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Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2002 and 2003

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EXECUTIVE SUMMARY

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This report summarises landings, catch-at-age, and biological data from New Zealand southern blue whiting fisheries in 2001. A stock assessment was carried out for the Bounty Platform stock using updated catch-at-age data and the results of an acoustic survey carried out in 2001. Biomass and yield estimates are given for the fishery. There was no new acoustic survey of the Campbell Island Rise or Pukaki Rise and so the assessments were not updated. There has been little fishing on the Auckland Island Shelf stock, and no abundance indices are available for this area.

The Bounty Platform data were analysed using the separable Sequential Population Analysis (sSPA) used in recent assessments of the SBW stocks. The model was fitted to landings, proportion-at-age data, and the pre-recruit and recruited acoustic survey indices. 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 results indicated that mid-season biomass increased to 1991 followed by a large decline from 1991 to 1993, as a result of the large catch taken in 1992. Biomass increased gradually to 1998, as the 1992 and 1994 year classes recruited into the fishery, but has since declined. The estimate of mid-season biomass in 2001 (B_{2001}) is 9000 t. The 90% confidence intervals of B_{2001} from the likelihood profile were 2800–10 800 t.

Compared to previous assessments of the Bounty stock, the results of the current assessment were relatively insensitive to the weightings used for the age and acoustic data, and to the other sensitivities examined. However, it is believed that the low biomass estimated in this assessment is probably overly pessimistic because it implies an adult acoustic q of 2.3, which is towards the upper end of its credible range (0.75–2.5). Therefore, an alternative assessment was also considered where the adult acoustic q was constrained towards the best estimate of 1.4. Under this constraint B_{2001} was estimated at about 20 000 t.

Several runs were also carried out where M was estimated in the model. In some runs the full age range was used and the model fitted back to the 1960s. Estimates of M varied considerably between model runs (i.e., a wide range of M values were possible and fitted the data equally well). It was concluded that the model was unable to reliably estimate M, probably due to the short time series of the data set.

The estimate of CAY for the Bounty Platform stock was 2000 t for 2002 and 2300 t for 2003. The 90% confidence intervals of CAY_{2002} from the likelihood profile were 700–4300 t. The CAY estimate for 2002 from the alternative assessment with q constrained at 1.4 is 5000 t. The model indicates that current biomass is at its lowest point in the time series. Recent catches have been considerably lower than the TACC and are probably sustainable. However, it is unlikely that the current TACC will allow the stock to rebuild unless there is good recruitment.

1. INTRODUCTION

1.1 Overview

Acoustic surveys and assessments of the two main southern blue whiting (SBW) stocks are carried out in alternate years. An acoustic survey of the Bounty Platform was carried out in August 2001 and the assessment for this stock was revised based on the results of that survey and on ancillary fisheries data. This report documents that stock assessment and updates length-frequency, reproductive data, and catch-at-age data for the Bounty Platform, Campbell Island Rise, and Pukaki Rise stocks. For the Bounty stock assessment, 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 stock biomass. Estimates of Current Annual Yield (CAY) are provided for the Bounty stock for 2002 and 2003.

1.2 Description of the fishery

In this paper the word fishing "season" refers to August and September, the months of intense fishing when spawning occurs (i.e., the 2001 season is part of the 2000–01 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 accurately be determined before 1978. 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 there at a low level sporadically since then. A catch limit of 32 000 t for all areas was introduced for the first time in 1993. This was increased to 58 000 t in 1996–97, lowered to 35 140 t in 1999–2000, and increased to 45 140 t for the 2000–01 fishing year (Table 1). Annual landings since 1992–93 have averaged about 25 000 t, most of which has been taken from the Campbell grounds. The fleet has comprised mainly Japanese surimi vessels, and Russian, Ukrainian, and Polish head and gut vessels. Fishing in most years has started in mid August and 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) and Dunn et al. (2001). Eight acoustic surveys of southern blue whiting spawning grounds have now been completed, and results of recent surveys were reported by Hanchet &

Grimes (2000, 2001, Hanchet et al. 2002). A re-analysis and decomposition of earlier acoustic survey results was carried out by Hanchet et al. (2000b), and Hanchet et al. (2000a) examined the diel variation in southern blue whiting density estimates. Results of recent acoustic target strength work were summarised by McClatchie et al. (1998) and Dunford (2001a, 2001b), and of target identification by McClatchie et al. (2000).

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 1998b, 2000b, 2002).

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, and 2, from MFish project SBW2001/01.

1. To determine catch at age from the commercial fisheries at Campbell Island, Auckland Island, Bounty Platform, and Pukaki Rise for 2000/01 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).

2. To update the stock assessments of the Bounty Platform stocks, including estimating biomass and sustainable yields.

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 (Table 1). The area sub-limits were revised for the 1995–96 fishing year, and the total catch limit increased to 58 800 t in 1996–97 for 3 years (Table 1). Before 1997–98 there was no separate catch limit for Auckland Islands, but in 1997–98 the industry agreed to a 1640 t limit for the Auckland Islands fishery.

The southern stocks of southern blue whiting were introduced to the Quota Management System on 1 November 1999 with the following TACCs: Auckland Islands (SBW 6A) 1640 t, Bounty Platform (SBW 6B) 15 400 t, Campbell Islands (SBW 6I) 35 460 t, and Pukaki Rise (SBW 6R) 5500 t. A nominal TACC of 8 t (SBW 1) was set for the rest of the EEZ. At the same time, the fishing year was also changed to 1 April to 31 March to reflect the timing of the main fishing season. TACC changes since 2000–01 are shown in Table 1. The total catch limit was increased to 45 140 t for the 2000–01 fishing year. About 5 t was reported from SBW 1 in 2000–01, and 1 t in 2001–02.

2.1.2 Landings

Estimates of the annual landings of SBW by fishing year are given in Table 1. The reported landings for the 2001 season from the Quota Monitoring Reports was 32 500 t. The TAC was undercaught on Bounty and Pukaki, but reached on Campbell.

2.1.3 The 2001 season

The location of trawls made during the 2001 season (mid August to mid October) is shown in Figure 1. Fourteen vessels, mainly from Japan and Ukraine, fished for southern blue whiting during the 2001 season (Table 2). The first vessels arrived on the Bounty Platform on 26 August. Vessels found SBW to the south of the Bounty Platform and gradually moved east over the next few days. However, vessels reported the schools were small and spent a considerable amount of time searching the entire area. Four vessels fished there during the short 7 day season and took 2300 t. Spawning occurred slightly later than usual on the Bounty Platform, lasting from 27 to 30 August (Section 2.2.3).

Three vessels fished the Pukaki Rise between 2 and 28 September, making only six trawls. Catches were generally low, although one trawl yielded over 90 t. Spawning probably took place shortly after 2 September, and the second spawning was underway on 28 September. The total catch on the Pukaki Rise was only 230 t, of which 224 t was taken during the main season. Two vessels made four trawls on the Auckland Islands Shelf this season, but caught very little.

