and yield refer to the August and September fishing season, the months of intense fishing at the end of the fishing year (the 1998 season refers to the October 1997–September 1998 fishing year).

A separable Sequential Population Analysis was used to model the Bounty and Pukaki stocks. The sSPA model has been used in previous stock assessments of the Campbell and Bounty stocks (e.g., Hanchet 1997) and is documented in Hanchet *et al.* (in press). It uses a maximum likelihood method to find the set of parameter values which minimises the following objective function:

$$- n_i \tilde{p}_{ij} \ln p_{ij} + \sigma_C \sum_i \left(\ln(\tilde{C}_i) - \ln(C_i)\right)^2 + \sigma_B \sum_i (\ln(\tilde{B}_i) - \ln(rB_i))^2$$

where n_i is the sample size and $\tilde{p}_{ij}$ and p_{ij} are the observed and predicted proportion of fish of age j in year i respectively. $\tilde{C}_i$ is the observed catch in year i, C_i is the predicted catch in year i, and σ_C and σ_B are standard deviations for catch and biomass which are described below. $\tilde{B}_i$ is the observed adult acoustic biomass estimate in year i, B_i is the modelled estimate of mid-season spawning stock biomass in year i, and r is the abundance scalar.

The model estimate of spawning stock biomass is:

$$B_i = \sum_j l_j \, w_{ij} \exp(-0.5 Z_{ij}) \, N'_{ij}$$

where l_j is the mean selectivity of fish in age class j, w_{ij} is the weight of fish in age class j in year i, Z_{ij} is the instantaneous total mortality rate for age class j in year i during the fishing season, and N'_{ij} is the number of age class j fish in the population at the beginning of the fishing period in year i.

In this formulation it is assumed that the average selectivity l_j is synonymous with maturity, which is probably valid for these spawning fisheries. It is assumed that the survey abundance estimates have a log-normal error distribution.

It was not possible to estimate the various standard deviations so they were fixed at values that represented the levels of confidence in the various data sets. A convenient way to do this was in terms of weights where $w_x = \sigma_x^{-2}$, for each variate x, and the corresponding *c.v.*s are given for each dataset considered. An estimate of the confidence came from a consideration of both the estimated variance and possible bias inherent in the data.

The proportion-at-age data are assumed to be multinomially distributed. The appropriate weighting for these data (sample size) can be determined from the *c.v.* of the observed age composition data. Although the observed *c.v.*s suggest a sample size of over 100, this is probably too high given factors such as ageing error and sampling bias, and, because of the large number of data points, gives too much weight to the age data relative to the acoustic data. For the base case a weighting of 10 (equivalent to a *c.v.* of about 0.63) was given to the age data. For the sensitivity analysis weightings of 100 and 0.1 (equivalent to *c.v.*s of about 0.2 and 6.3) were used.

Simulated data were used to estimate 90% confidence limits for the results. The length at age data within individual years were resampled (with replacement) and then scaled up to proportion-at-age using the weighted length frequency of the catch for that year. Uncertainty in the adult acoustics data, age 1 and age 2 acoustics data, M, and annual catch was captured by assuming the data were log-normally distributed with *c.v.s* of 0.5, 0.7, 0.7, 0.1, and 0.05 respectively. For each of the 500 bootstrap runs data were randomly selected from each distribution. The percentile method was used to estimate confidence intervals (Effron 1981): the estimate of the 90% confidence interval was computed as the 5th and 96th percentiles in the set of bootstrap estimates after sorting them into ascending order.

(i) **Bounty Platform**

The model was fitted to proportion-at-age data from 1990 to 1997 and the acoustic indices given in Table 9. For the reasons outlined in Section 4.2.1 the acoustic biomass index was converted to an index of fish 3 years or more old. The model estimates of this biomass (B_i) were therefore changed to:

$$B_i = \sum_j l_j w_{ij} \exp(-0.5 Z_{ij}) N'_{ij} \qquad \text{for } j = \text{ages 3 and greater}$$

For the reasons given in Section 4.2.1 the 1993 adult acoustic index was not fitted and the 1995 index was down-weighted in the base case assessment. The adult indices were fitted in the model as absolute estimates of abundance. Indices of 1 and 2 year olds were also fitted in the model as relative abundance indices. Details of the input parameters, and the sensitivity runs are given in Table 10.

The population trajectory and 90% confidence intervals are shown in Figure 7 and Table 11. Vulnerable biomass showed an increase to 1991 followed by a decline from 1991 to 1993, largely as a result of the 60 000 t catch taken in 1992, but has since increased towards 1990 levels. The fit of the model to the acoustic indices and proportion-at-age data are reasonably good (Figure 8), although it is unable to fit the large index of 1 year olds from the 1995 acoustic survey.

The results of sensitivity analysis for the Bounty stock are shown in Table 12. Estimates of the 1994 year class strength, and hence current biomass, are very sensitive to the relative weightings on the proportion-at-age data. A higher weighting to the proportion-at-age data resulted in a lower current biomass, but this provided a poor fit to the acoustic indices (Figure 9). The results were also particularly sensitive to the relative weightings on the 1 and 2 year old acoustics indices (Figure 10). Exclusion of the 1 year old index resulted in much lower estimates of current biomass and the size of the 1994 year class, and exclusion of the 2 year old index resulted in much higher estimates of current biomass and the size of the 1994 year class.

There is uncertainty over the estimated size of the 1994 year class due to the mismatch between the acoustic survey and proportion-at-age data. Extremely large numbers of this year class were estimated during the 1995 acoustic survey as 1 year olds. Substantially fewer were estimated as part of the 3+ biomass during the 1997 acoustic survey. Few 3 year old fish were present in the 1997 commercial catch, partly because they are not fully recruited at this age but also apparently because the fishery had low selectivity for this cohort. This cohort is now estimated as 1.97 times the size of an average cohort (157 million 2 year olds), which is much less than the 1 958 million 1 year olds estimated by the 1995 acoustic survey.

As estimates of mean recruitment are available for only 8 years, and some are poorly estimated, B_0 was not estimated.

(ii) Pukaki Rise stock

The model was fitted to proportion-at-age data from 1989 to 1997, and the acoustic indices given in Table 9. Unlike the Bounty Platform assessment, the adult acoustic indices on the Pukaki Rise are considered to be estimates of recruited biomass. For the reasons outlined in Section 4.2.1, the 1993 to 1995 adult biomass estimates were all downweighted compared to the 1997 estimate for the base case assessment. The adult indices were fitted in the model as absolute estimates of abundance. The index of 2 year olds was also fitted in the model as a relative abundance index. Details of the input parameters and the sensitivity runs are given in Table 13.

The population trajectory and 90% confidence intervals are shown in Figure 11 and Table 14. Under the base case assumptions the model is unable to track the series of acoustic estimates, and essentially fits a flat trajectory through their mean. The fully recruited instantaneous fishing mortality in 1993 (the year with the highest catch) was 0.19. The fit of the model to the acoustic index of 2 year old fish and proportion-at-age data are reasonably good (Figure 12).

The results of sensitivity analysis for the Pukaki stock are shown in Table 15. Estimates of current biomass were most sensitive to the weighting given to the proportion-at-age data (Figure 13). A higher weighting to the proportion-at-age data resulted in a lower current biomass, but this provided a poor fit to the acoustic indices and gave a declining biomass trend. A low weighting to the proportion-at age data resulted in a better fit to the acoustic indices but substantially contradicted the proportion-at-age data. The results were insensitive to the age 2 acoustic index, but when the 1995 adult acoustic index was dropped there was a 20% increase in current biomass.

As estimates of mean recruitment are available for only 8 years, and some are poorly estimated, B_0 was not estimated.

(b) Estimation of Maximum Constant Yield (MCY)

(i) Bounty Platform stock

No reliable estimates of B_0 are available so MCY has not been calculated.

(ii) Pukaki Rise stock

No reliable estimates of B_0 are available so MCY has not been calculated.

(c) Estimation of Current Annual Yield (CAY)

Estimates of CAY and their 90% confidence intervals were calculated for the Bounty Platform and Pukaki Rise stocks for 1998 and 1999.

The simulation method of Francis (1992) was used to determine u_{CAY}, the ratio of catch to pre-season biomass. Using the input parameters shown in Hanchet (1997), u_{CAY} equalled 0.21. This harvest rate 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 $0.38B_0$, and the mean yield to be $8.6\%B_0$.

(i) Bounty Platform stock

CAY was estimated by multiplying u_{CAY} by pre-season biomass in 1998 and 1999. Pre–season biomass in 1998 was calculated by projecting forward the 1998 beginning of year numbers at age. The number of 2 year olds in 1998 was assumed to be equal to the estimate of 1 year old fish from the 1997 acoustic survey, after accounting for M (*see* Table 9).

The projection was carried forward to 1999 by assuming the 1998 catch equalled (i) CAY_{1998} or (ii) the 1997 catch limit (20 200 t), and by assuming the number of 2 year olds in 1999 was equal to the arithmetic mean of the recruitment of 2 year olds over the period 1990 to 1994. The resulting CAY estimates and 90% confidence intervals are shown in Table 11.

(ii) Pukaki Rise stock

CAY was estimated by multiplying u_{CAY} by pre-season biomass in 1998 and 1999. Pre-season biomass in 1998 was calculated by projecting forward the 1998 beginning of year numbers at age. The number of 2 year olds in 1998 was assumed to be equal to the arithmetic mean of the recruitment of 2 year olds over the period 1989 to 1994.

The projection was carried forward to 1999 by assuming the 1998 catch equalled (i) CAY_{1998} or (ii) the 1997 catch limit (7700 t), and the same recruitment assumption as for the 1998 year. The resulting CAY estimates and 90% confidence intervals are shown in Table 14.

(d) Long-term sustainable yield

The long-term yield available from the SBW stocks depends on the strategy used to manage the fishery. The stock size will fluctuate because of recruitment variability, and maximising the long-term yield would require a CAY based management strategy. Based on simulation models incorporating stochastic recruitment and a CAY-based fishing strategy resulted in a mean yield (MAY) of 8.6% B_0. For comparison, an MCY-based constant catch strategy resulted in a yield (MCY) of 5.1% B_0.

5. MANAGEMENT IMPLICATIONS

For both stocks, CAY estimates for 1998 and 1999 are greater than recent catch levels but less than current catch limits. Estimates for 1998 are much better known than estimates for 1999.

