# STATUS OF THE WIDOW ROCKFISH FISHERY

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# INTRODUCTION

This is an update of the report on the Status of the Widow Rockfish fishery prepared by the Groundfish Management Team for the Pacific Fishery Management Council, April, 1983. This report changes considerably the aproach to assessment from the 1983 report. It also adds data from 1983 and revisions or some of the data from previous years.

This report presents a review of the 1983 report, reviews recent events in the fishery, discusses changes in methodology and presents results of the new assessment.

## SUMMARY OF PREVIOUS ASSESSMENT

The 1983 report utilized the methodology of cohort analyses (Murphy, 1965), stock reduction analyses (kimura and Tagart, 1982) and MSY approximations (Gulland, 1970 and Francis, 1974) to estimate MSY and ABC from data collected between 1979 and 1982. The results are summarized in Table 1. The previous report estimated that MSY (10714 mt) is considerably below landings prior to 1982 and about 15% above the estimate of ABC for 1984 (9209 mt).

## RECENT HISTORY OF THE FISHERY

Trends observed in previous assessments have continued. Fishermen often have had difficulties in finding large quantities of fish on most of the grounds. It becomes more difficult to interpret annual changes in landings because regulations had a significant impact on the fishery for the first time in 1983. Trip limits probably lowered landings through August and the fishery was essentialy closed in September when projections indicated that OY would be exceeded. Total 1983 landings were 10,211 mt (OY 10,400 mt). While regulations had an effect on the 1983 fishery, the data suggest that the decline observed in the Columbia area is a continuation of a trend, Figure 1, table 2. Further examination of Columbia area landings in detail, Figure 2, indicate that landings in all of the important grounds except the Newport Deeps peaked out prior to 1982. Landings in the Eureka area have slowly declined since 1980. Landings in 1984 through July indicate the landings in the Vancouver and Monterey areas will continue to decline, landings in the Eureka area will be about the same as 1983 and landings in the Columbia area will be slightly higher than in 1983. Reports by representatives of the industry to the April Council meeting indicated that effort was higher in the first quarter of 1984 than in the first quarter of 1983.

Age composition data continue to indicate juvenation, Table 3 and Figure 3. In 1983, for the first time, landings (in numbers of fish) were dominated by fish less than 7 years old. Widow rockfish are not fully mature until age 9. Landings of individual yearclasses indicated that peak catches have occured for all yearclasses through 1976, Figure 4.

The recent trends in the fishery continue to indicate that the stock(s) have been significantly impacted by the fishery. The trends also indicate that the fishery is close to being a recruitment fishery. Such fisheries are characterized by highly variable landings that are dependent on the strength of incoming yearclasses and because spawning stock is very low there is a great danger of poor recruitment. The data shown in Figures 3 and 4 indicate that the 1969-1971 yearclasses were exceptionaly strong. This suggests that a recruitment fishery may only experience good fishing about once a decade even if recruitment is not impaired by low spawning stock size.

## ASSESSMENT METHODOLOGY

Review of the results of previous assessments and additional experience with the SRA model indicated that several major changes in methodolgy were desirable. Data were analysed by sex previously. The results indicated that information is only increased marginally by seperate analyses by sex. Thus sexes are combined for the present analyses. Previous analyses used semester as the time unit. Now as the volume of the fishery has decreased it is difficult to obtain sufficient data on a semianual basis. This analysis is done on an anual basis. Previous analyses divided the fishery into seven areas and analyzed each area seperately. This assumes that there are seven seperate stocks. While fairly consistent differences in landing trends, Figure 1, and age composition, data presented in previous reports, suggest that there is not a great deal of interchange of fish among the areas, there is also evidence that the assumption of seperate stocks is not completely valid. A biochemical genetic study of several other important species of rockfish suggests that there is one or at the most a few distinct stocks off the three states (Wishard, Utter and Gunderson, 1980). Unpublished tagging studies on several species of rockfish indicate that some interchange of fish among areas is possible. An unpublished analysis of gill raker counts did not indicate any difference between Oregon and California widow rockfish (Lenarz). It would appear that there is at least some exchange of genetic material among the seven areas and that some interchange of fish is not unlikely. Thus it was decided to combine data from all areas for the analyses. The previous analyses assumed that natural mortality (M) is 0.25. Although it was known that the parameter k of the von Bertalanffy growth curve is about 0.15 and that widow rockfish reach an age (45 years in US waters and older in Canadian waters) that is not very consistant with M=0.25, most of the early data came from the Columbia area which never had many old fish present in landings. The fishery expanded into grounds containing older fish. It now appears to be reasonable to estimate that M is 0.15. The low value of M is more consistant with values of M being used for other species of rockfish and flatfish than the high value. Analyses were also made with the high value of M and are discussed in the discussion section.

Changes were also made in some aspects of the analytical methodology. The previous analyses used a combination of cohort analysis, stock reduction analysis (SRA) and MSY approximations (based on Gulland, 1970 and Francis, 1974) to estimate MSY and ABC. The SRA model used assumed constant recruitment even at low levels of spawning stock size. It also assumed knife-edged recruitment and recruitment was an abstract combination of numbers of recruited fish and growth of fish already present in the population. It became obvious that the SRA model was producing unrealistic results for low levels of stock size. Thus a new analytical approach was chosen.

Population estimates are still based on cohort analysis. However a dynamic pool model is used to estimate MSY and ABC. The dynamic pool model utilizes the classical catch equations to generate survival rates and catches (in numbers of fish). This is consistant with the cohort analysis. In addition the model uses the Beverton and Holt (1957) spawn-recruitment relationship to generate recruitment.

