

RESULTS OF VIRTUAL POPULATION ANALYSIS OF
ENGLISH SOLE IN THE INPFC COLUMBIA-VANCOUVER AREAS
FINAL REPORT

BY

JAMES T. GOLDEN^{1/}

ROBERT L. DEMORY^{1/}

ELLEN K. PIKITCH^{2/}

and

WILLIAM H. BARSS^{1/}

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^{1/} Oregon Department of Fish and Wildlife, Marine Region

^{2/} Oregon State University

ABSTRACT

Virtual population analysis (VPA) and survey estimates of female English sole abundance were used to reconstruct the stock biomass history from 1966-1985, in the INPFC Columbia and Vancouver areas. Average biomass over the 20 year period ranged from 5,702 to 6,780 mt for VPA estimates and averaged 10,951 mt for survey based estimates. For 1985 both methods produced estimates of biomass ranging from 3,030 to 5,634 mt.

Reduced abundance in recent years was attributed to the lack of strong recruitment. VPA estimates of age 5 recruits suggest that recruitment has been below average for the past three years.

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RESULTS OF VIRTUAL POPULATION ANALYSIS OF ENGLISH SOLE
IN THE INPFC COLUMBIA-VANCOUVER AREAS

INTRODUCTION

This report presents results of virtual population analysis (VPA) and survey base-based biomass estimates for stocks of English sole in the INPFC Columbia and Vancouver areas. The analysis presented is an update of a previous report by Demory (1984) submitted to the Groundfish Management Team of the Pacific Fishery Management Council. The previous report did not include VPA estimates because of known bias in the original catch-at-age estimates. Significant trends in mean length and weight at age had been detected which were responsible for the bias. The VPA results reported herein used new estimates of catch-at-age adjusted for these trends.

To facilitate comparisons of VPA and survey results the analysis was limited to the INPFC Columbia area and PMFC area 3B within the INPFC Vancouver area.

METHODS

Catch, Effort and Catch in Numbers at Age

Landed catch of English sole from 1966-1985 taken from the INPFC Vancouver and Columbia areas and PMFC area 3B were summarized from the PMFC data series, Agency TSC reports, and PacFin data series. Catch per unit effort (CPUE) data in metric tons per hour (mt/h) in the INPFC Vancouver area were based on Washington Department of Fisheries haul records of effort from any trip which had English sole landed, while INPFC Columbia area CPUE was based on effort in significant trips from Oregon trawl records. Significant trip effort is defined as the effort for a trip for which English sole comprises greater than or equal to 30% of the total catch. Tagging data suggested that English sole stocks are contiguous in the INPFC Columbia area and in PMFC area 3B (Demory, unpublished). In addition, biomass of English sole during 1973-76 in INPFC Columbia area and PMFC areas could be estimated from available data. For these reasons, and in order to compare VPA with the survey estimates, catches from the INPFC Columbia area and PMFC areas were combined for subsequent analysis.

Analysis of covariance of Vancouver and Columbia CPUE vs time was performed to examine the data for trends. Measures of effort in both statistical areas were different and required standardization. Since the analysis of trends revealed no difference in slopes between the two areas (i.e. change in CPUE with time), the Columbia area CPUE using the Oregon method of calculating significant effort was used to estimate effort in the INPFC Columbia area and PMFC area 3B. Effort was estimated by dividing the combined area landed catch by the Columbia area significant CPUE.

More than 90% of the landed catch of English sole is comprised of females, therefore VPA was confined to analysis of females. Market sample data were used to estimate landed weight of female English sole in the following manner:

$$W_j = P_j \times W_j$$

W_j = estimated landed catch of females in year j in kg
 P_j = proportion of females in market samples in year j
 W_j = estimated total landed catch of English sole in year j
in kg

Female English sole interopercles were used to determine age. Each annual landing in weight was converted to numbers landed by age group using the following relationship:

$$C'_{ij} = (P_{ij} \times W_{fj}) / w_{ij}$$

where: numbers of female English sole of age i landed in year j ,
uncorrected for discard

where: $P_{ij} = (n_{ij} \times w_{ij}) / \text{sum}(n_{ij} \times w_{ij})$
= the proportion by weight of female fish of age i landed in
year j

W_j = weight of females in kg landed in year j based on market
samples

w_{ij} = average weight (kg) of females age i in year j

n_{ij} = frequency of female English sole age i in year j in
market samples

The number of fish landed was also adjusted to account for fish discarded at sea because of small size. A length-specific retention rate was derived from regression analysis presented in Ten Eyck and Demory (1975). This rate is:

$$R_l = 1.307 + 0.065 L$$

where: R_l = the proportion of fish length l caught that are landed.

L = length in cm

Since mean length at age changes with time, discard rates were applied to numbers of fish by length category, within each age group for each year where:

$$C_{ij} = \text{sum}(Q_{lij} \times C'_{ij}) / R_l$$

C_{ij} = numbers of female English sole of age i landed in year j

(i.e. corrected for discard) and

Q_{lij} = proportion of fish of age i landed in year j that are length l .

In 1976 no market samples were collected. To derive catch at age for this year, market sample data from 1975 and 1977 were averaged and the procedures above were used to estimate C_{ij} .

Virtual Population Analysis

Virtual population analysis (VPA) was conducted on the catch-at-age data using Gulland's method as described by Pope (1972) and implemented by Tagart (1982), using two different methods. Initially, a starting value of F for a single brood year in the most recent fishing year was used to solve for all other brood years. This version of the model, described below, was called the linked VPA model. Using information from the linked VPA model, starting F values for each brood year were used in the second mode which we called the fixed F VPA model. The results of the fixed- F version of the VPA model were used in all subsequent calculations of stock biomass. The method used to initiate the first model was nearly identical to that described in Demory et al. (1984) with a few exceptions. The natural instantaneous mortality rate, M , was assumed constant for all ages and years and set equal to 0.26 (Anon. 1982)

Estimates of instantaneous rates of fishing mortality (F_{ij}) and population size (N_{ij}) were made using a single initial starting F value in 1983 for a pair of adjacent, fully recruited brood years. The method linking VPA equations by equating F for these adjacent yearclasses in each fishing year was described by Lenarz (1979). Comparisons of vulnerability ratios (ratio of average exploitation rate at age to exploitation rate at age of full recruitment) were made to an idealized vulnerability curve to select the final linkage. After selecting final linked-ages for the model, starting F values of 0.25, 0.50, and 0.75 were used to produce estimates of F_{ij} and N_{ij} .

Average catchability for each of the linked runs using the different starting values of F was estimated as follows:

$$q = \text{Sum}(F_j) / \text{Sum}(f_j)$$

where: q = average catchability

F_j = instantaneous fishing mortality rate for fully recruited fish in year j and

f_j = fishing effort in year j.

Starting F values for the fixed F version of the VPA model were developed using the formula,

$$F_{ij} = q \times f_j$$

where i = a fully recruited age in each year j with the exception of the first and last fishing year, age 9 was used for establishing starting F values in the fixed model. Additional starting F values were fixed for ages 10-13 in the first fishing year, and for ages 3-8 in the last fishing year.

To test the assumption that catchabilities were without trend, q_j 's were regressed against time j and tests of significance were made for regression slopes not equal to 0.

Once estimates of F_{ij} were made using the fixed-F version of the VPA model, biomass of female English sole was estimated from 1976-1983 using the following formula:

$$B_j = \text{Sum } (N_{ij} \times W_{ij} \times V_i/a_j)/1000$$

where: B_j = English sole biomass in year j in metric tons

N_{ij} = VPA derived population numbers at age i in year j

W_{ij} = mean weight in kg at age i in year j

V_i = average ratio of the exploitation rate at age i to exploitation rate at age K where K equals the age of full recruitment

i = age for ages 3 to 13

a_j = ratio of the catch in weight of ages 3 to 13 to the catch in weight of all ages, corrected for discard.

Area Swept Estimates of Biomass

Estimates of biomass used were those reported by Demory et al. (1976) and Barss et al. (1977) from surveys conducted during 1973-76. Results from the 1973-74 survey off Oregon were added to the mean of the 1975-76 surveys off Washington. Survey tows in the Vancouver Area were limited to PMFC area 3B. The few tows in PMFC Area 3C ($n=6$) did not contain any English sole; thus it was not possible to estimate biomass in PMFC Area 3C. Coefficients of variation of the original survey ranged from 21 to 30% of the mean biomass estimates.

Survey data from 1971-72 (off Oregon) were not used because a gear change occurred between the 1971-72 and 1973-74 surveys. Gear type, configuration, and rigging were therefore consistent for the 1973-76 surveys.

Although survey catch composition was comprised of nearly equal amounts of males and females, estimates of biomass were limited to females. Only 5 percent of the landed catch was composed of males because of their relatively

small size. Males would only be of concern for stock assessment and management if a decision was made to reduce mesh size and/or the processing sector chooses to utilize smaller fish than are currently being utilized.

The survey estimates of biomass overestimated the biomass available to the commercial fishery because the survey trawl cod end mesh size was 3.5 inch and not 4.5 inch. Some adjustment was necessary because some fish which would be caught by the survey trawl would not be caught by a commercial trawl. Adjustment was accomplished by first determining a cumulative length-weight frequency from survey data (females only) and from samples of landing that had been corrected for discard.

Secondly, the respective cumulative length-weight frequencies were graphed and the respective area under each curve measured by planimeter. The difference between the measured areas was expressed as a ratio which was used to reduce the biomass. The computed ratio was 0.928, thus the survey estimate of female biomass was reduced by approximately seven percent.

Stock Reconstruction

Since VPA estimates of female biomass of English sole spanned the years 1966-1983 and survey estimates were an average for the 1973-1976 period, we developed a means to reconstruct the biomass based on each method from 1966-1985.

