STATUS OF THE WASHINGTON-OREGON-CALIFORNIA SABLEFISH STOCK IN 1989

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Abstract

The stock synthesis model was used to estimate historical fishing mortality rates and population size for sablefish (Anoplopoma fimbria) along the coasts of California, Oregon and Washington. The model simultaneously analyzed 1971-1989 landings data, 1986-1988 fishery age and length composition data, estimates of age 1.5 recruit abundance in 1980, 1983, and 1986 from trawl surveys, and estimates of relative abundance in pot surveys from 1971 and 1979-1988. A revision in the ageing criteria has causes an increase in the observed proportion of old fish and a decrease in the estimate of natural mortality rate from 0.15 in the 1988 assessment to 0.0875. This change causes an increase in the estimate of current biomass, a decrease in the estimates of historical recruitment, and a decrease in the estimate of long-term potential yield. The estimates of mature female biomass and of age 3+ biomass at the beginning of 1990 are 58 thousand and 136 thousand metric tons, respectively. If recruitment is assumed to be reduced by 10% when mature female biomass is reduced by 50%, then the maximum long-term yield is 6,770 mt and the level of acceptable catch for 1990 is 7,020 mt. If recruitment is assumed to be constant over the range of biomass levels that will be observed and a $F_{0.1}$ fishing mortality rate is applied, then the maximum long-term yield will be 10,630 mt and the 1990 ABC could be 10,760 mt. The average of the two equilibrium yield levels is 8,700 mt which is a 500 mt increase from the estimate made in 1988. The average of the two 1990 ABC levels is 8,900 mt, which is 100 mt less than the 1989 ABC. The estimates of equilibrium yield and ABC assume that the trawl fishery will discard a level of biomass equal to 10% of its landings. Any projected discard in excess of this level should be subtracted from the ABC, or will cause a further reduction in the following year's stock abundance. The fishery continues to harvest high percentages of small, immature fish so that the above, standard harvest policies are expected to reduce spawning biomass to less than 25% of its unfished level. An alternative harvest policy which produces 30% of virgin spawning biomass would indicate a 1990 ABC of 8,000 mt.

Introduction

Sablefish off the coasts of California, Oregon and Washington is a major component of the west coast's groundfish fishery. Sablefish are a target species for the pot and longline fisheries, and are landed by the trawl fishery in association with other species. The Pacific Fishery Management Council has established an allocation of 52% for trawl and 48% for fixed gear. In 1988 the fixed gear fishery reached its allocation and was closed in August. The trawl fishery was placed on restrictive trip limits for sablefish so that the trawl fishery for other species could continue throughout the year.

The assessment of the sablefish stock in 1988 concluded that its abundance was slightly greater than that which would occur when the stock reached its optimal equilibrium and that the ABC was 9,000 mt. The PFMC opted for a faster approach to this equilibrium and set the quota at 10,400 - 11,000 mt. The assessment conducted in 1988 was was imprecise because it was based on only two years of fishery catch-at-age data and no comprehensive research survey. Annual updates to this assessment will be necessary until model discrepancies have been resolved, and sufficient information has been accumulated to produce stability in the results. The assessment documented here includes more recent data and incorporates new information on the age composition of the stock.

Sablefish fishery in 1988

Total Washington-Oregon-California sablefish landings since 1980 have ranged from 9,146 mt in 1980 to 18,592 mt in 1982 (Table 1). Fluctuations in landings have been due in part to changes in demand and to landings restrictions. The 1988 total landing was 10,890 mt, or about 14% less than in 1987. The reduction in 1988 was achieved through a combination of trip frequency and poundage limits, as well as a closure of the fixed gear fishery on August 26. The percentage of total landings by INPFC area was relatively constant from 1981-1988 (Figure 1). The most pronounced change was a gradual increase over time in the proportion of landings from the Columbia area.

The proportion of total landings due to trawl gear ranged from 43% in 1980 to 62% in 1984. After 1985, the fraction of total landings due to trawl and fixed gear was regulated through separate quotas for the two gear types.

Size and age composition of the catch

Estimates of the number of sablefish landed by gear type, sex, and length class generally were similar for 1986-1988 (Figures 2-3). We were unable to identify individual cohorts in the commercial length composition data. This may have been due to the minimum size regulation (restricting the landing of fish less than 52 cm fork length). Other possibilities are the rapid initial growth and high variability in length-at-age, although the strong 1977 year class was clearly evident in length and age composition data from commercial and research catches off British Columbia (McFarlane and Beamish 1985).

Fixed gear catches of fish less than the minimum size (52 cm fork length) appeared to decrease in 1988 relative to earlier years (Figure 3). The amount of those fish that could be landed has varied over the past three years (5,000 lbs: 1/1/86-12/31/86; 100 lbs: 1/1/87-4/26/87; 1,500 lbs: 4/27/87-8/2/88; 1,500 lbs or 3% of all sablefish on board, which ever is greater: 8/3/88-12/31/88). In addition, the minimum size regulation applied to catches north of Point Conception in 1986, but coastwide in 1987-1988. The decrease in catch of these small fish could be due to changes in depths or areas fished, fluctuations in year class strength, or to increased discarding. We do not have estimates for fixed gear vessels of either the rate of discarding or the probability that discarded sablefish survive.

Because of the large number of potential sampling strata (at least 3 gears, 5 market categories) and limits on sampling effort, the estimates were somewhat imprecise (Tables 2-4). At those sizes most common in the catch, coefficients of variation (CV=standard deviation/estimate X 100) were about 10-15% for trawl and 15-20% for fixed gear estimates. CVs were substantially higher for the smaller and larger fish that were less common in the catch. The higher precision for trawl estimates relative to fixed gear can probably be attributed to the higher sampling intensity. Port samplers collected 176, 170, and 121 trawl samples compared to 83, 121, and 48 fixed gear samples in 1986, 1987, and 1988 respectively. The precision of our estimates did not decline noticably in 1988 despite substantially lower sampling effort (Table 4).

Estimated length distributions for trawl-caught sablefish were similar for Oregon and California, except that a higher proportion of small (≤ 40 cm fork length) sablefish were landed in Oregon (Figure 4). This apparent difference in size at recruitment could be due to differences in depths or areas fished or to mesh size used. Flatfish bottom trawl mesh size must be at least 4.5 inches in all areas, except 3.0-inch mesh can be used in the Eureka, Columbia, and Vancouver areas if the net is equipped with roller gear (PFMC 1982). Thirty-five of 84 California samples (42%) were from the Eureka area, although it is not known what fraction of those sampled landings were made using roller gear. The estimates for Washington were based on only six samples; consequently, differences between results for Washington and the other two states may not be meaningful. We were unable to produce estimates by state for fixed gear landings because of inadequate sample sizes.

Preliminary results in the 1988 assessment indicated that selectivity patterns were similar for longline and pot gears. Final synthesis model runs were made using a single selectivity pattern and combined catches for the two gear types. The 1988 length frequency data supported the assumption that longline and pot vessels had similar selectivity patterns (Figure 5); therefore, a single fixed gear selectivity pattern was used in this assessment as well.

Estimates of the number of sablefish landed by gear type, sex, and age differed considerably among years (Figures 6-7). The most likely source for the differences was that different readers using different aging criteria produced the age data for each year. In all three years, old male sablefish were much more common than old females in trawl landings. This difference may have been due to trawl avoidance by the larger (older) females (Parks 1973), although selectivities for older males were about 50% greater than those for older females (Methot and Hightower, 1988) and this report will show that the fixed gear fishery harvests more females than males.

We were unable to identify (visually) strong or weak year classes in the age composition data. Possible explanations include that year-class strength was relatively constant or that aging errors obscure differences in year class strength. Considerable variation in year class strength has been observed for sablefish off the west coast of Canada (McFarlane and Beamish 1985). As for the length composition data, our estimates of number landed by age were moderately imprecise (Tables 5-7). CVs for those ages most common in the catch were about 10-15% for trawl compared to 10-20% for fixed gear.

Population assessment

The historical abundance and mortality of the west coast stock of sablefish was estimated in 1988 by application of the stock synthesis model (Methot, 1989; Methot and Hightower, 1988). Since application of that model there have been important additions to the data base. Also, a change in ageing criteria forces a re-interpretation of historical age composition observations. A generic version of the synthesis model has been developed. The new model incorporates nearly all features of the original sablefish synthesis model, but there are some changes that affect the details of the sablefish application. The following sections describe changes to the synthesis model and changes to the sablefish database.

Synthesis model - basics

The synthesis model (Methot, 1989) simulates the population's history and makes comparisons between the model's expected values and observations which have been made. The observations for west coast sablefish are catch biomass and age/size composition for the fixed gear and trawl fisheries, abundance and age/size composition for the northern and southern pot indexes, and abundance and size composition in the tri-ennial trawl surveys. The goodness of fit to these observations is evaluated in terms of log(likelihood). The total log(likelihood) is a weighted sum of the likelihood components for each type of data. The model assumes that fishing mortality can be separated into an age-specific component and a year-specific component. The parameters which the model must estimate are: population age composition in the first year, recruitment in each subsequent year, and availability (selectivity) to each fishery and survey. Selectivity to the fisheries and the surveys is specifed as functions of size. Equivalent age-specific selectivities can then be calculated from the distribution of size-at-age and the estimated size selectivities. The year-specific fishing mortality factors are not estimated as parameters, instead they are tuned to the level necessary to match the observed catch biomasses. The model parameters are estimated by an iterative process which involves numerical estimation of the first derivatives of total log(likelihood) with respect each parameter, and the Hessian matrix of mixed partial derivatives. The inverse of the Hessian matrix post-multiplied by the vector of first derivatives indicates how the parameters should be changed.

Synthesis model changes from 1988

1. Tag return data. Last year's model analyzed tag returns as the proportion returned in each year following a release. We have re-considered the wisdom of including these data because there has been no systematic program for return of the tags and no analysis indicating that the tag returns could be quantitatively interpreted. Because no west coast stocks have quantitative tag return programs, the tag analysis feature of the sablefish synthesis model has not been implemented in the generic model.

2. Selectivity pattern. Last year's assessment used a three-parameter gamma function to describe the pattern of size-specific selectivity to each type of fishery and survey. A more flexible option has been incorporated into the generic model so that the ascending side of the curve can be more completely de-coupled from the descending size. This new function is the product of two logistic curves and is described in Methot (1989) and Dorn and Methot (1989).

3. Sex ratios. The sablefish synthesis model did not examine sex ratio. The fit to age (and size) composition for females was treated independently of the fit to the male data. A member of the SSC noted that a more correct approach is to examine the joint distribution of age/sex or size/sex. The generic synthesis model implements this preferred approach. This implementation requires introduction of another parameter which describes the scaling of the male selectivity curve relative to the female selectivity curve.

4. Natural mortality. A simple, age-specific trend in natural mortality was used in last year's assessment to investigate the consequences of higher natural mortality at the youngest ages. This extra juvenile natural mortality was forced to decay at a specified, exponential rate. The option in the generic model that most closely mimics this pattern allows estimation of the natural mortality at age 1 and estimation of the age at which the natural mortality becomes equal to the adult natural mortality. A linear decline in natural mortality is assumed between age 1 and the inflection age.

5. Ageing imprecision. Last year's assessment had a saturation function that described the standard deviation of age determination as a function of mean age in the 1987 age data. The ageing criteria used in 1987 has been questioned, so we no longer utilize this ageing precision function. The generic synthesis model incorporates imprecision in age determination by assuming that the standard deviation of observed age increases linearly with true age over the age range from 1-20 years. The parameters which describe this pattern are the fraction mis-aged at the minimum modeled age, and the fraction mis-aged at the maximum modeled age.

6. Tuning. Last year's sablefish assessment was tuned to the mean number of age 1 recruits observed in the 1980, 1983 and 1986 trawl surveys. The survey observations were considered to be fully quantitative, and the abundance levels were extrapolated from the southern limit of the survey (Monterey Bay) to southward to Pt. Conception (a 6.5% increase). The assumption of the analysis was that by fixing the level of these three recruitments, then the other recruitments would be estimated relative to these three recruitments and the general level of abundance would be determined. There are two shortcomings to this approach. First, the survey observations are not very precise (average CV = 36%), so even the mean of the three surveys is not precisely known. Second,

once the possibility of extra natural mortality or high discard of juveniles is introduced, then value of a "known" recruitment level is diminished. Increases in the estimated abundance of recruits can be offset by increases in juvenile mortality so that the abundance of adults is unchanged. By this logic, we conclude that efforts to extrapolate the recruit abundance observations further south (perhaps to the U.S.A.-Mexico border) may be countered by increased estimated juvenile mortality if other data in the assessment are more consistent with lower levels of abundance. In this year's assessment we will continue to treat the survey observations as true measurements of the abundance of age 1 sablefish extrapolated southward to Pt. Conception. However, we make no special attempt in the model to assure that the mean of the three surveys is matched near perfectly by the model.

Data changes and additions

1. Ageing criteria. An inter-agency exchange of sablefish otoliths was completed in February 1989. This exchange resulted in agreement among the Tiburon, Seattle, and Nanaimo laboratories on ageing criteria for sablefish. Two outcomes affect the sablefish stock assessment conducted last year. First, the otoliths from the 1987 fishery were read by the Southwest Fisheries Science Center's Tiburon laboratory using criteria that cannot be calibrated to the current criteria. The differences in criteria were greatest for the younger fish so the 1987 fishery age compositions were compressed into 3 bins: 1-14, 15-19, and 20+. This compression preserves information on the relative contribution of old fish and information on the sex ratio of the catch. Second, the age compositions for the 1986 fishery, the 1983 northern pot survey, and the 1985 northern pot survey were read at the Alaska Fisheries Science Center with a criteria that can be calibrated to the new criteria because otoliths from the 1986 southern pot survey were read by both criteria (Figure 8). A complication in developing this calibration is the only otoliths that were re-read were those that had originally been assigned an age greater than 9. This truncates the lower tail of the distribution of old age at a given level of new age. We reduced the bias introduced by this truncation by fitting old age as a function of new age only for new ages greater than 13. The functional form was a three parameter saturation curve (the von Bertallanffy growth function) which was forced to pass through the point (old age=1, new age=1). Asymptotic old age was estimated to be 64.3 years, and the K parameter was estimated to be 0.149. This curve and the variance around this curve was used to generate a transition matrix (Table 8) that can be used to generate the expected distribution of old ages given a sample of new ages. In the synthesis model, this matrix is actually used to generate the expected distribution of old ages from an estimate of the true sample age composition.

Preliminary runs of the model indicated that the model was still overestimating the contribution of old fish to the 1983, 1985, and 1986 age compositions. The most probable cause of this problem is in the generation of the expected age code distribution for fish that have true ages of 20 or greater. Most of the age 20 fish are put into the bin for age code 15-19 but, at low levels of natural mortality, fish older than age 20 remain abundant and many are put into the bin for age code 20+. Reduction of this problem was attempted by accumulating the 1986 fishery age compositions at age code 15+, and the 1983 and

1985 survey age compositions at age code 10+. This greatly reduce the discrepancy for the 1986 observation, but the model still overestimated the contribution of old fish to the 1983 and 1985 surveys. Therefore, we deleted the 1983 and 1985 survey age compositions from the model.