A number of assumptions were made to estimate starting values of fishing mortality (F) for cohort analyses. Fish 12 years old and older were assumed to have the same value of F in a given year. This allowed linkage of the 1968 through 1971 yearclasses. Starting values for younger yearclasses were estimated by assuming that in 1983 the ratio of F of ages less than 12 to age 12 was the same as in earlier years: ie, the estimate of F for age 11 fish in 1983 was made by multipling F for age 12 fish by the sum of F for age 11 fish in 1980-1982 and dividing by the sum of F for age 12 fish during 1980-1982. By making these assumptions it was only necessary to make one more assumption to obtain estimates of F for all of the cohorts in the analyses. This was done by considering the effect of the regulations on fishing mortality in 1983. It seems reasonable to assume that since the 1983 fishery essentialy was closed in September that 1983 fishing mortality for 12 year old fish was reduced by at least 25%. The regulations probably also had some effect on fishing effort during the earlier months. It does not seem unreasonable to assume that fishing mortality for 12 year old fish was reduced by as much as 50%. 1983 landings were 61% less than 1982 landings, but the marked trend toward younger fish in 1983 landings indicates that a significant portion of the decrease was due to decreased abundance of older fish, Figures 3 and 4. Few fish less than 4 years old are landed, Figure 3, thus the analyses begin at age 4.

The dynamic pool model requires estimates of several parameters that describe the life history of widow rockfish. Estimates of size in length at age are from Lenarz (ms). The relationship between length and weight and maturity and age are from Barss and Echeverria (ms).

There are insufficient data to estimate parameters of the Beverton and Holt spawn-recruitment model. Consequently simulations were used to choose bounds for the parameters. The Beverton-Holt model can be expressed as

$$R=CP/(1-A(1-P/P(1))$$

where

R=recruitment in numbers of age 4 fish

P=spawning stock size (biomass of mature fish)

P(1)=equilibrium spawning stock size of unfished stock

C=constant

A=constant.

Examination of possible spawn-recruit relationships were made by assuming the R=10000 fish when P=P(1),(R(1)=10000). The P(1) was estimated by calculating the biomass of an unfished stock with R(1)=10000. If P=P(1), then C=R(1)/P(1). Trial estimates of A were made by assuming several values of R ,(R(.5)) when P=0.5P(1), (P(.5)). Manipulation of the recruitment relationship results in

$$A=2(1-.5CP(1)/R(.5)).$$

Since the literature suggests that the ratio of R(.5)/R(1) is close to 1 for marine fish with high fecundity, values of R(.5)/R(1) = 0.999,0.99,0.95 and 0.90 were examined.

Simulations using the dynamic pool model, four values of R(.5), and two estimates of F obtained from the cohort analysis were made to provide estimates of MSY and ABC.

The concept of equilibrium yield for 1985 is complex. The age distribution of the population is not that which would result from equilibrium conditions for two reasons. The population has been subjected to greatly increased fishing mortality during recent years and yearclass strength has been highly variable. In order to estimate equilibrium yield it is assumed that recruitment to the fishery in 1984 and 1985 is equal to recruitment in 1983 and that recruitment in 1986 is equal to that predicted by the spawn-recruitment relationship when R(.5)/R(1)=0.999. The assumptions are based on an examination of 1984 data which did not indicate the presence of exceptional numbers of three and four year old fish. No information is available on fish that would be entering the fishery in 1986. Equilibrium yield is defined as the yield that results in 1985 when application of the same fishing mortality rates in 1986 results in the same yield.

## RESULTS

**The results,** table 4, indicate that fishing mortality **increased sharply** from 1980 to 1981 and increased again in 1982. Eventhough 1983 estimates using low F were less than half of the estimates using a high value of F, estimates for 1980 only varied by about 25%. This is in agreement with the previous assessment that indicated that fishing mortality has been high enough over the history of the fishery to result in convergence of estimates of F for the first year of the fishery. The age of greatest exploitation ranged from 8 years in 1982 to 10 years in 1981. The sum of F by age during the first 3 years indicate that F is about equal between ages 8 and 11. The highest value of the sum is for age 10.

Estimates of population size, table 5, indicate that the population has decreased considerably since 1980. Estimates of recruitment of 4 year old fish indicate that it is highly variable, Figure 5. Size of the 1973 yearclass is about 10% of the 1970 yearclass. The 1972-1976 period produced 5 poor yearclasses in a row. While estimates of yearclass strength since 1977 are very tentative, it appears safe to conclude that the 1977 and 1978 yearclasses are strong compared to the previous five years. Estimates of biomass and spawning stock indicate that biomass has decreased by at least 50% and spawning stock by 70%, table 6.

The spawn-recruit relationships are ploted for 4 values of R(.5)/R(1) in figure 6. The relationship when R(.5)/R(1) =0.9 indicates a stronger relationship between spawning stock and recruitment than is found in the literature for highly fecund fish. The relationship when R(.5)/R(1)=0.999 indicates that there is almosts no effect on recruitment until spawning stock is reduced to extremely low levels. Then a drastic reduction in recruitment occurs. It seems likely that the relationship for widow rockfish, because of their high fecundity, falls somewhere between the two discussed values of R(.5)/R(1).

The dynamic pool model was used to estimate equilibrium yield under fairly wide ranges of parameter values. Estimates of relative age specific F(F at age/F at age 10) were made by dividing F at a given age summed over 1980-1982 by F at age 10. The results of the simulations were insensitive to whether relative F was calculated from the high F cohort analysis or the low F analysis. Only the low F results are presented.

Estimates of equilibrium yield and biomass as functions of F for 10 year old fish and R(.5)/R(1) are shown in figures 7 and 8. Maximum yield would occur if R(.5)/R(1)=0.999 and F=1.0. It is 6.4% of the original biomass. In the worst case (R(.5)/R(1) =0.90) maximum yield occurs when F=0.2. It is 3.9% of the original biomass. The highest estimate of original biomass is 121,430 mt. The lowest estimate is 102,260mt. Thus maximum yield probably falls between 3988mt and 7772mt. The average of the two estimates is 5880mt. Maintenance of a population at the level which produces maximum yield is difficult, because of variation in recruitment and uncertainties in knowledge. An approach that is similar to that used in the previous estimate of ABC is to maintain fishing mortality at the level which produces maximum yield. Figure 7 indicates that if F of 10 year old fish is 0.3, there is little risk of seriously over or under fishing. If R(.5)/R(1)=0.999, equilibrium yield would be 11% below maximum yield and the population would be slightly underfished. If F(.5)/F(1)=0.90, yield would be 7% below maximum yield and the population would be slightly overfished. Runs of the dynamic pool model indicate that if low F applies and F of 10 year old fish is 0.3, 1985 yield would be about 7400mt. If high F applies and 1985 yield is 7400mt F of 10 year old fish would be about 1.2. Under high F reduction of F of 10 year old fish to 0.3 in 1985 would result in a yield of about 2100 mt.