Estimates of average catchability (q) from each of the fixed-F VPA runs (low, midrange, and high starting F's) were used with effort data (f_j) for the years 1984 and 1985 to estimate F_j for these years using the relationship

$$F_j = q \times f_j.$$

Using the catch in weight of female English sole (W_j) corrected for discard and the catch equation, we derive

$$B_j = W_j \div [F_j/(F_j+M)] \times [1 - \exp -(F_j + M)]$$

to estimate biomass for the years 1984 and 1985.

The average catch of female English sole from 1973-1976 (W_s) and the survey estimate of biomass B_s during the same time period was used to calculate a survey based exploitation rate:

$$u_s = W_s/B_s$$

Using iterative substitution (Newton's method), and the catch equation above, the average rate of fishing mortality F_s for the survey period was determined. Using average effort f_s during the same time period, a survey based catchability coefficient was determined

$$q_s = F_s/f_s$$

The biomass history based on the survey catchability was determined by estimating annual instantaneous rate of fishing mortality for each of the years 1966-1985 via the relationship

$$F_j = q_s \times f_j$$

and using the catch equation

$$B_s = W_j \div [F_j/(F_j+ M)] \times [1 - e -(F_j + M)]$$

The biomass reconstructions provided a means of comparing VPA and survey estimates and also a way to generate more recent estimates of biomass. We recognize that they are heavily dependent on the assumptions that catchability is constant and fishing mortality is proportional to fishing effort.

RESULTS

Catch, Effort and Catch in Numbers at Age

The estimated catch including discard of female English sole taken from the INPFC Columbia area and PMFC area 3B averaged 1,331 mt per year and

reached a peak in 1976 of 2,513 mt (Table 1 and Figure 1). Catches declined following 1976 and reached a record low of 627 mt in 1984. However, trawl effort increased gradually over the 20 year catch history peaking in 1983 at 21,100 trawl hours (Figure 2 and Table 1). Catch per unit effort in the INPFC Columbia and Vancouver areas have both demonstrated a declining trend with similar slopes (Figure 3).

Catch per unit effort has increased slightly in 1984 and 1985 after reaching a historical low of 0.04 mt/hr in the Columbia area and 0.02 mt/hr in the Vancouver area. Note that the graphs are plotted for comparison of trends and not magnitudes since two different techniques were used to estimate catch per unit effort in the Columbia and Vancouver areas.

Mean length, and therefore mean weight-at-age, demonstrated a declining trend across nearly all age groups since 1966 (Table 2). This information and the estimated catch of female English sole enabled us to estimate catch at age in numbers required by the VPA model, properly corrected for discard and the effects of the size at age changes observed (Table 3).

Virtual Population Analysis

Estimates of fishing mortality rates and population numbers from 1966-1980 were insensitive to starting F values of 0.25, 0.50, and 0.75 used in 1983 in the linked brood year version of the VPA model. Fishing rates and population numbers during the survey years varied by less than 10% over the range of starting F's (Table 4).

The average ratio of exploitation rate at age to exploitation rate at age of full recruitment was estimated for different linkage combinations and assumed ages of full recruitment. Age 7 was determined to be the best estimate of the age of full recruitment, although age 8 could have been selected

as well (Figure 4, upper panel). Equally fished adjacent brood years for ages 8 and 9 were selected for linking equations used in VPA to solve for F_{ij} and N_{ij} (Figure 4, lower panel). This selection produced ratios of exploitation rate at age to exploitation rate at the age of full recruitment that most closely approximated the idealized vulnerability pattern. In this model, we assume that age specific vulnerability increases with age and remains constant after the age of full recruitment.

We felt that the linked VPA model provided the best approach to providing first estimates of catchability which could then be used to estimate starting F values in each year for the fixed F version of the VPA model. Regressions of q_j and j produced no slopes significantly different from 0, using results from the linked VPA model and starting F 's of 0.25 and 0.50. The slope of q 's $\times j$ for $F = 0.75$ was positive and significantly different than 0 at the 95% confidence level but not at the 99% confidence level ($t = 2.76, 16 \text{ df.}$). We concluded that catchabilities were without significant trends over the range of starting F values in the linked F model. Linked VPA estimates of average catchability ranged from 1.787 to 2.330×10^{-5} . Multiplying average q times fishing effort provided starting F values for each fishing year at age 9 (Table 5) for use in a fixed F version of the model and reduced the dependence on a single starting F value required of the linkage model.

Final estimates of fishing mortality and population numbers using the fixed F version of the model were similar to those derived using the linked F VPA model (Table 4). Fishing mortality rates (F_{ij}) and population numbers (N_{ij}) upon which the biomass estimates and stock reconstruction were based are tabulated in the appendix (Appendix Tables 1 and 2).

Area Swept Estimates of Biomass

The survey estimate of exploitable female biomass during 1973-1976 derived from the area swept method was 15,920 mt (Demory 1984). The coefficient of variation was approximately 26%, and 95% confidence intervals were \pm 8,116 mt. The upper and lower limits of the 95% confidence interval were 24,042 and 7,810 mt respectively.

Stock Reconstruction

Estimated rates of fishing mortality based on low, midrange and high starting F values used in the Fixed F version of the VPA ranged from 0.084 to 0.533 (Table 6). Peak rates of exploitation occurred in 1979 (Figure 5). Average rates of fishing mortality ranged from 0.260 to 0.314. Average catchabilities during 1966-83 ranged from 1.919 to $2.322 \times 10E-5$. Fishing mortality rates based on effort and catchabilities ranged from 0.284 to 0.343 in 1984 and from 0.272 to 0.329 in 1985. Biomass estimates of female English sole from the INPFC Columbia and PMFC area 3B based on VPA from 1966-1983 and exploitation rates in 1984-85 averaged 6,780, 6,111 and 5,782 mt for the low, midrange and high starting F values (Table 7). Biomass has exhibited a downward trend since 1975 with a recent upward turn in 1985 (Figure 6).

Survey stock reconstruction of female English sole using average survey catchability of $8.42 \times 10 E-6$, effort and catch resulted in lower estimates of fishing mortality (Table 6) and higher estimates of biomass (Table 7) compared to those derived from VPA. Trends in biomass were similar which is due to the fact that both methods of stock reconstruction depend on the same effort data (Figure 6). Peak female English sole biomass was estimated to be 19,981 mt in 1966 and averaged 10,951 mt over the 20 year period.

Estimates of biomass based on VPA and survey methodology ranged from 7,458 to 13,232 mt during the period 1973-1976. Coefficients of variation for

the survey were $\pm 26\%$ and VPA biomass estimates fall within the 95% confidence intervals of the survey estimate with the exception of the lowest estimate of biomass. While no rigorous statistical comparisons can be made, the stock reconstruction approach gives two different methods for estimating past and current levels of English sole biomass, both linked to fishing effort. Recent estimates of biomass based on stock reconstruction range from 3,030 to 5,634 mt in 1985.

DISCUSSION

In addition to dependency on assumptions of constant catchability, fishing mortality proportional to effort and constant natural mortality rate of $M = 0.26$, there are other sources of possible bias in stock reconstruction. If the VPA methods more accurately portrayed the biomass then it appears that the survey may have overestimated the biomass. The fact that fishing mortality from 1966-1983 was 0.34 based on the descending limb of the catch curve (age 7-13) supports this notion. VPA estimates of F averaging between 0.260 to 0.314 compare to an average survey based estimate of 0.126. The most likely source of error with the area swept method used in the survey estimates was the assumption that fish were not herded into the trawl. Fish herding would result in more fish being caught than were actually in front of the trawl, the width of which is used in calculating area swept. An underestimate of fishing mortality and an overestimate of biomass would result.

If fish herding were not a problem and the survey methods more accurately described the biomass history, then VPA methods overestimate mortality and underestimate biomass. This could happen if assigned ages underestimated true age. Canadian age readers (Chilton and Beamish, 1982) using sectioned

English sole otoliths found maximum ages and natural mortality rates which compared favorably with our surface-read interopercle bones. While some evidence exists for validity of the VPA estimates, we have no evidence of whether or not fish herding could possibly be biasing the survey based estimates. We tentatively conclude that the VPA estimates of biomass are superior to the survey estimates.

Both methods used to reconstruct the stock history indicate similar trends and in particular a recent decline in biomass. There is little doubt that the current low levels of biomass are, at least in part, the result of declining recruitment over the past several years (Figure 7).

Further research is needed to determine the causes of the observed decline in recruitment. Environmental factors have been shown to influence year class strength for this species by previous investigators (Ketchen 1956; Hayman and Tyler 1980). However, predictions of recruitment for recent years using updated environmental data have not yet been computed; consequently observed trends cannot be compared with predicted trends at this time. In addition, although a relationship between parent stock abundance and recruitment has not been documented for this species, it is plausible that the long-term declines in stock abundance may have contributed to the recent declines in recruitment.

Management of English sole presents a dilemma. Because they are a component of a multispecies trawl fishery, trip limits have little utility if other species caught within the same multispecies aggregations are allowed legal retention. Closing the fishery to all fishing, essentially all of the continental shelf, is probably not a viable option either. For example, during the period of 1980-1983, English sole landings into all Oregon ports

averaged 838 mt along with 10,687 mt of other groundfish species. Stated another way, English sole amounted to just over 7 percent of the landed catch from trips which contained English sole.

An increase in the minimum mesh size, perhaps to 5 inches, may be an alternative management measure but this would be effective only if most trawls were less than 5 inch mesh to begin with.

RECOMMENDATIONS

We recommend two vital areas of further high priority work. The first is to continue with routine age sampling so that effects of the 1982-1983 "El Nino" can be determined. Since this particular El Nino "event" was rare and of considerable magnitude we may be able to document presence and degree of severe environmental stress.

The second area of future work is to investigate the spawner-recruit relationship of English sole. This task is important because recruitment has been on the wane for the past three brood years. Combined with the current low stock levels and declining mean length at age it may be possible to determine whether or not, and at what point, fishing mortality is a critical factor impacting recruitment at low stock levels.