2. 1986 southern pot survey. Age composition from this survey is now available and indicates a large proportion of old fish (Figure 9).

3. 1988 southern pot survey. The pot survey conducted off the coast of California (Parks and Shaw, 1989) indicates an increase from 4.60 fish per pot in 1986 to 10.60 fish per pot in 1988 (Table 9). The increase seems due to an influx of small fish with mean size of females decreasing by about 4 cm.

4. Trawl surveys on continental slope. In 1984 and 1988 the National Marine Fisheries Service conducted trawl surveys on the continental slope off Oregon. The 1984 survey (Raymore and Weinberg, in prep.) was conducted over the latitudinal range 43.00 - 45.75 degrees and the depth range 60-500 fathoms. The 1988 survey (K. Weinberg, Alaska Fisheries Science Center, Seattle, WA, unpubl. data) was conducted over the latitudinal range 44.10 - 45.21 degrees and the depth range 100 - 700 fathoms. In order to make the two surveys comparable, sablefish biomass in the 60-99 fathom depth range was subtracted from the 1984 survey, and the 1988 survey was extrapolated to the latitudinal range of the 1984 survey. Because 60-99 fathom catches are excluded, the surveys probably encounter only a small fraction of the age 1 sablefish. The biomass values probably correspond most closely to the age 2+ biomass. The preliminary estimates of biomass are 34,000 mt in 1984 and 39,000 mt in 1988. Coastwide biomass must be several times greater than that estimated here for the southern Columbia INPFC area, but no quantitative extrapolation is attempted.

Other changes

1. Natural mortality. The change in ageing criteria generates age compositions with a greater proportion of old fish. These age compositions no longer seem consistent with the high (0.15) natural mortality used in last year's assessment. A natural mortality of 0.10 has been used in Canada, and a natural mortality of 0.08 is consistent with the observed maximum age (Hoenig, 1983). We explored various levels of natural mortality in last year's assessment and noted that lower levels of natural mortality produced higher estimates of current biomass, lower estimates of MSY, similar estimates of ABC for 1989, and slightly improved fits to the data. We have conducted this year's assessment with natural mortality of older sablefish set equal to 0.0875 in the baseline run, and explored natural mortality levels in the range 0.05 to 0.15. Note that the natural mortality at age 1 and the age at inflection in natural mortality are estimated by the model.

2. Discard. A logistic function of size was used in the 1988 assessment to describe retention by the trawl fishery. This function was based on size-specific retention data collected by Fujiwara and Hankin (1988) and by Pikitch (unpubl. data). The synthesis model also calculates an equivalent age-specific retention from the distribution of size-at-age for the fish available to that type of fishery. The synthesis model can multiply the age (size) retention

functions by a year-specific scalar. The scalar, which can be described as the maximum retention rate, is adjusted within the model so that an observed level of discard biomass can be matched. The basic procedure is for the model to first find the fishing mortality rate that will match the observed landings + discard biomass. Then the model finds the maximum retention rate that will match the observed landings biomass. The maximum retention rate scalar can take on values greater than 1.0, but the product of the scalar and the age-specific retention is not allowed to exceed 1.0.

Pikitch et al. (1988) estimated that the overall level of discard under size limit restrictions was 15.3% of total catch and that the amount of discard in 1985-1987 was 2680, 1406, and 2609 mt (26, 17, and 29% of catch; 35, 21, and 40% of landings) when extrapolated from primarily the Columbia area to a coastwide basis. Here we explore the sensitivity to annual discard levels ranging from 0% to 24% of the landings. The null model was run with an annual discard level of 10%. The annual maximum retention rates estimated in the null run were averaged and this retention value was used in determination of equilibrium yield and short-term forecasts.

Sablefish synthesis model

The sablefish population population is assumed to have an equilibrium age distribution at the beginning of the modelled time series, 1971. The recruitment which generates this age composition is set equal to the level of virgin recruitment estimated by the model. The mortality which sets the shape of the age composition is set equal to estimated natual mortality plus a level of fishing mortality necessary to obtain a catch of 3,017 mt which is the mean annual reported landings for 1956-1969. The selectivity pattern for this early fishery is assumed to be knife-edge at age 3. The weight-at-age for this early fishery is assumed to be equal to that of the later trawl fishery. Note that the parameter which defines virgin recruitment has a dual role; it sets the initial population abundance and it fits the stock-recruitment curve to the subsequent, estimated recruitments. Also note in the results that the spawning biomass in 1971 is already fished down by about 30,000 tons from the estimated virgin level.

Selectivity to the fisheries and to the surveys is defined as the product of two logistic curves. Selectivity is defined as an explicit function of size, and selectivity for a given length bin is calculated as the mean of the selectivities at the lower and upper edge of the bin. For each type of fishery or survey, four parameters define female selectivity, four more parameters define male selectivity, and a ninth parameter scales the male selectivity curve relative to the female selectivity curve so that sex ratios can be examined. We noted in early trials that the males and females had similar selectivities at small sizes and that trivial degradation in goodness of fit occurred if the two parameters that defined the ascending side of the male selectivity curve were set equal to the corresponding female parameters.

Modeling of the population dynamics still requires estimates of selectivity-at-age so that fishing mortality-at-age can be calculated. Selectivity-at-age is calculated from the selectivity-at-length weighted by the population fraction-at-length for that age. These weighted sums are calculated at length intervals set by the length bins in the data file. All selectivity patterns were scaled so that age 5 females had a selectivity of 1.0. The model also requires estimates of mean weight-at-age. These can be calculated as the weighted sum of the body weights-at-length.

Various constants used in the model are presented in Table 10.

Results

The results indicate that the biomass of age 3+ sablefish was 141,000 mt at the beginning of 1989 (Table 11). This biomass level appears reasonable relative to the trawl survey estimate of about 38,000 mt in the southern Columbia area. The estimated virgin level of spawning biomass is 200,000 mt. This level declined to 168,000 mt by 1971, the start of the modeled time series. The level at the beginning of 1989 was 61,500 mt which is 31% of the virgin level. The magnitude of the decline in abundance of females is greater than that of males because the females are more available to the fixed gear fishery. This differential mortality by sex was not examined in the 1988 assessment.

This year's estimate of the current abundance of age 3+ sablefish is approximately 50% greater than that estimated last year. This increase in biomass is due to an increase in the level of the early recruitments and greater survivorship of these fish. Both changes are a result of the new ageing criteria and a shift from inclusion of age compositions which have few old fish (e.g. the 1983 and 1985 northern pot surveys) to those that have high percentages of age 20+ fish (e.g. the 1987 and 1988 fixed gear fishery and the 1986 southern pot survey).

Availability patterns to the trawl and fixed gear fisheries were estimated in terms of size (Table 12). Mean availability-at-age (Table 13) was then calculated and scaled so that age 5 females had an availability of 1.0. Females had maximum availability to the fixed gear fishery at ages 5-6 (57 cm) and the age 20+ females have an availability of 45%. Males have maximum availability to the fixed gear fishery at ages 6-7 (55 cm), but at this age they still are only 49% available relative to the age 5 females. Male and female sablefish reach maximum availability to the trawl fishery at about 50-51 cm (ages 3-4 for females and ages 4-5 for males), and in this age/size range they have similar levels of availability. At age 1, females are 25% available and males are 19% available. At age 20+, females are 18% available to the trawl fishery, and males are 28% available. The age and size specific patterns of availability to the pot surveys continue to appear similar to the availability patterns in the trawl fishery. The weights-at-age used in the model to calculate population biomass, catch biomass, and discard biomass were calculated from the size-selectivity, distribution of size-at-age, and body weight-at-size (Table 14).

The fit to the age 1 abundance in the three tri-ennial trawl surveys is good (Table 15). The largest deviation occurs in 1983 when the expected value is 63% of the observed value. The mean of the three expected values is 87% of the mean of the three observed values.

The model continues to fit the pot survey observations less well than expected (Table 15). The coefficients of variation for the survey observations are typically in the range of 10-20%. Only 2 of the 7 northern pot survey observations are within 20% of the model's expected value, and only 1 of the 3 southern pot observations is within 20% of the expected value. The problem is that the surveys often exhibit two-fold changes over two year periods. The model could only track such rapid changes if a few age groups were contributing to the survey. However, the size compositions in the surveys, which determine the age-specific selectivity pattern, indicate that many age groups contribute to the surveys and that older fish remain about 30% available to the survey. The model also underestimates the magnitude of the decline in the survey's estimate of the abundance of large sablefish (Figure 10). This discrepancy will be the subject of further examination in the future.

The above result will be referred to as the null model to which the following results will be compared.

Sensitivity to level of adult natural mortality

Here we explore a range of natural mortality ranging from 0.050 to 0.150. A level of 0.150 was used in last year's assessment, and a level of 0.0875 was used in the current assessment because of the change in the ageing criteria. The best fit to the data was obtained at the lowest level (0.050) (Table 16). Low levels of natural mortality were associated with higher estimated levels of juvenile natural mortality, higher levels of estimated biomass, and lesser reductions in biomass over the duration of the modeled time series. Although the highest likelihood is obtained with the lowest level of natural mortality, there is an unreasonable aspect to this result. The estimate of virgin recruitment is 13.0 million age 1 fish, and the mean estimated recruitment for the 1974-1987 cohorts is 25.9 million fish. One would expect that mean recruitment would have declined slightly after the spawning biomass had been reduced from its virgin level, or one must conclude that cannibalism and a Ricker-type stock-recruitment curve holds. Natural mortality of 0.075 - 0.100 produces mean recruitments similar to virgin recruitments (Figure 11), and higher levels of natural mortality produce high estimates of virgin recruitment relative to mean subsequent recruitment. We provisionally judge natural mortality rates in the range 0.075 - 0.100 to be reasonable, but resolution of this uncertainty regarding natural mortality must await collection of more age composition data and a better fix on the relative abundance of older sablefish. Sensitivity of MSY and ABC to the level of natural mortality will be presented below.

Juvenile mortality

The synthesis model estimates the level of natural mortality at age 1 and the inflection age at which natural mortality becomes equal to the assumed level of 0.0875. When juvenile natural mortality is fixed at values of 0.10, 0.20, 0.30, or 0.40 we see trivial improvements in the log-likelihood and smaller biomass levels at higher levels of juvenile mortality (Table 17). At higher levels of juvenile mortality, the estimated level of age 1 recruitment increases. The increase is not enough to offset the higher level of mortality, so the estimated abundance of age 3 and older fish decreases. The level of juvenile natural mortality estimated in the null model was 0.45.

Discards from the trawl fishery

Discard levels of 0 - 24% of the trawl landings were found to have little effect on the model's results (Table 18). The overall log likelihood was essentially unchanged, the level of historical abundance and the mean level of age 1 recruitment increased slightly. All other model runs and calculations of potential yield assumed a discard level of 10% of landings.

Emphasis

The first aspect of emphasis which we explore is with regard the age 1 abundance in the tri-ennial trawl surveys (Table 19). We define the bias in the estimation as one minus the ratio of the sum of the three expected age 1 abundances in 1980, 1983 and 1986 to the sum of the corresponding observations. In the baseline run the bias was equal to 0.13 and most of the bias was due to the model underestimating the observation of age 1 abundance in the 1980 trawl survey. If an emphasis of 25. is placed on the fit to the three age 1 survey observations, then the bias is reduced to 0.06, the fit to the other data is not degraded, the mean recruitment increases 4%, and the ending biomass is increased about 2%. If an emphasis of 0.001 is placed on this likelihood component, then the bias increases to 19%, the mean recruitment decreases 7%, and the ending biomass increases 7%. A further exploration of model sensitivity to low levels of emphasis on this component should include varying the initial value for the reference recruitment level.

Model results were sensitive to the level of emphasis on age and size data (Table 20). When the emphasis on all age composition data is reduced to 0.1, then the log likelihood for the age composition degrades and there is a large improvement in the fit to the size composition data, especially for the northern pot survey. Converse changes occur when the emphasis on age composition is increased. The estimate of age 3+ biomass in 1989 is 53,000 mt at low levels of emphasis on age composition data, and 307,000 mt at high levels of emphasis. Both of these biomass values seem unrealistic with respect the survey estimates of biomass in the southern portion of the Columbia area (34,000 mt in 1984, and 39,000 in 1988; K. Weinberg, Alaska Fisheries Science Center, Seattle, WA, preliminary analysis of survey results). Results of changing the emphasis on size composition data (Table 20) are consistent with the above results for age composition. Low levels of emphasis on size composition data produces a better fit to the age composition data, and larger levels of estimated biomass.

Increased emphasis on the fit to the pot survey abundances improves the fit to these data, especially the southern pot index which doubled from 1986 to 1988 with the influx of large numbers of small fish. This improved fit is accompanied by a degradation in the fit to the survey size composition and to the fishery size and age composition. The estimated level of biomass is decreased as the emphasis on the pot survey data is increased.

Equilibrium yield

The equilibrium yield as a function of fishing mortality was calculated by an age-structured simulation model. The model incorporated all selectivity and discard features in the synthesis model and utilized output produced by the synthesis model. The ratio of the trawl fishery's fishing mortality multiplier to that of the fixed gear fishery was set equal to a value that produces a 52:48 ratio of trawl landings to fixed gear landings at MSY. The total yield, however, is not greatly sensitive to small changes in the ratio of the fishing mortality multipliers. Two assumptions with regard recruitment were investigated. The first assumed that recruitment followed a Beverton-Holt curve with respect to the biomass of mature females and that recruitment was reduced by 10% when spawning biomass was reduced by 50%. Under this assumption, the fishing mortality that produced maximum sustainable yield was calculated. The second assumption was that recruitment was constant at the mean of the estimated recruitments for the 1970 - 1986 cohorts. Under this assumption, we calculated the fishing mortality that would produce a spawning biomass equal to 30% of the unfished spawning biomass, and the fishing mortality rate which produces an incremental yield equal to 10% of the initial slope of the yield curve ($F_{0.1}$).

At an adult natural mortality of 0.0875 and with the 90% recruitment model, the MSY is estimated to be 6,770 mt, the equilibrium number of age 1 recruits is 17.7 million fish, and the equilibrium female spawning biomass is 52,000 mt (Table 21). This level of spawning biomass is 26% of the virgin spawning biomass. The spawning biomass at the beginning of 1990 is forecast to be 58,000 mt and the ABC for 1990 is 7,020 mt.

The mean of the estimated recruitments for the 1970 - 1986 year classes was 23.6 million fish. This level of recruitment is similar to the estimated virgin recruitment level of 23.4 million fish, and greater than the equilibrium recruitment level estimated above for the 90% recruitment assumption. The equilibrium $F_{0.1}$ yield is calculated to be 10,630 mt at a spawning biomass level of 42,000 mt. The biomass level in 1990 is above the optimum level and the ABC for 1990 is calculated to be 10,760 mt. A strong discentive to applying this policy is that it would reduce spawning biomass to only 21% of its unfished level. In other circumstances the $F_{0.1}$ policy is reasonably conservative, but Deriso (1987) demonstrates a sensitivity of the $F_{0.1}$ policy to the age at recruitment to the fishery. We expect that the $F_{0.1}$ policy is not conservative for west coast sablefish because the fishery, especially the trawl fishery, harvests many juvenile fish. Size at 50% maturity for females is in the range 55-58 cm. A size limit of 52 cm is intended to reduce the catch of small sablefish, but up to 5,000 lbs of under-sized sablefish could be landed with each trip. The size distribution of sablefish landed by the 1988 trawl fishery indicates that 53% of the females were smaller than 52 cm, and 80% were smaller than 58 cm.