(i) Bounty Platform stock

Estimates of current biomass are available. Because B_0 cannot be estimated, it is not known where current biomass is in relation to B_{MAY}.

There is uncertainty over the estimate of current biomass due to uncertainty over the size of the 1994 year class (there is a mismatch between the acoustic survey and catch-at-age data). This year class is now estimated as 1.97 times the size of an average year class, which is much less than was estimated as 1 year olds by the 1995 acoustic survey.

Yield estimates are uncertain largely because of uncertainty over the strength of the 1994 year class. The CAY estimates for 1998 and 1999 are below the current catch limit but well above catch levels since 1993.

(ii) Pukaki Rise stock

Estimates of current biomass are available. Because B_0 cannot be estimated, it is not known where current biomass is in relation to B_{MAY}.

There is considerable uncertainty over the estimate of current and historical biomass because of the highly variable acoustic indices. The model is unable to track the series of acoustic estimates without substantially contradicting the catch-at-age data, and essentially fits a flat trajectory through their mean. The fishery is currently supported by the 1990 and 1991 year classes, which appear relatively strong. Although there are no estimates of reference biomass, it appears that the stock has been only lightly exploited.

Yield estimates are uncertain because of uncertainty over current biomass and future recruitment. CAY estimates for both 1998 and 1999 are well above recent catch levels but below the current catch limit (which includes both the Pukaki and Auckland Islands fisheries). These yield estimates are at the same level as the highest historical landings from this fishery.

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Table 1: Reported annual landings (t) of SBW from 1971 to 1977. Source: MAF Unpubl. data

Year	USSR	Japan	Total
1971	10 400	0	10 400
1972	25 800	0	25 800
1973	48 500	0	48 500
1974	42 200	0	42 200
1975	2 100	278	2 378
1976	15 900	1 189	17 089
1977	26 000	435	26 435

Table 2: Estimated catches (t) of SBW by area for the period 1978 to 1996–97 from vessel logbooks. Estimates for 1996–97 are preliminary. –, no catch limit in place

Fishing	Bounty Platform		Campbell Island Rise		Pukaki Rise	Auckland	PR+AI		Total
year	Catch	Catch limit	Catch	Catch limit	Catch	Is. Catch	Catch limit	Catch	Catch limit
1978*	0	–	6 403	–	79	15	–	6 497	–
1978–79+	1 211	–	25 305	–	601	1 019	–	28 136	–
1979–80+	16	–	12 828	–	5 602	187	–	18 633	–
1980–81+	8	–	5 989	–	2 380	89	–	8 466	–
1981–82+	8 325	–	7 915	–	1 250	105	–	17 595	–
1982–83+	3 864	–	12 803	–	7 388	184	–	24 239	–
1983–84+	348	–	10 777	–	2 150	99	–	13 374	–
1984–85+	0	–	7 490	–	1 724	121	–	9 335	–
1985–86+	0	–	15 252	–	552	15	–	15 819	–
1986–87+	0	–	12 804	–	845	61	–	13 710	–
1987–88+	18	–	17 422	–	157	4	–	17 601	–
1988–89+	8	–	26 611	–	1 219	1	–	27 839	–
1989–90+	4 430	–	16 542	–	1 393	2	–	22 365	–
1990–91+	10 897	–	21 314	–	4 652	7	–	36 870	–
1991–92+	58 928	–	14 208	–	3 046	73	–	76 255	–
1992–93+	11 908	15 000	9 316	11 000	5 341	1 143	6 000	27 708	32 000
1993–94+	3 877	15 000	11 668	11 000	2 306	709	6 000	18 560	32 000
1994–95+	6 386	15 000	9 492	11 000	1 158	441	6 000	17 477	32 000
1995–96+	6 508	8 000	14 959	21 000	772	40	3 000	22 279	32 000
1996–97+	832	20 200	18 773	30 100	924	540	7 700	21 069	58 000

* 1 April – 30 September
\+ 1 October – 30 September

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

Year	Number of tows	Percentage zero tows	Standardised year effect	Unstandardised year effect	Catch (t)	Relative effort
1986	893	4.6	1.00	1.00	15 252	15 252
1987	637	5.3	0.68	0.85	12 804	18 829
1988	843	7.1	0.52	0.68	17 422	33 504
1989	1008	4.7	0.53	0.85	26 611	50 209
1990	994	7.8	0.48	0.65	16 652	34 692
1991	1057	3.7	0.36	0.70	21 314	59 206
1992	1091	18.7	0.24	0.33	14 208	59 200
1993	411	10.7	0.65	0.77	9 316	14 332
1994	384	6.8	0.54	0.80	11 668	21 607
1995	170	2.4	1.05	1.15	10 436	9 939
1996	342	5.9	1.46	1.38	16 504	11 304
1997	341	0.3	–	1.06	–	–

Table 4: Summary of data used to construct the catch-at-age matrix for the Campbell Island Rise, Bounty Platform, and Pukaki Rise. n, number of tows where fish were measured; N, number of fish measured; O, number of otoliths read for that year

Year	Campbell Island Rise			Bounty Platform			Pukaki Rise		
	n	N	O	n	N	O	n	N	O
1979	20	3 375	181	–	–	–	–	–	–
1980	10	1 563	241	–	–	–	–	–	–
1981	33	5 028	439	–	–	–	–	–	–
1982	16	5 879	448	–	–	–	–	–	–
1983	17	2 746	413	–	–	–	–	–	–
1984	13	5 351	387	–	–	–	–	–	–
1985	17	1 761	385	–	–	–	–	–	–
1986	28	2 564	466	–	–	–	–	–	–
1987	52	6 476	0	–	–	–	–	–	–
1988	206	39 428	598	–	–	–	–	–	–
1989	133	20 633	499	–	–	–	12	2 163	454
1990	94	18 136	628	23	4 259	252	20	3 674	376
1991	52	8 716	694	16	2 753	134	24	4 248	476
1992	121	18 126	503	161	24 915	600	37	5 049	499
1993	55	9 079	628	72	11 966	531	43	6 733	565
1994	80	13 175	779	39	7 148	449	22	3 771	397
1995	76	13 108	563	63	9 990	374	12	2 021	531
1996	97	18 072	529	22	4 636	481	–	–	–
1997	185	33 010	–	8	1 576	446	25	4 064	493

Table 5: Dates associated with sampling and changes in SBW gonad condition in 1997 in each of the four areas, and percentage of spent and reverted (fish which have spawned once and reverted back to the maturing stage) in the last sample (–, could not be determined)

Gonad stage	Bounty	Pukaki	Campbell	Auckland
1st sample	28/8	2/9	8/9	7/9
>10% ripe	<28/8	<2/9	<8/9	<7/9
>10% running ripe	29/8	<2/9	<8/9	<7/9
Main spawning	29–31/8	2–6/9	8–10/9	7–9/9
>10% spent	–	–	10/9	8/9
>10% reverted	–	–	10/9	8/9
>50% spent	–	–	30/9	–
2nd spawning	–	25/9	28/9–9/10	–
Last sample	31/8	27/9	14/10	9/9
% spent	0	25	90	17
% reverted	0	1	2	46

Table 6: Adult (recruited) biomass estimates (and *c.v.*s) from acoustic snapshots of the Bounty Platform. The vertical line indicates the onset of spawning (>10% running ripe). Bolded snapshots were used to derive the best estimate

Year	Snap 1	Snap 2	Snap 3	Snap 4	Snap 5	Estimate
1993	28.3 (39)	**94.6 (46)**	–	–	–	94.6 (46)
1994	23.6 (16)	13.1 (58)	**54.7 (22)**	48.8 (54)*	20.3 (53)*	54.7 (22)
1995	**34.4 (36)**	**36.0 (33)***	–	–	–	35.2 (24)
1997	**78.2 (49)**	**41.4 (42)**	–	–	–	59.8 (35)

* only part of the total area was surveyed

Table 7: Adult (recruited) biomass estimates (and *c.v.*s) from acoustic snapshots of the Pukaki Rise. The vertical line indicates the onset of spawning (>10% running ripe). The average of the two snapshots was taken as the best estimate

Year	Snap 1	Snap 2	Estimate
1993	57.4 (34)	42.2 (35)	49.8 (24)
1994	48.7 (68)	28.9 (32)	39.0 (45)
1995	10.7 (18)	14.8 (28)	12.8 (18)
1997	32.5 (41)	30.1 (57)	31.3 (35)

Table 8: Mid-season biomass estimates (t x 10^3), and *c.v.*s from acoustic surveys on Bounty Platform and Pukaki Rise

	Bounty Platform			Pukaki Rise	
Year	Adults (recruited)	Mainly age 2	Age 1	Adults (recruited)	Mainly age 2
1993	94.6 (46)	5.4 (43)	6.8 (46)	49.8 (24)	26.3 (20)
1994	55.0 (22)	*15.1 (50)	0.2 (80)	*39.0 (45)	0.0
1995	35.2 (24)	0.0	93.3 (37)	12.8 (18)	0.0
1997	*59.8 (35)	*9.3 (54)	0.2 (67)	31.3 (35)	3.1 (12)

* Includes some immature 3 year old fish.

Table 9: Revised mid-season estimates of adult biomass ('000 t) and numbers of 1 and 2 year old fish (millions) from acoustic surveys on Bounty Platform and Pukaki Rise.

