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EXECUTIVE SUMMARY

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This paper presents the 2000 stock assessment of southern blue whiting resources in New Zealand waters. The 1999 season and landings are summarised. Catch-at-age data for the Bounty Platform and Campbell Island Rise stocks are updated and presented for the years since 1990. Catch-at-age data for the Auckland Islands Shelf stock are presented for all years for the first time.

For the Campbell Island Rise stock the catch-at-age data and acoustic estimates of recruited and pre-recruit biomass were fitted using separable Sequential Population Analysis. The stock biomass showed a steady decline from the early 1980s until 1993, followed by a large increase to 1996 and a decline to 1999. The extent of this recent increase and subsequent decline is highly uncertain. The acoustic indices showed a decline between 1994 and 1995 followed by an increase to 1998. In contrast, the proportion-at-age data have been dominated by the strong 1991 year class throughout the time period. With higher weighting to the acoustic index the model gives a higher estimate of recruitment strength for recent years. With lower weighting to the acoustic index the model does not fit the 1998 acoustic estimate. The "base case" assessment is a compromise between these two extremes, but the choice for the weightings used was arbitrary.

Estimates of CAY for the Campbell stock depend on the size of the 1991 and subsequent year classes, and have wide confidence intervals. The base case CAY estimate for 2000 is 11 100 t. The base case assessment suggested that current biomass was below B_{MAY}. However, from the bootstrapping results the 1999 mid-season biomass is estimated to be above B_{MAY} (65% confidence).

For the Bounty Platform stock the catch-at-age data and acoustic estimates of recruited and pre-recruit biomass were also fitted using separable Sequential Population Analysis. Recruited biomass increased in the late 1980s as a result of the strong 1986 and 1988 year classes. Biomass dropped after the large catch in 1992 and has remained relatively stable until the present. The 1999 acoustic survey biomass estimate was relatively low suggesting the 1994 year class was not as large as had been predicted by the survey of pre-recruits in 1995.

Estimates of CAY for the Bounty stock depend largely on the size of the 1995 and subsequent year classes, and are uncertain. The base case CAY estimate for 2000 is 8000 t. The base case assessment and the bootstrapping results suggest that current biomass is below B_{MAY}.

Little fishing was carried out on the Pukaki Rise and Auckland Island Shelf stocks in 1999 and no new data were available, so the assessment for those areas was not updated.

1. INTRODUCTION

1.1 Overview

This paper reviews the stock assessment of southern blue whiting (SBW) resources in New Zealand waters. Length-frequency and reproductive data for all fishing grounds are summarised for the 1999 season and catch-at-age data for the Bounty Platform and Campbell Island Rise stocks are updated. Catch-at-age data for the Auckland Islands Shelf stock are presented for the first time. The catch-at-age data and estimates of recruited and pre-recruit biomass from acoustic surveys are used in a separable Sequential Population Analysis (sSPA) to estimate historic and current biomass for the Campbell Island Rise and Bounty Platform stocks. Estimates of Current Annual Yield (CAY) are provided for both stocks for 2000.

1.2 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 1999 season is part of the 1998–99 fishing year).

The SBW fishery was developed by Soviet vessels during the early 1970s, with landings exceeding 40 000 t in 1973 and 1974. 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. In some seasons (notably 1979, 1982, and 1983) vessels also targeted spawning fish on the Bounty Platform in August and September (Table 1).

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, the Pukaki Rise, and the southern Campbell Island Rise. Fishing effort increased markedly between 1990 and 1992, culminating in a catch of over 75 000 t in 1992. The increased catch came mainly from the Bounty Platform. In 1993, a fishery developed for the first time on the Auckland Islands spawning grounds and fishing has continued at a low level there since then. A catch limit of 32 000 t for all areas was introduced for the first time in 1993, and was later increased to 58 800 t (*see* Table 1). Catches during that period came mainly from the Campbell Island ground and have averaged about 25 000 t. The fleet has comprised mainly Japanese, Russian, and Ukrainian vessels, and fishing in most years has extended into October.

1.3 Recent papers

Stock structure was reviewed by Hanchet (1998a, 1999) who concluded that SBW should be assessed as four stocks. Various designs for acoustic surveys of SBW were investigated using simulation studies by Dunn & Hanchet (1998). Results of the 1998 acoustic survey of the Campbell Island Rise spawning grounds were given by Hanchet *et al.* (2000). Results of the 1999 acoustic survey of the Bounty Platform were given by Hanchet & Grimes (2000). Results of target strength work were summarised by McClatchie *et al.* (1998) and Macaulay (1999). A detailed account of the 1996 assessment of the Campbell Island stock and documentation of the sSPA model was provided by Hanchet *et al.* (1998). Other recent developments to the sSPA model, and a comparison with other models, were given by Hanchet (1998c). In the most recent stock assessments, catch-at-age and acoustic data were modelled using the sSPA model (Hanchet 1997, 1998b, 2000).

Cherel *et al.* (1999) found that juvenile (0+) SBW formed a large part of black-browed albatross diet during the summer chick-rearing period. They concluded that 0+ SBW are pelagic and occur in dense schools in the top 5 m of the water column close to the Campbell Islands during the summer months. Hanchet & Renwick (1999) found a strong negative correlation (r = -0.73) between year class strength and anticyclonic, stable atmospheric conditions centred over the Campbell Plateau.

Objectives

This report addresses objectives 1, 2, 5, and 6 from MFish project SBW9801.

1. To complete a descriptive analysis of the commercial catch and effort data with the inclusion of data up to the end of the 1998/99 fishing year for the following southern blue whiting fishery areas: Campbell Islands, Pukaki Rise, Bounty Platform, and Auckland Islands.

2. To determine catch at age from the commercial fisheries at Campbell Island, Bounty Platform, and Pukaki Rise for 1998/99 from samples collected at sea by Scientific Observers and other sources, with a target coefficient of variation (*c.v.*) of 20 % (mean weighted *c.v.* across all age classes).

5. To update the stock assessments of Campbell Island, Auckland Island, Pukaki Rise and Bounty Platform stocks, including estimating biomass and sustainable yields.

6. To determine catch at age from the commercial fishery at Auckland Island for the period 1992/93 to 1998/99 from samples collected at sea by Scientific Observers and other sources.

2. REVIEW OF THE FISHERY

2.1 TACs, catch, landings, and effort data

2.1.1 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 1). 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 and 1997–98 fishing years. A single combined catch limit was set for the Pukaki Rise and Auckland Islands fisheries of 7700 t, but in 1997–98 the industry agreed to a 1640 t limit for the Auckland Islands fishery. The 58 800 t catch limit was retained for 1998–99 with slight adjustments for the sub-area limits (*see* Table 1).

2.1.2 Landings

Estimates of the annual landings of SBW by fishing year are given in Table 1.

The reported catch for the 1999 season from the Licensed Fish Receiver Returns was about 39 000 t, and the TCEPR (processed) catch was about 40 500 t (Table 2). The estimated catch from the TCEPR logbooks (as at 1 February 2000) was about 37 600 t. The estimated catch was pro-rated by area to the TCEPR (processed) catch total. Because the main fishing season in recent years has been from August to October, catches for November to October were used in the stock assessment modelling when considering removals from the various stocks (Table 2).

2.1.3 The 1999 season

The location of trawls made during the 1999 season is shown in Figure 1. Twenty vessels from Japan, Russia, Ukraine, Poland, and New Zealand fished for southern blue whiting during the 1999 season (Table 3). The first vessels arrived on the Bounty Platform on 14 August. Vessels started fishing on the west of the Platform, but made very poor catches for the first 2 weeks of the season. They eventually found a large aggregation to the south of the Bounty Islands on the 27 August which moved east and then northeast over the next week. A total of 13 vessels fished there during the short 2 week season and took an estimated 11 400 t. The timing of spawning on the Bounty Platform was very late, starting on 1 September and finishing on 6 September (Section 2.2.3).

Four vessels fished the Pukaki Rise at various times during September. Large catches (over 100 t per tow) were made on 12, 15, and 17 September, but it is unknown whether these were on spawning fish because no vessels were observed this year. The total catch on the Pukaki Rise was 1000 t. Two vessels fished on the Auckland Islands Shelf during October 1999 making 10 tows and catching 210 t, but these did not carry observers.

Vessels started fishing on the Campbell Island Rise on 8 September and continued through until mid October. Vessels fished the northern ground from 8 to 20 September, the first week being primarily on spawning fish (Section 2.2.3). Vessels fished the southern ground from 21 September to 2 October. Spawning occurred on the southern ground from 24 September to 1 October. An estimated 18 800 t was taken from the northern ground, and 8800 t from the southern ground during the 1999 season by about 20 vessels.

2.1.4 CPUE analysis

A standardised CPUE analysis of the Campbell Island Rise fishery has been carried out by Ingerson & Hanchet (1995), Chatterton (1996), Hanchet & Ingerson (1996), and Hanchet (2000). This analysis was not updated to include data from the 1999 season.

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. Similarly an increase in biomass may not lead to a proportional increase in CPUE. For this reason the CPUE indices were not used in the base case of the stock assessment.

2.2 Other information

2.2.1 Size composition of the commercial catch

Length frequency data were collected by scientific observers from 25% of all tows in the commercial fishery during 1999 (*see* Table 3). The length frequency data were scaled up to the total catch for each stratum and each fishing ground following Hanchet & Ingerson (1995). Year classes have been assigned to modes on the basis of ageing work (Section 2.2.2).

The size distribution of the Campbell Island stock in 1999 was strongly bimodal, being dominated by the strong 1991 and 1995 year classes on both grounds (Figure 2). A few 2 year olds (1997 year class) were also present at 20–30 cm on the northern ground. The size distributions were consistent with earlier years (Figure 3). The catch has continued to be dominated by the 1991 year class, but the 1995 year class also appears strong relative to the intervening years. Fish in both year classes continue to show slow growth rates.

The 1999 catch on the Bounty Platform was dominated by the 1994 year class, although the mode of the 1992 year class can still be seen (Figure 4). The 1994 year class was predicted to be very strong by the 1995 and 1997 acoustic surveys. Although relatively large numbers of this year class were caught it has not recruited into the fishery in the numbers predicted.

The size distribution of the fish on the Auckland Islands Shelf is generally bimodal (Figure 5). In the first two years the catch was dominated by larger fish. Since 1995, the catch has been dominated by the strong 1991 year class, which reached a size of about 40 cm in 1998.

No observer data were collected in 1999 from the Auckland Islands Shelf and Pukaki Rise grounds.

2.2.2 Age composition of the commercial catch

Otoliths collected from the Bounty Platform and Campbell Island Rise fishing grounds during the 1999 season were read and used to derive age-length keys (Table 4). 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 resulting catch-at-age data are illustrated in Figures 6 and 7.

Otoliths from the Auckland Islands Shelf stock from 1993 to 1998 were read for the first time. The number of otoliths collected each year was small (Table 4), which led to low precision on the catch at age data (Figure 8). The 1993 catch was dominated by the 1986 to 1988 year classes and the older year classes in the plus group. Since then, the strong 1991 year class has dominated the catch.

2.2.3 Timing of spawning

Spawning on the Bounty Platform was considerably later than normal, starting on 1 September and ending on 6 September (Table 5). Spawning on the Bounty Platform appears to have been getting progressively later each year since 1992 (*see also* Hanchet 1998a). The reason for this is unknown.

Spawning on the northern Campbell Island Rise had already began when vessels arrived on the grounds on 8 September and continued through until 13 September (Table 5). Vessels remained on the northern ground until 21 September. When vessels started fishing the southern ground on 21

September fish were just starting to spawn. Observers stated that these fish had already spawned one batch of eggs and that this was therefore the second spawning event. Spawning continued until 1 October. The timing of the second spawning event on the northern ground and the first spawning event on the southern ground could not be identified.

3. RESEARCH

3.1 Stock structure

Stock structure of SBW was reviewed by Hanchet (1998a, 1999) who 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.

3.2 Acoustic surveys

A survey of the Bounty Platform was carried out in August 1999 (Hanchet & Grimes 2000). Two acoustic snapshots of the Bounty Platform were completed. Two small areas of adult fish were located on the Bounty Platform during snapshot 1. The first was in the southwest of the survey area in depths of 400–530 m, and was being fished by commercial vessels. The second aggregation was found in the east of the survey area in 400–450 m depth. In snapshot 2, a large aggregation of adult fish was found in the south of the survey area, in depths of 380–450 m. These marks were the densest seen during the survey. The estimate from snapshot 1 was particularly low and there was concern that the fish had not arrived on the grounds when this was completed. The estimate from the second snapshot was also carried out before spawning and was very imprecise (with a *c.v.* of 77%). The timing in relation to spawning was similar to that in 1997 but earlier than in the other previous surveys. For this reason only the second snapshot was used in the modelling, and this was given a low weight in the model (Section 3.3.1). The indices are shown in Table 6.

