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Offshore lingcod stock Assessment and recommended yield options for 1998

B.M. Leaman and G. A. McFarlane

Fisheries and Oceans Canada
Pacific Biological Station
Stock Assessment Division
Nanaimo, B.C. V9R 5K6

Abstract

Offshore lingcod stocks were examined for the northwest and southwest coasts of Vancouver Island, Queen Charlotte Sound, Hecate Strait and the west coast of the Queen Charlotte Islands. Interpretation of stock condition relies on recent trends in catch statistics, although a catch-age analysis is conducted for the stock off southwest Vancouver Is. Off the southwest coast of Vancouver Island (Area 3C) CPUE has declined in recent years from the historic high in 1993 and is well below the long term average. Catch-age analysis suggests declining biomass, low recruitment and the need for a conservative harvest regime. CPUE off northwest Vancouver Island (Area 3D) suggests stock abundance is declining. Recent declines in CPUE in Queen Charlotte Sound (Areas 5A-5B) may indicate stocks are below the long-term average abundance level. Recommended yield levels range from ≤1000 t, 400-800 t, and 1100-2200 t for Areas 3C, 3D, and 5A-B, respectively. The fishery in Hecate Strait (Area 5C-D) has recently undergone a dramatic increase in effort, but there is little biological information available to guide yield recommendations. A recommended yield level of 1000 t is provided out of concern for the sensitivity of the species to exploitation and the rapid expansion of the fishery.

Résumé

Les stocks hauturiers de morue-lingue des côtes nord-ouest et sud-ouest de l'île de Vancouver, du détroit de la Reine-Charlotte, du détroit d'Hecate et de la côte ouest des îles de la Reine-Charlotte ont fait l'objet d'un examen. L'interprétation de l'état des stocks repose sur les tendances récentes des statistiques des captures, mais une analyse des prises selon l'âge a été effectuée pour le stock du sud-ouest de l'île de Vancouver. Le PUE des pêches de la côte sud-ouest de l'île de Vancouver (zone 3C) a diminué ces dernières années, par rapport au maximum historique de 1993, et est bien en deçà de la moyenne à long terme. L'analyse des prises selon l'âge porte à croire à une baisse de la biomasse, à un recrutement faible et à la nécessité d'un régime de récolte prudent. Le PUE pour le nord-ouest de l'île de Vancouver (zone 3D) indique un déclin de l'abondance. Les baisses récentes du PUE dans le détroit de la Reine-Charlotte (zones 5A et 5B) pourraient indiquer un niveau d'abondance inférieur à la moyenne à long terme. Les niveaux de rendement recommandés sont de 1000 t au plus, de 400 à 800 t et de 1100 à 2200 t pour, respectivement, les zones 3C, 3D et 5A-B. La pêche dans le détroit d'Hecate (zones 5C-D) a récemment subi une très importante augmentation de l'effort, mais il existe peu de renseignements biologiques permettant d'orienter des recommandations de rendement. Un niveau de 1 000 t est recommandé étant donné la sensibilité de cette espèce à l'exploitation et l'expansion rapide de sa pêche.

2.0 LINGCOD

2.2 OFFSHORE LINGCOD

2.2.0 General Introduction

Stock assessments for offshore lingcod are presented. A catch-age analysis for Area 3C lingcod is implemented for the first time, and age composition data are presented for other areas where they are available. For this assessment, the catch-age analysis is implemented in basic form only, due to the departure of the primary analyst from the DFO during the course of the assessment. Additional planned estimations and sensitivity analyses were not completed prior to this event. Yield options have changed for some areas from the previous assessment (McFarlane and Leaman, 1996), and all yield options now apply to a April 1-March 31 Fishing Year.

We present updated tables of nominal and qualified catch, effort, and CPUE, to the end of the calendar year 1996. A significant change for 1996 is the conversion to tow-by-tow (TBT) catch data from the fishing ground-depth aggregation (ROLLUP) used previously. Prior to 1996, data reported in the assessment consisted of records of catch and effort in the data base, aggregated over the individual depth ranges and fishing grounds, during one fishing trip (ROLLUP). In 1991, the trawl fishery data collection was converted to a tow-by-tow (TBT) basis but the data reported in the lingcod stock assessments continued to be in the traditional ROLLUP format. For 1996 and future years, the data are maintained in a new database that does not permit the direct aggregation possible with the previous database. Therefore, the data reported in the present assessment are those on a TBT basis. We examined the impact of this change by comparing ROLLUP and TBT qualified CPUE over the 1991-1995 period for all areas (Table 2.1). The two indices track identically over this period, with the exception of Area 5C/D in 1991 where overall fishing effort was low. In almost all area instances, the TBT CPUE is higher than the comparable ROLLUP value, with an average ROLLUP:TBT ratio of 1.117 (1.064-1.225).

2.2.1 Southwest Coast Vancouver Island (Area 3C)

2.2.1.1 The Fishery

Lingcod stocks off southwest Vancouver Island are exploited by trawl, hook and line, and sport fisheries. The hook and line fishery includes targeted handline and longline fisheries, and incidental catches by rockfish longline and salmon troll vessels. The commercial trawl fishery accounts for the majority of the lingcod catch (Fig. 2.1). Prior to 1987, the only restrictions on the commercial catch of lingcod were occasional winter closures and a size limit of 58 cm, implemented initially as a weight limit in 1942. In 1987 a winter closure (January 1-April 30) was imposed to protect spawning lingcod. This closure was expanded to November 15-April 30 in 1988. Also in 1987, a 1400 t quota was implemented for Area 3C lingcod due to concerns over low CPUE. However, the quota was raised to 2000 t in 1991 based on increased CPUE and has been maintained at that level (Richards and Hand 1991). The 2000 t level was designated as sustainable and was calculated as the mean of the historical catches that were greater than the long-term mean catch of 1400 t. The quota was increased to 2100 t in 1995 as the midpoint of the 1400-2800 t range in yield options. For 1996, the Area 3C quota was reduced to 1540 t over concern about reliability of a major excursion in the CPUE index over the 1993-1994 period and ageing problems identified for some historical data. In 1996, a 65-cm coastwide minimum size limit was also introduced for all gears. For 1997, the quota was reduced to 1400 and the intersectoral allocations were 1225 t for trawl, and 175 t for hook and line.

The trawl fishery for lingcod changed substantially in 1996 with the introduction of on-board vessel observers, bycatch limits for halibut, and the provision that all catches of quota species, including discards, would be counted against vessel period limits. These changes resulted in reduced targeting on lingcod due to lower quarterly lingcod trip limits, the effects of bycatch limitations for halibut, and trip limits for canary and silvergrey rockfishes.

2.2.1.2 Catch Statistics

Fishery data for Area 3C lingcod are described in Cass et al. (1988). To determine qualified CPUE, records are included from interviewed trawl landings between May-September for vessels using double gear, and for which lingcod accounted for at least 25% of the total catch weight. The use of 25% qualified data is arbitrary and serves simply to remove observations of incidental capture of lingcod from consideration in the relative index series. The 25% qualified data have accounted for an average of 54% of the trawl catches since 1970, and the trawl fishery accounts for the majority of the landings. However, the qualified catch was a much smaller percentage (12%) of the total trawl catch in 1996 than in previous years, for reasons noted above.

The Area 3C lingcod commercial catch has varied between 450-3600 t (Table 2.2, Fig. 2.1). The 1996 trawl catch of 701 t was only slightly below that of 1995 (787 t). However, both qualified catch and fishing effort decreased substantially from 550 t to 85 t and 2365 h to 588 h, respectively. The qualified catch is the lowest on record and the effort is the second lowest. CPUE declined to 150 kg/h in 1996, also the lowest value on record. Similarly, the 1996 line (combined handline/troll and longline) catch of 111 t declined from 193 t in 1995. Consideration of these data should be made in the knowledge of the management program changes in 1997. Reports from industry through DFO port samplers (S. Hardy, N. Venables, pers. comm.) indicate vessels altered their normal lingcod fishing patterns to avoid bycatch of halibut and some shelf rockfish.

Lingcod in Area 3C are also the secondary target of a sport fishery, centred in the inshore waters of Barkley Sound, on returning salmon runs. The relationship of the lingcod in these inshore areas to the offshore commercial stocks has not been determined. Tagging studies of lingcod from inshore and offshore reefs off the coast of Oregon showed little exchange of fish between the two areas (R. L. Demory, Oregon Dept. Fish and Wildlife, pers. comm.). While we have conducted tagging studies for the offshore stock in Area 3C, there has been no comparable tagging of these inshore fish. No recoveries of offshore-tagged fish have been made in the inshore fishery.

Jagielo (1995) conducted studies of lingcod in the open coast, nearshore areas off Cape Flattery in northwest Washington. He concluded that nearshore fish migrated extensively to offshore waters but that there was considerable interannual variability in the proportion that might migrate. Sixteen percent of his recoveries were made from outside of the tagging area and 79% of these were from "offshore" waters. The average instantaneous rate of fish migrating away from the study area was 0.23. However, he noted that most of the fish tagged were males, whose behavioural patterns may not be indicative of the entire population, and that those fish recovered outside of the tagging area were of larger mean size than other recoveries. Ontogenetic emigration is therefore a possible factor for lingcod movement in these areas. Jagielo concluded that the coastal stocks should be modelled as a single open population with nearshore waters. A joint inshore-offshore tagging study would be helpful in resolving the relationship of the inshore/nearshore and offshore stocks for B.C. waters, as well as the relationship to lingcod in U.S. waters.

Since 1984, the lingcod sport catch in and around Barkley Sound has been monitored by a creel survey. The temporal and spatial coverage of the fishery has changed since its inception and previous assessments have presented statistics for Barkley Sound during August and September. The sport catch for this area and time period increased from approximately 3 t to 9.5 t between 1984-89, and has fluctuated between 3.3 and 6.7 t since 1990 (Table 2.3). The sport CPUE increased sharply from 1992 to 1994 but was relatively stable during 1994-1995, at about 1.4 kg/10 boat trips (Table 2.3). The 1996 fishery was affected by restrictions in the salmon fishery, so that overall fishing effort was down substantially (-79%) from recent years. Only 6500 boat trips were made in 1996 compared to the 1984-1995 yearly average of 34,500 boat trips. However, CPUE increased in 1996 by 1.24 times the 1995 value, to 3.16 kg/10 boat trips. This change is believed to be associated with the change in fishing patterns and intensity due to more restrictive salmon regulations, rather than a shift in lingcod stock abundance.

2.2.1.3 Condition of the Stock

2.2.1.3.1 Catch-at-age analysis

(i) Catch and effort data

Trawl and line catch data analyzed are those for Area 3C (Table 2.2). Initial investigation of the catch-at-age (CAA) model was undertaken with separate trawl and hook and line catch data. Separation of the data in this manner also requires the CAA model to estimate separate selectivity parameters for each catch data source. However, no sampling data are available for hook and line catches and estimation of these parameters is highly uncertain, at best. Therefore, the CAA analyses presented here combined these catch data and make the implicit assumption of common selectivity parameters for both fisheries. A common selectivity is unlikely to be strictly true but the absence of sampling data for the hook and line fishery precludes separate estimation. The implications of separate selectivity parameters will be examined later in this document.

(ii) Size and age composition

Biological samples were obtained from landings of commercial trawl vessels at Vancouver and west coast of Vancouver Island ports. In previous assessments (McFarlane and Leaman 1994, 1995) we have described the identification and resolution of problems in ageing of lingcod samples during the late 1980s and early 1990s. Historical samples for which these problems were detected have been re-aged. In addition, a complete review of the sample data set was conducted and additional age data were resolved and added to the data set. However, in the course of the sample review we also determined that samples for some years could not be used because no resolved ages were assigned, or ages were presented as ranges of possible values. Only samples for which resolved ages were determined and for which only reliable ageing methods were used are included here. The data set now comprises samples for the lower west coast of Vancouver Island (Area 3C), from 1977-1996. Sampling data are available for only the trawl fishery in this area.

Sampling intensity among years was variable, ranging from one to nine samples and 50-977 fish per year (Table 2.4). Since among-year variation in sampling intensity is large, a weighting algorithm for inputs to the CAA model was used. The among-year sample weights (N) are based on the square root of the number of samples in that year (n_j). Following Fournier and Archibald (1981), we use a maximum weighting for years having ≥ 20 samples and set this equal to 400. That is:

$$N = (\sqrt{n_j} / \sqrt{N_{MAX}})*400$$

For example, 10 samples in a given year yields an N value of 283, while a year with two samples is assigned a weight of only 126. The influence of the age data in fitting the model to the observations is controlled through a weighting parameter in the model.

(iii) Biological data

Growth rates of lingcod were obtained from research samples of length at age reported in Cass et al. (1990). Growth rates from commercial fishery samples are biased by the minimum size limit of the fishery, particularly for fish of ages 2-4 y. Growth parameters were estimated using the von Bertalanffy growth model as reformulated by Schnute (1981). Length-weight conversions were also taken from Cass et al. Weight-at-age estimates used in the model were fixed for the time series, i.e., growth was assumed invariant. The size during the seventh month was used as the reference month for annual size at age. These known lengths at age may be biased to an unknown degree by selectivity of the fishing gear and/or behavioural recruitment effects related to size. Lengths at 50% maturity were taken from Cass et al. (1990). Richards et al. (1991) computed separate and slightly different sizes at first maturity, however the samples analyzed in that study were obtained in mid-summer, rather than during the spawning period. The data so obtained will tend to overestimate the proportion of the younger age groups that are mature at the time of spawning, as well as to underestimate the size at first maturity. Maturity data obtained at the time when the gonads are functionally spawning are desirable for estimating these proportions. Since the samples in the Cass et al. study were obtained during the spawning period, they were chosen as more representative of size and age at maturity. Fecundity was assumed to be a linear function of body weight.

Natural mortality rate (M) was estimated as 0.259 for males and 0.193 for females (average 0.226). This estimate is based on Hoenig's (1983) relationship between maximum observed age and natural mortality and maximum observed ages of 17 y and 23 y for males and females, respectively. These biological data are presented in Table 2.5.

(iv) Catch-at-age model

For this assessment, a CAA model for the Area 3C stock was implemented for the first time. The Stock Synthesis Model (SSMOD) developed by Methot (1989) and applied to B.C. sablefish stocks in previous years (Saunders et al. 1995, 1996) was chosen for the assessment. A full description of the model is contained in Methot (1986, 1989, 1992) and only significant points of the present implementation will be covered here.

The SSMOD estimates the proportions of fish at each age and sex in the catch, and compares these estimates to those observed from catch sampling. The model calculates the proportions based on estimating fishing mortality and selectivity of each age by the fishing gear. This estimation uses the CPUE of qualified trawl catch as a tuning index, although the influence of this tuning index is varied. In general, CAA models perform poorly when no auxiliary variables with which to tune the model are available. For this implementation, we use the qualified trawl CPUE time series for tuning which invokes the assumption that CPUE is proportional to abundance.

We present details of model options briefly below. We use initial runs of the model to first establish a reasonable *baseline* set of estimates, evaluated on values of the objective function and residual error distribution. We then examine the sensitivity of the estimates to modified parameter and weighting choices.

Model Options

(a) Natural mortality rate. Instantaneous natural mortality rates were set at 0.193 and 0.259 for females and males respectively, as noted. Natural mortality rates were assumed to be age and time-invariant.