Allowable Biological Catch

Recommendations for allowable biological catch (ABC) of English sole in the INPFC Vancouver and Columbia areas can be approximated using 1985 exploitation rates for female English sole derived from stock reconstruction:

$$B_{85} = C_{85}/u_{85}$$

where: B_{85} = exploitable biomass in mt

C_{85} = the estimated landed catch of male and female English sole from the INPFC Vancouver and Columbia areas

u₈₅ = stock reconstruction based estimates of exploitation
rate in 1985

Landed catch in the INPFC Vancouver and Columbia areas totalled 769 mt, while exploitation rates ranged from 0.211 to 0.249 using VPA stock reconstruction rates of fishing mortality in 1985 and 0.111 using survey based estimates. Biomass, based on the survey exploitation rate, was 6,928 mt in the INPFC Columbia and Vancouver areas.

Using the exploitation rate at $F = M = 0.26$, $u_{ABC} = 0.20$. Thus, ABC_{85} would range between 618 and 1,386 mt. Excluding the survey estimate of biomass, the range of ABC_{85} would be 618 to 729 mt. Since current landings are close to this range, we recommend managing this species with current gear regulations and setting ABC equal to the landings obtainable with current levels of effort.

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Table 1. Total landed catch (mt), effort, landed weight and estimated catch including discard of female English sole from the INPFC Columbia area and PMFC Area 3B, and CPUE index (mt/hr), from 1966 to 1985.

Year	Total weight landed			Proportion Female wt ^{1/}	Landed Weight	Female Catch Ages 3-13	Catch All Ages	CPUE Index ^{2/} mt/hr	Trawl Effort Hr
	Columbia Area	PMFC Area 3B	Combined						
1966	1,491	784	2,275	0.917	2,086	2,233	2,246	0.19	11,974
1967	871	757	1,628	0.932	1,517	1,590	1,594	0.14	11,629
1968	716	1,120	1,836	0.920	1,689	1,781	1,785	0.12	15,300
1969	622	604	1,226	0.980	1,201	1,198	1,201	0.11	11,145
1970	679	269	948	0.891	845	915	918	0.11	8,618
1971	699	144	843	0.905	763	811	811	0.11	7,664
1972	912	287	1,199	0.922	1,105	1,202	1,210	0.13	9,223
1973	938	421	1,359	0.924	1,256	1,398	1,398	0.10	13,590
1974	719	379	1,098	0.956	1,050	1,136	1,152	0.13	8,446
1975	970	493	1,463	0.936	1,369	1,501	1,524	0.10	14,630
1976	1,718	695	2,413	0.928	2,239	2,483	2,513	0.15	16,087
1977	1,029	269	1,298	0.961	1,247	1,400	1,412	0.11	11,800
1978	1,053	480	1,533	0.928	1,423	1,620	1,625	0.11	13,936
1979	1,026	424	1,450	0.950	1,378	1,547	1,554	0.09	16,111
1980	758	281	1,039	0.950	987	1,136	1,146	0.07	14,843
1981	804	113	917	0.954	875	1,033	1,037	0.05	18,340
1982	824	193	1,017	0.942	958	1,158	1,167	0.06	16,950
1983	691	153	844	0.936	790	941	941	0.04	21,100
1984	357	234	591	0.957	566	N/A 617	-627-617	0.04	14,775
1985	532	174	706 ⁷³²	0.963	680	N/A	-653-770	0.05	14,164 ^{14,640}
	<u>639</u>	<u>239</u>	878	0.923	837	837	1121	0.11	711

^{1/} Based on ODFW sample data from PMFC areas 2B-3A

^{2/} Based on logbook records of Oregon vessel landing fish caught in the INPFC Columbia area.

Table 2. Mean weight (kg) at age of female English sole sampled from the INPFC Columbia area, 1966-1983.

WEIGHT AT AGE IN KILOGRAMS											
YEAR	3	4	5	6	7	8	9	10	11	12	13
1966	0.358	0.404	0.435	0.495	0.533	0.582	0.642	0.653	0.686	0.717	0.689
1967	0.368	0.424	0.470	0.506	0.569	0.578	0.711	0.678	0.630	0.693	0.850
1968	0.351	0.388	0.438	0.491	0.535	0.600	0.618	0.694	0.640	0.715	0.634
1969	0.322	0.376	0.427	0.473	0.528	0.558	0.604	0.613	0.635	0.684	0.643
1970	0.341	0.362	0.403	0.452	0.506	0.545	0.574	0.598	0.624	0.661	0.704
1971	0.392	0.427	0.450	0.468	0.507	0.549	0.619	0.612	0.704	0.584	0.747
1972	0.329	0.358	0.399	0.429	0.488	0.547	0.551	0.597	0.621	0.689	0.621
1973	0.323	0.368	0.402	0.454	0.471	0.522	0.603	0.629	0.694	0.658	0.792
1974	0.303	0.355	0.401	0.442	0.480	0.503	0.548	0.564	0.616	0.623	0.587
1975	0.294	0.360	0.389	0.422	0.457	0.475	0.558	0.557	0.575	0.598	0.686
1976	0.281	0.340	0.379	0.427	0.470	0.498	0.553	0.580	0.607	0.626	0.676
1977	0.267	0.320	0.368	0.431	0.482	0.520	0.547	0.603	0.639	0.654	0.665
1978	0.273	0.306	0.347	0.397	0.461	0.505	0.545	0.575	0.606	0.583	0.565
1979	0.296	0.312	0.358	0.403	0.459	0.506	0.568	0.616	0.629	0.754	0.658
1980	0.290	0.323	0.349	0.389	0.429	0.493	0.535	0.606	0.627	0.645	0.645
1981	0.287	0.311	0.331	0.357	0.397	0.446	0.485	0.538	0.572	0.599	0.725
1982	0.244	0.278	0.312	0.350	0.379	0.404	0.447	0.501	0.535	0.588	0.598
1983	0.234	0.300	0.321	0.346	0.377	0.424	0.544	0.498	0.604	0.594	0.622

Table 3. Estimated catch in numbers corrected for discard of female English sole from INPFC Columbia and PMFC area 3B, 1966-1873, used in VPA.

AGE	YEAR									
	1966	1967	1968	1969	1970	1971	1972	1973	1974	
3	238,881	254,086	250,256	821,723	110,596	212,315	99,528	440,698	131,136	
4	1,432,525	544,614	657,503	525,727	398,647	347,611	493,994	760,973	501,427	
5	2,115,194	950,645	663,482	602,414	506,056	542,576	663,215	1,000,435	440,210	
6	553,924	1,119,374	774,405	295,441	376,960	200,919	656,661	489,195	554,697	
7	334,304	188,564	923,097	404,631	206,838	103,286	327,053	384,644	287,718	
8	114,652	137,550	222,000	323,435	166,534	37,052	190,573	147,863	310,321	
9	85,685	30,319	106,918	103,226	169,552	58,376	105,357	79,820	151,828	
10	47,472	35,496	48,836	55,702	67,712	127,630	71,773	27,616	77,899	
11	32,685	16,486	33,339	16,849	24,026	28,336	90,047	17,084	55,302	
12	16,645	8,622	15,528	9,773	9,339	27,317	25,702	16,304	31,444	
13	12,324	3,984	12,129	6,943	5,952	8,878	12,417	5,476	36,137	
AGE	1975	1976	1977	1978	1979	1980	1981	1982	1983	
3	185,780	380,500	236,048	114,673	55,270	140,820	66,325	77,393	55,778	
4	521,462	1,146,800	733,273	548,604	567,628	498,663	272,183	461,221	234,617	
5	1,001,454	1,574,100	860,876	1,141,555	1,010,806	911,345	604,520	688,942	596,327	
6	812,887	1,066,100	565,890	875,850	979,303	635,794	712,058	651,606	552,069	
7	491,563	798,140	444,634	578,520	606,738	347,388	595,023	483,964	485,024	
8	232,607	430,430	256,089	430,434	267,013	159,832	265,286	518,899	262,694	
9	196,976	257,080	123,973	185,529	168,307	116,689	106,805	204,166	251,201	
10	97,907	155,430	85,529	92,571	85,088	64,520	71,432	75,997	91,444	
11	51,641	95,893	57,163	26,620	37,010	28,349	34,024	38,774	19,757	
12	43,975	66,757	35,833	25,070	12,563	21,570	13,634	24,698	13,966	
13	18,165	24,927	12,479	16,289	5,324	11,052	4,179	15,277	10,216	

Table 4. Virtual population analysis (VPA) weighted annual fishing mortality rates (ages 3-13) and average population size of fully recruited female English sole (ages 7-13) during 1973-76, from INPFC Columbia area and PMFC area 3B. Linked VPA model uses starting F values of F=0.25, 0.50, and 0.75 in 1983. Ages 8 and 9 assumed to be equally fished (linked). Fixed F VPA model uses average catchability from linked F model and effort to estimating starting F values for each brood year.

	Low F	Mid-range F	High F	Average
	Linked F			
Ave. F 73-76	0.285	0.299	0.304	0.296
Ave. N 73-76 (Millions)	5.70	5.51	5.45	5.55
	Fixed F			
Ave. F	0.234	0.263	0.281	0.259
Ave. N 73-76 (Millions)	6.36	0.560	5.21	5.72

Table 5. Adjusted starting F values by brood year and by fishing year used in the fixed F version of the UPA model, for female English sole from INPFC Columbia and PMFC area 3B. Low, mid-range, and high F refer to $F=.25$, $F=.50$ and $F=.75$ used in linked model to generate catchabilities and starting F values for the fixed F model.