A reasonable alternative to the $F_{0.1}$ policy is the fishing mortality that reduces spawning biomass to 30% of its unfished level. This policy would produce a long-term mean yield of 9,510 mt at a spawning biomass of 61,000 mt. The biomass in 1990 is below the optimal level and the recommended ABC would be 7,990 mt.

The above equilibrium yield calculations were also made for model results with natural mortality ranging from 0.05 to 0.15 (Table 21). Results from this full range are presented here, but only the range of M=0.075 to 0.100 produced reasonable estimates of mean recruitment relative to virgin recruitment. Low levels of natural mortality produced low estimates of recruitment (Figure 11), similar estimates of initial abundance (Figure 12), and high estimates of current abundance (Figure 12). These changes translated into much reduced levels of potential yield for the density-dependent recruitment case, but relatively little change in potential yield in the constant recruitment cases (Figure 13).

RECOMMENDATIONS

We recommend that the Acceptable Biological Catch for the 1990 fishing year be set at 8,900 mt. This level comes from synthesis model results with natural mortality set equal to 0.0875, and is the mean of the ABC levels calculated for density-dependent recruitment and constant recruitment with $F_{0.1}$ policy. This level of ABC has been calculated under the explicit assumption that the trawl fishery will discard a level of biomass equal to 10% of its landings. We have no ability to monitor or estimate the current level of discard, but if discard is expected to be greater than the assumed 10% level, then this excess discard should be subtracted from the ABC.

We call attention to the fact that a large fraction of the fish harvested by the trawl fishery are under-sized and immature. This causes standard estimates of optimal fishing mortality rate to produce great reductions in spawning biomass. A fishing policy that maintained spawning biomass at 30% of its unfished level indicates an ABC of 8,000 mt for 1990.

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Table 1. Landings of sablefish along the California, Oregon, Washington coast. Includes catches by foreign fishing vessels in this region and catches by non-Canadian foreign vessels throughout the Vancouver INPFC region. Catch by foreign vessels was assigned to a characteristic gear type (Methot and Hightower, 1988). Catch by miscellaneous gear was assigned proportionally to fixed and trawl gear categories.

					- Condensed -	
Year	LLine	Pot	Trawl	Misc	Fixed	Trawl
56	1129	0	2477	7	1131	2482
57	2051	0	914	1	2051	914
58	855	0	948	0	855	948
59	1398	0	1273	1	1398	1273
60	1980	0	1510	0	1980	1510
61	1121	0	935	482	1384	1154
62	1100	0	1794	163	1162	1895
63	931	0	1053	157	1005	1136
64	1341	0	922	299	1519	1043
65	1018	0	1023	493	1264	1270
66	789	0	427	474	1097	593
67	3341	0	795	372	3641	867
68	1787	0	815	365	2038	929
69	4087	0	1186	432	4422	1283
70	1391	114	2395	41	1521	2420
71	1511	193	2395	138	1761	2475
72	3492	355	3435	37	3866	3453
73	1124	863	3791	28	1997	3809
74	2439	3240	3044	13	5687	3048
75	1736	5689	3391	8	7431	3393
76	1219	19725	3553	22	20962	3556
77	1441	4140	3662	7	5585	3665
78	1709	5753	5748	405	7691	5924
79	4187	12333	7252	601	16939	7435
80	1378	3632	3721	416	5248	3898
81	1925	3896	5437	294	5973	5579
82	1626	6494	10158	314	8259	10333
83	1003	5399	7154	963	6857	7662
84	1022	3822	7933	1296	5335	8738
85	2753	3637	7198	707	6722	7573
86	3576	2115	6024	1470	6405	6780
87	4187	2031	6463	32	6234	6479
88	3269	2053	5568	0	5322	5568
89 (preliminary)					4400	5400

Table 2. Estimated number of sablefish landed by length class (fork length, in cm) in 1986 based on port samples from trawl (TWL) and fixed gear (longline, pot, and net) vessels. CV represents the coefficient of variation (%) for each estimate.

	TWL				FIX			
	Male		Female		Male		Female	
Length	Number	CV	Number	CV	Number	CV	Number	CV
40	53.0	30%	102.4	39%	12.9	56%	5.9	61%
42	71.6	25	75.9	24	3.7	53	14.3	60
44	164.1	15	104.2	16	7.6	38	26.2	50
46	197.2	19	168.1	15	53.1	32	79.2	36
48	341.1	10	212.2	12	71.1	27	66.4	27
50	396.5	11	232.9	10	150.9	28	154.3	29
52	357.9	7	176.3	12	221.5	18	215.9	15
54	331.7	14	172.4	11	165.7	15	204.8	15
56	226.6	10	149.6	10	136.5	15	176.2	10
58	126.7	13	106.2	14	154.7	13	194.5	13
60	124.4	13	170.9	14	142.8	13	266.7	10
64	47.9	20	60.9	12	82.1	14	240.8	13
68	19.3	41	35.7	14	28.1	19	155.3	13
72	1.3	40	14.2	23	2.1	58	98.6	18
76	0.1	98	7.2	21	0.4	65	38.7	27
80	0.0	0	10.8	17	1.0	105	53.3	24
90	0.0	0	2.9	31	0.0	0	6.4	54

Table 3. Estimated number of sablefish landed by length class (fork length, in cm) in 1987 based on port samples from trawl (TWL) and fixed gear (longline, pot, and net) vessels. CV represents the coefficient of variation for each estimate.

	TWL				FIX			
	Male		Female		Male		Female	
Length	Number	CV	Number	CV	Number	CV	Number	CV
40	147.8	23%	167.8	27%	4.0	49%	8.7	55%
42	201.3	19	143.8	20	10.6	40	5.6	39
44	272.7	14	211.6	21	29.8	30	15.2	29
46	262.9	15	258.9	16	46.3	29	28.0	31
48	265.3	21	224.6	10	68.9	24	32.0	28
50	298.0	8	229.6	11	105.6	16	38.1	19
52	315.7	11	209.5	9	177.3	17	105.6	14
54	291.9	13	217.9	11	253.4	23	133.8	21
56	186.5	13	139.2	10	217.1	21	157.5	21
58	110.9	24	131.8	11	153.1	17	136.3	9
60	113.2	18	121.8	11	153.7	16	251.6	16
64	15.8	23	62.8	15	62.2	13	221.4	11
68	6.4	35	29.8	20	36.8	16	143.3	16
72	4.3	46	23.2	20	1.0	71	107.1	18
76	0.1	101	9.4	23	0.0	0	29.3	34
80	0.0	0	7.5	32	0.5	77	25.9	22
90	0.0	0	1.5	66	0.0	0	4.8	61

Table 4. Estimated number of sablefish landed by length class (fork length, in cm) in 1988 based on port samples from trawl (TWL) and fixed gear (longline and pot) vessels. CV represents the coefficient of variation for each estimate.

	TWL				FIX			
	Male		Female		Male		Female	
Length	Number	CV	Number	CV	Number	CV	Number	CV
40	79.3	36%	64.2	33%	4.6	45%	3.7	37%
42	112.0	26	98.7	19	1.4	59	4.0	49
44	162.7	20	183.6	18	4.9	37	4.2	27
46	234.3	14	222.0	12	4.6	44	9.0	39
48	253.3	12	279.6	12	23.1	25	36.5	23
50	313.4	10	178.0	11	80.8	23	69.4	29
52	256.6	13	228.9	15	93.5	17	153.9	20
54	257.7	12	146.5	14	139.6	12	145.2	9
56	175.1	18	158.3	8	137.0	20	156.0	22
58	117.0	18	128.3	14	103.2	12	200.5	12
60	90.7	16	133.3	11	140.8	13	239.2	12
64	28.4	29	55.1	16	49.6	13	216.1	9
68	8.0	32	29.9	24	1.4	39	178.1	17
72	7.3	32	17.2	26	0.0	0	66.2	15
76	1.5	106	7.2	24	4.8	62	26.6	33
80	0.0	0	9.1	28	0.2	105	25.8	26
90	0.0	0	0.0	0	0.0	0	0.0	106

Table 5. Estimated number of sablefish (thousands of fish) landed by age class in 1986 based on port samples from trawl (TWL) and fixed gear (longline, pot, and net) vessels. CV represents the coefficient of variation for each estimate.

	TWL				FIX			
	Male		Female		Male		Female	
Age	Number	CV	Number	CV	Number	CV	Number	CV
1	62.3	23%	126.2	29%	9.5	49%	12.9	38%
2	206.6	13	299.7	10	30.3	20	111.2	18
3	215.9	13	215.4	11	56.9	16	119.8	15
4	312.1	11	201.3	11	97.0	13	176.9	11
5	323.0	11	257.0	10	145.5	12	290.0	9
6	276.0	11	207.2	11	146.0	11	280.1	9
7	227.1	13	139.1	13	137.3	10	245.7	9
8	147.3	15	91.3	15	95.2	12	168.1	11
9	149.2	15	49.4	19	104.9	12	124.7	13
10	127.3	17	49.2	21	85.9	13	98.8	14
11	98.4	19	36.2	23	75.3	14	82.3	15
12	44.6	26	22.4	28	38.9	19	54.1	19
13	52.5	25	23.3	30	41.3	19	44.6	21
14	58.3	24	24.4	28	48.8	18	57.5	19
15-19	132.0	16	28.7	24	107.1	12	73.2	16
20+	25.2	38	31.1	26	14.1	28	56.2	19

Table 6. Estimated number of sablefish (thousands of fish) landed by age class in 1987 based on port samples from trawl (TWL) and fixed gear (longline, pot, and net) vessels. CV represents the coefficient of variation for each estimate.

	TWL				FIX			
	Male		Female		Male		Female	
Age	Number	CV	Number	CV	Number	CV	Number	CV
1	34.2	43%	51.0	37%	0.9	61%	2.6	54%
2	403.1	12	482.8	11	37.4	19	42.2	16
3	261.3	14	400.4	11	47.7	16	71.5	12
4	182.1	16	247.9	12	52.4	16	78.7	12
5	165.1	17	190.0	13	53.1	16	110.3	12
6	130.7	17	127.1	16	61.0	15	79.1	13
7	190.8	14	114.5	14	117.8	13	121.9	12
8	141.7	16	92.8	15	99.9	15	139.5	11
9	109.7	18	89.3	16	65.2	15	122.6	12
10	182.2	13	109.6	14	142.6	12	187.7	10
11	59.1	24	27.6	28	38.4	21	40.0	19
12	62.7	23	32.0	25	52.1	19	48.3	19
13	59.6	23	31.0	27	47.1	20	40.1	20
14	38.3	28	13.7	34	40.7	22	28.4	25
15-19	171.8	13	74.7	15	171.5	10	151.6	11
20+	300.9	10	108.1	13	293.4	9	181.3	11

Table 7. Estimated number of sablefish (thousands of fish) landed by age class in 1988 based on port samples from trawl (TWL) and fixed gear (longline and pot) vessels. CV represents the coefficient of variation for each estimate.

	TWL				FIX			
	Male		Female		Male		Female	
Age	Number	CV	Number	CV	Number	CV	Number	CV
1	0.0	0%	20.0	41%	0.0	0%	0.0	49%
2	343.1	13	475.9	9	11.3	21	45.1	16
3	344.2	10	452.5	8	34.0	16	167.4	11
4	163.1	13	230.1	10	36.3	15	150.0	11
5	103.7	16	121.9	14	36.9	16	106.9	13
6	90.8	17	83.4	17	27.8	18	83.5	15
7	89.4	17	71.0	17	34.6	18	100.1	17
8	87.0	18	58.7	18	43.4	16	87.7	15
9	94.3	17	43.8	21	52.7	15	61.2	19
10	75.3	19	52.2	19	37.9	17	107.0	18
11	63.0	20	48.2	20	32.4	19	99.3	18
12	54.4	21	46.8	22	33.4	18	80.7	19
13	46.6	25	37.6	24	24.6	22	65.3	20
14	30.0	29	8.2	47	17.2	24	15.7	38
15-19	173.5	12	59.9	18	124.3	10	89.0	15
20+	339.7	9	128.8	12	228.9	8	258.3	11

Table 8. Estimated transition matrix relating otolith age (new criteria) to true age. The standard deviation of age determination is assumed to increase linearly with true age. The model is set up to estimate the fraction mis-aged at age 1 and at age 20, but the fraction mis-aged at age 1 was set equal to 0.05 in all model runs. Note that otolith ages 15-19 are accumulated into one category. The distributions are presented as parts per thousand and the columns sum to 1000 (within rounding error).

20-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	105	344	921
15-	0	0	0	0	0	0	0	0	0	0	0	2	53	305	685	914	970	892	655	78
14-	0	0	0	0	0	0	0	0	0	0	1	41	241	389	240	73	13	1	0	0
13-	0	0	0	0	0	0	0	0	0	0	32	240	409	241	66	10	1	0	0	0
12-	0	0	0	0	0	0	0	0	0	24	237	432	241	58	7	0	0	0	0	0
11-	0	0	0	0	0	0	0	0	17	231	457	240	49	5	0	0	0	0	0	0
10-	0	0	0	0	0	0	0	11	223	485	237	41	3	0	0	0	0	0	0	0
9-	0	0	0	0	0	0	6	212	516	231	32	2	0	0	0	0	0	0	0	0
8-	0	0	0	0	0	3	197	551	223	24	1	0	0	0	0	0	0	0	0	0
7-	0	0	0	0	1	179	591	212	17	0	0	0	0	0	0	0	0	0	0	0
6-	0	0	0	0	156	635	197	11	0	0	0	0	0	0	0	0	0	0	0	0
5-	0	0	0	129	685	179	6	0	0	0	0	0	0	0	0	0	0	0	0	0
4-	0	0	99	740	156	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-	0	68	800	129	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-	24	863	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-	975	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+

Transition matrix relating the old ageing criteria to the true age. The trend was described by a von Bertalanffy growth function fit to the trend of old ageing criteria relative to the new ageing criteria and forced through the point (1,1).

