APPENDIX C
DARKBLOTCHED ROCKFISH

AN INITIAL EXAMINATION OF THE STATUS OF THE DARKBLOTCHED ROCKFISH FISHERY OFF THE COASTS OF CALIFORNIA, OREGON AND WASHINGTON

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INTRODUCTION

During recent years the PFMC has expressed concern about the lack of knowledge on the status of stocks of minor groundfish species. Darkblotched rockfish (Sebastes crameri) is one of the more important of these species. Annual landings averaged 1384 mt between 1982 and 1991 (Table 1).

Some information that may be useful for an assessment of the status of the stock is available. Life history parameters are estimated in a MS thesis (Nichol, 1990), population length composition and biomass estimates are made from the triennial trawl survey (Gunderson and Sample, 1980) and length compositions of landings are available for California.

Ralston et al. (1990) showed that there was a significant decreasing trend in average size of male darkblotched rockfish landed in California between 1978 and 1988. There also was a trend for females, but it was not significant. They also showed that the size decline found for males is consistent with substantial fishing pressure.

Nichol (1990) expressed concern that, because the species is very long lived and fish recruit to the Oregon fishery before maturity, darkblotched rockfish appear to be vulnerable to overfishing. He also suggested that changes in sex ratio with age were consistent with heavy fishing pressure.

In this paper I review available information on life history, surveys, and fishery for dark blotched rockfish. I then estimate $F_{35\%}$ and $F_{20\%}$, and discuss possible management recommendations.

LIFE HISTORY

While there are earlier studies on some aspects of the life history of darkblotched rockfish, Nichol (1990) conducted a thorough study using modern techniques that were not available to the earlier workers. I will only use the results of Nichol for this study.

Several aspects of his study should be noted. Specimens were taken off Oregon and Washington. The majority of California landings come from the Eureka area and I assume that estimates by Nichol are also valid for fish off California. He presents length as total length (TL). I use his equation to convert to fork length (FL) to be consistent with other studies:

$$FL\ (mm) = -0.564 + 0.956TL\ (mm).$$

He used sectioned otoliths to estimate age. Edge analysis confirmed his ageing technique through 10 years. There was good agreement between age determinations made by him and readers from the Pacific Biological Station (PBS) through 60 years. The PBS readers used the break and burn method and found that Nichol's otoliths did not break properly beyond that age. Nichol's otoliths had been preserved in ethanol, which is not recommended by PBS for the break and burn method.

Results from ageing 800 fish ranging from 1 to 105 years were used to estimate the parameters of the Von Bertalanffy growth model. Females obtained a larger size than males but K was lower (Table 2). Nichol noted that the model tends to underestimate size of older males. Nichol's equation for size (converted to FL) of males greater than.30 years is

$$FL(mm) = 0.473AGE(y) + 366.0.$$

Examination of his plots of size at age actually indicated that there were trends in the residuals from the growth model for older ages for both sexes. It appears that he may have given too much weight to young fish in his estimation procedure. While there are minor trends in the residuals from the model, the fit is adequate for the uses of the growth model in latter sections of this study.

His estimate of the weight length relationship (converted to FL) is

$$W(kg) = (1.35 \times 10^{-5})\ (0.846 + 1.046FL(mm))^{3.0359}.$$

He estimated the age composition of catches off Newport Oregon and then estimated total mortality from the resulting catch curves. Nichol cautions the reader that his assumptions of constant selectivity and recruitment may not be valid. Also the number of samples was small and distribution of fishing for these samples may not be representative of the entire fishery. It appears that his mortality estimates are not meaningful.

He found that size and age increased with depth and that peak CPUE (kg/hr towed) occurred between 276 and 366m. CPUE between 367 and 457m was approximately 40% of the peak rate. Peak fishing effort occurred between 276 and 366m. The modal age of his catch data was 7.

His data indicate that females reach 50% maturity at age 8 (350 mm) and males at age 5 (283 mm). The proportion of mature females (P_f) is given by

$$P_f = 1/(1+e^{-0.7464AGE(y) + 6.2289}).$$

The proportion of mature males (P_m) is given by

$$P_m = 1/(1+e^{-3.4631AGE(y) + 17.9228}).$$

His estimate of the fecundity (F) length relationship (converted to FL) is

$$F = (4.3459 \times 10^{-10})\ (0.846 + 1.046FL(mm))^{5.6049}.$$

Maximum observed fecundity was 489,064 fully yolked advanced oocytes. Parturition occurred from December to March.

SURVEY INFORMATION

Biomass estimates are available from the triennial survey since 1977. The Conception area was only surveyed in 1977, 1989 and 1992, and the Monterey area was incompletely surveyed in most years. Only the Eureka, Columbia and US Vancouver area biomass estimates are used in this study. The swept area method was used to estimate biomass for the 55-183 m and 184-366 m strata for all years except 1977. In 1977 the survey did not extend shoreward of 91 m. The difference in the shoreward boundary should not have had a significant impact on the biomass estimates. It is not known if the assumptions of the swept area method are met, but similar estimates for other species of rockfish have been exceed by catches. Therefore I choose to treat the biomass estimates as indices of relative abundance.

The indices have wide confidence intervals and appear to be trendless (Table 3 and Figure 1). Total annual combined area indices range from 2528 to 8003 mt.

Biomass indices are also available from 1984 spring and fall slope surveys of the southern Columbia area between Tillamook Head and Coquille Point, Oregon and a 1988 slope survey that covered about half of the area of the 1984 surveys. The 1988 and 1984 autumn surveys covered 183-1280 m, but darkblotched rockfish were not captured deeper than 549 m. The 1984 spring survey covered 110-549 m. The spring survey biomass indices were more than twice the autumn indices (Table 4) but the confidence limits of the spring survey included the autumn index. The 1988 estimates are not comparable to the 1984, because of the reduced scale of the 1988 survey. A significant but varying portion of the biomass occurred deeper than 366 m in all three slope surveys. This and data presented by Nichol (1990) indicates that indices from the triennial surveys do not include the entire population.

Length compositions from the triennial surveys are in agreement with Nichol's finding that length tends to increase with depth (Figures 2 and 3). Modes in Columbia shallow strata composition correspond to ages 1,2,3 and perhaps 4. A large majority of the fish captured in the Eureka and Columbia deep strata appear to be less than 10 years old. In many of the surveys a majority of the fish captured in the deep strata are equal to or less than 300 mm, which is approximately the expected size of six year olds. The data suggest that the 1988 and 1987 yearclasses were relatively abundant in the shallow Columbia depth stratum in 1989 and had moved into the deep stratum by 1992.

Average size tended to decrease over time. The trend was particularly noticeable for the Eureka deep strata since 1986 (Figure 3). This trend could partially be explained by recruitment of strong yearclasses. However, very few large fish (> 300 mm) were captured in the Eureka area in 1992 (Figure 2a). Large fish dominated length compositions for the Eureka area prior to 1989. In 1992 average size of Columbia fish was larger than fish from the Eureka area for the first time (Figure 3). However large fish also virtually disappeared from the Columbia area (Figure 2c).