Brood year	Age class	Fishing year	Starting F		
			Low	Mid-range	High
1980	3	1983	0.039	0.046	0.050
1979	4	1983	0.160	0.185	0.201
1978	5	1983	0.297	0.343	0.352
1977	6	1983	0.346	0.403	0.440
1976	7	1983	0.377	0.446	0.491
1975	8	1983	0.377	0.446	0.491
1974	9	1983	0.377	0.446	0.491
1973	9	1982	0.303	0.358	0.394
1972	9	1981	0.328	0.388	0.427
1971	9	1980	0.265	0.314	0.345
1970	9	1979	0.298	0.340	0.375
1969	9	1978	0.249	0.294	0.324
1968	9	1977	0.211	0.249	0.274
1967	9	1976	0.287	0.340	0.374
1966	9	1975	0.261	0.309	0.340
1965	9	1974	0.151	0.178	0.196
1964	9	1973	0.242	0.287	0.316
1963	9	1972	0.165	0.195	0.215
1962	9	1971	0.137	0.162	0.178
1961	9	1970	0.154	0.182	0.200
1960	9	1969	0.199	0.235	0.259
1959	9	1968	0.273	0.323	0.356
1958	9	1967	0.208	0.246	0.271
1957	9	1966	0.214	0.253	0.279
1956	10	1966	0.214	0.253	0.279
1955	11	1966	0.214	0.253	0.279
1954	12	1966	0.214	0.253	0.279
1953	13	1966	0.214	0.253	0.279

Table 6. Estimated trawl effort (F), catchability ($q \times 10^5$), and annual rate of fishing mortality (F) of Female English sole from the INPFC Columbia and PMFC area 3B, 1966-1985, using fixed F model.

Year	Effort (hr)	UPA Estimated F						Survey
		Low F	q	Mid-range F	q	High F	q	($q \times F$) F
1966	11,974	0.301	2.514	0.335	2.798	0.355	2.965	0.113
1967	11,629	0.145	1.247	0.162	1.393	0.172	1.479	0.110
1968	15,300	0.313	2.045	0.352	2.301	0.376	2.458	0.144
1969	11,145	0.299	2.683	0.337	3.024	0.360	3.230	0.105
1970	8,618	0.166	1.925	0.225	2.611	0.206	2.390	0.081
1971	7,664	0.115	1.501	0.129	1.683	0.138	1.801	0.072
1972	9,223	0.167	1.811	0.192	2.082	0.207	2.244	0.087
1973	13,590	0.172	1.256	0.194	1.429	0.207	1.523	0.128
1974	8,446	0.153	1.812	0.174	2.060	0.187	2.214	0.080
1975	14,630	0.248	1.695	0.276	1.887	0.294	2.010	0.138
1976	16,087	0.364	2.263	0.409	2.542	0.436	2.710	0.152
1977	11,800	0.223	1.890	0.249	2.110	0.265	2.246	0.111
1978	13,936	0.360	2.583	0.402	2.885	0.427	3.064	0.132
1979	16,111	0.461	2.861	0.512	3.178	0.543	3.370	0.152
1980	14,843	0.191	1.287	0.216	1.455	0.231	1.556	0.140
1981	18,340	0.247	1.347	0.275	1.489	0.291	1.587	0.173
1982	16,950	0.357	2.106	0.408	2.407	0.440	2.596	0.160
1983	21,100	0.352	1.668	0.423	2.005	0.471	2.232	0.199
1984	14,775	0.284	1.920	0.323	2.186	0.343	2.321	0.139
* 1985	14,164	0.272	1.920	0.309	2.182	0.329	2.323	0.134

* Estimates of fishing mortality in 1984 and 1985 under UPA column headings were derived from average catchability and fishing effort.

Table 7. Estimated female biomass from the INPFC Columbia area and PMFC area 3B, 1966-1985. Estimates derived from fixed F UPA model, survey and stock reconstruction.

	Biomass in mt			
	UPA			Survey
	Low F	Mid-range F	High F	
1966	8,216	7,546	7,211	19,871
1967	7,917	7,168	6,861	14,517
1968	7,153	6,478	6,140	12,357
1969	6,400	5,709	5,364	11,407
1970	6,564	5,820	5,447	11,286
1971	7,783	6,934	6,512	11,204
1972	8,011	7,181	6,768	13,895
1973	8,539	7,683	7,255	10,895
1974	8,761	7,934	7,519	14,452
1975	8,742	7,981	7,599	11,035
1976	8,525	7,817	7,460	16,547
1977	7,591	6,900	6,558	12,678
1978	7,412	6,747	6,415	12,350
1979	7,269	6,585	6,243	10,219
1980	6,549	5,895	5,569	8,181
1981	5,619	5,023	4,726	5,988
1982	4,602	4,054	3,780	7,293
1983	3,511	2,998	2,742	4,724
* 1984	2,866	2,565	2,433	4,495
* 1985	3,572	3,195	3,030	5,634

* Biomass under UPA column headings estimated using effort, average catchability and catch in 1984-1985. Survey estimates based on average catchability during 1973-1976, effort and catch during 1966-1985.

FEMALE ENGLISH SOLE CATCH
IN INPFC COLUMBIA AND PMFC AREA 3B

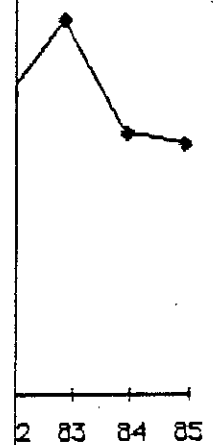
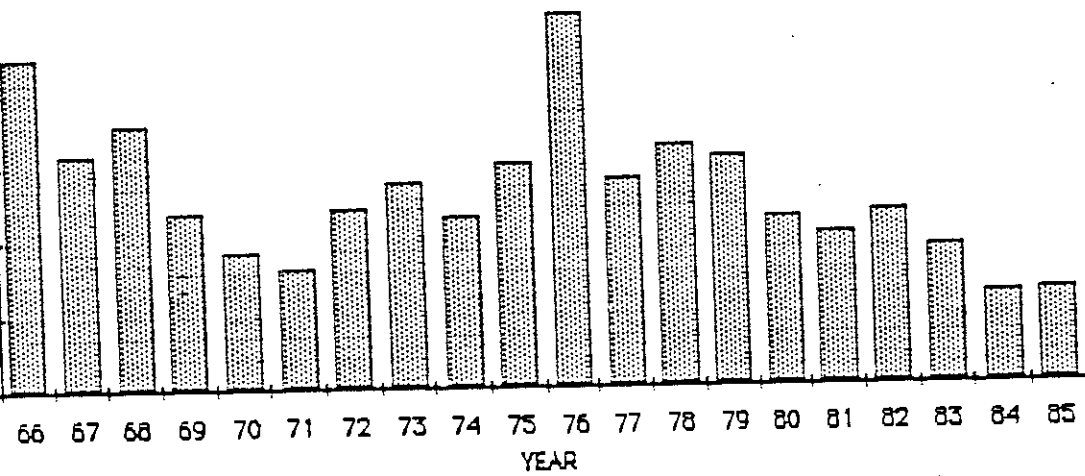


Figure 1. Estimated catch including discard in mt of female English sole from INPFC Columbia and PMFC area 3B, 1966-1985.

INPFC
1985.
CPUE in mt/hr)
based on hauls

ENGLISH SOLE CATCH PER UNIT EFFORT
IN INPFC VANCOUVER AND COLUMBIA AREAS

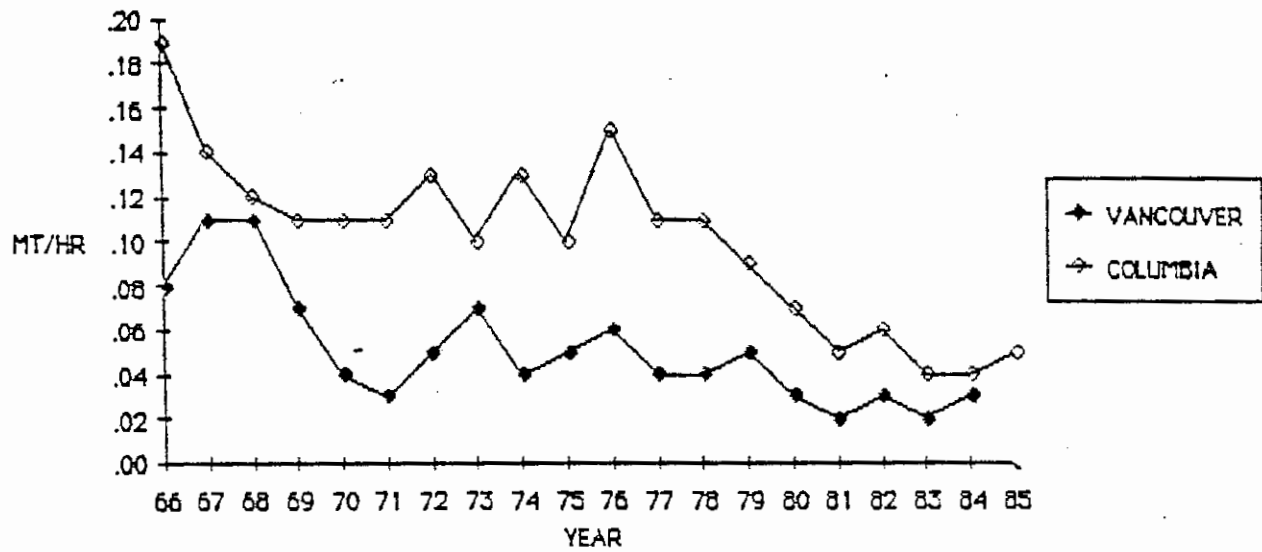


Figure 3. Estimated catch per unit effort (CPUE) in mt/hr for English sole in the INPFC Vancouver and Columbia areas, 1966-1985.