Estimates of equilibrium yield in 1985 ranged from about 3000mt to 9900mt, if the most optimistic recruitment function is valid for 1986. The average of the estimates is 6450mt.

## DISCUSSION

This stock assessment indicates that sustainable production of widow rockfish is significantly below previous estimates. The most optimistic estimate of maximum yield is 7772 mt. This is 27% below the previous estimate of 10714mt. The pessimistic estimate ,3988mt, is 73% below the previous estimate.

The marked decrease in catch of older fish in landings since 1981 and rapid decline in landings in most areas since 1981 and in the Northern Columbia and Nelson Island areas since 1980 are strong indications that the fishery has had a significant impact on the stock.

On the otherhand a cursory examination of samples collected from the 1984 landings indicates that age composition is not greatly different than 1983. This suggests that the condition of the stock may be closer to that estimated under low F than under high F. We thus recomend that ABC be set at 7400mt, estimated yield if F of 10 year fish =0.3 and low F applies. If high F conditions apply analyses of the 1984 data will reveal almost no fish older than 7 years and a rapid and significant reduction in ABC would be indicated.

If M is assumed to be 0.25, which as previously mentioned is too high with respect to estimates of M for other groundfish, runs of the dynamic pool model and cohort analysis indicate that maximum sustainable yield probably would fall between 7000mt and 15400mt. The average, 11200mt, is close to the average of the previous report. The estimates of ABC for 1985 would range from 2300mt to 13200mt. The average is 7750mt, which is close to the estimate when M=0.15 and Low F is used. Estimates of EY for 1985 would range from 3400mt to 9000mt. The average is 6200mt, which is close to the average when M is assumed to be 0.15.

## LITERATURE CITED


Barss, W.and T. Echeverria. MS. Maturity of widow rockfish, Sebastes entomelas from the Northeastern Pacific, 1977-1982.

Beverton, R. and S. Holt. 1957. On the dynamics of exploited fish populations. U.K. Min. Agric. Fish. Fish Invest. (Ser. 2) 19: 533p.

Francis, R. 1974. Relationship of fishing mortality to natural mortality at the level of maximum sustainable yield under the logistic stock production model. J. Fish. Res. Bd. Can. 31: 1539-1542.

Gulland, J. 1970. The fish resources of the ocean. FAO Fish Tech. Paper 97: 425p.

Kimura, D. and J. Tagart. 1982. Stock reduction analysis; another solution to the catch equation. Can. J. Fish. Aquat. Sci.39: 1467-1472.

Lenarz, W. MS. Aging and growth of widow rockfish.

Murphy, G. 1965. A solution to the catach equation. J. Fish. Res. Bd. Can. 22: 191-202.

Wishard, L., F. Utter and D. Gunderson. 1980. Stock seperation of five rockfish species using naturally occuring bioichemical genetic markers. Marine Fisheries Review. 42(3-4): 64-73.

Table 1. Estimates of widow rockfish production(mt). This is a summary of 1983 catch statistics and November, 1983 report on ABC calculations for widow rockfish

| AREA | MSY | 1983 ABC | 1983 LANDINGS | 1984 ABC |
|---|---|---|---|---|
| INPFC VANCOUVER | 714 | 372 | 1596 | 331 |
| Northern Columbia | 2378 | 1620 | 2490 | 1452 |
| Southern Columbia | 3915 | 4887 | 2129 | 3907 |
| INPFC COLUMBIA | 6293 | 6507 | 4619 | 5359 |
| INPFC EUREKA | 2009 | 1504 | 2442 | 1755 |
| INPFC MONTEREY | 1698 | 2081 | 1554 | 1764 |
| TOTAL | 10714 | 10464 | 10211 | 9209 |

Table 2. Landings (mt) of widow rockfish by area and year for 1979-1983

| AREA | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|
| INPFC VANCOUVER | 329 | 143 | 1991 | 3969 | 1596 |
| Northern Columbia | 432 | 9426 | 7969 | 4625 | 2490 |
| Nelson Island | 1680 | 3192 | 2056 | 489 | 0 |
| Newport Deeps | 0 | 0 | 272 | 4953 | 1337 |
| Hecate-Coquile | 214 | 2589 | 9973 | 1487 | 792 |
| Southern Columbia | 1894 | 5781 | 12301 | 6929 | 2129 |
| INPFC COLUMBIA | 2326 | 15207 | 20270 | 11554 | 4619 |
| INPFC EUREKA | 2166 | 4736 | 3430 | 3993 | 2442 |
| INPFC MONTEREY | 120 | 304 | 2000 | 6997 | 1554 |
| TOTAL | 4941 | 20390 | 27691 | 26513 | 10211 |

Table 3. Estimates of number of widow rockfish landed by yearclass, 1980-1983

| Yearclass | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|
| 1965+ | 1855590 | 1408840 | 2944965 | 1357328 |
| 1966 | 567370 | 579383 | 826214 | 191493 |
| 1967 | 855291 | 852624 | 1092779 | 279254 |
| 1968 | 1675004 | 1355925 | 1402731 | 364743 |
| 1969 | 2237354 | 2193596 | 1647261 | 364309 |
| 1970 | 5590000 | 5632986 | 3848929 | 690087 |
| 1971 | 3580382 | 5130376 | 1960380 | 391259 |
| 1972 | 903787 | 1482746 | 727175 | 221821 |
| 1973 | 459876 | 885004 | 933295 | 272289 |
| 1974 | 454478 | 1625798 | 1512799 | 321720 |
| 1975 | 299783 | 2219309 | 1924166 | 619730 |
| 1976 | 1331 | 689527 | 1511512 | 704844 |
| 1977 | | 898997 | 2599375 | 2484342 |
| 1978 | | | 509659 | 2271891 |
| 1979 | | | 15361 | 334306 |
| 1980 | | | | 14752 |

