Northwest and Alaska Fisheries Center Processed Report*

A Biological Report on Eight Species of Rockfish *(Sebastes spp.)* from Puget Sound, Washington

by

P.M. Washington, R. Gowan, and D.H. Ito

NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

April 1978

*This report does not constitute a publication and is for information only. All data herein are to be considered provisional.

NOTICE

NORTHWEST AND ALASKA FISHERIES CENTER PROCESSED REPORT*

A Biological Report on Eight Species of Rockfish (*Sebastes* spp.) From Puget Sound, Washington.

by

P. M. Washington, R. Gowan, and D. H. Ito

U. S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
Resource Ecology and Fisheries Management Division

*This report does not constitute a publication and is for information only. All data herein are to be considered provisional.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Approximately 100 species of the family Scorpaenidae occur in the northeasten Pacific Ocean, and two-thirds of these species are rockfish of the genus Sebastes (Mosher et al. 1977). Rockfish are an important commercial and recreational fishery resource in some areas along the northeastern Pacific coast, with over 126,341 metric tons landed in 1976 by trawlers (H. A. Larkins, NMFS Northwest and Alaska Fisheries Center, pers. comm.). In the marine sport fishery of California, over half the catch is rockfish (Young 1969).

Twenty-one species of rockfish are listed by DeLacy et al. (1972) as occurring in Puget Sound, with eight species commonly taken by the sport and commerical fishery. Rockfish are becoming a valued recreational and commercial resource in Puget Sound and adjacent waters. The catch of rockfish by draggers has increased from 7,000 kg in 1966 to over 13,000 kg in 1977 with the sport catch estimated at 90,063 fish in 1976 (G. Bargmann, Washington Department of Fisheries, pers. comm.). Until recently little research or management effort had been directed in the Puget Sound region toward rockfishes; and with the previously low level of fishing there was no real need to intensively manage the different species. In recent years, however, the pressure exerted on the more commonly occurring species has reached a level which requires a greater understanding of their population dynamics.

Smith (1936) reported that the copper rockfish S. caurinus was the most commonly caught rockfish in otter trawls in Puget Sound. DeLacy et al. (1964) reported on the fecundity of rockfish in Puget Sound and Patten (1973) reported on the growth, maturity, feeding habits, and ecology of copper rockfish at two locations in central Puget Sound. Other than the above, little biological information has been published concerning rockfish in Puget Sound.

The study presented is the result of the analysis of three years of collections by the Marine Recreational Fisheries task of the NMFS Northwest and Alaska Fisheries Center in Seattle, Washington. The study was designed to present basic biological information for the eight most commonly occurring species of rockfish in Puget Sound.

METHODS AND MATERIALS

Marine recreational fishery surveys in Puget Sound have by objective been aimed at the recreational resource user group. As such, collections of fishes have been made primarily by angling gears at sites throughout Puget Sound in 0 to 180 m of water.

Collecting fish at different depths and during periods of varying tidal current and wind velocity required the development of several types of angling equipment to insure the proper presentation of baits and lures. The tackle that we used ranged from light spinning to heavy dacron or wire jig gear (Washington 1976) which were used with terminal tackles of bait or artificial lures.

To examine for possible differences in rockfish data between different areas of Puget Sound, we divided the Sound into units of the smallest size that we could reasonably handle--units of one square nautical mile (3.43 km^2). All survey data were classified into these geographical units. Since insufficient data was collected to make comparisons between areas, data was combined for all regions sampled which are shown in Figure 1.

An effort was made to sample fish and to conduct hydroacoustical surveys in each of the study areas of one square nautical mile. Hydroacoustical surveys are generally limited to identifying habitat types inasmuch as most marine species of recreational interest are closely associated with the bottom and their "echoes" are generally lost in the bottom "signal". A bottom profile was made during each survey.

During the survey, location, tide, effort, date, time, species captured, fishing depth, terminal tackle, and bottom type information was recorded. Collections were processed within 24 h of capture (individuals having been identified by the insertion in a fleshy spot of a numbered dart tag), at which

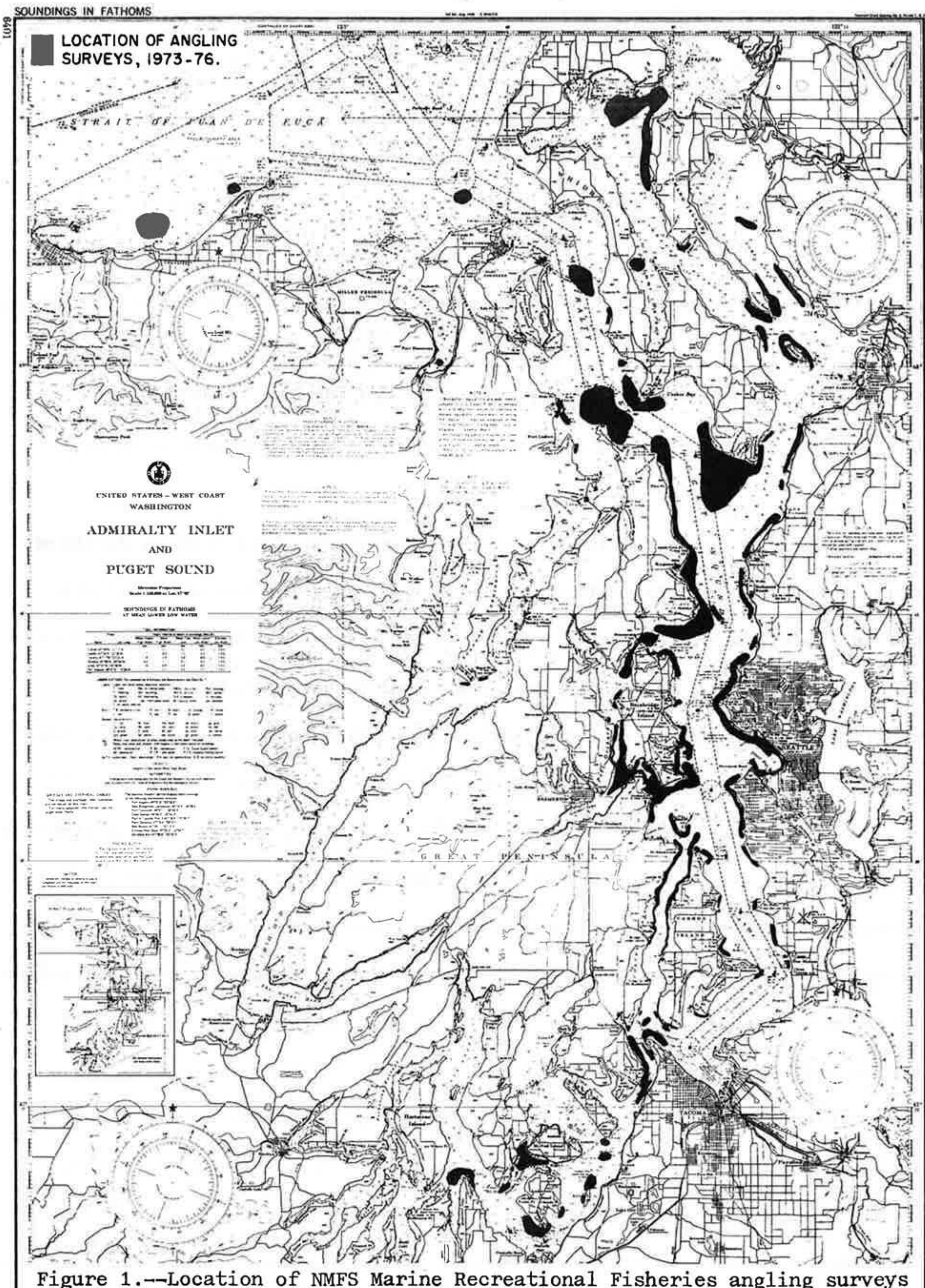


Figure 1.--Location of NMFS Marine Recreational Fisheries angling surveys in Puget Sound, Washington, 1973-76.