(b) Ageing imprecision. Lingcod are difficult to age, particularly concerning the identification of the first annulus and for the period near sexual maturity (S. E. MacLellan, pers. comm.), although the dorsal fin ray method used to age lingcod has been validated (Cass and Beamish 1983). For this assessment we have used the power relationship for ageing imprecision presented in Jagielo (1995). This relationship is based on lingcod ageing using the same method as in this assessment and results in a changing standard deviation of the estimated age with increasing age. It specifies the percent of fish correctly aged at both the minimum and maximum ages, and a power function of age that specifies the change in percent correct ageing between these two extremes. The resulting ageing error matrix (Table 2.6) shows greater imprecision at younger ages, reflecting the difficulty of ageing lingcod near the ages of sexual maturity.

In addition to addressing the imprecision in ageing in this manner, the input data were also compressed into fewer age groups than the estimated ages. Ages were estimated through direct age readings to a maximum age of 23 y for female lingcod. However, because the number of fish at older ages is very small and the confidence with which they are aged is low, ages ≥ 15 y were combined as a single age group.

(c) Selectivity. Selectivity of lingcod by the trawl and (initially) the line fishery was parameterized as double logistic function of fish age. Separate parameters are estimated for the slopes and inflections points for young and old fish, and for male and female lingcod. The user can fix any of these parameters to simulate particular selectivity hypotheses, e.g. constant selectivity past age of full recruitment. For this implementation, all parameters were allowed to vary for baseline runs. Additional investigations were undertaken using an asymptotic selectivity for females. Male abundance at older ages is quite low in most samples and it is not clear whether the higher natural mortality rate for males is also coupled with declining selectivity with age.

(d) Stock-recruitment relationship. The values for the first year age composition and the recruitment at age of first capture in the age composition estimated by the model are generated as the expected values of a stock recruitment relationship. That is, the age composition in the first year of observation is estimated on the basis of an equilibrium stock recruitment function and the average level of historical catch. Recruitments are estimated for the 1977-1990 cohorts in the baseline reconstructions, which incorporates recruitment at age 2 in the years 1979-1992. We also implement reconstructions in which recruitment of the 1991 and 1992 cohorts is estimated, although these estimations incorporate only three and two years of observation of these cohorts, respectively Our implementation assumes a Beverton-Holt stock-recruitment relationship, the emphasis of which is set at a negligible value (0.0001). However, the influence of a stock-recruit relationship can be profound and the sensitivity of the model fit to removing this relationship was examined by implementing a constant recruitment option.

(e) Emphasis values. Weightings (emphasis values, in SSMOD terminology) can be applied to data inputs and relationships of the model to impose greater adherence to these inputs or relationships in the estimated fit of the model to the data. The weightings can also be interpreted as the degree of confidence the analyst may have in a particular data input. The primary weightings employed in this implementation affect the likelihoods for fishery catch, fishery age composition, the CPUE index, and the influence of sample numbers. With the exception of the sample number weightings which are specified at the data input stage, the weightings are applied to the component likelihoods for the relationships of concern. In addition to the weightings of the likelihood components, the permissible variances of parameter inputs are specified through an error term for each parameter. In theory, if all of the processes are correctly parameterized and the variances of the component observations specified correctly, then the emphasis values should all be 1.0 and the model estimates robust to changes in the values. In reality, both data collection and process description are subject to error and the sensitivity of the model results to emphasis values should be examined.

(v) Stock Reconstructions

(a) Baseline reconstruction model characteristics **(Run R07)**

The baseline configuration for this implementation assigned equal emphasis to both fishery age and fishery CPUE data and with the stock-recruitment relationship included but with negligible emphasis (0.0001). This configuration assumes equal confidence in the age and CPUE inputs. Recruitment is estimated for the 1977-1990 cohorts. The stock reconstruction estimated an exploitable biomass of approximately 13000 t in 1996 associated with a fully exploited fishing mortality of 0.161 (Table 2.7). Available biomass had a major peak in 1982 and underwent a relatively steady decline through 1994, but the decline was buffered in the late 1980s by the appearance of the 1985 cohort (Fig. 2.2). Total biomass is estimated to have increased slightly since 1994, however this increase can be attributed largely to the use of fixed recruitment (at the mean value for the time series) for the past four years of the reconstruction. Recruitment of cohorts may be above average for the early 1990s, although spawning biomass has not yet received the full contribution of these cohorts and has been declining since 1990. Estimated recruitment has been highly variable in recent years, with both relatively strong (1985, 1989) and weak (1986, 1988, 1990) cohorts since 1985 (Fig. 2.2). While recent cohort strengths are estimated with less confidence than those spawned earlier, the variation in cohort success since 1984 has been substantially greater than that during 1977-1984. In general, there has been a pronounced downward trend in cohort strengths over the 1977-1984 period. The recruitment of the 1985-1990 cohorts has been particularly variable.

Estimated fishery selectivity, when unconstrained, peaks at ages 4 y and 5 y for males and females, respectively (Fig. 2.2). Selectivity declines gradually to about 50% for males at age 7 y and for females at age 11 y, and is 10-15% for both sexes by age 15 y. The baseline reconstruction presents major residuals in the estimated fishing effort for 1985 and 1993, when observed CPUE was much higher than normal (Fig. 2.3). However, the estimated fully-recruited fishing mortality was also higher in these years, particularly for 1985, which argues against stock changes as a causative agent in the CPUE increases. We interpret the conjunction of these observations to indicate a shift in the behaviour of the fishery in these years, perhaps involving higher degrees of targeting on lingcod than normal. Biomass declined sharply after the large removals in 1985 but the influence of the 1993 fishery is less well determined because of the lower ability of the reconstruction to estimate changes for the most recent years.

There is a general tendency for age proportions of females to be slightly overestimated, relative to observed, for this configuration of the model (Fig. 2.4). Major positive residuals (10-25%) represent underestimates of the relatively strong 1985, 1987 and 1991 cohorts but the proportions of ages 3-6 are overestimated generally by 2-7%, suggesting that female selectivity is overestimated slightly for these age groups.

The estimated fishing mortality in the terminal year was F=0.161 for the baseline reconstruction.. Short-term (5 y) projections of harvest at this F level and equilibrium recruitment suggests that available biomass will decline from approximately 13000 t to 11700 t, with a harvest of approximately 900 t/y.

(b) Modified reconstructions

We evaluated the influence of data emphasis values by alternately reversing the emphasis for CPUE and catch-at-age information from 1.0 to 0.1. The resulting reconstructions were effectively a catch-at-age (CAA) fit **(Run R08)** and a CPUE fit **(Run R09)** (Figs. 2.2-2.3). The CAA fit estimated an exploitable biomass of approximately 14300 t in 1996 associated with a fully exploited fishing mortality of 0.148 (Table 2.7). Fishery selectivity was qualitatively similar to that estimated for the balanced estimation. Spawning biomass is also estimated to have declined relatively steadily throughout the 1977-1994 period. The short term projections for this run suggest that a fishing mortality of 0.148 will produce yields of approximately 950 t/y and reduce the exploitable biomass from approximately 14300-13100 t over a five y period.

The CPUE weighted estimation **(Run R09)** produced much lower estimates of historical and present biomass than the other two reconstructions. Terminal biomass was estimated to be only 11480 t and fishing mortality estimated to be substantially higher than the other reconstructions, at 0.346. Fishery selectivity for males was also estimated to be much lower than for either the balanced or CAA fits (Fig. 2.2). Fishing mortality over the period examined was more variable and, reflecting the emphasis value, responded more strongly to the CPUE tuning index. Age residuals for the CPUE fit are exaggerated over the other reconstructions (Fig. 2.4). This should be expected because the other model runs adhere more strongly to the age composition inputs. The CPUE weighted reconstruction provides the most pessimistic results of those examined.

Recruitment in estimations R07-R09 was fixed for the last four years (1993-1996 cohorts) because of the limited period of observations for these cohorts. However, this fixed recruitment value is clearly influential in maintaining exploitable biomass in recent years. We examined this effect by allowing an additional two cohorts (1993-1994) to be estimated **(Run R10)**. While these cohorts are estimated with only two and three years of observation, respectively, we were concerned that the recent stock estimates not be unduly influenced by the use of fixed recruitment that was higher than that in recent years. This reconstruction is also more pessimistic than the balanced and CAA fits detailed earlier. Incorporating the 1993-1994 cohort estimation results in terminal biomass and fishing mortality estimates of approximately 10500 t and 0.207 (Fig. 2.2-2.3). The trend in fishing mortality is now also increasing in recent years compared with the relatively stable or decreasing trends seen in the other reconstructions. Short-term projections at 1996 fishing mortality (0.207) suggests biomass will decrease from approximately 10500 t to 9700 t over a 5-y period and yield approximately 950 t/y.

We also performed estimations comparable to Runs R08-R09 but including estimation of the 1993/1993 cohorts **(Runs R11-R12)** (Table 2.7). The CAA **(Run R11)** reconstruction was very similar to the more restricted fit although both biomass and fishing mortality were slightly higher (approx. 14700 t and 0.163 compared with 14300 t and 0.148). The CPUE **(Run R12)** fit once again demonstrated significant residual error in the estimated proportions at age (Fig. 2.4) but showed higher estimated biomass and lower terminal fishing mortality than the more restricted estimation (approximately 12000 t and 0.214 vs. 11500 t and 0.346).

To examine the issue of selectivity, we performed a set of estimations with asymptotic female selectivity, with the asymptote determined at the age of maximum selectivity and fixed thereafter. The overall effect of using an asymptotic selectivity is a substantial reduction in exploitable biomass and a greater estimate of maximum fishing mortality (Table 2.7). The ending biomass for a balanced CPUE-CAA fit (**Run R13**) was approximately 8820 t, but with a lower maximum fishing mortality (0.208). The lowest estimate of ending biomass was obtained with the CPUE weighted fit and asymptotic selectivity (**Run R15**). Ending biomass was only about 8000 t, while maximum fishing mortality peaked at 0.344. The use of asymptotic selectivity is a common assumption of CAA models. We note, however, that unconstrained selectivity estimation suggests sharply declining selectivity with increasing age. A resolution of this difference is not possible at this time. The reconstruction suggests this stock is somewhat more productive than other reconstructions. Short term projections from this reconstruction suggest yields averaging approximately 1020 t over the next five years.

(c) Evaluation

The CPUE time series available for tuning the reconstruction analyses has clear shortcomings in terms of its effect on residual error in fitted abundance at age. Rejecting any input from this time series leaves no auxiliary variable with which to condition the reconstruction. This poses a dilemma for analysis of the stock. Basing the reconstruction solely on the CAA data carries its own peril because fishing mortality, selectivity, and recruitment will be pitted against one another in determining abundance at age, with limited means of determining appropriate values. In addition, the reconstruction with only CAA weighting provides the most optimistic scenario of stock history, even though the trajectory of stock biomass and recruitment is generally down. We do not believe the CPUE time-series used in the reconstructions is entirely reliable for this purpose, however we are reluctant to adopt the CAA-weighted estimates at face value. In addition, we believe the decreasing and erratic trajectory of recruitment in recent years argues that the fixed 1991-1994 recruitment options is too optimistic. This erratic trajectory years is mitigated somewhat when estimation is CPUE-weighted and/or uses asymptotic selectivity.

The foregoing does not provide a clear picture of stock status at this time. It would be prudent to adopt the most conservative approach to the interpretation of stock status under such conditions of uncertainty. Accordingly, we recommend adopting the CPUE weighted fit with the 1993-1994 cohorts estimated and asymptotic selectivity, i.e. **Run R15**, as the most appropriate reconstruction of those examined.

2.2.1.5 Yield Options

In 1994, the recommended yields for lingcod in Area 3C range from a low risk option of 1400 t to a high risk option of 2800 t, with 400 t and 800 t as the equivalent values for Area 3D. These values were calculated using historical landing statistics where there was some indication of a negative impact of harvest levels on landings in subsequent years. The present analysis has included neither a risk analysis nor a simulation investigation of appropriate harvest rates reference point. Such analyses should be done for this stock in the future. All reconstructions conducted here suggest that stock biomass may be at approximately two-thirds the peak level of the mid 1980s and the trajectories of biomass are similar for all reconstructions.

The major differences in the reconstructions is the estimated level of fishing mortality. The present level of fishing mortality from the recommended reconstruction is 0.334, although short-term projections suggest the stock will decline modestly over a five-year horizon at this level of fishing mortality and the associated yield of about 1020 t. This reconstruction also indicates an increasing recruitment trend in the early 1990s but this should be interpreted extremely cautiously. Until there is additional information that the stock has initiated either a very strong cohort or a series of stronger cohorts, we recommend a conservative harvesting regime be used for this stock. We recommend that total removals from the 3C stock not exceed the 1000 t level for 1998.

2.2.2 Northwest Coast of Vancouver Island (Area 3D)

2.2.2.1 The Fishery

Lingcod stocks off northwest Vancouver Island are exploited by commercial trawl, hook and line, and localized sport fisheries. The hook and line fishery includes targeted handline and longline fisheries, and incidental catches by rockfish longline and salmon troll vessels. The line component of the catch has been increasing since the mid-1980s, partly in conjunction with increasing hook and line catches of rockfishes. Prior to 1987, the only restrictions on the commercial catch of lingcod were occasional winter closures and a size limit of 58 cm, implemented initially as a weight limit in 1942. In 1987 a winter closure (January 1-April 30) was imposed to protect spawning lingcod. This closure was expanded to November 15-April 30 in 1988 and the size limit was increased to 65 cm in 1996. The trawl fishery for lingcod in Area 3D was affected by the same changes regarding quarterly trip limits, bycatch reduction measures, and observers as noted for Area 3C.

Yield recommendations in Area 3D have remained unchanged at 400-800 t for low and high risk levels, respectively, since 1992. These recommendations applied to total removals and were not gear specific. A quota of 600 t has been in place for all gears since 1992. However, in 1996 a 180 t quota for the line fishery was introduced for the first time. For 1997 the intersectoral quota allocations of the overall 400 t quota for Area 3D were 180 t for hook and line, and 220 t for trawl.

2.2.2.2 Catch Statistics

Commercial landing statistics for Area 3D were compiled in a manner similar to the Area 3C statistics. The Area 3D lingcod catch has ranged from a low of 166 t in 1959 to a high of 1400 t in 1994 (Table 2.8, Fig. 2.5). A major change in the fishery occurred in 1983, when the trawl catch increased dramatically. This increase was attributed to relatively strong recruitment for the 1976-1978 cohorts (Cass 1985). The total catch has declined substantially since the peak in 1994. Total landings of just 371 t in 1996 reflect the imposition of quotas for the line fishery and more restrictive measures on trawl fishing. Trawl landings decreased to 189 t from 477 t in 1995. Qualified (25%) effort decreased to only 224 h from 1257 h in 1995. However, the 1996 qualified CPUE for the trawl fishery was 296 kg/h, a 55% increase from 1995 and is very close to the 1956-1995 median value of 308 kg/h.

Line catch of lingcod in Area 3D began increasing in 1985 and may have been a response to the increased recruitment noted in trawl fishery. Since 1985, the line catch has accounted for an average of 45% of the total landings. The line catch in 1995 (375 t) decreased (32%) following two years of 500+ t/y landings. For 1996, the fishery was restricted to a 180 t quota and the landings matched the quota very closely (182 t). Most of the lingcod caught by hook and line in Area 3C/D is incidental to the rockfish fisheries (Richards and Yamanaka 1992). However, recent higher line catches resulted from increased targeting on lingcod.