The estimates of backscatter were turned into biomass estimates by using the target strength–fish length relationship derived for blue whiting in the Northern Hemisphere (Monstad *et al.* 1992). Recent studies on gadoids in the Northern Hemisphere have suggested a higher target strength (similar slope but higher intercept) (Rose 1998). Using this relationship would reduce all survey biomass estimates by about 30%. This would affect their use if modelled as absolute indices of abundance, but not if modelled as relative indices of abundance. *In situ* target strength work carried out during the 1994 and 1998 SBW acoustic surveys and theoretical modelling studies suggest a steeper slope than the Northern Hemisphere studies. This would affect the use of the surveys in both an absolute and a relative sense, because the biomass of smaller fish would have been underestimated whilst the biomass of larger fish would have been overestimated. The target strength–fish length relationship used in previous years was retained in the current analysis because it is not yet known which alternative relationship is most likely.

3.3 Biomass estimates

3.3.1 Input data and weights

The data were analysed using the separable Sequential Population Analysis (sSPA) used in recent assessments of the stock (Hanchet 1997, 1998c, 2000). The model was fitted to proportion-at-age data, and the acoustic indices given in Table 6. Because of uncertainty over target strength, the acoustic indices were fitted in the model as relative estimates of mid-season abundance (i.e., after half the catch has been removed). The model assumes that the selectivity after age 4 is 1.0, estimates a single selectivity for age 4, and annual selectivity for ages 2 and 3. The selectivity of 2 and 3 year olds in the last three and two years respectively were fixed at the mean. No stock-recruitment relationship is assumed in the sSPA.

For the Campbell stock the sSPA model was used to estimate the numbers at age in the initial population in 1979 and subsequent recruitment. For the Bounty stock an equilibrium age structure in 1979 was assumed and subsequent recruitment was estimated.

The adult acoustic indices for the Bounty Platform for 1993–95 and 1997 were given a *c.v.* of 0.3, but the 1999 estimate was considered to be less precise (*see* Section 3.2) and given a *c.v.* of 0.5. Adult acoustic *c.v.*s for the Campbell Island Rise were weighted by the number of snapshots, resulting in *c.v.*s of 0.35 for the 1993–95 surveys and 0.25 for the 1998 survey (*see* Hanchet 2000). Sensitivity analyses were carried out using base *c.v.*s of 0.1 and 0.5. A *c.v.* of 0.5 was used for the pre-recruit acoustic survey indices.

The proportion-at-age data are assumed to be multinomially distributed. The appropriate weight for these data (sample size) can be determined from the *c.v.* of the observed age composition data. Although the observed *c.v.*s suggested a sample size of over 100, this is probably too high given factors such as ageing error and sampling bias. Also, because of the large number of data points, a value of 100 gave too much weight to the age data relative to the acoustic data. For the base case a weight of 10 (equivalent to a *c.v.* of about 0.63) was given to the age data. For the sensitivity analysis weights of 100 and 1 (equivalent to *c.v.*s of about 0.2 and 2) were used.

A number of other sensitivity tests were run to evaluate the sensitivity of the assessment to M, treatment of the acoustic surveys as relative or absolute, and to the fitting of the CPUE indices given in Table 6. Details of the input parameters, and sensitivity runs are given in Table 7.

3.3.2 Estimation of confidence intervals

The data were bootstrapped 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 2 acoustics data, and annual catch was captured by assuming the data were log-normally distributed with *c.v.*s of 0.3, 0.5, and 0.05 respectively. For each of the 500 bootstrap runs data were randomly selected from each distribution.

3.3.3 Estimation of virgin biomass

Virgin biomass (B_0) was estimated from the product of the spawning stock biomass per recruit (age 2) in an unfished stock (1.87 kg per recruit for Campbell and 2.17 kg per recruit for Bounty) and the arithmetic mean of the recruitment of 2 year olds from the period 1978–79 to 1995–96 calculated from the sSPA. (Note this value was revised using the projected weight at age for 2000.)

3.4 Results

3.4.1 Campbell Island stock

The assessment suggests that the stock biomass showed a steady decline from the early 1980s until 1993, followed by a large increase to 1996 and a decline to 1999 (Table 8, Figure 9). The extent of this recent increase and subsequent decline is highly uncertain as shown by the wide confidence intervals in current biomass. Selectivity at age was consistent with the results of previous assessments, with about 50% of fish being selected at age 3 and over 90% selected at age 4 (Table 9). The reason for the large increase in biomass was due to the 1991 year class which is estimated to almost eight times the average year class strength over the period 1979 to 1999 (Table 10). Apart from the 1994 year class, year classes since then have been relatively weak.

The base case assessment gave a mid-season biomass estimate of 53 000 t in 1999, which is slightly below B_{MAY}. However, from the bootstrapping results there is a 65% confidence that B_{mid99} is greater than B_{MAY}. If the bootstrap results are treated as a probability distribution the mean is seen to be much higher than the point estimate, which results from the large proportion of the distribution which is above 100 000 t in Figure 10. High values for current biomass are thought to be unrealistic as they imply catchability coefficients for the acoustic surveys which are well below one.

Selectivity of age 3 fish appears to be highly variable between years, ranging from 0.2 to 1.2 (Figure 11). Age 2 and age 3 fish appeared to have above average selectivity in the early 1980s, but have been closer to the average in recent years. There are generally good fits to the catch-at-age data, and the adult and 2 year old acoustic indices (Figure 12). Although the weights used in the base case were arbitrary, there is some support for them from the acoustic estimates. The adult acoustic q for the base case was 1.65 (Figure 12), which means that the modelled biomass is about 30% lower than the observed biomass from the acoustic surveys. These acoustic estimates were calculated using the target strength–fish length relationship derived for blue whiting in the Northern Hemisphere (Monstad *et al.* 1992). Recent studies on gadoids in the Northern Hemisphere (Rose 1998) have suggested a higher target strength which would reduce all survey biomass estimates by about 30%, which is in line with the current results.

The acoustic q for 2 year olds was slightly lower than for adults, suggesting that not all 2 year old fish are present in the survey area. This is consistent with the distribution of 2 year old fish in trawl surveys of the wider Campbell Plateau, which showed some immature 2 year old fish in the east of the Plateau away from the survey area.

The assessment was sensitive to several parameters tested (Table 11). A higher M, more weight (lower *c.v.*) for the adult acoustics index, less weight (lower sample size) for the catch-at-age data, and use of the acoustic estimates as absolute indices of abundance, all increased the estimates of current biomass. The assessment using the CPUE index was almost identical to the base case. Trends in year class strength were similar between runs.

Current biomass estimate for the Campbell Island stock is very uncertain. Uncertainty is indicated by the relatively wide 90% confidence intervals shown for the base case assessment, and the sensitivity of the assessment to changes in the relative weightings of the age and acoustic data, and to changes in M. The choice for the weightings used in the base case assessment was arbitrary. Assumptions concerning the model structure (including selectivity and maturity) may also impact on the model results.

3.4.2 Bounty Platform stock

The assessment suggests that recruited biomass increased in the late 1980s, as a result of the strong 1986 and 1988 year classes (Table 12, Figure 13). Recruited biomass dropped after the large catch in 1992 and has remained relatively stable until the present. The estimate of recruited biomass in 1999 is 35 000 t. However, the mode of the bootstrap results was only 25 000 t (Figure 14). Mean selectivity estimates at age tend to be lower than for the Campbell stock, with only about 30% of age 3 fish being recruited to the fishery (*see* Table 9). The model suggests that the 1994 year class is almost as strong as the strong 1986 and 1988 year classes, but subsequent year classes have been weak (*see* Table 9).

Selectivity of age 3 fish appears to be moderately variable between years, ranging from 0.1 to 0.7 (Figure 15). The model has some problems fitting the catch-at-age data and the adult and pre-recruit acoustic indices (Figure 16). Although the model is unable to fit the trend between the individual adult acoustic indices, the adult acoustic q is virtually identical to the Campbell assessment, and is in line with our beliefs regarding the target strength-fish length relationship (*see* Section 2.4.1). The acoustic q for the pre-recruits was slightly higher than for adults, suggesting that there are proportionally more 1 and 2 year old fish present in the survey area. The reason for this is unclear, but may be related to an increased proportion of other species in the acoustic backscatter. The model is unable to fit the extremely high estimate of 1 year old fish (1994) year class from the 1995 survey.

Estimates of the 1994 year class strength, and hence current biomass, are very sensitive to the relative weightings on the proportion-at-age data and acoustic indices (Table 13). Changes to M, less weight (higher *c.v.*) for the adult acoustics index, less weight (lower sample size) for the catch-at-age data, and use of the acoustic estimates as absolute indices of abundance, all increased the estimates of current biomass. Trends in year class strength were similar between runs.

Current biomass estimate for the Bounty Platform is very uncertain. Uncertainty is indicated by the relatively wide 90% confidence intervals shown for the base case assessment, and the sensitivity of the assessment to changes in the relative weightings of the age and acoustic data, and to changes in M. The choice for the weightings used in the base case assessment was arbitrary. Assumptions concerning the model structure (including selectivity and maturity) may also impact on the model results.

3.5 Yield estimates

3.5.1 Estimation of Maximum Constant Yield (MCY)

The simulation method of Francis (1992) was used to determine the appropriate reference harvest rate for MCY. Using the growth parameters and selectivity given by Hanchet (1997), together with a recruitment variability of 1.0 and a steepness parameter of 0.95, MCY was calculated as 5.1% of B_0 for the Campbell stock and 6.2% for the Bounty stock.

3.5.1.1 Campbell Island stock

MCY was estimated for the Campbell Island stock by multiplying the harvest rate by the estimate of B_0.

$$MCY = 0.051 * 158\,000 \text{ t} = 8\,100 \text{ t}$$

3.5.1.2 Bounty Platform stock

MCY was estimated for the Bounty Platform stock by multiplying the harvest rate by the estimate of B_0.

$$MCY = 0.062 * 106\,000 \text{ t} = 6\,600 \text{ t}$$

3.5.2 Estimation of Current Annual Yield (CAY)

Estimates of CAY and their 90% confidence intervals were calculated for the Campbell Island and Bounty Platform stocks for 2000. No estimates of CAY are available for the Pukaki Rise or Auckland Islands Shelf stocks.

The simulation method of Francis (1992) was used to determine u_{CAY}, the ratio of catch to pre-season biomass, which equalled 0.21. This harvest rate is the highest constant F policy that 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 $8.6\%B_0$ for both stocks.

3.5.2.1 Campbell Island stock

CAY was estimated by multiplying u_{CAY} by pre-season biomass in 2000. Pre-season biomass in 2000 was calculated by projecting forward the 2000 beginning of year numbers at age. The number of 2 year olds in 1999 and 2000 was assumed to be equal to the arithmetic mean of the recruitment of 2 year olds over the period 1978–79 to 1995–96.

The resulting CAY estimates (11 100 t) and 90% confidence intervals for the base case are shown in Table 8, and for the sensitivity analyses in Table 11.

3.5.2.2 Bounty Platform stock

CAY was estimated by multiplying u_{CAY} by pre-season biomass in 2000. Pre-season biomass in 2000 was calculated by projecting forward the 2000 beginning of year numbers at age. The number of 2 year olds in 2000 was assumed to be equal to the arithmetic mean of the recruitment of 2 year olds over the period 1978–79 to 1995–96.

The resulting CAY estimates (8000 t) and 90% confidence intervals for the base case are shown in Table 12, and for the sensitivity analyses in Table 13.

3.5.3 Other yield estimates

The long-term yield available from the southern blue whiting 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.

Applying this value to the Campbell stock would suggest a long-term yield of about 13 600 t based on the most recent estimate of B_0 from the sSPA model. In comparison, a constant catch (MCY) strategy would suggest a long-term yield of 8 100 t. Applying this value to the Bounty stock would suggest a long-term yield of about 9100 t based on the most recent estimate of B_0 from the sSPA model. In comparison a constant catch (MCY) strategy would suggest a long-term yield of 6600 t.

3.5.4 Stock projections

The effect of different catch levels in the 2000 fishery was also evaluated using the bootstrap results. For the Campbell Island stock, the bootstrap results suggest that even large catches of over 30 000 t will retain the biomass above B_{MAY} in 2000 (Table 14). The bootstrap distribution has a large proportion of the runs with current biomass well over 100 000 t. However, the mode of the distributions is well below 80 000 t. Although a large current biomass is possible for this stock, this would imply very low values of q for the acoustic surveys.