time the species identification was verified, total length (mm), body weight (to the nearest .01 kg), sex of fish, gonadal condition, gonad weight (g), and scales and/or otoliths (to determine age of fish) were taken. In addition, the stomachs of all specimens were inspected for qualitative content information. Contents were identified to species when possible, but in general, due to their state of digestion, were relegated to family groupings.

The aging techniques for Puget Sound rockfishes are for the most part still in the developmental stages and have been based on the procedures for interpreting otoliths of Pacific ocean perch, S. alutus. Rockfish otoliths were interpreted using diffused light and by reading along the posterior dorsal axis with corroborating evidence being gained by following the annulus around the otolith. The determination of an annulus is based on the length of the mark and the relative spacing of annuli, which is an indicator of the relative rate of growth.

The fecundity study in this report was based on 23 female copper rockfish selected from surveys during the first four months of 1977 off southern Bainbridge Island and in Colvos Passage (Figure 1). The specimens were caught during the early months of the year because copper rockfish in Puget Sound develop to maturity during the winter and subsequently spawn in the spring (DeLacy et at. 1964).

Individuals used in the fecundity study were selected after the biological data were recorded for those specimens. The ovaries were then carefully excised and examined for maturation and weighed (to the nearest .01 g). Only ovaries of mature adults (i.e., fish with large, yellow eggs) were used to determine fecundity. The use of large, yellow eggs minimized the probability of counting immature ova (DeLacy et al. 1964; Mac Gregor 1970; Raitt 1933).

The selected ovaries were slit longitudinally, turned inside out, and placed in modified Gilson's flud. This method of preservation was similar to that followed by Simpson (1951) for North Sea plaice, Platessa platessa; however, because of the highly toxic and environmentally dangerous mercury content of Gilson's fluid, the 20 g of mercuric chloride was replaced by 20 ml of Formalin.[1/] The resulting modification adequately softened the ovarian tissue and facilitated the separation of the eggs. The ovaries were allowed to remain in the modified Gilson's fluid for 3 weeks, during which they were periodically shaken to assist penetration of the preservative.

After the preservation treatment, the ovaries were broken into clumps of about 10 mm diameter. The eggs were then passed through a number 16 Tyler Standard Sieve; the resulting filtrate was decanted and washed until only a small amount of suspended material was seen. Finally, the cleaned and separated eggs were placed in 10% Formalin and stored prior to counting.

The method of enumeration was similar to that followed by Gunderson (1976). This method involved placing ova in a 3 liter beaker, then adding 2,000 ml of water. The beaker was then magnetically stirred until the ova were well distributed throughout the water medium. A 10 ml pipet was then drawn down through the well distributed mixture and a 7 ml subsample was withdrawn. The subsample was counted twice; then the eggs and water were returned to the beaker for the taking of the next subsample. Care was taken to evenly sample all parts of the water column.

The number of subsamples counted from each ovary depended on the coefficient of variation, i.e., the standard deviation divided by the mean of the subsample counts. If the coefficient of variation (c.v.) for the first 3

1/ Reference to trade names(s) in this report does not imply endorsement of commercial product(s) by the National Marine Fisheries Service, NOAA.

subsamples was greater than 10%, subsequent subsamples were taken until the c.v. was less than 10%. It was felt that if this was done, the variability due to the subsampling procedure would be adequately minimized.

After all the subsamples were counted, the average number of ova per ml was calculated for each specimen. The estimated fecundity was then calculated using the formula: $F = 2,000n$, where F = fecundity and n = mean numbers of eggs per ml in the subsamples of each ovary.

Calculations for the length-fecundity regression equations and analysis of covariance were accomplished by using the BMD 3R4V computer program.

Length/weight data were analyzed using a production computer program to calculate the bivarate regression of the equation LogW - a+bLogL. After obtaining relationships by sex, when sample size was large enough, the sexes were combined into a common length-weight line for the species.

Length-age data were fit to the Von Bertalanffy function for six species of rockfish by sex and combined. The function fit was of the standard form $W_t = L\infty (1-e^{-k\ (t-t\ )b}$ with a weighing factor calculated using GROWFIT, a production program by Somerton (1976). A weighing factor was used since the variability of length at age is a function of age. Variance is assumed to follow the relationship $VAR = Ae^{Bt}$ with t equal to age at time t with A and B as constants.

With the estimated age composition of the stock it is possible to estimate the annual mortality rate of the species. Mortality rates were estimated by the Hencke survivorship/ration (Ricker 1968).

RESULTS

Qualitative Study of Some Rockfish Food Items

It was not possible to obtain accurate quantitative data on rockfish stomach contents because of the large number of empty stomachs and the frequently observed regurgitation of food by fish during their capture. We did, however, examine (qualitatively) stomachs to determine what food items were being eaten and the frequency of their occurrence. All specimens examined were taken during the 1973-76 surveys. No attempt was made to relate diet to a specific area or size of fish. The stomach contents of brown, *S. auriculotus*; copper; yellowtail, *S. flavidus*; quillback, *S. maliger*; black, *S. melanops*; and yelloweye rockfish, *S. ruberrimus*; and bocaccio, *S. paucispinis*, are analyzed below.

Copper rockfish

The stomachs of 347 copper rockfish from the 1974-76 surveys were qualitatively examined (Table 1). Crustaceans and fish, in that order, were the most frequently observed organisms. Most of the stomachs were empty--a total of 178, or 52%.

The major types of food in terms of frequency of occurrence in stomachs were the crustaceans, of which 37% were crab and 20% shrimp. Shrimp species were primarily coonstripe shrimp, *Pandalus danae*.

Fish followed crustaceans in frequency of occurrence in stomachs. A number of different species were present and blennioiids were found most often. Of note were some spiny dogfish, *Squalus acanthias*, that had been eaten by large copper rockfish (Bargmann 1977).

All other items (mollusks, polychaetes, plant material, and foreign objects) made up 13% of the total occurrences.

Table 1.--Occurrence of various food items in copper rockfish, by months; 1974-76.