While the qualified trawl catch continues to represent the majority of the trawl landings, we caution that the increasing proportion of the total catch represented by line catches may erode the reliability of the qualified trawl CPUE as a relative abundance index.

2.2.2.3 Condition of the Stock

Stock abundance in Area 3D appears to be declining, based on CPUE. Both trawl landings and effort declined during in 1995 and 1996, from the historic high values in 1994. Landings in 1994 were about 60% higher than the quota, but landings in 1996 were limited and totalled less than the quota. CPUE for 1996 has rebounded from the lower level seen in 1995 but is still below the long-term average. We have no new information to revise the existing quota recommendation (400-800 t) but recommend managers adopt a conservative approach in consideration of the sharp declines in CPUE observed for this stock in recent years.

2.2.4 Queen Charlotte Sound (Areas 5A and 5B)

2.2.4.1 The Fishery

Lingcod stocks in Queen Charlotte Sound are exploited primarily by commercial trawl vessels although lingcod is a minor component of the total trawl fishery in this area, which is dominated by rockfish. There are also small catches of lingcod by hook and line vessels.

2.2.4.2 Catch Statistics

Trawl and line catches in Area 5A/B increased substantially between the mid-1980s (Table 2.9, Fig. 2.6), to a record high in 1990. However, the total catch has declined, to 764 t in 1996, from over 2300 t in 1990. The line catch increased slightly to 181 t in 1996; however the trawl catch decreased substantially to 583 t.

Qualified CPUE (25%) has decreased gradually since the historic peak of 433 kg/h in 1986, (Table 2.9, Fig 2.6). The qualified CPUE in 1995 is the lowest (168 kg/h) since the early 1970s, while qualified effort is the highest on record. CPUE in 1996 rebounded from the 1995 level to 271 kg/h.

2.2.4.3 Condition of the Stock

CPUE for lingcod stocks in Area 5A/B has been declining since the late 1980s and in 1995 was the lowest (168 kg/h) since 1973. CPUE increased in 1996 to 271 kg/h but we caution that this increase is in conjunction with greatly reduced catch and effort. The effort value of 1342 h in 1996 is only 25% of the 1995 effort (5412 h). The increase in CPUE in 1996 may not be reflective of stock abundance.

2.2.4.4 Yield options

In 1994, the recommended low and high risk yield options for the Queen Charlotte Sound lingcod stocks were 1100 and 2200 t, respectively. These estimates were based on equilibrium fishing model analyses (Schnute et al. 1989) and consideration of the productivity off the west coast of Vancouver Island. The model results suggested that Queen Charlotte Sound lingcod could sustain high levels of exploitation, although Richards and Yamanaka (1992) cautioned that the growth and mortality estimates they used were not well determined. Examination of ageing data has created additional uncertainty about these estimates (McFarlane and Leaman 1995).

The recommended low and high risk yield options are 1100 and 2200 t, the same as those in 1997. However, based on the uncertainty about mortality estimation, the high level of fishing effort and the declining CPUE values, we recommend strongly that managers consider a low risk approach to harvest for this stock.

2.2.5 Hecate Strait (Areas 5C/D) and West Coast Queen Charlotte Islands (Area 5E)

2.2.5.1 The fishery

Lingcod in Hecate Strait are fished by both trawl and line vessels, although they form a minor component of the total in either fishery. Landings by line gear were small prior to the mid-1980s, but since then have become an increasing proportion of the total catch. Lingcod has traditionally been an incidental component of line fisheries, such as the halibut fishery, and has increased in the line fisheries for rockfishes. In recent years the directed line fishery for lingcod has also increased.

Lingcod off the west coast of the Queen Charlotte Islands are a minor component of both the trawl and line fisheries. Landings of lingcod from this area have traditionally been incidental to other directed line fisheries. However, since 1992 some directed effort for lingcod has been reported and line catches have reached historic highs (Table 2.11).

Present landings for these areas are now near the recommended precautionary cap of 1000 t.

2.2.5.2 Catch statistics

Trawl lingcod catch in Hecate Strait (174 t) decreased substantially in 1996 from the 1995 catch of 554 t, and is the lowest catch since 1985 (Table 2.10, Fig. 2.7). The total catch of 269 t in 1996 is a 70% reduction from the 1995 catch (835 t).

In 1996 CPUE for the trawl fishery (388 kg/h) increased from 1995 (306 kg/h). This is coincident with a decrease in qualified effort (216 kg/h) from previous years (Table

2.10). However, the low level of historical effort for the fishery renders the CPUE time series of limited value.

For the west coast of the Queen Charlotte Islands (Area 5E), directed line fishing effort began to increase in 1992 but declined sharply in 1995, and increased again in 1996 to 105 t. Total landings were 109 t in 1996.

2.2.5.3 Condition of the stock

No biological information on lingcod stocks in the Hecate Strait/Queen Charlotte Islands areas is available at present. Based on the lack of a trend in CPUE in recent years, there is no indication that the stock in this area is over-exploited. However, some caution is advised because these fisheries have expanded and recent catch statistics may provide little information on sustainable yields for a fixed area. In addition, lingcod stocks have been shown to be susceptible to high catches in other areas.

2.2.5.4 Yield options

Managers are advised to exercise caution because of the rapid increase in this fishery in recent years and the uncertainty about stock boundaries and potential yields. A precautionary yield level of 1000 t is recommended for Areas 5C/D and 5E combined. We also recommend that the yield level imposed should be maintained for a period sufficiently long to evaluate whether it is appropriate. This period could be 3-5 y or longer, depending on our ability to monitor the fishery on a scale appropriate to stock distribution and movements. We caution that the fishery management areas used presently may be too large to prevent localized depletion of these relatively sedentary resources.

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Figure Captions

Fig. 2.1. Total catch (t), 25% qualified effort (h), and qualified catch per unit effort (kg/h) for lingcod stocks off the southwest coast of Vancouver Island (Area 3C).

Fig. 2.2. Reconstruction analyses of Area 3C lingcod by run, showing selectivity, recruitment and biomass trajectories. See text for details of runs.

Fig. 2.3 Reconstruction analyses of Area 3C lingcod by run, showing fits to effort and estimated fishing mortality. See text for details of runs.

Fig. 2.4 Residuals of estimated abundance at age for Area 3C by run. See text for details of runs.

Fig. 2.5 Total catch (t), 25% qualified effort (h), and qualified catch per unit effort (kg/h) for lingcod stocks off the northwest coast of Vancouver Island.

Fig. 2.6 Total catch (t), 25% qualified effort (h), and qualified catch per unit effort (kg/h) for lingcod stocks in Queen Charlotte Sound.

Fig. 2.7 Total catch (t), 25% qualified effort (h), and qualified catch per unit effort (kg/h) for lingcod stocks in Hecate Strait (lower).

Fig. 2.8 Total catch (t), 25% qualified effort (h), and qualified catch per unit effort (kg/h) for lingcod stocks off the west coast of the Queen Charlotte Islands.

Table 2.1 Comparison of tow-by-tow (TBT) and aggregated (ROLLUP) CPUE. Lingcod 25% qualified catch data.

Year	1991	1992	1993	1994	1995	Average
3C ROLL	260	307	607	219	234	
3C TBT	302	354	671	238	258	
TBT:ROLL	1.162	1.153	1.105	1.087	1.103	1.122
3D ROLL	260	236	172	286	191	
3D TBT	304	252	192	300	194	
TBT:ROLL	1.169	1.068	1.116	1.049	1.016	1.084
5AB ROLL	290	217	243	212	168	
5AB TBT	327	244	266	245	185	
TBT:ROLL	1.128	1.124	1.095	1.156	1.101	1.121
5CD ROLL	275	288	295	495	306	
5CD TBT	397	330	327	478	321	
TBT:ROLL	1.444	1.146	1.108	0.966	1.049	1.143
Average	1.225	1.123	1.106	1.064	1.067	1.117

Table 2.2. Lingcod trawl, line, and total catches, qualified lingcod catch, effort, CPUE, sample size (N), and the percent (P) of lingcod trawl catch that meets the qualification levels for Area 3C, 1956-1996. Note CPUE is based on tow-by-tow data after 1995; aggregated by tow within locality prior to 1995.

	TOTAL CATCH (t)			INTERVIEWED (25% QUALIFIED)				
Year	Trawl	Line	Total	Catch (kg)	Effort (h)	CPUE (kg/h)	N	P (%)
1956	1151	156	1307	429540	1385	310	64	37.3
1957	1070	295	1365	384610	1290	298	55	35.9
1958	1047	156	1203	333000	936	356	46	31.8
1959	1742	113	1855	226830	742	306	37	13.0
1960	1867	219	2086	288050	1348	214	46	15.4
1961	1972	136	2108	391000	1252	312	56	19.8
1962	890	228	1118	152100	669	227	27	17.1
1963	609	147	756	145899	413	353	35	24.0
1964	1127	101	1228	261492	624	419	44	23.2
1965	1812	122	1934	424005	1144	371	55	23.4
1966	2030	158	2188	435325	1415	308	97	21.4
1967	1779	246	2025	658182	1557	423	85	37.0
1968	1661	156	1817	456413	757	603	60	27.5
1969	1054	171	1225	437031	1513	289	71	41.6
1970	703	286	989	468604	1663	282	72	66.7
1971	979	231	1210	548546	1531	358	87	56.0
1972	625	267	892	265189	926	286	56	42.4
1973	876	185	1061	434358	1239	351	43	49.6
1974	1029	224	1253	528604	1742	303	53	51.4
1975	1630	216	1846	955063	2581	370	99	58.6
1976	1205	253	1458	456842	1845	248	78	37.9
1977	844	267	1111	363063	1265	287	69	43.0
1978	360	91	451	184618	820	225	49	51.3
1979	602	82	684	323404	1143	283	52	53.7
1980	623	97	720	270883	926	293	56	43.5
1981	603	240	843	321221	1227	262	56	53.3
1982	1510	221	1731	1101084	2673	412	89	72.9
1983	970	170	1140	506919	1343	377	61	52.3
1984	1731	128	1859	904281	2032	445	80	52.2
1985	3416	207	3623	1810835	3408	531	99	53.0
1986	834	241	1075	387544	1021	380	59	46.5
1987	492	234	726	236525	1150	206	67	48.1
1988	565	113	679	244008	1117	218	77	43.2
1989	850	131	981	543030	953	301	110	63.9
1990	1154	236	1390	721468	2760	261	166	62.5
1991	1265	181	1446	1114260	4284	260	173	88.1
1992	992	145	1137	682290	2224	304	170	68.7
1993	1478	210	1688	911530	1501	607	142	61.7
1994	687	197	884	302760	1383	219	107	44.1
1995	787	193	980	552990	2365	234	116	70.2
1996	701	111	812	85190	588	150	192	12.2

Table 2.3 Lingcod sport catch (numbers of fish or tons[a]), effort (boat trips), and the ratio of catch to effort (kg per 10 boat trips) for Barkley Sound, based on creel survey data during August and September, 1984-1995.

YEAR	CATCH Fish	t	EFFORT	CPUE
1984	1821	2.9	21439	1.36
1985	4016	6.4	21772	2.95
1987	3351	5.4	24383	2.20
1988	4163	6.7	24670	2.70
1989	5849	9.4	36946	2.53
1990	2154	3.4	42864	0.80
1991	2059	3.3	40792	0.81
1992	2840	4.5	55140	0.82
1994	4213	6.7	46276	1.45
1995	2729	4.4	30901	1.41
1996	1285	2.1	6504	3.16

[a] A value of 1.6 kg/fish used to convert numbers to weight.

Table 2.4. Lingcod age samples for Area 3C, 1977-1995. Includes only fin-aged samples with reliable ages.

YEAR	Number of samples	Number of fish
1977	5	466
1978	2	338
1979	3	853
1980	1	287
1981	2	314
1982	1	181
1983	2	334
1984	3	694
1985	5	216
1986	2	377
1987	4	200
1988	4	165
1989	3	211
1990	2	192
1991	2	80
1992	1	50
1993	2	100
1994	1	50
1995	9	977
1996	1	63

Table 2.5 Biological parameters for Area 3C lingcod used in the stock synthesis catch-age model. Data are arrayed by sex and age (2-16+ y).

0.7 2.2 3.1 3.9 4.8 5.7 6.6 7.7	
8.9 9.8 10.8 11.9 12.7 13.9 14.8 15.6	FEM Weight at age (WAA)
0.7 1.9 2.4 3.1 3.4 3.9 4.4 4.8	
5.2 5.7 5.9 6.1 6.2 6.3 6.4 6.5	MAL WAA
0.7 2.2 3.1 3.9 4.8 5.7 6.6 7.7	
8.9 9.8 10.8 11.9 12.7 13.9 14.8 15.6	TWL FEM WAA
0.7 1.9 2.4 3.1 3.4 3.9 4.4 4.8	
5.2 5.7 5.9 6.1 6.2 6.3 6.4 6.5	TWL MAL WAA
0.0853 0.1539 0.2618 0.4089 0.5743 0.7246 0.8369 0.9091	
0.9512 0.9744 0.9867 0.9931 0.9965 0.9982 0.9991 1.0	FEM % MATURE
1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0	
1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0	EGGS/GM
.5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5	% FEMALE

Natural mortality

Females	0.193
Males	0.259

Table 2.6. Example of the ageing error imprecision matrix used in the Area 3C lingcod stock reconstruction.

Age/Bin	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15-	0	0	0	0	0	0	0	0	0	0	0	1	142	966
14-	0	0	0	0	0	0	0	0	0	0	2	154	716	34
13-	0	0	0	0	0	0	0	0	0	3	166	690	142	0
12-	0	0	0	0	0	0	0	0	6	179	663	154	1	0
11-	0	0	0	0	0	0	0	9	193	635	166	1	0	0
10-	0	0	0	0	0	0	4	207	602	179	2	0	0	0
9-	0	0	0	0	1	22	220	568	193	3	0	0	0	0
8-	0	0	0	3	33	230	532	207	6	0	0	0	0	0
7-	0	1	7	46	238	494	220	9	0	0	0	0	0	0
6-	3	13	63	242	455	230	14	0	0	0	0	0	0	0
5-	24	81	243	418	238	22	0	0	0	0	0	0	0	0
4-	98	237	376	242	33	0	0	0	0	0	0	0	0	0
3-	227	337	243	46	1	0	0	0	0	0	0	0	0	0
2-	648	332	69	3	0	0	0	0	0	0	0	0	0	0

Table 2.7. Output estimates of stock biomass and terminal fishing mortality from stock reconstructions for Area 3C lingcod.

Run	CAA Emphasis	CPUE Emphasis	Selectivity	Recruits Estimated	Objective Function Value	Ending Biomass (t)	Terminal F
R07	1.0	1.0	Dome	1977-1990	-732.69	13070	0.161
R08	1.0	0.1	Dome	1977-1990	-590.71	14345	0.148
R09	0.1	1.0	Dome	1977-1990	-144.49	11482	0.346
R10	1.0	1.0	Dome	1977-1992	-722.36	10536	0.207
R11	1.0	0.1	Dome	1977-1992	-571.60	14678	0.163
R12	0.1	1.0	Dome	1977-1992	-147.77	11955	0.214
R13	1.0	1.0	Asymptotic	1977-1992	-732.40	8823	0.208
R14	1.0	0.1	Asymptotic	1977-1992	-598.53	9024	0.199
R15	0.1	1.0	Asymptotic	1977-1992	-149.15	7991	0.334

Table 2.8. Lingcod trawl, line, and total catches, May-September qualified lingcod catch, effort, CPUE, sample size (N), and the percent (P) of lingcod trawl catch that meets the qualification levels for Area 3D, 1956-1996. Note CPUE is based on tow-by-tow data after 1995; aggregated by tow within locality prior to 1995.