One vessel started fishing the Campbell Island Rise on 17 August and made reasonable catches through until early September. Most of the other vessels moved to the Campbell grounds in early September and fished for most of September. Spawning was again early this year, with fish on the northern ground spawning from 4 to 10 September, and fish on the southern ground spawning between 16 and 21 September. Catches peaked at the two spawning events but dropped in between them and after spawning had finished. By mid October, spawning was over and most vessels had left the area. A total of 30 000 t was taken during the 2001 season by 14 vessels.

Over the past two April–March fishing years there has been a small amount of SBW taken outside the main spawning season. Some has been taken as a bycatch of the hoki fishery, and the remainder has been targeted. In the 2000–01 fishing year about 350 t were taken between November and March, mainly from the Pukaki stock. In the 2001–02 fishing year, a vessel continued targeting SBW after the spawning season, but the amount caught and areas fished are not yet available.

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 (2000a). This analysis has not been updated because there are concerns that the CPUE series may not be monitoring abundance accurately. This is partly 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 use of CPUE to monitor the SBW fisheries will be evaluated later this year to meet the requirements of Objective 3 in project SBW2001/01.

2.2 Other information

2.2.1 Size and age composition of the commercial catch

Length-frequency data were collected by scientific observers from 41% of all tows in the commercial fishery during 2001 (Table 3). The length-frequency data were scaled up to the total catch for each fishing ground following Hanchet & Ingerson (1995). Otoliths collected from the Campbell Island and Bounty Platform fishing grounds during the 2001 season were read and used to derive age-length keys. 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 length-frequency data for the Campbell stock are shown in Figure 2, and the catch-at-age data in Figure 3. The catch was numerically dominated by 3 year old fish (the 1998 year class). They formed the mode of smaller fish in the size distribution of both males and females in Figure 2. The broader mode to the right comprised mainly the 1991, 1995, and 1996 year classes.

The 2001 catch on the Bounty Platform ranged from 30 to 50 cm, with the main mode in both sexes at about 40 cm (see Figure 2). Ageing showed that the catch comprised mainly the 1994 and 1997 year classes (Figure 4). However, neither year class dominates the catch nor appears to be particularly strong.

The target c.v. of 20% was achieved for both areas in 2001.

Only two trawls were observed on the Pukaki Rise – one at the beginning and one at the end of the season. The size distribution of the two trawls was quite different. Because of the small sample size and difference between the size distributions, the data have not been scaled up to the commercial catch. No observer data were collected in 2001 from the Auckland Islands Shelf.

2.2.2 Timing of spawning

The timing of spawning on the Bounty Platform in 2001 was difficult to determine precisely. Gonads were examined sporadically during the SBW acoustic survey on *Tangaroa* from 18 August to 6 September. Few running ripe fish were caught, but it was clear that by 3 September most fish had already spawned. Only two commercial vessels were observed this year, both from 27 August to 1 September, but the results from the two vessels were slightly different. One vessel caught running ripe fish on 27 and 29 August, whereas the second vessel caught running ripe fish only on 30 August. Overall, it appears that fish were probably spawning from about 27 to 30 August (Table 3). This is similar to 2000, but about a week earlier than in 1999. Spawning took place mainly on the southeast and east of the Bounty Platform.

Spawning started very early this year on the Campbell Island Rise. The first fish were sampled on the northern ground on 2 September, and they had started spawning by 4 September. The first spawning was finished by 10 September. Vessels then moved south and found fish spawning on the southern ground from 16 to 23 September. This appeared to be a separate aggregation to that on the northern ground because the size distribution was quite different. Small numbers of spawning fish (1–10%) were recorded in the southern area from 28 September to 3 October. By mid October most fish were spent.

Fish were sampled on the Pukaki Rise on 2 and 28 September. On 2 September over 50% of the fish were ripe, suggesting that spawning was imminent. On the second occasion over 50% of the fish were spawning, suggesting that this was the second spawning event.

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. There have been no genetic studies, 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

3.2.1 Bounty Platform

A survey of the Bounty Platform was carried out from 18 August to 3 September 2001 (Hanchet et al. 2002). Three acoustic snapshots of the area were completed during this time and adult biomass was quite variable between the three snapshots (Table 4). The first snapshot had the highest biomass estimate, principally due to one transect which hit a high-density mark, but it also had the highest c.v. of 59%. The second estimate was low, with a moderate c.v. of 37%. The estimate for the third snapshot was about the average of the first two snapshots and had the lowest c.v. of 30%. Spawning started midway through the second snapshot, and continued through the third snapshot. It was clear that the fish were already on the grounds at the start of the survey, and were still there at the end of the survey, therefore estimates from the three snapshots were averaged equalling about 24 000 t (c.v. = 35%). The biomass estimates were then decomposed into biomass at age for use in the modelling (Table 5).

3.2.2 Target strength-fish length relationship

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 2 dB 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. Theoretical modelling studies suggest a steeper slope than the Northern Hemisphere studies (Dunford 2001a, 2001b). 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.

3.2.3 Bounds on the acoustic *q* for Bounty Platform

The acoustic q is the estimated model parameter that relates the estimated model biomass to the expected value of the acoustic index (Cordue 1996). In some stock assessments the maximum likelihood estimate of q can be very high or low, leading to unreasonably low or high estimates of biomass respectively for a particular stock. In this year's assessment of the Pukaki Rise some members of the Middle Depths Working Group considered that the estimate of the adult acoustic q was too high, so bounds on acoustic q were obtained outside the model to determine the 'credible' range for q in the Pukaki Rise assessment.

Bounds for the adult (4+) acoustic q were obtained using the approach of Cordue (1996) and Hanchet (2002). Cordue (1996) took into account uncertainty over various transient population model parameters (to deal with turnover), mean target strength, acoustic system calibration, target identification correction, shadow or dead zone correction, and areal availability. There is no evidence for turnover in the SBW population during the spawning season, so following Hanchet (2002) the transient population parameters are not considered here. The other parameters are considered below. In addition to obtaining the bounds, an attempt at deriving a 'best estimate' for each factor has also been made. Because all transects for biomass purposes are carried out only at night, the bounds for some parameters are different from those of the Pukaki Rise.

Mean target strength

The abundance indices in acoustic surveys have been turned into absolute estimates using the target strength-fish length relationship used for blue whiting in the Northern Hemisphere by Monstad et al. (1992). *In situ* target strength data collected during the 1998 and 2000 southern blue whiting acoustic surveys agree with the recent Northern Hemisphere relationship (Dunford 2001a, 2001b). Preliminary results from recent swimbladder modelling studies suggest a higher target strength, and possibly also steeper slope, than the Northern Hemisphere studies.

If we assume that the recent target strength Northern Hemisphere estimates are correct then the best estimate would be 1.5. Using an "uncertainty" factor of 1.25 we obtained bounds of [1.2, 1.85].