Food Types	Jan 1	Feb 2	Mar 3	Apr 4	May 5	June 6	July 7	Aug 8	Sept 9	Oct 10	Nov 11	Dec 12	Total occur.	% of fish sampled	% Occur-rence
Empty stomachs	65%	63%	89%	87%	41%	28%	33%	49%	44%	73%	50%	52%	178	51.9	46.0
Unidentified															
Digested	0	0	0	0	5%	1%	21%	0	0	13%	0	0	13	3.8	3.0
Eggs	0	4%	0	0	0	0	0	0	0	0	0	0	1	0.3	0.3
Fish															
Unidentified	6%	4%	11%	7%	4%	6%	4%	10%	0	7%	0	9%	23	6.7	6.0
Blenny	0	0	0	0	8%	2%	0	0	0	0	25%	9%	15	4.4	4.0
Sandlance	0	0	0	0	0	1%	0	0	0	0	0	0	1	0.3	0.3
Surf perch	0	0	0	0	0	0	0	5%	0	0	0	0	2	0.6	0.5
Herring	0	0	0	0	2%	1%	0	3%	0	7%	0	0	5	1.4	1.0
Cottid	0	0	0	0	0	1%	0	0	0	0	0	0	1	0.3	0.3
Dogfish	0	0	0	0	0	1%	0	0	0	0	0	3%	2	0.6	0.6
Total Fish													49	14.3	13.0
Crustaceans															
Crab (sp.)	6%	11%	0	0	16%	5%	0	8%	0	0	0	9%	30	8.7	8.0
Rock crab	0	0	0	0	1%	20%	4%	0	14%	0	0	0	22	6.4	6.0
Kelp crab	0	0	0	7%	12%	6%	0	0	14%	0	0	0	19	5.5	5.0
Dungeness	0	0	0	0	4%	1%	0	5%		0	0	0	7	2.0	2.0
Shrimp (sp.)	12%	11%	0	0	2%	17%	4%	21%	14%	0	25%	15%	41	11.9	11.0
Euphasids	0	0	0	0	0	0	4%	0	0	0	0	0	1	0.3	.3
Other	0	7%	0	0	1%	4%	29%	0	0	0	0	0	14	4.1	4.0
Total Crustaceans													134	39.1	34.6
Molluscs															
Squid	6%	0	0	0	0	0	0	0	0	0	0	0	1	0.3	0.3
Bivalves	0	0	0	0	1%	1%	0	0	14%	0	0	0	3	0.9	0.8
Chitton	0	0	0	0	1%	0	0	0	0	0	0	0	1	0.3	0.3
Plant material															
Kelp	0	0	0	0	0	1%	0	0	0	0	0	0	1	0.3	0.3
Eel grass	0	0	0	0	0	1%	0	0	0	0	0	0	1	0.3	0.3
Misc. Extrania	0	0	0	0	0	2%	0	0	0	0	0	3%	6	1.7	2.0
Total occurrences	17	27	9	15	93	96	24	39	7	15	12	33	387		100
Sample size	16	24	9	15	83	71	19	38	6	14	11	26	343	100	

Some information has been published on the feeding habits of copper rockfish. Patten (1972) found surfperches, family Embiotocidae, to be the major fish prey species in his study areas, which were artificial reefs, in Puget Sound. (In our studies embiotocids occurred very rarely.) Prince and Gotshall (1976) found copper rockfish eating a much wider variety of food items than the fish examined by Patten and us, which is to be expected from a study conducted off California in waters having a much larger number of possible prey species. We agree with Prince and Gotshall's categorization of copper rockfish as an opportunistic carnivore.

Quillback rockfish

During the course of our surveys 216 quillback rockfish stomachs were examined (Table 2), of which 100 (46%) were empty. This represents a 6% decrease from the 52% occurrence of empty stomachs in copper rockfish--in spite of the increased average depth of capture of quillback rockfish which would presumably cause increased voiding of stomach contents. Of the 139 stomachs in which food items were found, it was readily apparent that copper and quillback rockfish utilized the same food items, but in markedly different proportions (Table 3). Quillback rockfish consumed far less fish (7% - 23% in copper rockfish), and crabs (9% - 37% in copper rockfish) than did copper rockfish. Various shrimp species were similar in amount in the diet of quillback and copper rockfish (17% - 20%). A number of crustaceans were combined under the "other" category and made up the remainder of the total crustaceans (46%).

Mollusks, polycheates, unidentifiable digested materials and plant materials were 47% of the occurrences.

Table 2.--Occurrence of major food items in quillback rockfish, by months; 1974-76.

Food Types	Jan 1	Feb 2	Mar 3	Apr 4	May 5	June 6	July 7	Aug 8	Sept 9	Oct 10	Nov 11	Dec 12	Total occur.	% of fish sampled	% Occur-rence
Empty stomachs	60%	94%	70%	50%	35%	16%	26%	43%	78%	80%	100%	36%	100	46.1	41.7
Unidentified															
Digested	0	6%	0	50%	45%	34%	39%	26%	0	0	0	9%	62	28.6	25.8
Eggs	0	0	0	0	0	0	0	3%	0	0	0	0	1	0.5	0.4
Fish															
Unidentified	10%	0	9%	0	0	6%	0	0	0	0	0	9%	8	3.7	3.3
Sandlance	0	0	0	0	0	0	0	0	11%	0	0	0	1	0.5	0.4
Herring	0	0	4%	0	0	0	0	0	0	0	0	0	1	0.5	0.4
Total Fish													10	4.6	4.2
Crustaceans															
Rock crab	10%	0	0	0	0	3%	0	0	0	0	0	0	3	1.4	1.2
Kelp crab	0	0	0	0	0	1%	0	0	0	0	0	0	1	0.5	0.4
Unidentified crab	0	0	13%	0	0	6%	0	6%	0	0	0	0	9	4.1	3.7
Coonstripe	20%	0	4%	0	10%	8%	3%	23%	11%	20%	0	36%	24	11.1	9.8
Other	0	0	0	0	10%	26%	29%	0	0	0	0	9%	27	12.4	11.0
Total Crustaceans													64	29.5	26.7
Molluscs															
Bivalves	0	0	0	0	0	0	3%	0	0	0	0	0	1	0.5	0.4
Polychaete	0	0	0	0	0	1%	0	0	0	0	0	0	1	0.5	0.4
Plant material															
Kelp	0	0	0	0	0	1%	0	0	0	0	0	0	1	0.5	0.4
Total occurrences	10	16	23	6	20	70	39	35	9	5	1	11	240		100
Sample size	9	16	23	6	20	46	37	33	9	5	1	11	217	100	

Table 3.--Occurrence (percentage of frequency) of major food items in the stomachs of seven species of rockfish captured in Puget Sound, 1974-76.