20-	0	0	0	0	0	0	0	0	0	0	0	0	1	4	15	35	69	115	173	481
15-	0	0	0	0	0	0	0	0	0	3	17	54	117	200	288	367	426	462	475	371
14-	0	0	0	0	0	0	0	0	1	9	30	61	92	113	123	123	115	104	92	46
13-	0	0	0	0	0	0	0	0	7	28	63	100	124	135	131	120	106	91	78	35
12-	0	0	0	0	0	0	0	4	25	65	108	137	146	141	125	107	90	74	61	25
11-	0	0	0	0	0	0	2	20	65	118	153	160	149	129	107	87	70	56	45	17
10-	0	0	0	0	0	0	15	64	128	170	176	157	131	104	82	64	50	39	31	11
9-	0	0	0	0	0	9	60	140	191	193	166	131	100	75	56	42	32	25	20	6
8-	0	0	0	0	4	52	152	216	212	173	130	93	66	48	35	26	19	15	12	3
7-	0	0	0	1	40	166	247	234	178	123	83	56	38	27	19	14	10	8	6	2
6-	0	0	0	24	175	289	257	178	112	69	43	28	19	13	9	7	5	4	3	1
5-	0	0	8	180	342	279	170	95	53	31	19	12	8	5	4	3	2	2	1	0
4-	0	0	169	415	299	151	72	35	19	11	6	4	3	2	1	1	1	0	0	0
3-	0	128	521	303	117	45	19	9	5	3	2	1	1	0	0	0	0	0	0	0
2-	49	682	276	70	20	7	3	1	1	0	0	0	0	0	0	0	0	0	0	0
1-	950	189	24	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+

Table 8 (continued). Transition matrix used to generate the estimate of female size composition from female age composition. Note that the size bins are not of uniform width.

Size																				
80-	0	0	0	0	0	0	4	17	40	70	105	141	175	206	234	259	281	299	315	358
76-	0	0	0	0	0	4	17	39	65	88	106	120	129	135	139	142	143	144	144	147
72-	0	0	0	0	3	19	51	89	119	140	152	158	160	160	159	157	155	152	150	146
68-	0	0	0	1	17	62	115	153	172	178	177	173	166	159	153	147	143	138	135	126
64-	0	0	0	11	68	142	187	201	196	183	169	156	144	134	126	119	113	109	105	95
60-	0	0	4	62	167	222	223	200	174	151	132	116	105	95	88	82	78	74	71	62
58-	0	0	10	73	122	123	104	84	68	56	47	41	36	33	30	28	26	25	23	20
56-	0	0	28	109	136	115	89	68	53	43	36	31	27	24	22	20	19	18	17	14
54-	0	1	62	141	133	99	71	52	39	31	26	22	19	17	15	14	13	13	12	10
52-	0	7	111	156	117	77	52	36	27	21	17	15	13	11	10	10	9	8	8	7
50-	0	29	158	147	91	55	35	24	17	14	11	9	8	7	7	6	6	5	5	4
48-	0	79	183	119	63	35	22	14	11	8	7	6	5	4	4	4	3	3	3	2
46-	1	154	171	83	39	20	12	8	6	5	4	3	3	2	2	2	2	2	2	1
44-	14	216	129	49	21	11	6	4	3	2	2	2	1	1	1	1	1	1	1	1
42-	67	219	78	25	10	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1
40-	185	160	38	11	4	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0
32-	730	129	21	6	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+

Transition matrix used to generate the estimate of male size composition from male age composition.

Size:																				
80-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2
76-	0	0	0	0	0	0	0	0	0	0	1	2	3	5	7	8	9	11	12	15
72-	0	0	0	0	0	0	0	1	3	7	11	17	23	29	35	41	46	50	54	63
68-	0	0	0	0	0	0	4	12	24	41	58	76	91	105	117	127	135	142	148	162
64-	0	0	0	0	1	12	34	68	106	141	170	193	211	223	233	240	245	248	251	259
60-	0	0	0	2	24	77	145	205	247	271	284	288	288	285	281	277	273	269	265	257
58-	0	0	0	9	46	97	136	154	158	154	146	138	130	123	117	112	108	104	101	94
56-	0	0	2	31	93	145	165	164	152	137	123	111	102	94	87	82	78	75	72	65
54-	0	0	11	74	147	176	168	146	124	105	90	78	69	62	57	53	50	47	45	40
52-	0	1	39	136	185	174	141	110	86	69	57	48	41	36	33	30	28	26	25	21
50-	0	8	97	190	185	140	99	70	51	39	31	25	21	18	16	15	14	13	12	10
48-	0	35	173	204	147	92	58	38	26	19	14	11	9	8	7	6	6	5	5	4
46-	1	102	223	167	93	50	28	17	11	8	6	4	3	3	2	2	2	2	2	2
44-	14	198	208	105	46	21	11	6	4	2	3	2	1	1	1	1	1	1	1	0
42-	67	255	140	50	18	7	3	2	1	1	0	0	0	0	0	0	0	0	0	0
40-	185	216	68	18	5	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
32-	730	181	32	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+

Table 9. Survey observations of sablefish abundance. Trawl surveys were conducted in the 30-200 fathom depth zone so do not contain larger and older fish; values are in thousands of fish. The northern pot survey (N Pot) covers Oregon and Washington and the 150-450 fathom depth range. The southern pot survey covers California and southern Oregon and the 225-525 fathom depth range. Pot survey values are in numbers of fish per pot. The CV for the small fish component of the trawl survey is assumed to be the same as the calculated CV for the entire size range.

Year	Trawl <42 cm		Trawl All		N Pot		S Pot	
	value	CV	value	CV	value	CV	value	CV
71	---		---		10.30	.245	---	
72	---		---		---		---	
73	---		---		---		---	
74	---		---		---		---	
75	---		---		---		---	
76	---		---		---		---	
77	---		---		---		---	
78	---		---		---		---	
79	---		---		11.40	.316	---	
80	32253	.461	50158	.461	6.80	.124	---	
81	---		---		4.80	.200	---	
82	---		---		---		---	
83	16875	.368	38097	.368	10.60	.092	---	
84	---		---		---		9.80	.108
85	---		---		7.40	.193	---	
86	19267	.264	28973	.264	---		4.60	.096
87	---		---		2.80	.189	---	
88	---		---		---		10.60	.109

Table 10. Constants in the sablefish synthesis model. All sizes are in fork lengths.

Male growth:	
Length at age 1	38.4
von Bertalanffy K	.184
Asymptotic length	64.5
c.v. length at age 1	0.068
c.v. length at age 20	0.0902
Female growth:	
Length at age 1	38.4
von Bertalanffy K	.152
Asymptotic length	77.5
c.v. length at age 1	0.068
c.v. length at age 20	0.1452
Length-Weight power function (length in cm, weight in kg)	
intercept	2.3319E-6
exponent	3.3639
Maturity-Length logistic	
slope	0.2491
Length at 50% maturity	58.3
Trawl fishery logistic retention	
slope	0.809
Length at 50% retention	41.4
Stock-recruitment density dependence	0.889
Ageing error	
frac. misaged at age 1	0.050
frac. misaged at age 20	estimated

Table 11. Estimated time series of sablefish recruitment and biomass. Numbers are in thousands of fish at the beginning of the year. Biomass is in mt at the beginning of the year (BEGIN) and the mean within the year (MEAN). Recruitment of the 1987 and 1988 year classes were set equal to the value expected from the spawner-ercruitment relationship.

	FOR AGES 1+				FOR AGES 3+			
YR	BEGIN BIOMASS	MEAN BIOMASS	BEGIN SPWN BIO	NUMS @ AGE 1	BEGIN BIOMASS	MEAN BIOMASS	BEGIN SPWN BIO	NUMS @ AGE 3
VIRGIN			200325	23364				
71	348683	328445	168443	23139	326193	309655	168443	11307
72	350060	327321	167586	31018	323907	305647	167586	11133
73	348538	326208	164443	33442	317467	300364	164443	10894
74	343793	320803	162396	22984	316659	298013	162396	14553
75	335375	312125	158358	20314	314513	294705	158358	15725
76	324949	294424	153238	20182	305437	278209	153238	10790
77	298078	277419	138810	19610	278918	261471	138810	9440
78	300265	275052	134620	42814	270105	250426	134620	9416
79	280936	251629	127557	10714	255429	230263	127557	8986
80	262247	242298	113498	37036	239194	223541	113498	19119
81	258833	237287	109292	26578	228280	211876	109292	4918
82	248014	223390	104866	18046	226646	205847	104866	16933
83	227024	206516	97210	14236	211666	193865	97210	11629
84	209722	190372	91593	10358	197992	180750	91593	7922
85	194969	175894	86041	16296	182206	165539	86041	6186
86	185333	166383	79280	27852	164175	149228	79280	4473
87	176681	158126	72514	26889	150578	136786	72514	7049
88	165988	149764	66126	19540	143902	131552	66126	12063
89	159097	144036	61517	19068	140639	128879	61517	11808

		RECRUITS AT AGE: 1		
YRCLASS	SPAWNBIO	ESTIMATE	EXPECT	DEVIATE
70	168444	23140	22883	.01
71	168444	31018	22883	.30
72	167586	33442	22868	.38
73	164443	22984	22811	.01
74	162396	20314	22774	-.11
75	158358	20182	22696	-.12
76	153238	19610	22593	-.14
77	138810	42814	22269	.65
78	134621	10714	22163	-.73
79	127558	37036	21973	.52
80	113498	26578	21535	.21
81	109293	18046	21387	-.17
82	104867	14236	21220	-.40
83	97211	10358	20903	-.70
84	91594	16296	20644	-.24
85	86042	27852	20362	.31
86	79280	26890	19978	.30
87	72515	---	19541	---
88	66126	---	19069	---
MEAN		23618		

Table 12. Size-specific selectivities estimated as the product of two logistic functions. Selectivities, except for the trawl survey, have been scaled so that age 5 females have selectivity = 1.0. Trawl survey selectivities are scaled so that age 1 selectivity is 1.0.

TYPE:	FIXED GEAR		TRAWL GEAR		TRAWL SURV		N-POT SURV		S-POT SURV	
SEX:	FEMA	MALE	FEMA	MALE	FEMA	MALE	FEMA	MALE	FEMA	MALE
32	.001	.002	.167	.121	1.015	1.015	.003	.006	.008	.012
40	.005	.008	.387	.289	.978	.816	.013	.027	.036	.053
42	.016	.020	.596	.463	.931	.671	.050	.102	.121	.176
44	.045	.049	.858	.697	.853	.517	.182	.341	.354	.497
46	.124	.115	1.136	.961	.737	.374	.533	.884	.766	1.007
48	.312	.246	1.360	1.186	.589	.255	1.042	1.492	1.170	1.373
50	.660	.443	1.465	1.286	.428	.166	1.366	1.641	1.363	1.325
52	1.076	.621	1.427	1.217	.283	.104	1.381	1.342	1.366	1.000
54	1.353	.673	1.276	1.010	.173	.064	1.257	.962	1.275	.642
56	1.407	.604	1.066	.748	.100	.039	1.110	.657	1.139	.370
58	1.320	.491	.847	.505	.055	.023	.971	.440	.978	.199
60	1.106	.344	.575	.271	.025	.012	.795	.252	.727	.086
64	.825	.202	.313	.097	.007	.004	.599	.109	.433	.022
68	.591	.117	.162	.032	.002	.001	.449	.047	.229	.005
72	.412	.067	.082	.010	.001	.001	.335	.020	.112	.001
76	.282	.039	.041	.003	.000	.000	.249	.008	.052	.000
80	.155	.018	.016	.001	.000	.000	.156	.003	.019	.000

Table 13. Estimated selectivity-at-age. Calculated from the size-specific selectivity (Table 12) and the distribution of size-at-age (Table 8).

TYPE:	FIXED GEAR		TRAWL GEAR		TRAWL SURV		N-POT SURV		S-POT SURV	
SEX:	FEMA	MALE	FEMA	MALE	FEMA	MALE	FEMA	MALE	FEMA	MALE
AGE										
1	.003	.004	.249	.185	1.000	.947	.011	.023	.027	.039
2	.089	.042	.741	.494	.854	.684	.272	.259	.375	.321
3	.454	.160	1.135	.844	.592	.440	.806	.772	.898	.775
4	.838	.320	1.160	1.023	.364	.278	1.025	1.088	1.068	.963
5	1.000	.435	1.000	1.022	.222	.181	1.000	1.105	1.000	.896
6	1.005	.484	.817	.929	.143	.123	.904	.985	.863	.745
7	.945	.489	.664	.813	.098	.089	.805	.842	.729	.599
8	.869	.472	.548	.706	.071	.067	.720	.717	.617	.483
9	.797	.448	.461	.616	.055	.053	.651	.617	.529	.397
10	.733	.424	.397	.544	.045	.044	.595	.541	.461	.334
11	.680	.401	.349	.488	.037	.037	.551	.482	.409	.287
12	.636	.382	.312	.444	.032	.032	.515	.437	.368	.253
13	.600	.365	.284	.410	.029	.029	.487	.402	.337	.227
14	.570	.351	.262	.382	.026	.026	.464	.375	.312	.207
15	.546	.340	.245	.361	.024	.024	.446	.354	.292	.192
16	.526	.331	.231	.343	.022	.023	.431	.337	.276	.180
17	.510	.323	.220	.329	.021	.022	.418	.323	.263	.171
18	.496	.316	.211	.318	.020	.021	.408	.312	.253	.163
19	.485	.311	.204	.309	.019	.020	.400	.303	.244	.157
20+	.451	.297	.179	.284	.016	.018	.373	.279	.216	.140

Table 14. Estimated body weight-at-age (kg). The weights in the trawl fishery have been separated into landed and discarded categories based on the size-specific retention function.

	POPULATION		FIXED GEAR		---- TRAWL GEAR ------			
					FEMALE		MALE	
AGE	FEMALE	MALE	FEMALE	MALE	LANDED	DISC	LANDED	DISC
1	.486	.486	----	----	.663	.494	.668	.496
2	.794	.720	1.143	.992	.948	.657	.881	.642
3	1.139	.964	1.461	1.219	1.218	.731	1.071	.729
4	1.505	1.197	1.730	1.400	1.466	.765	1.240	.786
5	1.883	1.419	1.980	1.549	1.685	.778	1.385	.827
6	2.255	1.627	2.213	1.678	1.872	.779	1.506	.856
7	2.615	1.815	2.427	1.791	2.030	.775	1.608	.877
8	2.960	1.982	2.620	1.892	2.160	.770	1.694	.892
9	3.282	2.129	2.791	1.979	2.268	.763	1.766	.902
10	3.576	2.256	2.943	2.055	2.357	.757	1.827	.910
11	3.836	2.366	3.077	2.120	2.430	.751	1.877	.916
12	4.062	2.459	3.195	2.175	2.491	.746	1.919	.920
13	4.255	2.539	3.297	2.222	2.543	.742	1.954	.923
14	4.418	2.607	3.387	2.262	2.586	.738	1.983	.926
15	4.556	2.664	3.465	2.296	2.623	.734	2.007	.928
16	4.672	2.713	3.533	2.324	2.654	.732	2.027	.929
17	4.770	2.754	3.591	2.348	2.681	.729	2.043	.930
18	4.852	2.788	3.642	2.368	2.704	.727	2.057	.931
19	4.921	2.817	3.686	2.385	2.723	.725	2.069	.932
20	5.129	2.895	3.841	2.434	2.821	.728	2.106	.939

Table 15. Model fit to survey data. Deviations are calculated as the logarithm of observed/expected.