Target identification

Target identification on Bounty Platform is typically less problematic than on the Campbell and Pukaki grounds. Because all transects are done at night, there is little mixing with benthic species, and the small mesopelagic species are dispersed and in low densities. Trawls for mark identification using *Tangaroa* have been carried out mainly during the day and so are of limited value for quantifying species composition. Observer data from the SBW fishery were examined for species composition, but as in the other areas, SBW usually makes up about 99% of the catch. The *Tangaroa* data were therefore analysed to determine which species might be important.

A total of 82 bottom and midwater trawls have been made on the Bounty grounds during the six *Tangaroa* surveys. The percentage composition of SBW (calculated as the total weight of SBW divided by the total weight of all species) has varied from 63 to 99% between surveys and has averaged 66%. The main bycatch species were ghost shark (12%), ling (8%), and oblique banded rattail (7%), but only oblique banded rattail is likely to provide significant backscatter at night in the water column.

It is likely that the backscatter categorised as adult SBW does include other species, in particular smooth rattail, and that the biomass will be slightly overestimated. However, there may also be situations where small numbers of SBW occur in light marks, which have not been categorised as SBW. We therefore consider that the best estimate is 1.05, and using a factor of 1.2, obtained bounds of [0.85, 1.25].

Vertical availability

Because transects are carried out at night the adult fish are all off the bottom and vertical availability is of minor importance. We have assumed a best estimate of 0.95, and bounds of [0.9, 1.0].

Areal availability

It is believed that most of the adult fish are within the survey area at the time of spawning. However, a small proportion may be deeper or shallower, or not spawning in any particular year, leading to a slight underestimate of biomass. We have used arbitrary bounds of [0.90, 1.00], and a best estimate of 0.95.

Acoustic system calibration

Following Cordue (1996) we have assumed the calibrations are reasonably reliable and have used bounds within 10% [0.9, 1.1], and a best estimate of 1.0.

Overall acoustic q

Multiplying all the factors together gives a best estimate of 1.4 and bounds on the acoustic q of [0.75, 2.5].

3.3 Biomass estimates for the Bounty Platform

3.3.1 Input data and weights

The data were analysed using the separable Sequential Population Analysis (sSPA) used in recent assessments of the SBW stocks (Hanchet 2000b, 2002). The model was fitted to proportion-at-age data, and the acoustic indices given in Table 5. 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).

Adult (4+) and age 3 acoustic indices for Bounty Platform were given c.v.s of 0.5 for each survey. A c.v. of 0.7 was used for the age 2 index. The age 1 index was not fitted because in previous years models have been unable to fit the high 1995 index (Hanchet 2000b). It is possible that the high index in that year was partly due to large numbers of mesopelagic fish on which the juvenile SBW were feeding. Although the observed c.v.s suggested sample sizes of over 100, these are probably too high given factors such as ageing error and sampling bias. Also, because of the large number of data points, a value of more than 100 gave too much weight to the age data relative to the acoustic data. For the base case a weight of 30 (equivalent to a c.v. of about 0.4) was given to the age data.

Fishing selectivity was estimated for each age from age 2 to 4. The sSPA model was used to estimate the numbers at age in the initial population in 1990 and subsequent recruitment. As a sensitivity analysis, an equilibrium age structure in 1979 was assumed and subsequent recruitment was estimated. A number of other sensitivity tests were run to evaluate the sensitivity of the assessment to M, and to the relative weightings or c.v.s used for the age and acoustic survey data. Details of the input parameters, and sensitivity runs are given in Table 6.

3.3.2 Estimation of uncertainty

Parametric bootstrapping was used to estimate uncertainty in the biomass estimates following Hanchet (2002). 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 acoustics data was included by resampling from the MLE estimate with an acoustic c.v. calculated empirically from the model fits. For each of the 500 bootstrap runs, data were randomly selected from each distribution. Bias corrected confidence intervals were obtained by "inverting" the bootstrap distribution following Gilbert et al. (2000).

The Middle Depths Working Group (WG) considered that the confidence intervals obtained from the bootstrapping were too tight and that a more credible measure of the uncertainty in the assessment was available from the likelihood profile. The likelihood profile for the distribution of mid-season biomass in 2001 (B_{2001}) was therefore also calculated and presented.

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 (2.17 kg per recruit) and the arithmetic mean of the recruitment of 2 year olds from the period 1990 to 1998 calculated from the sSPA.

3.4 Results and discussion

The biomass trajectory is shown in Figure 5, and the biomass estimates are given in Table 7. Mid-season biomass showed a large decline from 1991 to 1993, as a result of the large catch taken in 1992. Biomass increased gradually to 1998, as the 1992 and 1994 year classes recruited into the fishery, but has since declined. The estimate of B_{2001} is 9000 t.

The modelled biomass fits the adult (4+) acoustic indices very well (Figure 5). Fits to the 2 and 3 year old acoustic indices are less good, particularly for the larger observations, but there appear to be no strong patterns. The model also fits the age data very well (Figures 5, 6). The largest residuals occur in years with few observations, and there are no strong undesirable patterns in the data.

The confidence intervals from the bootstrapping are given in Figure 7 and Table 7. The 90% confidence intervals of B_{2001} from the bootstrapping were 2800 to 10 800 t. The likelihood profile for the distribution of B_{2001} is given in Figure 8. The 90% confidence intervals of B_{2001} from the likelihood profile were 2400 to 21 600 t.

The results of the sensitivity analysis for the Bounty stock are shown in Table 8. Compared to previous assessments of the Bounty stock, the results of the current assessment were relatively insensitive to the relative weightings used for the age and acoustic data, and to the other sensitivities examined. However, the estimate of the adult (4+) acoustic q for the base case assessment was 2.3 and q ranged from 2.0 to 2.5 in the sensitivity tests. In effect, this meant that the acoustic survey was overestimating the biomass in the survey area by a factor of up to 2.5. An independent evaluation of the bounds on the acoustic q suggested a range of 0.75–2.5, with a best estimate of 1.4 (Section 3.2.3). The q from the base case is towards the upper bound of q. When the model was run by fixing the acoustic q at 1.4 B_0 increased to 122 000 t and B_{2001} increased to 22 000 t.

The WG also discussed possible approaches to improving the estimation of M. The current estimate of M is based on the maximum observed age (Hanchet 1991). However, the estimates from both this method and other methods such as Chapman Robson can be biased when there is high recruitment variability (Dunn et al. 1999). The WG agreed that in principal it is better to estimate M within the model, because the model can take into account factors such as variation in recruitment. Therefore several runs were carried out where M was estimated in the model. (In some runs the full age range was used and the model fitted back to the 1960s.) Estimates of M varied considerably between model runs (i.e., a wide range of M values were possible and fitted the data equally well). The model was unable to reliably estimate M, probably due to the short time series of the data set. The much longer time series of age data for the Campbell stock (back to 1979) may provide a better data set for the estimation of M.

3.5 Yield estimates

3.5.1 Estimation of Current Annual Yield (CAY)

Estimates of CAY and their 90% confidence intervals were calculated for the Bounty Platform stock for 2002 and 2003.

