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Assessment of northern gemfish stocks (SKI 1 and SKI 2) for 1998

R. J. Hurst, R. P. Coburn, S. M. Hanchet, P. L. Horn, A. D. Langley, and N. W. Bagley

NIWA
PO Box 14-901
Kilbirnie
Wellington

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1. EXECUTIVE SUMMARY

Northern (SKI 1 and SKI 2) gemfish (*Rexea solandri*) catches increased during the 1980s and were maintained at about 2000–2300 t for 7 years. The Total Allowable Catch (TAC) also increased during this period to a maximum of 2452 t in 1993–94. A significant proportion of the catch is target fished, both on non-spawning fish in SKI 2 and on fish migrating to spawn in SKI 1. The SKI 1 fishery takes place in three main areas, Bay of Plenty and east Northland (both in QMA 1) and west Northland (QMA 9).

Catches in the last two fishing years have declined and catch-per-unit-effort (CPUE) indices show declines in all fisheries. CPUE indices for SKI 1E, from 1988–89, and SKI 2, from 1989–90, have declined by about 75%; CPUE indices for SKI 1W show a decline of 50% since 1993–94.

Time series of age frequency data have been developed from commercial catch sampling programmes in SKI 1 (E and W) and SKI 2. These data indicate that patterns of strong and weak year classes can be followed through the fisheries over time. Strong year classes were spawned in 1980, 1982, 1984, and 1991. The comparable data for 1996–97 for SKI 1E and SKI 1W show no evidence of a separate stock in the newer SKI 1W fishery.

For the 1998 northern gemfish assessment, all relevant biological parameters and commercial catch, CPUE, and proportion at age data were incorporated into two population models, one using MIAEL estimation techniques (as used in the 1997 assessment) and the other using the sequential Separable Population Analysis (sSPA) method. Estimates of virgin biomass, current biomass, and yields were obtained. Results from the MIAEL model suggest that the stock has declined since 1990 and will continue to decline further at current levels of catch and estimated recruitment. However, all MIAEL biomass estimates had moderately low information indices (20–30%) and are therefore not well estimated within the range of values estimated by the least squares method. Results of the sSPA model showed similar trends in stock biomass and point estimates of current biomass were less than 20% B_0. Results from both models indicate that the northern stock is likely to be below the level that would support the MSY and likely to decline further if catches at the level of the 1997–98 TACCs are taken.

2. INTRODUCTION

2.1 Overview

The gemfish fishery in New Zealand is managed as five Fishstocks (SKI 1, 2, 3, 7, 10) but is modelled as two stock units, northern (SKI 1+2) and southern (SKI 3+7) (Figure 1). This paper reviews the commercial fishery for gemfish in 1996–97 and describes the northern stock modelling input data, techniques, and results from the 1998 assessment. It also reviews the stock hypotheses relating to the relationship between the three main fisheries; the two spawning fisheries in SKI 1, (i.e., SKI 1E which is east of North Cape in QMA 1 and SKI 1W which is west of North Cape in QMA 9), and the non-spawning fishery in SKI 2.

Model input data presented here include: commercial catches, split into non-spawning season (SKI 2) and spawning season (SKI 1 E and W, separately and combined); three CPUE time series SKI 1E from 1988–89, SKI 1W from 1993–94, and SKI 2 from 1989–90); three age frequency time series from commercial catches (SKI 1, 1989 to 1994, 1997; SKI 1W, 1996, 1997; SKI 2, 1996, 1997).

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2.2. Literature review

Gemfish has been an important fishery in Australian waters and there are numerous published reports on the biology and fishery. Rowling (1994) reviewed the southeast fishery for gemfish, including data from unpublished reports. Key published references are: Paxton & Colgan (1993) on stock structure; Lyle & Ford (1993) on reproductive biology; Withell & Wankowski (1989), Rowling (1990), & Rowling & Reid (1992) on age and growth; Rowling (1994) and Tilzey *et al.* (1990) on the fishery.

In New Zealand, specific publications on gemfish include: a review of the early development of the domestic inshore fisheries (Holton 1987); background to the early stock assessments (Hurst 1988); CPUE analyses for the northern fishery (Langley 1995, Ingerson & Colman 1997); the 1997 assessment for northern gemfish (SKI 1, 2) and southern gemfish (SKI 3, 7) stocks (Annala & Sullivan 1997); details of the biology, fishery, and assessment for southern gemfish (SKI 3, 7) stocks in 1997 (Hurst & Bagley 1998); and the influence of ocean climate on southern gemfish recruitment patterns (Renwick *et al.*, in press). Research on age validation and stock structure of New Zealand gemfish (Horn & Hurst, in press) was carried out in conjunction with work reported on here.

A number of trawl survey reports since 1980 have included biomass and length frequency data on gemfish. Those relevant to northern gemfish are the series of reports on surveys of the east coast of the North Island, 1993 to 1996, by RV *Kaharoa*, which sampled juvenile gemfish reasonably well (Kirk & Stevenson 1996, Stevenson & Kirk 1996, Stevenson 1996a, 1996b). Reports relevant to southern gemfish stocks were listed by Hurst & Bagley (1998).

3. COMMERCIAL FISHERY

3.1 Catch history

3.1.1 Annual catches

Holton (1987) and Hurst (1988) summarised the development of the gemfish fishery up to the mid 1980s. Reported New Zealand domestic gemfish landings did not exceed 200 t per annum until 1967. They then fluctuated between 200 and 700 t, peaking in 1971. Foreign licensed vessels operating in New Zealand waters during this period also probably caught gemfish but it was largely unreported during the early and mid 1970s. Hurst & Bagley (1998) made estimates of catches from 1972 to 1977 for stock assessment modelling for SKI 3 and

SKI 7, based on Japanese fishing patterns. No estimates were made for foreign catches in SKI 1 and SKI 2 for the same period as activity in gemfish areas appears to have been minimal.

On 1 March 1978, the 200 mile Exclusive Economic Zone (EEZ) was established and annual catches increased significantly, mainly due to reported catches by foreign licensed and N.Z. chartered deepwater vessels fishing around the South Island (*see* Hurst & Bagley 1998). For the fishing years 1978–79 to 1985–1986, catches were unrestrained and peaked at 8250 t in 1985–86, of which nearly 7000 t was caught in southern waters (Table 1).

The gemfish fisheries in northern waters, SKI 1 and SKI 2, developed through the 1980s, peaking at about 2300 t in 1992–93. Catches were maintained at about or just below quota levels (Table 2) until 1994–95, when they started to decline, particularly in SKI 2. The catch history used for stock reduction modelling, divided into spawning (SKI 1) and non-spawning (SKI 2) season and sub-areas of SKI 1 (1E and 1W), is given in Table 3. Catch for 1997–98 and 1998–99 (given as catch years 1998 and 1999) was assumed based on the TACC for 1997–98 and the same percentage split between SKI 1E and SKI 1W as in 1996–97.

3.1.2 Total Allowable Catch (TAC)

On 1 October 1986, Individual Transferable Quota controls were introduced under the Quota Management System (QMS). The quotas for gemfish were initially based on 1983 catch levels (1984 for SKI 1) which were the highest levels of catch recorded at the time yields were estimated (*see* Table 2). This assumed that all gemfish fisheries were still developing. Initial TACs for SKI 1 and SKI 2 were 550 and 860 t, respectively. These were gradually increased over time through Quota Appeal Authority decisions to 1152 and 1300 t. The TACs for both areas were reduced for the 1997–98 fishing year, as a result of declining CPUE and the 1997 stock assessment modelling results. The 1997–98 TACs are 753 for SKI 1 and 850 t for SKI 2.

3.2 Catch-per-unit-effort (CPUE)

Standardised CPUE analyses of three gemfish fisheries are presented here; the analyses for SKI 1E and SKI 2 update previous analyses reported by Langley (1995) and Ingerson & Colman (1997); the analyses for SKI W are new, but follow the general methodology outlined in previous reports.

3.2.1 General methodology

All data used are for bottom trawls targeting gemfish. These vessels fill out either Catch, Effort and Landing Returns (CELR) or Trawl, Catch, Effort and Processing Returns (TCEPR). All data were summarised into CELR format, i.e., vessel, day, and statistical area (statarea). In SKI 1 fisheries, target fishing occurs from April to September in statistical areas 001–010 (SKI 1 E) and 046, 047 (SKI 1W). In SKI 2 target fishing occurs throughout the year but is minimal in winter. Statistical areas included are 013–015.

For all areas, an all vessel model is presented. Where the data are sufficient (SKI 1E and SKI 2), a categorical vessel model is also presented, which includes data only for vessels that were in the fishery for at least 3 years. For the SKI 1W fishery, a model including only TCEPR *data is also presented.*

Raw data were checked and cleaned, as for previous years, and added to the database. Indices of relative abundance were calculated from the commercial catch and effort data using a multiple regression technique (Vignaux 1992). Tows with a zero catch were arbitrarily assigned a catch of 1 kg to avoid taking the log of zero. The index log (catch per vessel-statarea-day) was regressed against each of the possible predictor variables (*see* Ingerson & Colman 1997) to determine which of these variables explained most variability in the CPUE. Seasonday and L*B*D (length*breadth*draught) were included in the regression analysis as third order polynomial functions. Year and statarea were included as catagoric variables. The remainder of the variables were included in the model as linear variables.

A stepwise linear regression was used to determine predictor variables to be added to the model, until the addition of an extra variable gave less than 3% improvement in the sum of squares.

3.2.1 SKI 1E

Data inputs for the two models are given in Table 4, stepwise regression results in Tables 5 and 6 and resulting CPUE indices in Table 7. Year was selected as a significant variable in both models. Plots of the CPUE index from each model, and the index from the previous assessment, are shown in Figures 2 and 3. Both models showed a similar trend, with CPUE index falling from 1.0 in 1989–90 to 0.20 to 0.24 by 1996–97.

3.2.2 SKI 2

Data inputs for the two models are given in Table 4, stepwise regression results in Tables 8 and 9 and resulting CPUE indices in Table 7. Year was selected as a significant variable in both models. Plots of the CPUE index from each model, and the index from the previous assessment, are shown in Figures 4 and 5. Both models showed a similar trend, with CPUE index falling from 1.0 in 1990–91 to 0.23 to 0.24 by 1996–97.

3.2.3 SKI 1W

A summary of the data inputs for the two models agreed by the working group are given in Table 4 and resulting CPUE indices in Table 7. A more detailed description of the new model follows.

TCEPR and CELR data for the SKI 1 west coast fishery, statistical areas 046 and 047, from 1989–90 to 1996–97, were extracted. Target fishing for gemfish occurred from April to August, although the peak of the season was in June each year. For this analysis, 9 June was defined as the peak of the season and all days fishing were assigned a "seasonday" relative to this date.

There were 30 vessels in the fishery during the period 1989–90 to 1996–97, but few were involved for more than 3 years (Table 10). Therefore, it was not appropriate to include vessel as a categorical variable in the CPUE model. Instead variables defining the size and power of the individual vessel were included in the analysis. During the period 1990–91 to 1993–94, a substantial proportion of the catch was taken by vessels completing CELR forms, whereas in recent years most of the catch has been reported on TCEPR forms (Table 11). Form type was not included in the analysis in case it became confounded with the year coefficients, but a separate analysis of TCEPR data only was carried out. This analysis included additional variables, specifically trawl start time, start longitude, headline height, trawl speed, trawl direction, depth at start of trawl, and environmental variables (wind direction, and wind speed). Data included in this model covered the period 1992–93 to 1996–97 (Table 12).

In the preliminary analysis, the base year was set at 1992–93. Stepwise regression results for both the all vessel and TCEPR only models are shown in Tables 13 & 14 and the resulting CPUE indices are shown in Table 7. Year was selected as a significant variable in both models. The CPUE index fluctuated quite widely in both models but was based on few data in the earlier years of the time series, including the base year 1992–93. Therefore, the working group recommended restandardising the time series to a base year in 1993–94, as this was the first year to record substantial effort and catch (i.e., over 100 tows and 400 t in the all vessel model). The resulting CPUE index for all vessels is shown in Table 15 and suggests a decline of about 50% since 1993–94. Standard errors for the all data model and indices and standard errors for the TCEPR data only model were not recalculated for the purposes of inclusion in the stock reduction model.

3.3 Size and age composition of commercial catches

Otoliths and length frequency data have been collected from the three main commercial fisheries: SKI 1E, 1989 to 1994, 1997; SKI 1W, 1996, 1997; SKI 2, 1996, 1997. For the 1997 assessment, catch-at-age was available for SKI 1E only, from 1989 to 1994. For the 1998 assessment, the 1996 and 1997 data were also available.

3.3.1 Length frequencies

Catch sampling data collected by the Ministry of Agriculture and Fisheries (MAF) up to 1992 were presented by Langley *et al.* (1993). From 1995–96, catch sampling has been carried out in SKI 2 by NIWA, and for 1996–97 in SKI 1 by NIWA and Sanford Ltd. Details of the numbers of samples taken in each year are given in Table 16.

Before combining the SKI 1 NIWA and Sanford length data, the length frequencies sampled by each company were compared. There was no indication of any major differences (Figure 6) and the data were pooled.

Data for SKI 1E and SKI 1W were scaled up to catch separately, to allow alternative stock hypotheses to be used in the modelling. Comparison of the length frequencies during the season showed no major differences which might be apparent in separate stocks. Although there was some suggestion of slightly larger males on the western side at the start of the season, the females distributions were similar and not what might be expected if the western stock was a more recent, less exploited, fishery (Figure 7).

3.3.2 Age frequencies

The full time series of otoliths was aged by using the technique developed during 1997 (Horn & Hurst, in press). A separate age-length key was then derived for each sex, fishery area, and year, and applied to the scaled length frequency in order to determine the age frequency. The resulting proportions-at-age are given in Table 16 and Figures 8–11.

The SKI 1E time series now includes 7 years of data and indicates relatively strong year classes were spawned in 1980, 1982, 1984, and 1991 (Figure 8). These year classes are also apparent in the age frequencies for SKI 1W (Figure 9) and provide support for the hypothesis that fisheries in SKI 1 are based on the same stock. If the newly developed SKI 1W fishery was totally separate from SKI 1E, the age frequency would have been expected to show a greater proportion of older fish which had been less subjected to exploitation.

The age frequencies for SKI 2 (Figures 10 and 11) also show the same strong year classes as in SKI 1, also supporting the hypothesis that fisheries in SKI 1 and SKI 2 are based on the same stock. The greater prominence of the 1991 year class in SKI 2 is explained by the spawning or non-spawning nature of the fisheries. The SKI 1 fisheries are on adults migrating to spawn. These fish are not fully recruited into the fishery until about age 7 or 8 (see stock assessment section). The SKI 2 fishery is on non-spawning fish and includes younger immature fish not recorded in SKI 1.

3.4 Non-commercial fisheries

3.4.1 Recreational fisheries

There was no recreational catch reported in marine recreational fishing catch and effort surveys of the MAF Fisheries South and Central regions (1991–92 and 1992–93, respectively). However, there is known to be a target recreational fishery in the Bay of Plenty. Reported gemfish catch in the North region recreational survey December 1993 to November 1994 was negligible (3 fish) and scaled up to about 1 t. Gemfish harvest estimates from the 1996 national recreational survey were 5000 fish from SKI 1 and 2 and less than 500 fish from SKI 7.

3.4.2 Maori customary fisheries

Quantitative information on the current level of Maori customary take is not available.

3.4.3 Illegal catch

The amount of gemfish misreported is not available.

3.4.4 Other sources of mortality

There may have been some gemfish discarded before the introduction of the EEZ, but this is likely to have been minimal since the early 1980s as gemfish is a medium value species. Juvenile gemfish are a bycatch in scampi fisheries off the east coast of the North Island, but the level of catch has not been quantified.

4. RESEARCH

Hurst & Bagley (1998) reviewed gemfish stock structure in New Zealand waters as part of the stock assessment for southern gemfish. Horn & Hurst (in press) presented age frequency data for all gemfish fisheries, estimated age and growth parameters, and updated the review of gemfish stock structure. A summary of these papers, relevant to the northern gemfish stock assessment, is presented here. Other important biological parameters for stock assessment are also listed.

4.1 Stock structure

The current issue for the northern gemfish assessment is the relationship of SKI 1E, SKI 1W, and SKI 2 to each other.

The location of gemfish target tows is shown in Figure 12. In SKI 1, target catches come from three main locations; Bay of Plenty, east Northland (both in QMA 1), and west Northland (QMA 9). In SKI 2, target fishing extends from the Wairarapa coast up to Hawke Bay.

Seasonal patterns in SKI 1 and SKI 2 fisheries have continued to exhibit the same seasonal patterns as found by Hurst (1988). In the northern fisheries (SKI 1), about 70% of the catch is taken in May and June. In SKI 2, catches are spread fairly evenly throughout the year, except for an almost zero catch during the winter in June to August (Figure 13). Running ripe females are recorded only from SKI 1 and the distribution of young fish (15–30 cm, 6–12 months old) is quite localised and consistent with the distribution of ripe females (*see* Hurst & Bagley, 1998, figures 24, 25).

Age frequency data for the main SKI 1 and SKI 2 fisheries are presented and discussed in Section 3, Figures 8–11. These data show the same pattern of strong year classes, 1980, 1982, 1984 and 1991 and provide support for the hypothesis of one stock in SKI 1 and2.

Horn & Hurst (in press) derived von Bertalanffy parameters for northern gemfish from the age-length data from the commercial fisheries, as well as length frequency data for juvenile fish from the trawl surveys off the Wairarapa coast (Table 17). A comparison of the von Bertalanffy parameters calculated for the different areas using the combined otolith and length-based data sets showed some significant between-samples differences in the L_∞ and k parameters, but the differences were not consistent between areas or sexes.

There were no significant differences in mean length at age of gemfish from SKI 1E and 1W in 1997 (Table 18). No comparison was made with gemfish from SKI 2 as the samples were taken at a different time of year and included more than just the spawning part of the population.

All the above data provide evidence for an autumn spawning migration from central North Island waters (SKI 2) into more northern waters (SKI 1). The main outstanding issue for stock assessment of northern gemfish is the origin of the west Northland spawners. One hypothesis is that they are from SKI 2, via the east or west coasts of the North Island. An alternative hypothesis is that they may represent a separate western stock which is fished only during the spawning migration. The non-spawning season distribution is unknown, but it could be that fish disperse off the west coast of the North Island and across the Challenger Plateau. A few commercial and research catches have been recorded in these areas (*see* Hurst & Bagley 1998, figure 10). The possibility of SKI 1W gemfish being a separate stock was considered in the stock assessment models in 1997 and 1998.

4.2 Mortality estimates

Horn & Hurst (in press) found that ageing of northern gemfish samples from the current population indicated an A_{max} (i.e., age reached by 1% of the population) of about 15 years for males and 16 years for females.

A range of estimates of natural mortality (M) can be derived from the equation

$$M = \log_e(100)/A_{max}$$

where A_{max} is the age reached by 1% of the virgin population (Sparre *et al.* 1989).