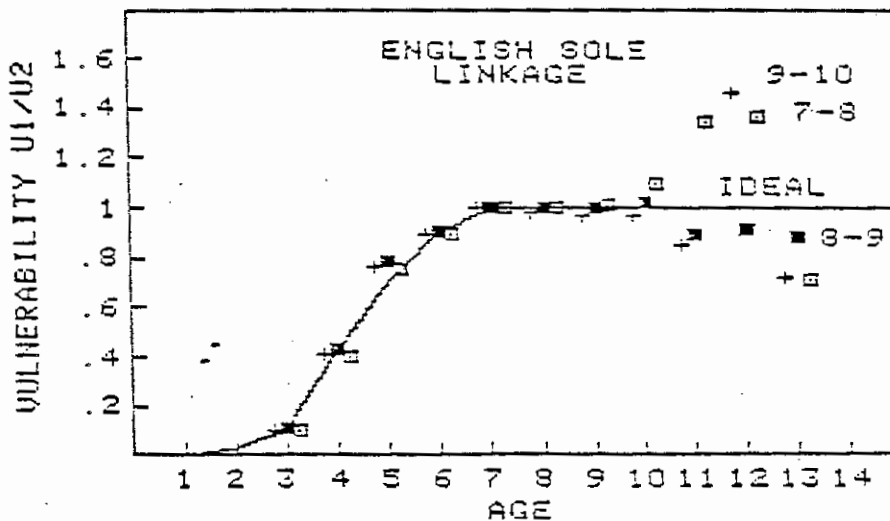
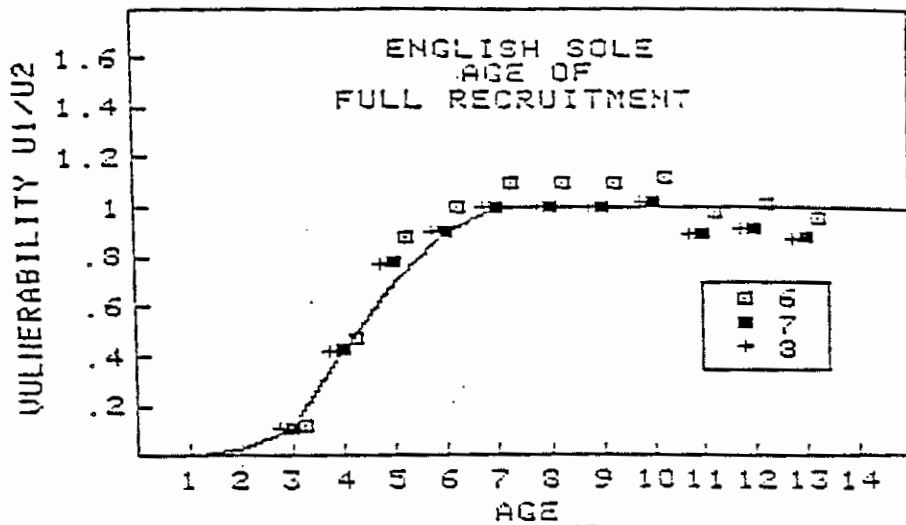


Figure 4. **Upper panel:** English sole vulnerability (u_1/u_2) or average ratio of exploitation rate at age (i_1) to exploitation rate at age of full recruitment (u_2) estimated from virtual population analysis derived rates of fishing mortality. Age of recruitment varied from age 6 to 8 while linkage was held constant with ages 8 and 9 assumed equally fished.

Lower panel: English sole vulnerability (u_1/u_2) with age of recruitment held constant at age 7 with linkage between assumed equally fished age groups of 7-8, 8-9, and 9-10.

FISHING MORTALITY RATE OF
 FEMALE ENGLISH SOLE AGE 3-13
 IN INPFC COLUMBIA AND PMFC AREA 38

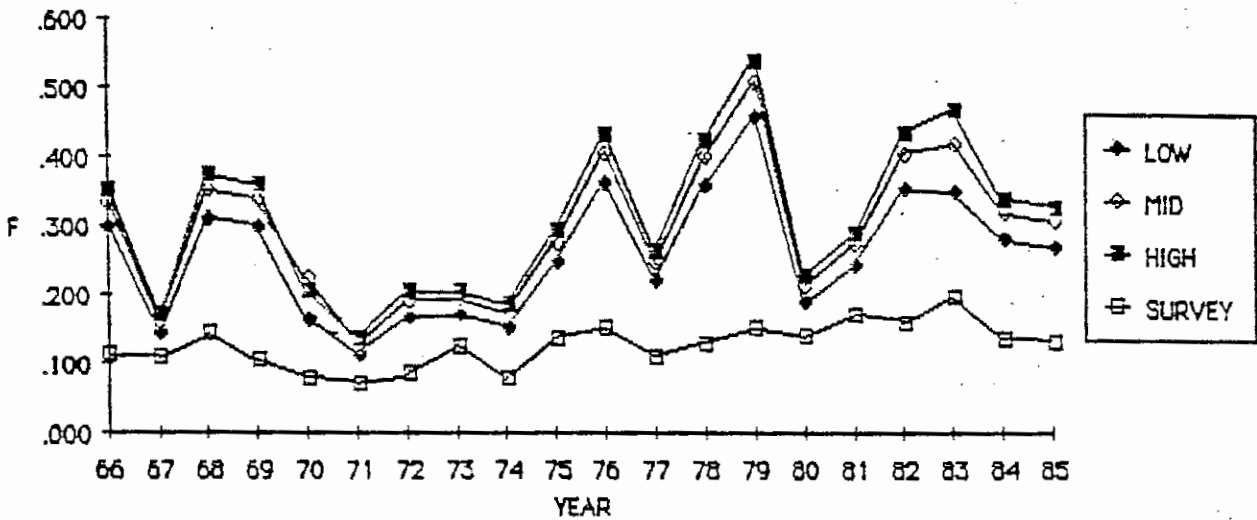


Figure 5. Instantaneous rates of fishing mortality (F) for female English sole ages 3-13 in the INPFC Columbia and PMFC area 38, 1966-1985. Low, mid and high refer to range of starting F values used in the fixed F version of VPA. F in 1984-1985 based on VPA catchabilities and effort. Survey derived F's from 1966-1985 were based on average catchability during 1973-1976 and annual effort from 1966-1985.

FEMALE ENGLISH SOLE BIOMASS
IN INPFC COLUMBIA AND PMFC AREA 3B

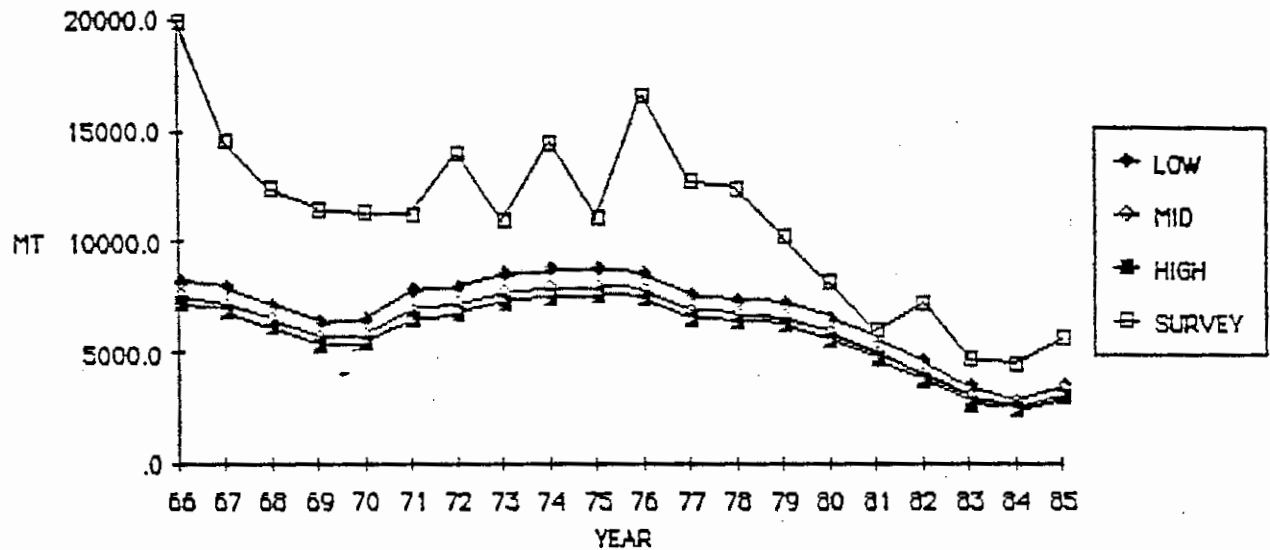


Figure 6. Stock reconstruction estimates of biomass of female English sole in the INPFC Columbia and PMFC area 3B, 1966-1985. Low, mid and high refer to the range of starting F values used in the fixed F version of VPA. Biomass estimates in 1984-1985 based on VPA average catchabilities from 1966-1983, catch and effort in 1984-1985. Survey based biomass estimates use average catchability from 1973-1976, annual effort and catch from 1966-1985.