The simulation method of Francis (1992) was used to determine u_{CAY}, the ratio of catch to preseason 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 $8.6\%B_0$. Note that the model of Francis (1992) does not use the selectivities or maturities estimated from within the model. Because of this, the estimates for the reference biomasses will not correspond exactly to the equivalent estimates in the assessment. For instance, B_0 will be defined differently by each model.

CAY was estimated by multiplying u_{CAY} by pre-season biomass in 2002. Pre-season biomass in 2002 was calculated by projecting forward the 2001 beginning of year numbers at age. The number of 2 year olds in 2002 and 2003 was assumed to be equal to the arithmetic mean of the recruitment of 2 year olds over the period 1990 to 1998. The numbers at age were projected forward to 2003 assuming the 2002 catch equalled CAY_{2002}. The estimate of CAY was 2000 t for 2002 and 2300 t for 2003. The 90% confidence intervals of CAY_{2002} from the likelihood profile were 700–4300 t.

Estimates of CAY_{2002} from the sensitivity runs ranged from 1700 to 5000 t (Table 8).

4. MANAGEMENT IMPLICATIONS

The results of the base case assessment suggest that the current biomass could be very low. However, it is believed that the low biomass estimated in this assessment is probably overly pessimistic because it implies an adult acoustic q of 2.3, which is towards the upper end of its possible range (0.75–2.5). Therefore, an alternative assessment was also considered where the adult acoustic q was constrained towards the best estimate of 1.4. Under this constraint B_{2001} increased to about 20 000 t. The CAY estimate for 2002 from the base case assessment is 2000 t (range 700–4300 t), and for the alternative assessment is 5000 t.

The model indicates that current biomass is at its lowest point in the time series. Recent catches have been considerably lower than the TACC and are probably sustainable. However, it is unlikely that the current TACC will allow the stock to rebuild unless there is good recruitment.

5. ACKNOWLEDGMENTS

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Table 1: Estimated catches (t) of southern blue whiting by area for the period 1978 to 2001–02 from vessel logbooks and QMRs.– no catch limit in place. Estimates for 2001–02 are preliminary. *, before 1997-98 there was no separate catch limit for Auckland Islands.

Fishing yr	Bounty Platform		Campbell Island Rise		Pukaki Rise		Auckland Island		Total	
	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit*	Catch	Limit
1978*f*	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	–	22 367	–
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	6 000	1 143	–	27 708	32 000
1993–94+	3 877	15 000	11 668	11 000	2 306	6 000	709	–	18 560	32 000
1994–95+	6 386	15 000	9 492	11 000	1 158	6 000	441	–	17 477	32 000
1995–96+	6 508	8 000	14 959	21 000	772	3 000	40	–	22 279	32 000
1996–97+	1 761	20 200	15 685	30 100	1 806	7 700	895	–	20 147	58 000
1997–98+	5 647	15 400	24 273	34 900	1 245	5 500	0	1 640	31 165	58 000
1998–00†	8 741	15 400	30 386	35 460	1 049	5 500	750	1 640	40 926	58 000
2000-01#	3 997	8 000	18 055	20 000	2 864	5 500	37	1 640	24 963	35 140‡
2001–02#	2 261	8 000	29 999	30 000	230	5 500	10	1 640	32 500	45 140‡

f 1 April-30 September
\+ 1 October-30 September
† 1 October 1998-31 March 2000
\# 1 April -31 March
‡ SBW 1 (all EEZ areas outside QMA6) had a TACC of 8 t, and a reported catch of 1 t in 2001–02

Table 2: Number of vessels, tows, and catch (t) for observed and all vessels for each area for the 2001 season. #, tows for which LF data were collected.

Area	Number of vessels		Number of tows		Total catch	Dates
	observed	total	#observed	total	(t)	
Bounty	2	4	12	25	2 261	26 Aug – 1 Sep
Pukaki	2	3	2	6	230	2 Sep –28 Sep
Auckland	0	2	0	4	10	7 Sep – 6 Oct
Campbell	11	14	336	634	29 999	17 Aug – 15 Oct

Table 3: Dates of sampling and changes in SBW gonad condition in 2001 on Bounty, north and south Campbell and Pukaki, 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 Auckland Islands Shelf.

Gonad stage	Bounty	Campbell		Pukaki
		North (< 52° 30')	South (> 52° 30')	
1st sample	18/8	17/8	14/9	2/9
>10% ripe	27/8	3/9	15/9	2/9
>10% running ripe	27/8	4/9	16/9	–
Main spawning	27–30/8	4–10/9	16–21/9	–
>10% spent	1/9	8/9	16/9	–
>10% reverted	1/9	8/9	–	–
>50% spent	–	2/10	4/10	–
2nd spawning	–	?	28/9–29/10	28/9
Last sample	6/9	19/10	22/10	28/9
% spent	27	70	99	30
% reverted	73	6	1	2

Table 4: Estimates of biomass (t) and c.v. by snapshot for immature, sub-adult, and adult fish categories from the 2001 acoustic survey of Bounty Platform (from Hanchet & Grimes in press).

Snapshot	Immature		Subadult		Adult	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1	6 023	55	2 298	24	41 373	59
2	3 735	96	2 304	13	9 698	37
3	5 379	60	1 327	28	21 671	30
Mean	5 046	28	1 976	11	24 247	35

Table 5: Estimates of biomass (t) for age 1, 2, 3 and 4+ fish from acoustic surveys of Bounty Platform used in modelling the fisheries (from Hanchet & Grimes in press).

Year	Age 1	Age 2	Age 3	Age 4+
1993	8 814	6 870	1 410	62 857
1994	94	5 871	32 066	27 672
1995	59 284	4 856	6 658	30 770
1997	1 679	4 144	24 598	37 518
1999	429	745	4 969	42 722
2001	135	2 551	6 010	21 677

Table 6: Values for the input parameters to the separable Sequential Population Analysis for the base case and sensitivity runs for the Bounty Platform. Adult acoustic c.v.s given for individual surveys for base case. Relative c.v.s between years were retained for the sensitivity runs.

Parameter	Base case	Sensitivity
M	0.2	0.15, 0.25
Acoustic age 3 and 4+ c.v.	0.5	0.3, 0.7
Acoustic age 2 c.v.	0.7	0.5, 1.0
Median weighting on proportion-at-age data	30	3, 300
Years used in analysis	1990-2001	1979-2001
Acoustic q	estimated	1.4

Table 7: Bounty Platform estimates of B_0, B_{mid01} (mid-season spawning stock biomass), $B_{pre2002}$ (pre-season spawning stock biomass), CAY_{2002}, CAY_{2003}, and their bias corrected 90% confidence intervals. All values in t x 10^3.