FISHERY INFORMATION

Landings of darkblotched rockfish ranged from 404 mt in 1978 to 2310 mt in 1987 (Table 1 and Figure 4). Highest average landings occurred in the Columbia area where landings were very consistent since 1985. Average landings in the Eureka area were 35% lower than from the Columbia area, but the variance was much higher and Eureka landings in 1987 were more than twice the highest Columbia landing. Anecdotal evidence indicates that the unusually high 1987 landings were the result of a few vessels targeting on the species and then leaving the fishery for social-economic reasons. Trip size information from port samples indicated that a large portion of the 1987 landings came from trips that exceeded 15000 lbs. This is quite different than the distribution of landings in 1985 and suggests that vessels were targeting on the species.

Length composition data are available for California landings, but sample sizes were small in some years. Because of this length compositions were combined into four time periods (Figure 5). Large fish became less common in the landings as time progressed. The average size decreased from 1979 to 1988 as documented by Ralston et al. (1990) for males (Figure 6). The data through 1990 suggest that the average size of females also decreased.

The average size of fish from California landings was higher than fish captured by the triennial survey in the Eureka and Columbia deep strata (Figures 3 and 6).

ESTIMATION OF $F_{35\%}$ AND $F_{20\%}$

The life history parameters from Nichol (1990) were used to estimate $F_{35\%}$ and $F_{20\%}$. Nichol estimated maximum age to be 105 years, but age estimates by independent experienced agers from the PBS did not agree with ages by Nichol beyond age 60. Nichol's explanation that the discrepancy was caused by the method of preservation causing otoliths from very old fish to be unsuitable for the technique used by the PBS agers seems plausible. However, to cover the range of maximum age estimates, I will assume that maximum age is either 60 or 105 years for estimation of natural mortality (M).

The Hoenig (1983) method was used to estimate M from maximum age under the assumption that F was minimal prior to the recent history of the fishery. The estimate of M is 0.05 and 0.025 for maximum ages of 60 and 105 years respectively. The estimates of M are biased on the high side because they include some fishing mortality.

Nichol's catch composition data indicate that the fish are fully recruited to the fishery by age 7 and about 50% recruited at 6. However, since his sample size was small and may not be representative of the fishery, I chose to derive a selectivity curve from the female length compositions of the California landings. I assumed that selectivity could be described with a logistic curve. The data shown in Figure 5 indicate that selectivity is 0.50 at about 32 cm and that the slope of the curve is steep. The following equation results in selectivity estimates that agree with the interpretations of Figure 5.

$$Sel_{FL} = 1/(1+e^{(24-0.75FL)}).$$

Sel_{FL} is selectivity at fork length (cm). I then estimated selectivity as a function of age (Sel_{Age}) by first assuming that length at age has a normal distribution. The standard deviation was assumed to be 15 as indicated by data presented in Nichol (1990). Sel_{Age} was then estimated as a average of Sel_{FL} weighted by the probability generated from a normal distribution of FL within each age. The results (Table 5) indicated that Sel_{Age} was 0.63 at 7 years and exceeded 0.9 by 9 years. Nichol's data represented catches and there could be some discards of young fish. Also the difference between the results in Table 5 and Nichol's data could be the result of inaccuracies due to his small sample size, and/or different fishing practices along the coast.

The results of estimates of relative population fecundity per recruit are shown in Figure 7. $F_{35\%}$ ranges from 0.04 to 0.06. $F_{20\%}$ ranges from 0.07 to 0.11. These estimates are low and are in agreement with the concern of Nichol (1990) that the species could not sustain heavy fishing.

DISCUSSION

Darkblotched rockfish are very longlived and, as the estimates of $F_{35\%}$ and $F_{20\%}$ indicate, are not capable of supporting a heavy fishery. Unfortunately there are few data available to assess the status of the stock or the current rate of fishing. The triennial survey does not cover the depth range of the species and biomass indices have very wide confidence limits and appear to be trendless. However, all available length frequency data indicate that size has decreased during the past decade and the data indicate that there are fewer large fish than before. This is consistent with an impact from fishing although there could be other causes.

It appears unlikely that the decrease in size is due to increased recruitment alone, because there was a decreasing trend in the catch of large fish. It is possible that the size selectivity curve for the fishery is domed shaped and that the size of peak selectivity has decreased. Pacific ocean perch (POP) have a life history that is similar to darkblotched rockfish and occurs at similar depths. The maximum size of POP is about 5% less than darkblotched rockfish. Ianelli et al. (1992) estimated peak selectivity for POP to occur at age 13 and decrease to about 50% of peak levels at age 24 during the 1981-1991 period. Prior to 1981 selectivity was estimated to be asymptotic. It is possible that the decreased commercial catches of large darkblotched rockfish are at least partially due to a shift in the shape of the selectivity curve as occurred for POP and the shift occurred at a latter date than for POP. This would not explain decreased catches of large darkblotched rockfish by the triennial survey. Perhaps changes in the distribution and/or behavior of darkblotched rockfish caused the observed changes in length distributions.

The estimated age specific selectivity curve and life history parameters were used to estimate the change in average forklength of female darkblotched rockfish in landings that would occur over a 10 year period of time if fishing mortality increased at the beginning of the period. It was assumed that the population was at equilibrium at the beginning of the period and that fishing mortality was four times higher during the period than prior to it, which is consistent with the increase in landings. The standard catch equation was used for the simulation. The results (Figure 8) show that average size would decrease about 2cm if fishing mortality increased from .05 to .20. Average size of female darkblotched rockfish in California landings decreased about 2cm in a 10 year period (Figure 6). These results indicate that under the assumptions of the model fishing mortality considerably above $F_{20\%}$ would be necessary to explain the observed decrease in average length.

As previously mentioned POP are similar to darkblotched rockfish. Even though the landing limits are considerably smaller for POP than for darkblotched rockfish, exploitation rates for POP during recent years are estimated to be higher than the $F_{20\%}$ level for darkblotched rockfish.

There is not as much data available for the darkblotched rockfish fishery as there are for some of the more important fisheries. A reasonable interpretation of the data suggests that fishing is substantial and could very well be above the $F_{20\%}$ level. Also fishing mortality for POP, which has very similar life history parameters and depth distribution, is estimated to be higher than the $F_{20\%}$ level for darkblotched rockfish. It would seem prudent to not allow the fishery to expand unless additional data indicate room for an increased fishery. It could be argued that landings should be reduced. The Council may also wish to consider managing the species as part of the deepwater rockfish complex. None of the members of this complex appear to be capable of sustaining high fishing rates and probably should be conservatively managed.

LITERATURE CITED

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Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. U.S. Fish. Bull. 82(1): 898-902.