NUMBER OF 5 YEAR OLD
ENGLISH SOLE IN INPFC COLUMBIA
AND PMFC AREA 3B

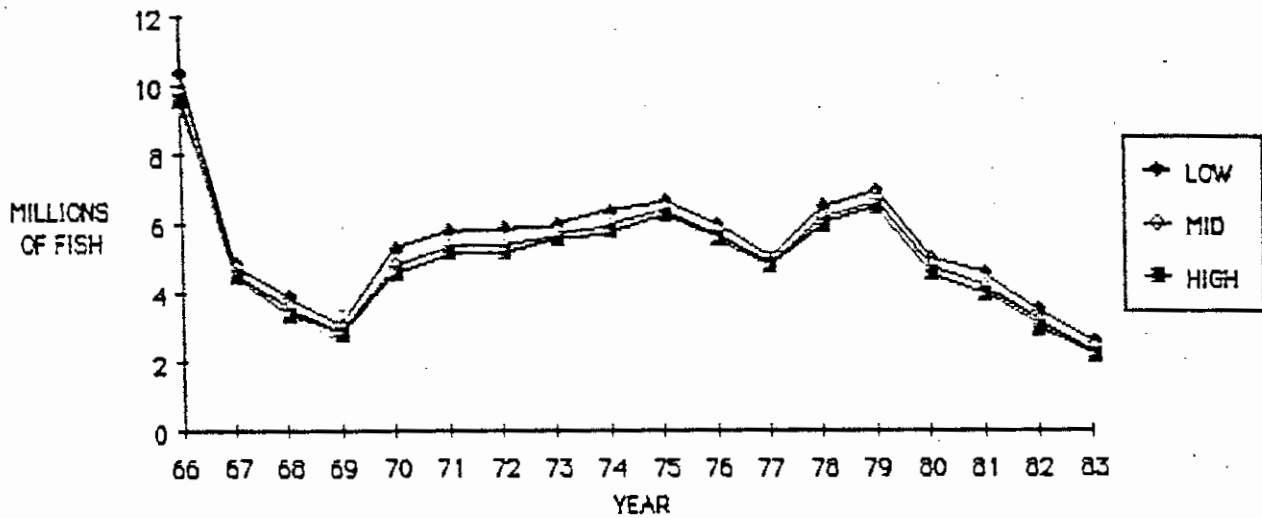


Figure 7. VPA estimated numbers of 5-year-old female English sole in INPFC, Columbia and PMFC area 3B, 1966-1983. Low, mid and high refer to the range of starting F values used in the fixed F version of VPA.

Appendix 1. Instantaneous fishing mortality rate, F , of female English sole of ages 3-13. Estimates of F were derived from virtual population analysis of INPFC Columbia and PMFC area 3B English sole catch at age data from 1966-1983, using the fixed F model.

Low Starting F

AGE	FINAL F VALUES CATCH YEAR														
	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0363	.0457	.0288	.0330	.0119	.0220	.0095	.0436	.0137	.0207	.0352	.0210	.0139	.0074	.0024
4	.2294	.1154	.1705	.0828	.0586	.0542	.0694	.0993	.0630	.0738	.1632	.0934	.0660	.0929	.0913
5	.2616	.2504	.2143	.2492	.1139	.1116	.1366	.2084	.0815	.1841	.3553	.2155	.2193	.1777	.2266
6	.2597	.2296	.3569	.1488	.2606	.0642	.2065	.1508	.1921	.1960	.3206	.2206	.3807	.3193	.1727
7	.3067	.1406	.3225	.3437	.1573	.1123	.1506	.1916	.1325	.2607	.3753	.2335	.3952	.3369	.1905
8	.4354	.2128	.2613	.1906	.2474	.0405	.3328	.1003	.2490	.1609	.4112	.2106	.3993	.3437	.2798
9	.2140	.2080	.2730	.1990	.1540	.1370	.1650	.2420	.1510	.2410	.2870	.2110	.2490	.2280	.2650
10	.2140	.1373	.6516	.2387	.2072	.1775	.2659	.0631	.4228	.1468	.3693	.1546	.2582	.1347	.1818
11	.2140	.1138	.1974	.5314	.1636	.1338	.1956	.0991	.1844	.6002	.2237	.2396	.0702	.1664	.0919
12	.2140	.0853	.1593	.0869	.6971	.3012	.1842	.0522	.2843	.0000	.0000	.1264	.1673	.0656	.1472
13	.2140	.5771	.1770	.1057	.0743	.0000	.2346	.0577	.1667	.2832	.2159	.0000	.0852	.0518	.0547

AGE

AGE	81	82	83
1	.0000	.0000	.0000
2	.0000	.0000	.0000
3	.0147	.0371	.0395
4	.0652	.1434	.1601
5	.1627	.2490	.2569
6	.3010	.2329	.3456
7	.2594	.3698	.3770
8	.2329	.4064	.3770
9	.3280	.3030	.3770
10	.2757	.4422	.2298
11	.1463	.2531	.2081
12	.0620	.1611	.1444
13	.0408	.0975	.0983

Mid-Range Starting F

AGE	FINAL F VALUES CATCH YEAR														
	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0391	.0479	.0314	.0325	.0129	.0230	.0100	.0423	.0147	.0212	.0369	.0219	.0146	.0081	.0027
4	.2337	.1249	.1793	.0908	.0625	.0585	.0727	.1050	.0657	.0765	.1877	.0981	.0691	.0089	.0591
5	.2783	.2635	.2355	.2654	.1261	.1197	.1487	.2201	.0866	.1931	.3703	.2235	.2330	.1873	.2429
6	.2829	.2486	.3826	.1669	.2828	.0719	.2244	.1664	.1947	.2105	.3468	.2344	.4001	.1873	.2429
7	.3385	.1561	.3585	.3798	.1799	.1240	.1708	.2121	.1485	.2935	.4135	.2536	.4296	.5815	.1833
8	.4906	.2422	.2976	.2190	.2835	.0471	.3773	.1158	.2831	.1838	.4135	.2536	.4296	.5815	.1833
9	.2530	.2460	.3230	.2350	.1820	.1620	.1950	.2870	.1780	.3090	.3400	.2400	.4486	.3886	.3159
10	.2530	.1690	.8569	.2350	.2350	.2168	.3277	.0762	.5412	.1731	.4692	.2400	.4486	.3886	.3159
11	.2530	.1399	.8569	.9315	.2163	.1720	.2502	.1281	.2291	.9492	.2838	.3362	.3199	.2280	.2253
12	.2530	.1033	.2011	.1158	.1019	.4382	.2491	.0694	.3915	.3094	.0000	.1731	.2588	.0593	.2040
13	.2530	.0938	.2224	.1385	.1019	.0000	.3923	.0817	.2301	.4448	.3027	.0000	.1184	.0853	.0722

AGE

AGE	81	82	83
1	.0000	.0000	.0000
2	.0000	.0000	.0000
3	.0164	.0422	.0459
4	.0717	.1607	.1846
5	.1786	.2783	.3429
6	.3259	.3183	.4029
7	.2805	.4140	.4460
8	.2640	.4540	.4460
9	.3880	.3580	.4460
10	.3464	.5722	.2873
11	.1900	.3446	.3026
12	.0811	.2193	.2134
13	.0587	.1308	.1408

High Starting F

AGE	FINAL F VALUES CATCH YEAR														
	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0437	.0490	.0323	.0336	.0134	.0236	.0103	.0432	.0144	.0215	.0372	.0224	.0143	.0084	.0023
4	.2436	.1305	.1841	.0956	.0646	.0609	.0746	.1082	.0672	.0779	.1906	.1007	.0703	.1015	.1033
5	.2873	.2705	.2481	.2742	.1335	.1242	.1554	.2265	.0895	.1081	.3788	.2278	.2402	.1025	.2507
6	.2964	.2592	.3967	.1779	.2952	.1266	.2144	.1753	.2017	.2187	.3537	.2417	.4105	.3593	.1900
7	.3572	.1655	.3796	.4006	.1942	.1308	.1834	.2240	.1578	.2966	.4359	.2655	.4686	.0966	.2224
8	.5242	.2605	.3204	.2364	.3055	.0513	.4040	.1258	.3037	.1976	.4959	.2581	.4789	.4149	.3376
9	.2790	.2710	.3560	.2590	.2000	.1780	.2150	.3160	.1960	.3400	.3740	.2740	.3240	.3750	.3450
10	.2790	.1900	.9233	.5413	.2892	.2435	.3702	.0853	.6237	.2000	.5421	.2179	.3640	.2591	.2571
11	.2790	.1568	.2937	.5570	.2584	.2015	.2904	.1496	.2615	.5557	.3292	.4202	.1033	.2595	.1371
12	.2790	.1169	.2322	.1396	.0000	.5664	.3039	.0828	.4813	.3681	.0000	.2093	.3537	.6695	.2534
13	.2790	.1055	.2559	.1647	.1258	.0000	.5958	.1037	.2835	.6205	.3959	.0000	.1481	.1251	.0856

AGE

AGE	81	82	83
1	.0000	.0000	.0000
2	.0000	.0000	.0000
3	.0174	.0455	.0501
4	.0755	.1713	.2005
5	.1878	.2959	.3723
6	.3400	.3396	.4397
7	.2924	.4404	.4910
8	.2829	.4823	.4910
9	.4270	.3940	.4910
10	.3958	.6714	.3287
11	.2240	.4131	.3911
12	.0962	.2694	.2778
13	.0756	.1585	.1812

Appendix 2. Virtual population analysis estimated population size numbers of female English sole in INPFC Columbia area and PFMC area 3B.