Food Item	Copper No.	Copper %	Quillback No.	Quillback %	Brown No.	Brown %	Black No.	Black %	Yellowtail No.	Yellowtail %	Bocaccio No.	Bocaccio %	Yelloweye No.	Yelloweye %
Fish	49	23.3	10	7.2	17	32.7	21	25.0	13	50.0	1	100	15	100
Crustaceans														
Crabs	78	37.1	13	9.4	6	11.5	4	4.8	4	15.4	0	-	0	-
Shrimp	41	19.5	24	17.3	14	26.9	4	4.8	0	0.0	0	-	0	-
Other	15	7.1	27	19.4	7	13.5	1	1.2	5	19.2	0	-	0	-
Total	134	63.8	64	46.0	27	51.9	9	10.7	9	34.6	0	-	0	-
Molluscs	5	2.4	1	0.7	0	-	0	-	0	-		-	0	-
Ctenophores/ Jelly fish	0	-	0	-	0	-	3	3.6	0	-	0	-	0	-
Misc.	22	10.5	64	46.0	8	15.4	51	60.7	4	15.4	0	-	0	-
Total Occurrences 1/	210	-	139	-	52	-	84	-	26	-	1	-	15	-

1/ Sum of instances in which a food item occurred (empty or voided stomachs were excluded).

Table 4. Occurrence of major food items in brown rockfish stomachs, by months; 1974-76.

Food Types	Jan 1	Feb 2	Mar 3	Apr 4	May 5	June 6	July 7	Aug 8	Sept 9	Oct 10	Nov 11	Dec 12	Total occur.	% of fish sampled	% Occurrence
Empty stomachs	57%	100%	100%	100%	59%	50%	32%	40%	33%	-	30%	100%	60	57.7	53.6
Unidentified digested	0	0	0	0	6%	0	37%	0	0	-	0	0	8	7.7	7.1
Fish															
Unidentified	26%	0	0	0	0	0	5%	0	0	-	15%	0	10	9.6	8.9
Sandlance	4%	0	0	0	0	0	0	0	0	-	25%	0	6	5.8	5.4
Perch	4%	0	0	0	0	0	0	0	0	-	0	0	1	1.0	0.9
Total Fish													17	16.4	15.2
Crustacean															
Kelp crab	0	0	0	0	0	0	0	0	33%	-	0	0	1	1.0	0.9
Unidentified crab	0	0	0	0	12%	17%	0	40%	0	-	0	0	5	4.8	4.5
Shrimp (unidentified)	9%	0	0	0	18%	0	11%	0	33%	-	30%	0	14	13.5	12.5
Other	0	0	0	0	6%	33%	16%	20%	0	-	0	0	7	6.7	6.3
Total Crustaceans													27	26.0	24.1
Total occurrences	23	4	11	2	17	6	19	5	3	-	20	2	112		100
Sample size	20	4	12	2	17	6	18	5	2	-	16	2	104	100	

Brown rockfish

The stomachs of 104 brown rockfish (Table 4) were examined and 60 (58%) were empty. The remaining 44 stomachs had food: crustaceans (52% of the occurrences) and fish (33%). Most of the fish remains in brown rockfish stomachs were unidentifiable. However, Pacific sandlance, *Ammodytes hexapterus*, and embiotocids were 14% and 2%, respectively, of the occurrences.

Crustaceans in brown rockfish stomachs included crabs (12%), shrimp (27%), and a grouping of "other" (14%). Most of the crabs were unidentifiable, with the exception of one kelp crab; shrimp and "other" categories were combined for the same reason.

Black rockfish

Black rockfish stomachs totaled 200, of which 59% were empty. In another 26% of the stomachs, the contents were digested beyond recognition. From the remains in the stomachs, we were able to gather the following qualitative information on food organisms: (1) fish made up 64% of the identifiable food items; (2) crustaceans were 27% of the identifiable food items; and (3) jellyfish and ctenophora were 6% and 3% of the identifiable items respectively. A breakdown of food items in black rockfish stomachs as a percent of the frequency of occurrence is listed in Table 5. Pacific herring, *Clupea harengus pallasi*, and Pacific sandlance were the most frequent organisms (27% and 24% respectively), followed by crab larvae (12%), shrimp (12%), jellyfish (6%), euphasids (3%), and ctenophoras (3%).

Yellowtail rockfish

Food preference of yellowtail rockfish was similar to black rockfish (Table 6). Again, most of the stomachs were empty (60%) and the contents of 8% were digested beyond recognition. The remaining 18 stomachs contained fish (13 stomachs) and crustaceans (5 stomachs). In terms of occurrence of

Table 5.--Occurrence of major food items in black rockfish, by months; 1974-76.

Food Types	Jan 1	Feb 2	Mar 3	Apr 4	May 5	June 6	July 7	Aug 8	Sept 9	Oct 10	Nov 11	Dec 12	Total occur.	% of fish sampled	% Occur-rence
Empty stomachs	-	1	-	-	89%	31%	36%	78%	77%	-	-	-	116	58.9	58.0
Unidentified digested material	-	0	-	-	0	60%	35%	3%	4%	-	-	-	51	25.9	25.5
Fish															
Unidentified	-	0	-	-	5%	0	6%	0	0	-	-	-	4	2.0	2.0
Sandlance	-	0	-	-	0	5%	0	3%	15%	-	-	-	8	4.1	4.0
Herring	-	0	-	-	3%	2%	0	15%	4%	-	-	-	9	4.6	4.5
Total Fish													21	10.7	10.5
Crustacean															
Crab larvae	-	0	-	-	0	0	12%	0	0	-	-	-	4	2.0	2.0
Shrimp	-	0	-	-	0	3%	6%	0	0	-	-	-	4	2.2	2.1
Euphasids	-	0	-	-	0	0	3%	0	0	-	-	-	1	0.5	0.5
Total Crustaceans													9	4.6	4.5
Scyphozoans															
Jellyfish	-	0	-	-	0	0	3%	3%	0	-	-	-	2	1.0	2.1
Ctenophora	-	0	-	-	3%	0	0	0	0	-	-	-	1	0.5	0.5
Total Scyphozoans													3	1.5	1.5
Total occurrences	-	1	-	-	37	62	34	40	26	-	-	-	200		100
Sample size	-	1	-	-	37	62	33	37	26	-	-	-	197	100	

Table 6.--Occurrence of major food items in yellowtail rockfish, by months; 1974-76.

Food Types	Jan 1	Feb 2	Mar 3	Apr 4	May 5	June 6	July 7	Aug 8	Sept 9	Oct 10	Nov 11	Dec 12	Total occur.	% of fish sampled	% Occur-rence
Empty stomachs	-	-	100%	-	0	33%	75%	56%	67%	-	-	60%	29	58.0	56.9
Unidentified digested	-	-	0	-	0	0	25%	12%	0	-	-	12%	4	8.0	7.8
Fish															
Sandlance	-	-	0	-	100%	11%	0	4%	33%	-	-	0	4	8.0	7.8
Herring	-	-	0	-	0	0	0	28%	0	-	-	0	7	14.0	13.7
Total Fish													13	26.0	25.5
Crustacean															
Crab larvae	-	-	0	-	0	44%	0	0	0	-	-	0	4	8.0	7.8
Euphasids	-	-	0	-	0	11%	0	0	0	-	-	0	1	2.0	2.0
Total Crustaceans													5	10.0	9.8
Total occurrences	-	-	4	-	1	9	4	25	3	-	-	5	51		100
Sample size	-	-	4	-	1	8	4	25	3	-	-	5	50	100	

identifiable items as a percent of frequency, the following food organisms were found: Pacific herring (39%), Pacific sandlance (22%), crab larvae (22%), and euphausids (6%).