A maximum age of 15 in the current population produces an estimate of M of 0.3. As the samples were clearly not from virgin populations, it seems likely that M for gemfish is in the range 0.2–0.3, with the current best point estimate being 0.25.

4.3 Trawl survey biomass estimates

Biomass estimates are available for northern gemfish from SKI 2, from a series of four east coast North Island surveys, 1993 to 1996, by RV *Kaharoa* (Kirk & Stevenson 1996, Stevenson & Kirk 1996, Stevenson 1996a, 1996b). These surveys sampled out to 400 m depth and may therefore have missed some gemfish, which are known to occur deeper (Hurst & Bagley 1998). Gemfish are also frequently caught by midwater trawl gear off the east coast of the North Island and vertical availability may vary between surveys. The biomass estimates are therefore not used in the stock assessment modelling. However, the surveys did appear to sample younger age classes (up to about age 4) quite well and these data were used to determine the length at age of northern juvenile gemfish (Horn & Hurst in press).

5. STOCK ASSESSMENT

In 1997 a stock reduction analysis was carried out for the northern and southern gemfish stocks. In 1998, stock reduction analysis for the northern stock was updated using MIAEL estimation (Cordue 1993, 1996). In addition, a new separable Sequential Population Analysis (sSPA) of the northern stock was carried out using a similar method to that used on southern blue whiting (Hanchet *et al.* in press). Estimates of mid-spawning season virgin biomass (B_0), mid-spawning season mature biomass for 1997–98 (B_{mid98}), and 1998–99 (B_{mid99}), and estimates of 1999 beginning of year total biomass (B_{beg99}) are presented below. Estimates of MCY and CAY are presented from the MIAEL model.

5.1 Stock hypotheses

Two stock hypotheses were modelled for northern gemfish because of uncertainty about the stock affinities of SKI 1W gemfish. The first hypothesis assumed fish from SKI 1 and SKI 2 comprised a single stock. The second hypothesis assumed that the recently developed west coast North Cape fishery in QMA9 is a separate stock and, consequently, modelled data from the SKI 1E and SKI 2 fisheries only. The SKI 1W fishery was not modelled separately.

5.2 The MIAEL model

The model used was similar to that used for the 1997 assessment (Annala & Sullivan 1997). It was an age-structured, two-sex population model which used the input parameters listed in Table 19. These were the same as used in the 1997 assessment, except that the base case steepness value was assumed to be 0.9, M was revised from 0.23 to 0.25, and the maturity ogive was estimated in the model in 1998.

5.2.1 MIAEL input data and year class strength estimates

The pre-spawning (SKI 2) and spawning season (SKI 1) landings used in the modelling are given in Table 3. Catches for 1998 and 1999 were assumed to be at the level of the 1997–98 TACC, split between QMAs 1 and 9 using the same proportion as in 1997.

Commercial catch-at-age data included in the models (SKI 1E, 1989 to 1994, 1997; SKI 1W, 1996, 1997; SKI 2, 1996, 1997) are given in Table 20 (note that both sexes sum to 1.0 for each year, unlike the raw data in Table 16). A median *c.v.* of 35% was assumed for each year's age data and weighted by the number of samples per year. Ageing error applied was ± 5% from age 5.

Standardised CPUE indices for SKI 1E, SKI 1W, and SKI 2 are shown in Table 15. The results are based on models including vessel as a categorical variable for SKI 1E and SKI 2. All data were included for SKI 1W as the time series was not long enough to carry out a meaningful categorical vessel analysis. The longer time series has shown a decline of 70%. All time series show a decline of 30 to 50% between 1994 and 1997.

In preliminary runs of the model, year class strength was estimated for the years 1978 to 1994 (Table 21), a maturity ogive was estimated for ages 2 to 8 (Table 22), and a home selectivity ogive was estimated for ages 1 to 8 (Table 23). These were re-estimated for each sensitivity run of the model. These values were then used as input data for the estimation of biomass.

5.2.2 MIAEL biomass estimates

Estimates and ranges of mid-spawning season virgin biomass (B_0), mid-spawning season mature biomass for 1997–98 (B_{mid98}), and 1998–99 (B_{mid99}), and estimates of 1999 beginning of year total biomass (B_{beg99}) were obtained for both stock hypotheses using the MIAEL estimation procedure.

The estimate of B_0 for the SKI 1, 2 hypothesis was about 12 700 t and was similar to the SKI 1E,2 hypothesis (Table 24). For the SKI 1, 2 hypothesis, sensitivity tests were conducted to examine the effects of a steepness value of 0.75, r_{mmx} (minimum exploitation in the year of maximum catch) of 0.03, and M of 0.2 and 0.3. Estimates of B_0, B_{mid98}, B_{mid99}, and B_{beg99} were lowest when r_{mmx} = 0.03 and highest when M = 0.3. The model was particularly sensitive to the value chosen for r_{mmx}. Estimates of biomass for the base case tended to be higher than most sensitivity runs. In only one run was mid-season biomass in 1997–98 above B_{MAY} (35%B_0), and in all cases, the mid-season biomass in 1998–99 declined further. Information indices ranged mainly between 20 and 35%, indicating that the point estimates of biomass are not well known.

The biomass trajectories of minimum and maximum biomass and the MIAEL estimates of B_{mid98} and B_{mid99} as a percentage of B_0 are shown in Figure 14. Trajectories for both stock hypotheses are similar and suggest a substantial increase in biomass in the late 1980s, followed by a decline caused by lower recruitment and increased fishing pressure. Recent recruitment is estimated to be low but are poorly determined. They do not affect the current assessment as they are only just beginning to enter the fisheries.

Model fits to SKI 1, 2 proportion-at-age and CPUE data are shown in Appendix 1.

5.2.3 MIAEL estimation of Maximum Constant Yield (MCY)

The method used to estimate MCY was MCY = pB_0, where p is determined for each stock using the method of Francis (1992) such that the biomass does not go below 20% B_0 more than 10% of the time: p was estimated at 6.7% using the parameters in Table 17 and 19. Details of the MIAEL modelling procedures which produced the B_0 estimates from which MCY was estimated are given above. MCY estimates are given in Table 25.

5.2.4 Estimation of Current Annual Yield (CAY)

The method of Francis (1992) was used to estimate CAY from the MIAEL estimates of current biomass ($B_{beg\ 99}$). Results are given in Table 26.

5.3 The sSPA model

The overall sSPA model approach is essentially the same as that used in recent southern blue whiting assessments (Hanchet *et al.* in press). The model was adapted and used for modelling the northern stock under the SKI 1, 2 hypothesis only. The model was used to estimate the numbers at age in the initial population in 1989 and subsequent year class strengths. A second "initial equilibrium" model (Hanchet in press) was also used as a sensitivity analysis, and to estimate B_0. This model assumed an equilibrium age structure in 1951, and estimated year class strength from 1978 to 1994. Because of the nature of the SKI 1, 2 fishery, the season was split into pre-spawning and spawning fisheries, consistent with the MIAEL model assumptions. Selectivity ogives were estimated for ages 3 to 7 in the SKI 1 fishery and ages 3 to 6 in the SKI 2 fishery, and older fish were assumed to be fully selected.

5.3.1 sSPA input data and year class strength estimates

Details of the input parameters and the sensitivity runs are given in Table 27.

The model was fitted to proportion-at-age data (Table 16, both sexes combined, SKI 1E and W combined) and CPUE data from the SKI 1E and SKI 2 fisheries (*see* Table 15). The CPUE indices were converted to effort data and fitted with a weight equivalent to a *c.v.* of about 30%. A weight equivalent to a *c.v.* of about 5% was given to each year's estimated annual catch. The proportion-at-age data were assumed to be multinomially distributed. The appropriate weighting for these data (sample size) can be determined from the *c.v.* of the observed age composition data. Although the observed *c.v.*s suggest a weighting of over 200, this is probably too high given factors such as ageing error and sampling bias. Furthermore, because of the large number of data points, a value of 200 gave too much weighting to the age data relative to the CPUE data. For the base case a weighting of 10 (equivalent to a *c.v.* of about 63%) was given to the age data. For the sensitivity analysis, weightings of 1 and 100 (equivalent to *c.v.*s of about 200% and 20%) were used.

Mean weights at age were calculated from the weight–length regression and von Bertalanffy growth parameters (*see* Table 17), and were assumed to be constant in all years. Projections were run to mid 1999 assuming recruitment was equal to the arithmetic mean over the period 1989 to 1994, and that the 1998 and 1999 catch was equal to the TACC. The sensitivity of the results to *M* and the sample size used for the proportion-at-age data were examined.

Simulated data were used to estimate 90% confidence limits for the results of the base case run. 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 SKI 1 and SKI 2 effort data, *M*, and annual catch was captured by assuming the data were log-normally distributed with *c.v.*s of 70%, 70%, 10% and 5% respectively. For each of the 500 bootstrap runs data were randomly selected from each distribution. The percentile method was used to estimate confidence intervals (Effron 1981): the estimate of the 90% confidence interval was computed as the 5th and 96th percentiles in the set of bootstrap estimates after sorting them into ascending order.

The sSPA model differed from the MIAEL model in a number of respects. The main differences were that the sSPA model was single sex, had no stock-recruit relationship, estimated all parameters simultaneously, did not fit the SKI 1W CPUE indices, fitted the SKI 1E and SKI 1W catch-at-age data combined, and fitted only ages 3 or above.

5.3.2 sSPA biomass estimates

Estimates and ranges of mid-spawning season recruited biomass for 1988–89 (B_{1989}), mid-spawning season mature biomass for 1997–98 (B_{mid98}), and 1998–99 (B_{mid99}), and estimates of 1999 beginning of year total biomass (B_{beg99}) were obtained for the SKI 1, 2 stock hypothesis using the sSPA model. Estimates of mid-spawning season virgin biomass (B_0) were also were obtained from the equilibrium sSPA model.

The results of the assessment are shown in Table 28. The estimates of mid-spawning season biomass are for mature fish on the spawning ground and allow for comparisons of current biomass with virgin biomass. The estimate of beginning of year biomass are for all fish on the home ground. The mid-season recruited biomass trajectory and fit to the SKI 1 CPUE indices are shown for the base case and equilibrium models in Figures 15 and 16. The model is unable to fit the steep early decline in CPUE in either model. Biomass estimates and trajectories since 1989 are similar in both sSPA models. The confidence intervals for the base case model suggest that the biomass estimates are not well known (Appendix 2). The fit to the proportion-at-age data is reasonably good, although it appears to overestimate the size of the 1991 year class (Appendix 2). This is probably to compensate for the steep decline in the CPUE index in the early years.

The estimated selectivity ogives for the two fisheries are shown in Table 29. They suggest that fish are fully recruited to the SKI 2 fishery by age 5, but not into the SKI 1 spawning fishery until age 8. Estimates of recruitment obtained from the sSPA model were standardised to 1 (Table 30). Both sSPA models gave very similar estimates of year class strength and suggest recruitment has been low since 1991.

Sensitivity analyses to examine the effect of changes in the proportion-at-age weightings and *M* on the results of the sSPA base case assessment are shown in Table 31. The results were quite sensitive to the weight given to the proportion-at-age data. The biomass estimates were highest when *M* was 0.3 and lowest when *M* was 0.2.

5.4 Comparison of MIAEL and sSPA model results

Although the two models differed in a number of respects their results were reasonably similar. Both models which cover the longer time series of the fishery (from 1951) estimate similar levels of virgin biomass of about 12 000 t, followed by a gradual decline to the mid 1980s. This was followed by an increase in recruitment in the early 1980s and an increase in biomass in the late 1980s to fit the steep decline in the CPUE indices from 1990 on. Estimates of biomass in 1999 (B_{mid99}) differ between the two models but both suggest that it is will be below B_{MSY}, at about 15% of B_0.

6. Management Implications

There are more data available on which to determine stock relationships for northern gemfish than were available for the 1997 assessment. Data on the seasonality of the fisheries, known spawning locations, distribution of juvenile fish, and age frequencies indicate that SKI 1 and SKI 2 gemfish are separate from SKI 3 and SKI 7 gemfish (Hurst & Bagley 1998, Horn & Hurst, in press). It appears that the SKI 1W gemfish are probably part of the same stock as SKI 1E and SKI 2, although there are only 2 years of catch sampling data for SKI 1W and SKI 2. Therefore, two alternative stock hypotheses were retained for the 1998 assessment; SKI 1 and SKI 2 fisheries combined; and SKI 1E and SKI 2 combined with SKI 1W separate.

The assessment is particularly dependent on the assumption that CPUE is an index of abundance. Standardised CPUE indices for all fisheries show strong declines and the stock status is believed to be poor. There are different trends in unstandardised CPUE between statistical areas within the SKI 1 fishery and it is not clear how well the overall standardised analysis may reflect changes in stock abundance. Year classes since 1988 appear to have been relatively weak, except for one strong cohort in 1991. Year classes from 1992–1994 are particularly weak but are poorly estimated.

Estimates of virgin and current biomass for the northern gemfish stock were carried out under the two alternative stock hypotheses (SKI 1, 2; SKI 1E,2). Estimates of biomass and yield were similar under both hypotheses. Model results suggest the northern stock is most likely to be below the level that would support the MSY and likely to decline further if catch levels at the level of the current TACCs are taken.

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Table 1: Reported landings (t) of gemfish by fishing year and area, by foreign licensed and joint venture vessels, 1978–79 to 1985–86. The EEZ areas (*see* figure 2 of Baird & McKoy 1988) correspond approximately to the QMA as indicated. No data are available (N/A) for the 1980–81 fishing year

EEZ area	B	C	D	E - E(A)	E(A) §	F(E)	F(W)	G	H	Total
QMA area	1 & 2	3	4	6	5	5	5	7	8 & 9	
1978–79*	87	638	0	0	342	263	65	1 093	154	2 642
1979–80*	284	369	29	18	944	352	214	303	34	2 347
1980–81*	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981–82*	0	112	5	0	321	223	361	1 063	167	2 252
1982–83*	0	13	3	0	883	135	310	458	408	2 209
1983–83†	0	92	2	0	44	100	16	1 125	11	1 391
1983–84‡	0	59	2	0	298	582	2 234	1 395	86	4 657
1984–85‡	0	29	1	3	262	758	1 204	1 317	37	3 686
1985–86‡	0	293	7	32	403	2 213	2 315	1 268	28	6 558

* 1 April–31 March.
† 1 April–30 September.
‡ 1 Oct–30 Sept.
§ Catches in EEZ area E(A) were mostly from the part of FMA 5 south of 48°30' S.

Table 2: Reported landings (t) of gemfish by Fishstock from 1983–84 to 1996–97 and actual TACs for 1986–87 to 1996–97

Fishstock	SKI 1		SKI 2		SKI 3		SKI 7		SKI 10		Total	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*	588	-	632	-	3 481	-	1 741	-	0	-	6 442§	-
1984–85*	388	-	381	-	2 533	-	1 491	-	0	-	4 793§	-
1985–86*	716	-	381	-	5 446	-	1 468	-	0	-	8 011§	-
1986–87†	773	550	896	860	2 045	2 840	1 069	1 490	0	10	4 783	5 750
1987–88†	696	632	1 095	954	1 664	2 852	1 073	1 543	0	10	4 528	5 991
1988–89†	1 023	1 139	1 011	1 179	1 126	2 922	1 083	1 577	0	10	4 243	6 827
1989–90†	1 230	1 152	1 043	1 188	1 164	3 259	932	1 609	0	10	4 369	7 218
1990–91†	1 058	1 152	949	1 188	616	3 339	325	1 653	0	10	2 948	7 342
1991–92†	1 017	1 152	1 208	1 197	287	3 339	584	1 653	0	10	3 096	7 350
1992–93†	1 292	1 152	1 020	1 230	371	3 345	469	1 663	0	10	3 152	7 401
1993–94†	1 156	1 152	1 058	1 300	75	3 345	321	1 663	0	10	2 616	7 470
1994–95†	1 031	1 152	905	1 300	160	3 355	103	1 663	0	10	2 215	7 480
1995–96†	801	1 152	789	1 300	49	3 355	81	1 663	0	10	1 720	7 480
1996–97†	965	1 152	978	1 300	58	1 500	238	900	0	10	2 240	4 862

* FSU data.

† QMS data.

§ The totals do not match those in Table 1 as some fish were not reported by area (FSU data before 1986–87).

Table 3: Spawning (SKI 1) and non-spawning (SKI 2) catch (t) of gemfish. *, assumed catch based on TACC for 1997–98

Year	SKI 1E & W	SKI 1E	SKI 1W	SKI 2
1952	5	5	0	50
1953	5	5	0	25
1954	5	5	0	60
1955	5	5	0	35
1956	5	5	0	35
1957	5	5	0	55
1958	5	5	0	30
1959	5	5	0	45
1960	5	5	0	85
1961	5	5	0	70
1962	5	5	0	60
1963	15	15	0	70
1964	15	15	0	65
1965	20	20	0	130
1966	15	15	0	140
1967	35	35	0	240
1968	40	40	0	250
1969	100	100	0	375
1970	95	95	0	400
1971	100	100	0	420
1972	130	130	0	400
1973	45	45	0	300
1974	35	35	0	230
1975	10	10	0	170
1976	30	30	0	190
1977	60	60	0	180
1978	90	90	0	240
1979	120	120	0	200
1980	140	140	0	450
1981	120	120	0	500
1982	100	100	0	320
1983	360	360	0	730
1984	588	588	0	632
1985	388	388	0	381
1986	716	716	0	381
1987	773	773	0	896
1988	696	696	0	1 095
1989	1 023	1 023	0	1 011
1990	1 230	1 230	0	1 043
1991	1 058	1 048	10	949
1992	1 017	940	77	1 208
1993	1 292	1 137	155	1 020
1994	1 156	606	550	1 058
1995	1 032	438	594	906
1996	801	485	316	789
1997	965	385	580	978
1998*	753	300	453	850
1999*	753	300	453	850

Table 4: Number of tows (n) and tonnes (t) captured in CPUE data analyses for SKI 1E, SKI 1W and SKI 2. All, all data; categorical, categorical vessel data; tcepr, trawl catch and effort processing return data

Year	SKI 1E all		SKI 1E categorical		SKI 1W all		SKI 1W tcepr		SKI 2 all		SKI 2 categorical	
	n	*t*	*n*	*t*	*n*	*t*	*n*	*t*	*n*	*t*	*n*	*t*
1988–89	139	364	125	345								
1989–90	434	954	420	916	2	1			355	676	270	528
1990–91	459	854	450	839	5	8			341	423	317	396
1991–92	486	696	454	678	30	42			550	758	514	732
1992–93	629	856	574	816	30	101	9	33	629	595	596	586
1993–94	344	494	330	484	112	440	101	290	625	527	540	456
1994–95	245	382	233	369	149	518	139	459	362	258	248	167
1995–96	412	311	344	264	192	312	215	291	353	303	280	258
1996–97	353	253	279	193	161	483	181	429	422	457	333	384

Table 5: Stepwise selection matrix for SKI 1E, all data CPUE model. Inclusion of variables above the dashed line resulted in more than 3% improvement in r^2. L*B*D, length*breadth*draught; statarea, statistical area; NA, not applicable