For the Bounty Platform stock, the values suggest that even at very low catch levels of 5000 t, the biomass will be below B_{MAY} in 2000 (Table 14). The bootstrap results show a large proportion of the runs with current biomass less than the base case. These low biomass estimates imply high exploitation rates in recent years.

4. MANAGEMENT IMPLICATIONS

4.1 Campbell stock

There is considerable uncertainty over the estimate of current biomass and yields for this stock. The acoustic indices showed a decline between 1994 and 1995 followed by a large increase to 1998. In contrast, the proportion-at-age data have been dominated by the strong 1991 year class throughout the time period. The model is unable to fit this large increase in the acoustic indices given the proportion-at-age data. The size of this year class and of other recently recruited year classes remain uncertain.

Estimates of CAY depend largely on the size of the 1991 and subsequent year classes, and therefore have wide confidence intervals. The base case CAY estimate for 2000 is 11 100 t. However, from the bootstrapping results the 1999 mid-season biomass is estimated to be above B_{MAY} (65% confidence).

4.2 Bounty Platform stock

There is uncertainty over the estimate of current biomass and yields for this stock. The acoustic indices were similar in 1993, 1994, and 1997, but showed a decline in 1995 and again in 1999, but this last point is very uncertain. The sSPA model suggests mid-season biomass has been relatively stable since the large catch was removed in 1992. Uncertainty in current biomass is due to uncertainty over the size of recent year classes.

Yield estimates are uncertain largely because of uncertainty over the size of recent year classes. The CAY estimate for 2000 is 8000 t.

5. ACKNOWLEDGMENTS

I am grateful to the scientific observers for the collection of the length frequency data and otoliths, and to Kim George for processing all otoliths and reading otoliths collected from the Pukaki Rise. This assessment benefited from discussions with many members of the Middle Depths Working Group. Thanks to Patrick Cordue for comments on an earlier draft of the manuscript. This work was funded by the Ministry of Fisheries, Project Number SBW9801.

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Table 1: Estimated catches (t) of SBW by area for the period 1978 to 1998–99 from vessel logbooks. Estimates for 1998–99 are preliminary. –, no catch limit in place

Fishing year	Bounty Platform		Campbell Island Rise		Pukaki Rise	Auckland Island	PR+AI	Total	
	Catch	Catch limit	Catch	Catch limit	Catch	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+	1 761	20 200	15 685	30 100	1 806	895	7 700	18 374	58 000
1997–98+	5 647	15 400	24 273	34 900	1 245	0	7 700	31 165	58 000
1998–99+	10 567	15 400	27 681	35 460	965	535	7 140	38 251	58 000

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

Table 2: Catch history (t) of the Campbell and Bounty stocks used in the modelling

Season	Campbell	Bounty	Season	Campbell	Bounty
1979	25 305	1 211	1990	16 542	4 430
1980	12 828	16	1991	21 314	10 897
1981	5 989	8	1992	14 208	58 928
1982	7 915	8 325	1993	9 316	11 908
1983	12 803	3 864	1994	11 668	3 877
1984	10 777	348	1995	10 436	6 386
1985	7 490	0	1996	16 504	6 508
1986	15 252	0	1997	18 923	1 761
1987	12 804	0	1998	27 164	6 508
1988	17 422	18	*1999	27 528	11 367
1989	26 611	8			

* LFRR catch for the 1999 season was 38 969 t, and TCEPR (processed) catch was 40 465 t.
TCEPR (estimated) catch for the 1999 season was 37 617 t (Bounty 10 567, Pukaki 955, Campbell 25 590 t, and Auckland 195 t). The estimated catch was pro-rated by area to the TCEPR (processed) catch total.

Table 3: Number of vessels, tows, and catch (t) for observed and all vessels for each area for 1999 season

Area	Number of vessels		Number of tows		Catch	Dates
	observed	total	#observed	total	(t)	
Bounty	5	13	73	245	11 400	14 Aug – 6 Sep
Pukaki	0	4	0	20	1 027	8 Sep – 26 Sep
Auckland	0	2	0	9	195	1 Oct – 18 Oct
Campbell	9	20	175	705	27 528	8 Sep – 17 Oct

tows for which LF data were collected.

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 . – no data available

	Campbell Island Rise			Bounty Platform			Pukaki Rise			Auckland Island Shelf		
Year	n	N	O	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	5	759	65
1994	80	13 175	779	39	7 148	449	22	3 771	397	7	1164	136
1995	76	13 108	563	63	9 990	374	12	2 021	531	10	1706	126
1996	97	18 072	529	22	4 636	481	–	–	–	–	–	–
1997	185	33 010	494	8	1 576	446	25	4 064	493	11	1846	240
1998	255	50 239	620	68	13 918	450	18	3 442	342	6	1199	120
1999	175	30 550	418	73	12 362	578	–	–	–	–	–	–

Table 5: Dates of sampling and changes in SBW gonad condition in 1999 on Bounty and Campbell 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). No observer data from Pukaki or Auckland

Gonad stage	Bounty	Campbell	
		North	South
1st sample	14/8	8/9	–
>10% ripe	31/8	<8/9	–
>10% running ripe	1/9	<8/9	–
Main spawning	1/9–6/9	?–13/9	–
>10% spent	6/9	13/9	–
>10% reverted	5/9	11/9	–
>50% spent	–	–	28/9
2nd spawning	–	–	22/9–1/10
Last sample	6/9	11/10	2/10
% spent	5	93	55
% reverted	90	5	14

Table 6: Estimates of adult biomass ('000 t) and numbers of age 1 and 2 fish (millions) from acoustic surveys, and CPUE indices of abundance, used in modelling the fisheries. SSB, spawning stock biomass. –, no data

	Bounty Platform			Pukaki Rise		Campbell Island Rise			
Year	Adults (≥Age 3)	Age 1	Age 2	Adults (SSB)	Age 2	Adults (SSB)	Age 2	Age 1	CPUE
1986	–	–	–	–	–	–	–	–	1.00
1987	–	–	–	–	–	–	–	–	0.72
1988	–	–	–	–	–	–	–	–	0.59
1989	–	–	–	–	–	–	–	–	0.60
1990	–	–	–	–	–	–	–	–	0.52
1991	–	–	–	–	–	–	–	–	0.52
1992	–	–	–	–	–	–	–	–	0.27
1993	66.9	149.7	105.1	49.8	259.2	18.5	739.9	–	0.69
1994	65.6	2.4	19.7	39.0	2.0	161.4	109.2	–	0.74
1995	38.4	1499.8	40.4	12.8	0.3	121.1	121.1	–	1.30
1996	–	–	–	–	–	–	–	–	1.54
1997	66.6	42.0	36.6	31.0	33.9	–	–	–	1.03
1998	–	–	–	–	–	171.5	84.2	56.2	0.99
1999	45.5	9.0	4.8	–	–	–	–	–	–

Table 7: Values for the input parameters to the separable Sequential Population Analysis for the base case and sensitivity runs for both assessments. Adult acoustic *c.v.*s given for individual surveys for base case. Relative *c.v.*s between years were retained for the sensitivity runs. NF, not fitted. –, not tested

Parameter	Base case	Sensitivity
M	0.2	0.15, 0.25
Acoustic time series	relative	absolute
Acoustic adult *c.v.* (Campbell)	0.35, 0.35, 0.35, 0.25	0.1, 0.5
Acoustic adult *c.v.* (Bounty)	0.3, 0.3, 0.3, 0.3, 0.5	0.1, 0.5
Acoustic pre-recruit *c.v.*	0.5	–
Median weighting on proportion-at-age data	10	1, 100
CPUE series *c.v.* (Campbell only)	NF	0.5

Table 8: Campbell Island estimates of B_0, B_{mid99} (mid-season spawning stock biomass), $B_{pre2000}$ (pre-season spawning stock biomass), MCY, CAY_{2000}, and their 90% confidence intervals. All biomasses and yields in t x 10^3. From the bootstrapping results there is a 65% confidence that B_{mid99} is greater than B_{MAY}

	B_0	B_{mid99}	$B_{pre2000}$	B_{mid99} (% B_0)	MCY	CAY_{2000}
Base case	158	54	53	34	8.1	11.1
CI	154–446	23-355	22-397	15–87	7.8–22.7	4.9-84.2

Table 9: Mean selectivity of 2, 3 and 4 year old fish estimated by the model for the base case runs for the Campbell Island and Bounty Platform stocks

Age	Campbell	Bounty
2	0.03	0.01
3	0.57	0.26
4	0.92	0.83

Table 10: Relative indices of 2 year old fish in the Campbell Island and Bounty Platform

Year	Relative indices of 2 year olds	
	Campbell Island Rise	Bounty Platform
1979	0.02	0.01
1980	0.07	0.01
1981	1.58	0.01
1982	1.88	0.71
1983	0.40	0.36
1984	0.04	0.47
1985	0.57	0.79
1986	0.46	0.52
1987	0.39	0.57
1988	1.10	4.74
1989	0.47	0.52
1990	1.30	4.20
1991	0.10	0.88
1992	0.44	0.05
1993	7.74	1.34
1994	1.40	1.04
1995	0.73	0.33
1996	0.21	3.50
1997	1.20	0.29
1998	0.74	0.66
1999	0.18	0.04

Table 11: Changes in parameter estimates as a result of alternative model assumptions (see Table 7) for the Campbell Island stock. B_{mid}, mid-season spawning stock biomass (t x 10^3); $N_{2,1993}$ size of the 1991 year class (millions)

Parameter	B_0	$B_{mid\ 79}$	$B_{mid\ 99}$	$N_{2,1993}$	$B_{mid\ 99}$ (% B_0)	$B_{mid\ 99}$ (% B_{may})	MCY	CAY
Base case	**158**	**157**	**54**	**587**	**34**	**90**	**8.1**	**11.1**
M = 0.15	190	114	44	427	23	68	8.2	7.7
M = 0.25	146	221	67	834	46	124	9.5	15.8
Acoustic = absolute	189	166	105	781	56	146	9.6	22.1
Acoustic *c.v.* = 0.1	201	159	123	902	61	161	10.3	26.5
Acoustic *c.v.* = 0.5	143	152	26	479	18	48	7.3	5.3
Proportion-at-age weighting = 1	203	160	131	903	65	170	10.4	27.9
Proportion-at-age weighting = 100	142	152	25	465	18	46	7.2	4.8
+ CPUE	157	157	52	572	33	87	8.0	10.7

Table 12: Bounty Platform estimates of B_0, B_{mid99} (mid-season spawning stock biomass), $B_{pre2000}$ (pre-season spawning stock biomass), CAY_{2000}, and their 90% confidence intervals. All values in t x 10^3. From the bootstrapping results there is a 10% confidence that B_{mid99} is greater than B_{MAY}

	B_0	B_{mid99}	$B_{pre2000}$	B_{mid99} (% B_0)	MCY	CAY_{2000}
Base case	106	35	38	33	6.6	8.0
CI	87-120	15-26	14-66	17-50	5.4-7.4	2.9-13.9

Table 13: Changes in parameter estimates as a result of alternative model assumptions (see Table 7) for the Bounty Platform stock. B_{mid}, mid-season spawning stock biomass ('000 t); $N_{2,1996}$ size of the 1994 year class (millions)

Parameter	B_0	$B_{mid\ 90}$	$B_{mid\ 99}$	$N_{2,1996}$	B_{1999}/B_0	B_{1999}/B_{may}	MCY	CAY
Base case	**106**	**61**	**35**	**145**	**33**	**92**	**6.6**	**8.0**
M = 0.15	139	55	41	130	29	82	6.3	8.6
M = 0.25	100	73	44	213	44	110	6.7	11.0
Acoustic = absolute	149	82	78	240	52	139	9.2	12.9
Acoustic *c.v.* = 0.1	95	61	21	115	22	58	5.9	4.4
Acoustic *c.v.* = 0.5	142	67	81	286	57	150	8.8	7.3
Proportion-at-age weighting = 1	344	207	272	958	79	208	21.3	66.1
Proportion-at-age weighting = 100	95	59	21	58	22	58	5.9	0.9

Table 14: Effect of different catch levels in 2000 on the confidence B_{2000}>B_{MAY} and the mean of B_{2000}>B_{MAY} from the bootstrap runs for the Campbell Island and Bounty Platform stocks. –, not estimated