	Bounty Platform			Pukaki Rise	
Year	Adults (≥ age 3)	Age 2	Age 1	Adults (recruited)	Mainly age 2
1993	94.6	52.5	264.5	49.8	259.2
1994	64.0	41.8	5.4	39.0	2.0
1995	35.2	0.0	1957.8	12.8	0.3
1997	67.4	17.2	5.1	31.0	33.9

Table 10: Values for the input parameters to the separable Sequential Population Analysis for the base case and sensitivity runs for the Bounty Platform stock. Acoustic surveys carried out in 1993, 1994, 1995, 1997. NF, not fitted. –, not tested

Parameter	Base case	Sensitivity
M	0.2	0.15, 0.25
Acoustic time series	absolute	–
Acoustic adult *c.v.s* for the 4 surveys	NF, 0.3, 0.5, 0.3	0.3, 0.3, 0.3, 0.3
Weighting on proportion–at–age data	10	0.1, 100
Proportion-at-age data	1990–97	–
Acoustic age 1 index *c.v.*	0.5	NF
Acoustic age 2 index *c.v.*	0.5	NF

Table 11: Bounty Platform estimates of mid-season vulnerable (≥ 3+) biomass for 1990 and 1997, pre-season vulnerable (≥ 3+) biomass) for 1998, $N_{2,1996}$) number of fish in the 1994 year class, CAY_{1998}, CAY_{1999} assuming a catch in the 1998 season equal to (i) CAY_{1998} or (ii) 20 000 t, and their 90% confidence intervals. All biomass and yields in t x 10^3, and numbers in millions. –, not estimated

	B_{mid90}	B_{mid97}	B_{pre98}	$N_{2,1996}$	CAY		
					1998	1999	
						(i)	(ii)
Base case	79	65	73	157.0	15.4	12.2	11.6
CI	65–112	34–139	38–162	48–540	8–34	6–27	–

Table 12: Relative changes (expressed as percentages) of selected parameter estimates as a result of alternative model assumptions for the Bounty Platform stock. B, mid-season vulnerable biomass; $N_{2,1996}$, size of the 1994 year class. Figures with an absolute value larger than 20% are shown in bold

Parameter	B_{mid90}	B_{mid97}	$N_{2,1996}$
M=0.15	-12.7	4.6	-17.8
M=0.25	13.9	-3.1	22.3
Proportion-at-age weighting =100	-5.1	**-43.1**	**-67.5**
Proportion-at-age weighting =0.1	8.9	-4.6	**-31.2**
No 1+ acoustic index	3.8	-7.7	**-77.7**
No 2+ acoustic index	-6.3	**29.2**	**126.8**
No 1+ or 2+ acoustic index	-3.8	3.1	**-57.3**
All 4 acoustic indices (equal weight)	12.7	3.1	-15.3

Table 13: Values for the input parameters to the separable Sequential Population Analysis for the base case and sensitivity runs for the Pukaki Rise stock. Acoustic surveys carried out in 1993, 1994, 1995, 1997. NF, not fitted; –, not tested

Parameter	Pukaki	Sensitivity
M	0.2	0.15, 0.25
Acoustic time series	absolute	–
Acoustic adult *c.v.s*	0.5, 0.5, 0.5, 0.3	0.5, 0.5, NF, 0.3
Weighting on proportion–at–age data	10	0.1, 100
Proportion–at–age data	1989–1997	–
Acoustic age 2 index *c.v.*	0.7	NF

Table 14: Pukaki Rise estimates of B_{mid89}, B_{mid97} (mid-season spawning stock biomass), B_{pre98} (pre-season spawning stock biomass); F_{1993}, instantaneous fishing mortality on fully recruited ages in 1993, CAY_{1998}, CAY_{1999} assuming a catch in the 1998 season equal to (i) CAY_{1998} or (ii) 7700 t, and their 90% confidence intervals. All biomass and yield estimates in t x 10^3. –, not estimated

	B_{mid89}	B_{mid97}	B_{pre98}	F_{1993}	CAY		
					1998	1999	
						(i)	(ii)
Base case	33	27	26	0.19	5.5	4.8	4.5
CI	22–49	16–46	38–162	–	3.4–10.1	3.0–9.2	–

Table 15: Relative changes (expressed as percentages) of selected parameter estimates as a result of alternative model assumptions for the Pukaki Rise stock. B, mid-season spawning stock biomass; F, fishing mortality

Parameter	B_{mid89}	B_{mid97}	F_{1993}
M=0.15	-18.2	3.7	10.5
M=0.25	21.2	-7.4	-10.5
Proportion-at-age weighting =100	-24.2	-40.7	47.4
Proportion-at-age weighting =0.1	9.1	18.5	-21.1
No 95 acoustic index	12.1	22.2	-15.8
No 2+ acoustic index	3.0	0.0	-5.3

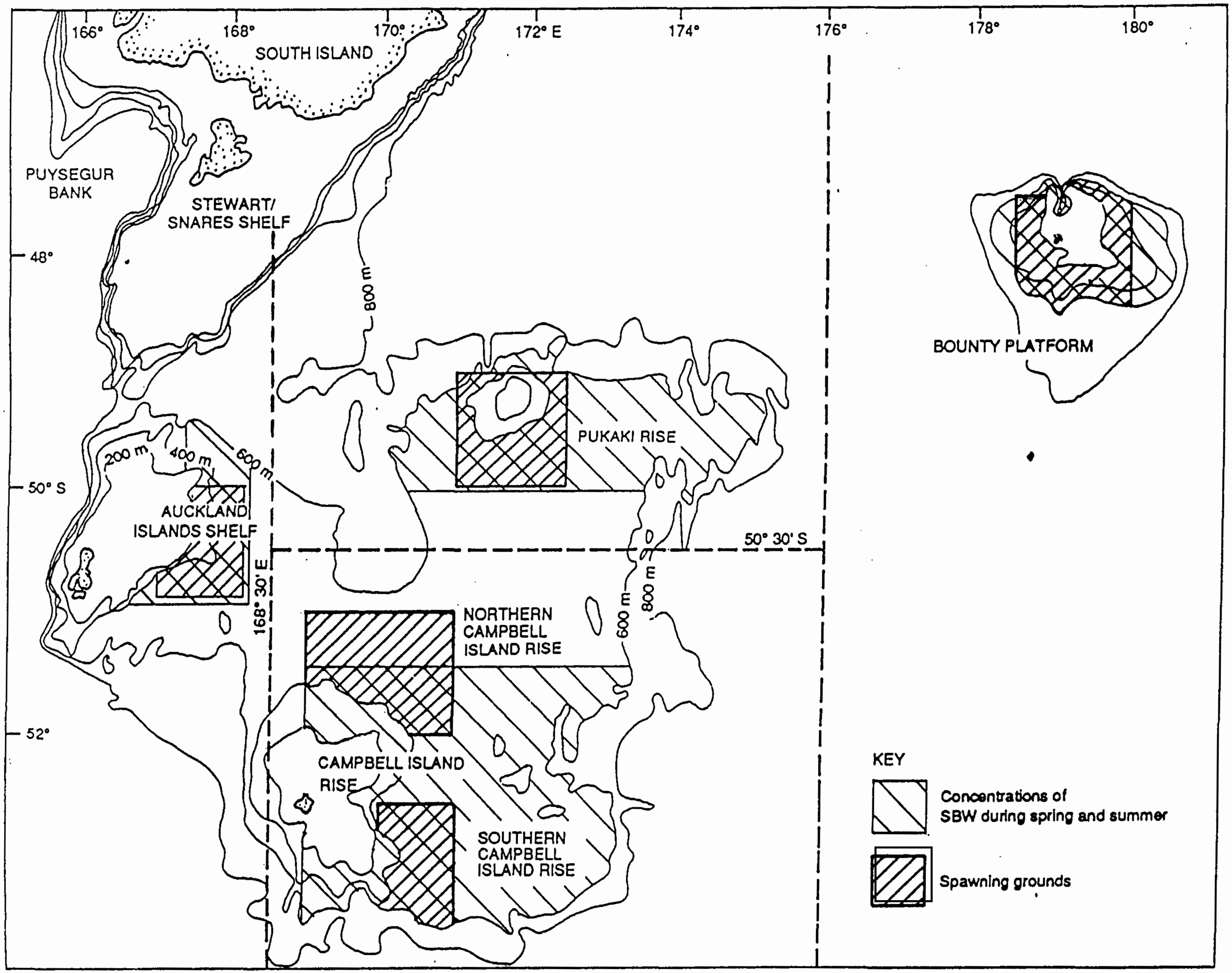


Figure 1: Main concentrations of SBW during spring and summer (feeding grounds) and spawning grounds of southern blue whiting, showing stock boundaries proposed by Hanchet (1998).

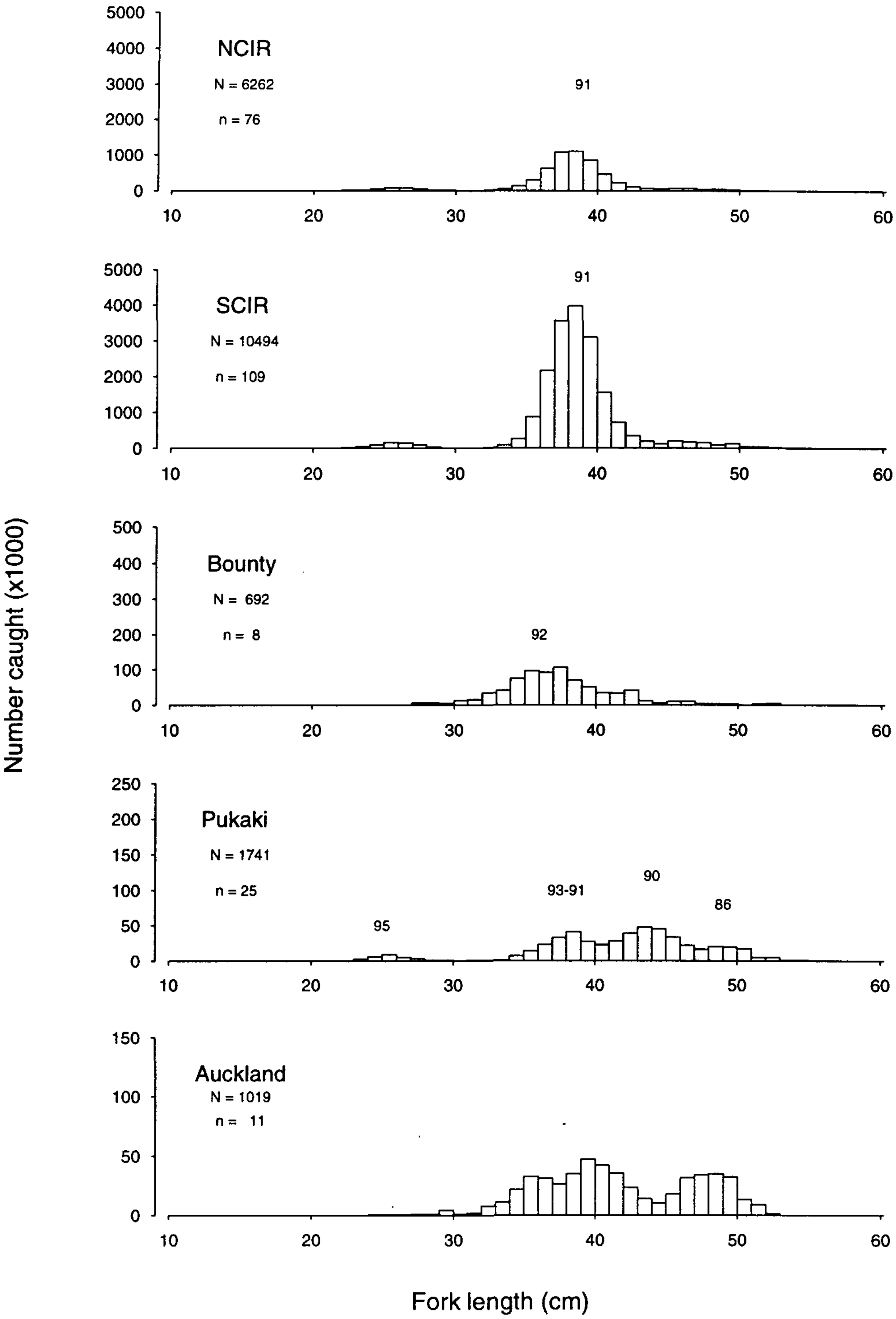


Figure 2a: Weighted length frequency distribution of males in the 1997 catch from the northern Campbell Island Rise (NCIR), southern Campbell Island Rise (SCIR), Bounty Platform, Pukaki Rise, and Auckland Island Shelf. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