Variable	step 0	step 1	step 2	step 3	step 4	step 5
seasonday	9.49	NA	NA	NA	NA	NA
L*B*D	7.84	17.25	NA	NA	NA	NA
year	7.29	14.12	23.99	NA	NA	NA
statarea	6.49	15.80	20.39	26.82	NA	NA
season	5.02	12.21	19.47	26.80	28.56	NA
power	3.89	13.34	18.04	24.38	26.93	28.62
yearbuilt	3.43	12.73	17.83	24.32	26.87	28.61
tonnage	5.65	14.78	17.25	24.00	26.85	28.59
day	1.33	10.55	17.86	25.66	27.82	28.59
length overall	6.29	15.63	17.41	24.09	26.83	28.56
draught	6.49	15.90	17.25	23.99	26.82	28.57
breadth	7.91	16.91	17.62	24.13	26.83	28.57
Improvement	NA	7.76	6.74	2.84	1.74	0.05

Table 6: Stepwise selection matrix for SKI 1E, categorical vessel CPUE model. Inclusion of variables above the dashed line resulted in more than 3% improvement in r^2. L*B*D, length*breadth*draught; statarea, statistical area; NA, not applicable

Variable	step 0	step 1	step 2	step 3	step 4	step 5
vessel	14.83	NA	NA	NA	NA	NA
seasonday	10.46	23.14	NA	NA	NA	NA
year	7.36	21.26	27.3	NA	NA	NA
statarea	6.69	16.85	25.3	29.47	NA	NA
season	4.75	17.92	24.4	29.03	30.93	NA
L*B*D	10.47	15.01	23.5	27.68	29.75	31.19
yearbuilt	3.64	14.84	23.1	27.36	29.49	30.95
length overall	6.78	14.96	23.4	27.58	29.65	31.11
tonnage	7.44	15.29	23.5	27.36	29.50	30.96
day	0.65	15.34	23.4	28.11	30.15	30.94
power	6.22	15.07	23.2	27.34	29.48	30.94
Improvement	NA	8.31	4.2	2.14	1.46	0.25

Table 7: Standardised CPUE indices (*index*) and standard errors (*se*) for SKI 1E, SKI 1W and SKI 2, normalised to 1.0 in the first year of each series

Year	SKI 1E all		SKI 1E categorical		SKI 1W all		SKI 1W tcepr		SKI 2 all		SKI 2 categorical	
	index	*se*	*index*	*se*	*index*	*se*	*index*	*se*	*index*	*se*	*index*	*se*
1988–89	1.00	0.00	1.00	0.00								
1989–90	0.74	0.10	0.73	0.10	0.08	0.19			1.00	0.00	1.00	0.00
1990–91	0.63	0.08	0.57	0.08	0.97	0.97			0.80	0.10	0.92	0.13
1991–92	0.34	0.04	0.37	0.05	0.90	0.37			0.67	0.07	0.68	0.08
1992–93	0.34	0.04	0.38	0.05	1.00	0.00	1.00	0.00	0.38	0.04	0.37	0.04
1993–94	0.37	0.05	0.39	0.06	1.37	0.43	2.43	1.61	0.41	0.04	0.34	0.04
1994–95	0.26	0.04	0.27	0.04	0.90	0.28	2.66	1.74	0.27	0.03	0.22	0.03
1995–96	0.20	0.03	0.23	0.03	0.48	0.15	1.11	0.73	0.35	0.04	0.37	0.06
1996–97	0.20	0.03	0.24	0.04	0.69	0.22	0.73	1.01	0.23	0.03	0.24	0.04

Table 8: Stepwise selection matrix for SKI 2, all data CPUE model. Inclusion of variables above the dashed line resulted in more than 3% improvement in r^2. L*B*D, length*breadth*draught; statarea, statistical area; NA, not applicable

Variable	step 0	step 1	step 2	step 3	step 4
month	5.42	NA	NA	NA	NA
year	3.28	8.77	NA	NA	NA
year built	2.24	7.89	12.18	NA	NA
tonnage	1.61	7.19	11.79	13.64	NA
length overall	0.38	5.85	9.40	12.58	13.92
draught	0.35	5.74	9.70	12.29	13.74
breadth	1.54	6.88	10.07	12.67	13.85
statarea	0.01	5.49	8.83	12.22	13.65
L*B*D	0.91	6.39	10.33	12.94	13.88
power	0.78	6.16	10.43	12.66	13.64
Improvement	NA	3.35	3.41	1.46	0.29

Table 9: Stepwise selection matrix for SKI 2, categorical vessel CPUE model. Inclusion of variables above the dashed line resulted in more than 3% improvement in r^2. L*B*D, length*breadth*draught; statarea, statistical area; NA, not applicable

Variable	step 0	step 1	step 2	step 3	step 4
vessel	9.41	NA	NA	NA	NA
month	5.53	14.48	NA	NA	NA
year	3.51	13.37	19.06	NA	NA
statarea	0.16	9.76	14.96	19.43	NA
year built	3.06	9.65	14.71	19.35	19.68
tonnage	1.92	10.02	15.19	19.08	19.45
L*B*D	1.07	10.00	15.06	19.07	19.44
breadth	2.27	10.01	15.04	19.09	19.44
draught	0.61	10.31	15.46	19.07	19.43
length overall	0.53	9.62	14.65	19.10	19.46
power	0.95	9.41	14.49	19.13	19.47
Improvement	NA	5.07	4.59	0.362	0.26

Table 10 : Summary of data extracted for the full SKI 1W CPUE model

Vessel	Number of records								
	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	Total
1				4			11		15
2		2		4	6		9		21
3				2	9	1	3	8	23
4					4	9	5	18	36
5					3	14	4	12	33
6					9	5	4	14	32
7	2				8	8			18
8				2	5	6	1	6	20
9		3			7	12	8		30
10			9	2	10	13	12		46
11						2	16	17	35
12			12	6	1	1	8	3	31
13					14	11	16	14	55
14				8		10	21	13	52
15					6	3	3		12
16						1	3		4
17								11	11
18			2						2
19					1				1
20			2		8	9	3	7	29
21					9				9
22			2						2
23				2	7	11	25	12	57
24							10		10
25						17	6	13	36
26					4		10		14
27			3						3
28						13			13
29					1	3	14	5	23
30								8	8
Total	2	5	30	30	112	149	192	161	681

Table 11 : SKI 1W CPUE data, by form type

Year	Catch (kg) by form type	
	TCEPR	CELR
1989–90	730	0
1990–91	0	7921
1991–92	0	41575
1992–93	32670	68420
1993–94	289921	150080
1994–95	458630	59630
1995–96	291254	21110
1996–97	428853	53590

Table 12: Summary of data extracted for the SKI 1W, TCEPR data only, CPUE model

Vessel	No. of Records					
	1993	1994	1995	1996	1997	Total
285				16		16
286		11		9		20
307		9	2	3	11	25
316		4	11	7	20	42
324		3	14	4	16	37
327		15	5	5	18	43
333		12	10			22
337		8	12	9		29
347			2	20	23	45
356				10	3	13
359		22	18	19	17	76
360	9		10	22	16	57
442		6	3	4		13
455				3		3
529		1				1
1045				3	8	11
2022		10				10
3788			16	35	16	67
3869				13		13
3870			23	6	17	46
3903				12		12
5244			13			13
5468				15	5	20
12600					11	11
Total	9	101	139	215	181	645

Table 13 : Stepwise selection matrix for SKI 1W, all data CPUE model. Inclusion of variables above the dashed line resulted in more than 3% improvement in r^2. L*B*D, length*breadth*draught; statarea, statistical area; NA, not applicable

Variable	step 0	step 1	step 2	step 3
seasonday	21.83	NA	NA	NA
L*B*D	12.30	29.83	NA	NA
year	6.17	24.86	34.26	NA
statarea	0.08	20.91	30.12	34.49
length	8.02	25.88	30.19	34.50
draught	9.51	27.64	30.46	34.70
breadth	8.14	26.11	30.24	34.55
power	6.87	25.53	30.04	34.76
year built	3.25	22.43	30.30	34.45
crew	3.53	23.23	30.10	34.36
Improvement	NA	8.00	4.43	0.23

Table 14: Stepwise selection matrix for SKI 1W, TCEPR data only CPUE model. Inclusion of variables above the dashed line resulted in a more than 3% improvement in r^2. L*B*D, length*breadth*draught; NA, not applicable

Variable	step 0	step 1	step 2	step 3	step 4
seasonday	15.58	NA	NA	NA	NA
L*B*D	13.76	25.76	NA	NA	NA
start time	9.61	24.24	34.16	NA	NA
year	5.43	19.81	29.20	38.00	NA
depth	3.77	19.05	31.07	35.97	39.80
month	11.72	18.26	27.42	36.11	39.20
start longitude	0.78	16.75	26.67	34.77	38.62
headline height	3.56	18.53	26.09	34.44	38.12
trawl speed	0.14	15.66	28.33	36.61	39.08
trawl direction	4.32	18.12	28.63	35.83	39.47
length	10.06	22.18	26.21	34.69	38.56
draught	10.46	23.71	26.18	34.86	38.76
breadth	10.71	22.90	25.80	34.35	38.31
power	7.84	21.46	25.89	34.26	38.44
year built	2.77	17.56	26.62	35.12	38.22
crew	4.42	19.07	26.28	34.54	38.03
wind speed	0.00	15.58	25.83	34.19	38.04
wind direction	0.26	16.06	26.23	34.82	38.21
weather type	0.63	16.50	26.84	35.86	
Improvement	NA	10.18	8.40	3.84	1.80

Table 15: Standardised CPUE indices used for stock assessment modelling of SKI 1 and SKI 2. SKI 1W indices have been restandardised to 1993–94. Note that a *c.v.* of 35% was assigned for all years in the stock assessment models

	SKI 1E	SKI 1W	SKI 2
Year	Categorical vessel	Categorical vessel	All data
1988–89	1.00	–	–
1989–90	0.73	–	1.00
1990–91	0.57	–	0.92
1991–92	0.37	–	0.68
1992–93	0.38	–	0.37
1993–94	0.39	1.00	0.34
1994–95	0.27	0.66	0.22
1995–96	0.23	0.35	0.37
1996–97	0.24	0.50	0.24

Table 16. Percentage at age (PAA) and coefficients of variation (*c.v.*) for gemfish from commercial catches in SKI 1E, SKI 1W and SKI 2. M, males; F, females; *wt.c.v.*, mean weighted *c.v.* across all age classes; *n.samp* = number of samples; *n.age* = number of fish aged

Age	SKI 1(E)														SKI 1(W)				SKI 2			
	1989		1990		1991		1992		1993		1994		1997		1996		1997		1996		1997	
M	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*
2	0.0	0.00	0.0	0.00	0.0	0.00	0.2	0.73	0.0	0.00	0.0	0.00	0.2	1.28	0.0	0.00	0.0	0.00	0.0	0.00	0.2	0.64
3	1.0	0.54	7.2	0.32	0.0	0.00	4.1	0.26	0.1	1.30	1.8	0.44	0.1	1.22	0.2	1.03	0.0	0.00	0.6	0.41	1.2	0.47
4	3.4	0.23	7.0	0.29	2.1	0.47	1.7	0.34	1.4	0.32	0.0	0.00	3.4	0.22	2.5	0.31	0.2	1.23	1.9	0.26	4.9	0.22
5	19.9	0.13	15.0	0.20	10.4	0.22	5.4	0.25	3.9	0.26	5.1	0.19	4.2	0.22	18.4	0.16	1.7	0.35	54.4	0.05	18.5	0.15
6	11.5	0.22	21.4	0.15	4.5	0.43	13.8	0.19	9.9	0.23	12.0	0.22	36.1	0.09	3.8	0.41	22.0	0.10	4.2	0.22	47.4	0.08
7	37.9	0.10	12.7	0.20	22.1	0.18	19.1	0.16	16.2	0.25	15.4	0.21	6.9	0.31	6.2	0.36	5.5	0.31	5.0	0.21	4.1	0.41
8	6.9	0.27	20.8	0.16	10.9	0.27	32.6	0.12	26.8	0.17	17.8	0.21	8.7	0.27	10.9	0.28	5.2	0.31	5.7	0.20	2.8	0.48
9	12.9	0.19	4.9	0.33	33.1	0.14	7.4	0.28	25.7	0.17	4.4	0.48	15.2	0.18	12.0	0.26	16.8	0.18	4.7	0.23	8.7	0.28
10	0.8	0.65	6.6	0.28	5.2	0.40	12.0	0.21	7.2	0.29	22.0	0.19	8.1	0.27	15.6	0.21	13.8	0.20	5.8	0.20	4.0	0.48
11	1.0	0.66	0.7	1.04	6.2	0.35	1.8	0.50	7.9	0.28	6.0	0.36	7.8	0.24	6.3	0.34	15.8	0.17	2.7	0.25	3.2	0.82
12	4.1	0.29	1.2	0.68	0.5	1.01	1.9	0.44	0.4	0.72	10.3	0.27	1.1	0.58	17.4	0.20	3.9	0.41	6.4	0.19	1.6	0.71
13	0.0	0.00	2.5	0.53	3.9	0.41	0.0	0.00	0.6	0.71	2.2	0.62	5.7	0.23	1.4	0.64	10.5	0.18	0.9	0.40	2.6	0.42
14	0.0	0.00	0.0	0.00	0.0	0.00	0.1	1.41	0.0	0.00	2.6	0.50	0.5	0.71	3.9	0.38	1.5	0.59	5.8	0.20	0.0	0.00
15	0.5	0.87	0.0	0.00	0.6	1.10	0.0	0.00	0.0	0.00	0.3	1.39	1.2	0.44	0.0	0.00	2.9	0.46	0.6	0.42	0.8	0.90
16	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.8	0.58	0.4	1.00	0.0	0.00	0.6	0.41	0.0	0.00
17	0.0	0.00	0.0	0.00	0.5	1.05	0.0	0.00	0.0	0.00	0.1	0.71	0.2	1.02	0.4	1.06	0.0	0.00	0.2	0.48	0.0	0.00
18	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.5	1.02	0.2	0.58	0.5	0.84	0.0	0.00

Table 16 *continued*

Age														SKI 1(E)				SKI 1(W)				SKI 2
		1989		1990		1991		1992		1993		1994		1997		1996		1997		1996		1997
F	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*	PAA	*c.v.*
2	0.0	0.00	0.7	0.75	0.0	0.00	2.3	0.31	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
3	0.3	2.17	3.2	0.35	0.0	0.00	5.8	0.19	0.0	0.00	2.5	0.45	0.2	1.08	0.3	1.11	0.1	1.32	0.4	0.43	1.1	0.31
4	0.4	0.70	1.3	0.53	1.1	0.62	5.3	0.19	0.2	0.50	0.4	0.84	2.1	0.25	1.1	0.77	0.1	1.56	1.2	0.33	2.5	0.36
5	7.0	0.26	2.3	0.42	2.3	0.45	3.8	0.29	1.2	0.46	0.3	1.20	1.4	0.36	7.9	0.23	0.6	0.63	42.9	0.05	16.9	0.15
6	5.1	0.34	15.9	0.20	2.7	0.42	4.7	0.31	5.7	0.27	2.2	0.40	22.4	0.11	5.6	0.33	20.3	0.11	2.8	0.22	44.5	0.07
7	33.4	0.12	11.4	0.24	18.3	0.21	10.1	0.22	13.7	0.18	11.0	0.26	5.4	0.31	10.3	0.25	4.3	0.35	4.8	0.19	4.1	0.33
8	10.1	0.23	35.7	0.13	12.8	0.27	19.8	0.16	14.0	0.23	11.2	0.28	5.9	0.28	14.5	0.20	7.2	0.27	6.5	0.15	4.5	0.27
9	22.7	0.17	8.3	0.28	27.3	0.18	15.7	0.16	29.5	0.15	6.7	0.40	10.3	0.22	10.3	0.24	14.9	0.18	2.4	0.24	8.0	0.19
10	1.3	0.60	11.4	0.25	8.1	0.33	15.7	0.18	7.0	0.33	27.7	0.17	8.8	0.23	9.7	0.26	8.4	0.26	6.7	0.15	2.6	0.32
11	8.2	0.26	0.3	1.08	16.6	0.23	3.7	0.35	18.4	0.18	11.4	0.25	12.7	0.18	9.2	0.26	12.1	0.21	2.8	0.23	6.5	0.22
12	7.3	0.30	5.4	0.38	3.5	0.48	9.8	0.21	2.1	0.46	18.8	0.19	5.6	0.29	15.8	0.21	5.2	0.30	14.2	0.10	1.0	0.58
13	2.1	0.42	1.2	0.73	5.1	0.36	1.7	0.52	7.2	0.28	0.6	0.88	18.2	0.13	3.6	0.43	18.9	0.16	3.2	0.21	4.8	0.28
14	1.6	0.54	2.9	0.42	0.6	0.92	1.3	0.64	0.8	0.61	5.0	0.35	1.5	0.44	7.4	0.31	2.9	0.39	8.2	0.16	1.1	0.63
15	0.0	0.00	0.0	0.00	0.5	0.84	0.3	1.08	0.2	1.08	0.3	1.18	4.9	0.30	0.2	1.29	3.4	0.35	0.3	0.64	1.8	0.43
16	0.6	0.55	0.0	0.00	0.0	0.00	0.0	0.00	0.3	0.89	1.9	0.67	0.3	1.03	2.1	0.50	0.9	0.76	2.7	0.24	0.1	1.80
17	0.0	0.00	0.0	0.00	0.6	1.31	0.0	0.00	0.0	0.00	0.1	1.89	0.0	0.00	1.7	0.63	0.0	0.00	0.0	36.34	0.5	0.79
18	0.0	0.00	0.0	0.00	0.6	0.93	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.4	1.20	0.7	0.47	0.4	0.62	0.0	0.00
19	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.4	0.98	0.0	0.00	0.0	0.00	0.3	0.70	0.0	0.00
wt. c.v.		0.19		0.23		0.26		0.20		0.22		0.26		0.20		0.27		0.21		0.13		0.20
n.samp		9		7		8		9		10		8		15		5		14		21		11
n.age		311		375		295		340		337		321		419		373		404		698		399

Table 17: Von Bertalanffy growth parameters (with 95% confidence intervals) for northern gemfish, by sex and area, from otolith readings and length-based estimates of juvenile growth

	Area	*n*	L_∞ (cm) range	*k* range	t_0 (yrs) range
Female	SKI 1E	1 016	108.5	0.167	–0.71
			106.3–110.7	0.155–0.179	–0.93 to –0.50
	SKI 2	733	103.4	0.231	–0.10
			102.3–104.5	0.220–0.243	–0.24 to 0.05
	SKI 1W	429	103.4	0.209	–0.37
			101.7–105.1	0.194–0.224	–0.57 to –0.18
	All areas	2 058	105.0	0.194	–0.55
			103.8–106.1	0.185–0.204	–0.72 to –0.38
Male	SKI 1E	1 082	88.4	0.235	–0.54
			87.1–89.7	0.219–0.250	–0.73 to –0.35
	SKI 2	483	90.8	0.287	0.00
			89.5–92.0	0.269–0.306	–0.18 to 0.19
	SKI 1W	468	86.3	0.295	–0.11
			85.3–87.2	0.276–0.315	–0.28 to 0.05
	All areas	1 913	87.4	0.266	–0.35
			86.7–88.2	0.252–0.280	–0.52 to –0.18