Bocaccio

All but one of the nineteen bocaccio stomachs were empty, due to regurgitation. The one item noted was a fish digested beyond further recognition.

Yelloweye rockfish

The stomachs of 47 yelloweye rockfish were examined and 68% (32 stomachs) were empty, mostly due to distention from extreme depth changes at time of capture (Table 7). The remaining 16 contained a variety of fish species which included walleye pollock, *Theragra chalcogramma*; Pacific hake, *Merluccius productus*; Pacific cod, *Gadus macrocephalus*; and a poacher (family Agonidae). In over half the occurrences the fish remains were digested beyond recognition.

Timing of Maturation and Reproduction

Numerous investigators during the past century have investigated *Sebastes* species of the northeastern Pacific Ocean, and it is generally accepted that all are live-bearers (Moser et al. 1977). Information available on the reproduction of a number of these species is found in Westrheim (1975). Of the species dealt with in this paper, brown and copper rockfish are the only ones whose reproduction and reproductive timing in Puget Sound have been investigated (DeLacy et al. 1964; Patten 1973).

Rockfish were collected from various locations in Puget Sound during most months of the year from July 1973 to January 1977. Male and female gonads of individuals were inspected, and categorized as to maturity stage according to the criteria listed in Table 8. These criteria generally

Table 7.--Occurrence of major food items in yelloweye rockfish, by months; 1974-76.

Food Types	Jan 1	Feb 2	Mar 3	Apr 4	May 5	June 6	July 7	Aug 8	Sept 9	Oct 10	Nov 11	Dec 12	Total occur.	% Occurrences
Empty stomachs	100%	-	26%	-	-	100%	80%	90%	50%	0	-	-	32	68.1
Fish														
Unidentified	0	-	17%	-	-	0	0	0	25%	0	-	-	9	19.1
Walleye pollock	0	-	0	-	-	0	0	10%	0	0	-	-	1	2.1
Cottid	0	-	0	-	-	0	0	0	1%	0	-	-	1	2.1
Poacher						0	20%	0	0	0	-	-	2	4.3
Pacific cod	0	-	2%	-	-	0	0	0	0	100%	-	-	2	4.3
Total Fish													15	31.9
Total occurrences	2	-	12	-	-	8	10	10	8	1	-	-	47	100
Sample size	2	-	12	-	-	8	10	10	8	1	-	-	47	

Table 8.--Initial criteria for the observed stages of maturity for rockfish males and females.

Stage of maturity[1/]	Code	Characteristics of gonads
1	10	Maturity unknown
2	20	Juvenile
3	30	Adult: immature-maturing
4	40	Adult: mature ripe
5	50	Adult: spent or resting

1/ Described by DeLacy et al. (1964).

coincide with those of DeLacy et al. 1964. The period of development of brown and copper ova and embryos was found to be somewhat similar to that found by DeLacy et al. (1964) and Patten (1973). During the winter-spring of 1975-76, the rate and timing of gonad development seemed related to physical phenomena. Insemination, gestation, and parturition were delayed one month during these seasons which were marked by prolonged cold, rainy weather conditions--possible evidence for a relationship between photo period, temperature, and reproduction in rockfish in Puget Sound.

Male brown rockfish began to show signs of the onset of maturity in December, and by April most were spent. Most female brown rockfish were mature by March, and parturition of their eggs occurred in June.

Male copper rockfish normally began to show signs of the onset of maturity in December and were normally ripe in January and spent by March. Female copper rockfish usually had mature ova in January, and parturition of their eggs usually occurred in April. In 1975 and 1976 unusually high rainfall and cold temperatures extended parturition through May. There was also evidence that some fish spawned in late summer; there was, however, no indication of multiple spawning by these late summer spawners.

Mature yellowtail rockfish were not captured during our surveys in Puget Sound. Examination of catch records of Puget Sound trawling operations (by commercial and research vessels) indicate that adult yellowtail rockfish were not taken. The implications are that yellowtail rockfish do not spawn in Puget Sound, nor are adults of this species found in those waters.

Male and female quillback rockfish began showing signs of maturation in December. Insemination in Puget Sound stocks probably occurred in March and parturition usually occurred in May. Quillback rockfish, as was the case with brown and copper rockfish, exhibited delays in parturition during the 1975 and

1976 seasons, which may be linked in some way with unusually cold and wet weather conditions.

Information on the period of reproduction for black rockfish is very limited. Three males were collected in central Puget Sound in early January 1977 and found to be spent (condition code 50 of Table 8). In late January 1977 a spent female (condition code 51) that was 58 cm was taken by a set-net fisherman in Puget Sound. The female had been taken in 50 m of water while the males caught earlier in the month were found near the surface in an area that black rockfish were known to inhabit. Numerous efforts during December and January 1977 failed to produce any other adult specimens from areas where they were normally abundant. This would seem to indicate the movement of adults from feeding areas to areas used for reproduction.

Little can be said about the reproduction of bocaccio in Puget Sound, other than the fact that several adult male bocaccio in ripe condition (condition code 40) were collected in mid to late January 1977.

The reproduction period for yelloweye rockfish from Puget Sound is probably early spring and late summer. Sparse data from our surveys indicate two periods of insemination annually, as evidenced by the availability of ripe males in July and December. Equally sparse data gives evidence of maturation during winter and summer, spawning in early spring and mid-late summer, and a period of the spent and/or resting stage in late spring and fall. Females ripe with prepartuition larvae have been captured in both early spring and mid-late summer. During early spring and mid-late summer all females captured were either preparturition or postparturition (spent or resting).

Fecundity of Copper Rockfish

The results of the enumeration proceedings are shown in the appendix ($\bar{x}$ ova/ml, s_x, and $s_{\bar{x}}$ have been rounded off to 3 and 4 significant figures; s_x is the standard deviation from the actual subsample counts from each specimen). Note that in only 2 cases the c.v. was greater than 10%, that is, only twice was it necessary to count more than 3 subsamples.

The length-fecundity data was assumed to follow the power curve relationship; $F = al^b$, where F = fecundity, L = total length in mm, and a and b the intercept and slope respectively. The method of least squares was used to fit ln F and ln L to a straight line.

Fecundity was shown to increase at a rate proportional to about the fifth power of the total body length ($F = 2.7404 \times 10^{-8} L^{4.9567}$). The correlation coefficient (r) for the above regression was 0.94.