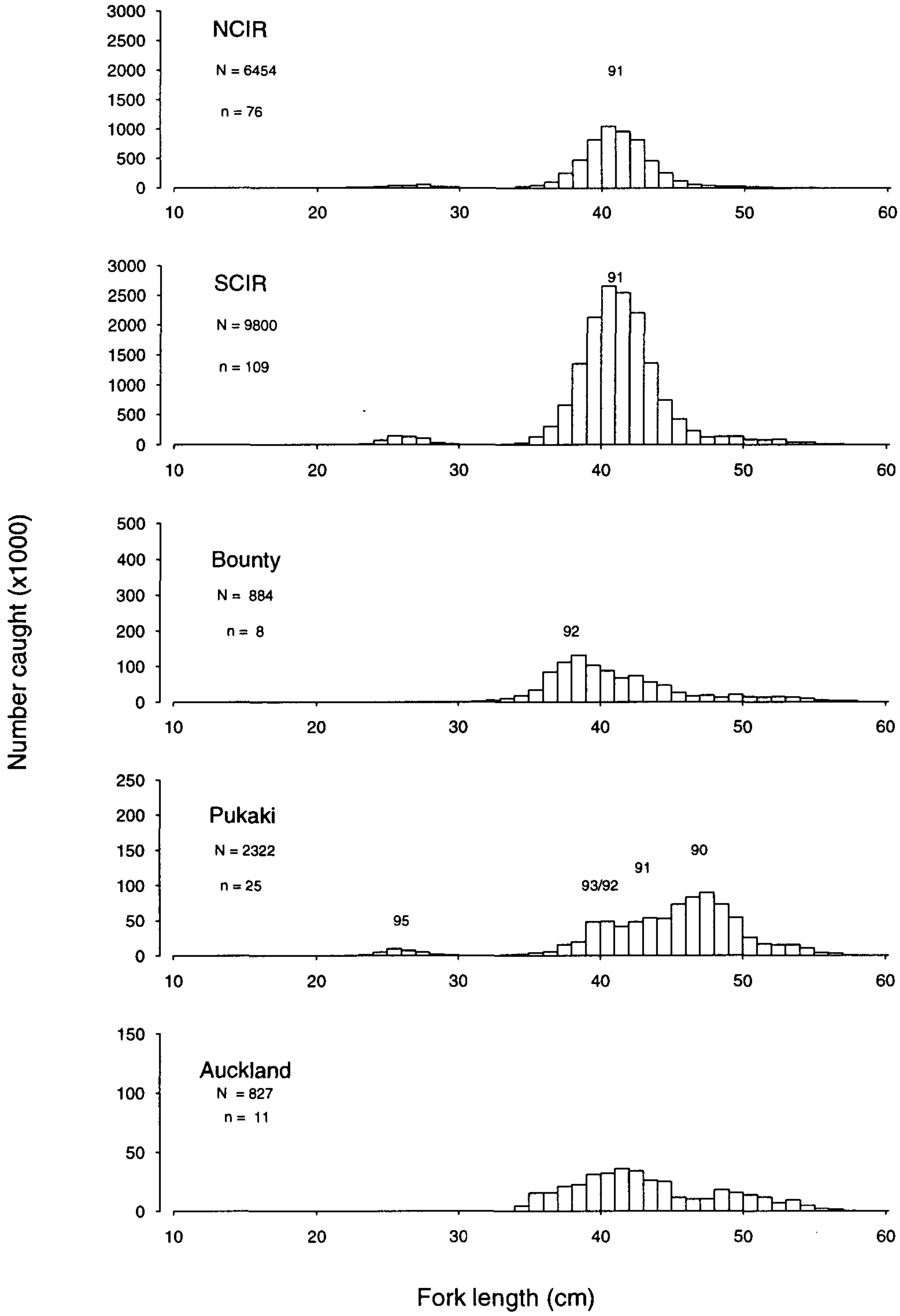


Figure 2b: Weighted length frequency distribution of females in the 1997 catch from the northern Campbell Island Rise (NCIR), southern Campbell Island Rise (SCIR), Bounty Platform, Pukaki Rise, and Auckland Island Shelf. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

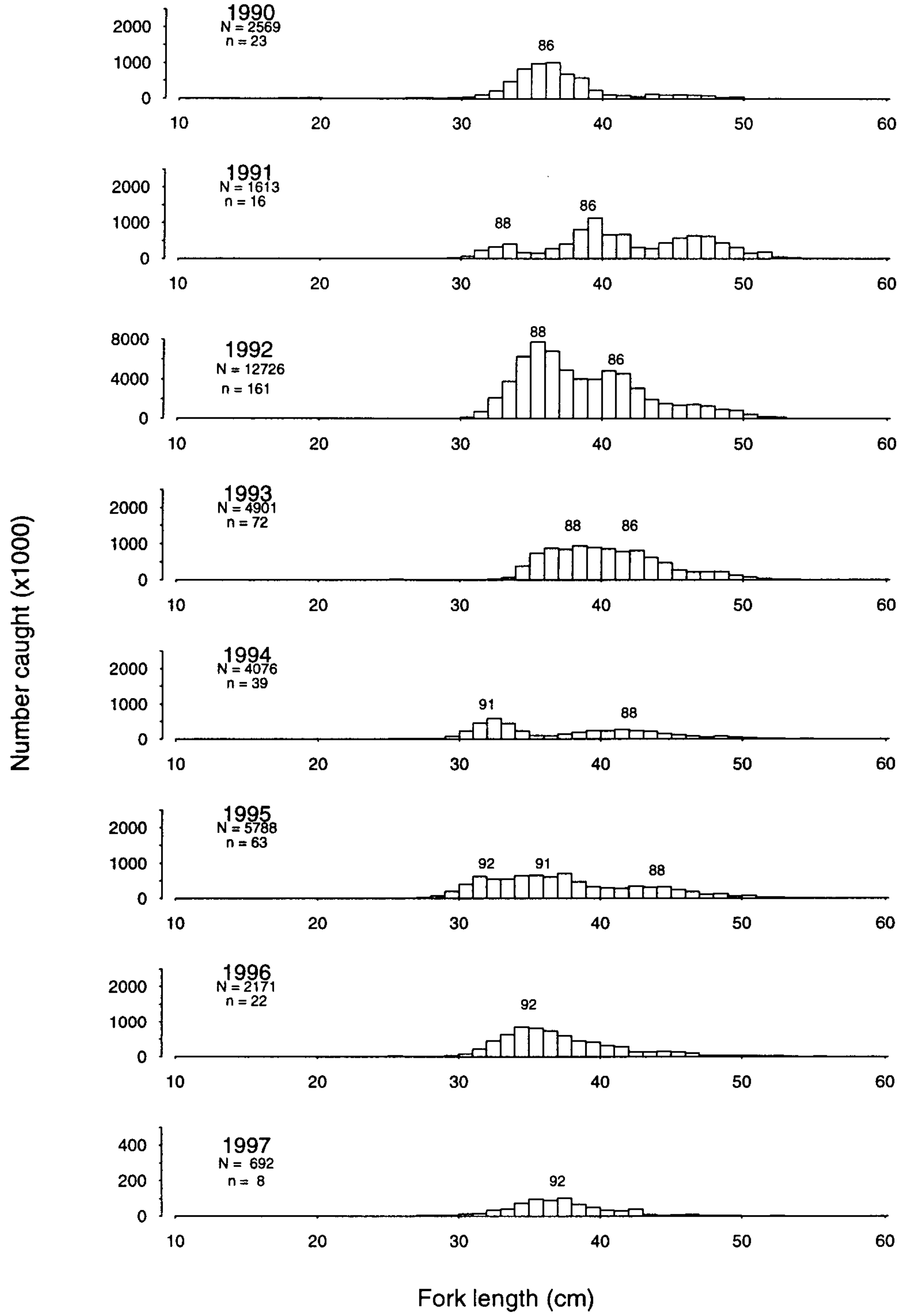


Figure 3a: Weighted length frequency distribution of males in the catch from the Bounty Platform. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