	B_0	B_{mid01}	$B_{pre2002}$	B_{mid01} (%B_0)	CAY_{2002}	CAY_{2003}
Base case	93	9	9	9	2.0	2.3
CI (corrected)	74–95	3–11	3–12	4–11	0.6–2.6	0.8–2.7

Table 8: 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 (t x 10^3); $N_{2,1996}$ size of the 1994 year class (millions).

Parameter	B_0	$B_{mid\ 90}$	$B_{mid\ 01}$	$N_{2,1996}$	$B_{mid\ 01}$ (%B_0)	$B_{mid\ 00}$ (%B_{may})	CAY 2002
Base case	**93**	**56**	**9**	**53**	**9**	**24**	**2.0**
M = 0.15	123	51	8	41	7	18	2.0
M = 0.25	79	64	10	68	13	32	2.5
Acoustic c.v. = 0.7	92	56	7	50	8	21	1.7
Acoustic c.v. = 0.3	95	56	9	56	9	25	2.1
Proportion-at-age weighting = 300	95	56	12	54	12	32	2.8
Proportion-at-age weighting = 3	97	56	10	67	10	27	2.3
1979-2001 data	71	56	9	53	12	32	2.0
Acoustic q = 1.4	108	61	22	68	20	54	5.0
Acoustic q = 1.4 and free M	72	84	15	115	20	54	–

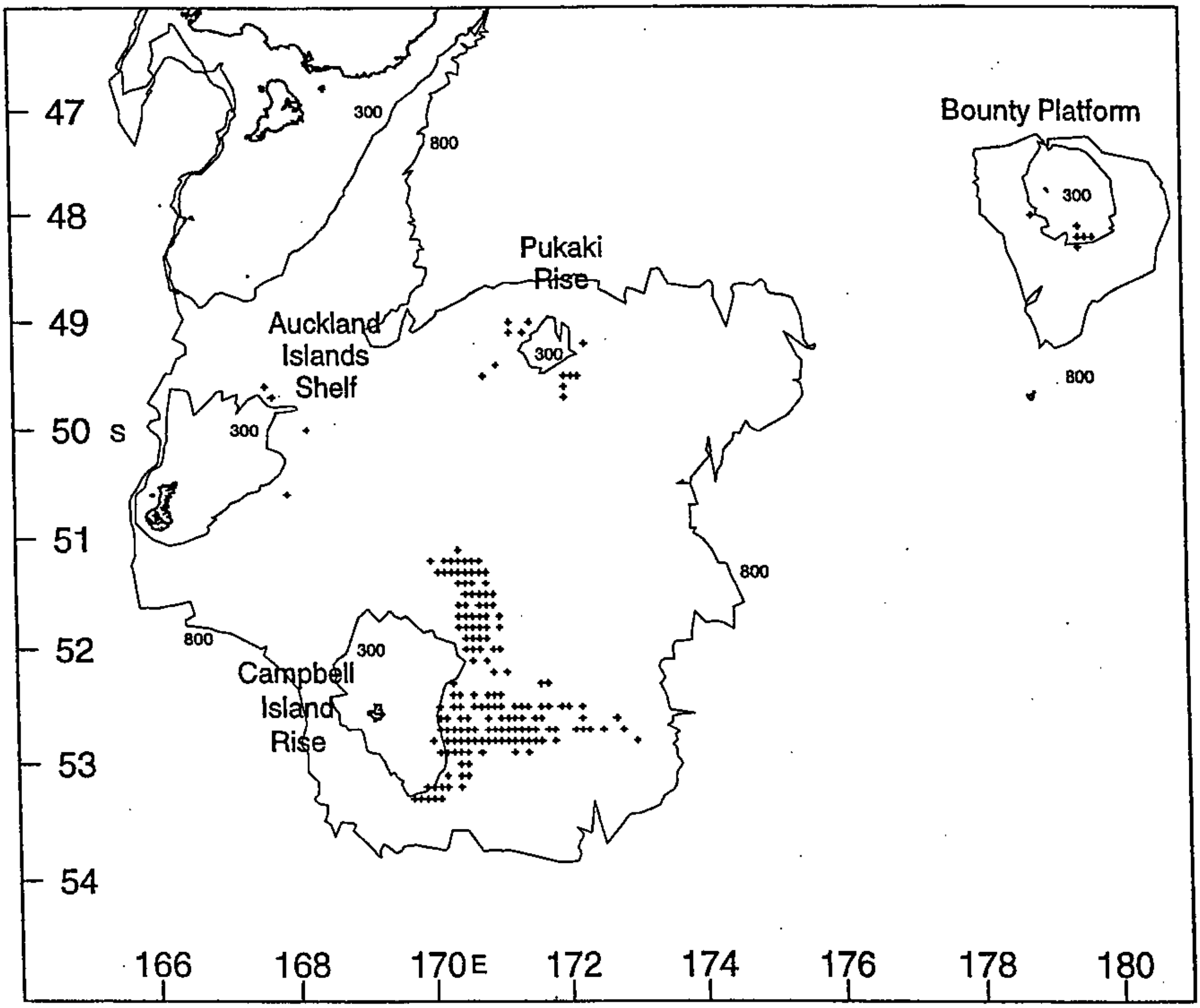


Figure 1: Commercial trawls made during the 2001 season targeting southern blue whiting.