Ianelli, J. N., D. H. Ito, and M. E. Wilkens. 1992. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1992. Appendix C In: Status of the Pacific Coast groundfish fishery through 1992 and recommended acceptable biological catches for 1993. Pacific Fishery Management Council, Portland, Oregon.

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Ralston, S., A. D. MacCall, and D. E. Pearson. 1990. Reduction in mean length and exploitation of central and northern California rockfish. Appendix L In: Status of the Pacific Coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991. Pacific Fishery Management Council, Portland, Oregon.

Raymore, P. A. Jr., and K. L. Weinberg. 1990. 1984 spring and autumn surveys of Pacific west coast upper continental slope groundfish resources. NOAA Tech. Mem. NMFS F/NWC-179: 196 p.

Table 1. Landings (mt) of darkblotched rockfish by year and INPFC area of the coasts of California, Oregon and Washington, 1978-1991. INPFC Conception landings were small and combined with INPFC Monterey landings. California landings were estimated by Don Pearson (NMFS Tiburon, CA) from data provided by the Calif. Dept. of Fish and Game. Oregon landings from 1984-1991 were obtained from PACFIN. All Washington landings and Oregon landings prior to 1984 were provided by Jack Tagart (Wash. Dept. of Fisheries).

	INPFC Area				
Year	Conception-Monterey	Eureka	Columbia	US-Vancouver	Total
1978	41	11	202	150	404
1979	16	89	746	72	923
1980	114	37	320	63	534
1981	68	121	354	28	571
1982	54	637	526	30	1247
1983	304	218	391	21	934
1984	363	386	447	78	1274
1985	344	613	734	73	1764
1986	167	214	612	176	1169
1987	117	1551	608	34	2310
1988	144	661	719	66	1590
1989	104	264	738	62	1168
1990	339	223	730	26	1318
1991	120	135	732	86	1073
Total	2295	5160	7859	965	16279

Table 2. Estimates of parameters of Von Bertalanffy growth model for darkblotched rockfish (Nichol 1990). C is a constant added to the growth equation to convert to fork length (mm).

Sex	Sample Size	Parameter	Estimate
MALE	383	L_∞	378.1000
		K	0.2352
		t_0	-0.5800
		C	-0.6000
FEMALE	417	L_∞	435.6000
		K	0.1779
		t_0	-0.9200
		C	-0.6000

Table 3. Darkblotched rockfish biomass indices (mt) by INPFC area and depth from the triennial west coast groundfish surveys. Data were provided by Mark Wilkins of the AFSC.

Year	Depth	Eureka	Area Columbia	US-Vancouver	Total
1977	91-183 m	6	650	51	707
1977	184-366 m	465	1231	125	1821
1977	Total	471	1881	176	2528
1980	50-183 m	17	235	1	253
1980	184-336 m	1103	1241	58	2402
1980	Total	1120	1476	59	2655
1983	50-183 m	171	1945	180	2296
1983	184-336 m	708	4883	116	5707
1983	Total	879	6828	296	8003
1986	50-183 m	61	470	126	657
1986	184-336 m	1346	2942	948	5236
1986	Total	1407	3412	1074	5893
1989	50-183 m	127	677	63	867
1989	184-336 m	1021	801	150	1972
1989	Total	1148	1478	213	2839
1992	50-183 m	118	861	192	1171
1992	184-336 m	317	4515	120	4952
1992	Total	435	5376	312	6123

Table 4. Biomass indices (mt) of darkblotched rockfish from the 1984 spring and autumn slope surveys (Raymore and Weinberg, 1990) and 1988 slope survey (Mark Wilkins AFSC). The 1988 survey covered a smaller area than the 1984 surveys.

	Biomass index			
Survey	110-183 m	183-366 m	366-549 m	Total
1984 Spring	332	11371	2061	13764
1984 Autumn	400	4663	424	5487
1988	-	329	436	765

Table 5. Estimates of Selectivity as a function of age (Sel_{Age}) for darkblotched rockfish.

Age	Sel_{Age}
4	0.01
5	0.09
6	0.33
7	0.63
8	0.84
9	0.93
10	0.97
11	0.98
12	0.99
>13	1.00