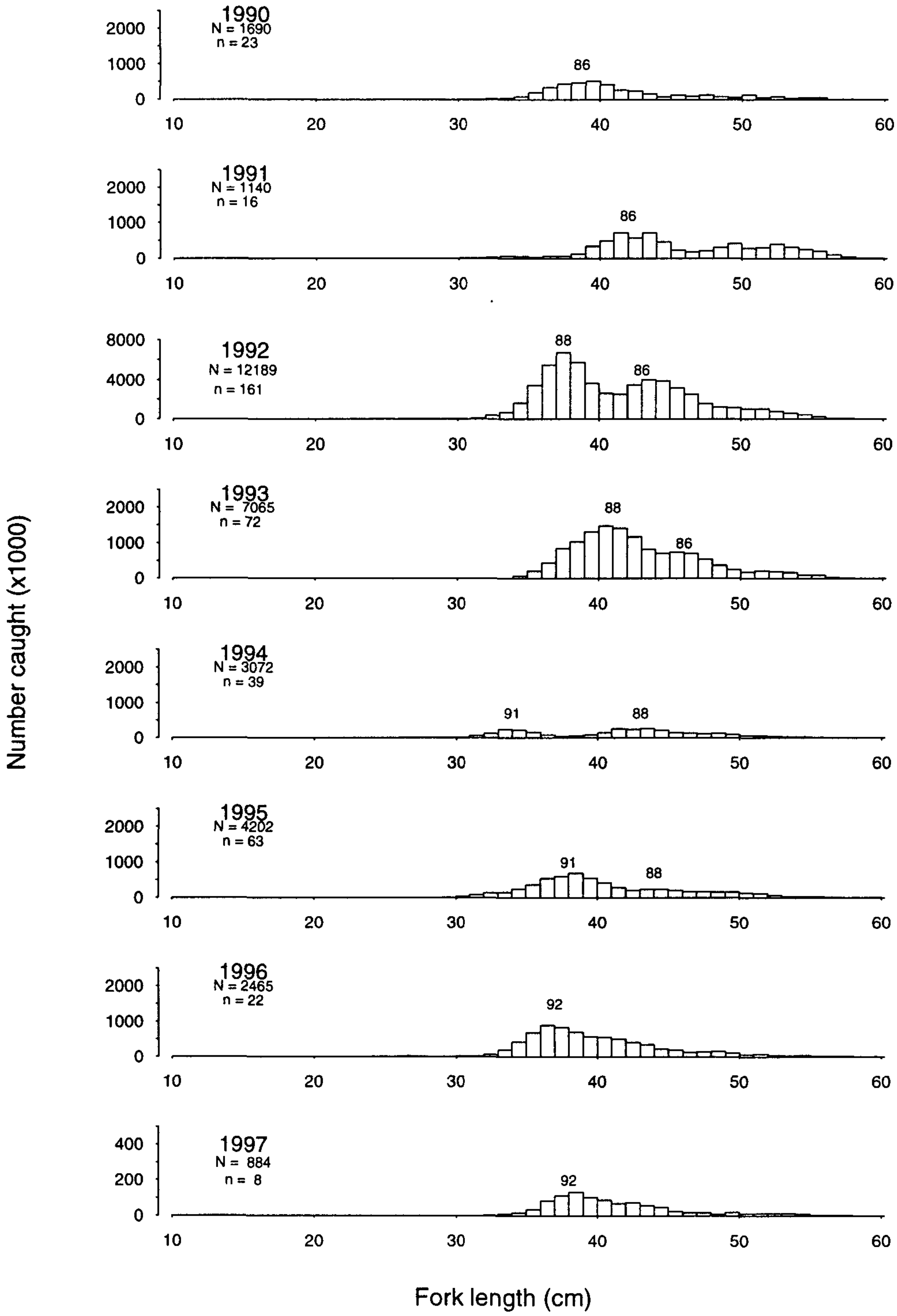


Figure 3b: Weighted length frequency distribution of females in the catch from the Bounty Platform. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

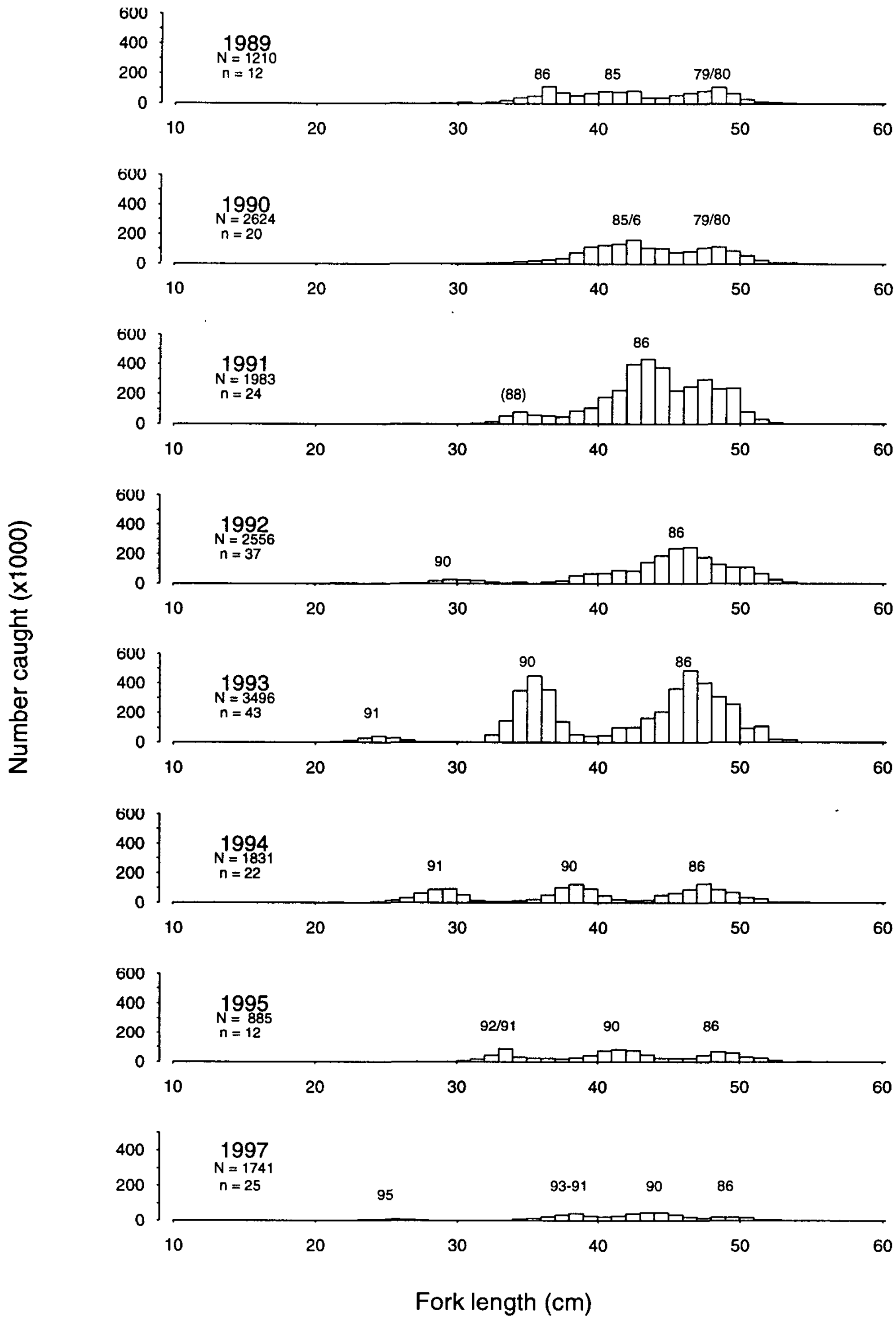


Figure 4a: Weighted length frequency distribution of males in the catch from the Pukaki Rise. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

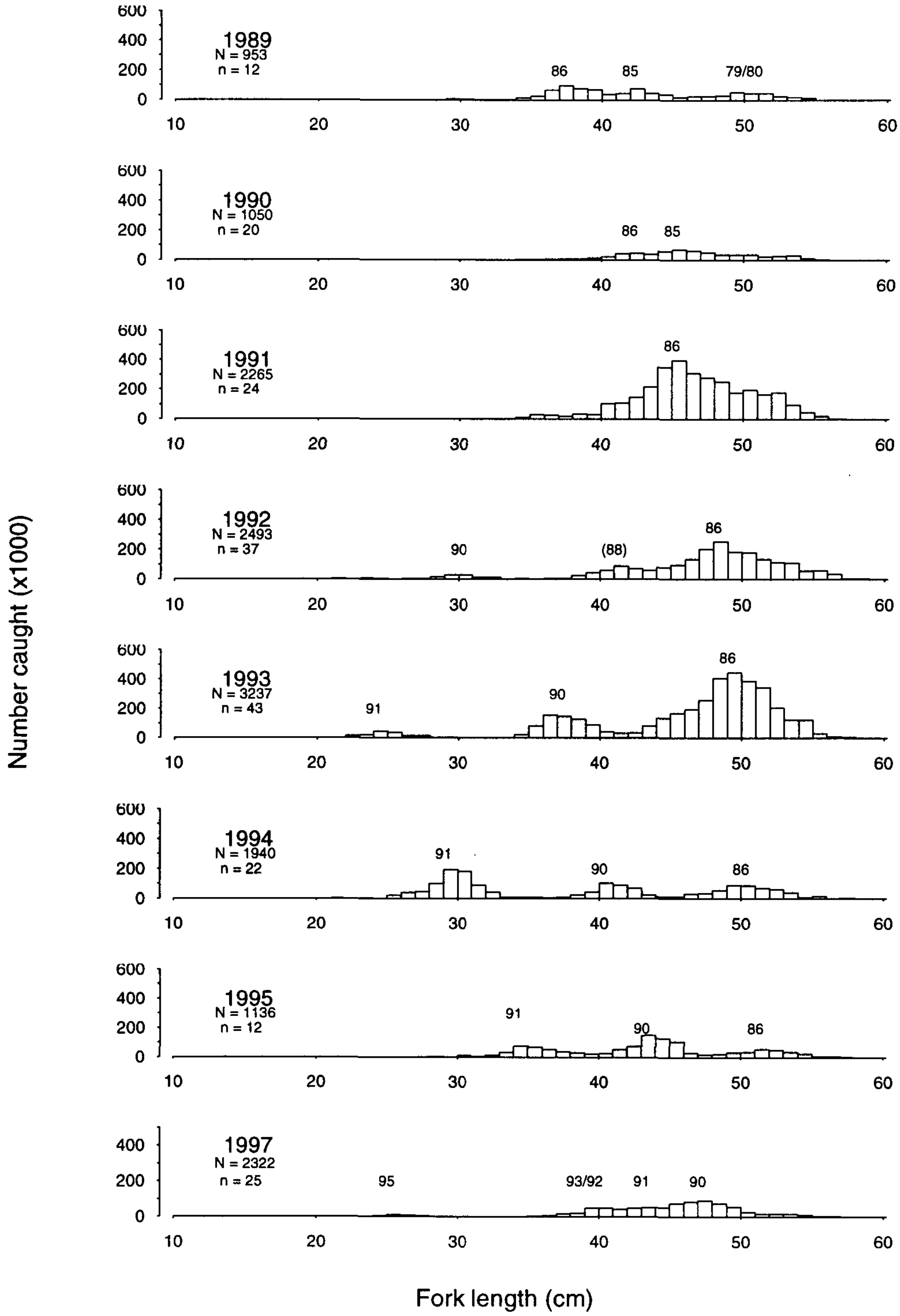


Figure 4b: Weighted length frequency distribution of females in the catch from the Pukaki Rise. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