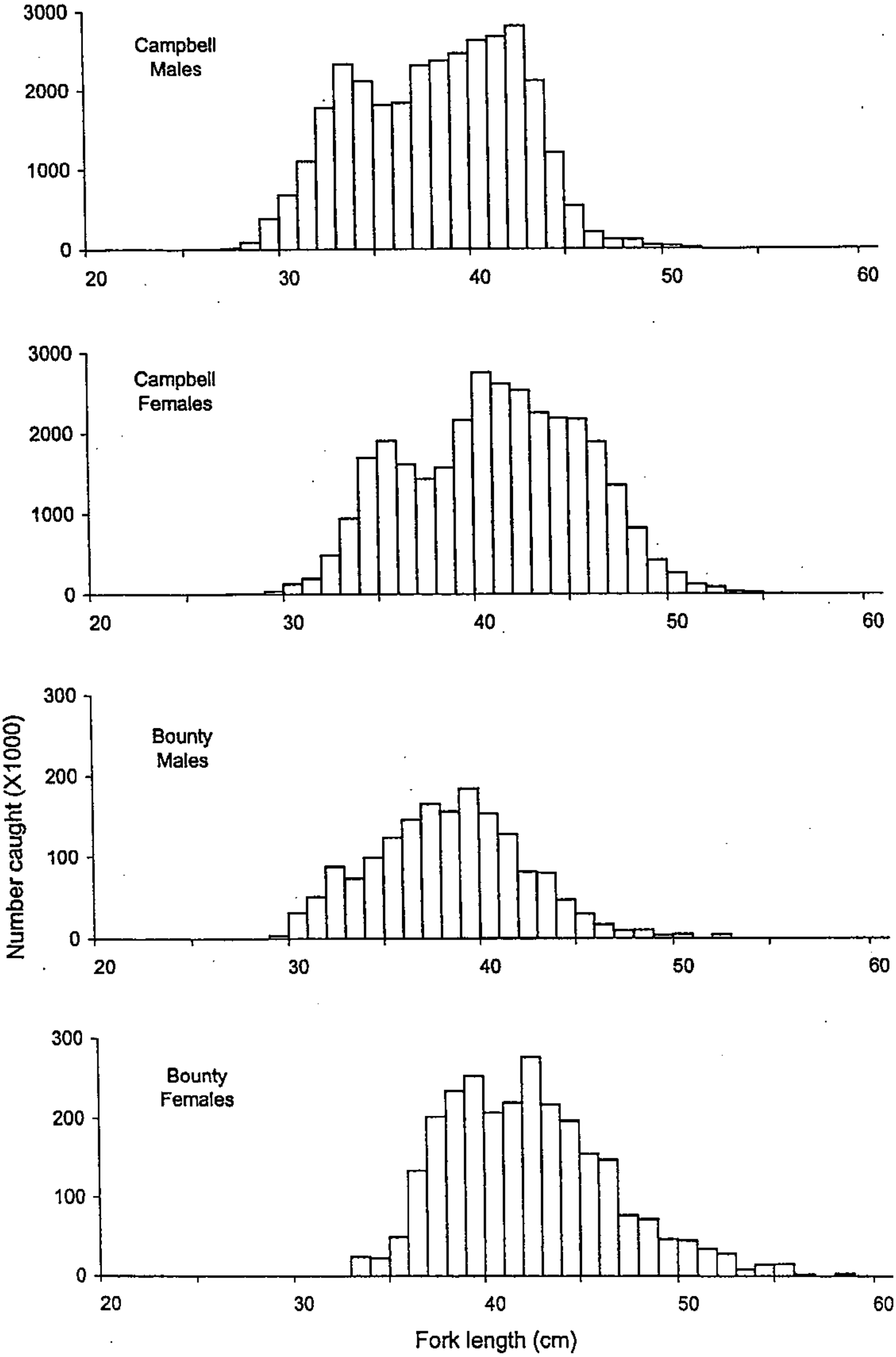


Figure 2: Weighted length frequency distribution of SBW by area and sex in the 2001 season.

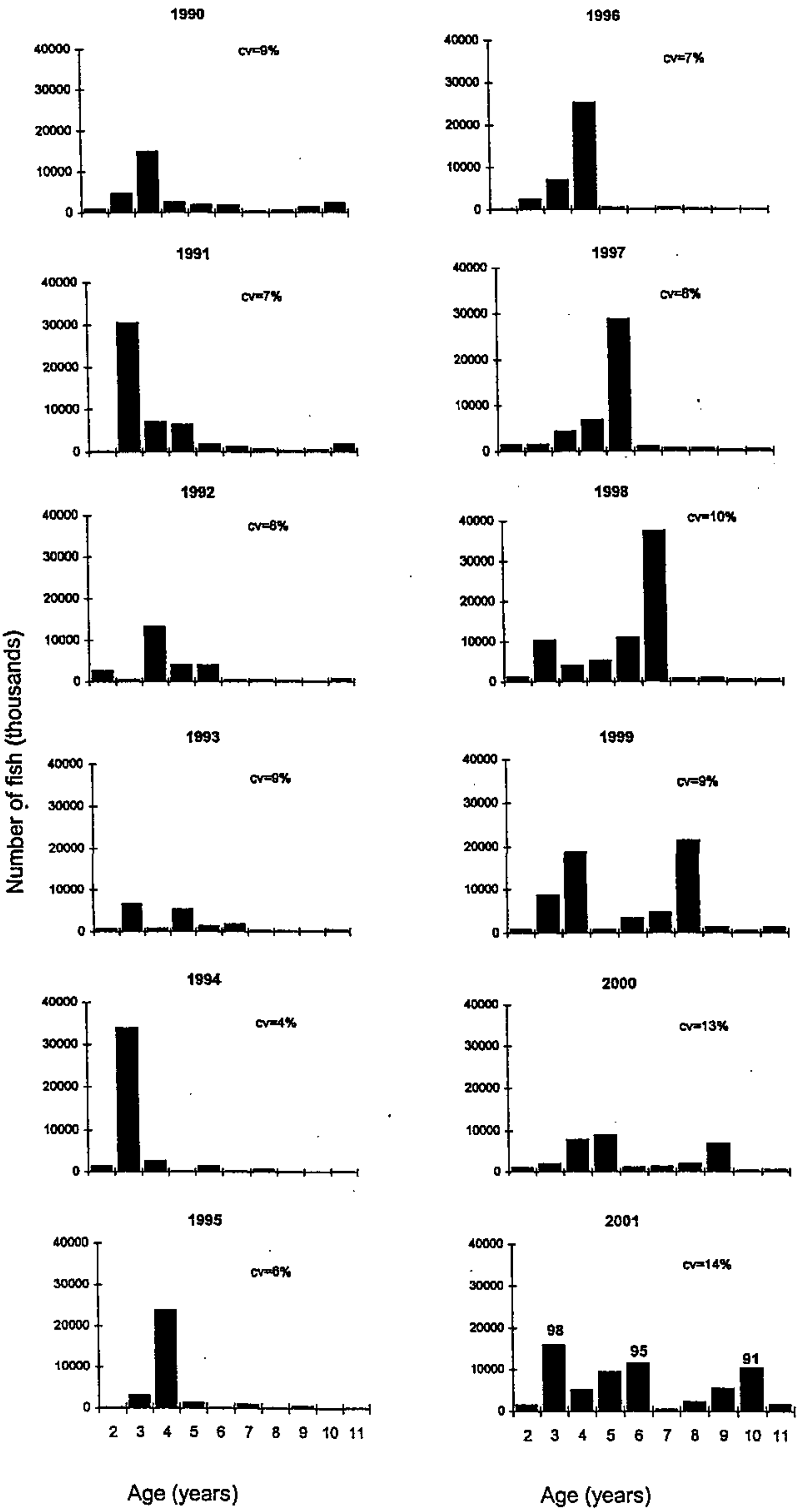


Figure 3: Age composition of Campbell catch from 1990 to 2001, with mean weighted c.v. (%). Strong year classes labelled for 2001.