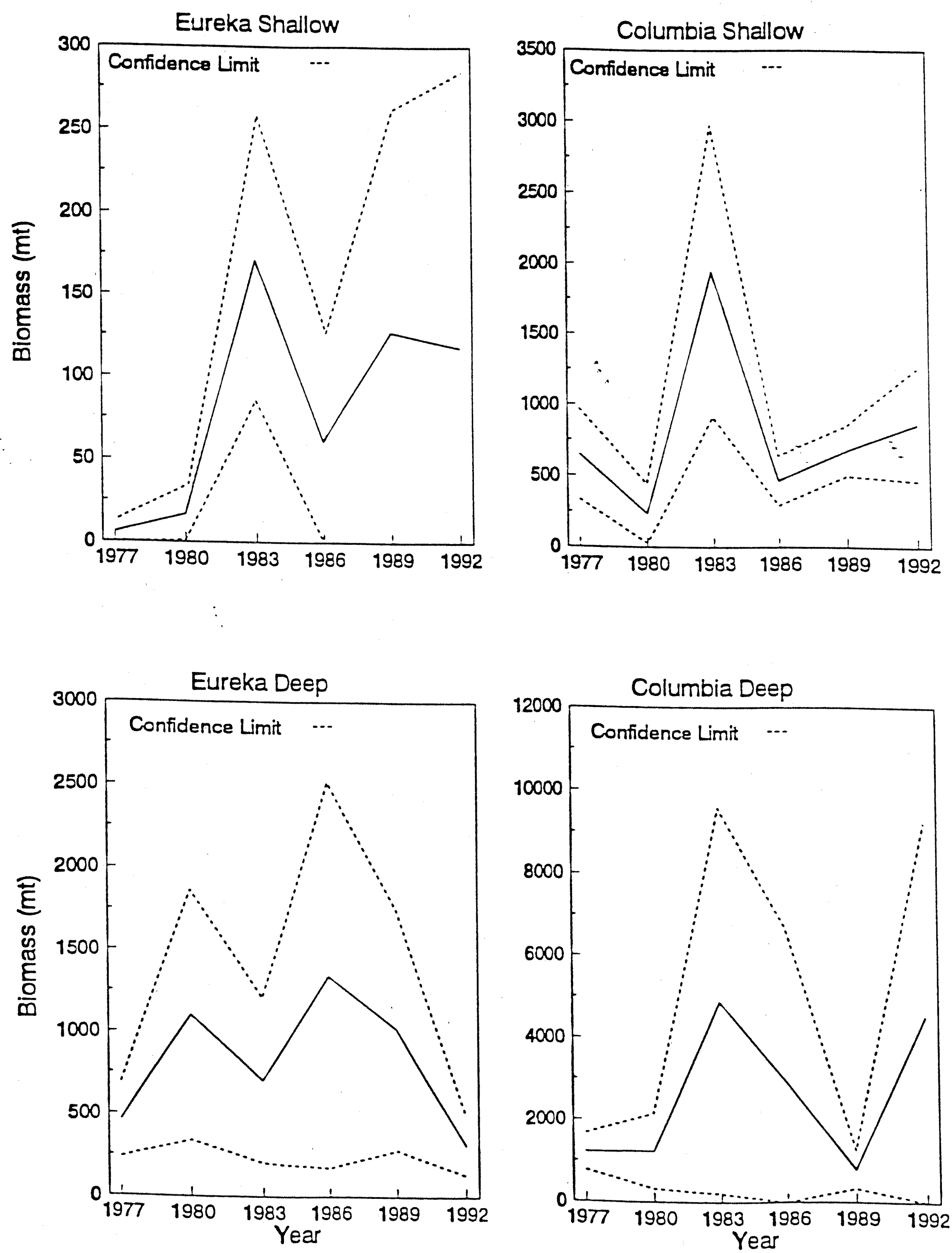

Figure 1. Biomass indices of darkblotched rockfish with 90% confidence limits for shallow (50-183 m) and deep (184-366 m) depth strata of the Eureka and Columbia INPFC areas from triennial westcoast groundfish surveys. Data were provided by Mark Wilkins of the AFSC.

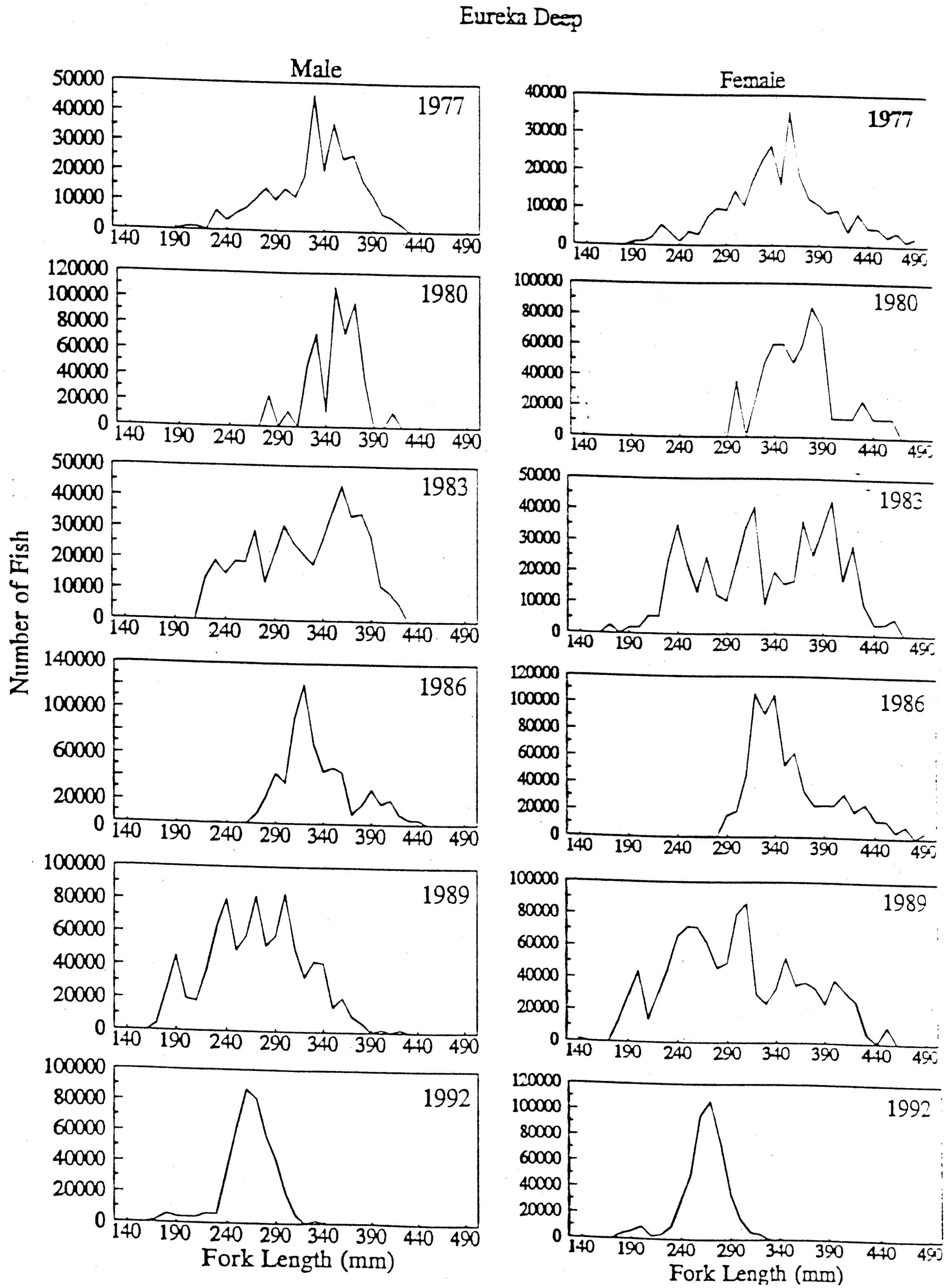

Figure 2a. Length compositions of darkblotched rockfish captured by the triennial surveys a) Eureka 184-366 m, b) Columbia 50-183 m, c) Columbia 184-366 m. Data were provided by Mark Wilkins of the AFSC.