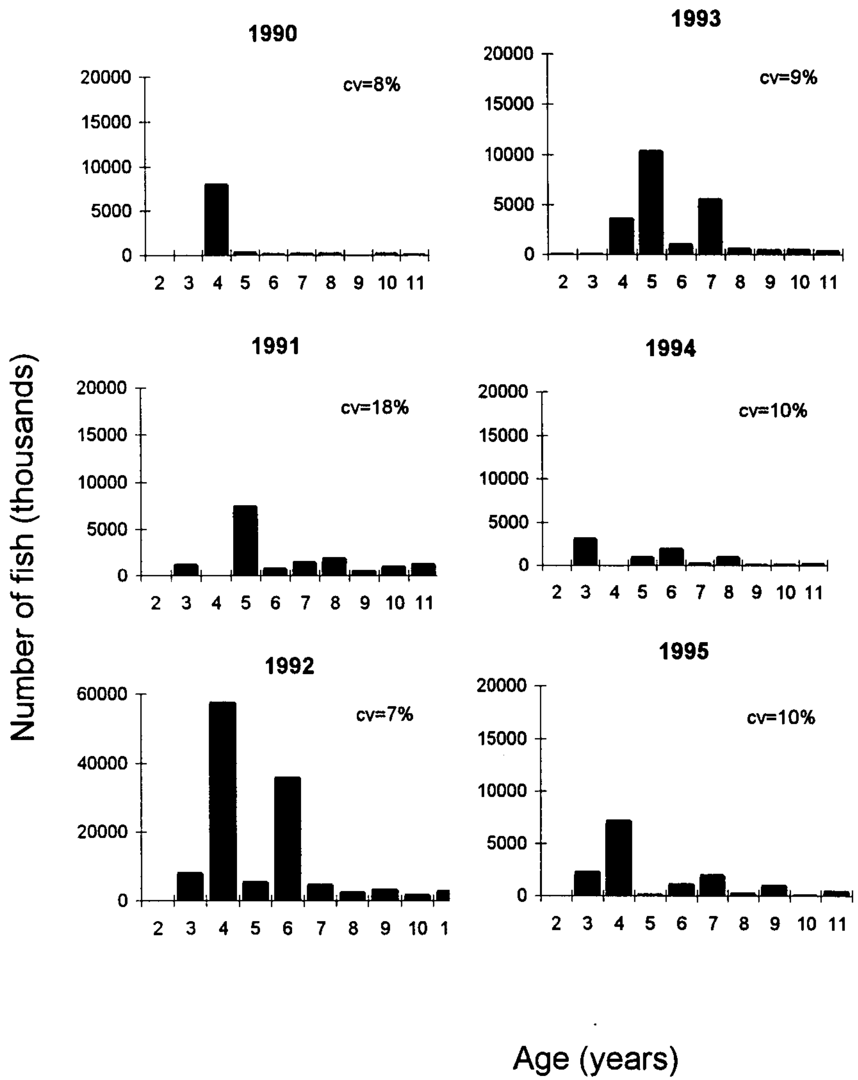


Figure 5: Age composition of the catch on the Bounty Platform from 1990 to 1997, with the mean weighted cv (%).

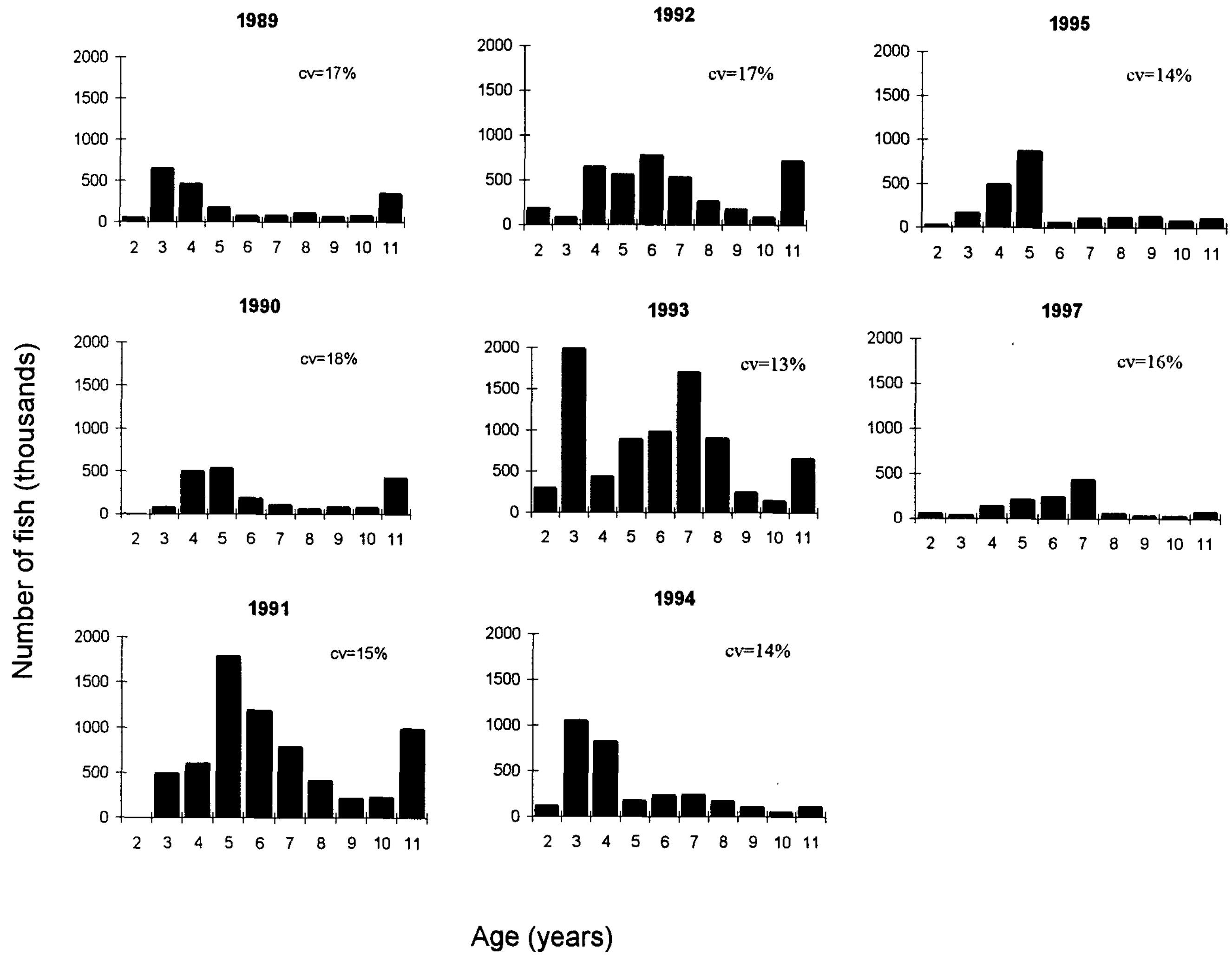


Figure 6: Age composition of the catch on the Pukaki Rise from 1989 to 1997, and mean weighted cv (%).