Table 4. Estimates of F by age and year for two values of starting F

| AGE | 1980 | 1981 | 1982 | 1983 | SUM 1980-1982 |
|---|---|---|---|---|---|
| | | | LOW F | | |
| 4 | .000 | .046 | .016 | .017 | .063 |
| 5 | .036 | .124 | .174 | .091 | .334 |
| 6 | .082 | .380 | .410 | .237 | .872 |
| 7 | .125 | .435 | .623 | .321 | 1.183 |
| 8 | .212 | .352 | .882 | .392 | 1.446 |
| 9 | .281 | .594 | .724 | .443 | 1.599 |
| 10 | .265 | .770 | .619 | .448 | 1.654 |
| 11 | .186 | .437 | .724 | .364 | 1.347 |
| 12 | .212 | .265 | .571 | .285 | 1.048 |
| | | | HIGH F | | |
| 4 | .000 | .080 | .041 | .055 | .121 |
| 5 | .043 | .176 | .327 | .247 | .576 |
| 6 | .092 | .474 | .667 | .558 | 1.233 |
| 7 | .146 | .510 | .936 | .721 | 1.592 |
| 8 | .244 | .429 | 1.247 | .869 | 1.920 |
| 9 | .313 | .741 | 1.056 | .955 | 2.110 |
| 10 | .318 | .936 | .979 | 1.011 | 2.233 |
| 11 | .234 | .574 | 1.158 | .890 | 1.966 |
| 12 | .266 | .357 | .949 | .712 | 1.572 |

Table 5. Estimates of population size (millions of fish) by age and year

LOW F

| AGE | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|
| 4 | 7.4 | 21.3 | 34.6 | 21.4 |
| 5 | 9.1 | 6.3 | 17.5 | 29.3 |
| 6 | 6.2 | 7.5 | 4.8 | 12.6 |
| 7 | 4.2 | 4.9 | 4.4 | 2.8 |
| 8 | 5.1 | 3.2 | 2.8 | 2.0 |
| 9 | 15.7 | 3.5 | 1.9 | 1.0 |
| 10 | 25.7 | 10.2 | 1.7 | .8 |
| 11 | 14.2 | 17.0 | 4.1 | .8 |
| 12 | 9.4 | 10.1 | 9.5 | 1.7 |
| 13+ | 18.4 | 19.3 | 19.5 | 14.7 |

HIGH F

| AGE | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|
| 4 | 5.3 | 12.6 | 13.7 | 6.7 |
| 5 | 7.6 | 4.6 | 10.0 | 11.3 |
| 6 | 5.5 | 6.3 | 3.3 | 6.2 |
| 7 | 3.6 | 4.4 | 3.4 | 1.5 |
| 8 | 4.5 | 2.7 | 2.3 | 1.1 |
| 9 | 14.3 | 3.0 | 1.5 | .6 |
| 10 | 22.0 | 9.0 | 1.2 | .5 |
| 11 | 11.5 | 13.8 | 3.0 | .4 |
| 12 | 7.7 | 7.8 | 6.7 | .8 |
| 13+ | 15.1 | 15.0 | 13.7 | 6.8 |

Table 6. Estimates of biomass and spawning stock size (mt) for widow rockfish, 1980-1983

| | BIOMASS | | SPAWNING STOCK | |
|---|---|---|---|---|
| YEAR | LOW F | HIGH F | LOW F | HIGH F |
| 1980 | 121430 | 102260 | 107530 | 90700 |
| 1981 | 101610 | 80230 | 83920 | 67710 |
| 1982 | 83310 | 53960 | 57880 | 41220 |
| 1983 | 62090 | 27640 | 33760 | 16490 |