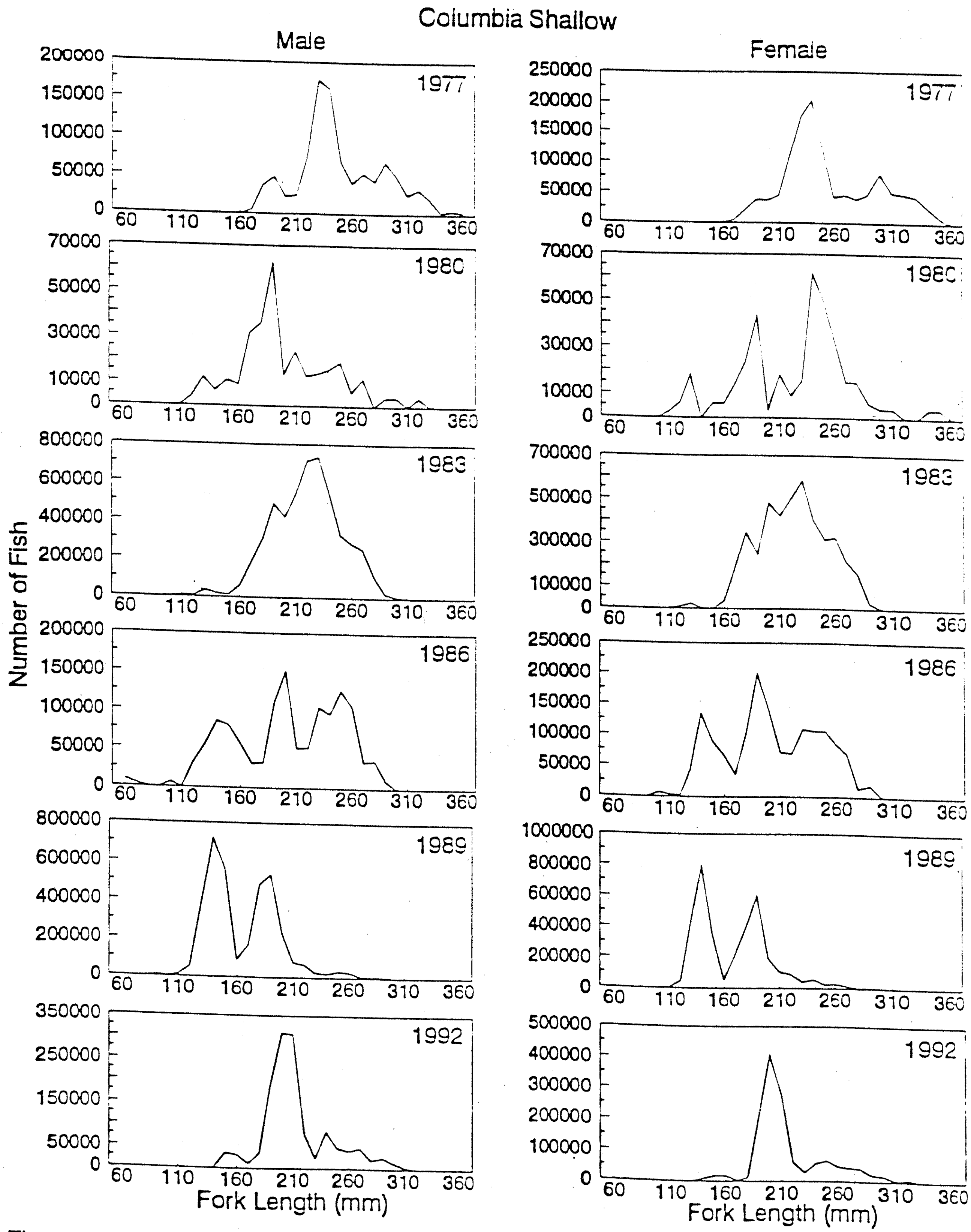

Figure 2b. Length compositions of darkblotched rockfish captured by the triennial surveys a) Eureka 184-366 m, **b**) Columbia 50-183 m, c) Columbia 184-366 m. Data were provided by Mark Wilkins of the AFSC.

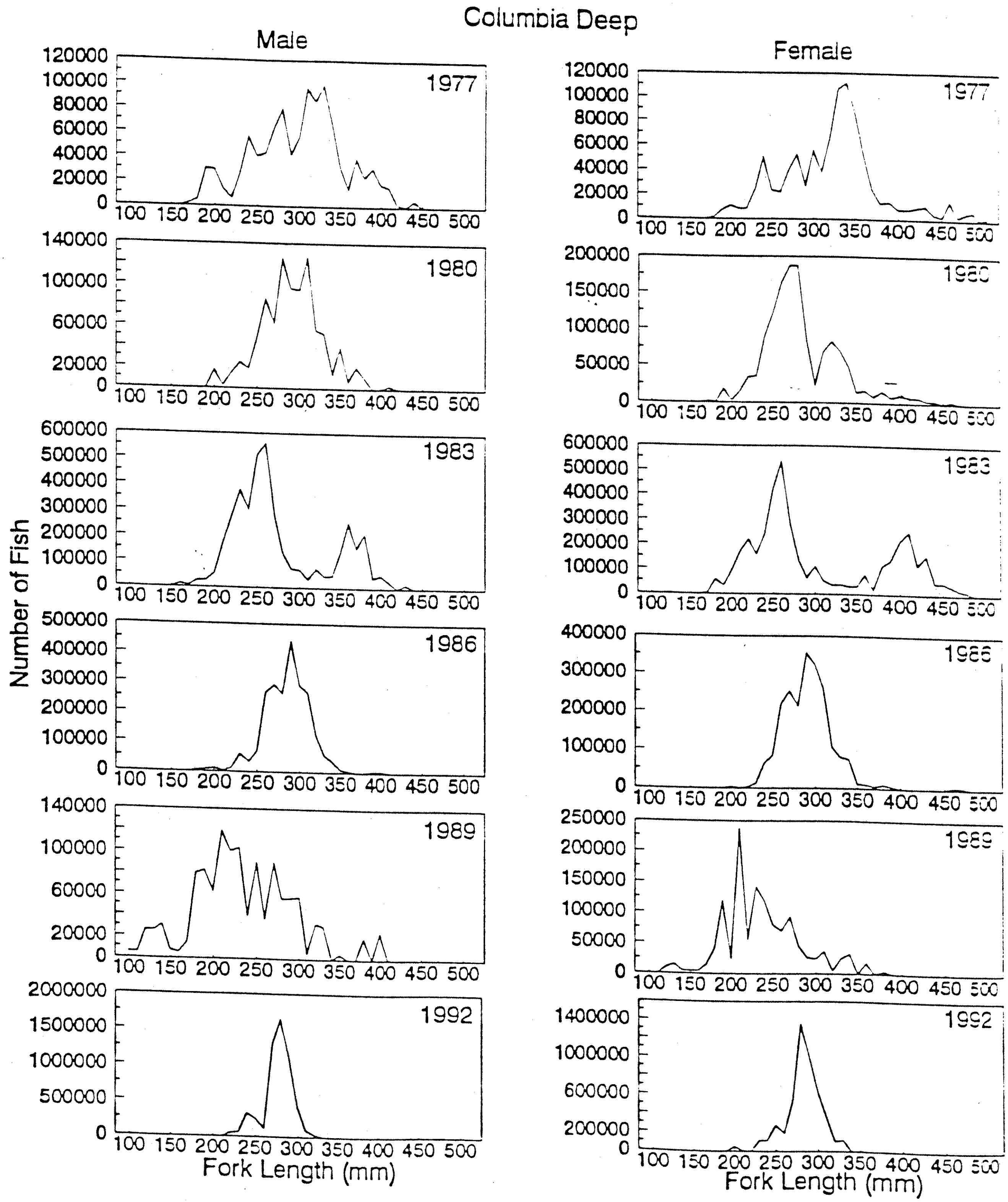

Figure 2c. Length compositions of darkblotched rockfish captured by the triennial surveys a) Eureka 184-366 m, b) Columbia 50-183 m, **c**) Columbia 184-366 m. Data were provided by Mark Wilkins of the AFSC.