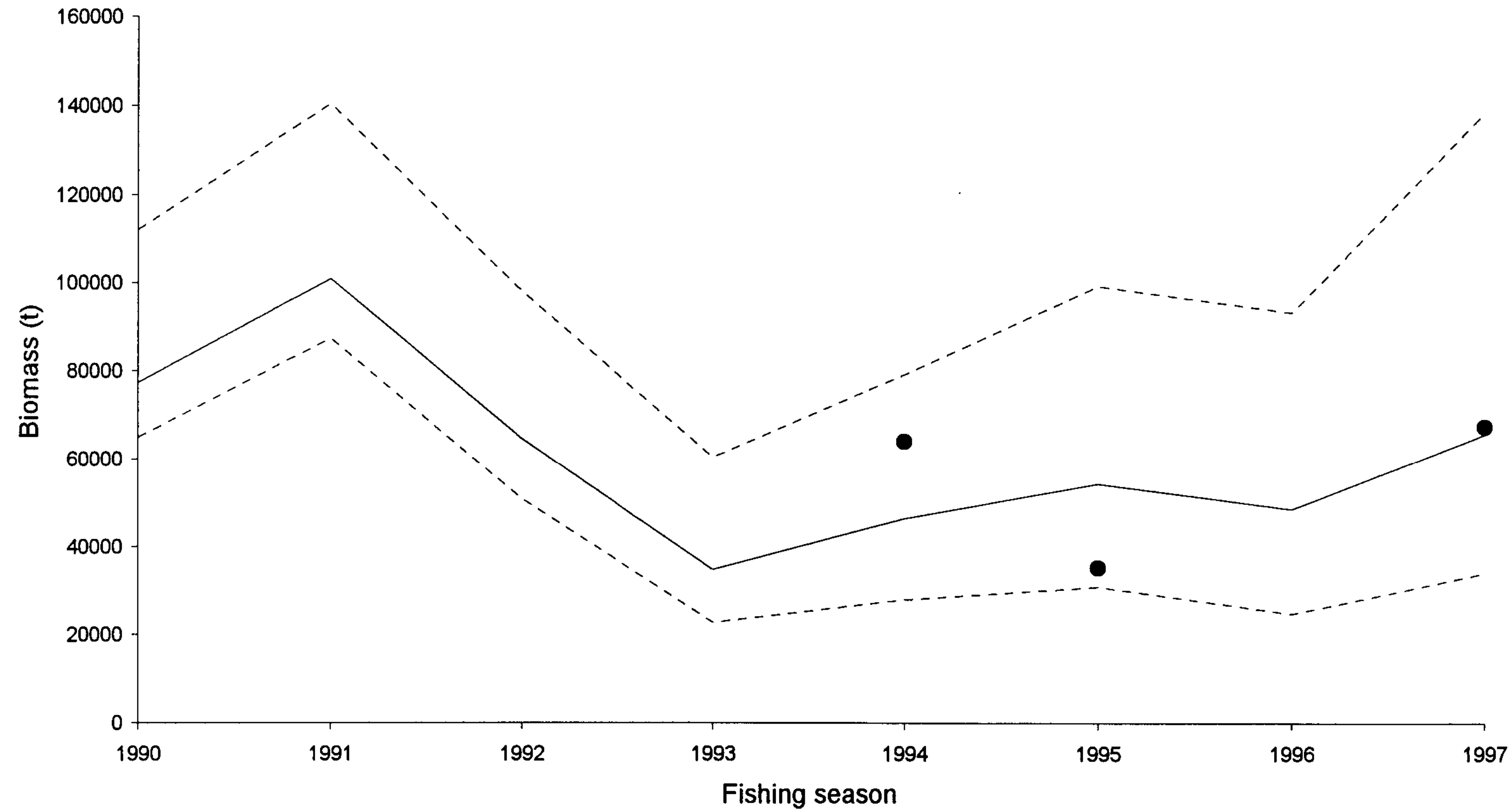
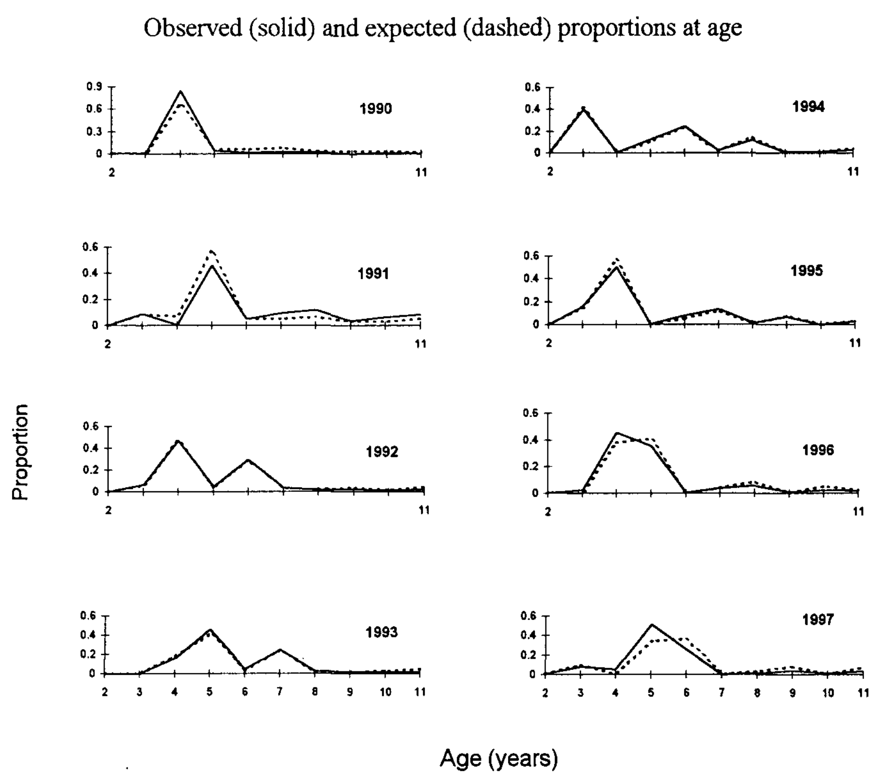
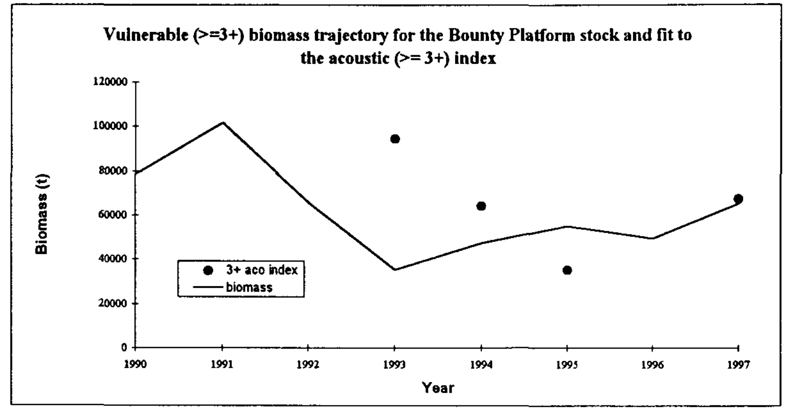


Figure 7: Mid season vulnerable (3+) stock biomass trajectories and 90% confidence intervals for the Bounty Platform stock showing the fit to the acoustic indices.



Selectivity ogive

Age	2	3	4	5
Selectivity	0.0058	0.085	0.999	1



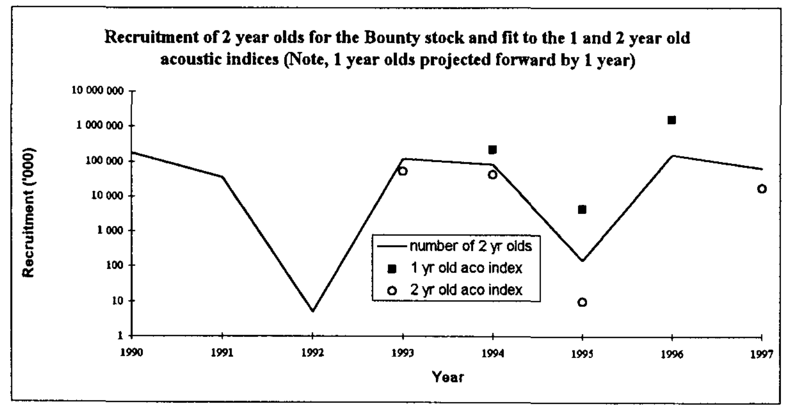


Figure 8: Diagnostics for the Bounty Platform assessment showing the fit to the proportion-at-age, adult, 1+ and 2+ acoustic indices; the values of the selectivity at age are also shown.

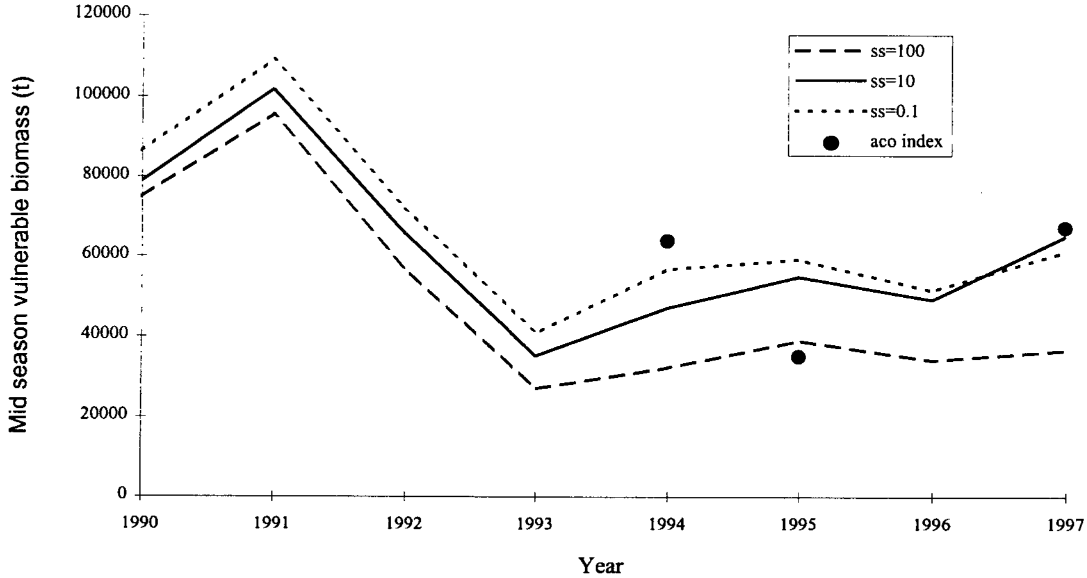


Figure 9: Sensitivity of the Bounty Platform assessment to the sample size (weighting) used for the proportion-at-age data.

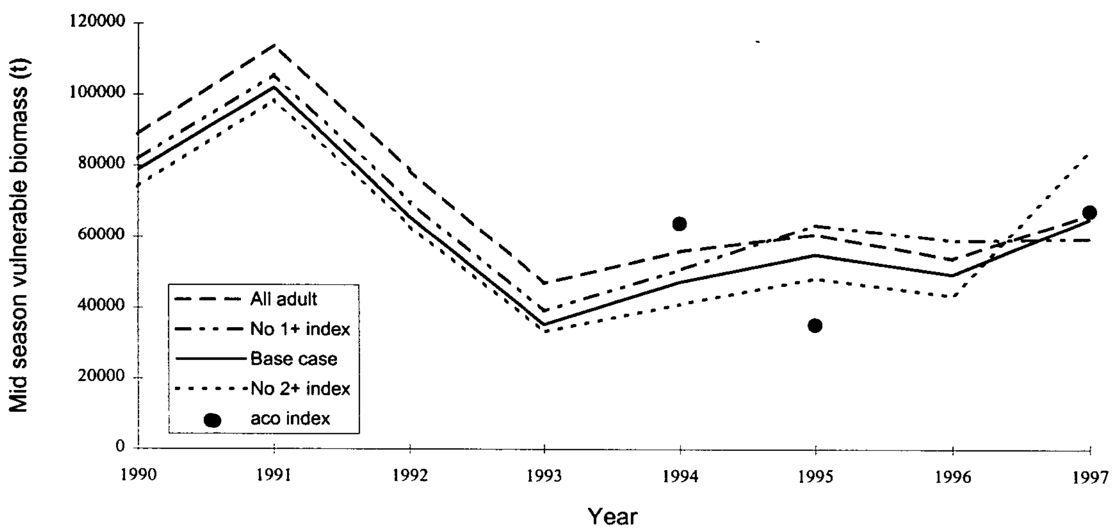


Figure 10: Sensitivity of the Bounty Platform assessment to the weighting given to the acoustic indices.