	Campbell Island		Bounty Platform	
Catch (t)	Confidence $B_{2000}>B_{MAY}$	Mean B_{2000}/B_{MAY}	Confidence $B_{2000}>B_{MAY}$	Mean B_{2000}/B_{MAY}
5 000	–	–	0.15	0.73
10 000	0.63	1.40	0.12	0.66
15 000	0.62	1.37	0.11	0.59
20 000	0.61	1.34	0.09	0.53
25 000	0.60	1.32	–	–
30 000	0.59	1.29	–	–

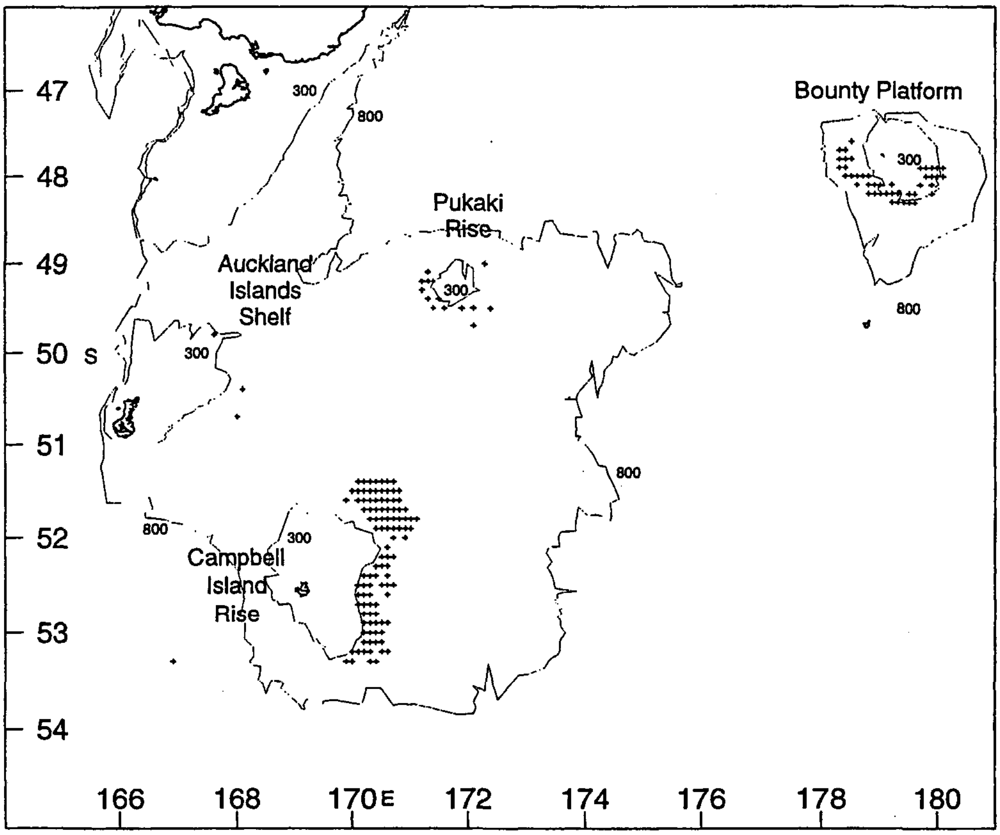


Figure 1: Commercial trawls made during the 1999 season targeting southern blue whiting.

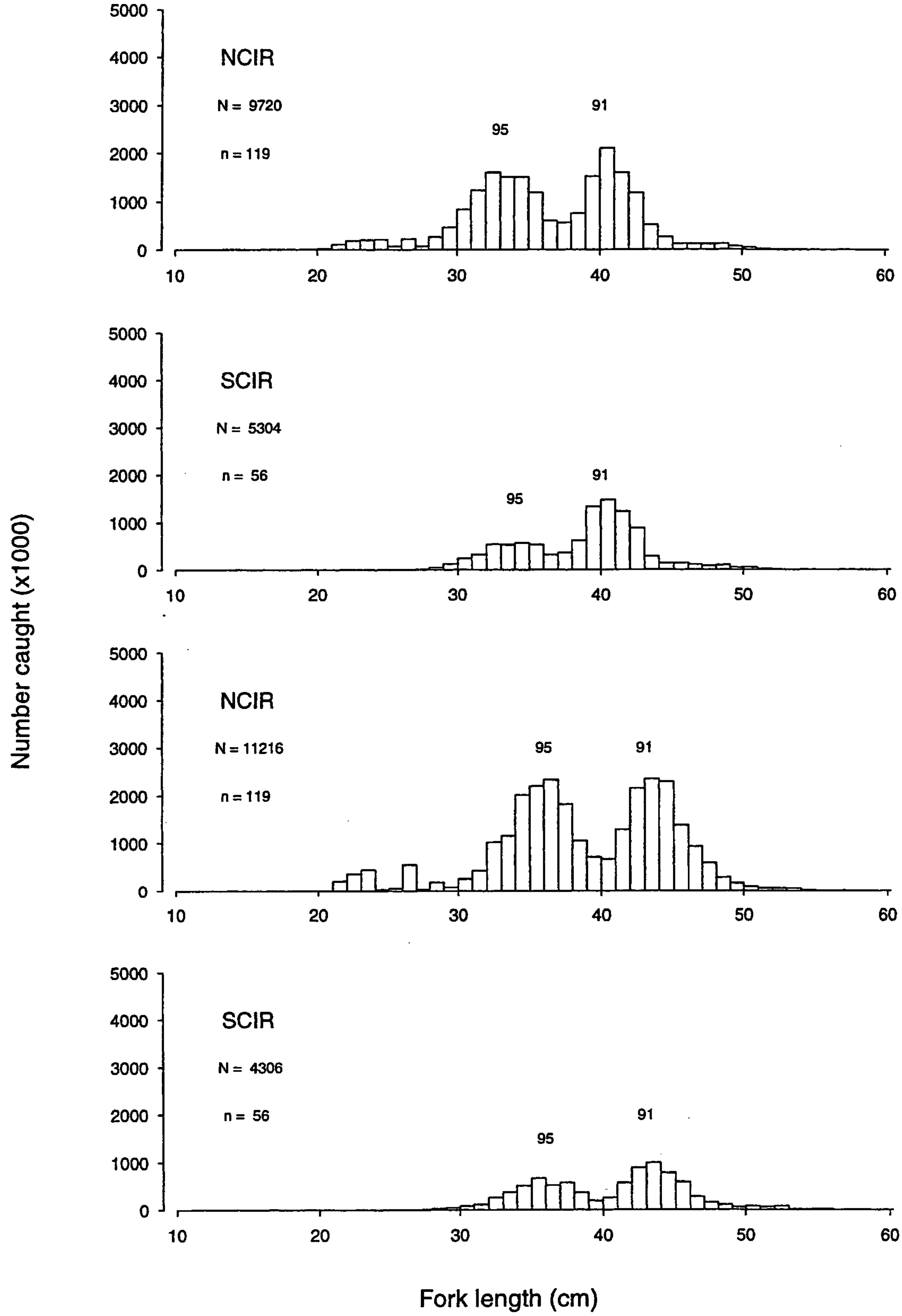


Figure 2: Weighted length frequency distribution of males (top) and females (bottom) in the 1999 catch from the northern Campbell Island Rise (NCIR), and southern Campbell Island Rise (SCIR). (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

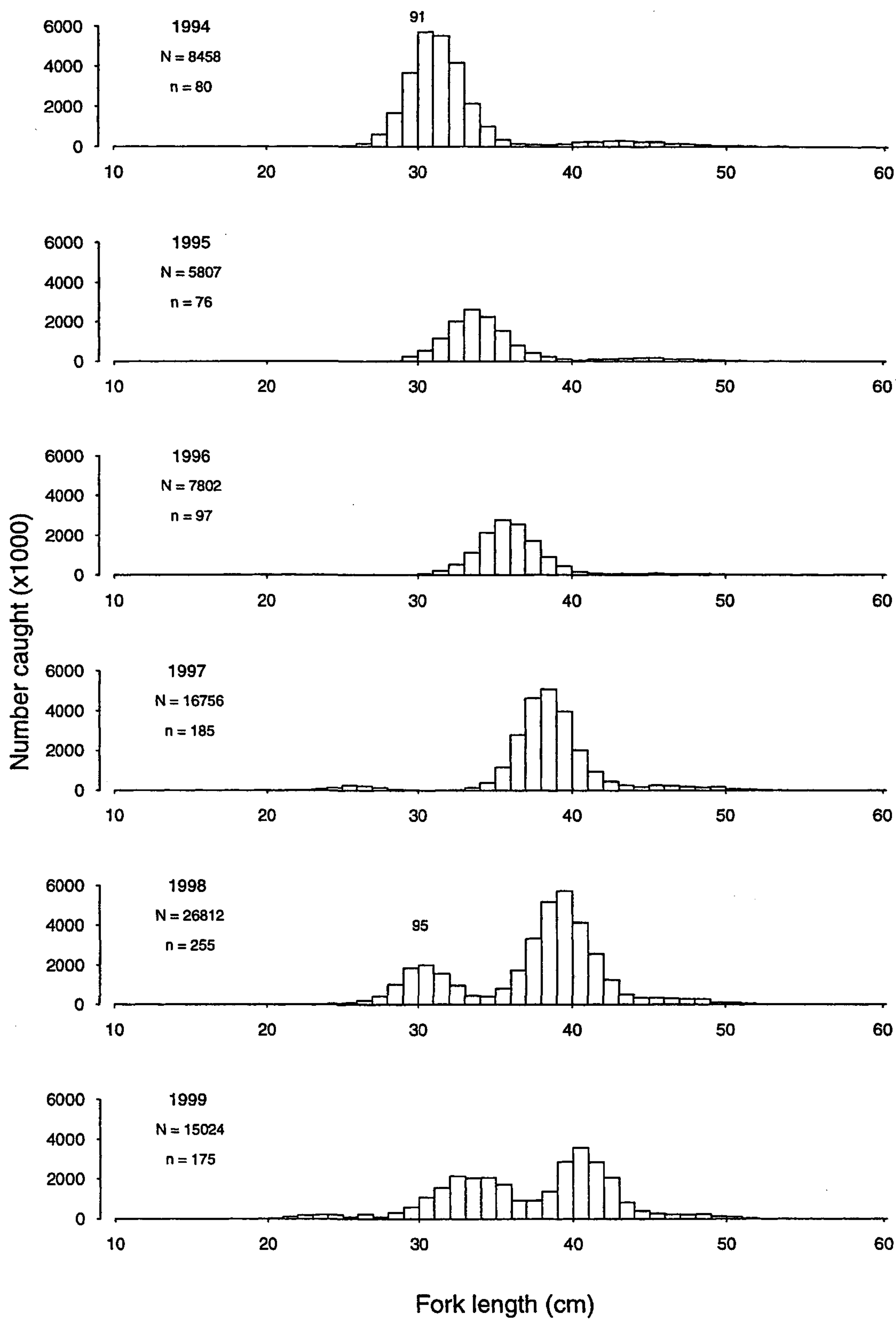


Figure 3a: Weighted length frequency distribution of males in the catch from the Campbell Island Rise. (N, number of fish measured; n, number of samples). Modal lengths of 3 year old fish from strong year classes determined from otolith readings are shown.