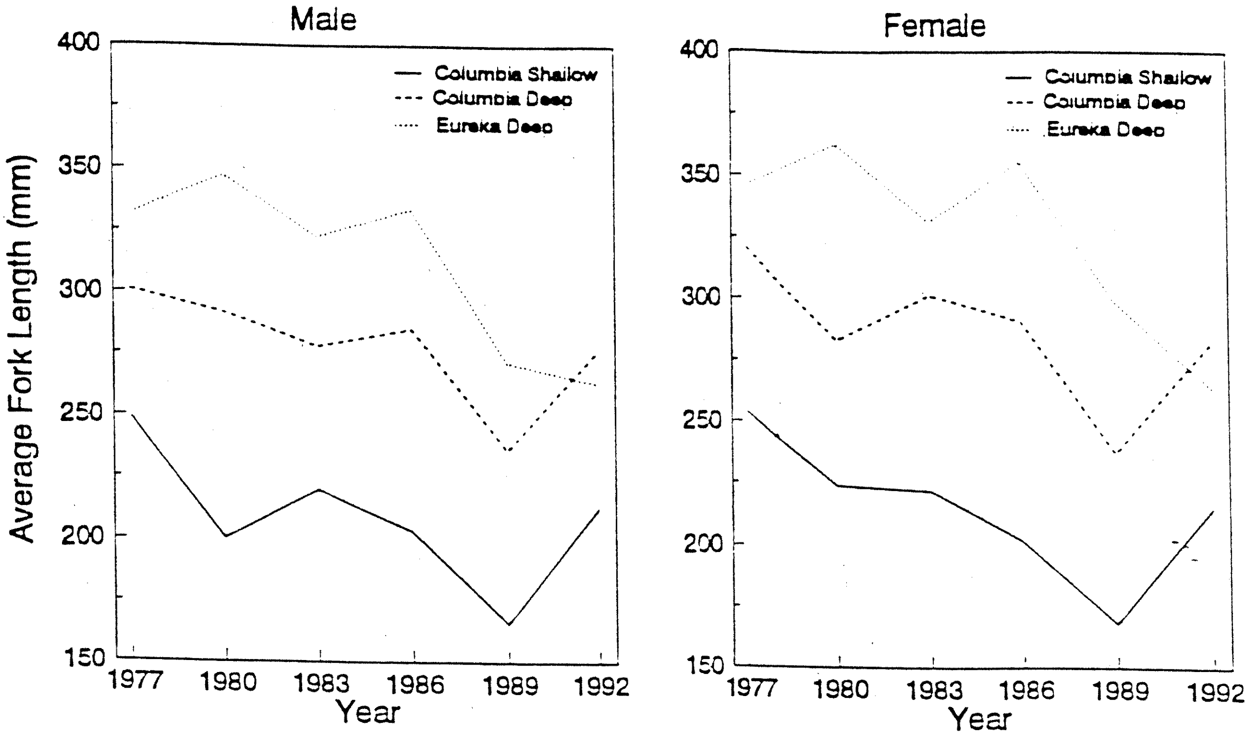

Figure 3. Average length of darkblotched rockfish captured by the triennial surveys in the Eureka and Columbia INPFC areas: shallow (50-183 m), deep (184-366 m). Data were provided by Mark Wilkins.

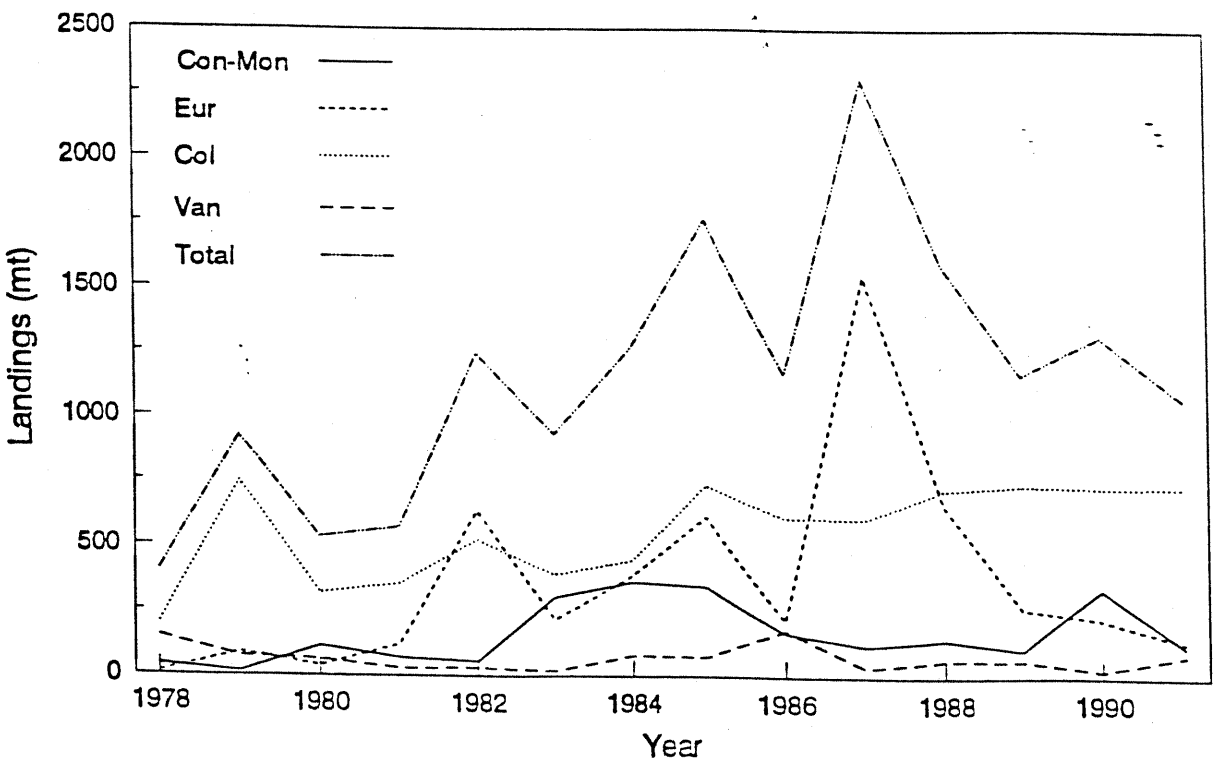

Figure 4. U.S. landings (mt) of darkblotched rockfish by year and INPFC area. Data sources as for Table 2.