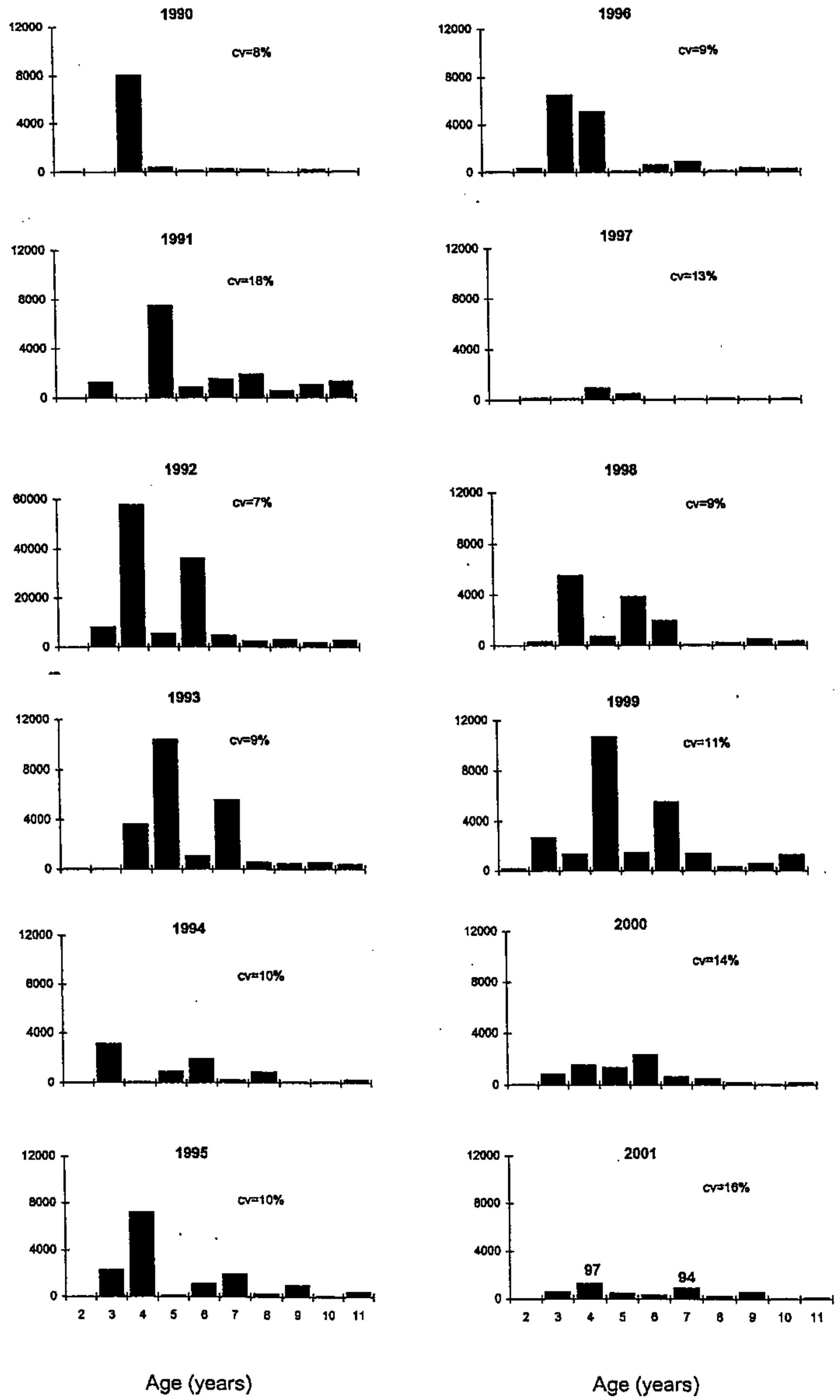
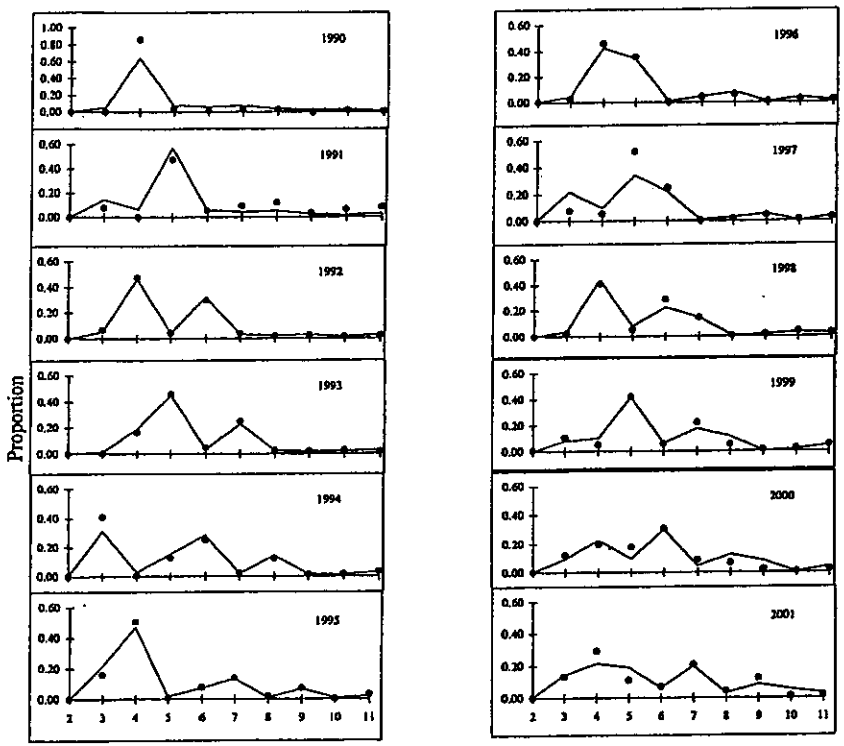
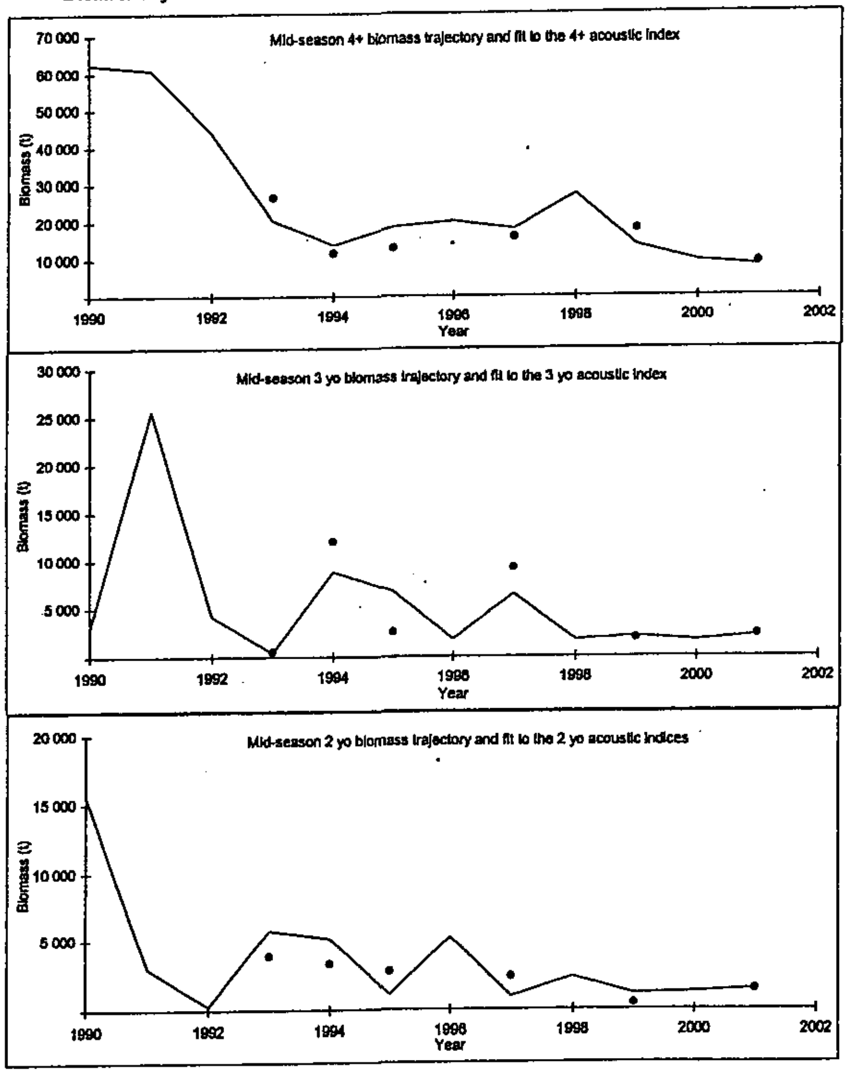