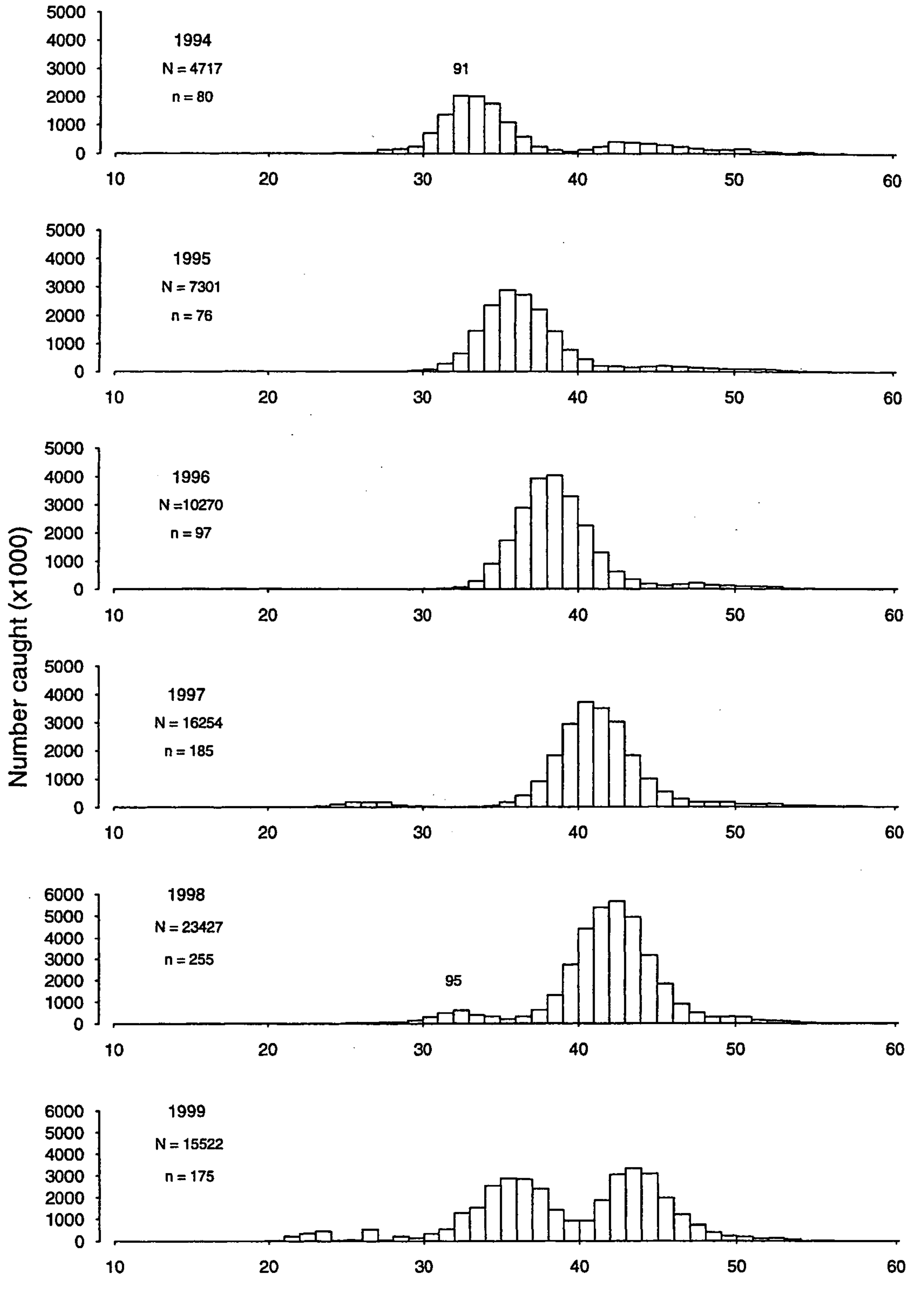


Figure 3b: Weighted length frequency distribution of females in the catch from the Campbell Island Rise. (N, number of fish measured; n, number of samples). Modal lengths of 3 year old fish from strong year classes determined from otolith readings are shown.

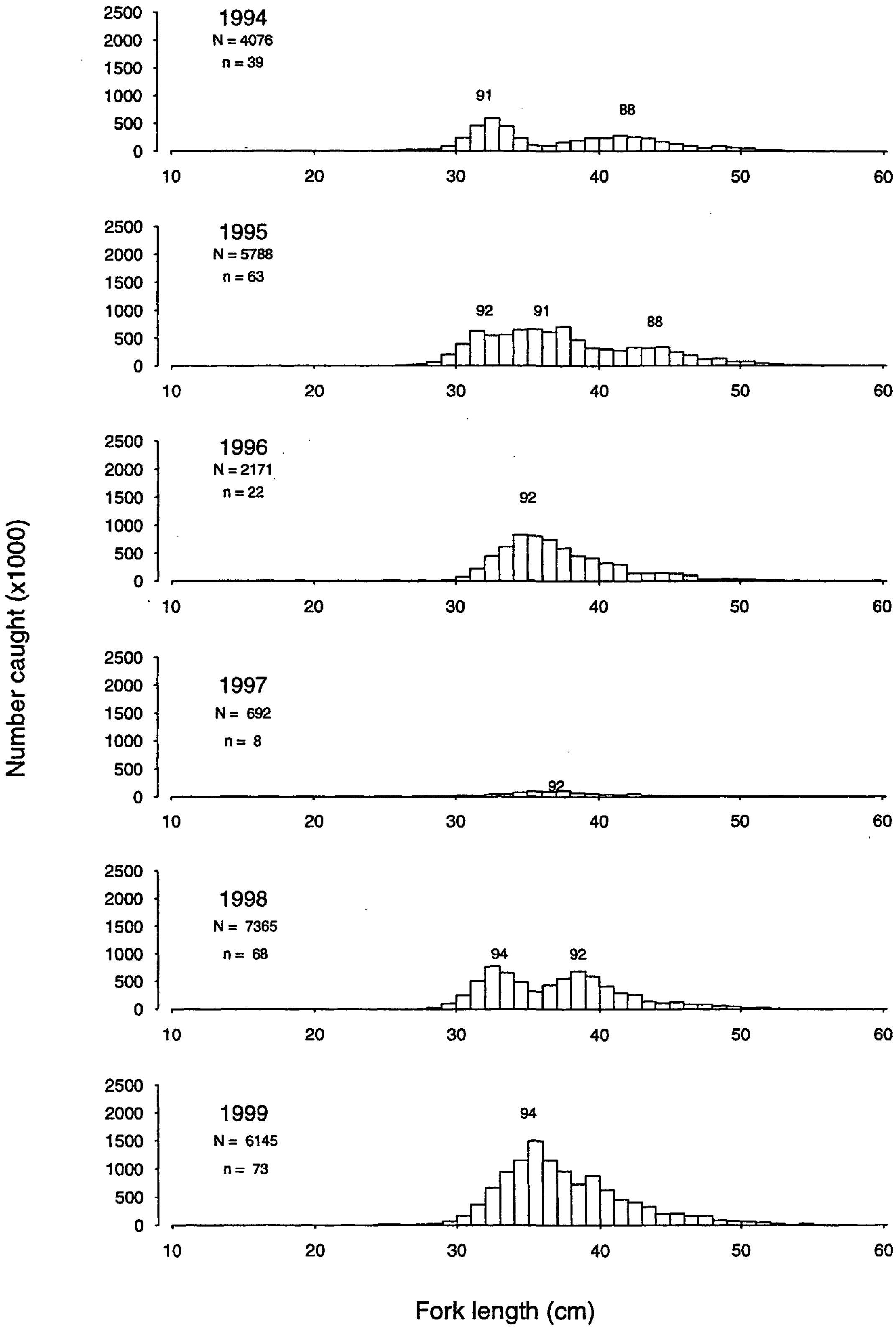


Figure 4a: Weighted length frequency distribution of males in the catch from the Bounty Platform. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

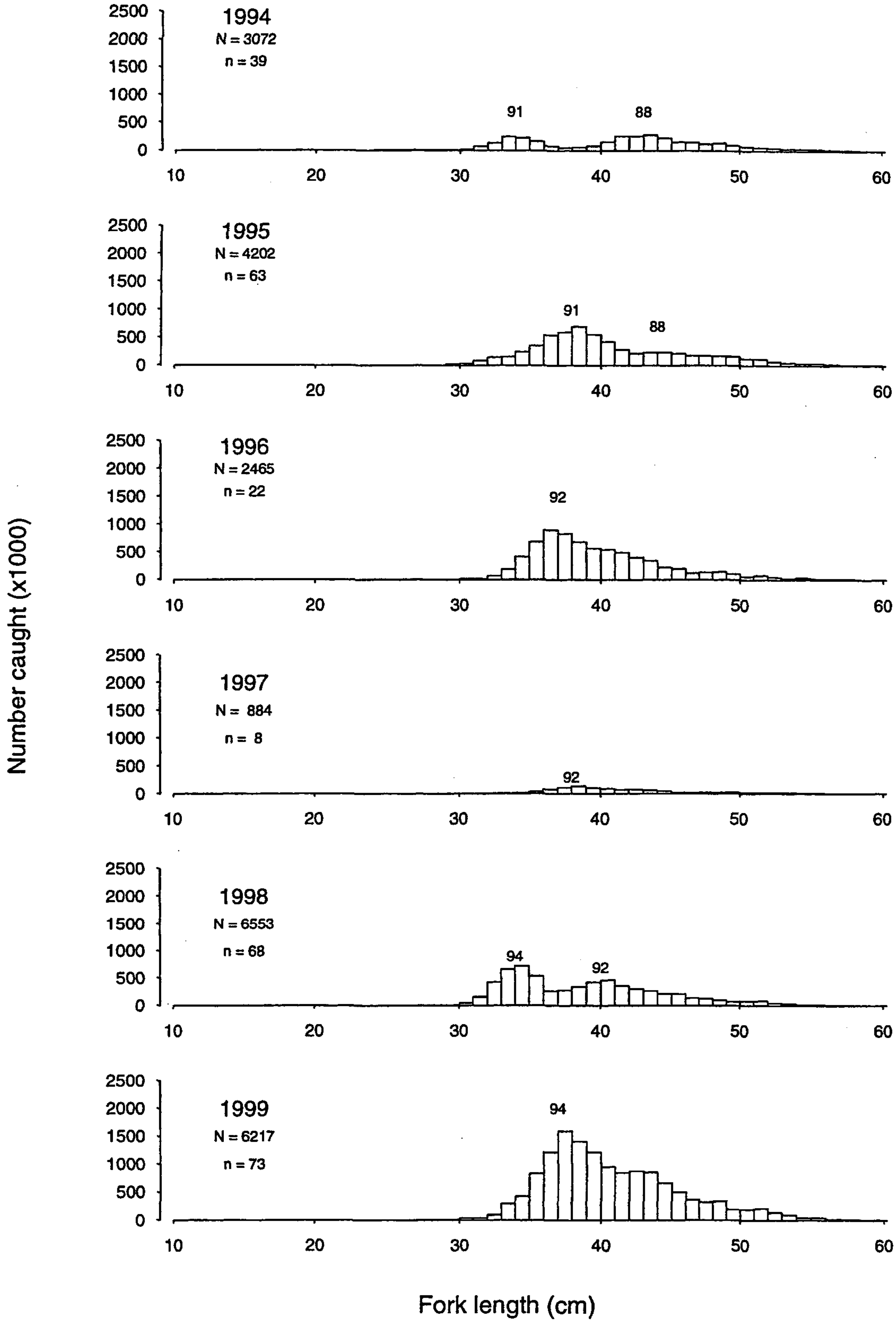


Figure 4b: Weighted length frequency distribution of females in the catch from the Bounty Platform. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

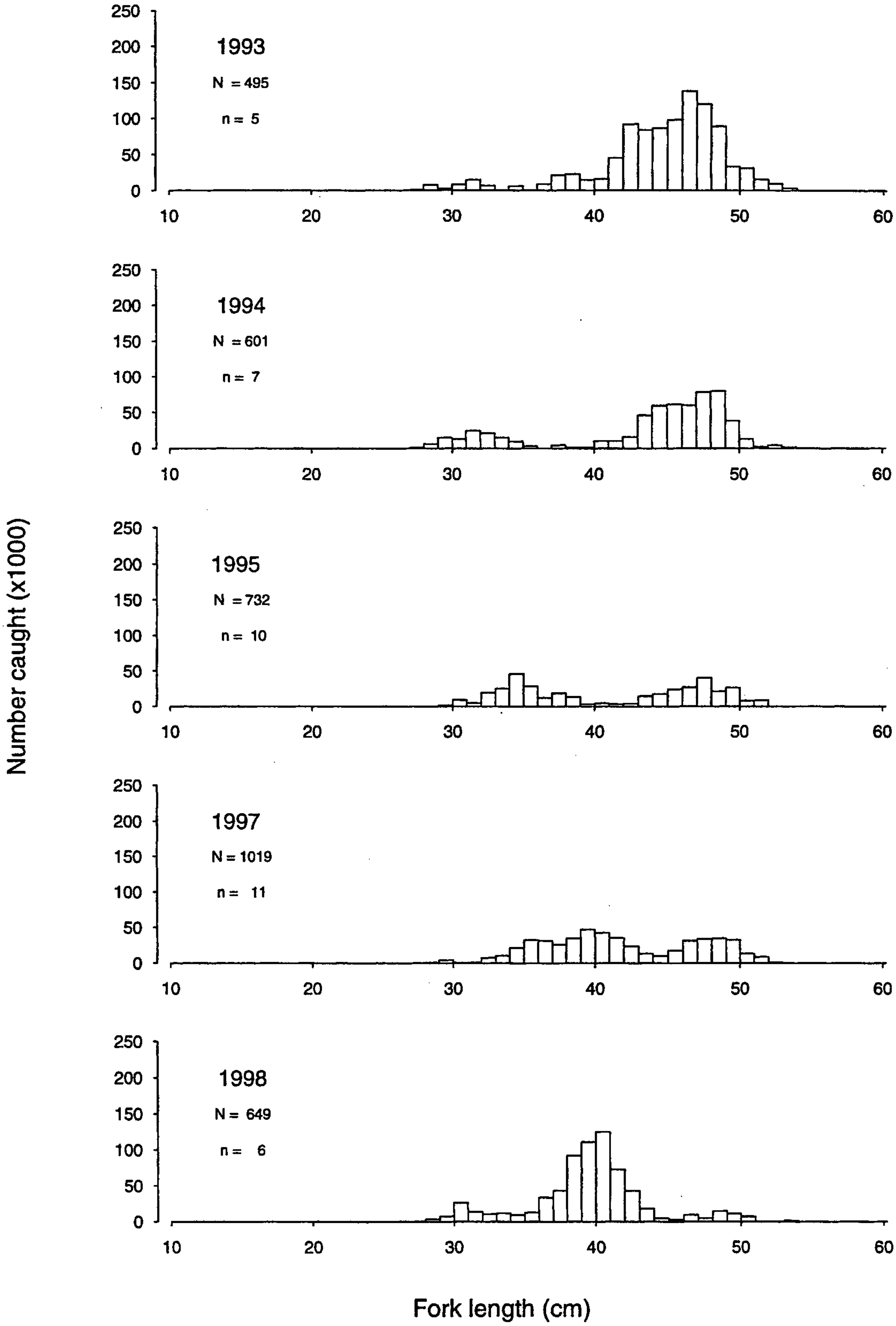


Figure 5a: Weighted length frequency distribution of males in the catch from the Auckland Islands Shelf. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