Table 18: Mean length at age for SKI 1E and SKI 1W gemfish sampled in 1997 (where $n \geq 5$). sd, standard deviation

	Male				Female			
	SKI 1E		SKI 1W		SKI 1E		SKI 1W	
Age	Mean	sd	Mean	sd	Mean	sd	Mean	sd
4	62.1	3.16	65.4	3.45	–		–	
5	72.0	3.33	72.2	2.85	79.0	3.54	78.8	2.95
6	74.8	3.31	76.7	3.20	82.9	4.65	83.0	3.62
7	77.5	4.07	80.3	2.92	84.1	3.33	82.9	3.87
8	80.4	4.26	80.4	4.50	85.8	3.42	87.8	4.53
9	83.2	4.30	81.5	3.84	90.2	6.29	93.4	5.90
10	85.2	3.81	83.8	4.26	94.6	4.63	95.7	5.50
11	86.7	4.04	84.8	6.52	95.5	7.80	96.8	3.42
12	89.1	3.16	86.1	3.57	97.8	4.79	97.6	4.69
13	–		–		102.3	3.77	101.5	4.27

Table 19: Base case and sensitivity input parameters for the MIAEL model for SKI 1 and 2

Parameter	Fishstock	Base case	Sensitivity
Steepness	SKI 1, 2	0.9	0.75
	SKI 1E,2	0.9	Nil
Recruitment variability	SKI 1, 2; SKI 1E,2	1.0	Nil
Proportion spawning	SKI 1, 2; SKI 1E,2	0.95	Nil
M	SKI 1, 2	0.25	0.2, 0.3
	SKI 1E,2	0.25	Nil
Maximum exploitation (r_{max}) pre-spawning, spawning	SKI 1, 2; SKI 1E,2	0.3, 0.5	Nil
Minimum exploitation when largest catch (r_{mmx})	SKI 1, 2	0.01	0.03
	SKI 1E,2	0.01	Nil
Spawning selectivity (age 3-8)	SKI 1, 2; SKI 1E,2	1.0	Nil

Table 20: Proportion at age (of the total number of fish per year) for male and female gemfish used in the stock assessment modelling. Data are presented for both the SKI 1, 2 and SKI 1E, 2 models, with the area from which the data were collected

Model	1,2 1E,2	1,2 1E,2	1,2 1E,2	1,2 1E,2	1,2 1E,2	1,2 1E,2	1,2	1,2	1E,2	1,2 1E,2	1,2 1E,2
Area	1E	1E	1E	1E	1E	1E	1W	1E+W	1E	2	2
Year	1989	1990	1991	1992	1993	1994	1996	1997	1997	1996	1997
Male age											
3	0.005	0.033	0.001	0.022	0.001	0.012	0.001	0.001	0.001	0.008	0.021
4	0.018	0.032	0.011	0.009	0.007	0.001	0.015	0.006	0.019	0.234	0.079
5	0.104	0.068	0.056	0.028	0.019	0.032	0.110	0.014	0.024	0.018	0.202
6	0.060	0.097	0.024	0.073	0.050	0.076	0.023	0.156	0.209	0.022	0.018
7	0.198	0.058	0.118	0.101	0.081	0.097	0.037	0.037	0.040	0.025	0.012
8	0.036	0.094	0.058	0.172	0.134	0.113	0.065	0.043	0.050	0.020	0.037
9	0.068	0.022	0.176	0.039	0.129	0.028	0.071	0.098	0.088	0.025	0.017
10	0.004	0.030	0.028	0.063	0.036	0.139	0.093	0.067	0.047	0.012	0.014
11	0.005	0.003	0.033	0.009	0.040	0.038	0.038	0.073	0.045	0.027	0.007
12	0.022	0.005	0.003	0.010	0.002	0.065	0.104	0.017	0.006	0.004	0.011
13	0.001	0.011	0.020	0.001	0.003	0.014	0.008	0.051	0.033	0.025	0.001
14	0.001	0.001	0.001	0.001	0.001	0.016	0.023	0.006	0.003	0.003	0.004
15	0.003	0.001	0.003	0.001	0.001	0.002	0.001	0.012	0.007	0.003	0.001
Female age											
3	0.001	0.018	0.001	0.027	0.001	0.009	0.001	0.001	0.001	0.007	0.014
4	0.002	0.007	0.005	0.025	0.001	0.002	0.004	0.003	0.009	0.244	0.097
5	0.033	0.013	0.011	0.018	0.006	0.001	0.032	0.003	0.006	0.016	0.255
6	0.024	0.087	0.012	0.022	0.028	0.008	0.022	0.079	0.095	0.027	0.024
7	0.159	0.062	0.086	0.048	0.068	0.040	0.042	0.022	0.023	0.037	0.026
8	0.048	0.195	0.060	0.094	0.070	0.041	0.059	0.028	0.025	0.014	0.046
9	0.108	0.045	0.128	0.074	0.147	0.025	0.042	0.055	0.044	0.038	0.015
10	0.006	0.062	0.038	0.074	0.035	0.102	0.039	0.039	0.037	0.016	0.037
11	0.039	0.002	0.078	0.017	0.092	0.042	0.037	0.059	0.054	0.081	0.006
12	0.035	0.030	0.016	0.046	0.010	0.069	0.064	0.023	0.024	0.018	0.027
13	0.010	0.006	0.024	0.008	0.036	0.002	0.014	0.074	0.077	0.047	0.006
14	0.008	0.016	0.003	0.006	0.004	0.018	0.030	0.009	0.006	0.002	0.010
15	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.018	0.021	0.016	0.001

Table 21: Estimated or assumed (*) year class strengths for the two stock hypotheses base case (base) runs and sensitivity tests for SKI 1 and 2 from the MIAEL model

Year class	SKI 1, 2				SKI 1E, 2
	base & $r_{mmx} = 0.03$	Steepness = 0.75	$M = 0.2$	$M = 0.3$	base
1977	1.00*	1.00*	1.00*	1.00*	1.00*
1978	1.55	1.55	1.66	1.45	1.52
1979	0.12	0.12	0.12	0.11	0.13
1980	4.88	4.90	5.41	4.42	4.58
1981	0.46	0.46	0.51	0.41	0.64
1982	7.45	7.50	8.45	6.57	6.65
1983	1.40	1.42	1.61	1.21	1.23
1984	4.96	5.06	5.70	4.31	4.27
1985	1.23	1.25	1.45	1.04	0.99
1986	1.95	1.98	2.32	1.63	1.63
1987	1.62	1.63	1.96	1.35	1.42
1988	1.07	1.06	1.31	0.88	0.81
1989	0.76	0.74	0.93	0.61	0.61
1990	0.19	0.19	0.24	0.15	0.15
1991	3.50	3.40	4.50	2.72	3.29
1992	0.14	0.14	0.17	0.11	0.31
1993	0.22	0.22	0.28	0.18	0.66
1994	0.09	0.09	0.11	0.07	0.07
1995	1.00*	1.00*	1.00*	1.00*	1.00*
1996	1.00*	1.00*	1.00*	1.00*	1.00*
1997	1.00*	1.00*	1.00*	1.00*	1.00*
1998	1.00*	1.00*	1.00*	1.00*	1.00*

Table 22: Estimated maturity ogive for the two stock hypotheses base case (base) runs and sensitivity tests for SKI 1 and 2 from the MIAEL model. (Note that these figures are expressed as the proportion of remaining immature fish in each age group which will mature)

						SKI 1, 2		SKI 1E, 2
Age	base & steepness = 0.75		$M = 0.2$		$M = 0.3$		base	
	Male	Female	Male	Female	Male	Female	Male	Female
2	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02
3	0.04	0.01	0.04	0.01	0.03	0.01	0.03	0.01
4	0.22	0.03	0.23	0.03	0.21	0.03	0.27	0.02
5	0.55	0.10	0.57	0.10	0.52	0.11	0.40	0.10
6	0.99	0.55	0.99	0.57	0.99	0.56	0.99	0.43
7	0.91	0.50	0.99	0.50	0.99	0.50	0.99	0.50
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 23: Estimated home selectivity ogive for the two stock hypotheses base case runs and sensitivity tests for SKI 1 and 2 from the MIAEL model

						SKI 1, 2		SKI 1E, 2
Age	base & steepness = 0.75		$M = 0.2$		$M = 0.3$		base	
	Male	Female	Male	Female	Male	Female	Male	Female
1	0.05	0.01	0.05	0.01	0.03	0.01	0.05	0.01
2	0.50	0.01	0.50	0.01	0.50	0.01	0.50	0.01
3	0.50	0.30	0.52	0.31	0.48	0.30	0.13	0.10
4	0.76	0.49	0.74	0.48	0.77	0.52	0.43	0.32
5	1.35	1.03	1.26	1.03	1.44	1.10	0.95	0.62
6	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
7	1.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80
8	1.00	1.03	1.00	0.97	1.00	1.13	1.00	0.80

Table 24: Least squares (LS) and bestk estimates of biomass and MIAEL estimates of p, biomass (MIAEL) and information indices (Info.), for alternate stock hypotheses and sensitivity runs. All biomass estimates are in tonnes. SKI 1E refers to SKI 1 with the catch west of North Cape removed. Steep. = steepness parameter in the Beverton & Holt recruitment relationship, r_{mmx} = minimum exploitation rate when the largest catch was taken. Biomass estimates are: spawning season virgin biomass (B_0), mid-spawning season mature biomass for 1997–98 (B_{mid98}), and 1998–99 (B_{mid99}), and 1999 beginning of year total biomass (B_{beg99}). MIAEL estimates of B_{mid98} and B_{mid99} are also expressed as a percentage of virgin biomass (% B_0)

Estimate	Stock	Run	B_{min} - B_{max}	LS	bestk	p	MIAEL	Info. (%)	% B_0
B_0	SKI 1, 2	**Base case**	**6 923– 41 056**	**7 611**	**14 823**	**0.29**	**12 731**	**21**	
		Steep.=0.75	6 923–41 212	7 750	14 843	0.29	12 786	22	
		r_{mmx} = 0.03	6 923–16 600	7 611	10 323	0.42	9 184	31	
		M = 0.2	7 027–42 606	7 388	15 166	0.78	9 099	22	
		M = 0.3	7 105–45 699	8 586	15 659	0.22	14 103	29	
	SKI 1 E,2	**Base case**	**6 142–43 091**	**7 076**	**13 955**	**0.21**	**12 524**	**17**	
B_{mid98}	SKI 1, 2	**Base case**	**1 171–59 738**	**2 468**	**4 697**	**0.28**	**4 072**	**29**	32
		Steep.=0.75	949–60 607	2 526	4 008	0.29	3 578	33	28
		r_{mmx} = 0.03	1 029–18 166	2 468	3 132	0.43	2 846	43	31
		M = 0.2	1 145–76 792	2 037	4 888	0.44	3 634	21	40
		M = 0.3	1 113–53 632	3 246	4 404	0.28	4 080	31	29
	SKI 1 E,2	**Base case**	**621–57 794**	**2 228**	**2 846**	**0.21**	**2 716**	**27**	22
B_{beg99}	SKI 1, 2	**Base case**	**3 338–80 885**	**5 150**	**11 098**	**0.29**	**9 379**	**29**	
		Steep.=0.75	2 905–82 261	5 182	10 068	0.30	8 602	31	
		r_{mmx} = 0.03	3 135–26 034	5 150	7 545	0.41	6 553	38	
		M = 0.2	2 650–95 393	3 817	9 767	0.33	7 804	16	
		M = 0.3	4 226–82 349	7 541	13 229	0.29	11 579	28	
	SKI 1 E,2	**Base case**	**2 780–84 616**	**5 445**	**9 818**	**0.22**	**8 895**	**25**	
B_{mid99}	SKI 1, 2	**Base case**	**449–52 527**	**1 303**	**2 152**	**0.26**	**1 928**	**31**	15
		Steep.=0.75	332–52 809	1 356	1 694	0.27	1 601	33	13
		r_{mmx} = 0.03	373–15 256	1 303	1 419	0.35	1 379	34	15
		M = 0.2	434–69 261	953	2 215	0.28	1 867	14	21
		M = 0.3	440–45 186	1 958	2 058	0.25	2 034	28	14
	SKI 1 E,2	**Base case**	**253–52 312**	**1 656**	**1 355**	**0.22**	**1 422**	**34**	11

Table 25: Estimates of B_{MCY} (as % of B_0), MCY(as %B_0) and MCY (t) and information indices (Info.), from the MIAEL model for base case assessments (SKI 1, 2 and SKI 1E, 2). SKI 1E refers to SKI 1 with the catch west of North Cape removed.

Fishstock	B_{MCY} (% B_0)	MCY (% B_0)	MCY range	MCY	Info. (%)
SKI 1, 2	57.1	6.7	460 – 2 750	850	21
SKI 1E,2	57.4	6.7	410 – 2 890	840	17

Table 26: Estimates of B_{MAY}, MAY(as %B_0) and CAY (t)) and information indices (Info.), from the MIAEL model for base case assessments (SKI 1, 2 SKI 1E, 2). SKI 1E refers to SKI 1 with the catch west of North Cape removed.

Fishstock	B_{MAY} (% B_0)	MAY (% B_0)	CAY range	CAY	Info. (%)
SKI 1, 2	35.4	10.0	350 – 8 460	980	29%
SKI 1E,2	34.9	10.2	290 – 8 880	930	25%

Table 27: Input parameters and sensitivity tests for the sSPA model. –, not estimated

Parameter	Base case	Sensitivity
M	0.25	0.2, 0.3
Weighting on proportion-at-age data	10	1, 100
Proportion-at-age data SKI 1E+W	1989–1997	–
Proportion-at-age data SKI 2	1996–1997	–
SKI 1E CPUE indices	1989–1997	–
SKI 2 CPUE indices	1990–1997	–
CPUE *c.v.*	0.3	–
Years used in analysis	1989–1997	1951–1997

Table 28: Estimates of B_0, B_{mid89}, B_{mid98}, B_{beg99} and B_{mid99} and their 90% confidence intervals (CI) from the sSPA model. Biomass estimates are given as tonnes. –, not estimated

	B_0	B_{mid89}	B_{mid98}	B_{beg99}	B_{mid99}
Base case estimate	**–**	**11 200**	**2 250**	**6 240**	**1 490**
90% CI	–	8 100–16 900	380–7 690	1 640–13 700	0–7 000
Equilibrium model	12 300	11 200	2 300	7 200	1 700

Table 29: Selectivity ogives for the SKI 1 and SKI 2 fisheries.

Age	SKI 1		SKI 2	
	Base case	Equilibrium model	Base case	Equilibrium model
3	0.04	0.04	0.14	0.07
4	0.07	0.06	0.21	0.17
5	0.16	0.16	1.00	1.00
6	0.32	0.31	0.96	0.97
7	0.72	0.70	1.00	1.00
8	1.00	1.00	1.00	1.00

Table 30: Estimated or assumed (*) year class strengths for base case runs using age frequency data for SKI 1, 2 from the sSPA base case assessment and equilibrium models

Year class	SKI 1, 2 base case	SKI 1, 2 equilibrium
1977		1.00*
1978		1.09
1979		0.24
1980		2.17
1981		0.74
1982		2.82
1983		0.99
1984		2.13
1985		0.79
1986	2.07	0.97
1987	1.39	0.70
1988	1.20	0.58
1989	0.61	0.29
1990	0.30	0.17
1991	2.73	2.68
1992	0.51	0.36
1993	0.19	0.26
1994	0.01	0.00
1995	1.00*	1.00*
1996	1.00*	1.00*
1997	1.00*	1.00*
1998	1.00*	1.00*

Table 31: Sensitivity of sSPA estimates of B_0, B_{mid89}, B_{mid98}, B_{beg99} and B_{mid99} to alternate model assumptions for northern gemfish (SKI 1, 2). Proportion-at-age weightings of 1 and 100 equate to *c.v.*s of 200% and 20%, respectively. 100 equates to a *c.v.* of 20%. Biomass estimates are given in tonnes. –, not estimated

Model run	B_0	B_{mid89}	B_{mid98}	B_{beg99}	B_{mid99}
Base case	–	**11 200**	**2 250**	**6 240**	**1 490**
$M = 0.20$	–	7 400	1 160	3 600	250
$M = 0.30$	–	11 500	3 180	9 700	2 800
Proportion-at-age weighting = 1	–	15 900	3 590	8 650	3 650
Proportion-at-age weighting = 100	–	9 100	1 600	5 000	760
Equilibrium model	12 300	11 200	2 300	7 200	1 700

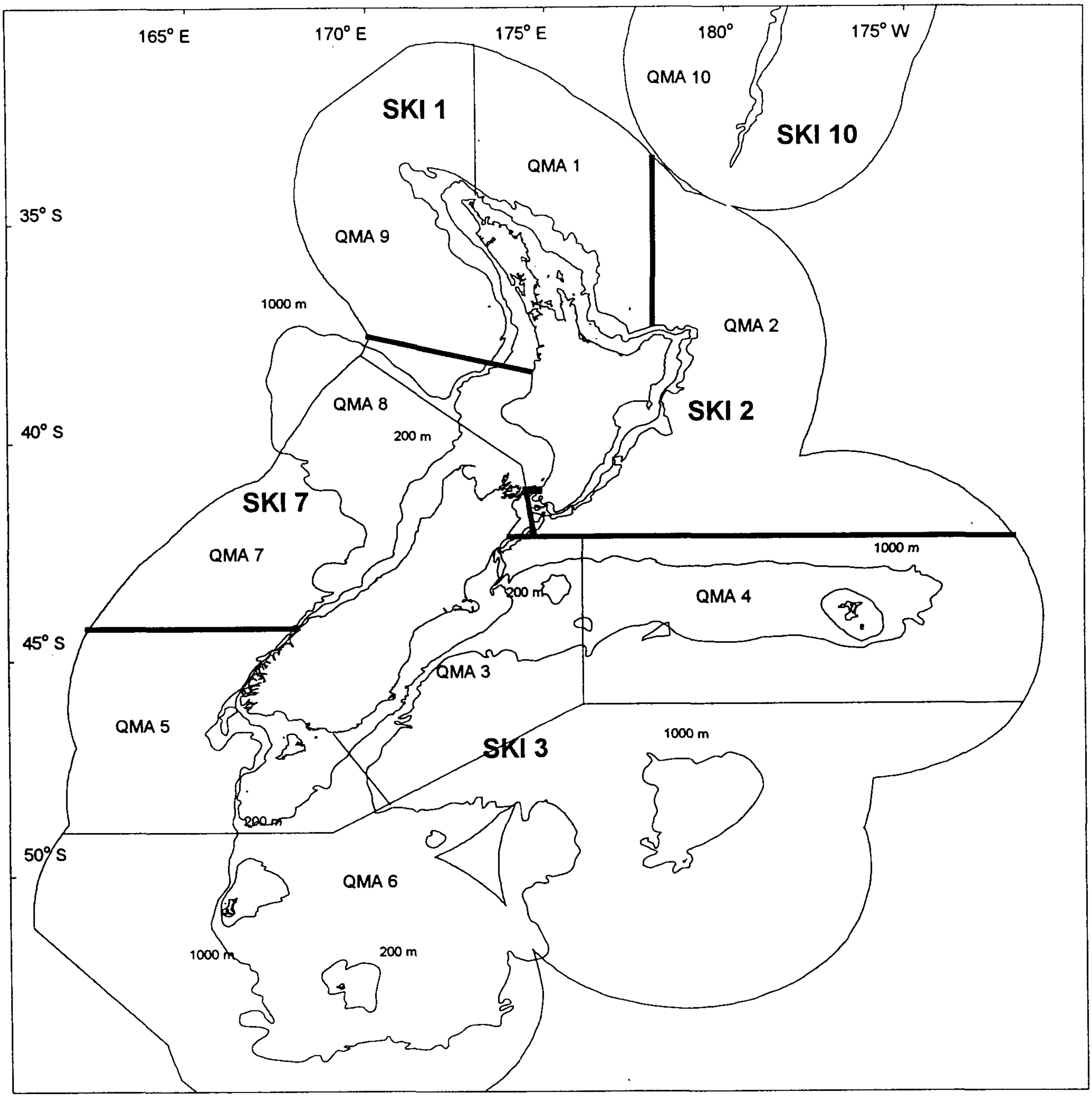


Figure 1: Map of the New Zealand 200 mile Exclusive Economic Zone (EEZ), Quota Management Areas (QMA), and gemfish Fishstock areas (**SKI**)