To date the only known fecundity study on the copper rockfish in the Puget sound area was performed by DeLacy et al. (1964). Their fecundity data was recalculated and the results showed a slight discrepancy between the published and recalculated regression equations. This discrepancy, although relatively small, may have been a typographical or a computational error on the part of the investigators. Any comparisons dealing with the DeLacy et al. (1964) study will be based on the published data.

Analysis of covariance was used to test for a common line between the length-fecundity data obtained from this and the DeLacy et al. studies. However, in order for the analysis to be completed, it was assumed that there were equal variances about each regression, i.e.,

$$/\overline{\text{yox}}^{\,2}_{\text{DeLacy et al. study}} = /\overline{\text{yox}}^{\,2}_{\text{This study}}$$

The results of the analysis showed no significant differences between the regression coefficients ($F = 0.405$; $F_{.05} \sim 4.01$) or the intercepts ($F = 0.001$; $F_{0.05} \sim 4.02$). Thus, a common line was justified for the combined length-fecundity data ($F = 5.8157 \times 10^{-9} L^{5.2156}$). The observed fecundity estimates and regression curves obtained from both studies are plotted in Figure 2.

Length-Weight Relationships

The legnth-weight relationship is one of the basic biological parameters whose estimation is necessary for the development of population models. Despite increasing commercial and recreational fishing for these species, little specific research has been directed toward rockfish in Puget Sound. The length-weight conversions obtained are used in a later section to analyze growth of the six species of rockfish.

Species analyzed represent collections primarily by hook and line with some trawl collections. Species were separated by sex and in some instances by area; however, there were too few data to separate into sex, maturity, and season as suggested by Tesch (1968). All rockfish lengths shown are total lengths and weights taken to the nearest 10 g. The equation fitted was the standard allometric growth equation $W\text{-}aL^b$ in its log-linear form, that is, $\log W = \log a + b \log L + \log e$ where a and b are coefficients and e is an error term. It was assumed that the log linear model was appropriate for all species of rockfish and that the regression coefficient (R^2) was a sufficient indicator of the fit of the model. The non-linear form of the model was not used since it is not possible to test for significance (Skillman et al. 1973).

The relationships were computed using production computer programs. The results of the analysis were then compared, when possible, with those of other researchers, i.e., Patten (1973) for copper rockfish. Patten divided his samples into seasonal groupings while this study grouped by sex. Either

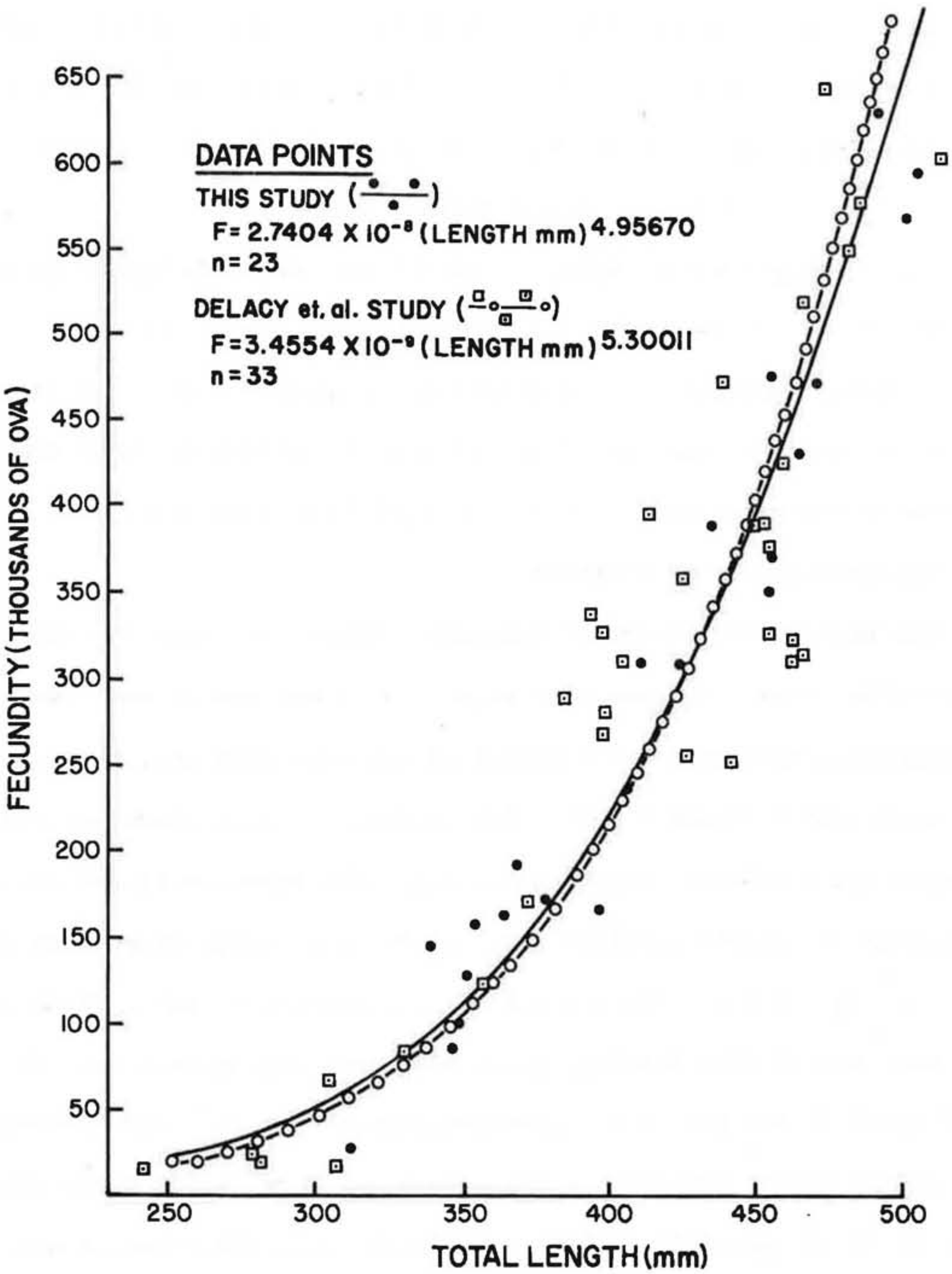


Figure 2.--Plotted length fecundity data and regression curves obtained from this study and the DeLacy et al. (1964) study.

approach is justified and the optimum approach is probably grouping by sex by area by season. The relationships obtained are valid only within the range of lengths given. The relationship described may change at lengths above or below the length interval sampled due to changes in body shape at different intervals (Tesch 1968). The results obtained from this study for copper rockfish show lower weight for a given length than reported by Patten (1973). Miller et al. (1967) stated that for blue rockfish, S. mystinus, growth is highly variable due to location and as regards this study it is likely that condition is also highly dependent upon location.

A test for allometric growth was not done (i.e., B = 3) since it is obvious that there is a significant difference between sexes for some species which renders the test for allometric growth meaningless. T tests for differences in relationships were done for species with a sufficient sample size for the test. The reamining species were analyzed using both sexes to derive common length-weight relationship, and the coefficients are shown in Table 9.