	TOTAL CATCH (t)			INTERVIEWED (25% QUALIFIED)				
	Trawl	Line	Total	Catch	Effort	CPUE	N	P
Year				(kg)	(h)	(kg/h)		(%)
1956	168	135	303	44060	140	315	13	26.2
1957	130	146	276	71110	259	336	11	54.7
1958	109	130	239	23000	127	181	10	21.1
1959	64	102	166	9244	23	402	4	5.6
1960	87	115	202	33046	68	486	8	38.0
1961	200	125	325	39202	103	381	10	19.6
1962	286	112	398	36767	185	199	25	13.0
1963	115	132	247	31688	123	258	10	27.6
1964	226	92	318	186512	510	366	26	82.5
1965	505	97	602	413973	1445	286	49	82.0
1966	585	147	732	509054	1159	439	54	87.0
1967	459	180	639	328859	833	395	41	72.0
1968	868	117	985	649257	1196	543	70	75.0
1969	619	84	703	492318	1684	292	104	79.5
1970	456	171	627	367111	1352	272	95	81.0
1971	264	124	388	169580	819	207	66	64.2
1972	85	197	282	60231	317	190	19	71.0
1973	172	91	263	88824	229	389	13	34.0
1974	242	123	365	119368	220	542	28	49.3
1975	347	97	444	109024	384	284	33	31.4
1976	245	98	343	86759	277	313	28	35.4
1977	158	116	274	86302	283	305	41	54.6
1978	197	95	292	132527	277	478	44	67.3
1979	147	110	257	25615	81	315	17	17.4
1980	127	95	222	20492	95	215	16	16.1
1981	87	122	209	31696	145	219	17	36.4
1982	49	175	224	6628	35	191	7	13.5
1983	447	153	600	224935	687	327	45	50.3
1984	322	153	475	135116	480	282	29	42.0
1985	380	194	574	56970	114	498	12	15.0
1986	246	229	475	51568	154	322	26	21.0
1987	88	327	415	28589	92	310	13	32.5
1988	283	236	519	103893	315	329	34	37.0
1989	300	196	496	170919	601	284	38	57.0
1990	396	241	637	269436	772	349	56	68.0
1991	549	284	833	344030	1323	260	76	62.7
1992	554	309	863	252040	1069	236	109	45.5
1993	448	591	1039	125430	729	172	103	28.0
1994	847	553	1400	580750	2033	286	124	68.6
1995	477	375	852	240510	1257	191	111	50.4
1996	189	182	371	66333	224	296	106	35.1

Table 2.9. Lingcod trawl, line, and total catch, May-September qualified lingcod catch, effort, CPUE, sample size (N), and the percent (P) of lingcod trawl catch that meets the qualification levels for Area 5A/B, 1956-1996. Note CPUE is based on tow-by-tow data after 1995; aggregated by tow within locality prior to 1995.

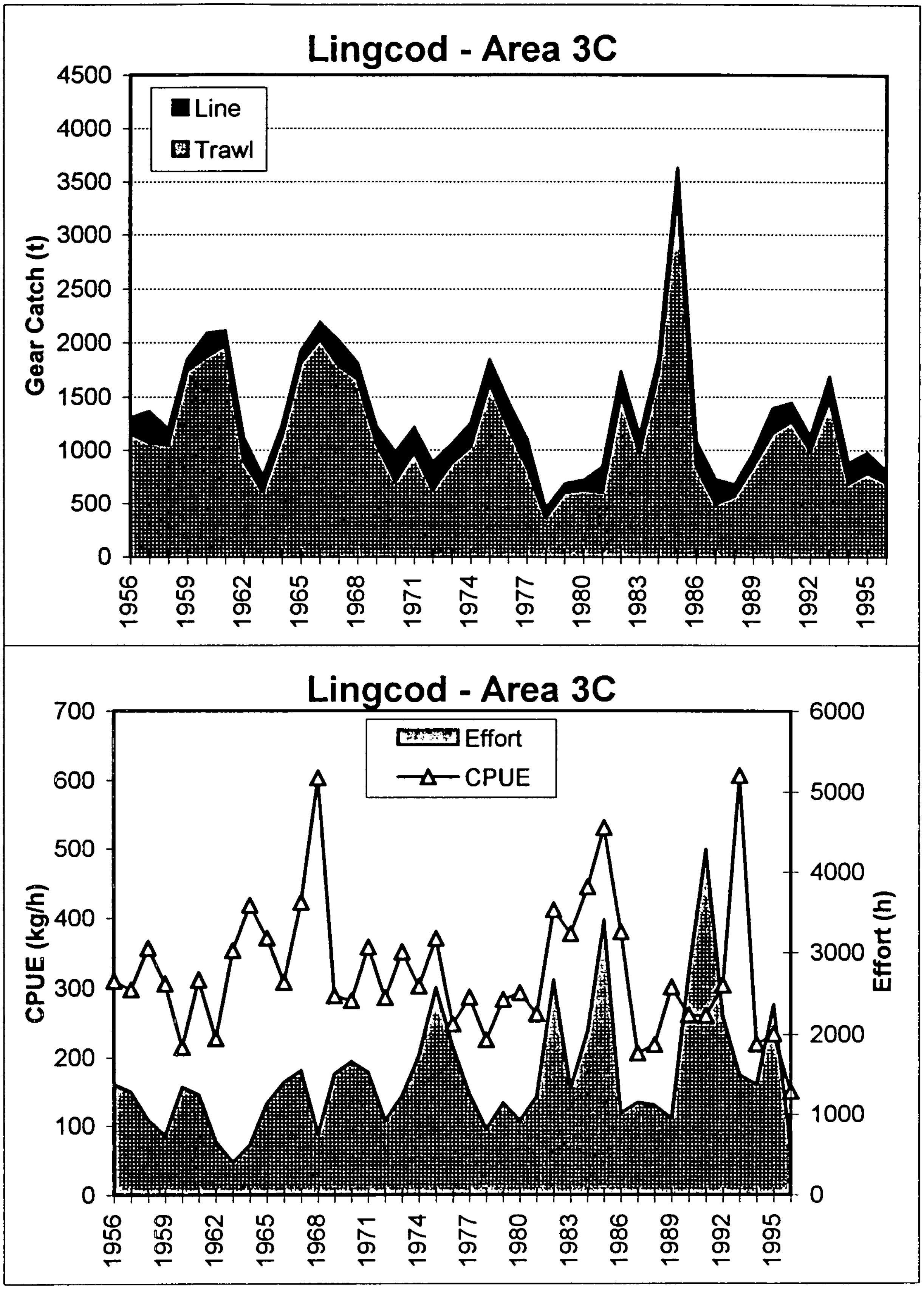
	TOTAL CATCH (t)			INTERVIEWED (25% QUALIFIED)				
	Trawl	Line	Total	Catch	Effort	CPUE	N	P
Year				(kg)	(h)	(kg/h)		(%)
1956	600	28	628	135100	457	296	24	22.5
1957	603	8	611	141290	572	494	29	23.6
1958	572	1	573	206510	1012	204	43	36.1
1959	621	2	623	275660	883	312	43	44.4
1960	657	16	673	184050	732	251	40	28.0
1961	711	22	733	298330	922	324	35	42.0
1962	938	41	979	406610	1602	254	61	43.4
1963	642	43	685	172444	842	205	63	27.0
1964	687	16	703	238176	942	253	69	34.7
1965	897	13	910	122223	502	243	52	13.6
1966	1532	31	1563	368181	1239	297	95	24.0
1967	1660	27	1687	257010	846	304	81	15.5
1968	2270	28	2298	657745	2360	279	167	29.0
1969	1134	36	1170	261452	1828	143	111	23.0
1970	980	46	1026	202127	917	220	90	20.6
1971	645	40	685	176880	1292	137	75	27.4
1972	640	74	714	121295	625	194	35	19.0
1973	581	58	639	102527	634	162	34	17.6
1974	871	71	942	131287	523	251	20	15.1
1975	533	54	587	125033	707	177	43	23.5
1976	603	70	673	172205	692	249	52	28.6
1977	379	67	446	137419	721	191	42	36.2
1978	290	32	322	117680	540	218	34	40.6
1979	342	44	386	82692	352	235	28	24.2
1980	410	45	455	167430	767	218	62	41.0
1981	731	45	776	551349	2038	271	114	75.4
1982	1048	43	1091	803102	2982	269	149	76.6
1983	1345	47	1392	977096	2990	327	152	72.6
1984	716	57	773	360590	1700	212	76	50.4
1985	877	67	944	586722	2092	280	67	67.0
1986	1652	48	1700	1319542	3008	439	107	80.0
1987	1432	109	1541	714278	2223	321	120	50.0
1988	1291	121	1412	747552	2070	361	109	58.0
1989	1617	149	1766	962816	3009	320	131	60.0
1990	2137	178	2315	1380330	4595	300	228	64.6
1991	1861	305	2206	1122070	3872	290	186	60.3
1992	1263	262	1525	544570	2555	217	162	43.9
1993	1372	98	1470	614770	2526	243	174	44.8
1994	1335	127	1462	958730	4518	212	204	71.8
1995	1162	140	1302	910970	5412	168	285	78.4
1996	583	181	764	363971	1342	271	601	62.4

Table 2.10. Lingcod trawl, line, and total catches, May-September qualified lingcod catch, effort, CPUE, sample size (N), and the percent (P) of lingcod trawl catch that meets the qualification levels for Area 5C/D, 1956-1996. Note CPUE is based on tow-by-tow data after 1995; aggregated by tow within locality prior to 1995.

	TOTAL CATCH (t)			INTERVIEWED (25% QUALIFIED)				
	Trawl	Line	Total	Catch	Effort	CPUE	N	P
Year				(kg)	(h)	(kg/h)		(%)
1956	25	-	25	3317	15	221	1	13.3
1957	27	-	27	6104	7	872	1	22.6
1958	16	-	16	742	6	124	3	4.6
1959	41	-	41	1771	22	80	3	4.3
1960	67	-	67	4778	34	141	3	7.1
1961	34	-	34	2573	24	107	4	7.6
1962	69	-	69	1189	7	170	2	1.7
1963	90	-	90	33434	73	458	7	37.1
1964	153	-	153	75003	165	455	13	49.0
1965	189	-	189	67776	76	892	12	36.0
1966	212	-	212	40012	100	399	11	19.0
1967	224	-	224	100821	290	347	22	45.0
1968	307	-	307	120429	476	253	37	39.2
1969	197	-	197	65609	418	157	38	33.3
1970	155	-	155	49474	252	196	16	32.0
1971	225	-	225	143922	531	271	40	64.0
1972	106	-	106	28020	71	397	8	26.4
1973	84	-	84	15541	43	359	6	18.5
1974	74	-	74	1933	26	76	4	2.6
1975	109	-	109	30857	51	611	9	28.3
1976	42	-	42	6738	24	281	6	16.0
1977	83	-	83	1824	10	192	3	2.2
1978	24	-	24	181	8	23	1	0.8
1979	80	-	80	16604	72	232	10	21.0
1980	106	-	106	6427	59	109	15	6.1
1981	178	-	178	21507	96	224	17	12.1
1982	161	-	161	61999	229	271	11	39.0
1983	109	-	109	43136	213	203	16	39.6
1984	117	-	117	6216	55	113	8	5.3
1985	91	176	267	33538	135	248	10	37.0
1986	112	177	289	22986	97	236	13	20.5
1987	285	324	609	49642	120	413	18	17.4
1988	273	290	563	86654	254	342	27	32.0
1989	213	286	499	25853	79	327	12	12.1
1990	263	371	634	67419	223	302	25	25.6
1991	529	317	846	163130	594	275	47	30.8
1992	445	290	735	101000	351	288	48	22.7
1993	456	288	744	148660	505	295	69	32.6
1994	545	204	749	153860	311	495	38	28.2
1995	554	281	835	207810	679	306	64	37.5
1996	174	95	269	83691	216	388	114	48.1

Table 2.11. Lingcod trawl, line, and total catches, May-September qualified lingcod catch, effort, CPUE, sample size (N), and the percent (P) of lingcod trawl catch that meets the qualification levels for Area 5E, 1970-1996. Note CPUE is based on tow-by-tow data after 1995; aggregated by tow within locality prior to 1995.

	TOTAL CATCH (t)			INTERVIEWED (25% QUALIFIED)				
	Trawl	Line	Total	Catch	Effort	CPUE	N	P
Year				(kg)	(h)	(kg/h)		(%)
1970	-	-	-	-	-	-	-	-
1971	-	15	-	-	-	-	-	-
1972	-	11	-	-	-	-	-	-
1973	-	7	-	-	-	-	-	-
1974	-	13	-	-	-	-	-	-
1975	-	16	-	-	-	-	-	-
1976	0.03	10	10	-	-	-	-	-
1977	5	4	9	-	-	-	-	-
1978	3	5	8	-	-	-	-	-
1979	1	5	6	-	-	-	-	-
1980	4	14	18	-	-	-	-	-
1981	1	14	15	-	-	-	-	-
1982	2	25	27	-	-	-	-	-
1983	1	13	14	80	6.5	12.3	1	6
1984	9	45	54	-	-	-	-	-
1985	15	28	43	200	2.5	80	1	2
1986	13	50	63	-	-	-	-	-
1987	6	54	60	2420	12	202	1	3
1988	20	79	99	-	-	-	-	-
1989	21	73	94	-	-	-	-	-
1990	28	73	101	-	-	-	-	-
1991	10	58	69	-	-	-	-	-
1992	9	106	115	50	2.0	26	1	0.5
1993	10	127	137	490	2.3	212	2	4.9
1994	12	132	144	110	5.7	19	2	0.9
1995	8	69	77	770	2.7	285	1	9.6
1996	8	101	109	-	-	-	-	0.0



Lingcod - Area 3C
Line
Trawl
Gear Catch (t)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
Lingcod - Area 3C
Effort
CPUE
CPUE (kg/h)
Effort (h)
700
600
500
400
300
200
100
0
6000
5000
4000
3000
2000
1000
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995

Fig. 2.1

Selectivity | Recruitment | Biomass Trajectories

Run R09 - CPUE Weighted Fit; CPUE emphasis at 1.0, CAA emphasis 0.1; last 4 yrs recruitment at time-series mean

RUN R08 CAA weighted fit; CAA emphasis at 1.0, CPUE emphasis at 0.1; last 4 yr recruitments at time-series mean

RUN R07 Balanced CPUE-CAA fit; CPUE and CAA emphasis at 1.0; last 4 y recruitments at time-series mean.