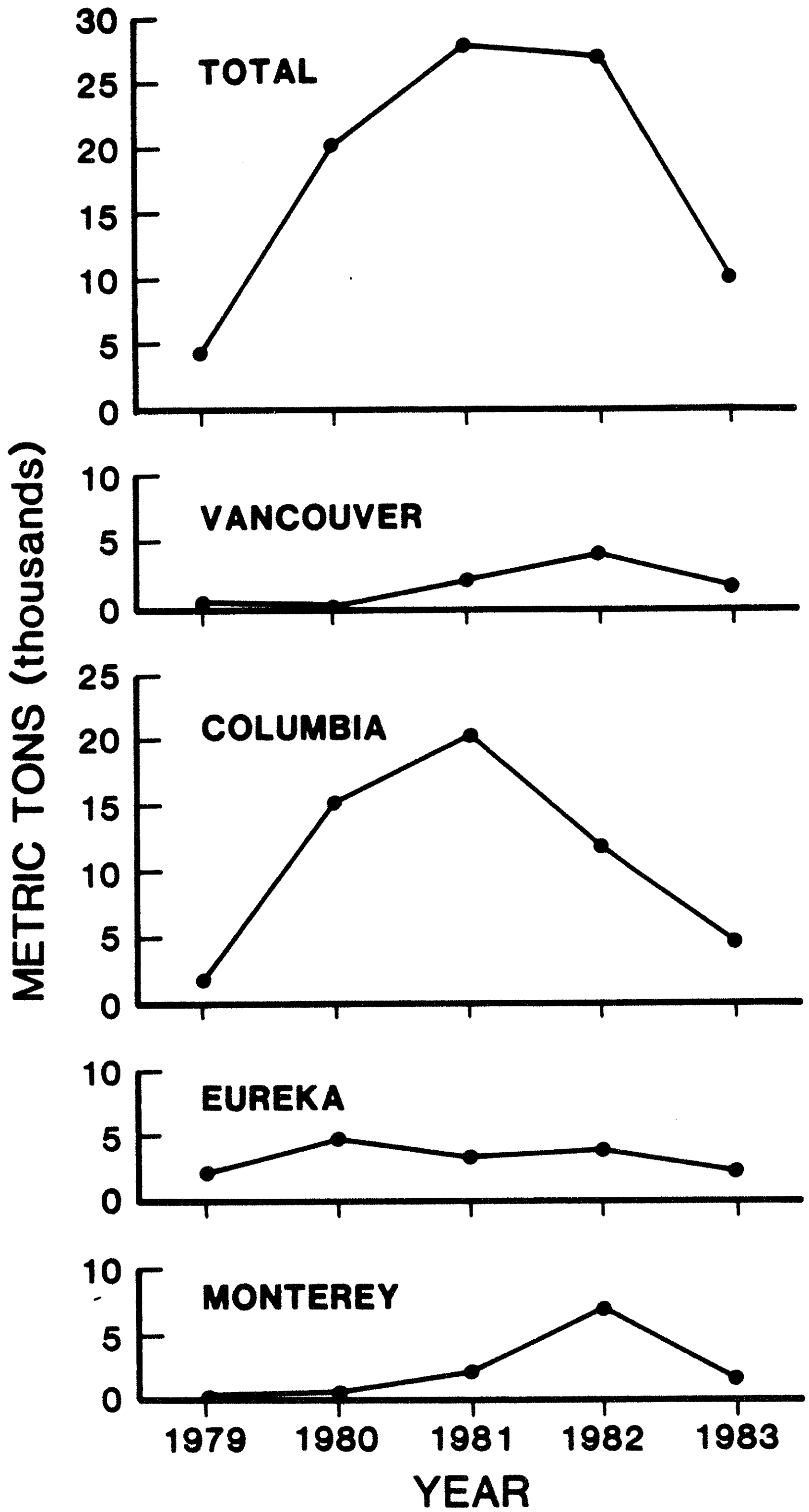


Figure 1. Landings of widow rockfish in California, Oregon, and Washington and by INPFC area, 1979-1983.

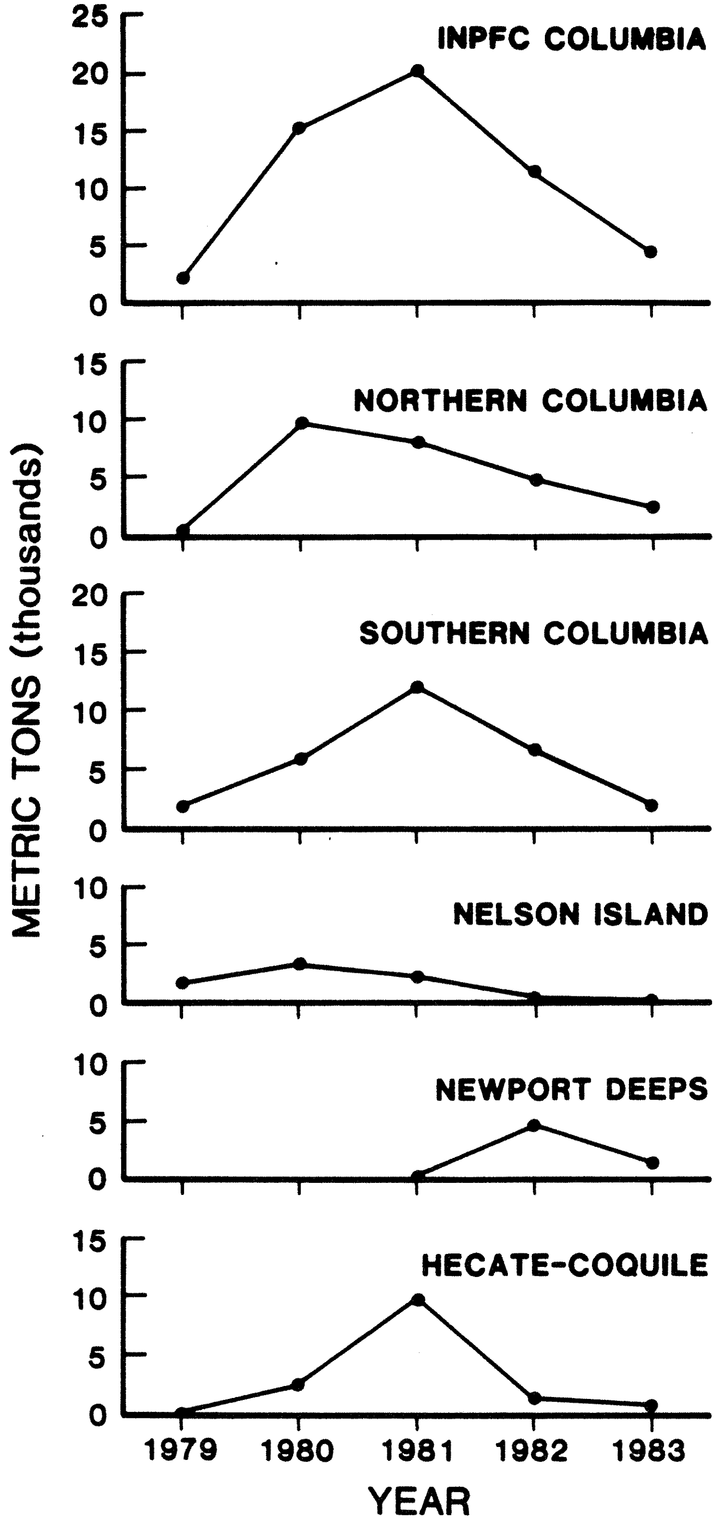


Figure 2. Landings of widow rockfish in the INPFC Columbia area and grounds within the area, 1979-1983.