Figure 4: Age composition of Bounty catch from 1990 to 2001, with the mean weighted c.v. (%). Strong year claases labelled for 2001.

Observed (circle) and expected (line) proportion at age



Biomass trajectories and fits to acoustic indices



Selectivity at age

2	3	4	5
0.00	0.29	0.83	1.00

Acoustic qs

Adults	2.36
2 year olds	1.78
3 year olds	2.67

Likelihoods

Adults	0.7
2 year olds	3.0
3 year olds	2.7
Age data	20.9

Figure 5: Diagnostics for the Bounty Platform assessment showing the fit to the proportion-at-age, and acoustic indices.

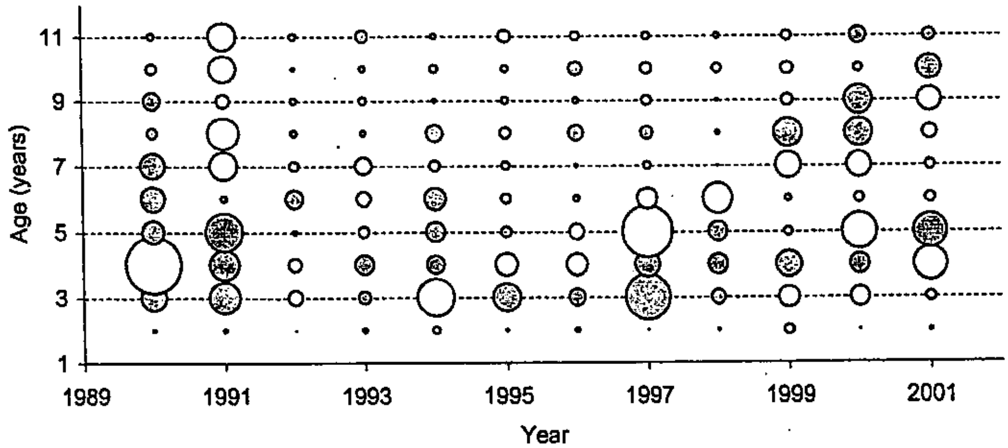


Figure 6: Residuals for the fit to the age data. Positive residuals are plotted with filled circles and negative residuals with open circles.

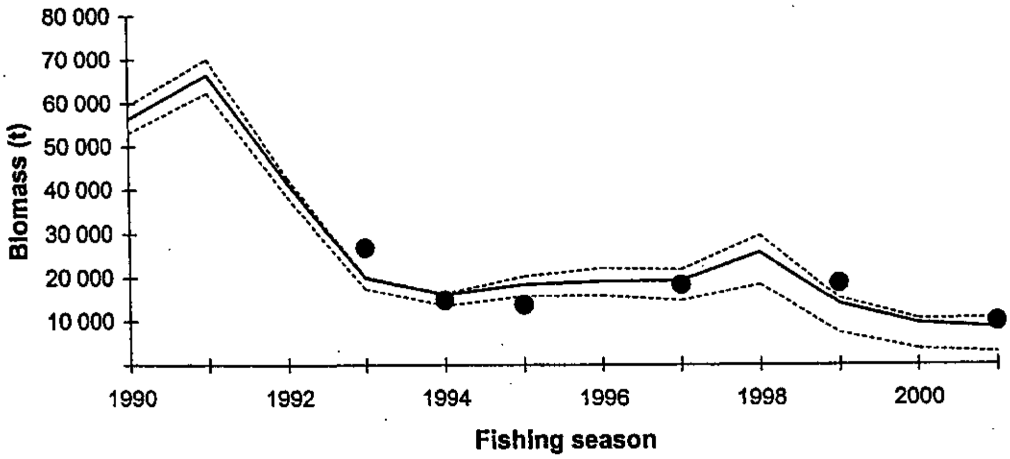


Figure 7: Mid-season spawning stock biomass trajectories and 90% confidence intervals for the Bounty Platform stock from bootstrapping and fit to acoustic indices.

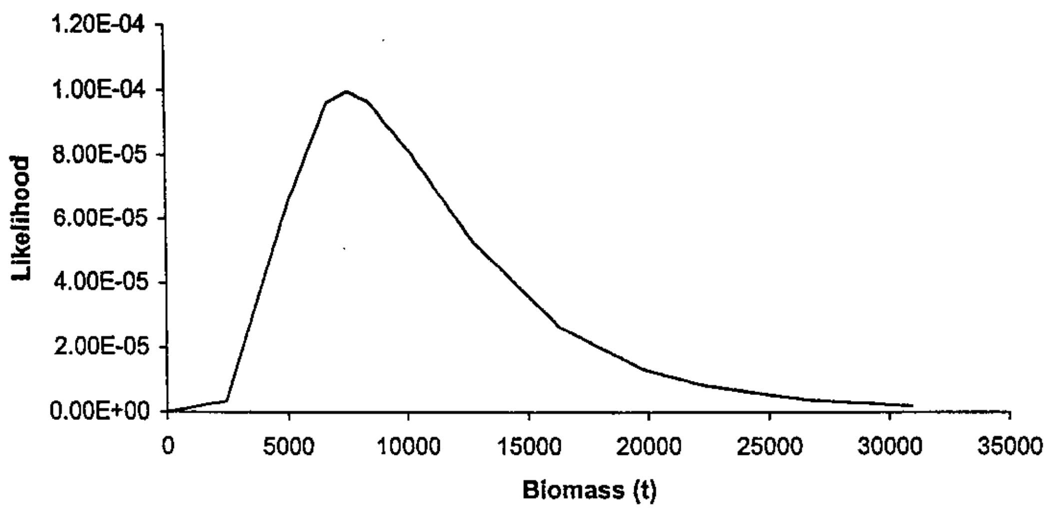


Figure 8: Likelihood profile for B_{2001}