AGE	Low Starting F									
	POP SIZE IN NOS CATCH YEAR									
	66	67	68	69	70	71	72	73	74	75
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	7606601	644044	10007574	10608619	10568526	11080809	11648616	12569454	10927315	10312232
5	7898032	5656075	4743900	7497470	7933272	8052157	8358055	9125869	9306149	8310872
6	10375732	4841629	3885964	3084466	5321419	5769675	6012586	6012586	4371615	6737597
7	2734445	1615857	2906144	2418297	1853622	3661489	3978312	3955533	3763939	4528535
8	1427985	1626233	3774353	1568225	1606758	1101330	2647511	2495053	2622961	2418985
9	365444	810254	1089481	2107932	857491	1358570	758062	1755922	1588401	1771534
10	502760	182319	504991	646946	1343279	516265	783797	4195221	1224714	954802
11	278544	312972	114173	296350	408752	887909	347103	512423	253944	811970
12	191780	173396	210363	458888	179978	256200	573295	205147	370956	1282904
13	97665	119385	119313	133147	20796	117828	172803	363525	143252	237854
14	72312	69797	94524	78453	94122	0	67088	110824	266036	83123

AGE	POP SIZE IN NOS CATCH YEAR									
	76	77	78	79	80	81	82	83		
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	12487104	12984372	9438202	8458105	6498886	5145446	2409162	1630226	1789875	1789875
5	7788662	6295275	9728536	7177114	6473243	4837792	3909347	350745	2511700	2511700
6	5952233	5005299	6528269	7022251	5037933	4585621	399767	339745	222164	222164
7	4321612	3231643	3111251	4040313	4532821	309767	2985143	176367	173460	173460
8	2870143	2405248	1902369	1639444	2263670	2940641	176367	173460	939470	939470
9	1437151	1519795	1468350	1034714	738908	1442603	1749277	881199	898373	898373
10	1162974	734547	949286	750777	565743	430687	239220	501841	118536	118536
11	567082	672994	458635	570612	438826	334666	195860	187822	117258	117258
12	540612	302229	444494	273147	365763	292109	195860	117258	123270	123270
13	145086	333273	225779	119563	235353	118675	186437	123270		

AGE	Mid-Range Starting F									
	POP SIZE IN NOS CATCH YEAR									
	66	67	68	69	70	71	72	73	74	75
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	7075565	6160486	9184803	9985153	9817615	10595853	11332979	12085757	10554431	10038878
5	7621764	4246631	4523745	6863083	7452557	7473167	7984138	8651181	8933208	8023361
6	9829833	4628863	3570360	2918140	4832354	5398049	5434593	5724303	6005690	640062
7	2537718	5738274	2742323	2175203	1725559	3284511	3692622	3611486	3541882	4246430
8	1312587	1474632	3450680	1442280	1419429	1092743	2356871	2274901	2357327	2247898
9	332239	721474	972644	1853982	760653	914217	682969	1531948	1418870	1567188
10	432941	156872	436613	556909	1151499	441710	672498	361084	1052062	824688
11	239862	259201	94579	243727	339476	740125	289645	426665	209895	694373
12	165148	143605	168923	309556	139464	202843	459441	160927	304839	93773
13	84102	98873	96351	101229	9404	86610	131684	275820	109165	189921
14	62270	50352	68712	60760	69517	0	43089	79150	198424	56903

AGE	POP SIZE IN NOS CATCH YEAR									
	76	77	78	79	80	81	82	83		
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	11928733	12331631	8992618	7826312	5945332	4636530	2123719	1406742	1569781	1569781
5	7577893	4886475	9302347	6833547	5986104	4460930	3516948	3209729	2309729	2309729
6	5730574	4488237	6096383	69733670	4773042	4190331	3201684	2695763	1869118	1869118
7	4100380	3305212	2986167	3794694	4279650	2886794	2695763	2274901	1511911	1511911
8	2652824	2234249	1861104	1543313	2067040	2745567	1606737	1599099	818865	818865
9	1305443	6352785	1337131	933870	665289	1291123	1599099	764554	783041	783041
10	1005513	633407	820652	658289	488206	374024	764554	195848	412111	412111
11	466619	551837	380739	471585	361277	274991	195848	149951	85123	85123
12	438083	225055	351136	213193	289477	222367	149951	141786	881916	881916
13	105875	294331	123985	24715	152128	198432	141090	87800		

AGE	High Starting F									
	POP SIZE IN NOS CATCH YEAR									
	66	67	68	69	70	71	72	73	74	75
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	6803934	6022384	8762348	9676393	9448594	10350145	11017771	11835940	10373301	9902546
5	7485564	5037197	4421567	6537356	7214493	7188634	7794683	8408139	8740594	7883700
6	3559491	4523977	3408932	2836098	4581248	5214505	5245220	5578245	5818338	6301561
7	2436880	5530183	2461574	2050891	1662399	3090966	3351145	3442422	3229330	4101996
8	1254257	1397020	3290454	1380221	1323639	954131	2207655	2166029	2227552	2161227
9	315550	676616	912835	1735800	712968	840414	645500	1416972	1334940	1486790
10	397282	144037	402072	510888	1056624	403004	615504	322296	963437	759688
11	220106	233174	84696	217159	304037	6670330	241359	382829	186793	610640
12	151545	128395	147770	23478	119024	175563	403144	139174	271044	76811
13	77175	88401	84629	84945	0	70873	110664	232490	92400	160897
14	57141	45019	60639	51730	56965	0	31016	62965	165011	44028

AGE	POP SIZE IN NOS CATCH YEAR									
	76	77	78	79	80	81	82	83		
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	11648090	12055543	8770064	7510917	5664543	4375323	1976081	1291336	1455960	1455960
5	7472776	8648371	9089472	6661948	5742919	4244481	3315546	2154091	2154091	2154091
6	5982903	4761886	6029573	6529550	4640765	3992614	3034771	2551321	1740548	1740548
7	3985672	2968442	2923788	3656230	4153203	2784930	2551321	2274901	1400797	1400797
8	2541569	2146870	1797361	1495385	1968250	2648143	1528381	1524113	756684	756684
9	1238736	1269332	1269393	384924	628604	1215032	1524113	705975	725403	725403
10	928162	588225	754851	66209	450597	345809	705975	173571	367080	367080
11	416926	492358	341332	420953	321300	246059	173571	127738	68545	68545
12	385474	196947	305316	182884	250486	191581	127738	118070	64322	64322
13	85858	213848	94691	212102	108787	168399	118070	117931	69537	69537

h and Wildlife

G. NO. 3, NEWPORT, OREGON 97365

completion report which has biomass estimates of
sole in the INPFC Columbia and PMFC area 3B using
tion spanning 1966-1985. I chose to use a different
estimating biomass of English sole in the paper you
er method includes some assumptions about recruitment,
biomass in 1984-1985 (Table 7) will be different than
ou here.

es of biomass that you desire from 1984-1986 are included
enclosed. Please feel free to call me if you have questions.



Golden
Wildlife Biologist

ures

Robinson
Demory
Lenarz

Table 3a. Estimated yield, spawning biomass (B_S) and exploitable biomass (B_E) in metric tons of female English sole (Parophrys vetulus) in the INPFC Columbia area and PMFC area 3B, 1984-1986.

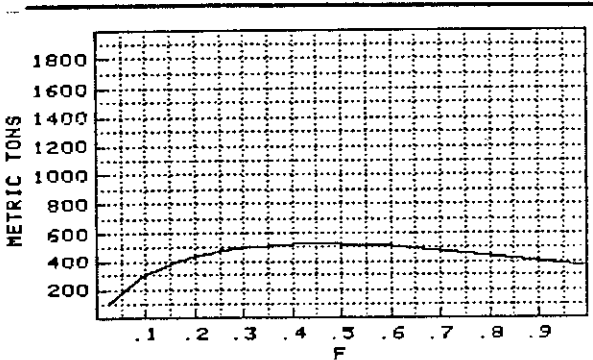
Year	Low Recruitment					Average Recruitment			
	Historical ^{1/} Yield	F	Estimated ^{2/} Yield	B_S	B_E	F	Estimated ^{2/} Yield	B_S	B_E
1984	627	0.31	624	2,234	2,536	0.29	625	2,278	2,702
1985	653	0.40	651	1,739	2,122	0.29	653	2,178	2,821
1986	626	0.39	620	1,495	2,042	0.22	618	2,328	2,364

^{1/} Historical yield from Table 1 of Golden, J.T., R.L. Demory, E.K. Pikitch, and W.H. Barss, 1986. Results of virtual population analysis of English sole in the INPFC Columbia and Vancouver areas, Final Report NMFS Commercial Fisheries Research and Development Act Contract No. 85-ABC-001001, Proj. No. 1-180-122, 32p. Yield in 1986 is projected catch.

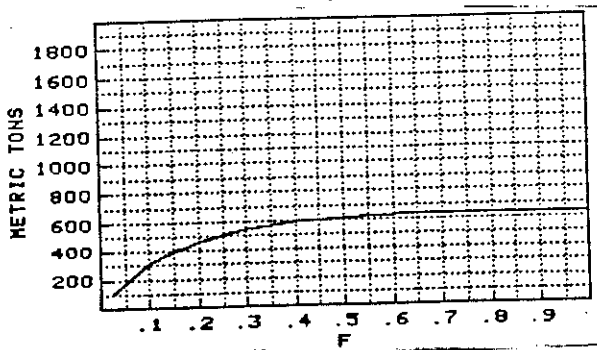
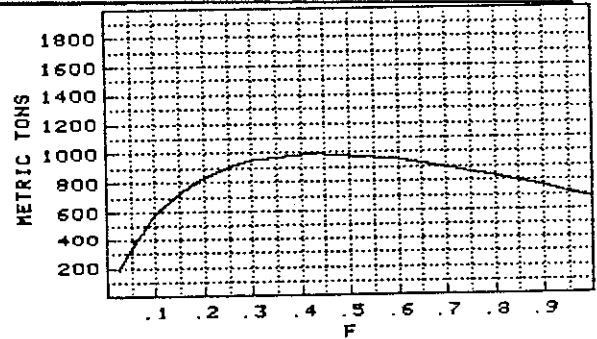
^{2/} Trial values of F were adjusted until estimated yields matched or nearly matched historical catches.

Table 2. Equilibrium (EY) or maximum sustainable yields (MSY) and biomass (B_{ey} or B_{msy}) sustainable yield in metric tons for female English sole (Parophrys vetulus) in the INPFC Columbia area and PMFC Area 3B.