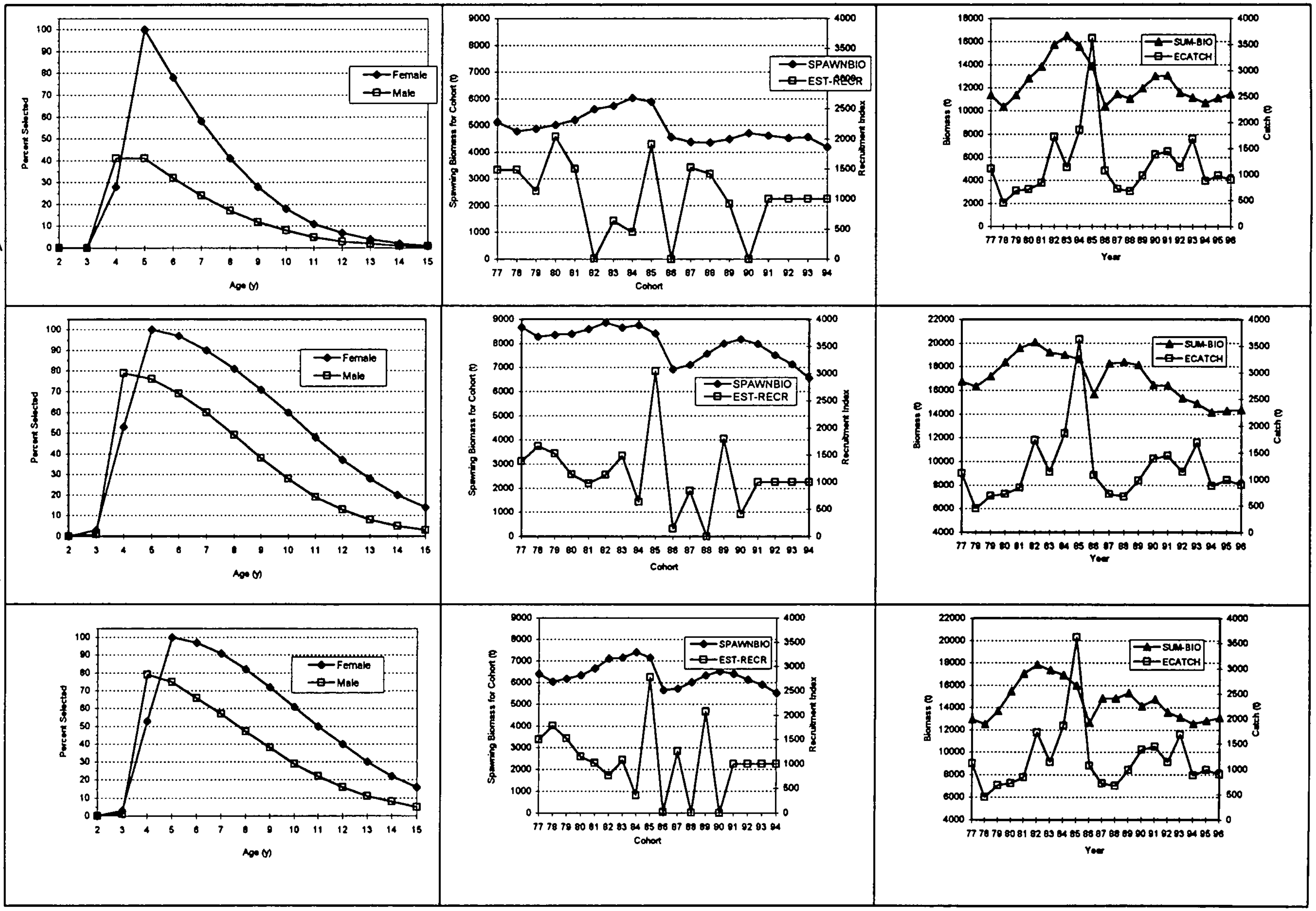


Fig. 2.2

Selectivity | **Recruitment** | **Biomass Trajectories**

RUN R10 as R07: CAA and CPUE emphasis at 1.0; last 2 y recruitments at time-series mean

RUN R12 as R09: CPUE Weighted fit; CPUE at 1.0; CAA at 0.1;last 2 recruitments at time series mean

RUN R13 as R10: CAA and CPUE emphasis at 1.0; last 2 y recruitments at time-series mean; female selectivity fixed at max.

RUN R15 as R12: CPUE Weighted fit; CPUE at 1.0; CAA at 0.1;last 2 recruitments at time series mean; female selectivity fixed at max.

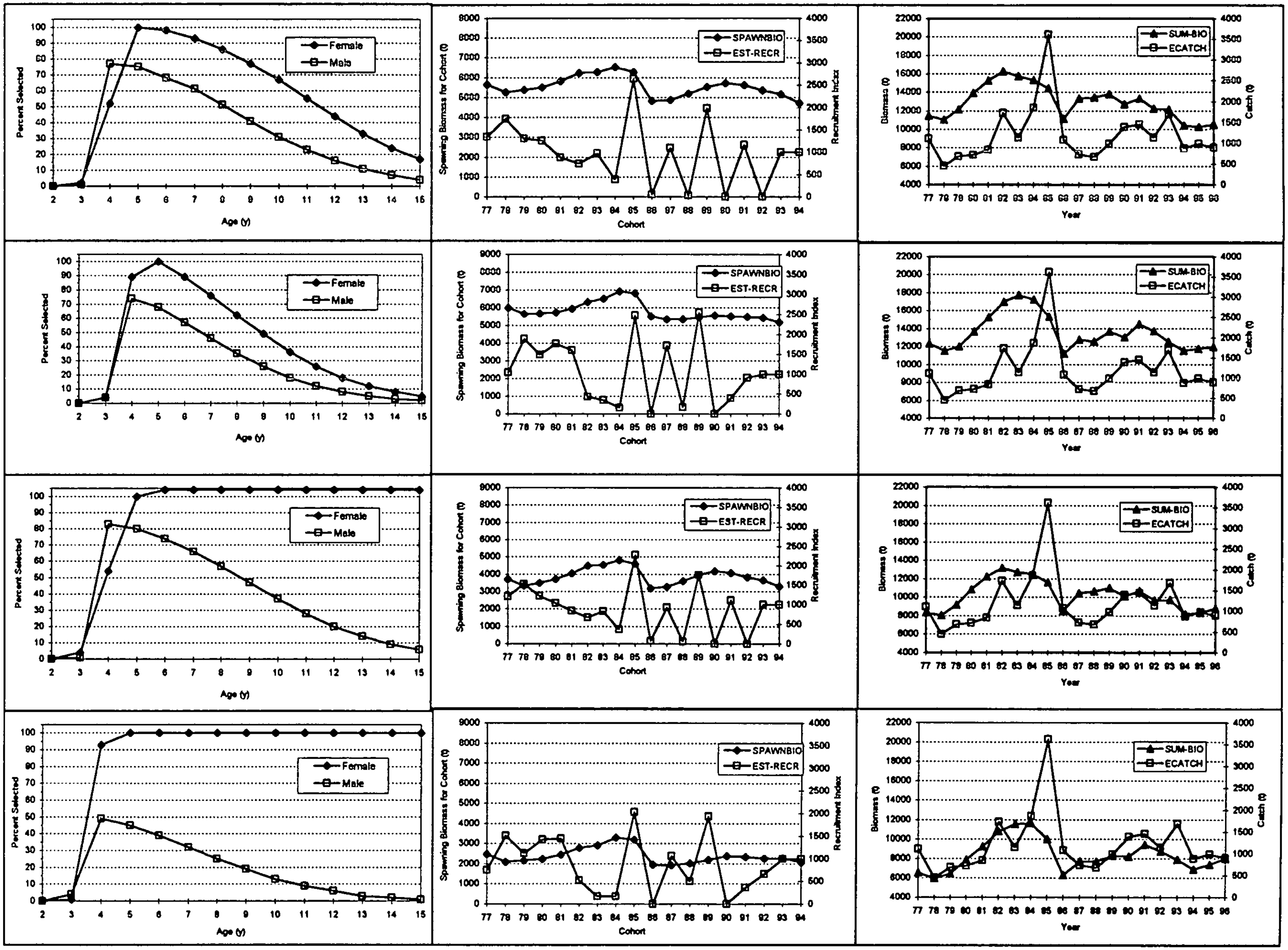
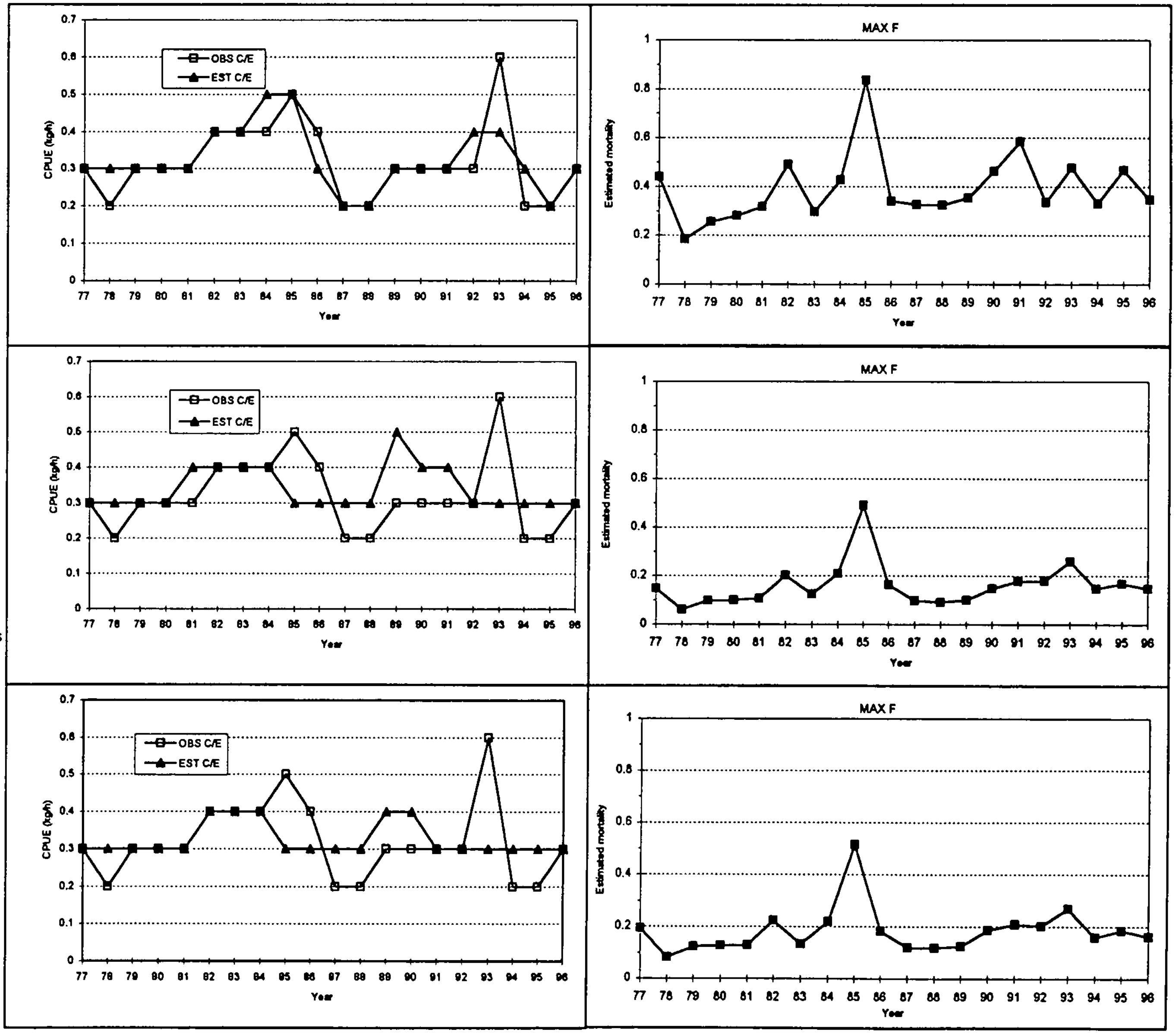


Fig. 2.2 (Cont.)

Effort | Estimated fishing mortality



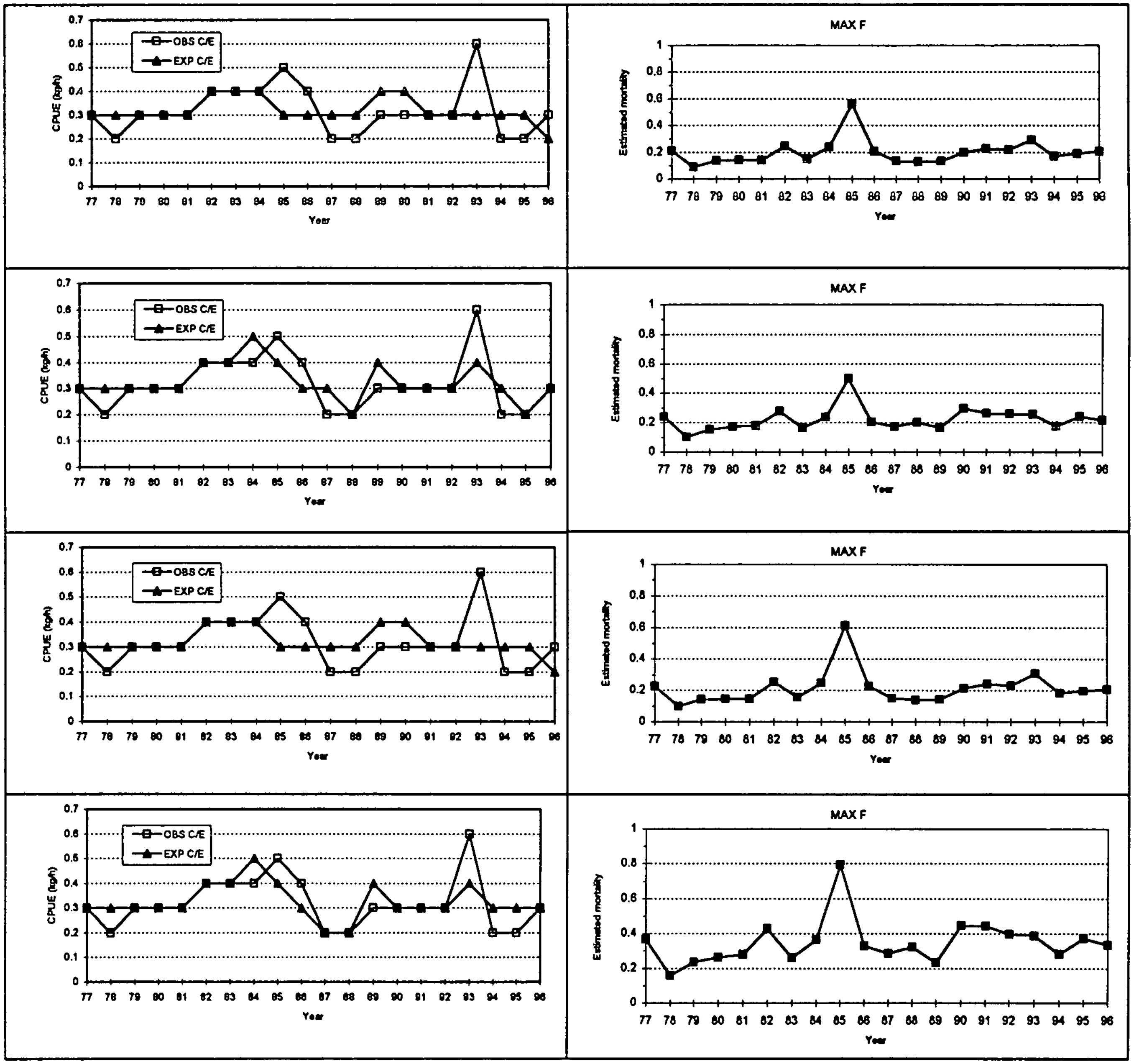
Run R09 - CPUE Weighted Fit; CPUE emphasis at 1.0, CAA emphasis 0.1; last 4 yrs recruitment at time-series mean

RUN R08 CAA weighted fit; CAA emphasis at 1.0, CPUE emphasis at 0.1; last 4 yr recruitments at time-series mean

RUN R07 Balanced CPUE-CAA fit; CPUE and CAA emphasis at 1.0; last 4 y recruitments at time-series mean.