Four species (brown, copper, quillback, and black rockfish) were tested for differences in relationships by sex. The test used was the standard t test (Zar 1974) to test for common slopes and intercepts. All four species were found to have different relationships by sex at the .05 level.

Age Frequencies and Mortality Rates

The age frequency histograms shown in Figures 3 to 10 represent fish collected in the period 1974-77. The ages were determined by otolith readings in diffused light. The frequencies are in absolute numbers and reflect bias due to varying yearly recruitment and predominately single capture method.

Recruitment into the sport fishery for all rockfish begins at age 3-4, except for yelloweye rockfish which begins at approximately age 9. With the

Table 9.--Length-weight relationship for six species of rockfish.

Species	Male				Female				Combined			
	No. fish	a	b	R^2	No. fish	a	b	R^2	No. fish	a	b	R^2
Brown rockfish	52	3.76×10^{-6}	2.87	.914	107	2.61×10^{-6}	2.95	.940	177	1.72×10^{-6}	3.02	.925
Copper rockfish	162	4.60×10^{-6}	2.84	.960	167	2.99×10^{-6}	2.92	.951	340	3.11×10^{-6}	2.91	.967
Yellowtail rockfish 1/	-	-	-	-	-	-	-	-	29	1.49×10^{-6}	3.00	.915
Quillback rockfish	135	4.97×10^{-6}	2.83	.925	181	3.05×10^{-6}	2.92	.910	340	2.95×10^{-6}	2.92	.951
Black rockfish	93	1.15×10^{-6}	3.05	.955	43	1.30×10^{-6}	3.03	.980	146	8.19×10^{-7}	3.11	.978
Canary rockfish		(1)				(1)			25	1.12×10^{-7}	3.39	.854
Yelloweye rockfish	37	5.90×10^{-7}	3.18	.974	34	4.08×10^{-7}	3.25	.958	71	4.63×10^{-7}	3.22	.960

1/ Insufficient data for analysis by sex.

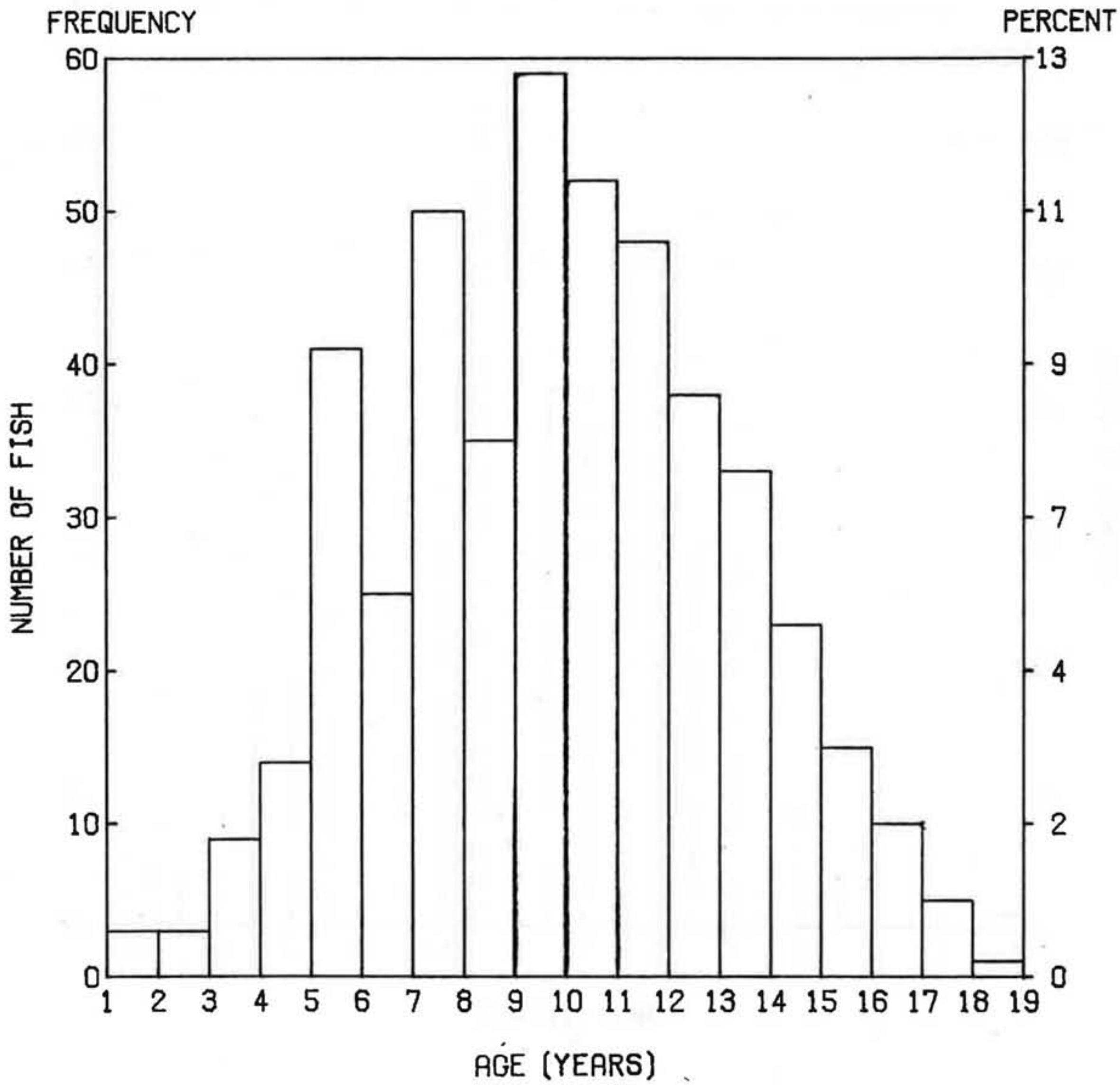


Figure 3.--Age frequency histogram of copper rockfish (males and females combined) collected in Puget Sound, 1973-76.