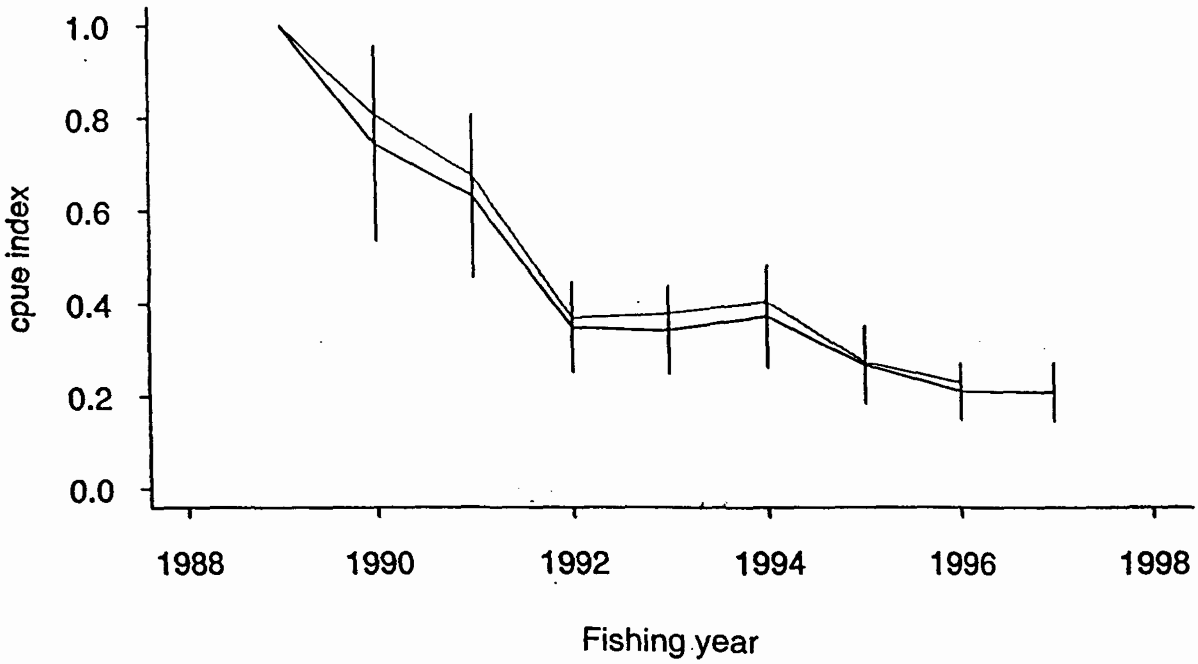


Figure 2: Comparison of the CPUE index for the 1998 SKI 1 E all vessel model with the index from the 1997 model.

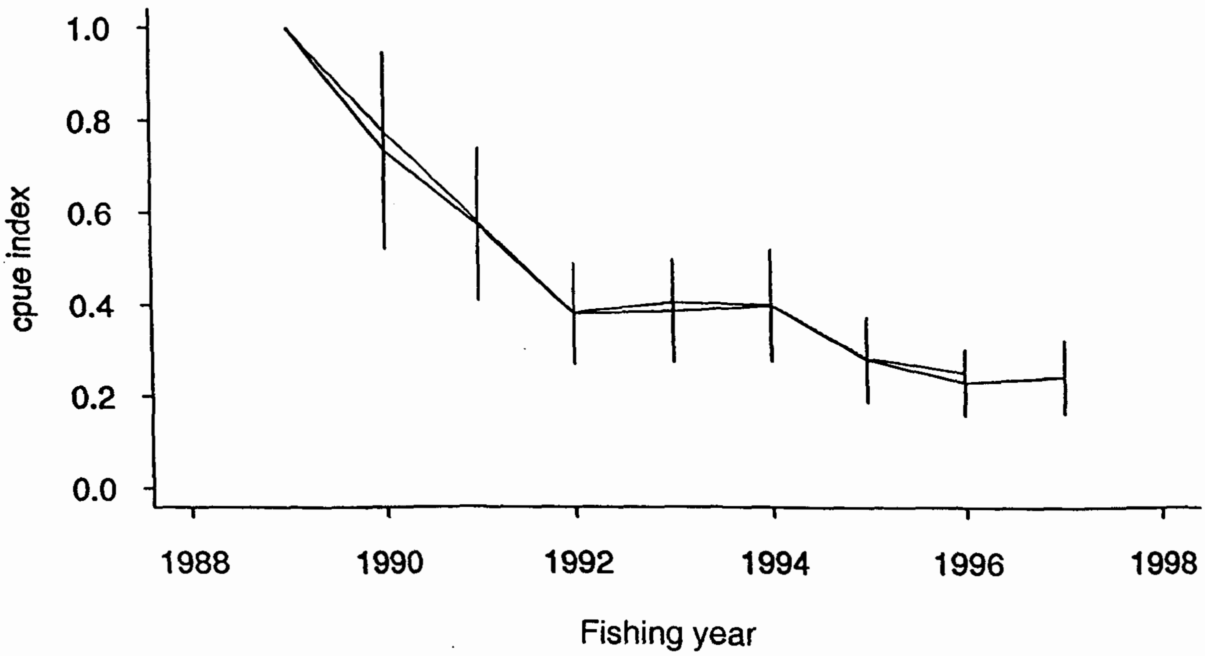


Figure 3: Comparison of the CPUE index for the 1998 SKI 1 E categorical vessel model with the index from the 1997 model.

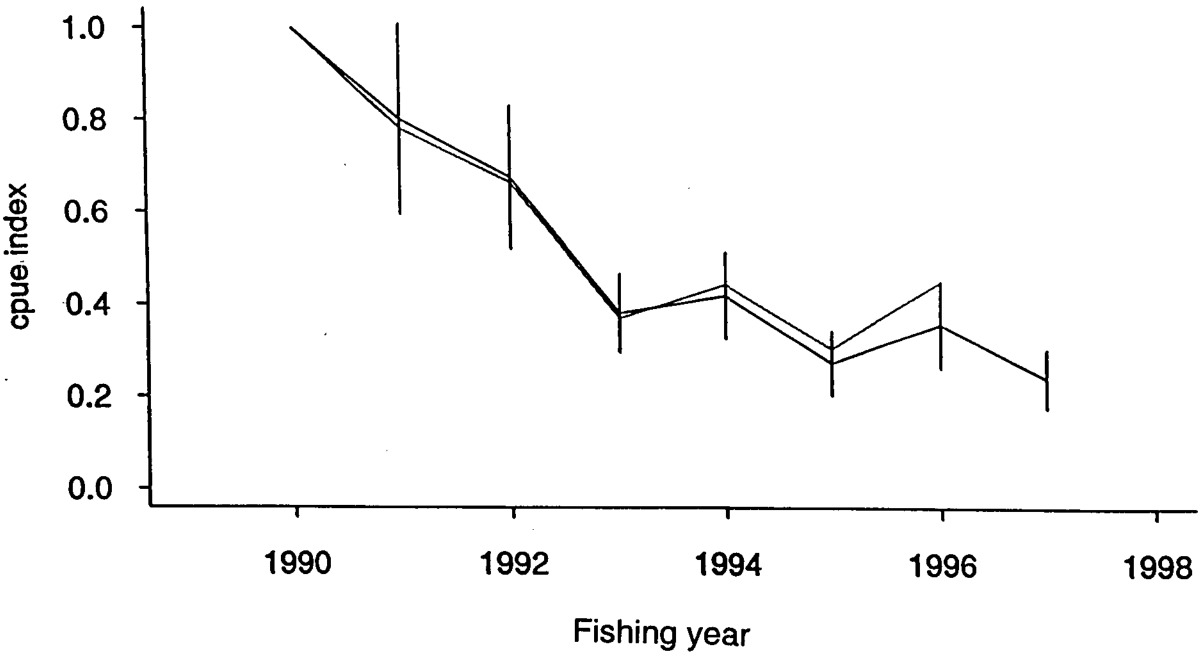


Figure 4: Comparison of the CPUE index for the 1998 SKI 2 all vessel model with the index from the 1997 model.

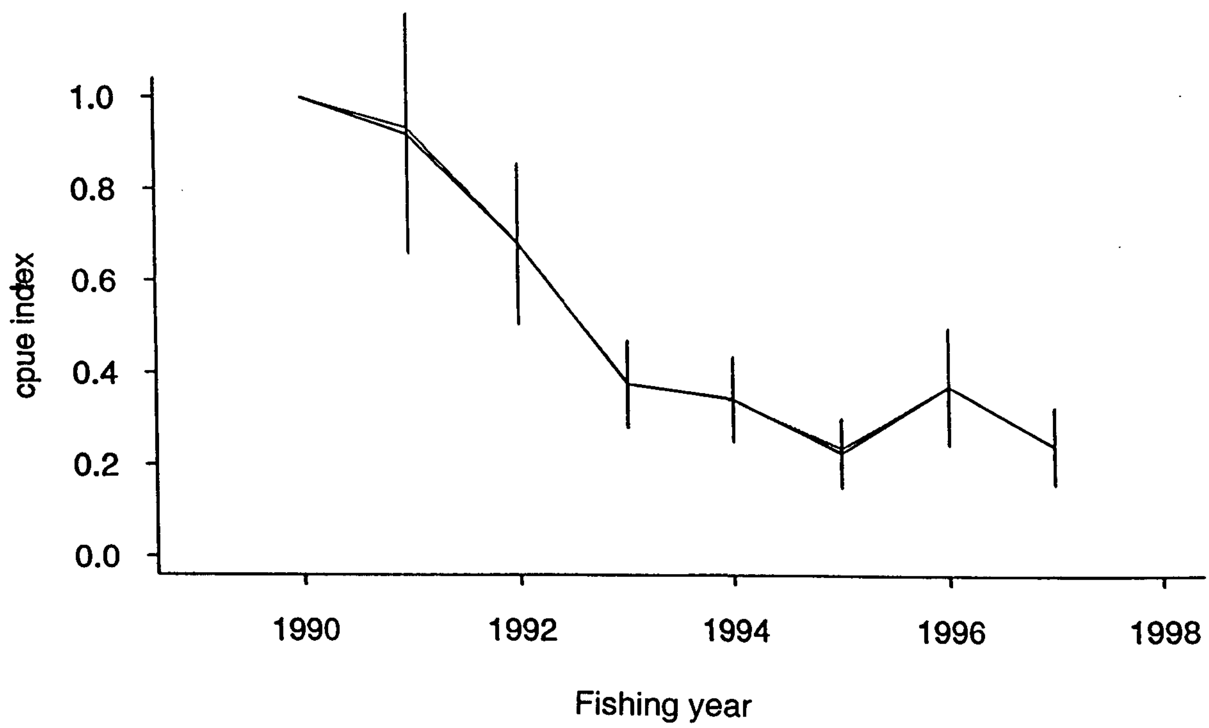


Figure 5: Comparison of the CPUE index for the 1998 SKI 2 categorical vessel model with the index from the 1997 model.

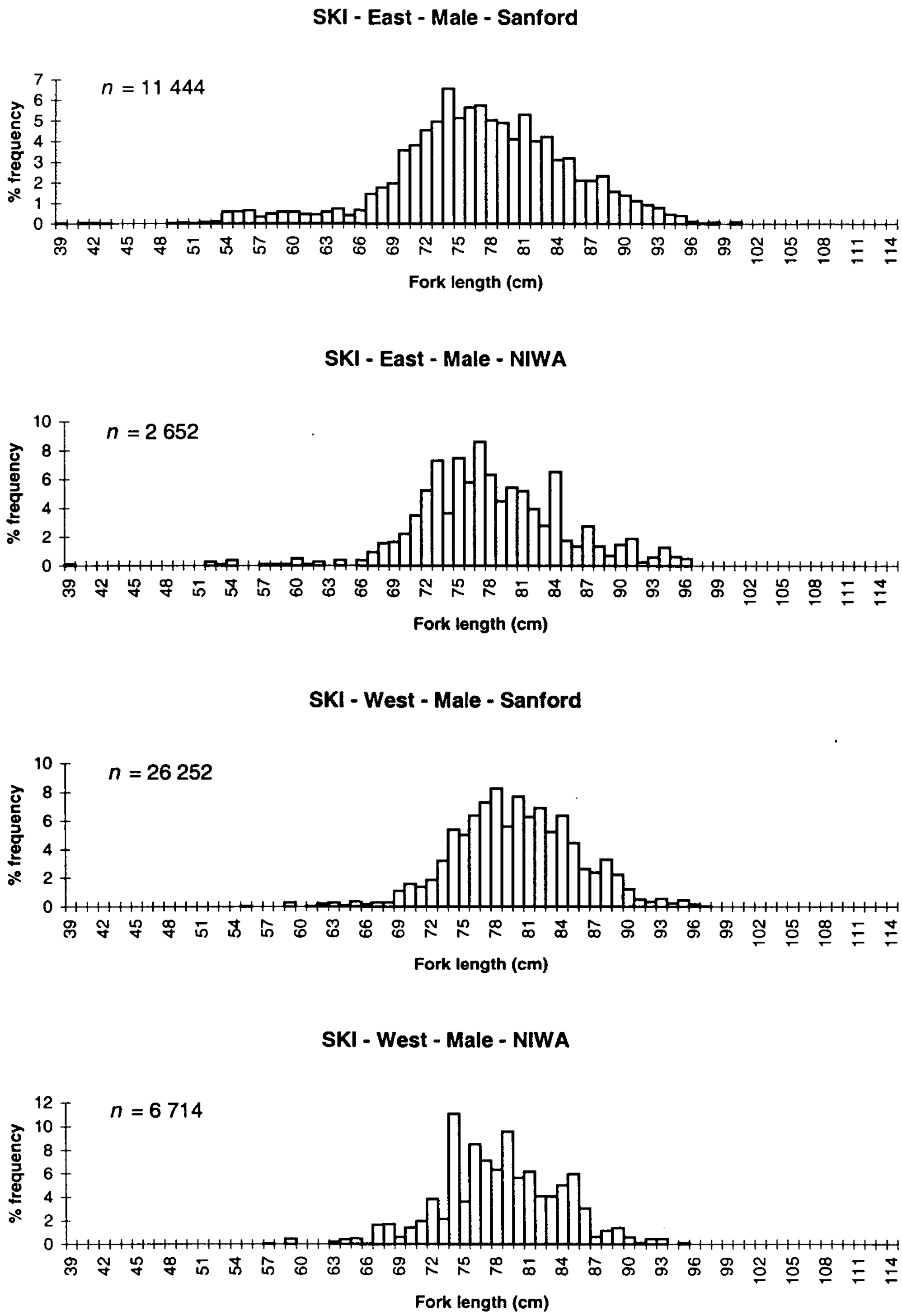


Figure 6: Scaled male length frequencies for SKI 1E & W from NIWA and Sanford catch sampling 1996–97. *n*, number of fish measured scaled to percentage sampled.

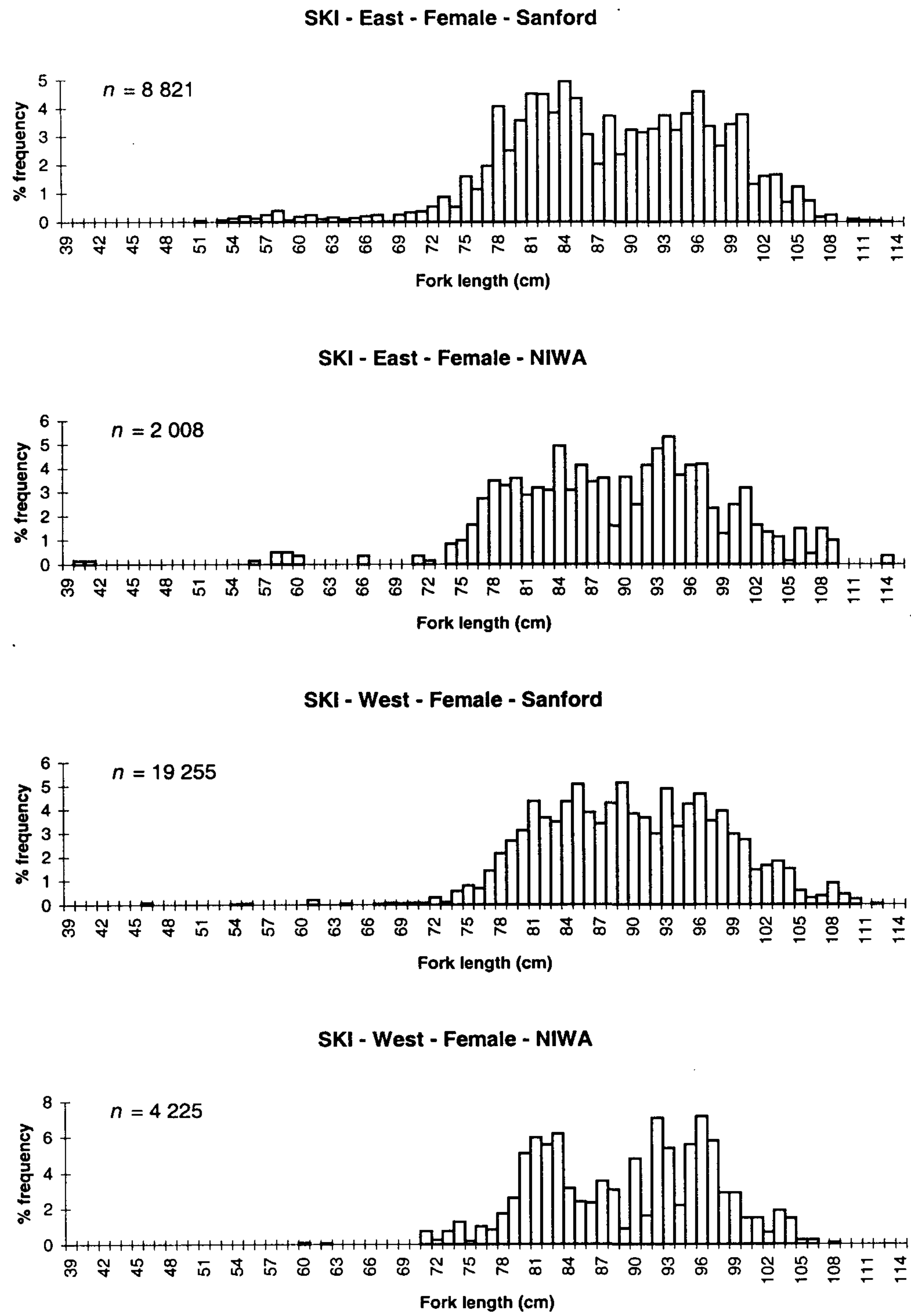


Figure 7: Scaled female length frequencies for SKI 1E & W from NIWA and Sanford catch sampling 1996–97. *n*, number of fish measured scaled to percentage sampled.