Fig. 2.3

Effort | Estimated fishing mortality



RUN R10 as R07: CAA and CPUE emphasis at 1.0; last 2 y recruitments at time-series mean

RUN R12 as R09: CPUE Weighted fit; CPUE at 1.0; CAA at 0.1;last 2 recruitments at time series mean

RUN R13 as R10: CAA and CPUE emphasis at 1.0; last 2 y recruitments at time-series mean; female selectivity fixed at max.

RUN R15 as R12: CPUE Weighted fit; CPUE at 1.0; CAA at 0.1;last 2 recruitments at time series mean; female selectivity fixed at max.

Fig. 2.3 (Cont.)

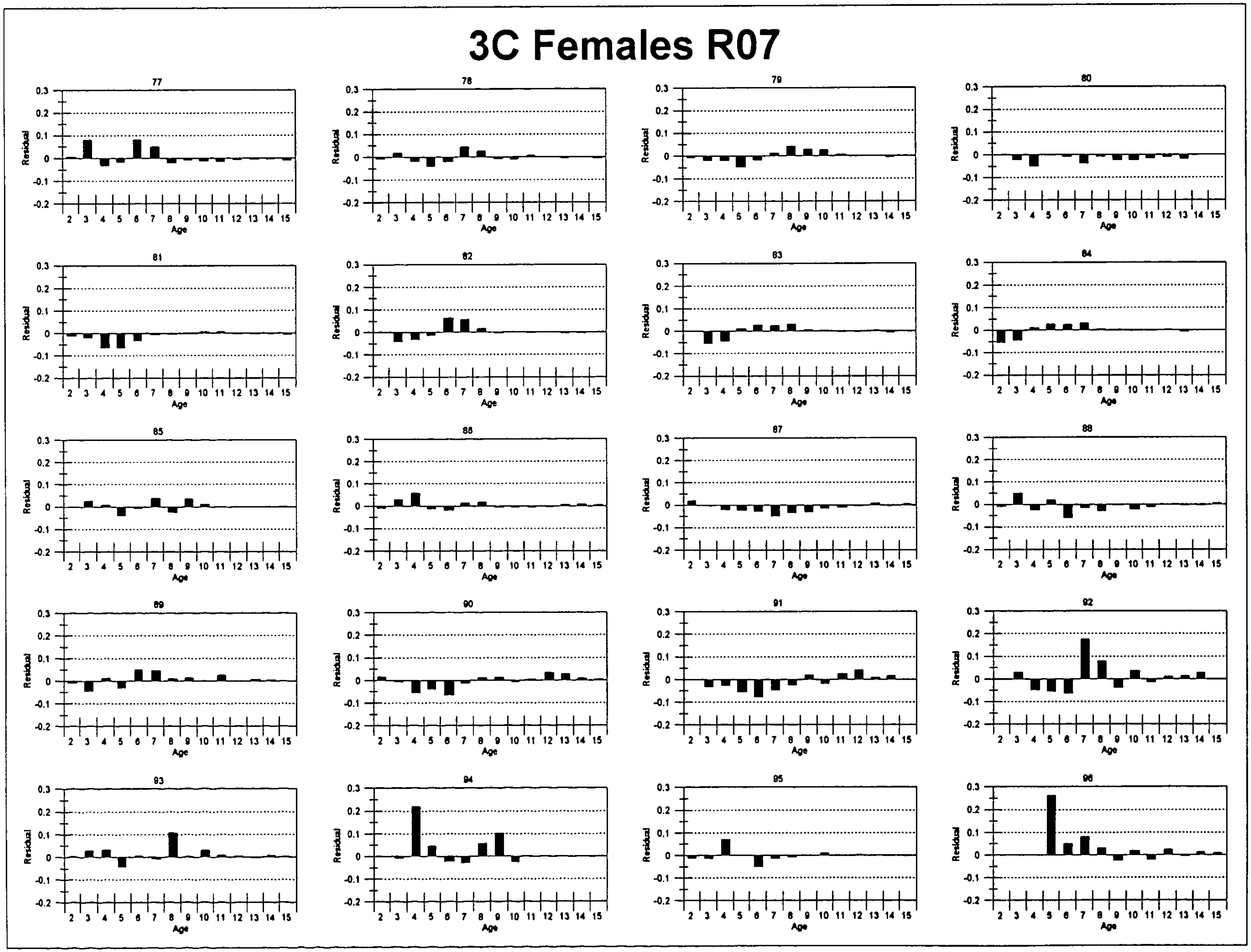

3C Females R07
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
Residual
Age

Fig. 2.4

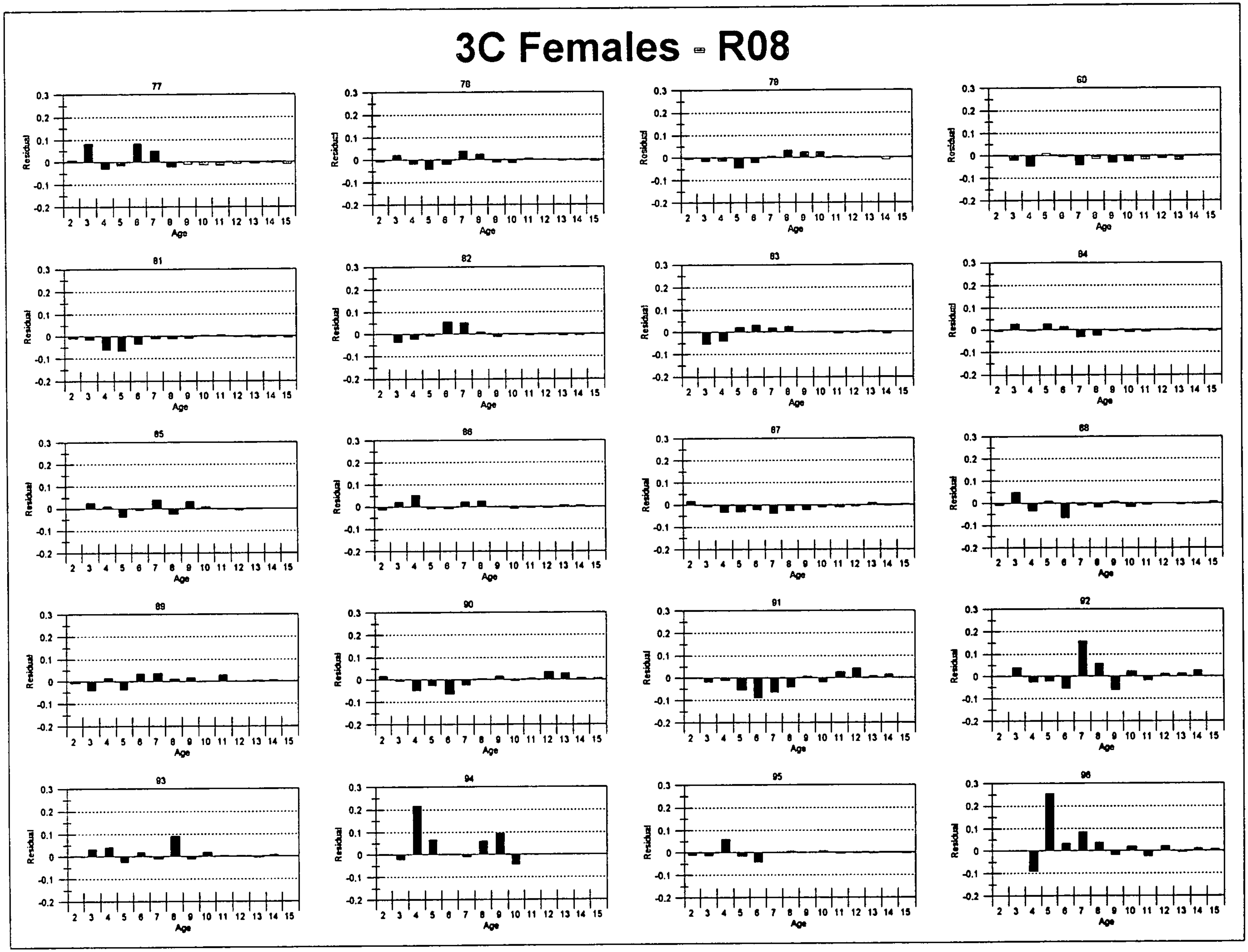

3C Females - R08
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
Residual
Age

Fig. 2.4 (Cont.)

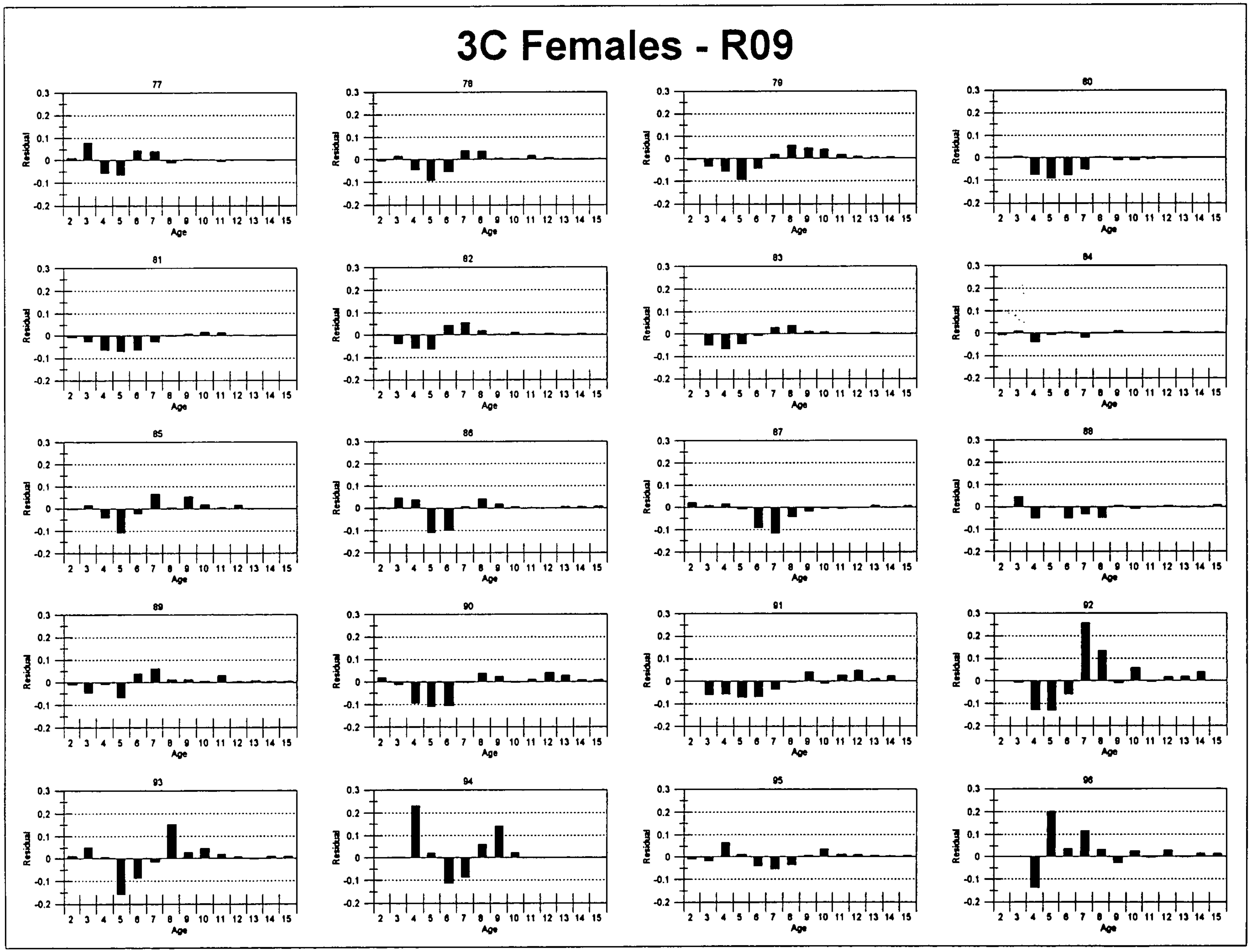

3C Females - R09
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
Residual
Age

Fig. 2.4 (Cont.)

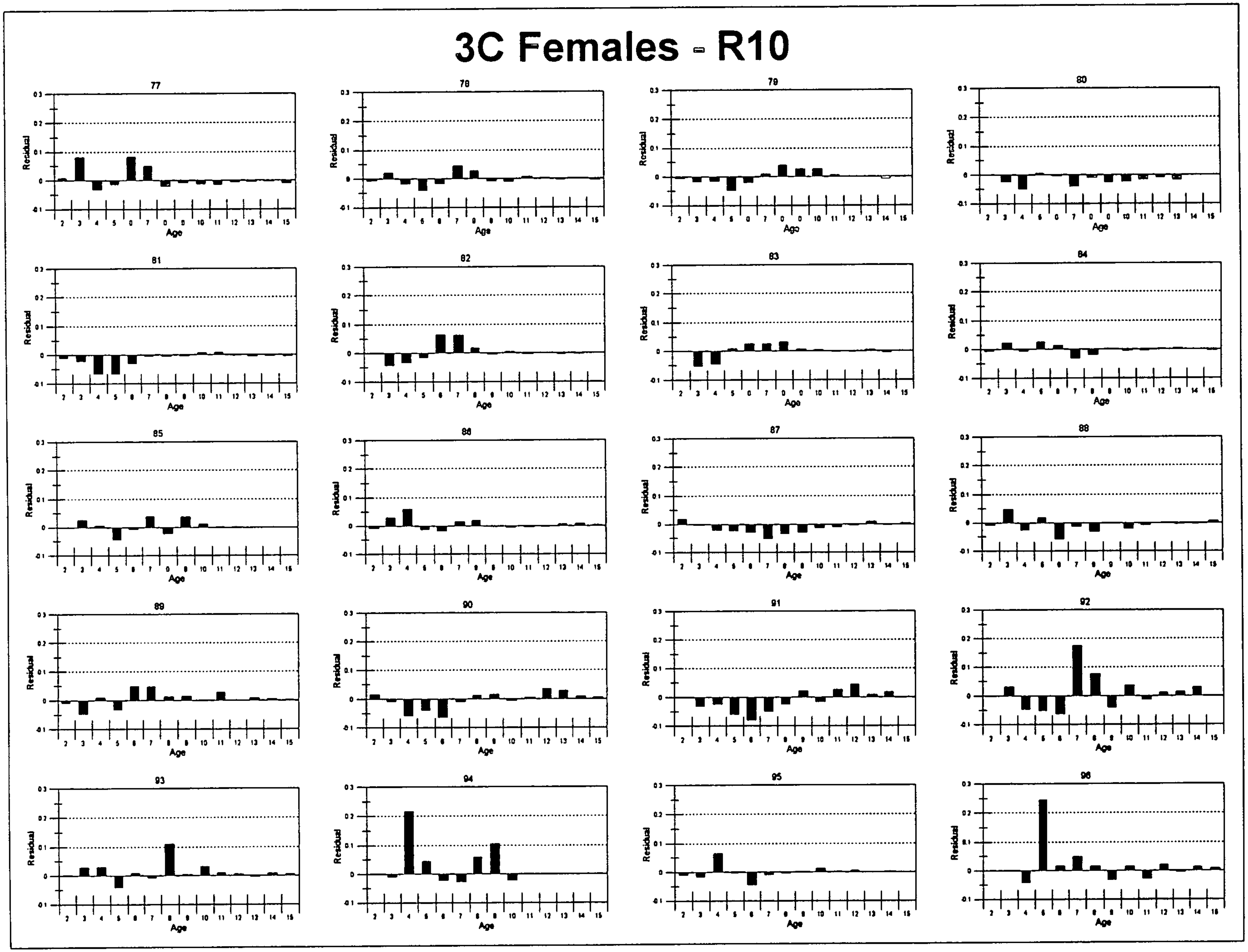

3C Females - R10
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
Residual
Age

Fig. 2.4 (Cont.)