AGE 1 ABUNDANCE IN TRAWL SURVEY (QUANTITATIVE)

YR	OBSERVE	EXPECT	DEVIATE
80	34349	29635	.148
83	17972	11327	.462
86	20519	22110	-.075

N	SUME/SUMO	MEAN DEV	STD.DEV.
3	.866	.178	.269

ALL FISH IN TRAWL SURVEY (NON-QUANTITATIVE)

YR	OBSERVE	EXPECTE	DEVIATE
80	46384	46059	.007
83	37194	29309	.238
86	24630	32838	-.288

N	SUME/SUMO	MEAN DEV	STD.DEV.
3	1.045	-.014	.264

NORTHERN POT SURVEY

YR		OBSERVED	EXPECTED	DEVIATE
71		10.30	10.64	-.032
79		11.40	8.31	.316
80		6.80	8.22	-.189
81		4.80	8.24	-.540
83		10.60	7.66	.324
85	1	7.40	6.02	.207
87	1	2.80	5.01	-.582

N	SUME/SUMO	MEAN DEV	STD.DEV.
7	7170.	-.071	.383

SOUTHERN POT SURVEY

YR	OBSERVED	EXPECTED	DEVIATE
84	9.80	9.82	-.002
86	4.60	7.33	-.466
88	10.60	7.85	.301

N	SUME/SUMO	MEAN DEV	STD.DEV.
3	4285.	-.056	.386

Table 16. Influence of adult natural mortality on model's fit. Tabulated values are in log-likelihood, except as indicated. Less negative values indicate better fits. The column with natural mortality equal to 0.0875 is the null run used to generate management recommendations.

NAT.MORT.	.050	.075	.0875	.100	.125	.150
FIXED GEAR:						
87-88 AGE	-38	-40	-41	-44	-53	-72
86 AGE	-29	-27	-25	-23	-19	-16
SIZE	-60	-61	-60	-63	-65	-66
TRAWL GEAR:						
87-88 AGE	-21	-26	-28	-32	-44	-56
86 AGE	-15	-14	-13	-12	-11	-11
SIZE	-42	-43	-42	-43	-46	-49
TRAWL SURVEY:						
AGE 1 AB	2.3	2.3	2.2	2.2	2.3	2.6
ALL ABUND	1.9	2.2	2.2	2.3	2.3	2.4
SIZE	-49	-50	-52	-53	-50	-48
N-POT SURVEY:						
ABUNDANCE	-8.0	-4.6	-5.0	-5.2	-5.6	-6.1
SIZE	-190	-202	-210	-214	-223	-230
S-POT SURVEY:						
ABUNDANCE	-8.1	-10.0	-10.0	-10.4	-11.2	-11.7
86 AGE	-30	-34	-35	-38	-48	-58
SIZE	-44	-43	-42	-42	-41	-41
SPAWN/RECR	-7.2	3.1	7.8	7.4	-2.7	-6.2
TOTAL LIKELIHOOD:	-537	-545	-553	-569	-616	-666
AGE 3+ BIOMASS (thousand mt)						
1989	215	142	141	128	123	121
RECRUITMENT (millions of age 1 fish)						
VIRGIN	13.0	19.9	23.4	26.4	34.6	40.0
71-87	25.9	24.3	23.6	23.1	22.9	25.8

Table 17. Effect of the level of juvenile natural mortality on model results. The indicated level of natural mortality is for age 1 sablefish. Natural mortality was assumed to change linearly up to an estimated inflection age, and sablefish older than the inflection age were assumed to have a natural mortality of 0.0875. The model typically estimated the inflection age to be about 3.0 years. The bias in age 1 abundance refers to the three observations of age 1 abundance and bias is defined as the ratio of the mean observed abundance to the mean expected abundance. A value of 1.0 indicates no bias.

AGE 1 NATURAL MORTALITY	0.10	0.20	0.30	0.40	0.45 (estimated)
TOTAL LOG LIKELIHOOD	-558	-557	-556	-557	-553
AGE 3+ BIOMASS IN 1989	288	230	178	150	141
AGE 1 RECRUITMENT (millions of fish)					
VIRGIN	19.1	19.8	20.8	23.8	23.4
MEAN 1971-87	19.3	20.1	21.1	23.8	23.6
VIRGIN AGE 3 RECRUITMENT	15.7	14.0	12.6	12.2	11.3

Table 18. Effect of the level of trawl discard on model results.

DISCARD LEVEL (% of landings)	0	6	12	18	18+[1]	24
AGE 1 NATURAL MORTALITY:	.41	.43	.41	.47	.37	.41
TOTAL LOG LIKELIHOOD:	-555	-555	-556	-554	-554	-557
AGE 1 RECRUITMENT (millions of fish) MEAN 1971-87	22.4	23.2	24.0	24.2	23.4	24.0
AGE 3+ BIOMASS (thousands of mt) IN 1989	157	148	165	148	149	158

[1]Discard level set equal to 18% of landings in all years except 1985-1987 when the levels estimated by Pikitch, et al. (1988) were used.

Table 19. Influence of emphasis factors on model results. Tabulated values are log-likelihoods summed over all observations of the indicated type (AB indicates abundance, AGE indicates age composition, SIZE indicates size composition). The 3+ biomass values are in thousands of tons at the beginning of 1989.

MODEL CONDITION:	AGE SURVEY NULL	.001x	AGE COMPOSITION 25x	.1x	10x
FIXED GEAR:					
87-88 AGE	-41	-41	-41	-115	-24
86 AGE	-25	-25	-26	-35	-23
SIZE	-60	-59	-59	-56	-74
TRAWL GEAR:					
87-88 AGE	-28	-26	-27	-84	-14
86 AGE	-13	-13	-14	-37	-10
SIZE	-42	-43	-43	-36	-58
TRAWL SURVEY:					
AGE 1 AB	2.2	1.8	3.0	2.0	1.9
ALL AB	2.2	2.2	2.5	1.9	2.3
SIZE	-52	-56	-54	-46	-69
N-POT SURVEY:					
AB	-5.0	-5.0	-4.5	-5.6	-5.1
SIZE	-210	-213	-209	-130	-267
S-POT SURVEY:					
AB	-10.0	-9.9	-11.3	-13.2	-11.1
86 AGE	-35	-34	-38	-98	-13.5
SIZE	-42	-42	-44	-43	-85
SPAWN/RECR	7.8	10.6	8.8	5.2	6.3
AGE 3+ BIOMASS 1989	141	150	143	53	307

Table 20. Influence of emphasis factors on model results. Tabulated values are log-likelihoods summed over all observations of the indicated type (AB indicates abundance, AGE indicates age composition, SIZE indicates size composition). The 3+ biomass values are in thousands of tons at the beginning of 1989.

MODEL CONDITION:	NULL	POT ABUNDANCE .1x	10.x	25.x	POT SIZE COMPOSITION .1x	10.x	25.x
FIXED GEAR:							
87-88 AGE	-41	-39	-52	-67	-31	-129	-210
86 AGE	-25	-26	-26	-29	-24	-26	-32
SIZE	-60	-59	-75	-97	-56	-72	-82
TRAWL GEAR:							
87-88 AGE	-28	-27	-38	-63	-22	-84	-134
86 AGE	-13	-14	-13	-17	-11	-27	-34
SIZE	-42	-43	-50	-70	-41	-52	-58
TRAWL SURVEY:							
AGE 1 AB	2.2	1.9	1.5	1.5	2.4	.1	.0
ALL AB	2.2	2.2	1.8	2.2	2.4	1.3	1.9
SIZE	-52	-57	-51	-62	-54	-52	-70
N-POT SURVEY:							
AB	-5.0	-5.2	-0.9	4.0	-5.0	-7.4	-7.4
SIZE	-210	-207	-216	-230	-260	-112	-101
S-POT SURVEY:							
AB	-10.0	-11.1	-2.0	4.0	-10.5	-9.1	-11.2
86 AGE	-35	-37	-36	-42	-17	-112	-145
SIZE	-42	-44	-42	-83	-95	-41	-44
SPAWN/RECR	7.8	11.9	-1.6	-9.7	6.8	-3.0	-3.0
AGE 3+ BIOMASS 1989	141	146	137	100	275	66	51

Table 21. Results of equilibrium yield calculations and ABC for 1990. Management recommendations are based on the results for the column with natural mortality equal to 0.0875.

NATURAL MORTALITY	0.050	0.075	0.0875	0.100	0.125	0.150
RESULTS OF SYNTHESIS MODEL:						
VIRGIN RECR	13.0	19.9	23.4	26.4	34.6	40.0
MEAN RECR 71-87	25.9	24.3	23.6	23.1	22.9	25.8
VIRGIN SPAWN.BIO.	216	195	200	197	208	201
VIRGIN 3+BIO	377	358	378	382	426	435
1990 SPAWN.BIO.	100	60	58	52	49	47
1990 3+BIO	210	136	136	125	122	124
EQUILIBRIUM CONDITIONS WITH DENSITY-DEPENDENT RECRUITMENT						
RECRUITMENT	10.0	15.5	17.7	20.8	26.3	30.4
SPAWN. BIO.	59	55	52	58	54	52
AGE 3+ BIOMASS	118	123	123	141	146	155
F FIXED	0.041	0.049	0.057	0.056	0.066	0.071
F TRAWL	0.054	0.059	0.066	0.061	0.073	0.079
MSY	4080	5530	6770	7770	10860	13140
TRAWL DISCARD	194	285	368	413	631	807
1990 ABC	7730	5990	7020	6520	8350	9690
CONSTANT RECRUITMENT AT MEAN OF 1971-1987						
UNFISHED SPAWN. BIO.	430	237	203	173	138	129
UNFISHED 3+ BIO	752	436	383	335	283	280
FISH DOWN TO 30% OF UNFISHED SPAWNING BIOMASS						
SPAWN. BIO.	129	71	61	52	41	39
3+ BIO	265	166	149	134	116	120
F FIXED	0.049	0.059	0.065	0.069	0.076	0.082
F TRAWL	0.063	0.071	0.074	0.076	0.083	0.090
EQUIL. YIELD	11260	9390	9510	9530	10030	11800
TRAWL DISCARD	563	511	540	540	610	760
1990 ABC	9330	7440	7990	8070	9340	10810
FISH AT $F_{0.1}$						
SPAWN. BIO.	98	47	42	33	26	24
3+ BIO.	211	123	114	98	86	88
F FIXED	0.062	0.082	0.090	0.100	0.111	0.122
F TRAWL	0.080	0.099	0.099	0.110	0.122	0.135
EQUIL. YIELD	12120	10470	10630	10800	11410	13540
1990 ABC	11730	10200	10760	11460	13360	15770

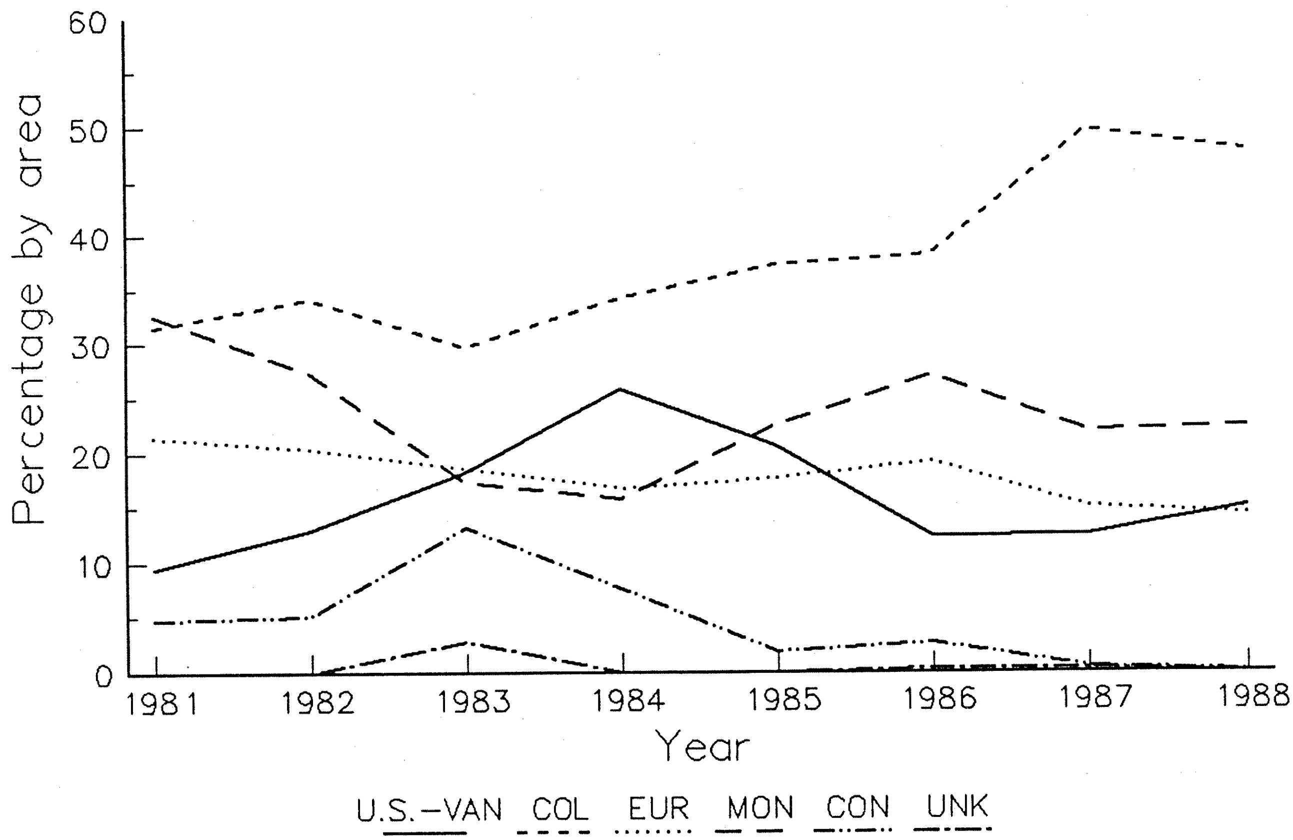

Figure 1. Percentage of total sablefish landings by INPFC area for 1981-1988 (based on PacFIN data as of 8/24/89).