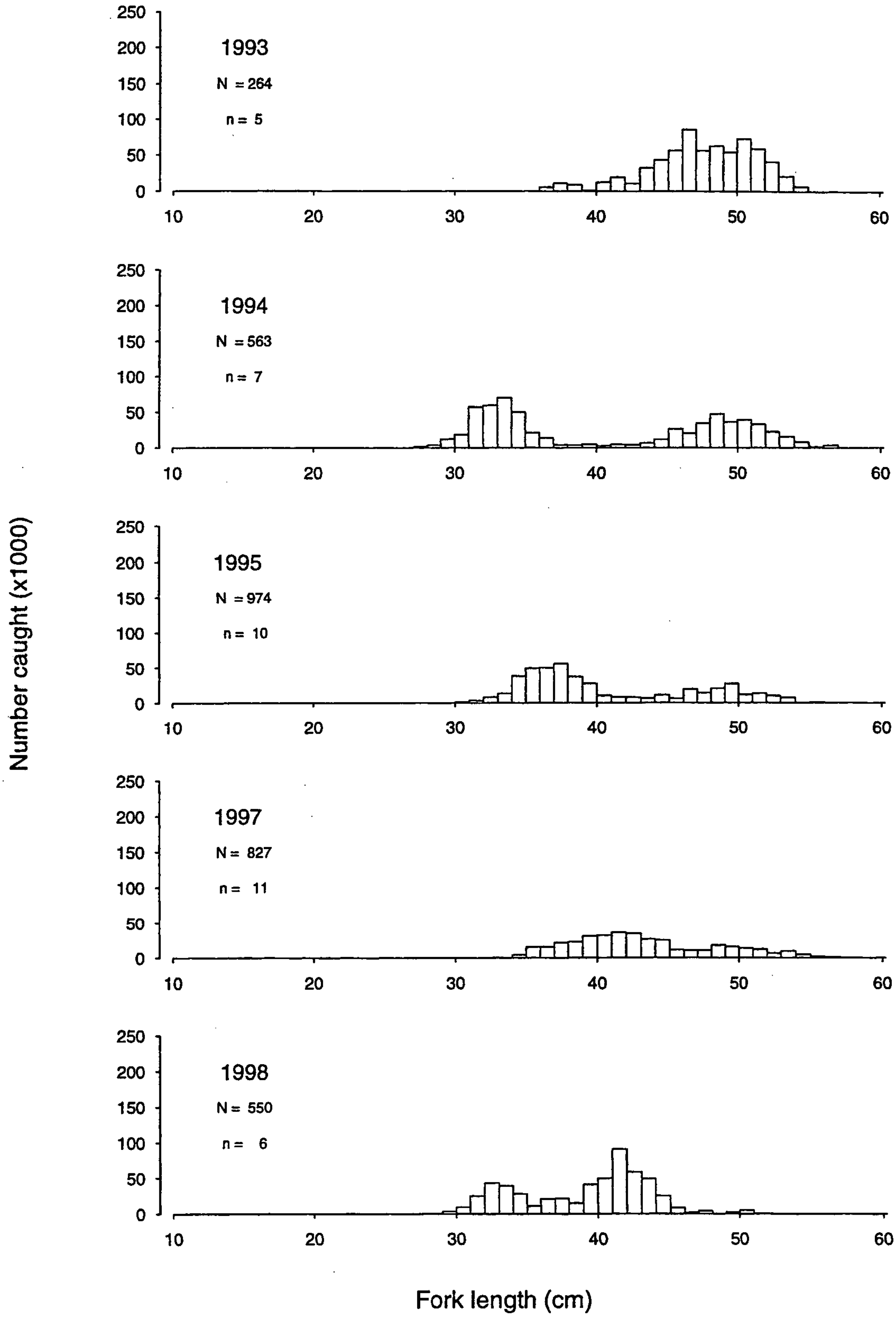


Figure 5b: Weighted length frequency distribution of females in the catch from the Auckland Islands Shelf. (N, number of fish measured; n, number of samples). Modal lengths of strong year classes determined from otolith readings are shown.

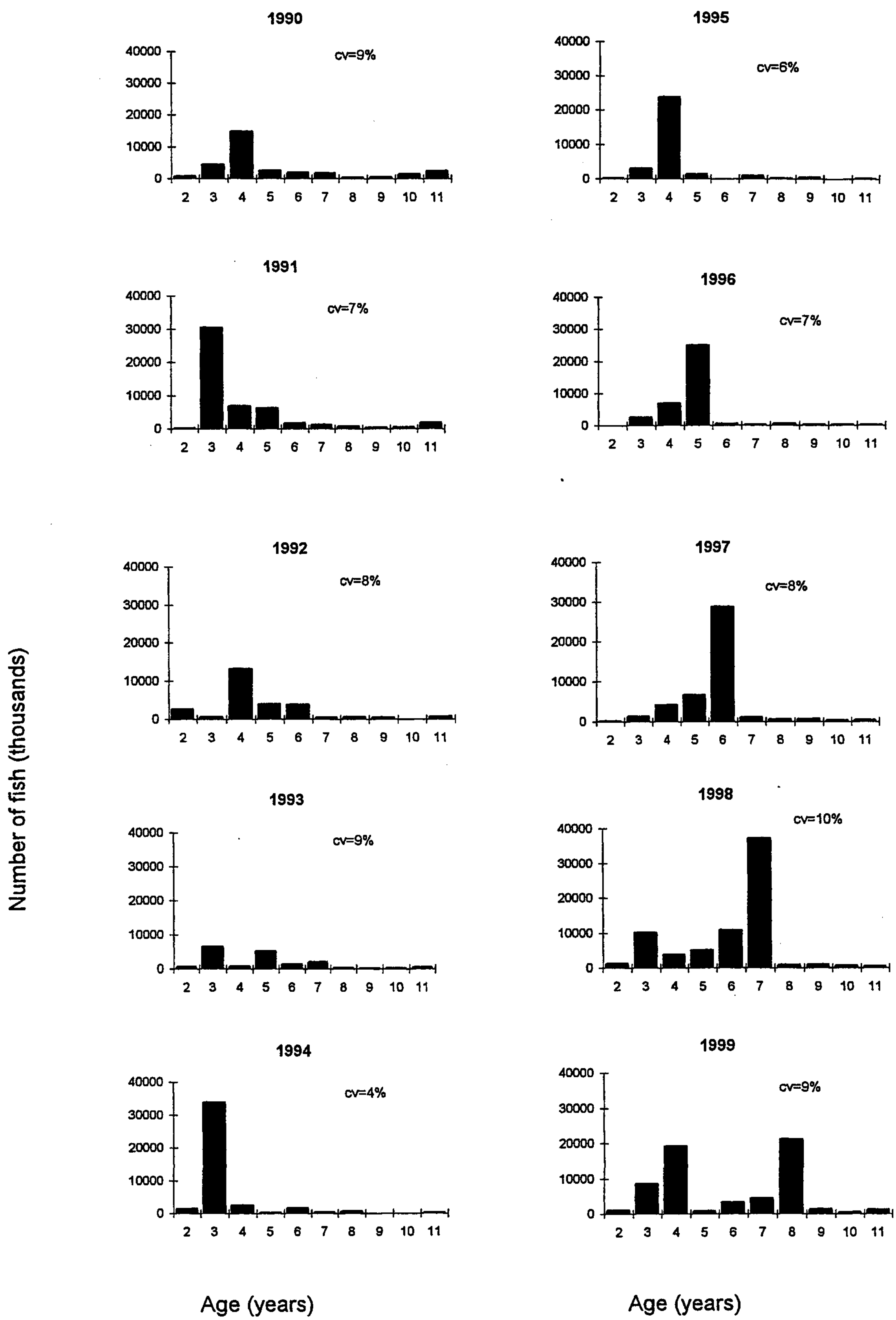


Figure 6: Age composition of Campbell catch from 1990 to 1999, with mean weighted *c.v.* (%).

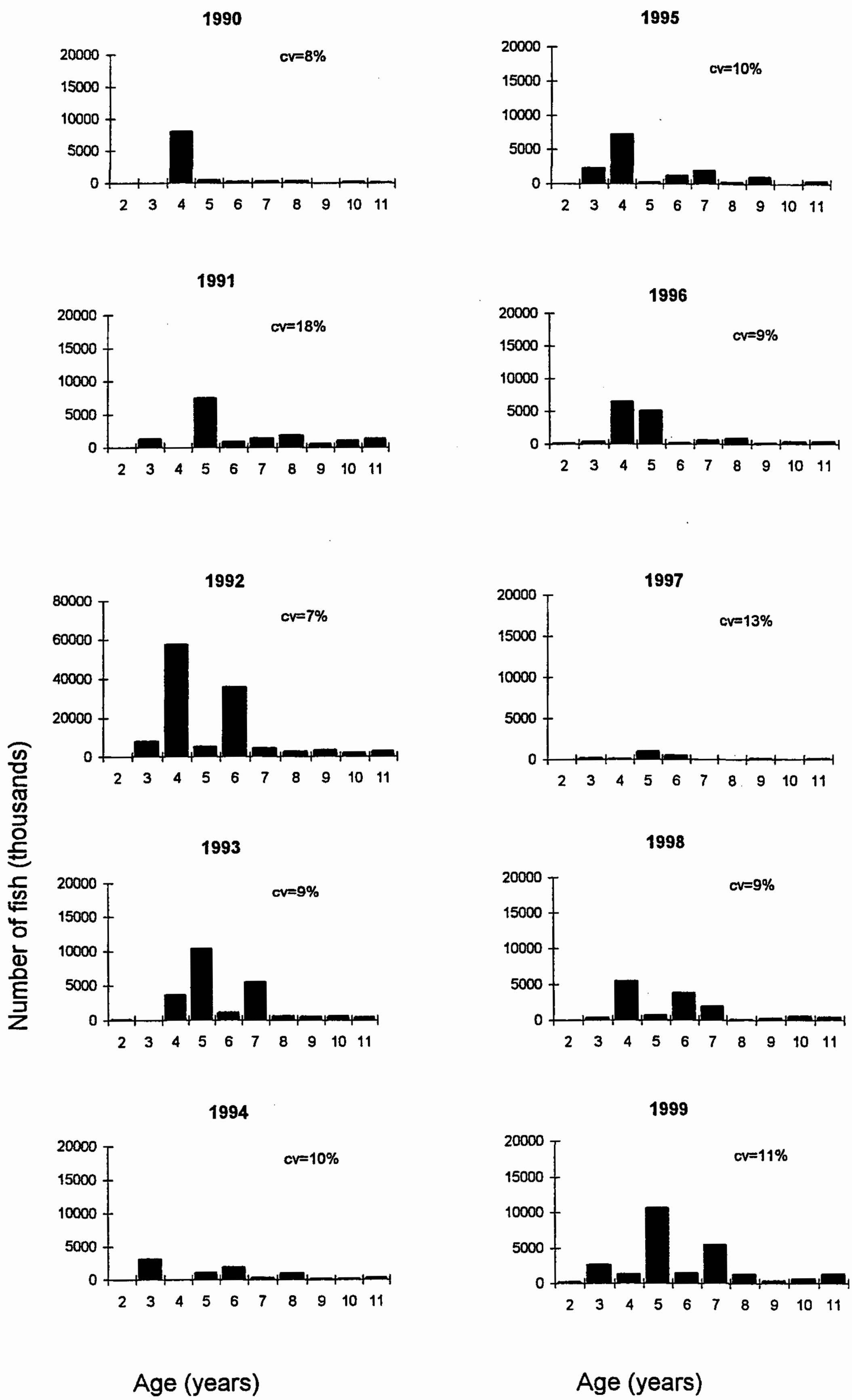


Figure 7: Age composition of the catch on the Bounty Platform from 1990 to 1999, with the mean weighted *c.v.* (%).