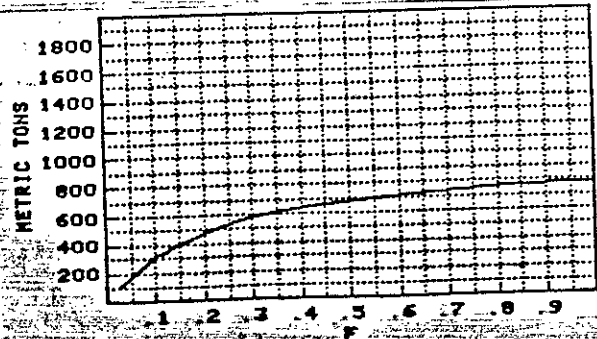
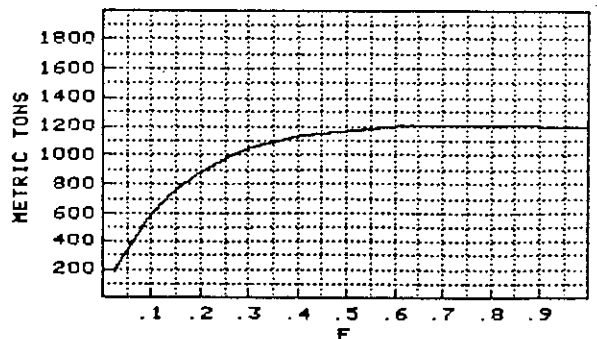
		R(0.5)/(RC1.0)								
		0.90			0.95			0.99		
Recruitment		Low	Mid	High	Low	Mid	High	Low	Mid	High
F=M	E _y	482	910	2,050	520	982	2,214	543	1,026	2,312
	B _{ay}	2,400	4,534	10,218	2,592	4,896	11,032	2,706	5,112	11,520
	F	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
F0.1	E _y	505	954	2,150	603	1,147	2,556	686	1,297	2,922
	B _{ay}	2,132	4,026	9,073	1,964	3,593	8,362	1,886	4,437	8,029
	F	0.30	0.30	0.30	0.40	0.43	0.40	0.50	0.50	0.50
F _{max}	MSY	524	990	2,232	642	1,213	2,733	789	1,491	3,360
	B _{msy}	1,709	3,228	7,274	1,152	2,176	4,904	1,178	2,225	5,014
	F	0.40	0.40	0.40	0.80	0.80	0.80	>1.0	>1.0	>1.0



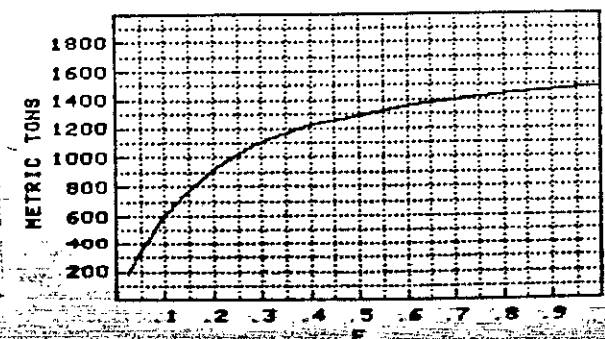
R_{0.5}/R_{1.0}
0.90



0.95



0.99



LOW RECRUITMENT

AVERAGE RECRUITMENT

FEMALE ENGLISH SOLE

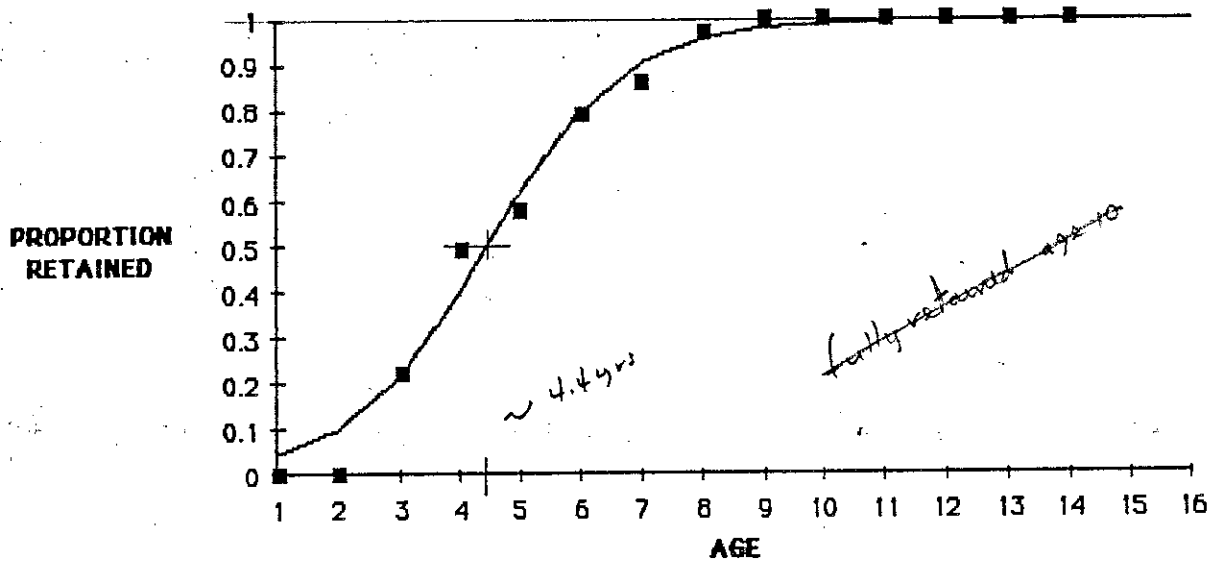


Table — Age specific retention (proportion) of female English sole from at sea sampling in 1986.

Female

Age	Number discarded	Number retained	Prop. retained
1	0.7	0	0
2	4.2	0	0
3	10.0	2.8	0.22
4	8.2	7.9	0.49
5	6.7	9.5	0.59
6	2.1	7.9	0.79 ← 1.79
7	0.9	5.6	0.86
8	0.1	4.8	0.98
9	0	1.6	1.00
10	0	0.9	1.00
11	0	1.3	1.00
12	0	1.8	1.00
13	0	0.7	1.00
14	0	0.2	1.00

Table —. Age specific retention (proportion) of female English sole from at sea sampling in 1986.

Female

Age	Number discarded	Number retained	Prop. retained
1	0.7	0	0
2	4.2	0	0
3	10.0	2.8	0.22
4	8.2	7.9	0.49
5	6.7	9.5	0.59
6	2.1	7.9	0.79 ← .79
7	0.9	5.6	0.86
8	0.1	4.8	0.98
9	0	1.6	1.00
10	0	0.9	1.00
11	0	1.3	1.00
12	0	1.8	1.00
13	0	0.7	1.00
14	0	0.2	1.00

FOR PORT OF AST+GAR+NPT+WB+CB+BOK
 PFIC INTERNATIONAL GROUND FISH STATISTICAL AREAS

	1C	2A	2B	2C	3A	3B	3C	3D	5A
ROCKFISH									
POUNDS	52910.48	105415.90	1897799.65	1302360.65	1681969.91	418985.41	.00	.00	.00
KILOGM	24000.04	47816.34	860836.27	590746.92	762936.55	190050.54	.00	.00	.00
HOURS	97.21	428.97	3523.56	2297.00	3260.96	1158.40	.00	.00	.00
CPUE LB	544.29	245.74	538.60	566.98	515.79	361.69	.00	.00	.00
CPUE KG	246.89	111.47	244.31	257.18	233.96	164.06	.00	.00	.00
M.TONS	24.00	47.82	860.84	590.75	762.94	190.05	.00	.00	.00
CPMT	.25	.11	.24	.26	.23	.16	.00	.00	.00
P.O.P.									
POUNDS	.00	147672.00	.00	386779.00	880674.00	.00	.00	.00	.00
KILOGM	.00	66983.58	.00	175441.80	399471.11	.00	.00	.00	.00
HOURS	.00	78.55	.00	554.71	2195.52	.00	.00	.00	.00
CPUE LB	.00	1879.97	.00	697.26	401.12	.00	.00	.00	.00
CPUE KG	.00	852.75	.00	316.28	181.95	.00	.00	.00	.00
M.TONS	.00	66.98	.00	175.44	399.47	.00	.00	.00	.00
CPMT	.00	.85	.00	.32	.18	.00	.00	.00	.00
PETRALE									
POUNDS	.00	225194.56	478281.86	387058.43	486477.15	.00	.00	.00	.00
KILOGM	.00	102147.58	216947.23	175568.55	220664.59	.00	.00	.00	.00
HOURS	.00	1031.43	2671.51	2291.64	2457.72	.00	.00	.00	.00
CPUE LB	.00	218.33	179.03	168.90	197.94	.00	.00	.00	.00
CPUE KG	.00	99.03	81.21	76.61	89.78	.00	.00	.00	.00
M.TONS	.00	102.15	216.95	175.57	220.66	.00	.00	.00	.00
CPMT	.00	.10	.08	.08	.09	.00	.00	.00	.00
DOVER									
POUNDS	222856.32	1679638.24	3877785.18	1031336.62	3320623.95	714274.69	.00	.00	.00
KILOGM	101086.96	761878.91	1758951.82	467811.22	1506225.14	323992.87	.00	.00	.00
HOURS	547.70	3705.00	12381.77	3417.79	7223.26	1521.24	.00	.00	.00
CPUE LB	406.89	453.34	313.19	301.76	459.71	469.53	.00	.00	.00
CPUE KG	184.57	205.64	142.06	136.88	208.52	212.98	.00	.00	.00
M.TONS	101.09	761.88	1758.95	467.81	1506.23	323.99	.00	.00	.00
CPMT	.18	.21	.14	.14	.21	.21	.00	.00	.00
ENGLISH									
POUNDS	11892.70	22821.30	190982.32	111997.86	884686.05	32861.77	.00	.00	.00
KILOGM	5394.49	10351.67	86629.01	50801.90	401290.96	14906.00	.00	.00	.00
HOURS	19.41	280.17	848.46	1502.03	2410.91	254.24	.00	.00	.00
CPUE LB	612.71	81.46	225.09	74.56	366.95	129.25	.00	.00	.00
CPUE KG	277.92	36.95	102.10	33.82	166.45	58.63	.00	.00	.00
M.TONS	5.39	10.35	86.63	50.80	401.29	14.91	.00	.00	.00
CPMT	.28	.04	.10	.03	.17	.06	.00	.00	.00