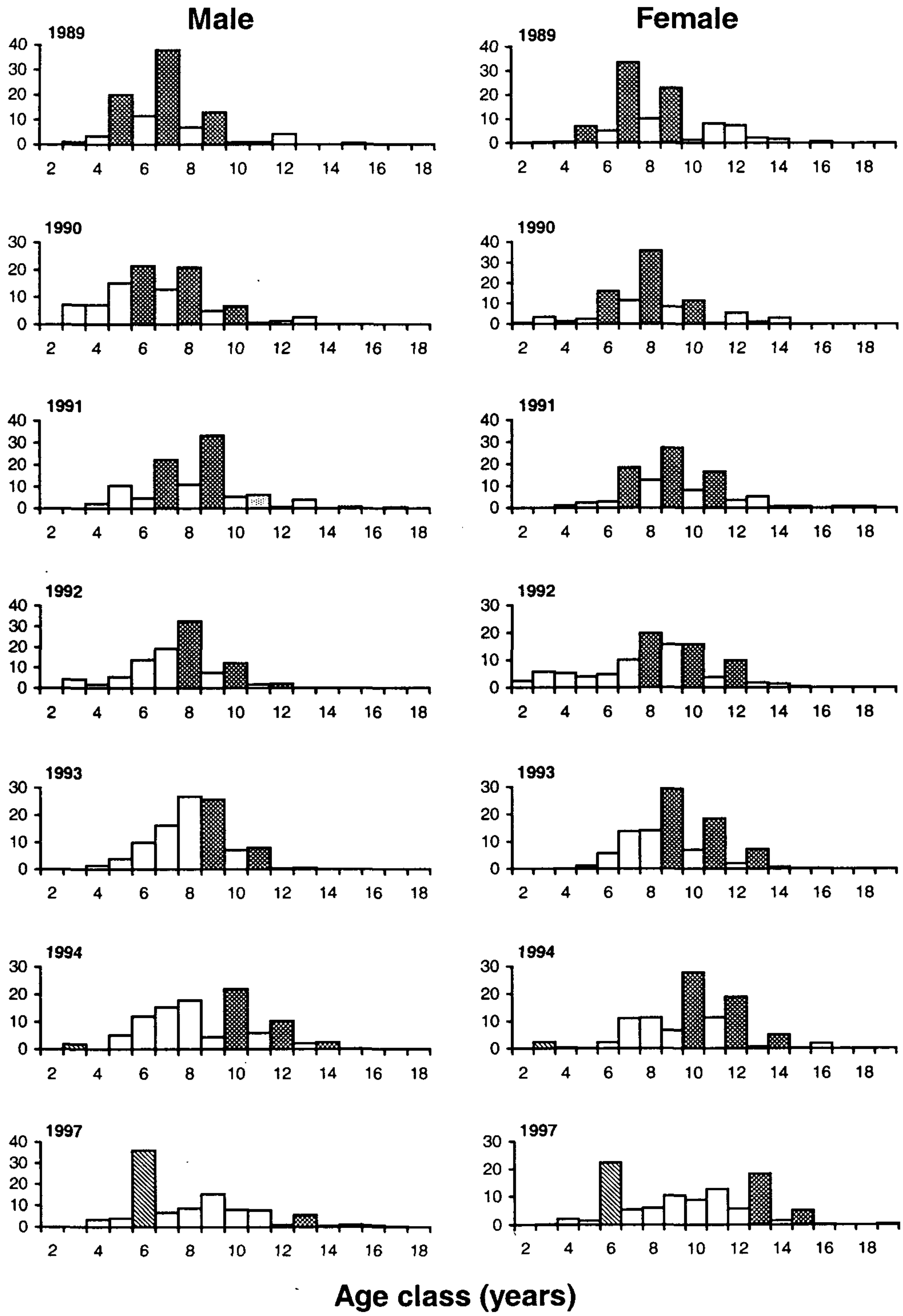


Figure 8: Age-frequency distributions, by sex, for the sampled catch of gemfish from SKI 1E, from the 1989 (1988–89) to 1997 (1996–97) seasons. Similarly shaded bars represent individual strong year classes.

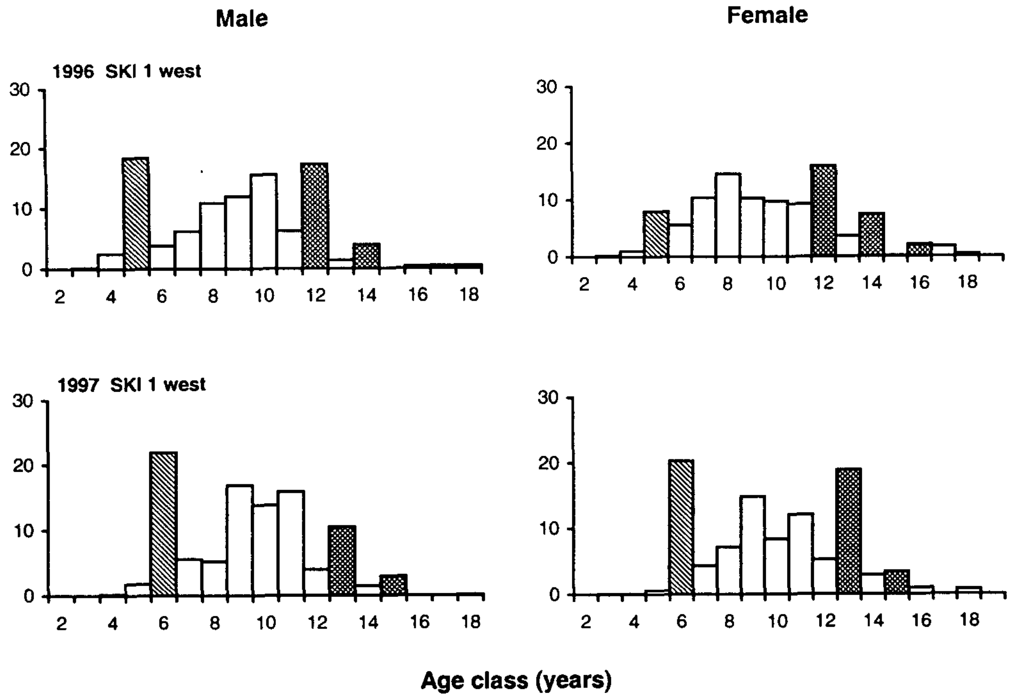


Figure 9: Age-frequency distributions, by sex, for the sampled catch of gemfish from SKI 1W, from the 1996 (1995–96) and 1997 (1996–97) seasons. Similarly shaded bars represent individual strong year classes.

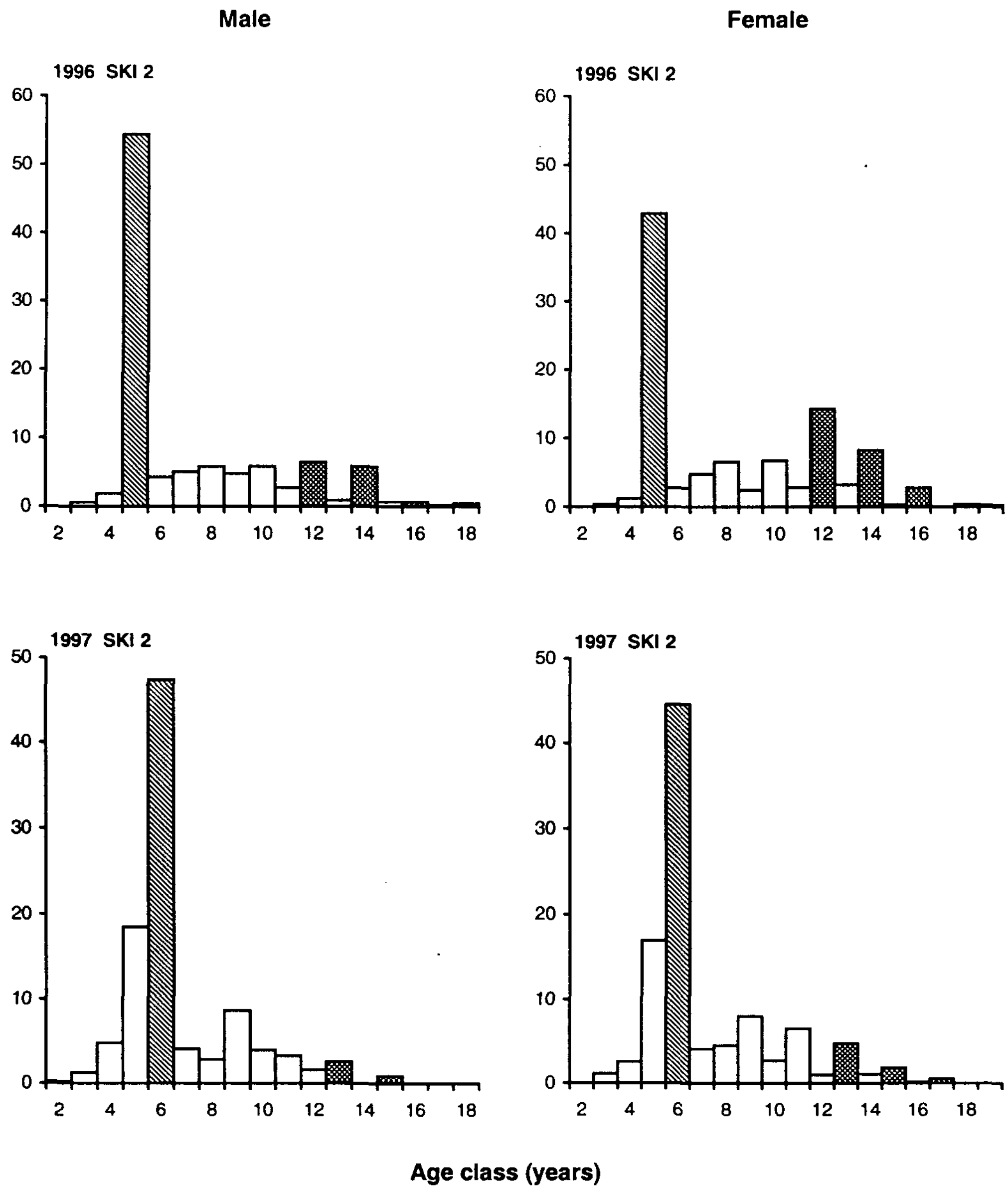


Figure 10: Age-frequency distributions, by sex, for the sampled catch of gemfish from SKI 2, from 1996 (1995–96) and 1997 (1996–97) seasons. Similarly shaded bars represent individual strong year classes.

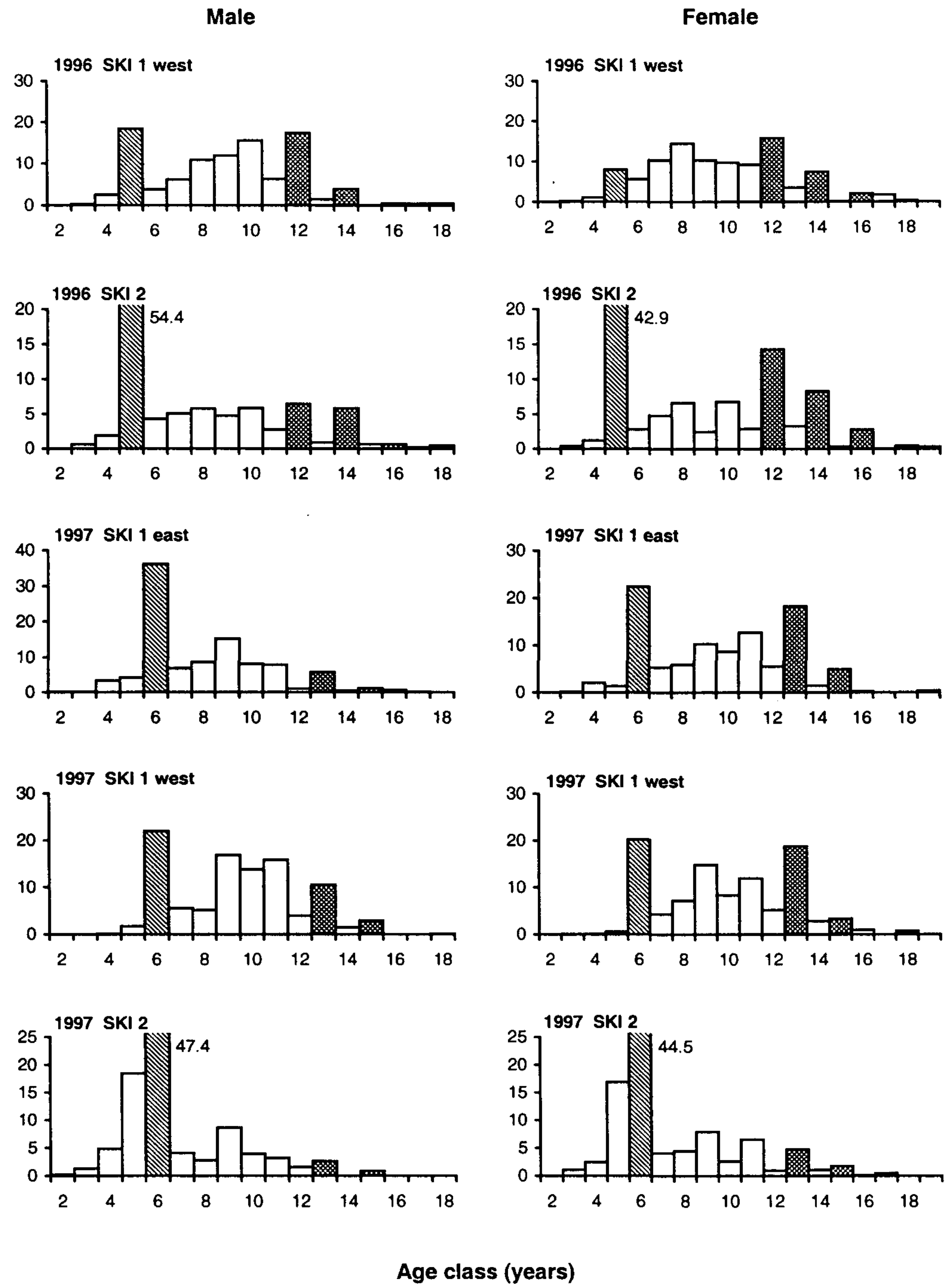


Figure 11: Age-frequency distributions, by sex, for the sampled catch of gemfish from SKI 1E, 1W and 2 in the 1996 (1995–96) and 1997 (1996–97) seasons. Similarly shaded bars represent individual strong year classes. Values adjacent to bars in the SKI 2 distributions indicate the true extent of these bars; they have been truncated to more clearly show the frequency distribution of the other relatively less abundant year classes.

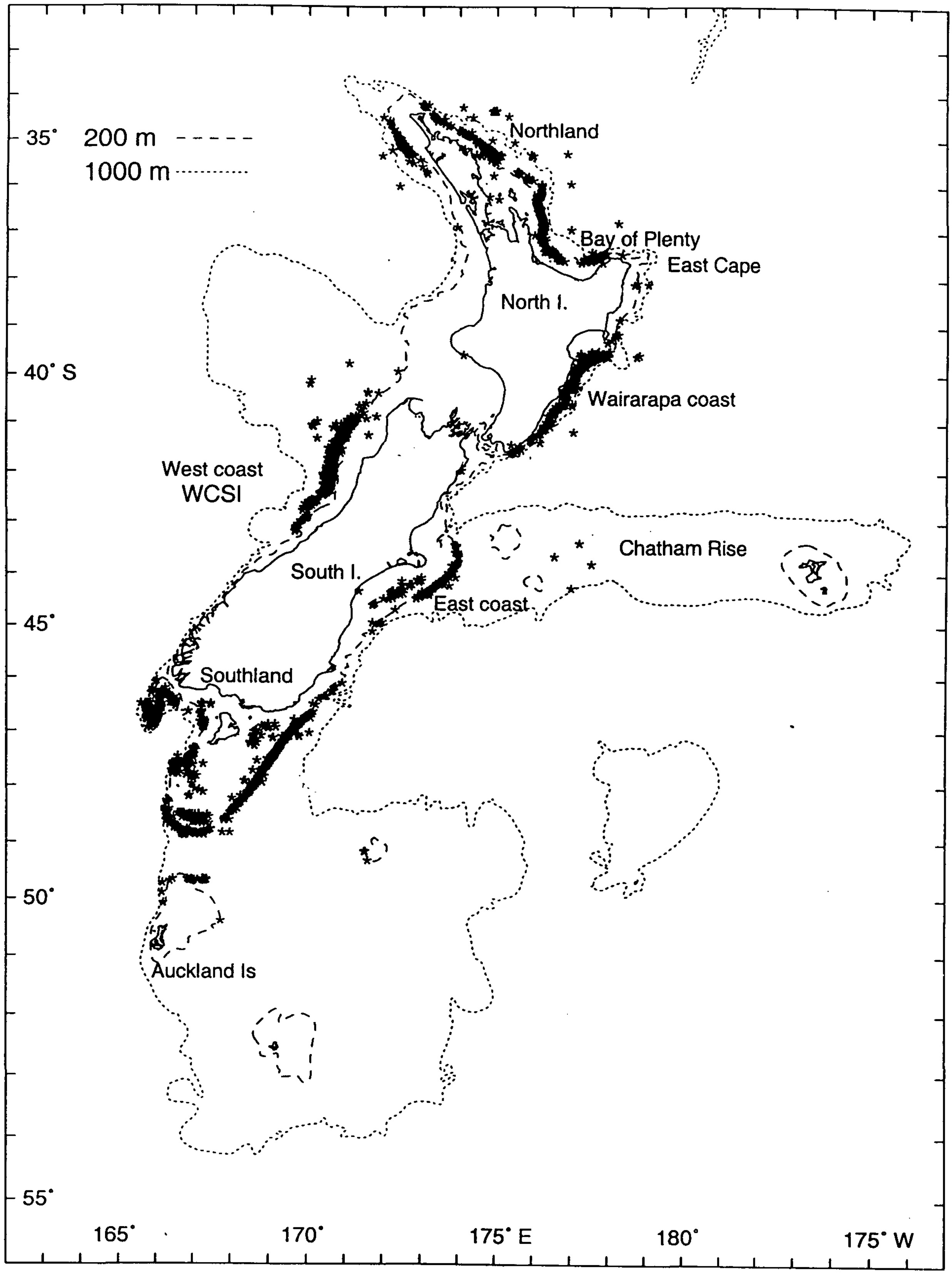


Figure 12: Location of gemfish target tows around New Zealand.