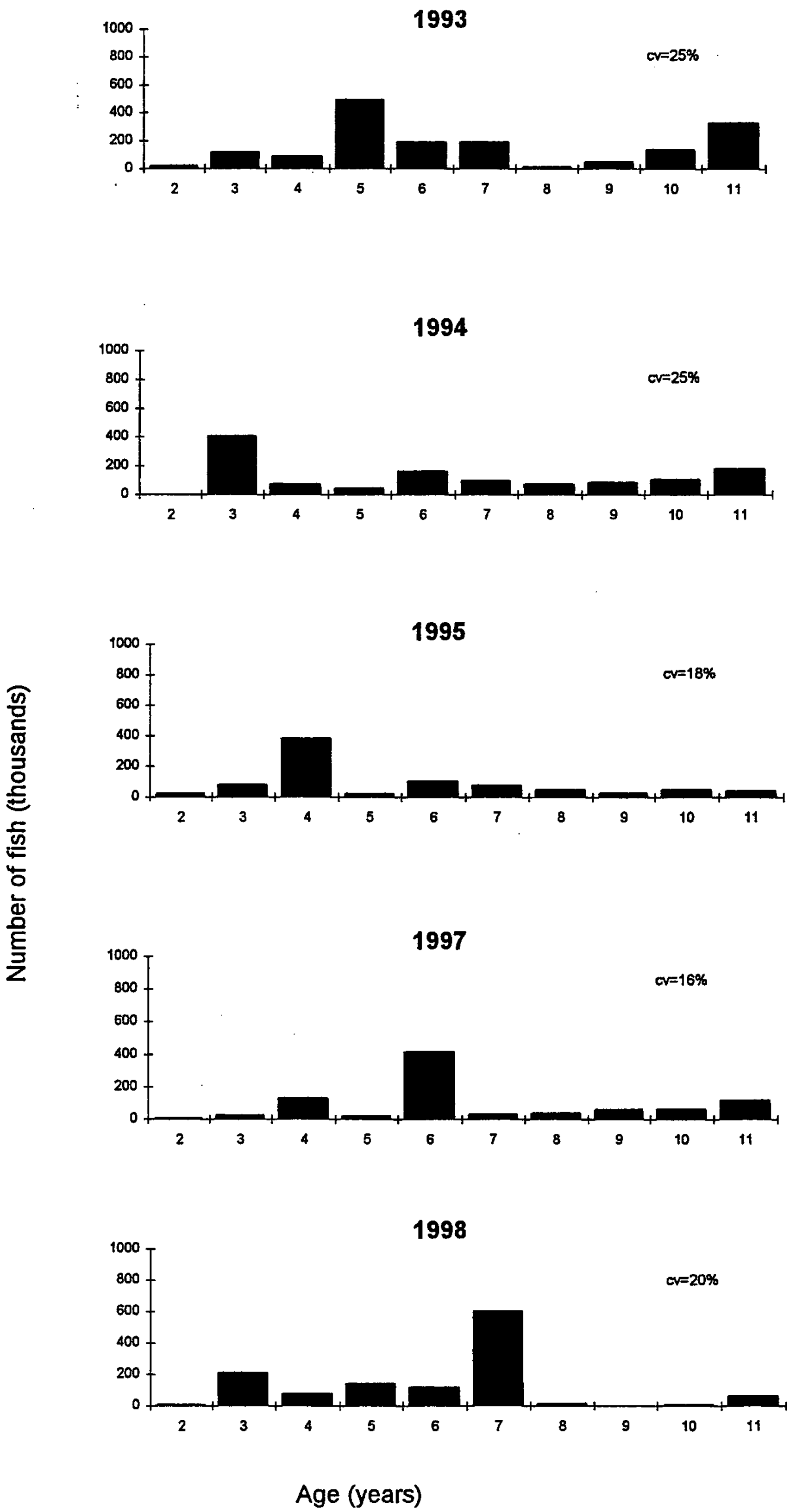


Figure 8: Age composition of the catch on the Auckland Island Shelf from 1993 to 1998, with the mean weighted *c.v.* (%).

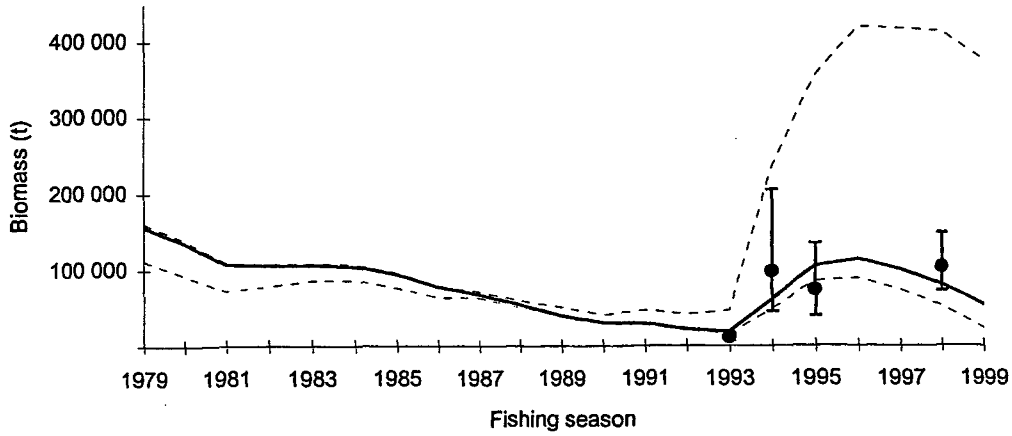


Figure 9: Mid-season spawning stock biomass trajectories and 90% confidence intervals for the Campbell Island stock showing the fit to the adult acoustic indices.

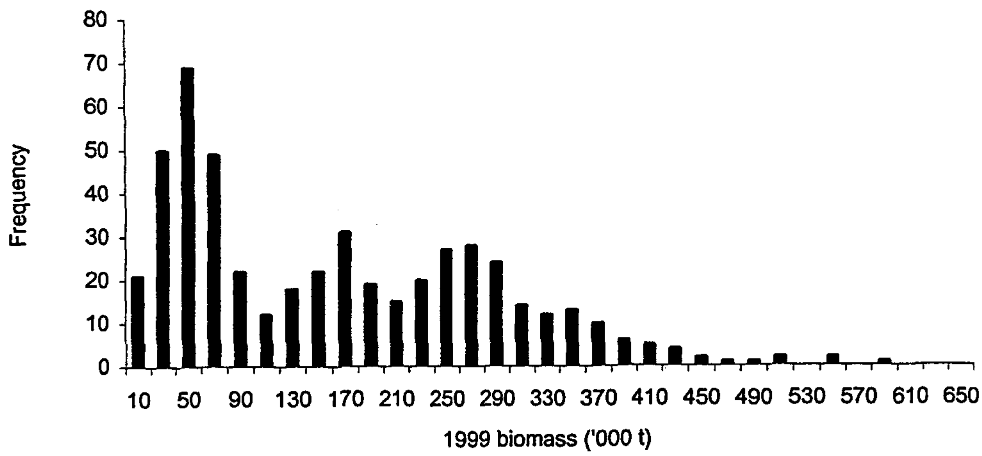


Figure 10: Distribution of mid-season 1999 spawning stock biomass on the Campbell Island from bootstrapping the acoustics and catch at age data.

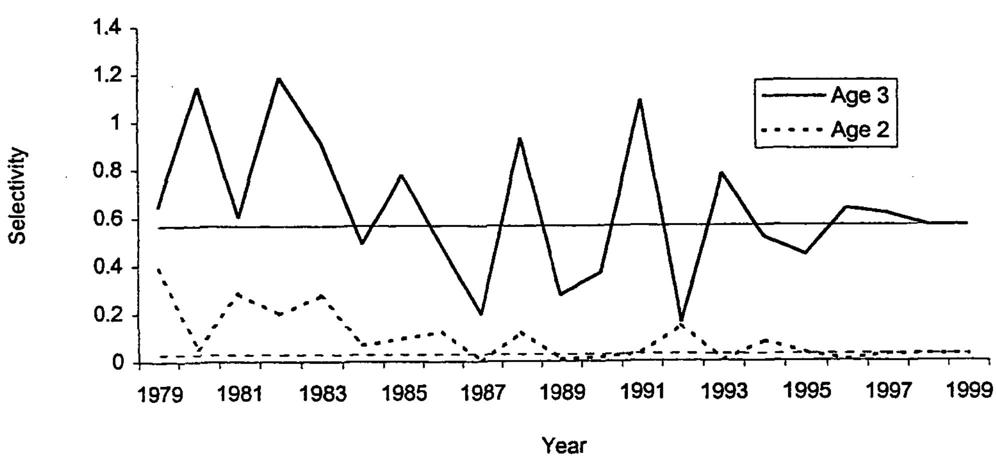
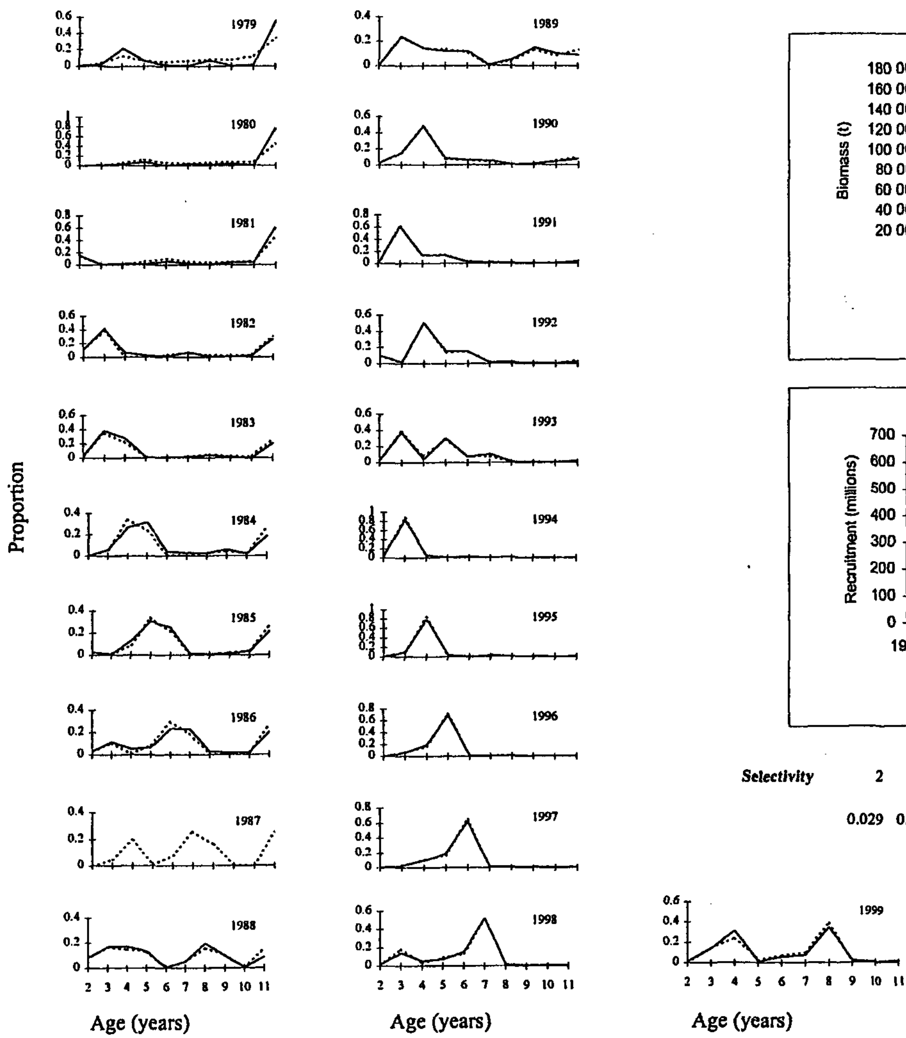
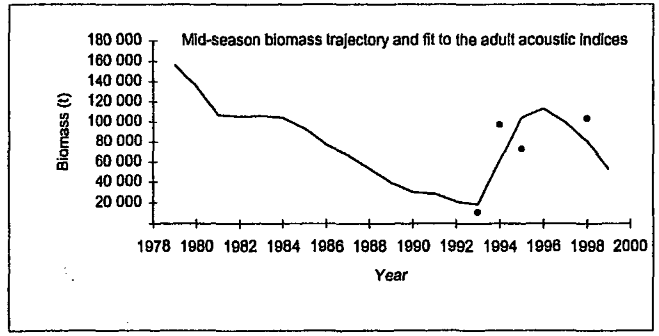
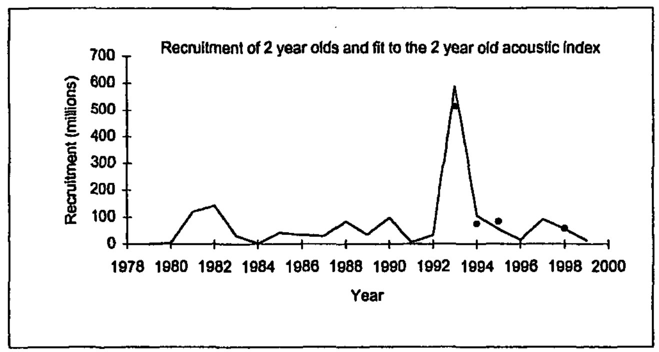


Figure 11: Estimated annual deviations in the selectivity for age 2 and 3 and their means.