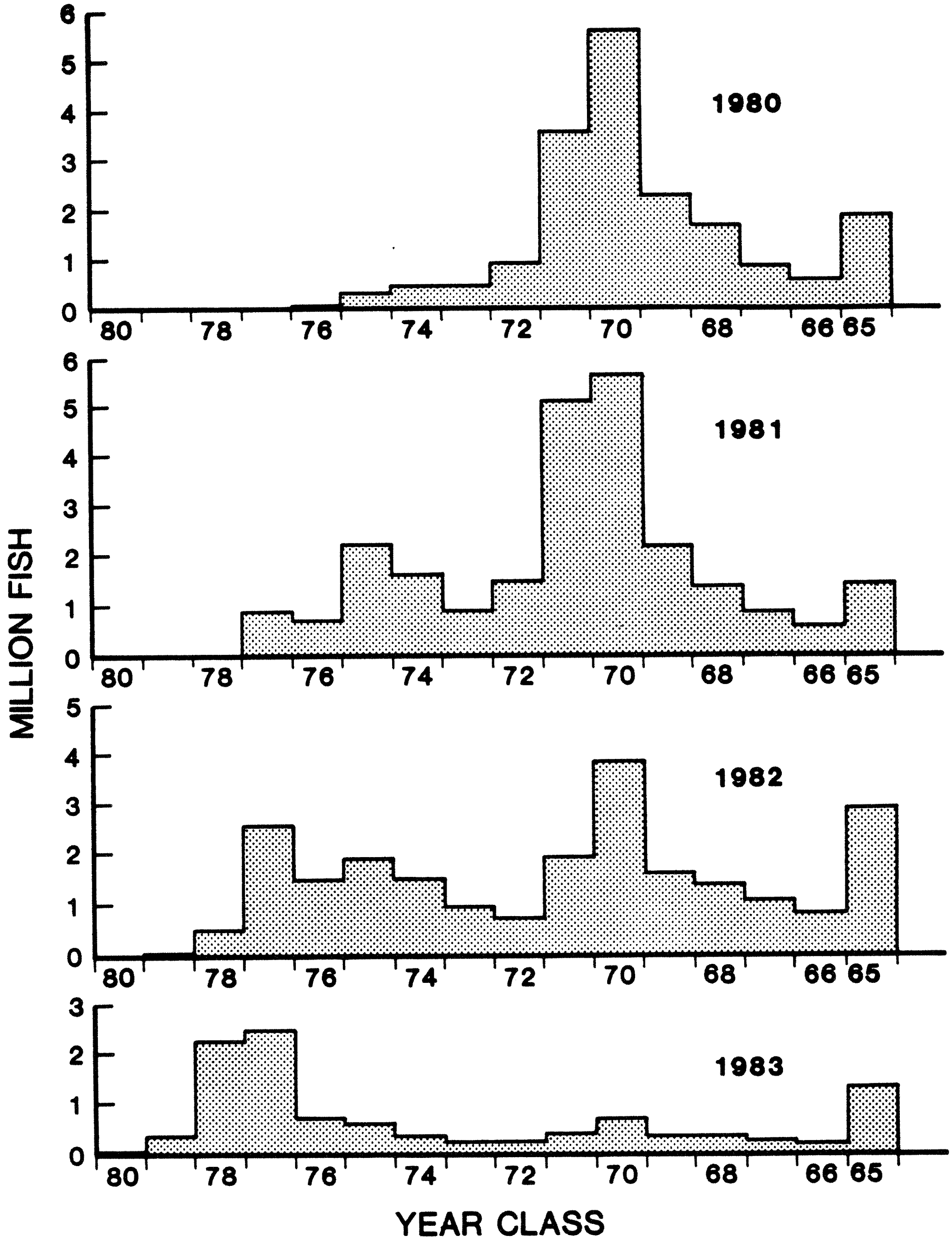


Figure 3. Yearclass composition of widow rockfish landings in California, Oregon, and Washington, 1980-1983.