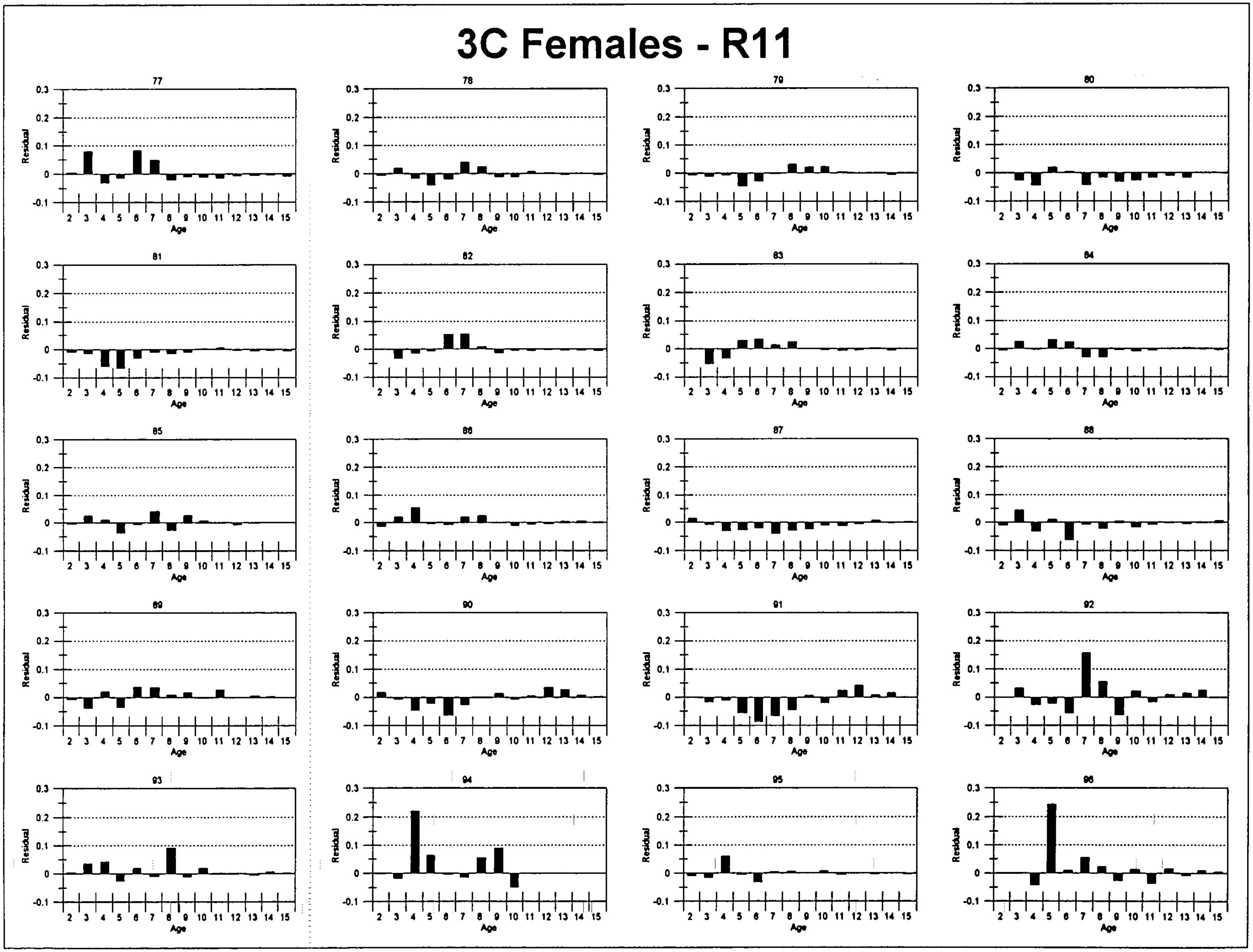

3C Females - R11
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
Residual
Age

Fig. 2.4 (Cont.)

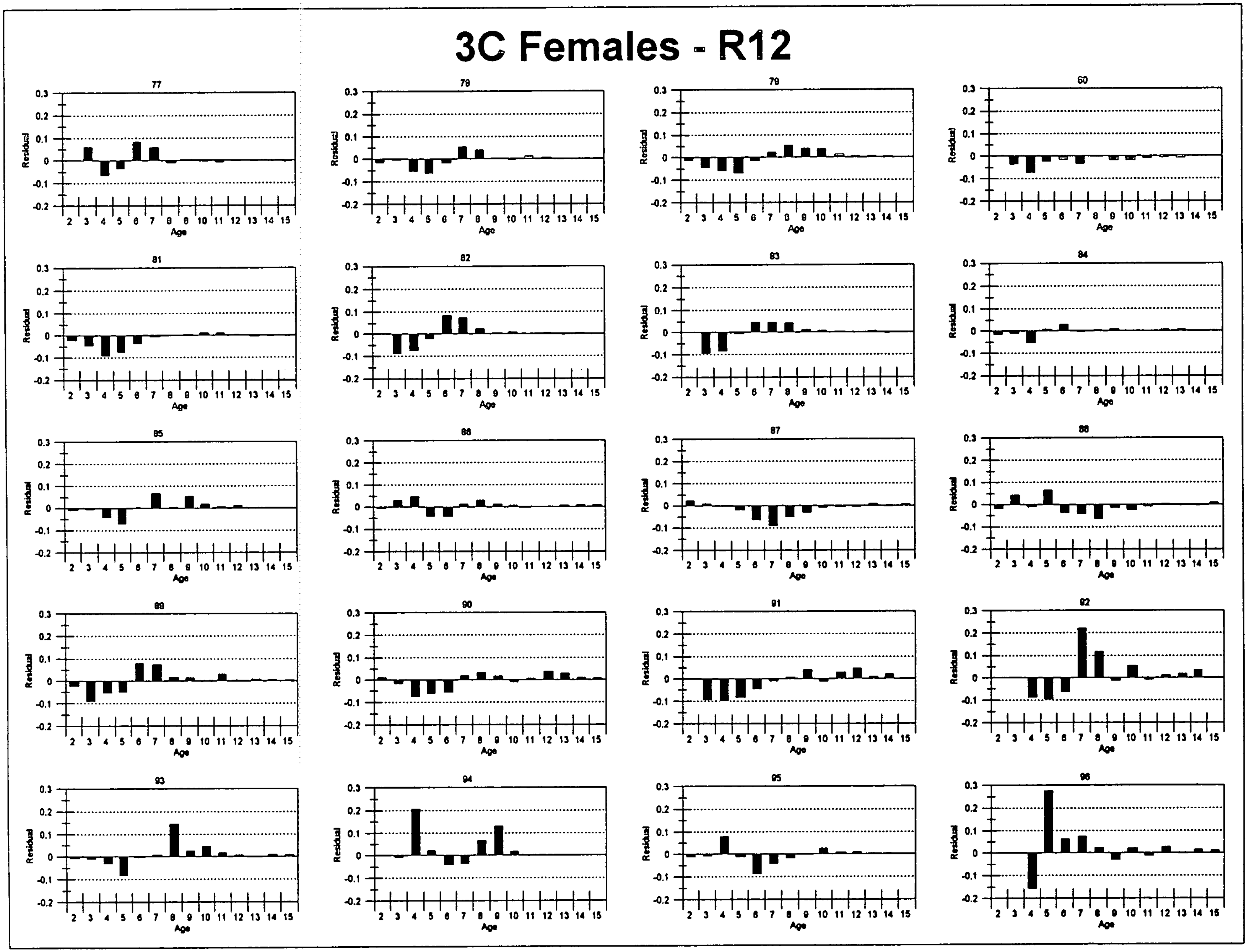

3C Females - R12
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
Residual
Age
0.3
0.2
0.1
0
-0.1
-0.2
2 3 4 5 6 7 8 9 10 11 12 13 14 15

Fig. 2.4 (Cont.)

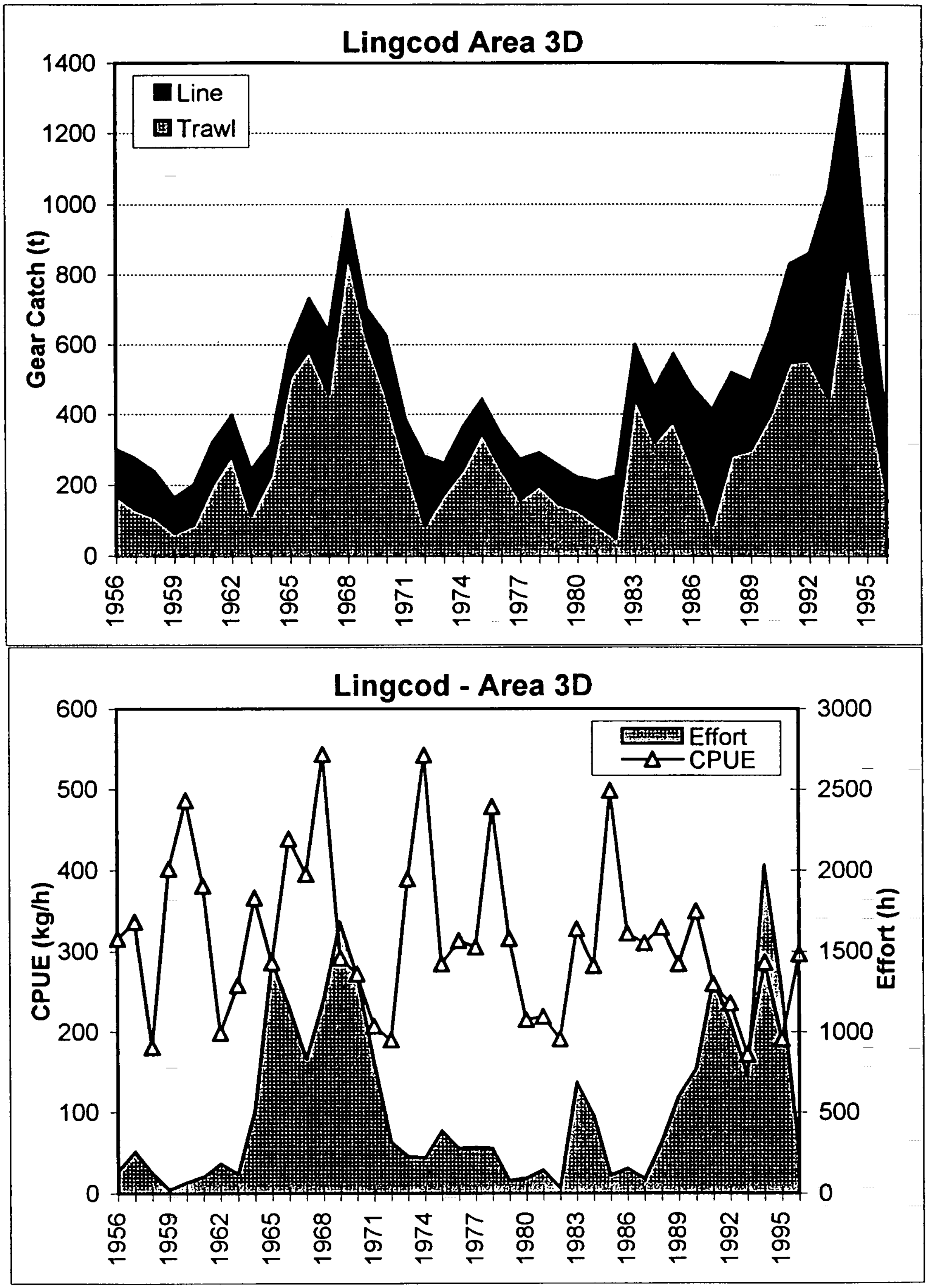
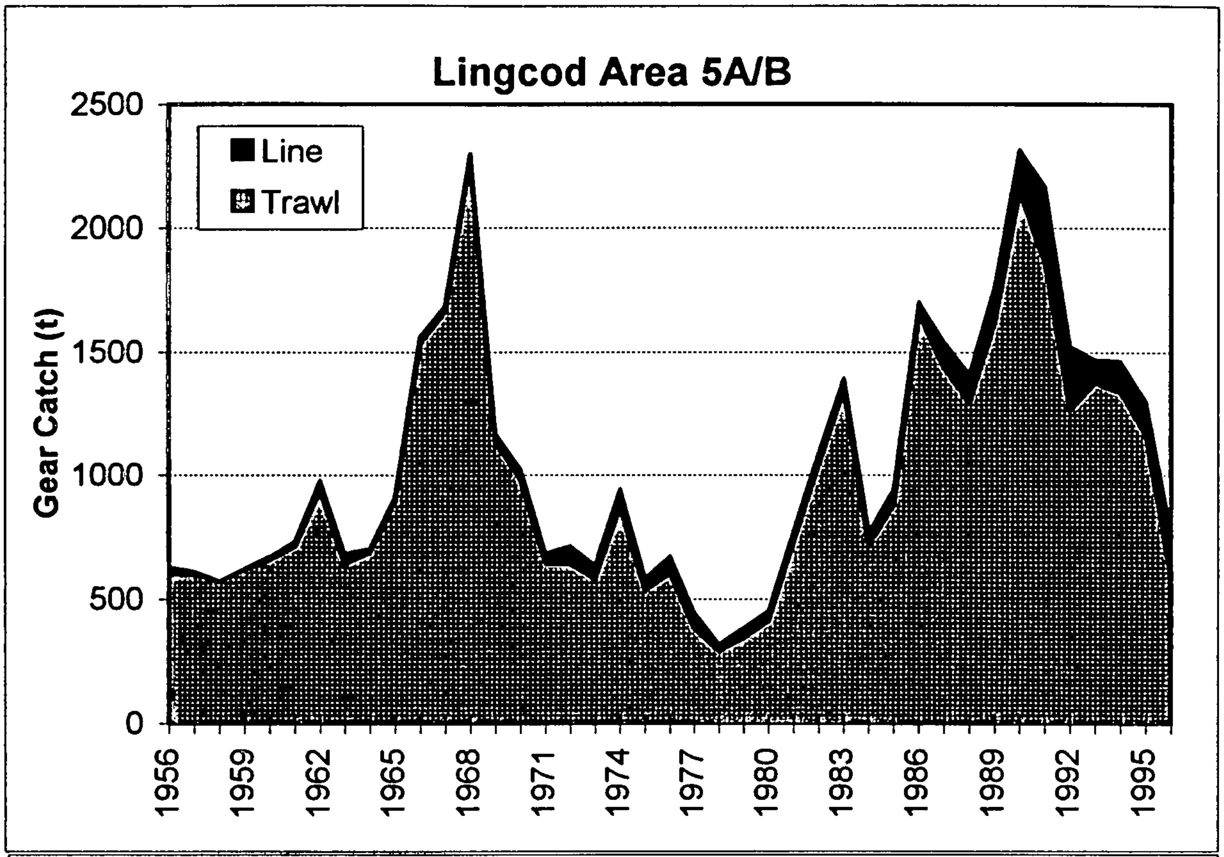
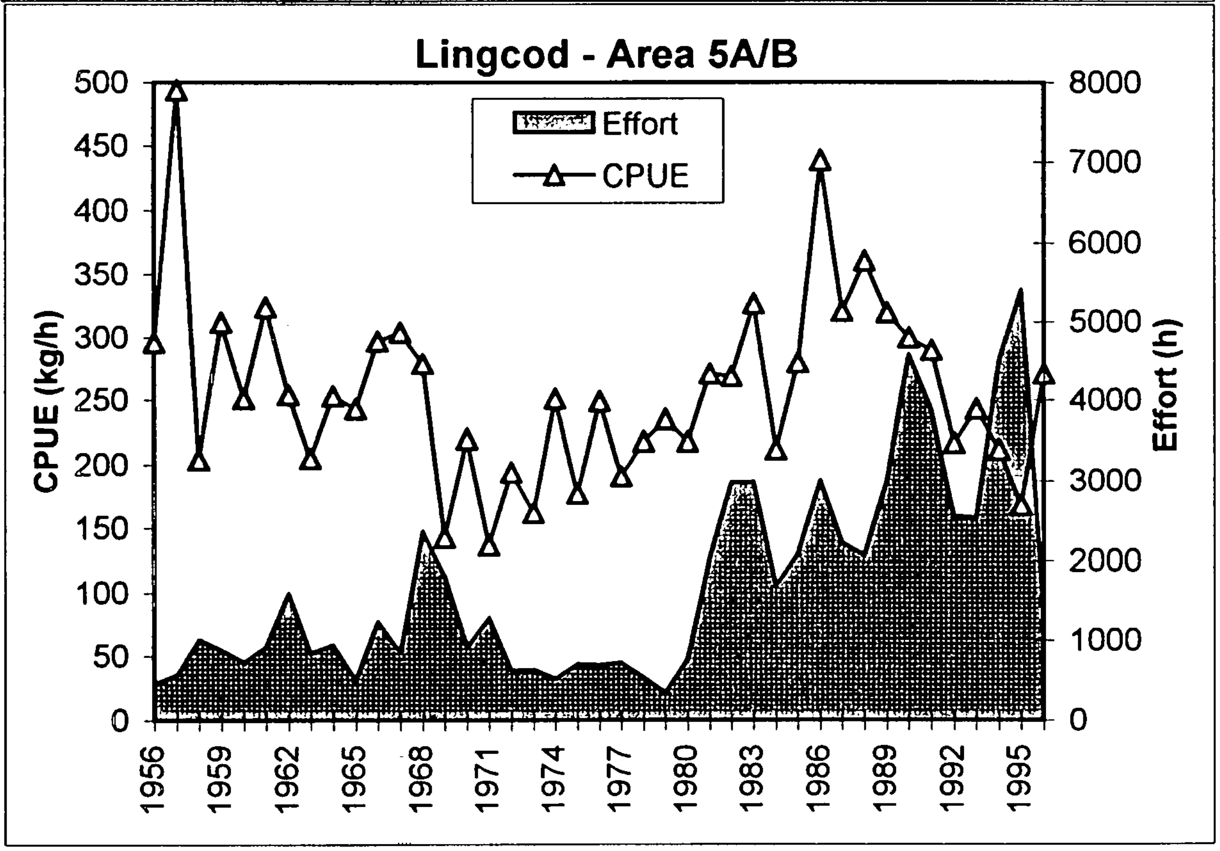