Observed (solid) and expected (dashed) proportion at age for the Campbell Island stock







Selectivity	2	3	4	5	Catchability coefficients (*q*)	
	0.029	0.566	0.924	1	Adults	1.652
					2 year olds	1.44

Figure 12: Diagnostics for the Campbell Island assessment showing the fit to the proportion-at-age, adult and 2+ acoustic indices, the selectivity at age, and the catchability coefficients.

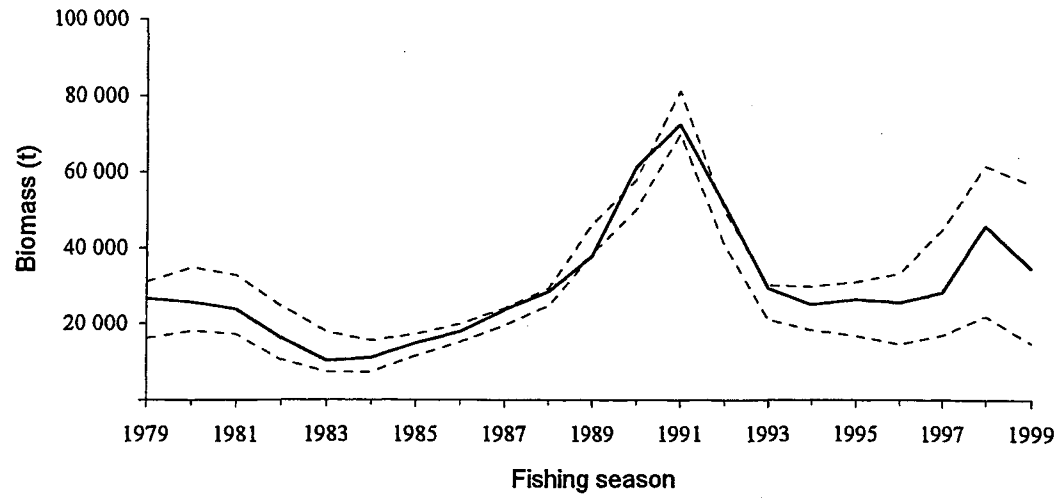


Figure 13: Mid-season spawning stock biomass trajectories and 90% confidence intervals for the Bounty Platform.

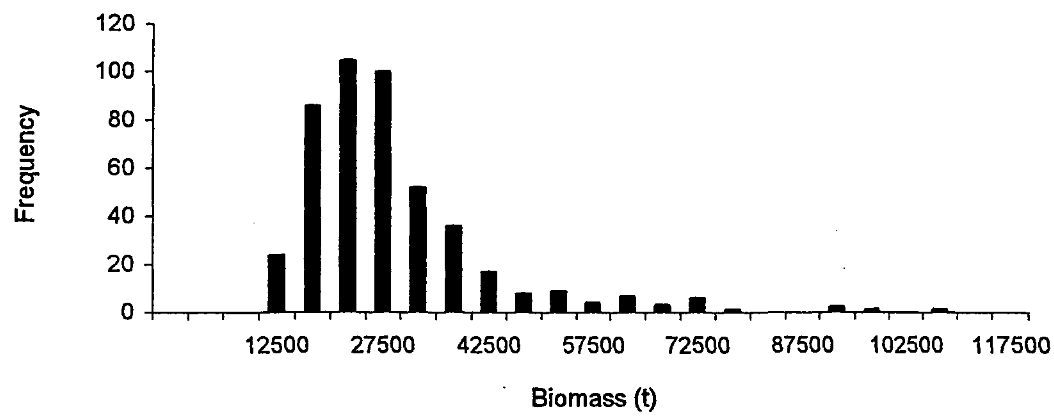


Figure 14: Distribution of mid-season 1999 spawning stock biomass on the Bounty Platform from bootstrapping the acoustics and catch at age data.

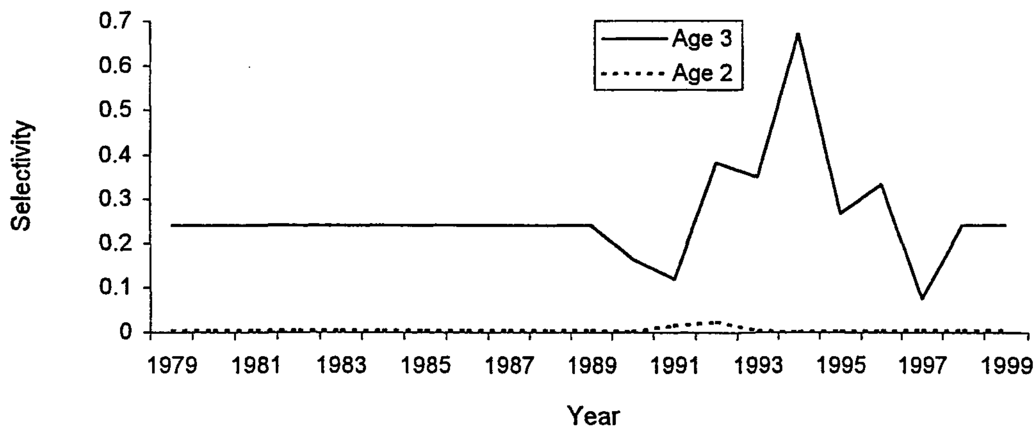
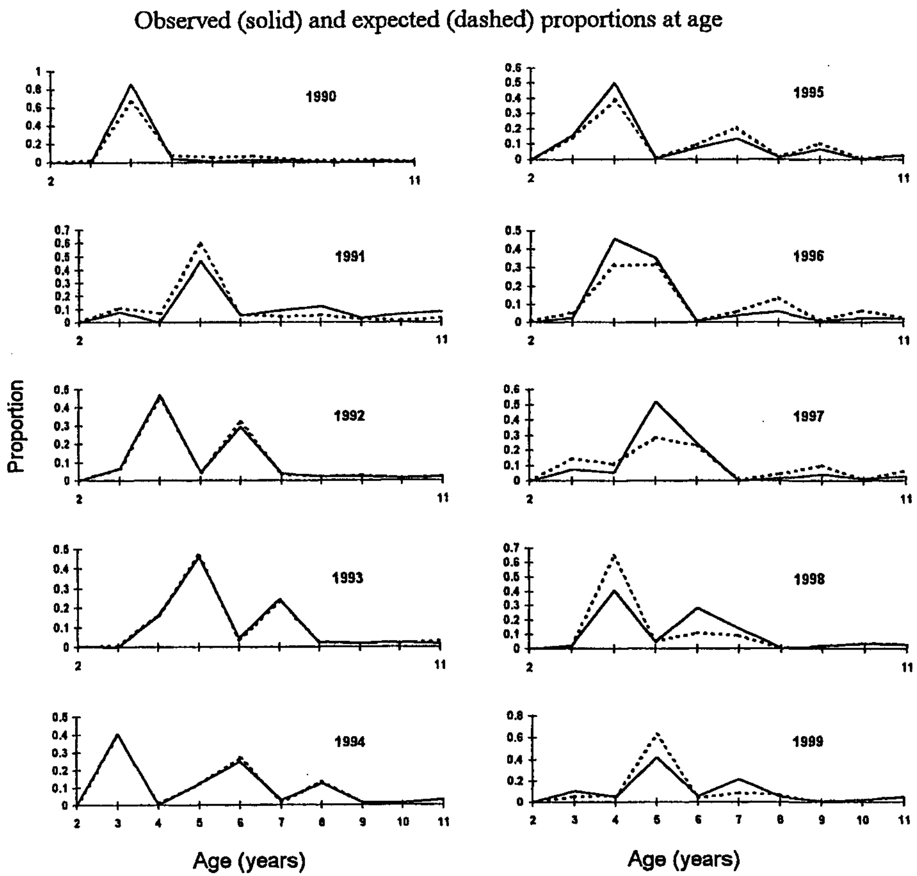
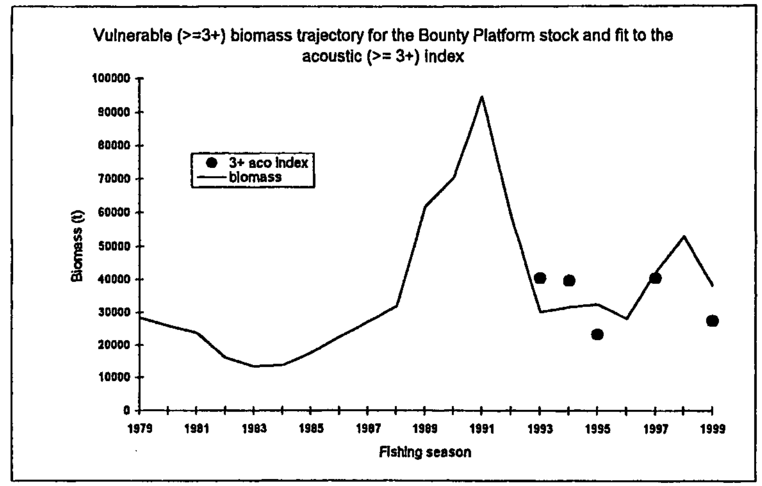
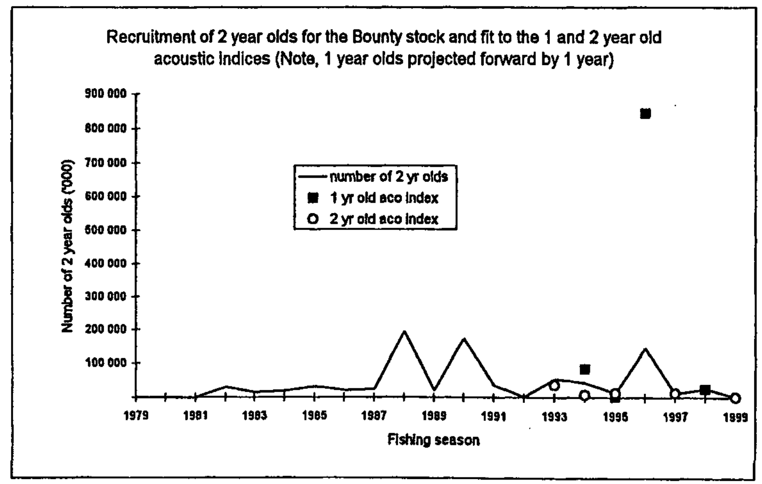


Figure 15: Estimated annual deviations in the selectivity for age 2 and 3.







Selectivity

Age	2	3	4	>=5
Selectivity	0.006	0.242	0.815	1

Catchability coefficients (q)

Adults	1.652
2 year olds	2.957
1 year olds	1.773

Figure 16: Diagnostics for the Bounty Platform assessment showing the fit to the proportion-at-age, adult, 1+ and 2+ acoustic indices; the selectivity at age, and the catchability coefficients.