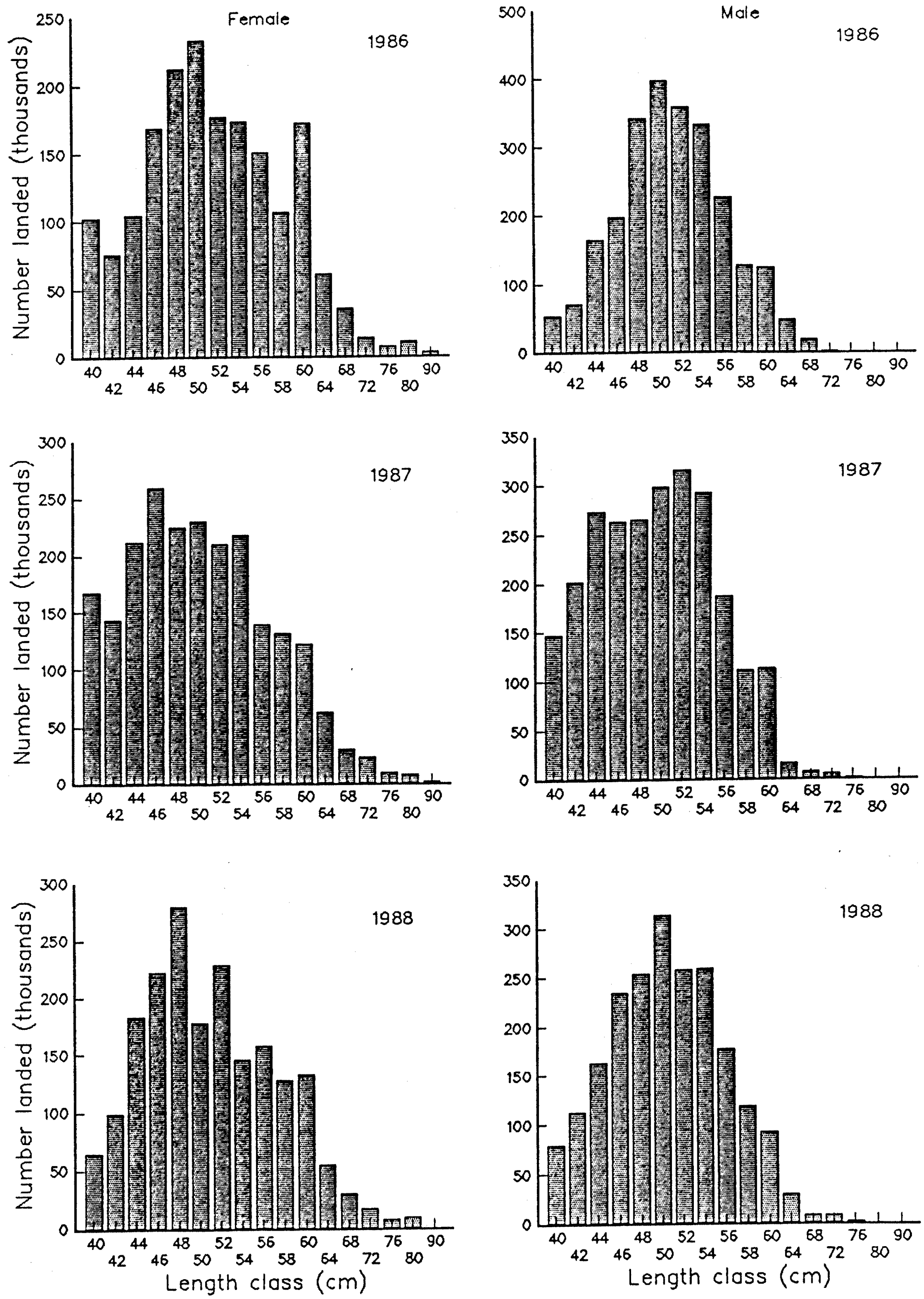

Figure 2. Number of female and male sablefish by fork length class landed by trawl vessels, based on 1986-1988 port sampling.

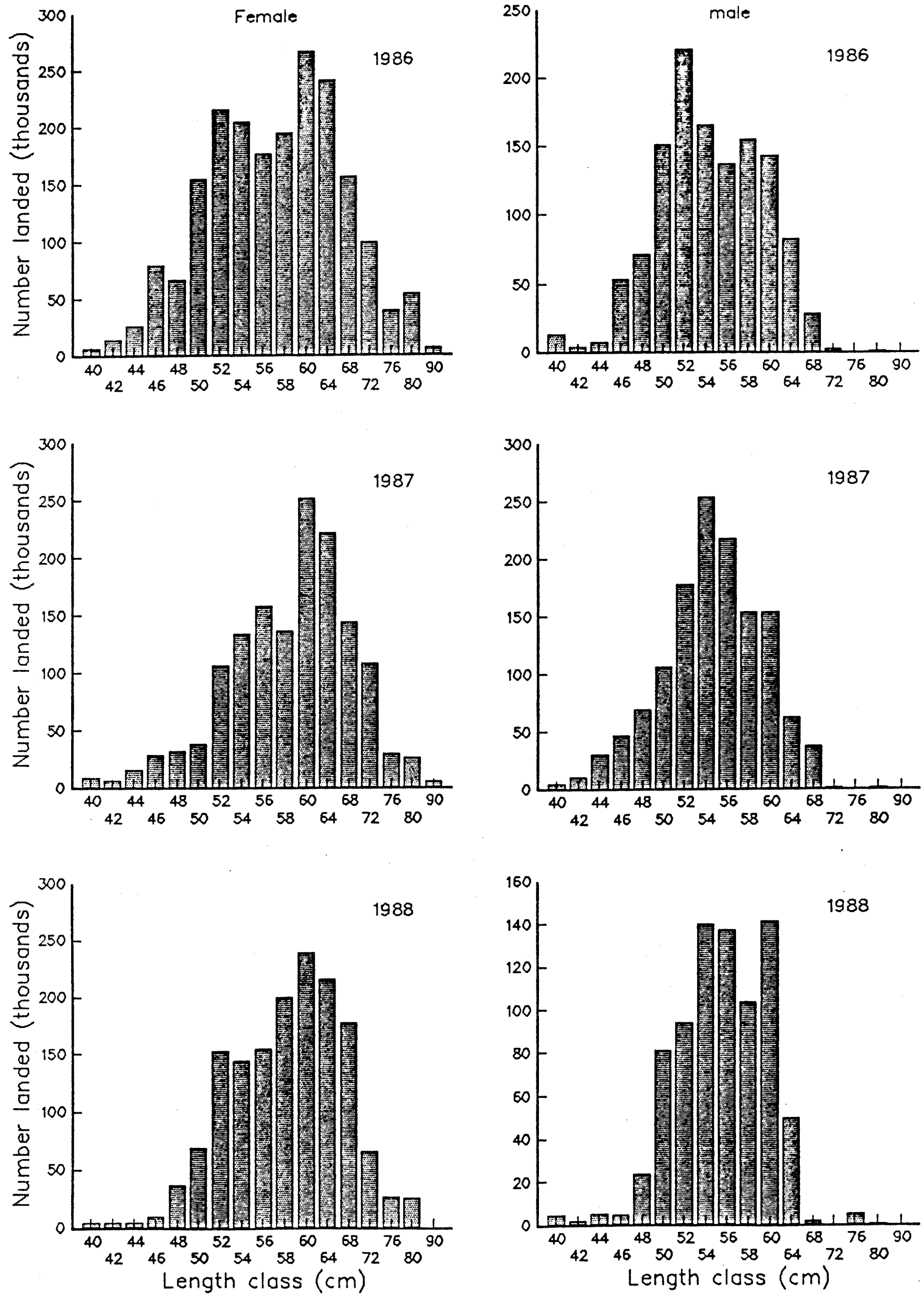

Figure 3. Number of female and male sablefish by fork length class landed by fixed gear vessels, based 1986-1988 on port sampling.

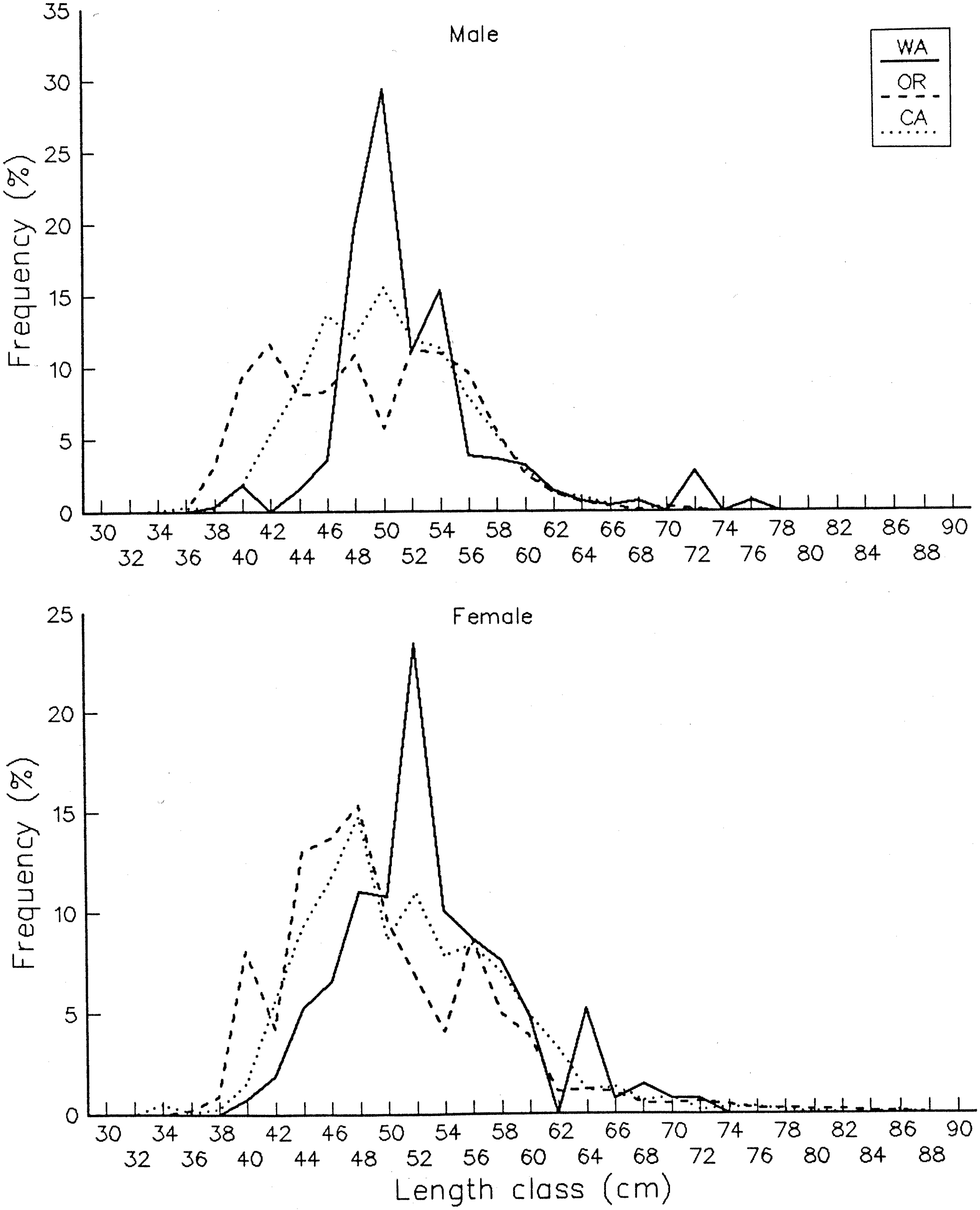

Figure 4. Fork length frequency distribution for trawl sablefish landings by state, based on 1988 port sampling.

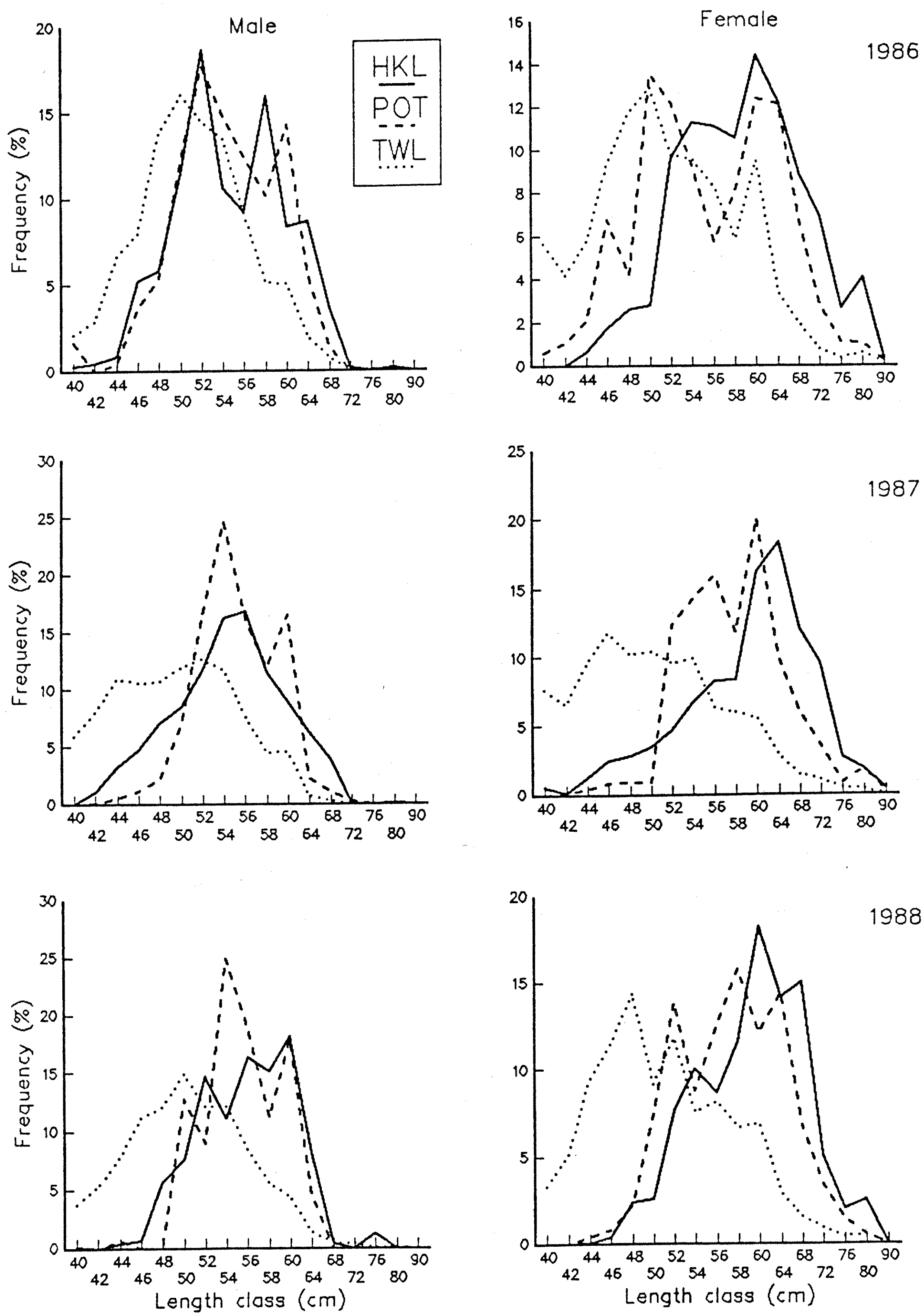

Figure 5. Fork length frequency distributions for sablefish landed by longline (HKL), pot (POT), and trawl (TWL) vessels, based on 1986-1988 port sampling.