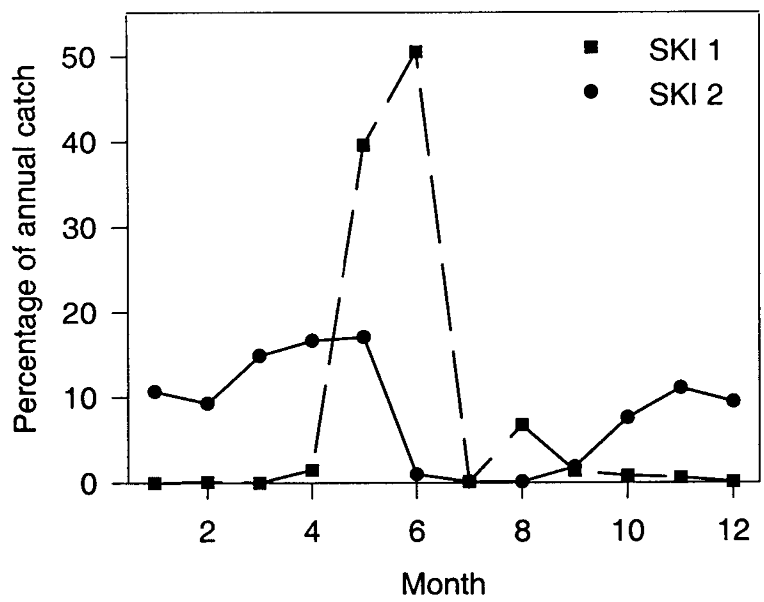


Figure 13: Seasonal patterns in northern gemfish catch, by area, for peak fishing years 1988–89 to 1994–95.

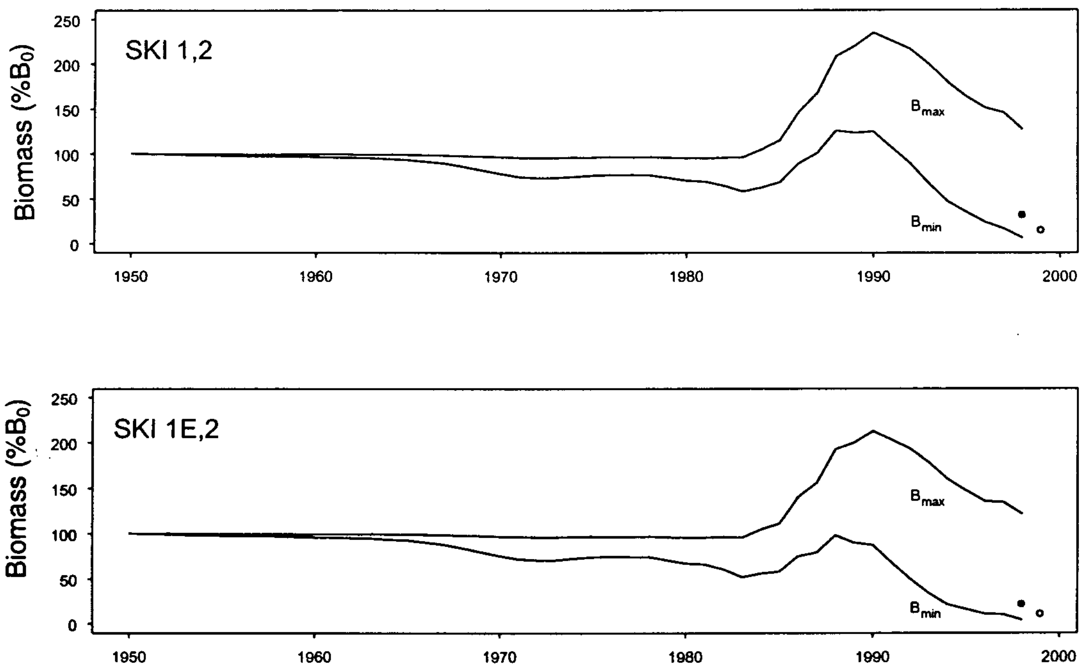


Figure 14: Trajectories for minimum (B_{min}) and maximum (B_{max}) estimates of biomass for base case gemfish stock assessments SKI 1,2, and SKI 1E, 2. The black circle indicates $B_{mid\ 98}$, the open circle $B_{mid\ 99}$.

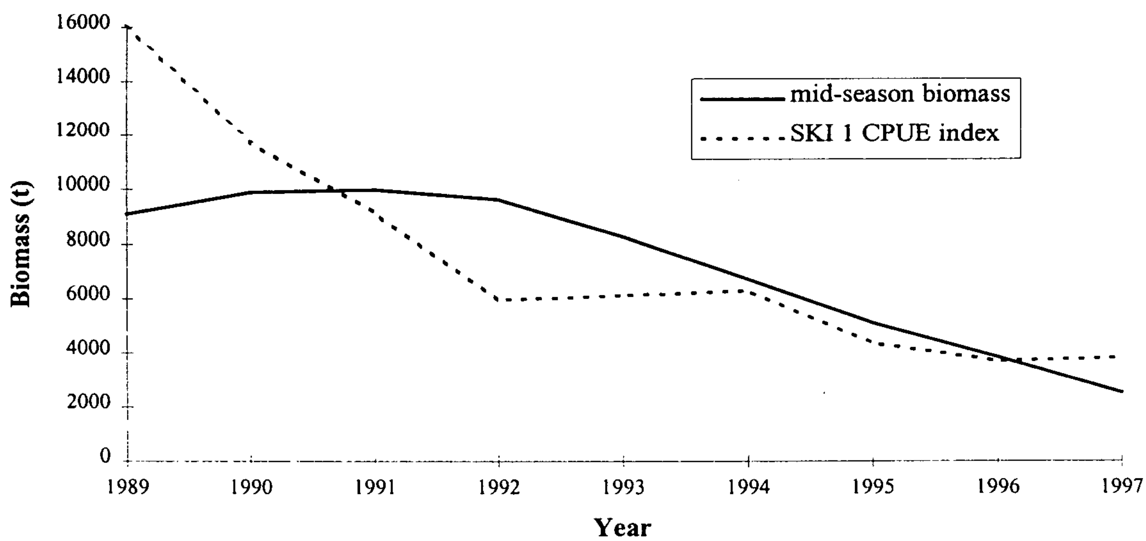


Figure 15: Mid-spawning season recruited biomass trajectory for the sSPA base case assessment of SKI 1,2, showing the fit to the SKI 1 CPUE index.

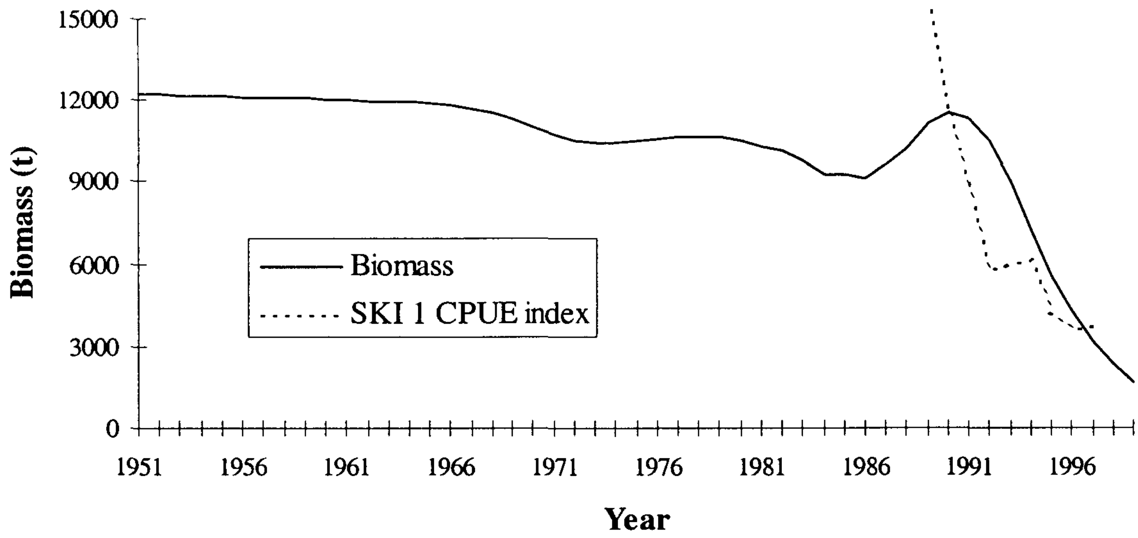


Figure 16: Mid-spawning season recruited biomass trajectory for the sSPA equilibrium model of SKI 1, 2, showing the fit to the SKI 1 CPUE index.

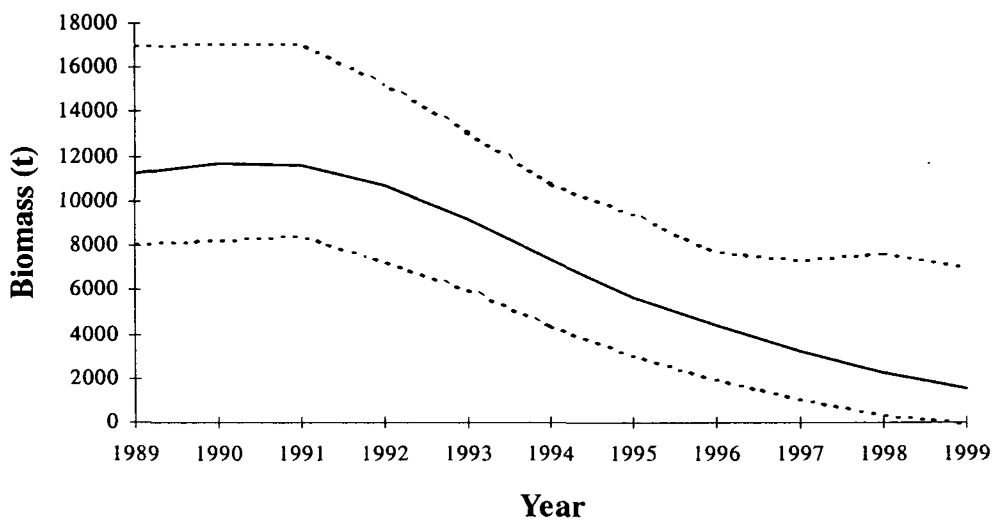
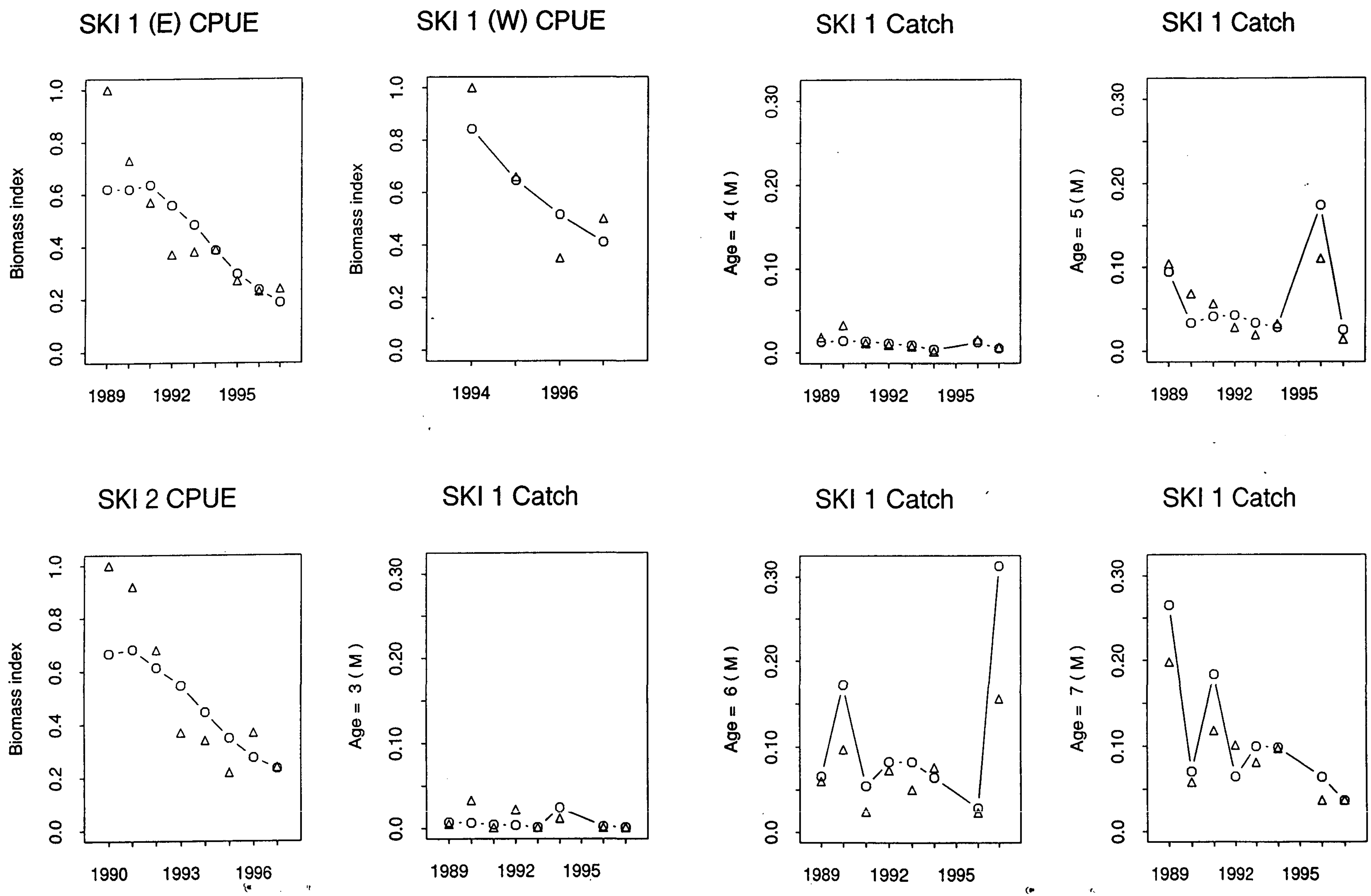
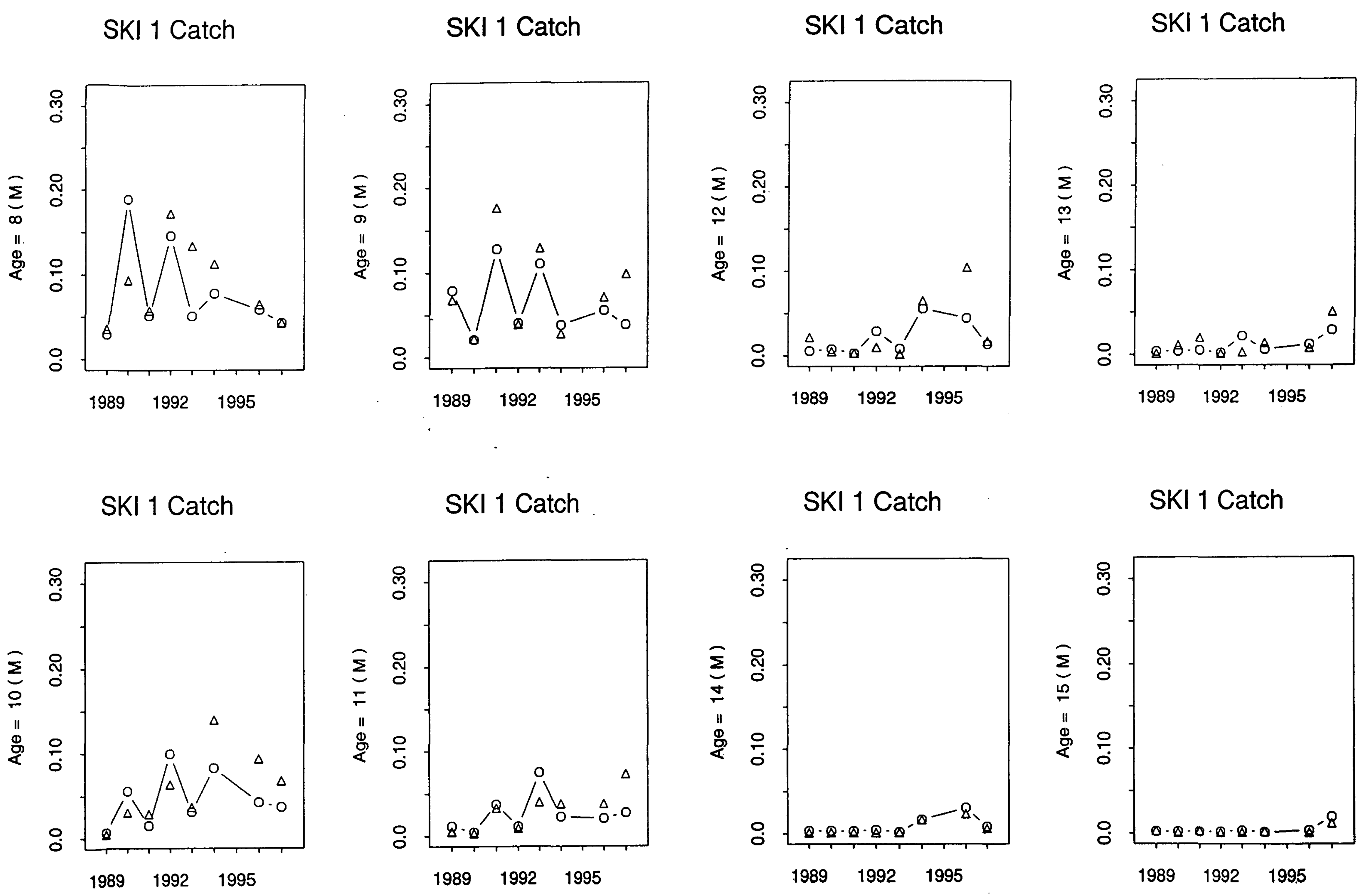


Figure 17: Mid-spawning season recruited biomass trajectory with 90% confidence intervals for the sSPA base case assessment of SKI 1, 2.