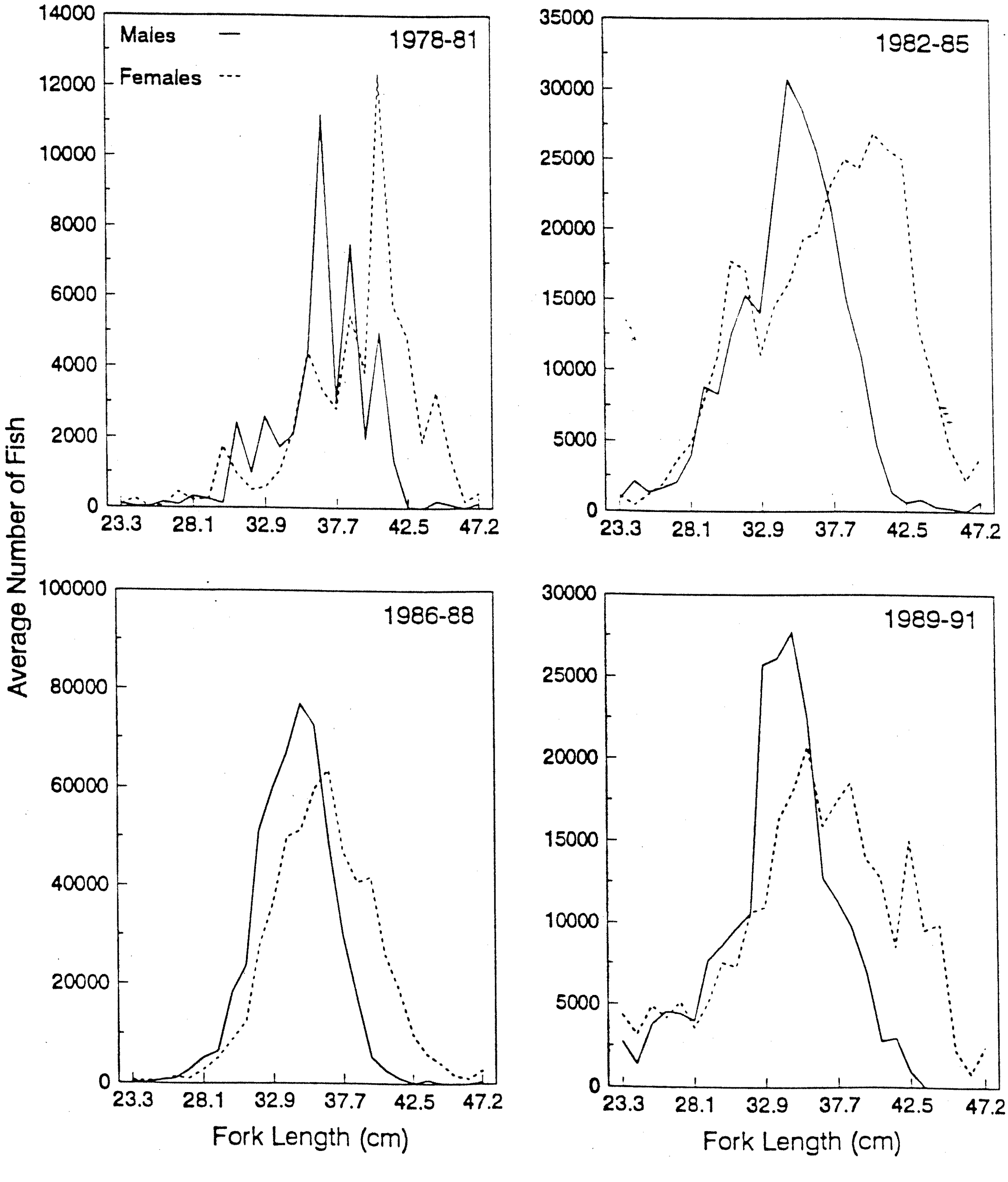

Figure 5. Average length compositions of California landings of darkblotched rockfish during (1978-81), (1982-85), (1986-88), and (1989-91). Data were compiled by Don Pearson (SWFSC) from California portsamples.

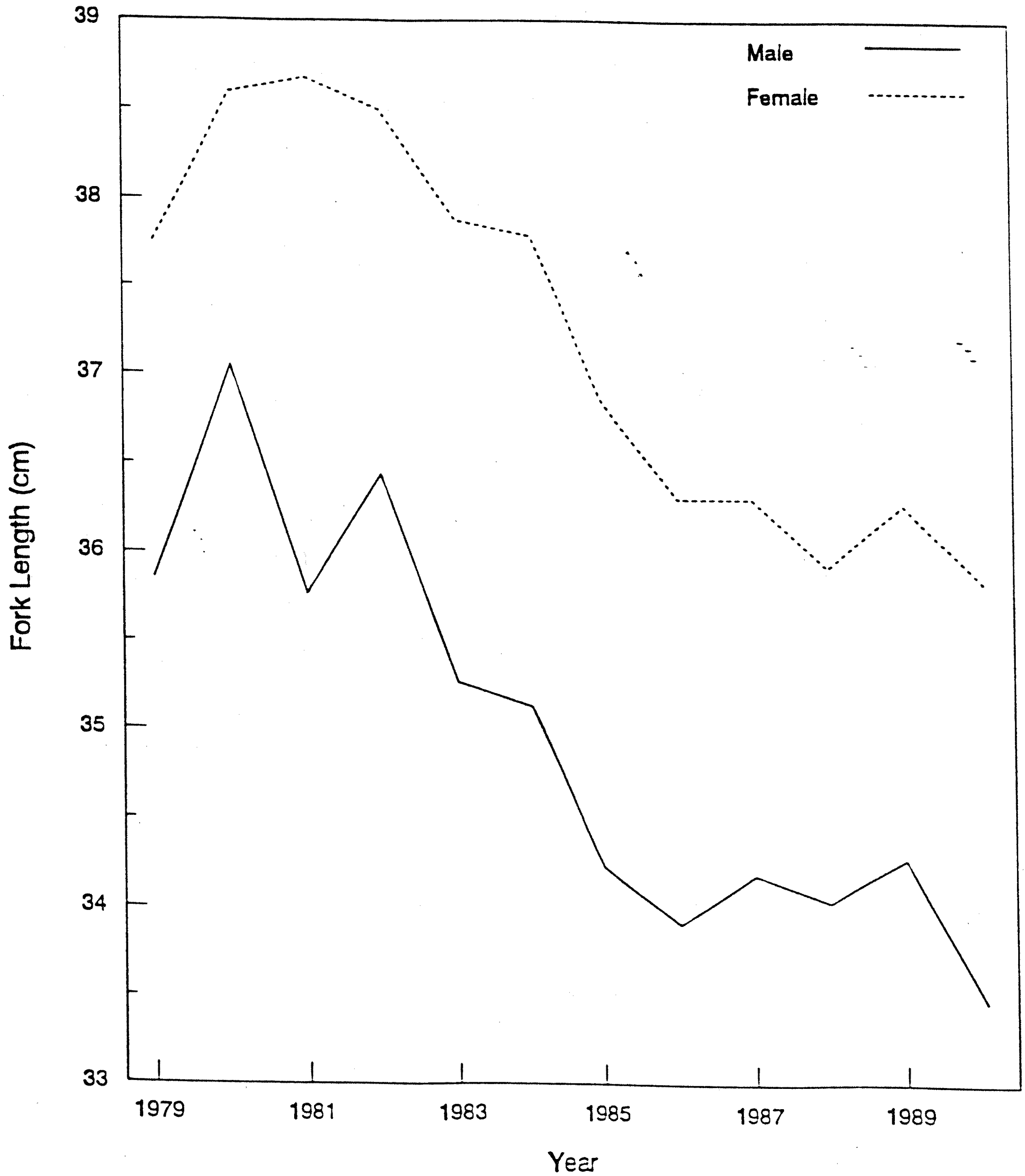

Figure 6. Three year moving averages of lengths of darkblotched rockfish landed in California (1979-90).