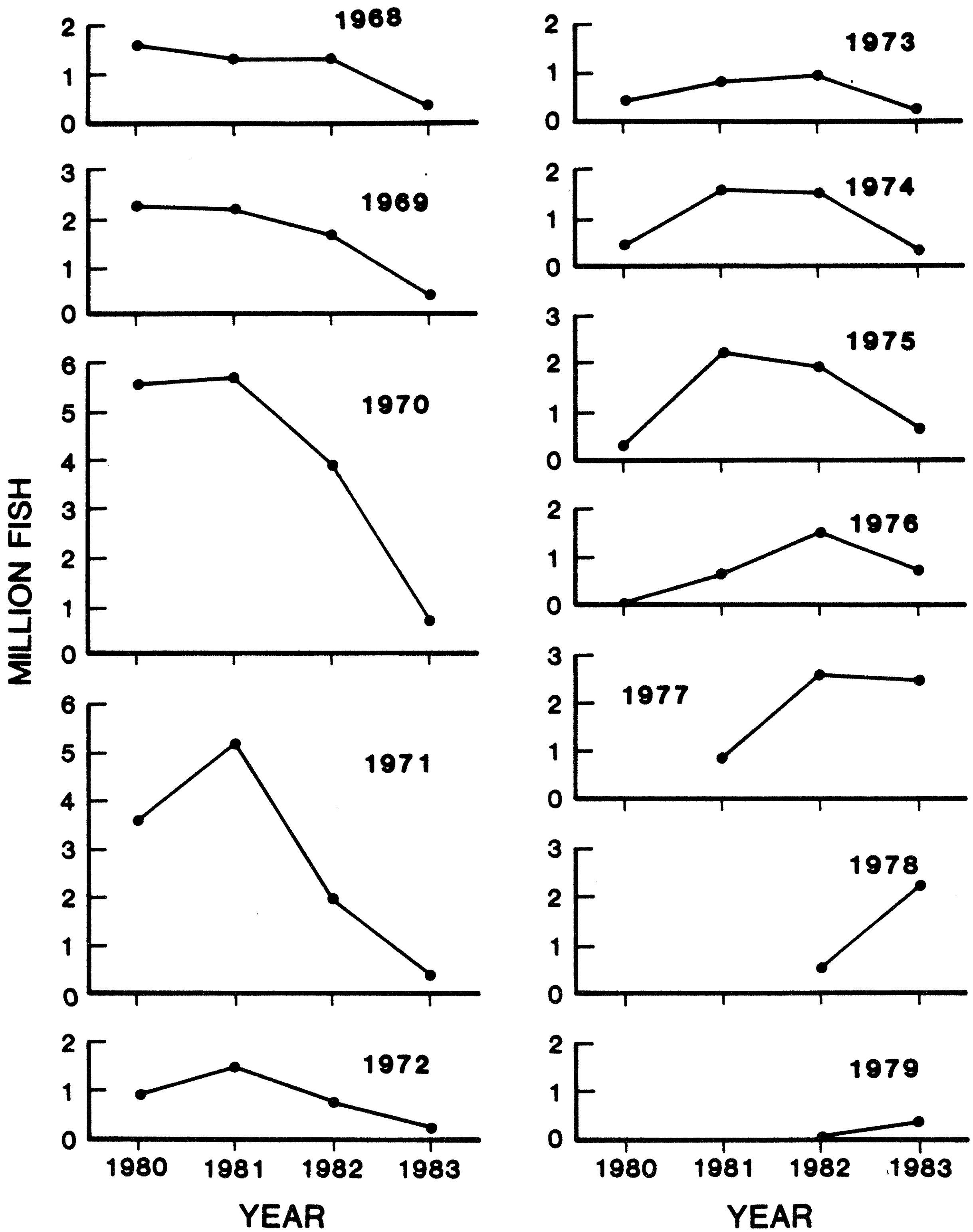


Figure 4. Landings of the 1968-1979 yearclasses of widow rockfish in California, Oregon, and Washington 1980-1983.

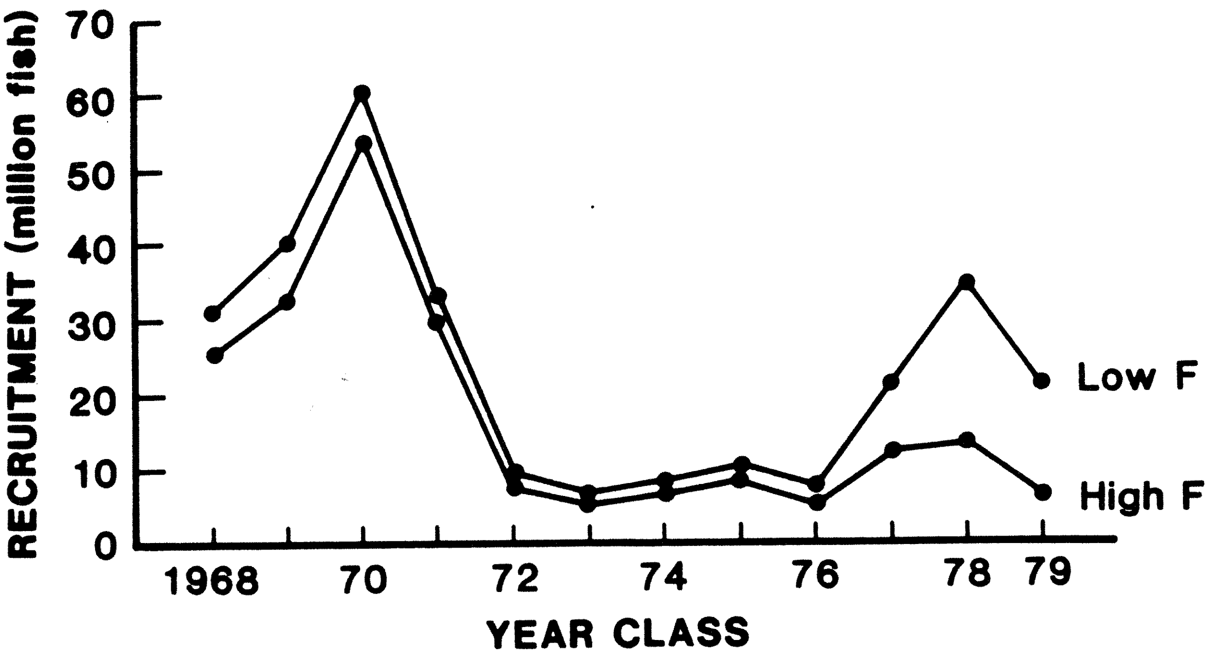


Figure 5. Estimates of number of recruits at age 4 for the 1968-1979 yearclasses of widow rockfish.