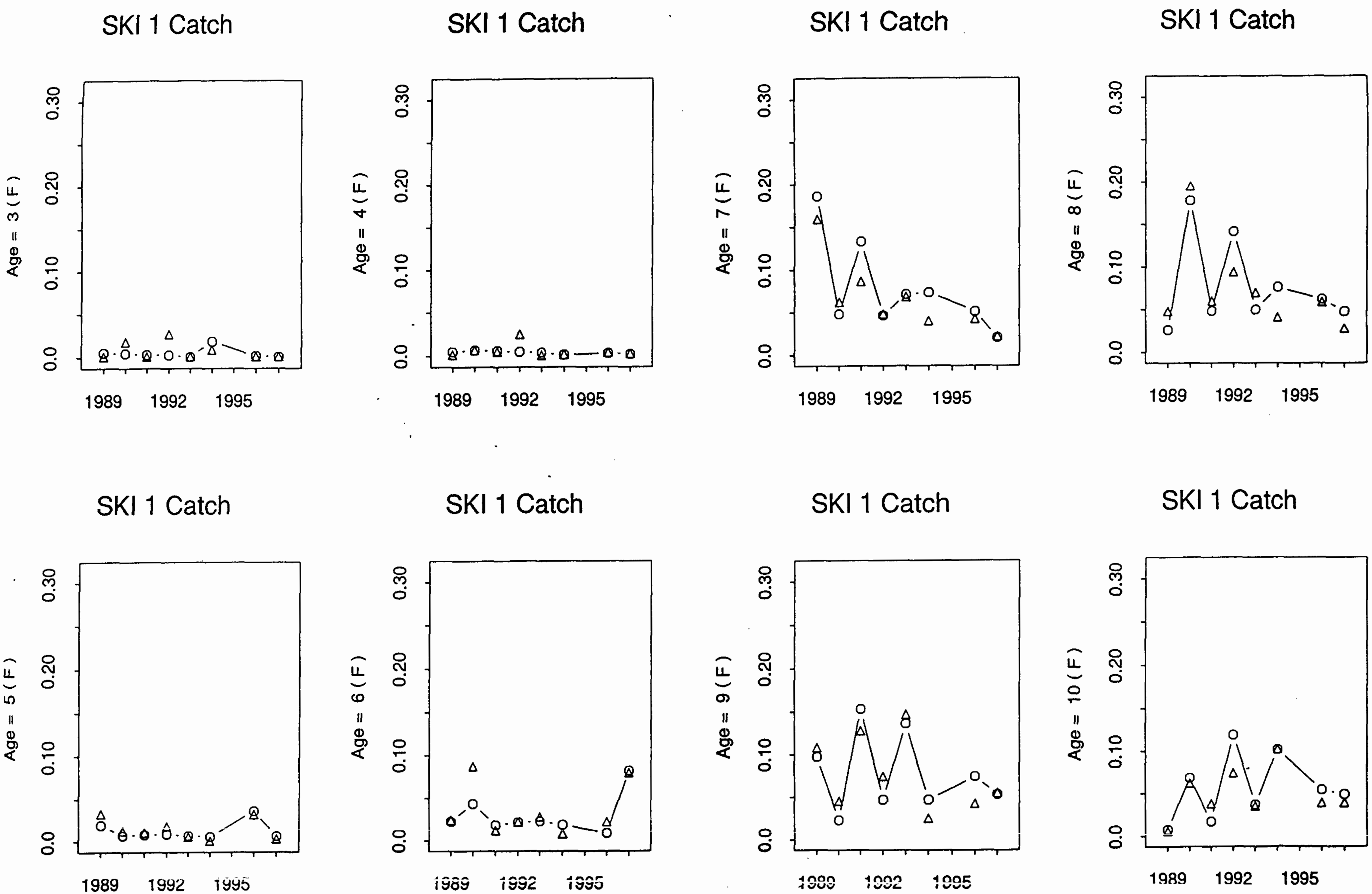
Appendix 1: MIAEL base case (SKI 1,2) model fits to the CPUE and proportion-at-age data. M, male; F, female.



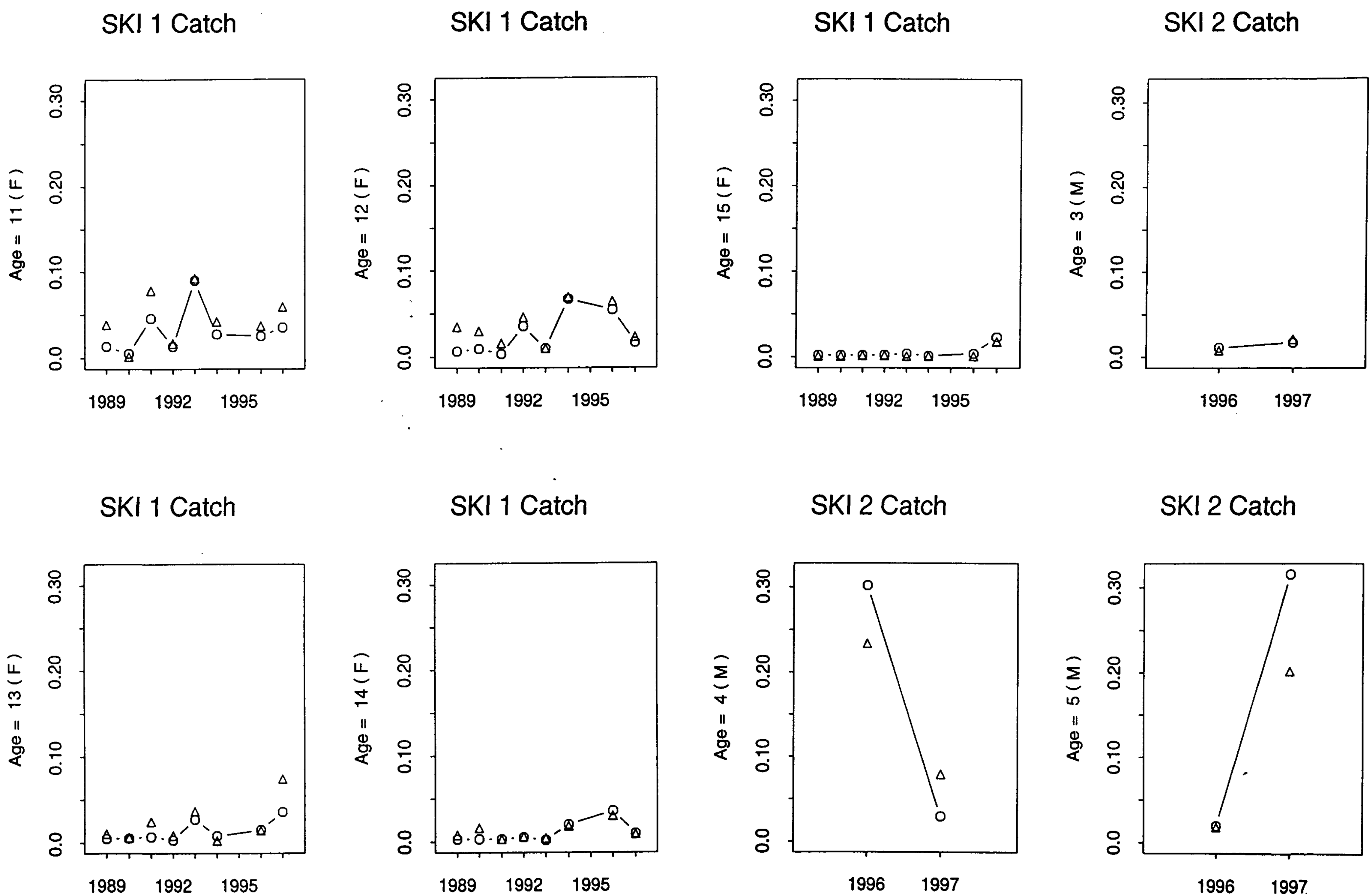
Appendix 1: *continued*



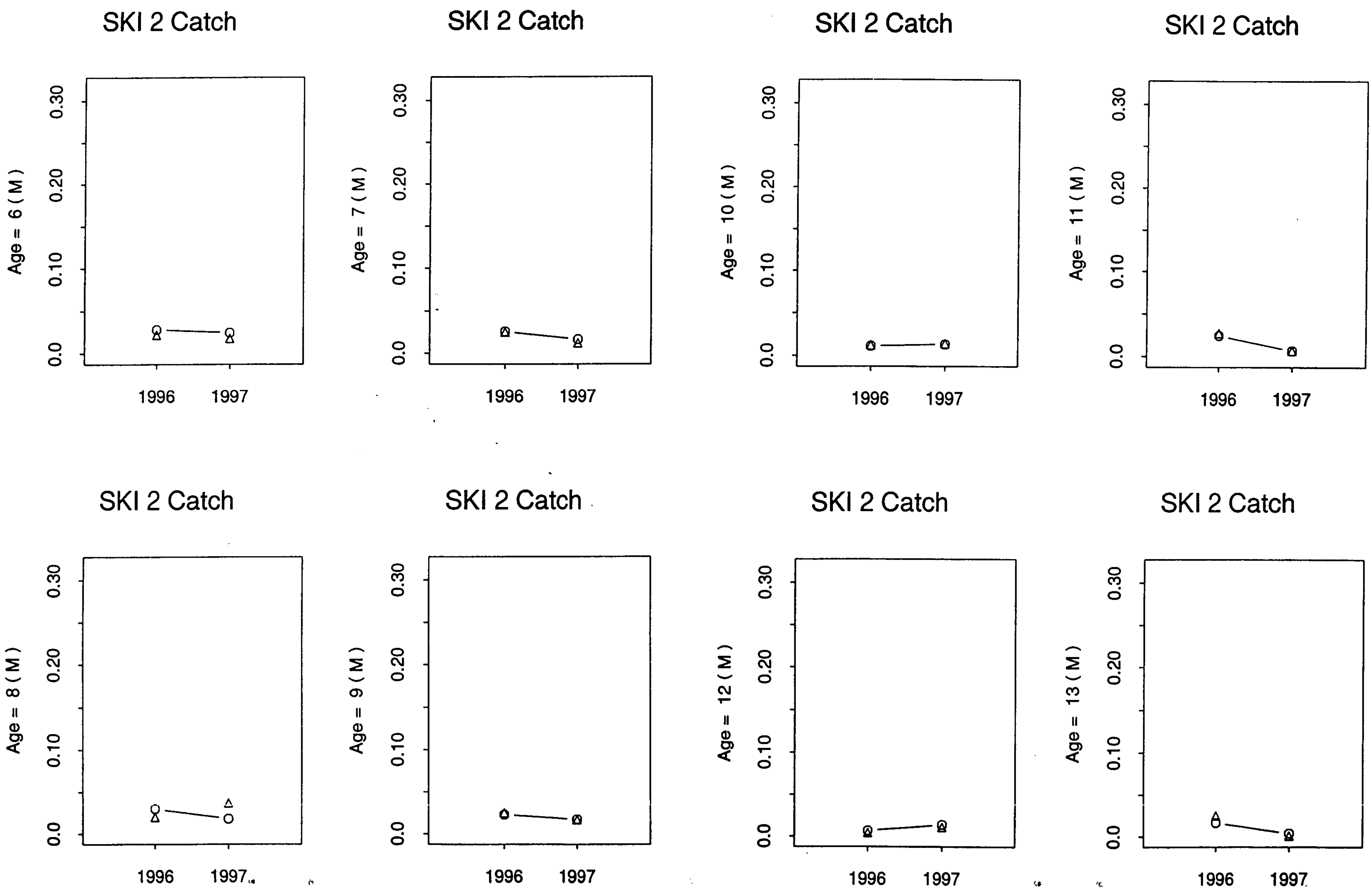
Appendix 1: *continued*



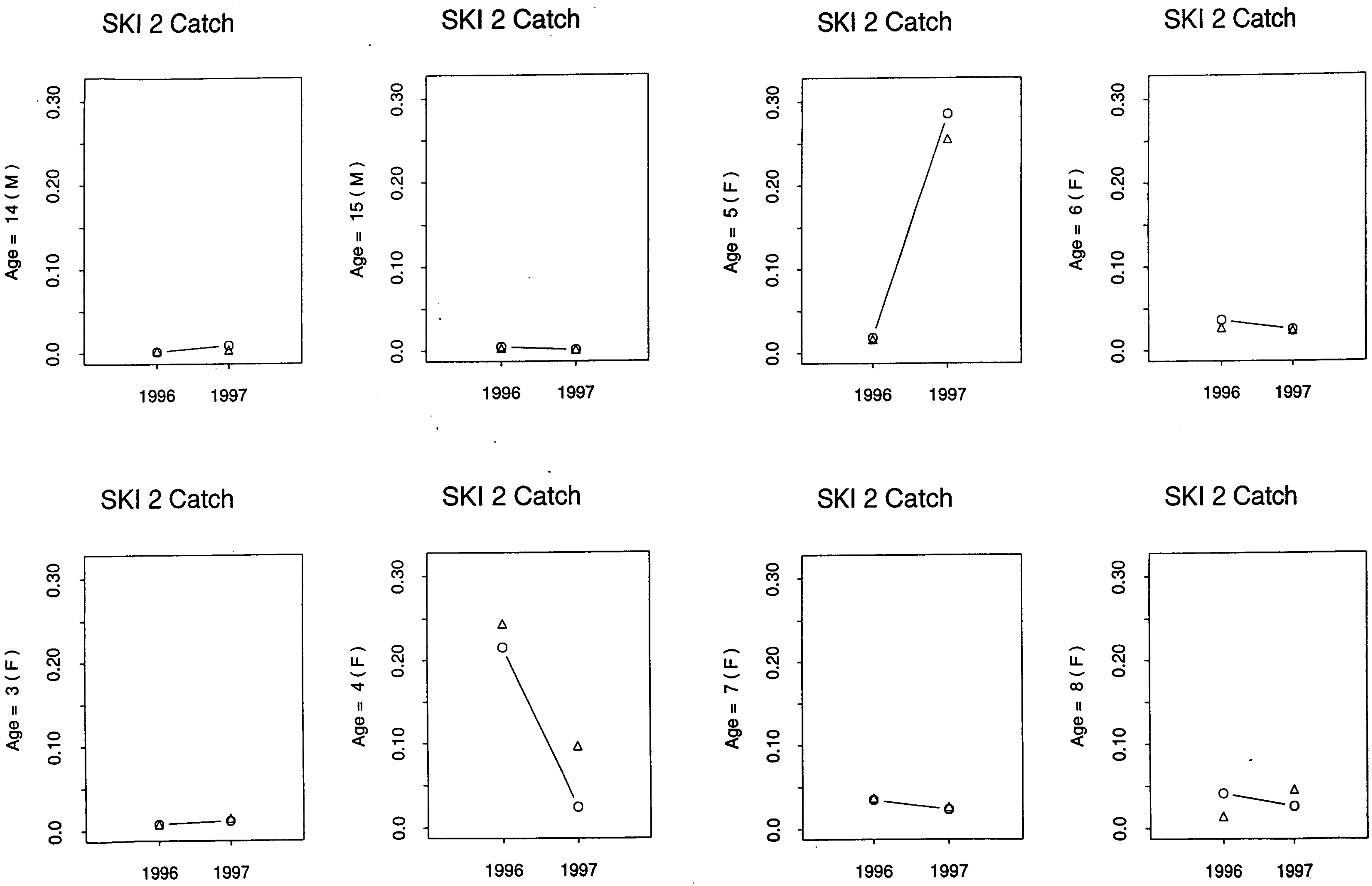
Appendix 1: *continued*



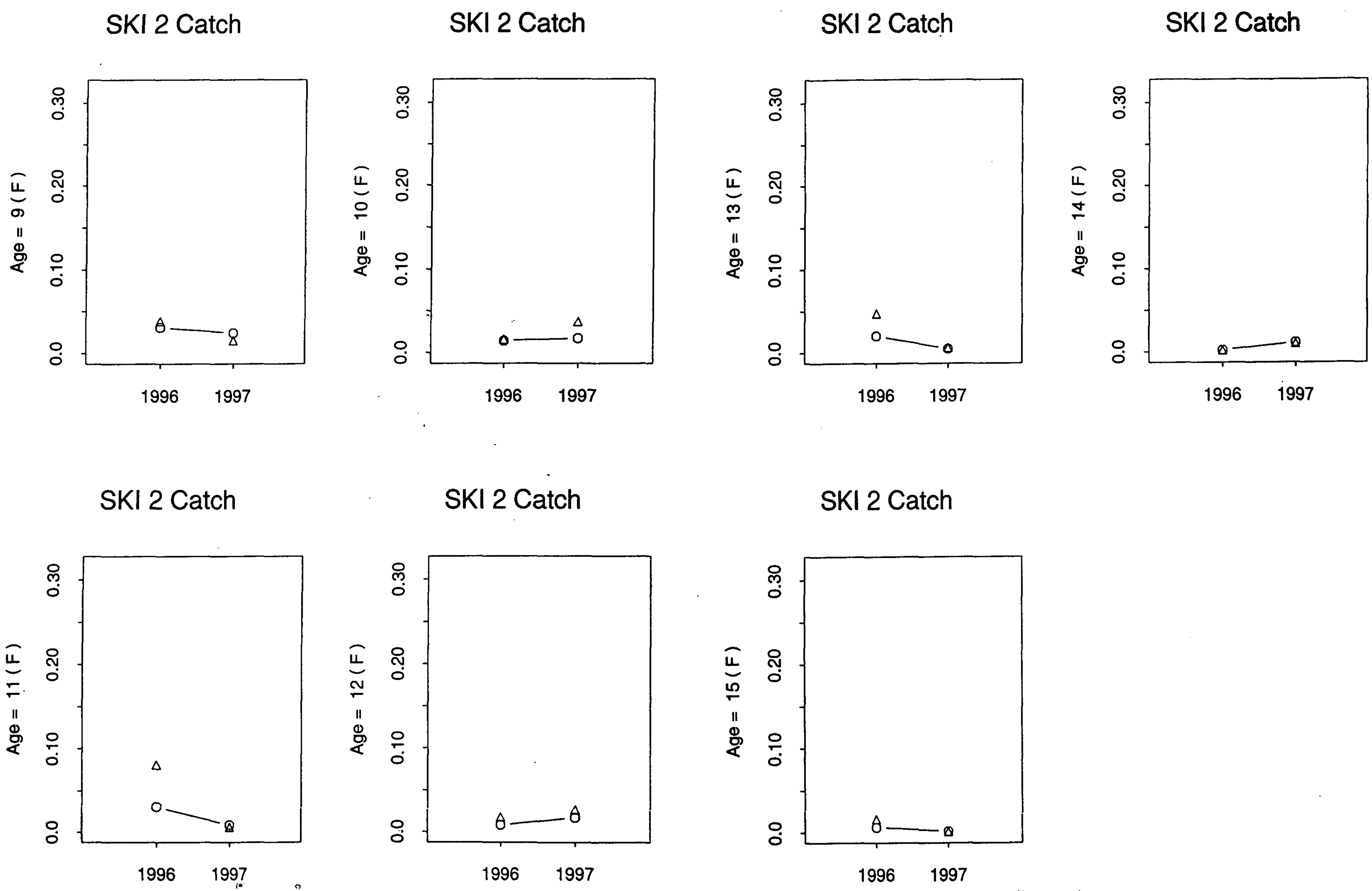
Appendix 1: *continued*



Appendix 1: *continued*



Appendix 1: *continued*



Appendix 2: sSPA model fits (dashed line) to observed (solid line) proportion-at-age data.