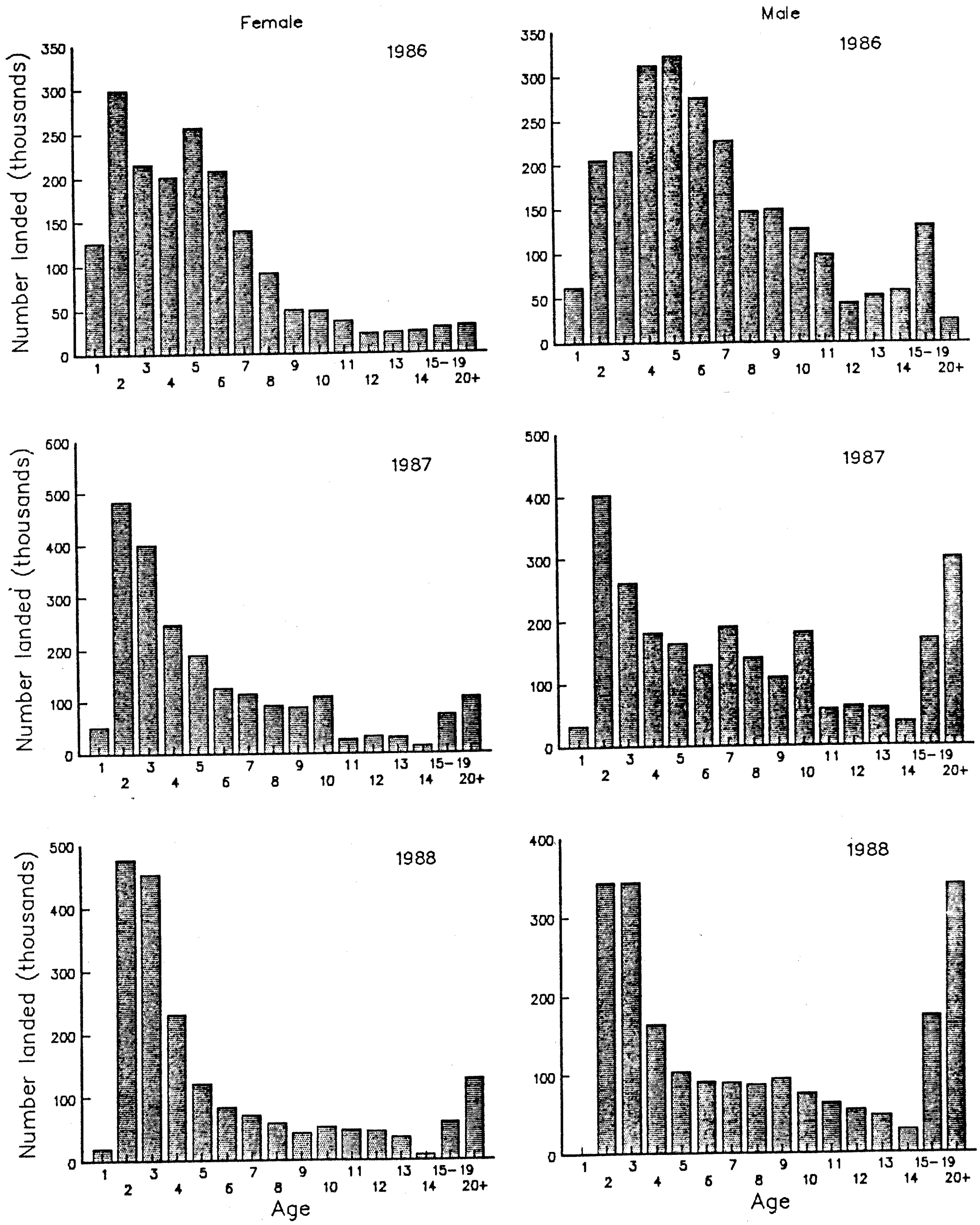

Figure 6. Number of female and male sablefish by age landed by trawl vessels, based 1986-1988 on port sampling.

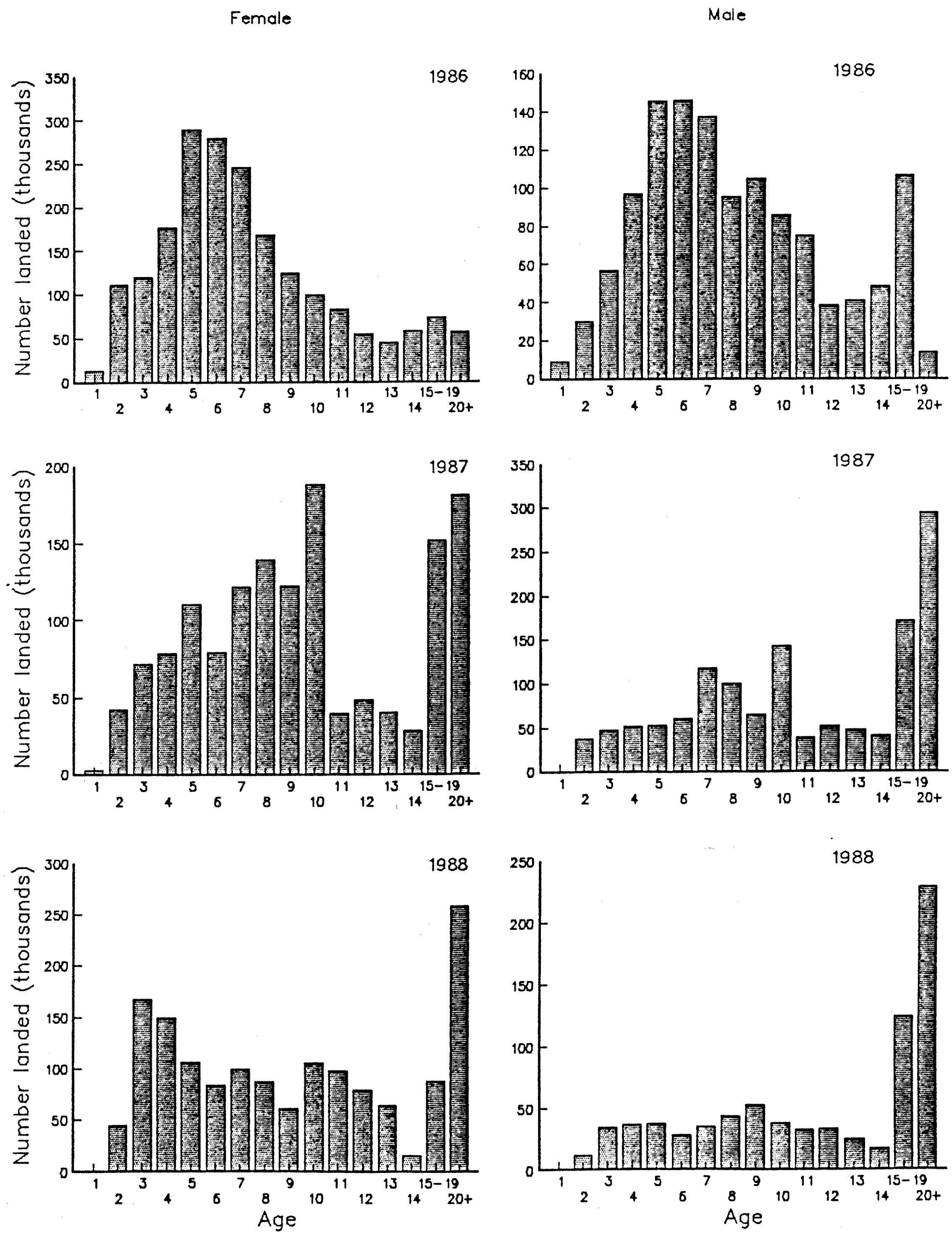

Figure 7. Number of female and male sablefish by age landed by fixed gear vessels, based 1986-1988 on port sampling.

SABLEFISH AGEING CALIBRATION

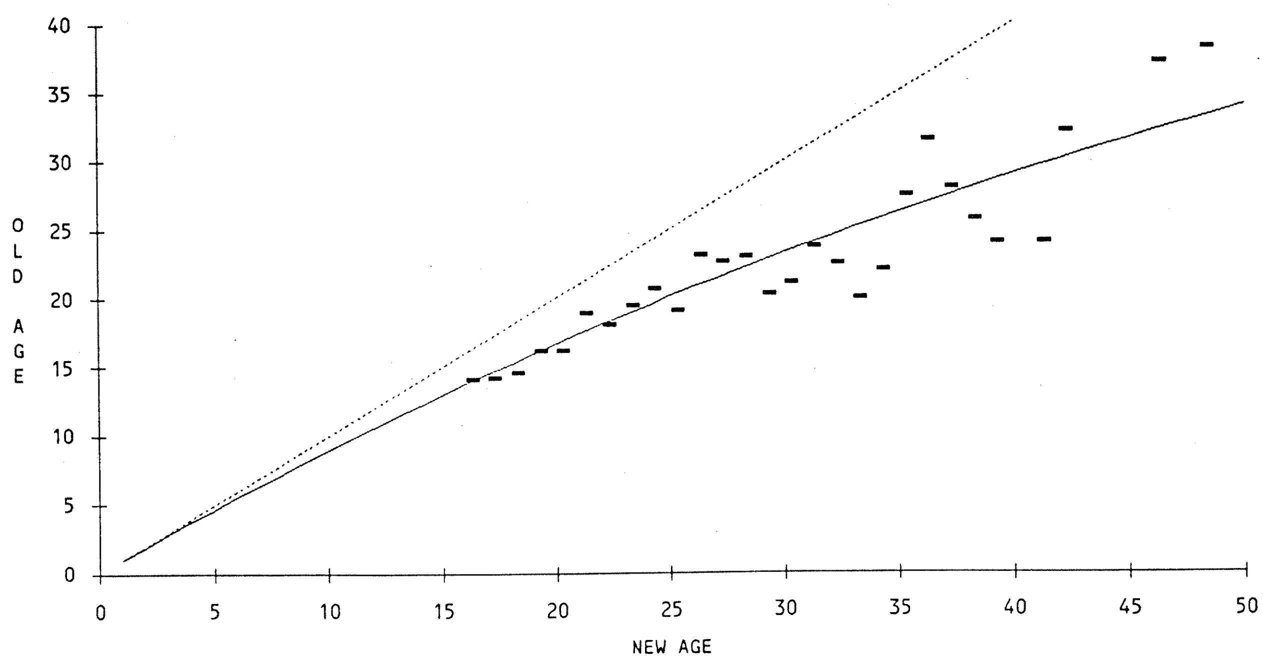

Figure 8. Relationship between old and new age criteria for reading broken and burned sections of sablefish otoliths. Data are from the 1986 southern pot survey (C. Kastelle, Alaska Fisheries Science Center, Seattle, WA). No otoliths with old age less than 10 were re-read by the new criteria.

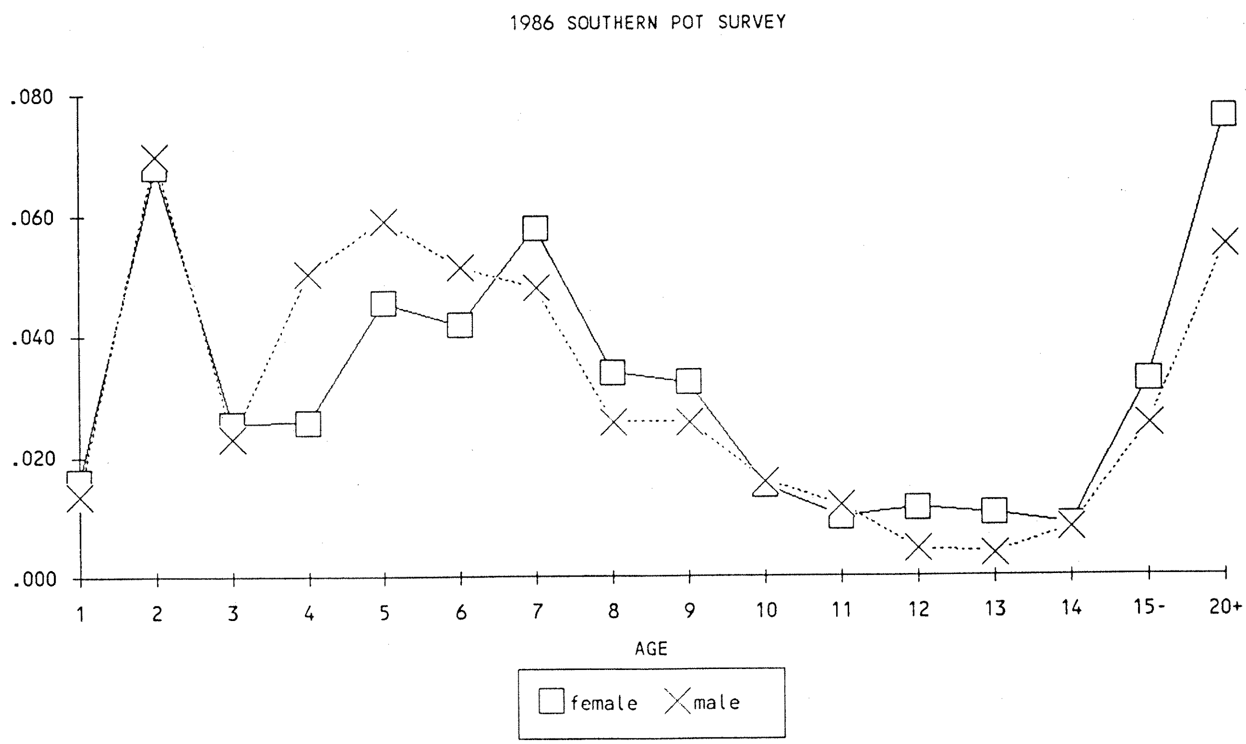

Figure 9. Age composition from the pot survey conducted off California in 1986.

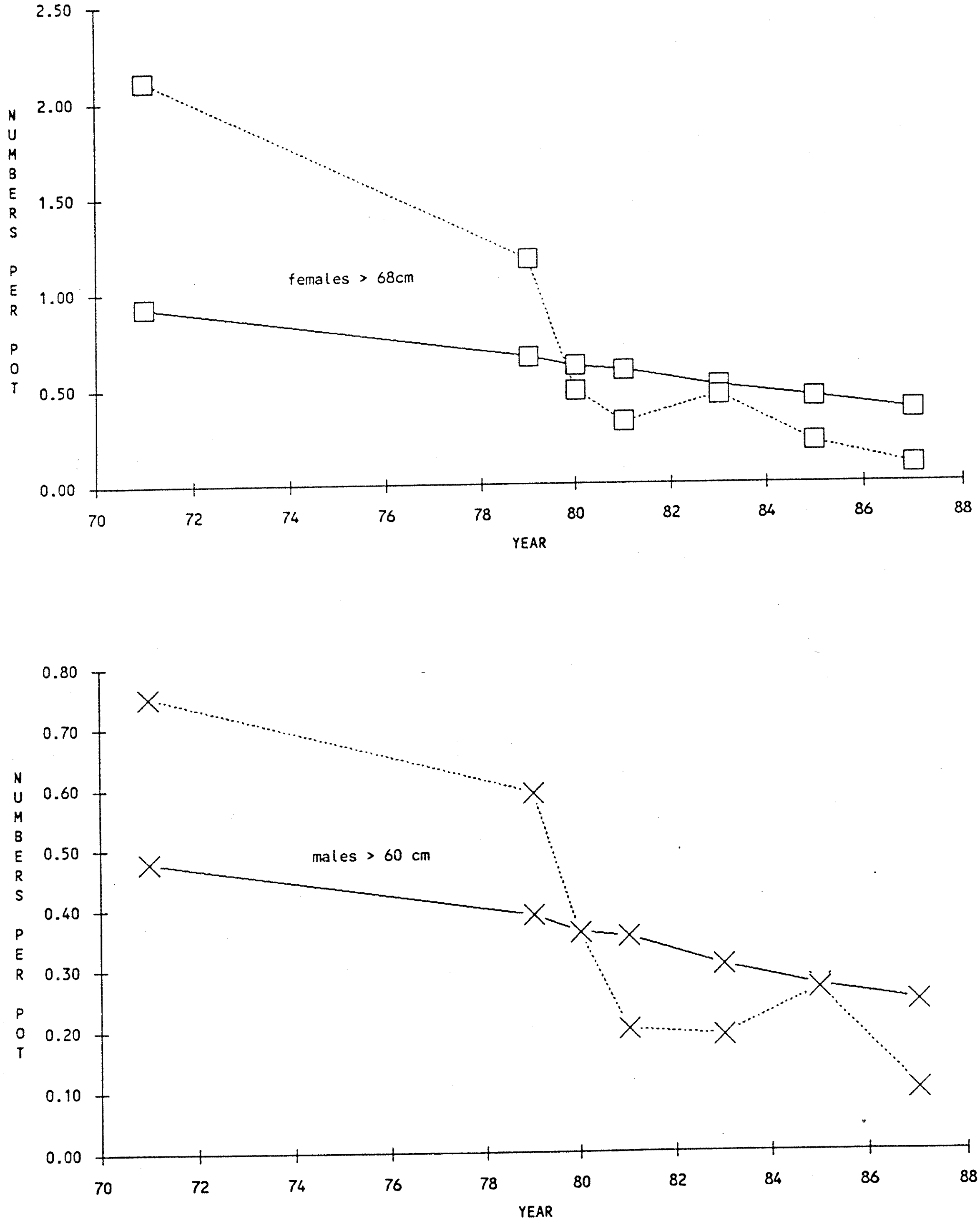

Figure 10. Trend in the abundance of large sablefish (dotted line) in the pot survey conducted off Oregon and Washington (Parks and Shaw, 1988). Large females (upper panel) are defined as those greater than 68 cm fork length, and large males (lower panel) are greater than 60 cm. Values are in mean numbers per pot. The model (solid line) underestimates the magnitude of the decline, especially for females).