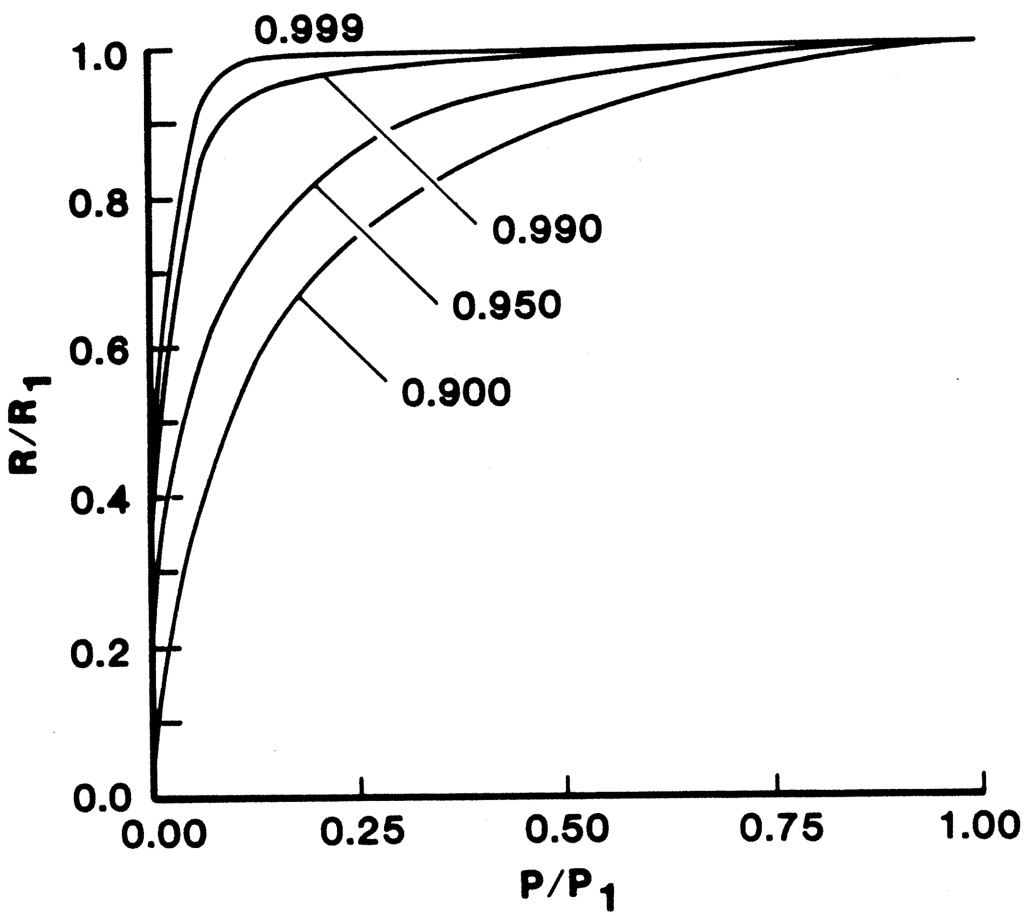


Figure 6. Recruitment divided by recruitment of an unfished population (R/R(1)) as a function of spawning stock size divided by spawning stock size of an unfished population (P/P(1)). The Beverton and Holt relationship is assumed. Estimates are shown for R(.5)/R(1)=0.999, 0.99, 0.95, and 0.9.

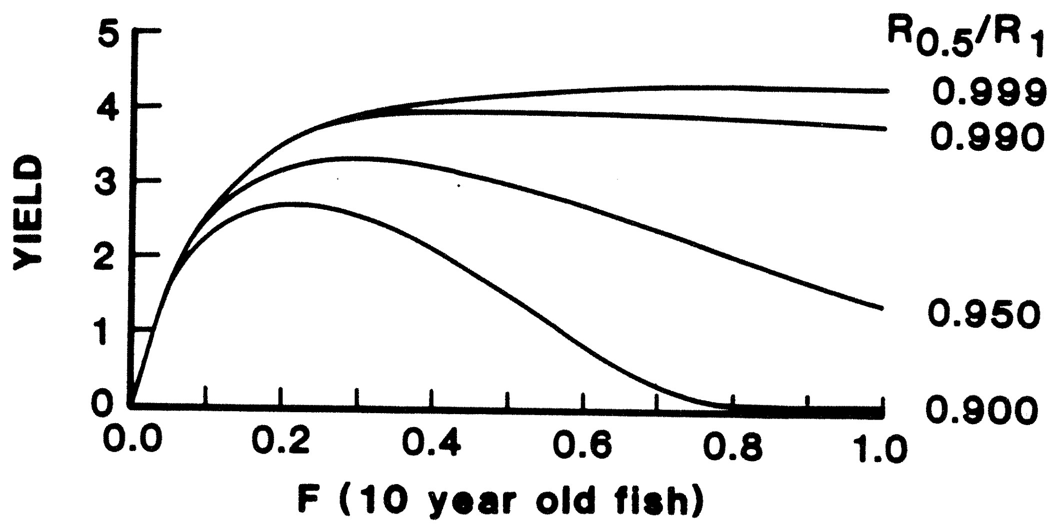


Figure 7. Estimates of equilibrium yield (after 100 years) of widow rockfish (mt/10,000 recruits of 4 year fish to an unfished population) as a function of fishing mortality of 10-year-old fish and R(.5)/R(1).

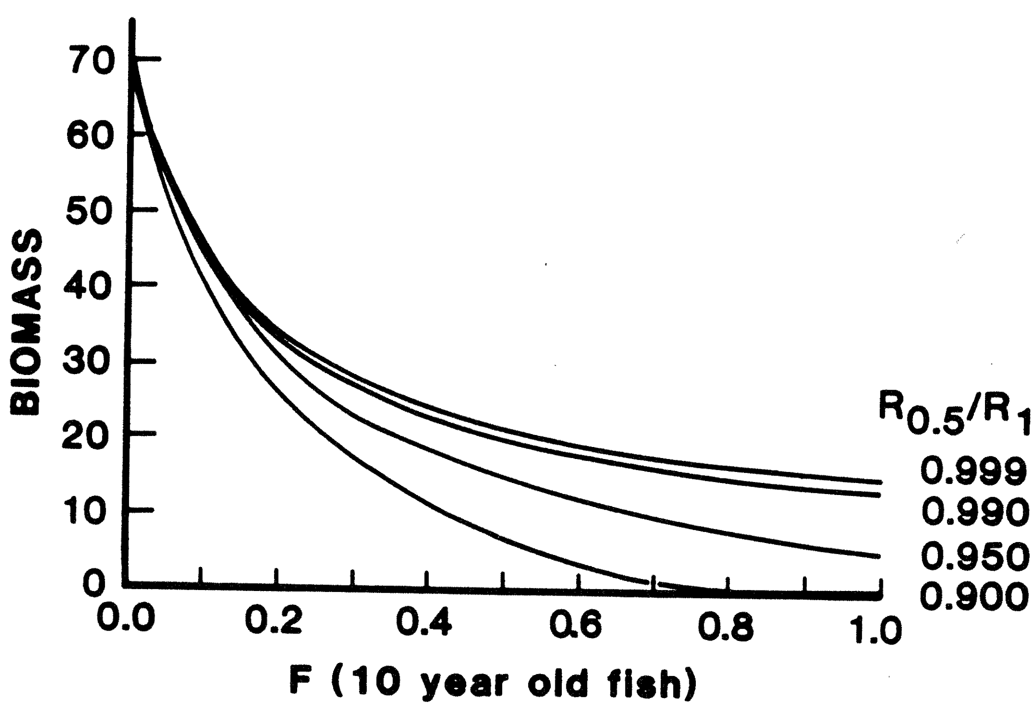


Figure 8. Estimates of equilibrium biomass (after 100 years) of widow rockfish (mt/10,000 recruits of 4-year-old fish to an unfished population) as a function of fishing mortality of 10-year-old fish and R(.5)/R(1).