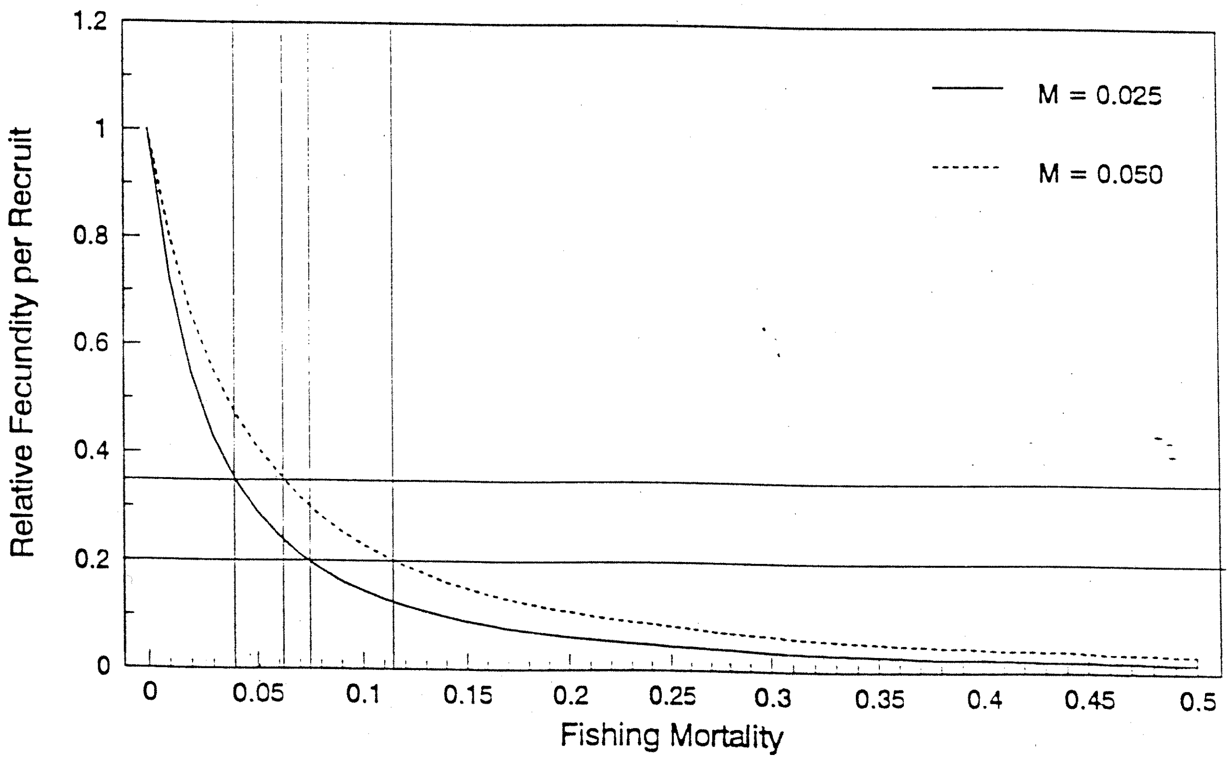

Figure 7. Estimates of relative population fecundity of darkblotched rockfish as a function of natural and fishing mortality. The gridlines are drawn to illustrate F_{35} and F_{20}.

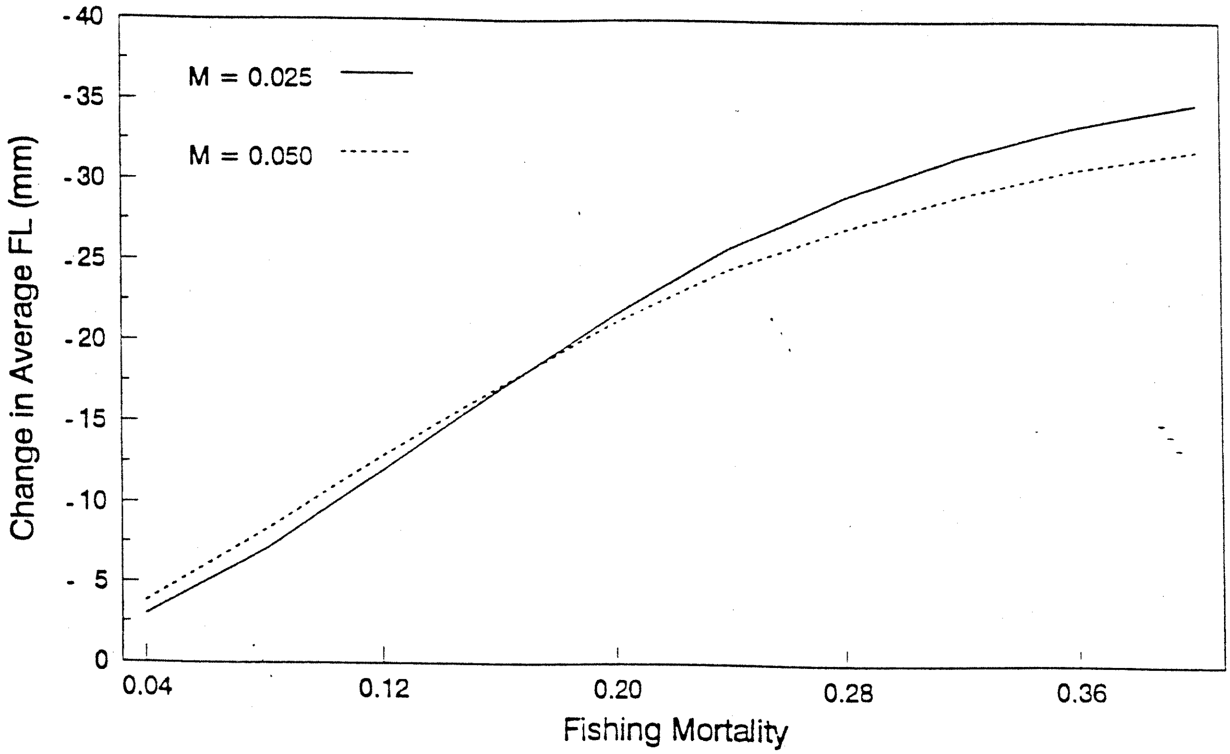

Figure 8. Estimates of the change in length of female darkblotched rockfish during a 10 year period. The simulated population was at equilibrium at the begining of the period and fishing mortality had been 25% of the mortality that occured during the period.