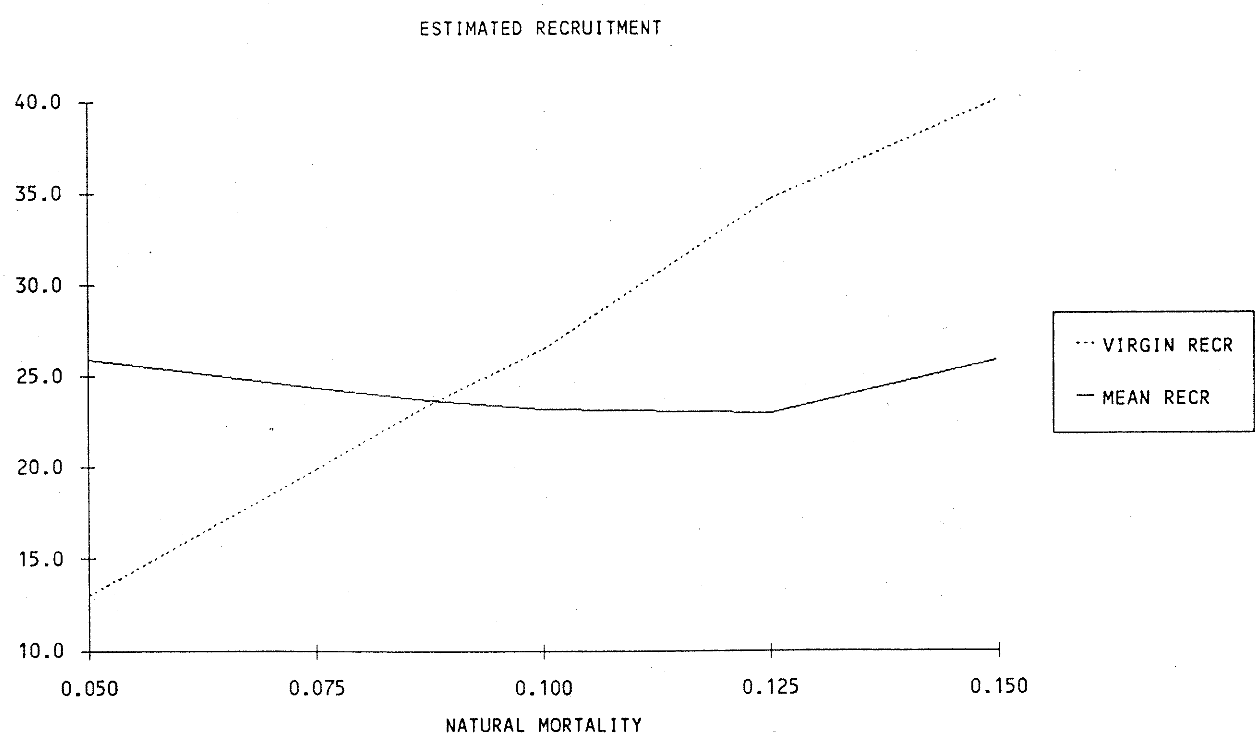

Figure 11. Relation between the assumed level of natural mortality and the estimate of virgin recruitment (dotted line) and the mean of the estimated recruitments for the 1970-1986 year classes (solid line).

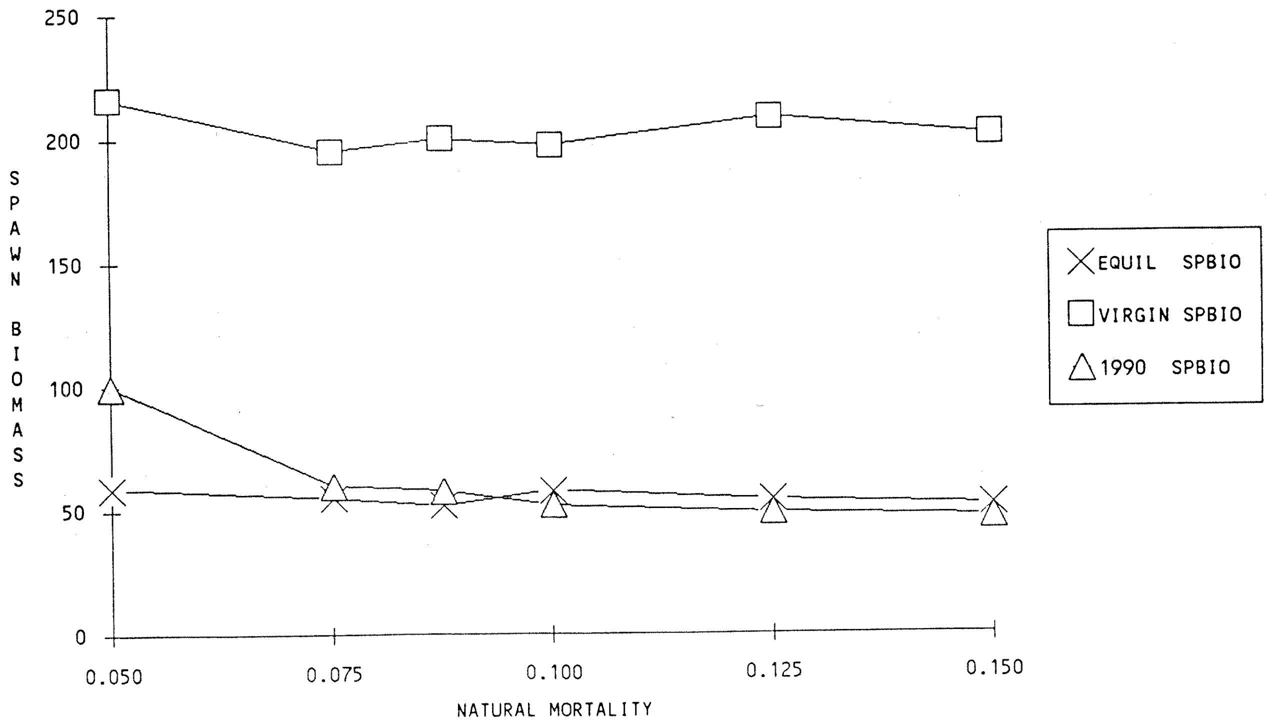

Figure 12. Relation between the assumed level of natural mortality and spawning biomass. The equilibrium spawning biomass is calculated assuming a 10% reduction in recruitment at a 50% reduction in spawning biomass.

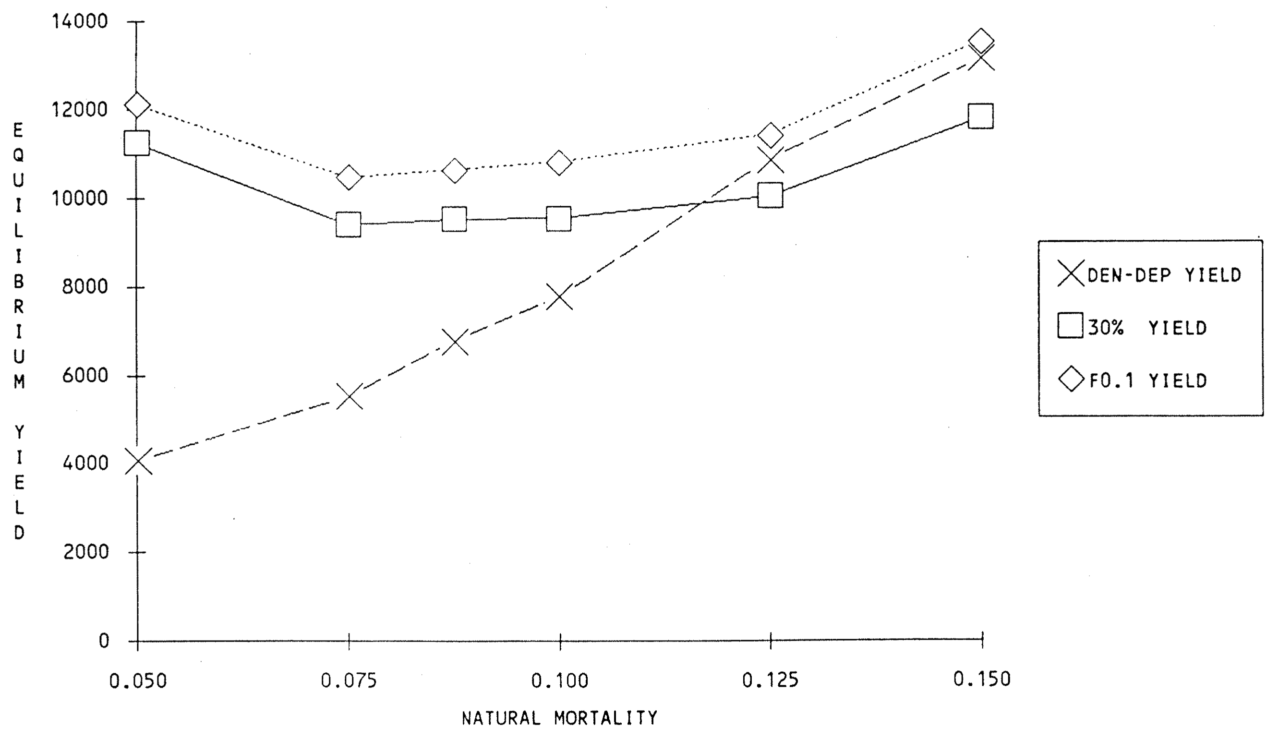

Figure 13. Relation between the assumed level of natural mortality and estimated equilibrium yield. The density-dependent yield is the maximum long-term yield with an assumed 10% reduction in recruitment at a 50% reduction in spawning biomass. The other two scenarios assume constant recruitment and apply fishing mortality rates which will reduce spawning biomass to 30% of its unfished level (30%), or which will produce marginal yields equal to 10% of the initial slope of the yield curve ($F_{0.1}$). A 10% trawl discard is assumed to occur in addition to the landed yield.

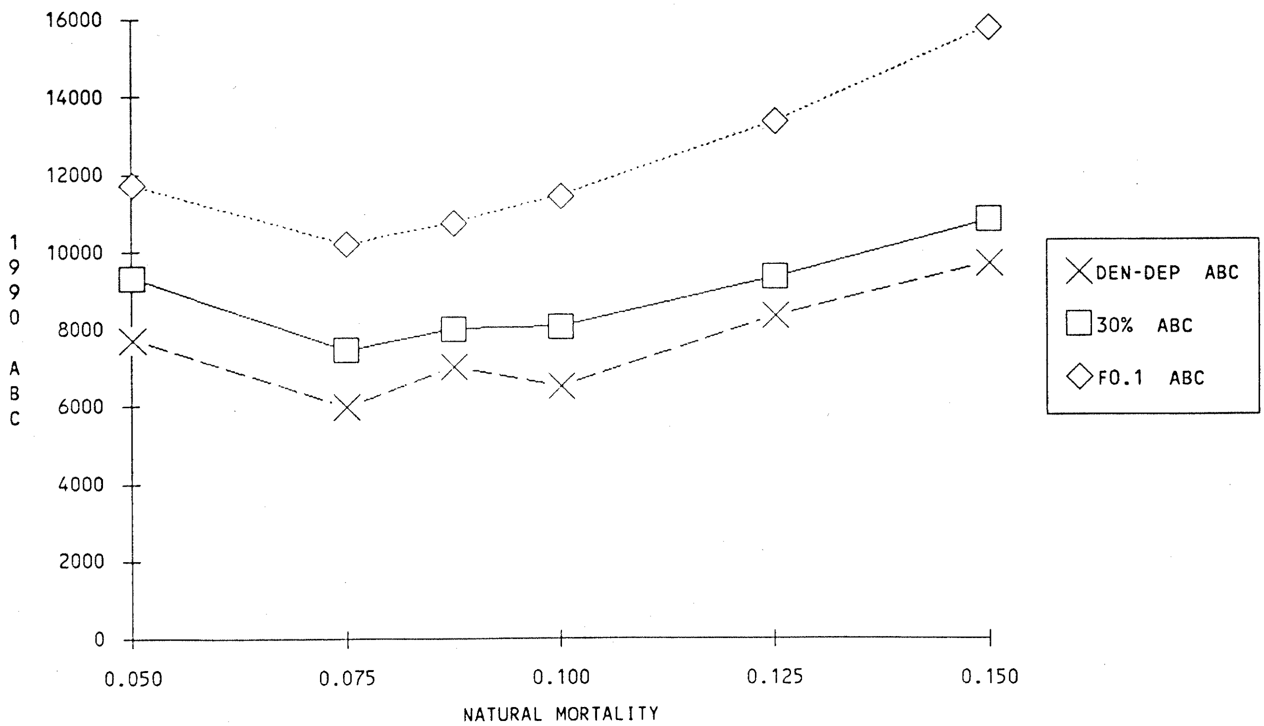

Figure 13. Relation between the assumed level of natural mortality and the level of acceptable biological catch (ABC) in 1990. A 10% trawl discard is assumed to occur in addition to the level of ABC. Definitions are as in Figure 12.

STATUS OF THE PACIFIC COAST GROUNDFISH FISHERY THROUGH 1989 AND RECOMMENDED ACCEPTABLE BIOLOGICAL CATCHES FOR 1990

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October 1989