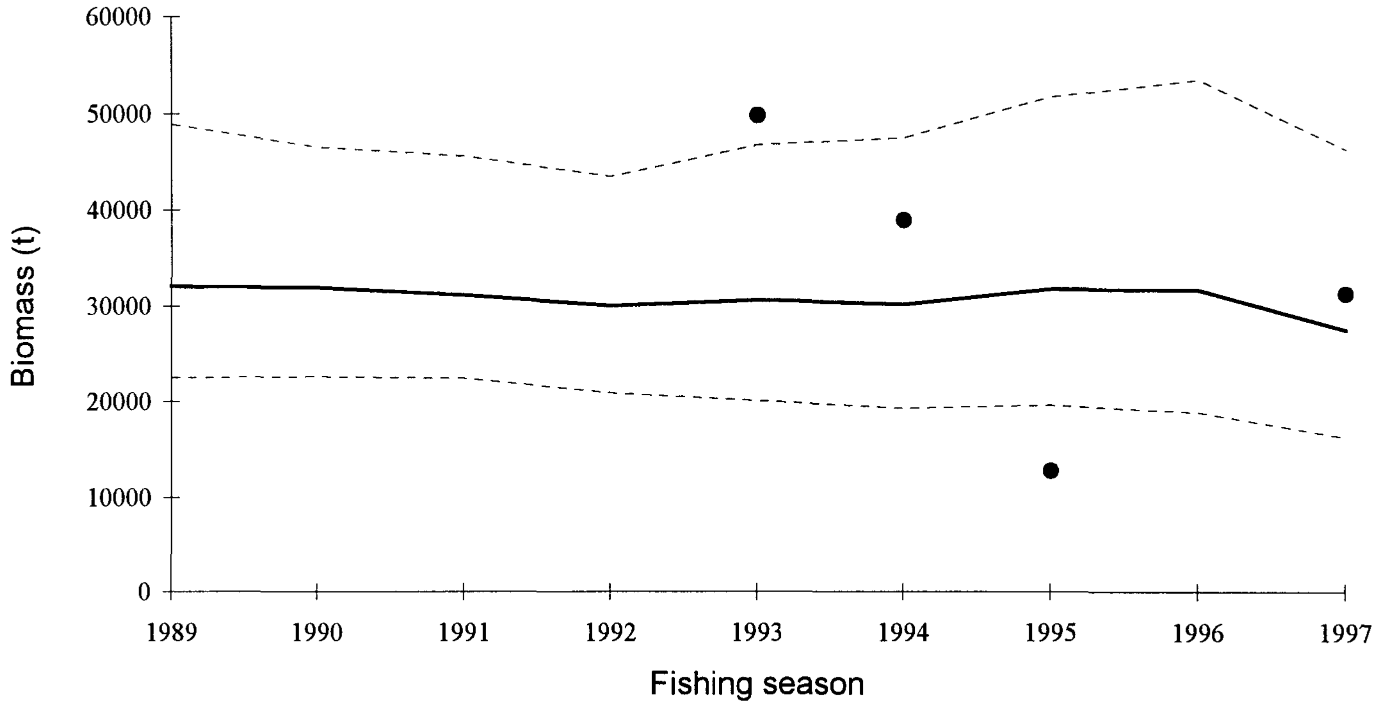


Figure 11: Mid season spawning stock biomass trajectory and 90% confidence intervals for the Pukaki Rise stock showing the fit to the adult acoustic indices

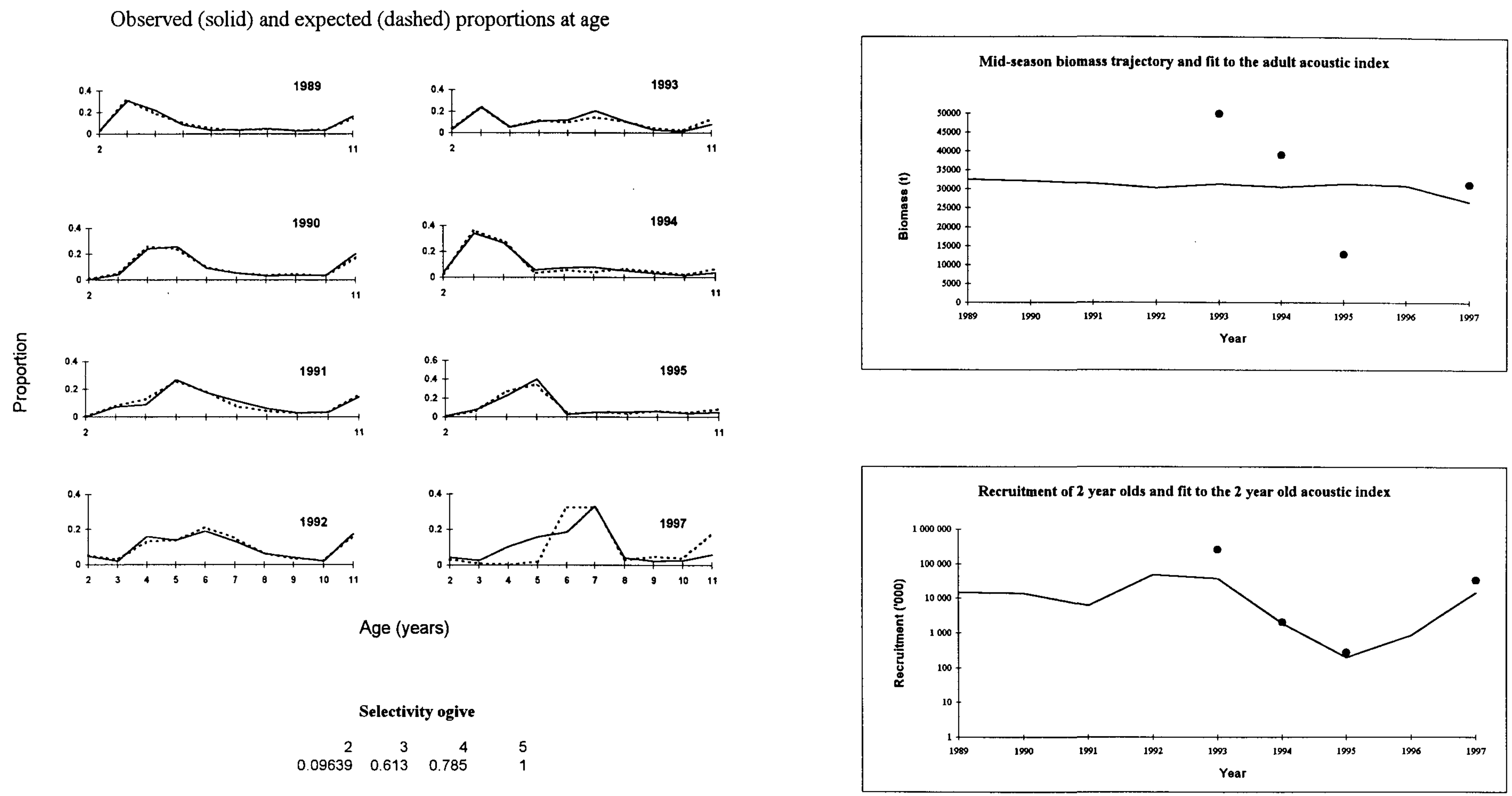


Figure 12: Diagnostics for the Pukaki Rise assessment showing the fit to the proportion-at-age, adult and 2+ acoustic indices; the values of the selectivity at age are also shown.

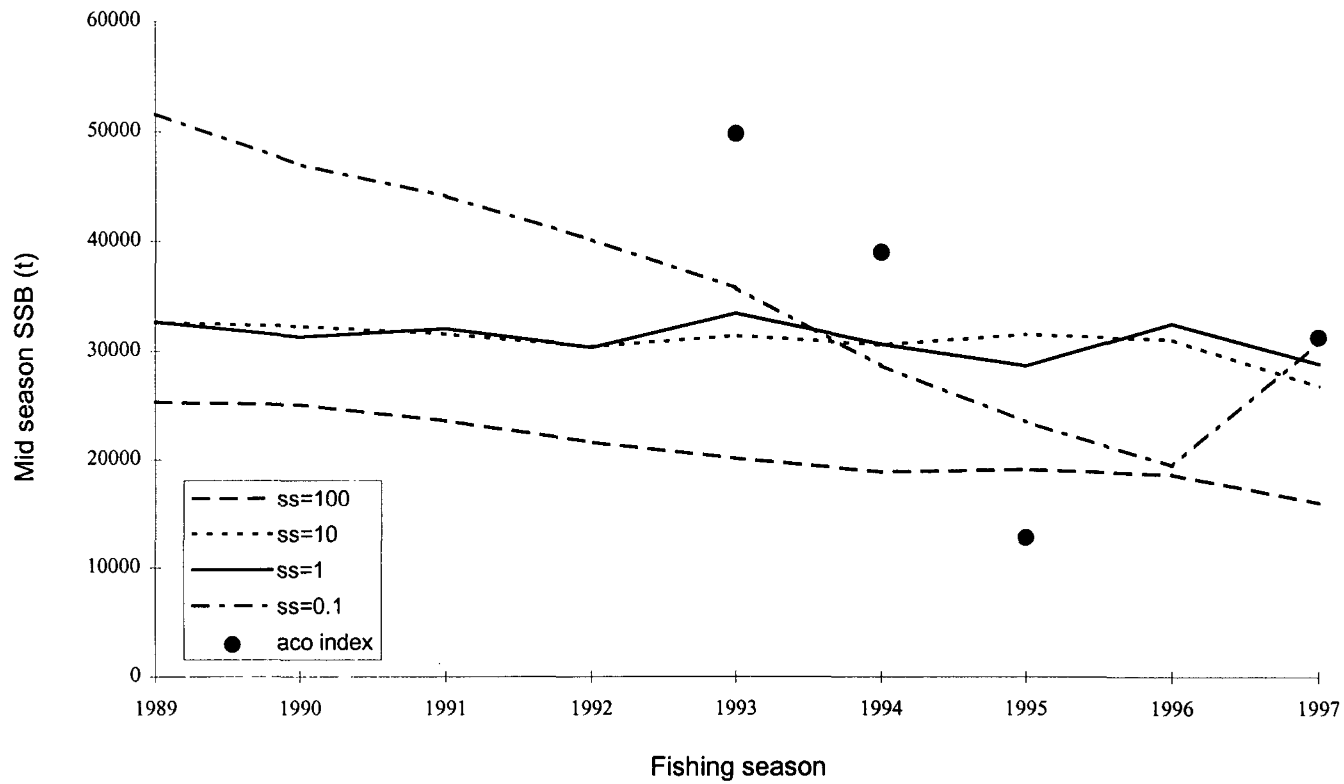


Figure 13: Sensitivity of the Pukaki Rise assessment to the sample size (ss) used for the proportion-at-age data.