Lingcod Area 3D
Line
Trawl
Gear Catch (t)
1400
1200
1000
800
600
400
200
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
Lingcod - Area 3D
Effort
CPUE
CPUE (kg/h)
Effort (h)
600
500
400
300
200
100
0
3000
2500
2000
1500
1000
500
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995

Fig. 2.5

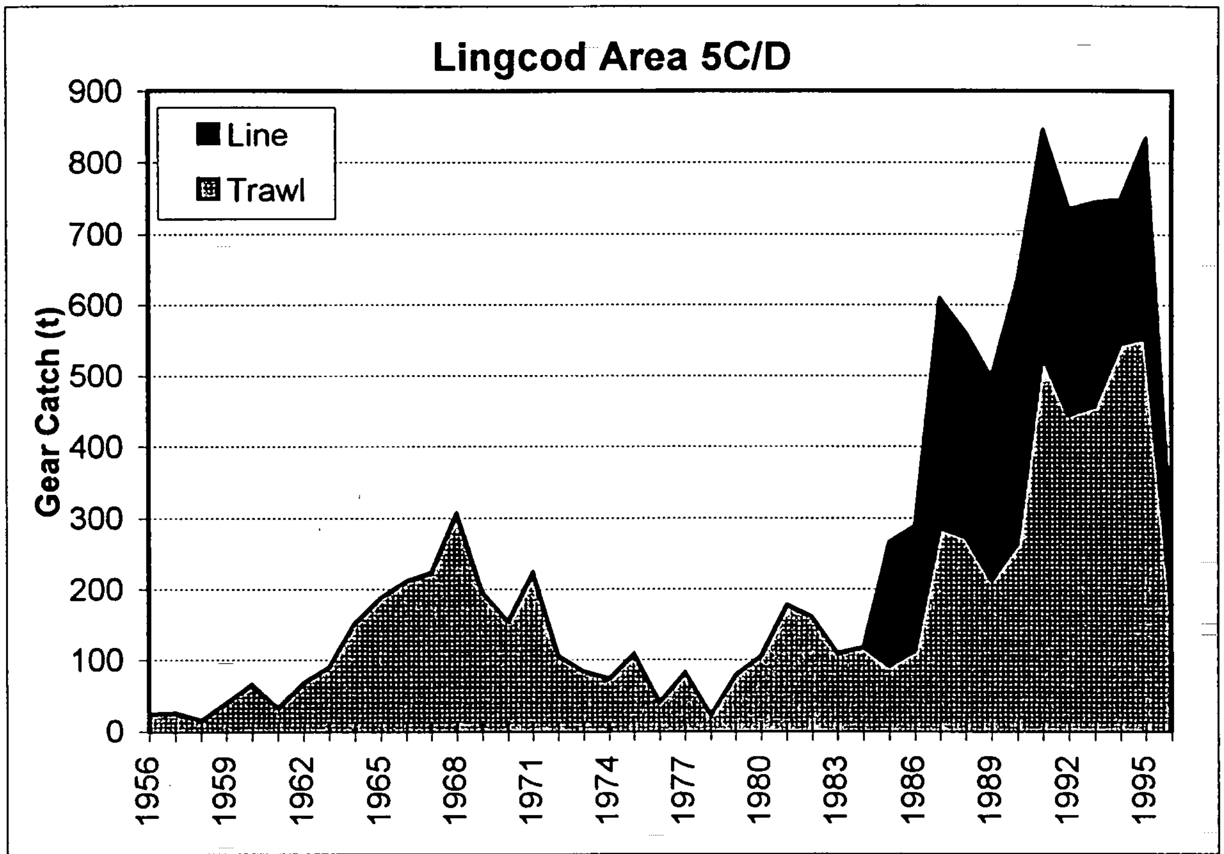


Lingcod Area 5A/B
Line
Trawl
Gear Catch (t)
2500
2000
1500
1000
500
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995

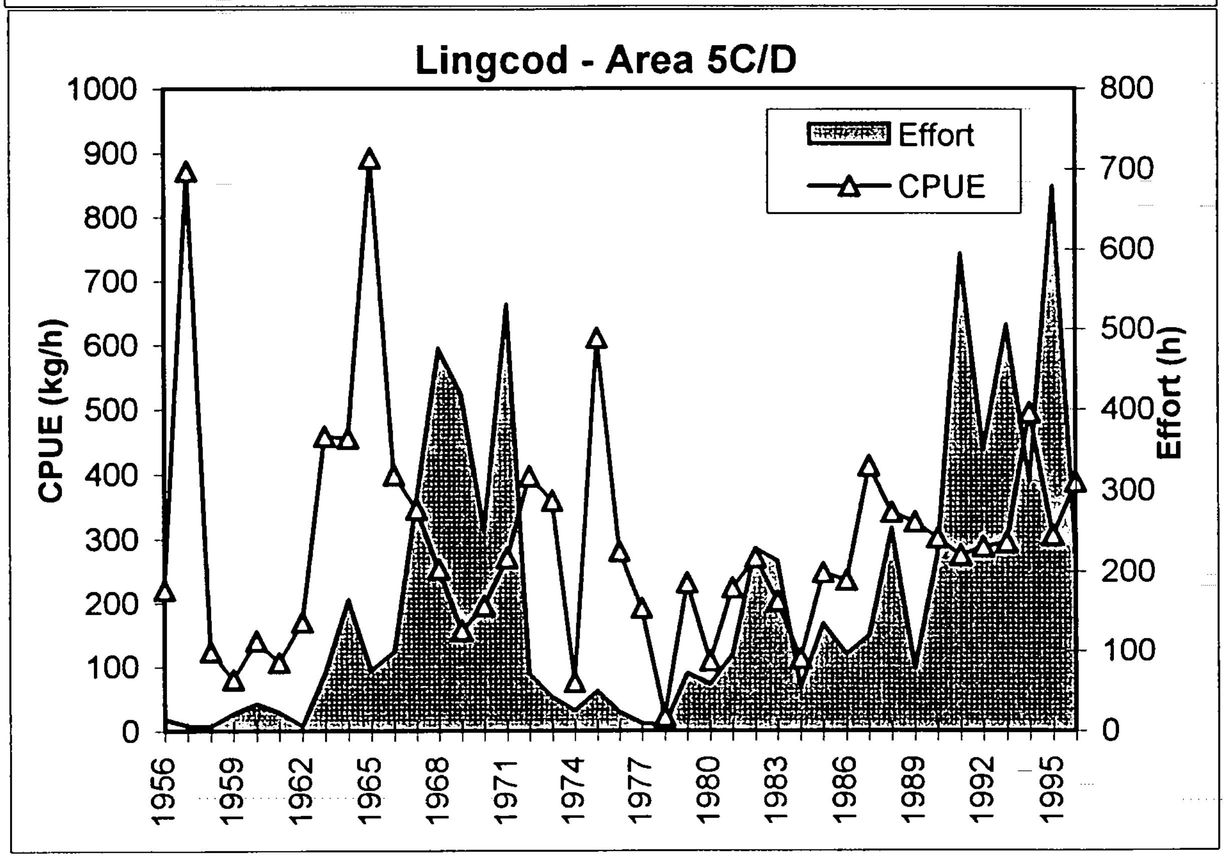


Lingcod - Area 5A/B
Effort
CPUE
CPUE (kg/h)
Effort (h)
500
450
400
350
300
250
200
150
100
50
0
8000
7000
6000
5000
4000
3000
2000
1000
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995

Fig. 2.6

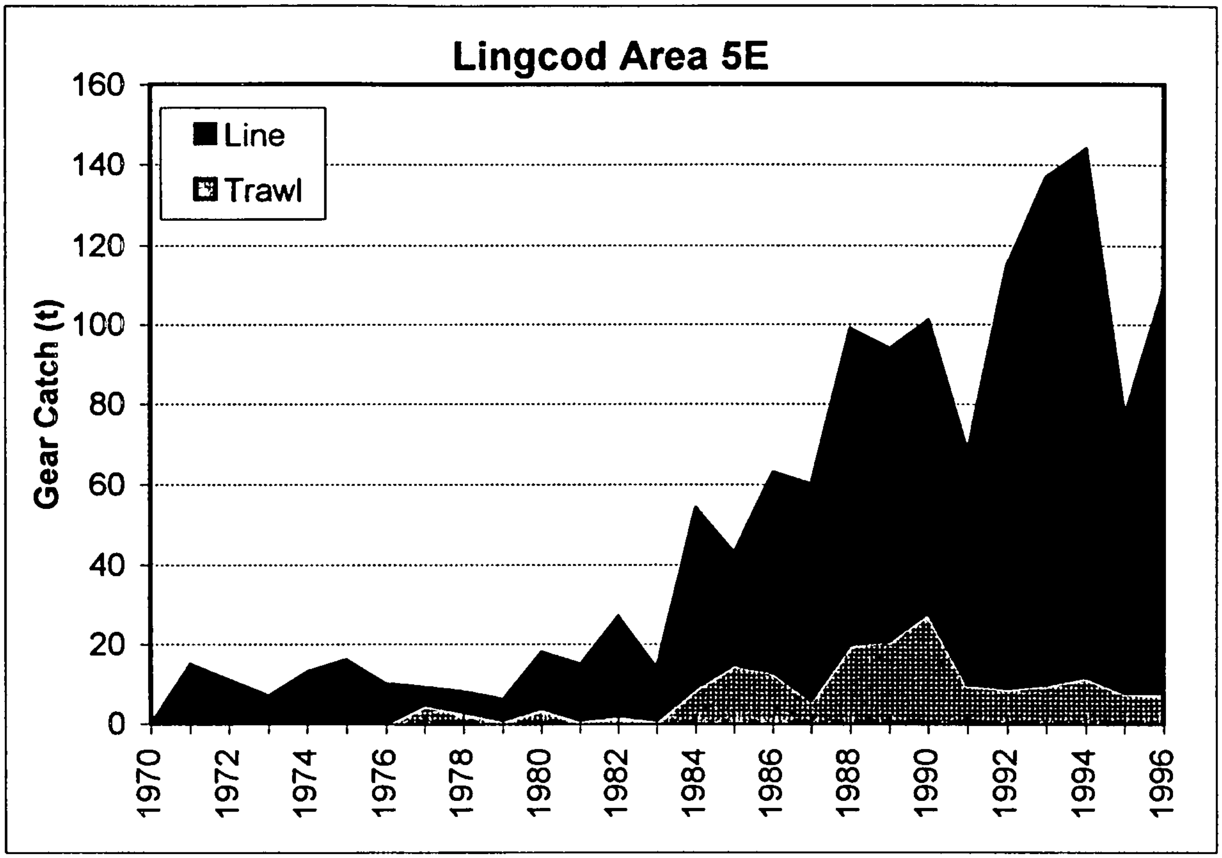


Lingcod Area 5C/D
Line
Trawl
Gear Catch (t)
0
100
200
300
400
500
600
700
800
900
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995



Lingcod - Area 5C/D
Effort
CPUE
CPUE (kg/h)
Effort (h)
0
100
200
300
400
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
800
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995

Fig. 2.7



Lingcod Area 5E
Line
Trawl
160
140
120
100
80
60
40
20
0
Gear Catch (t)
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996

Fig. 2.8