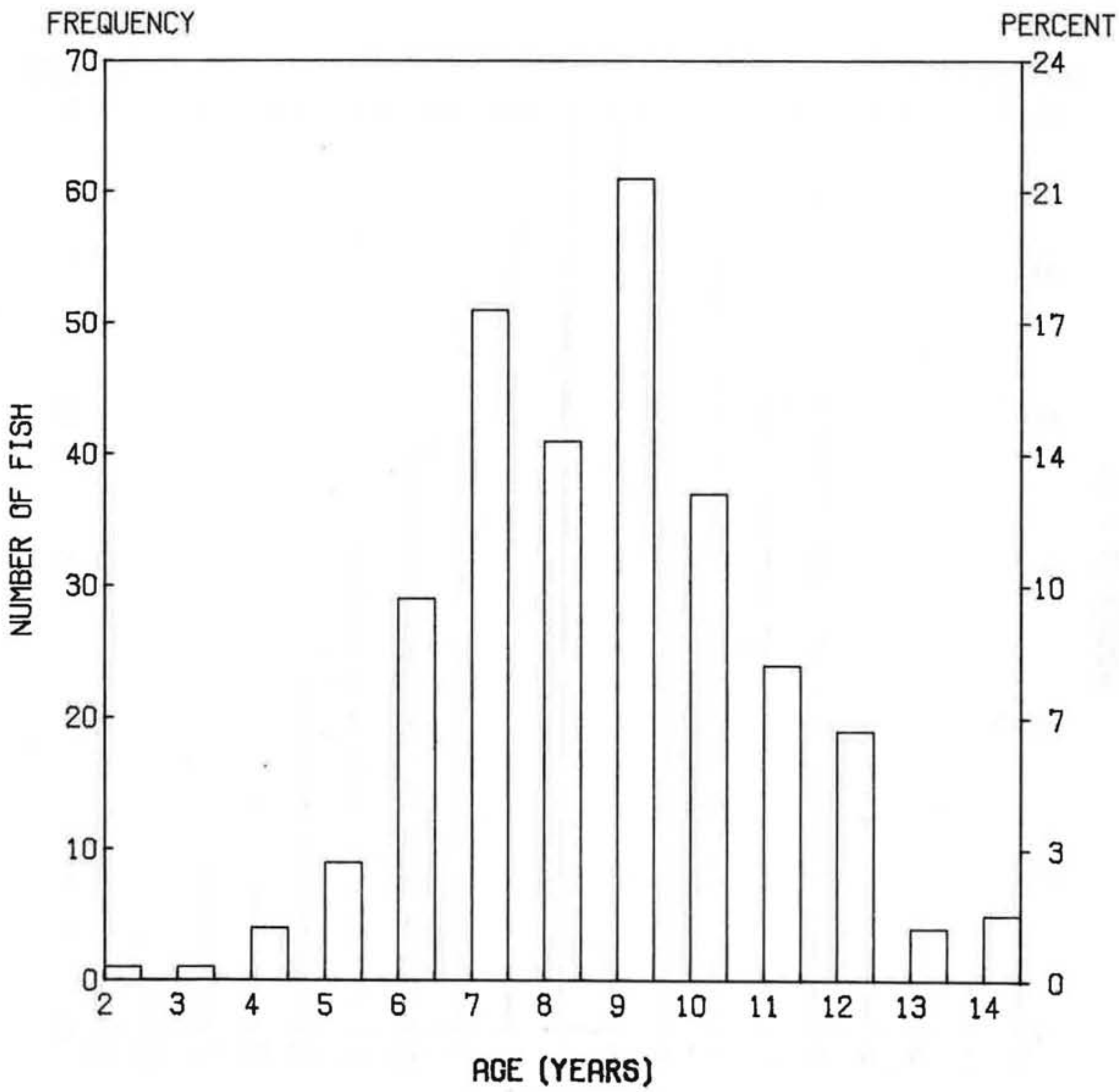


Figure 4.--Age frequency histogram of brown rockfish (males and females combined) collected in Puget Sound, 1973-76.

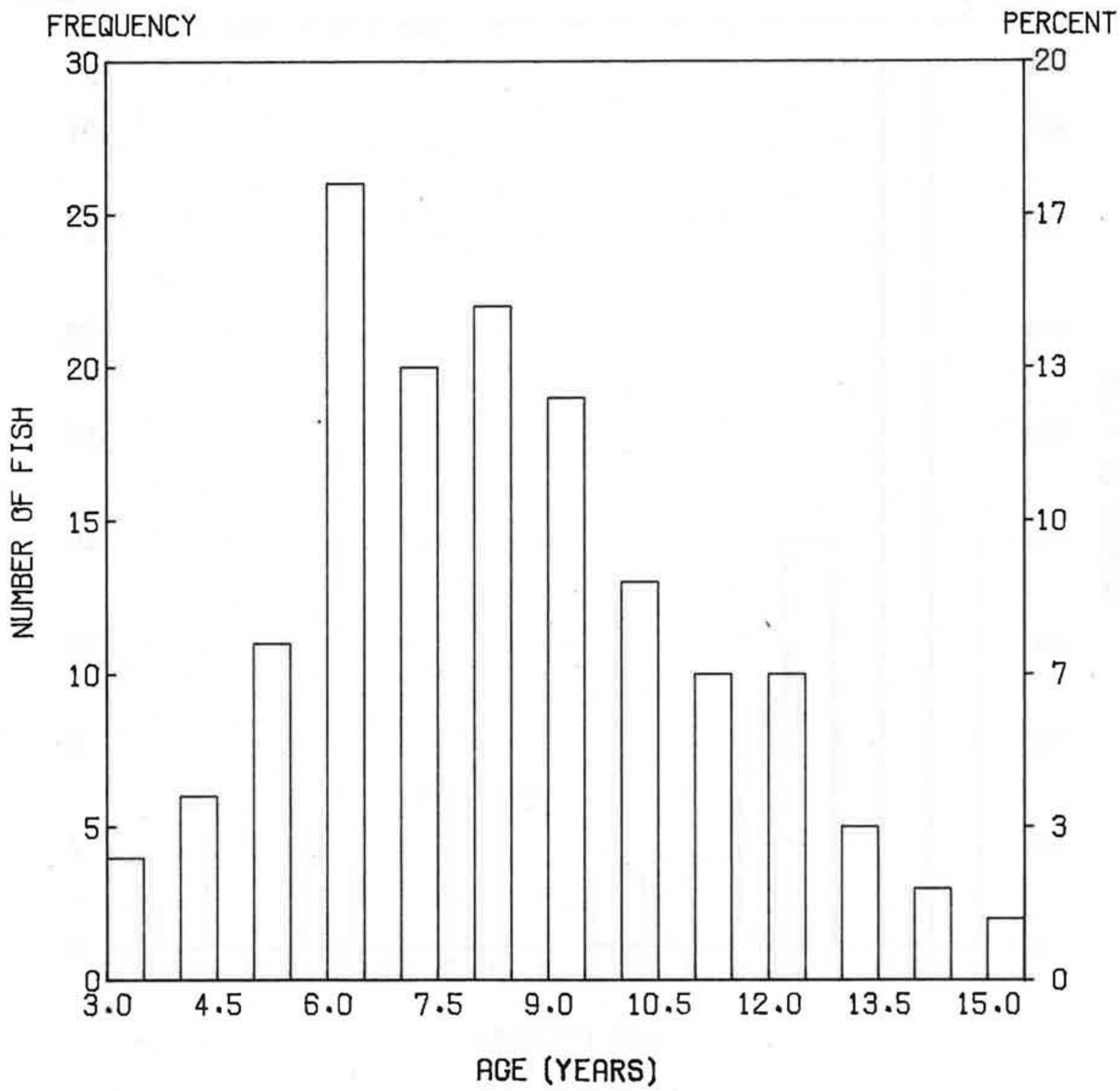


Figure 5.--Age frequency histogram of quillback rockfish (males and females combined) collected in Puget Sound, 1973-76.

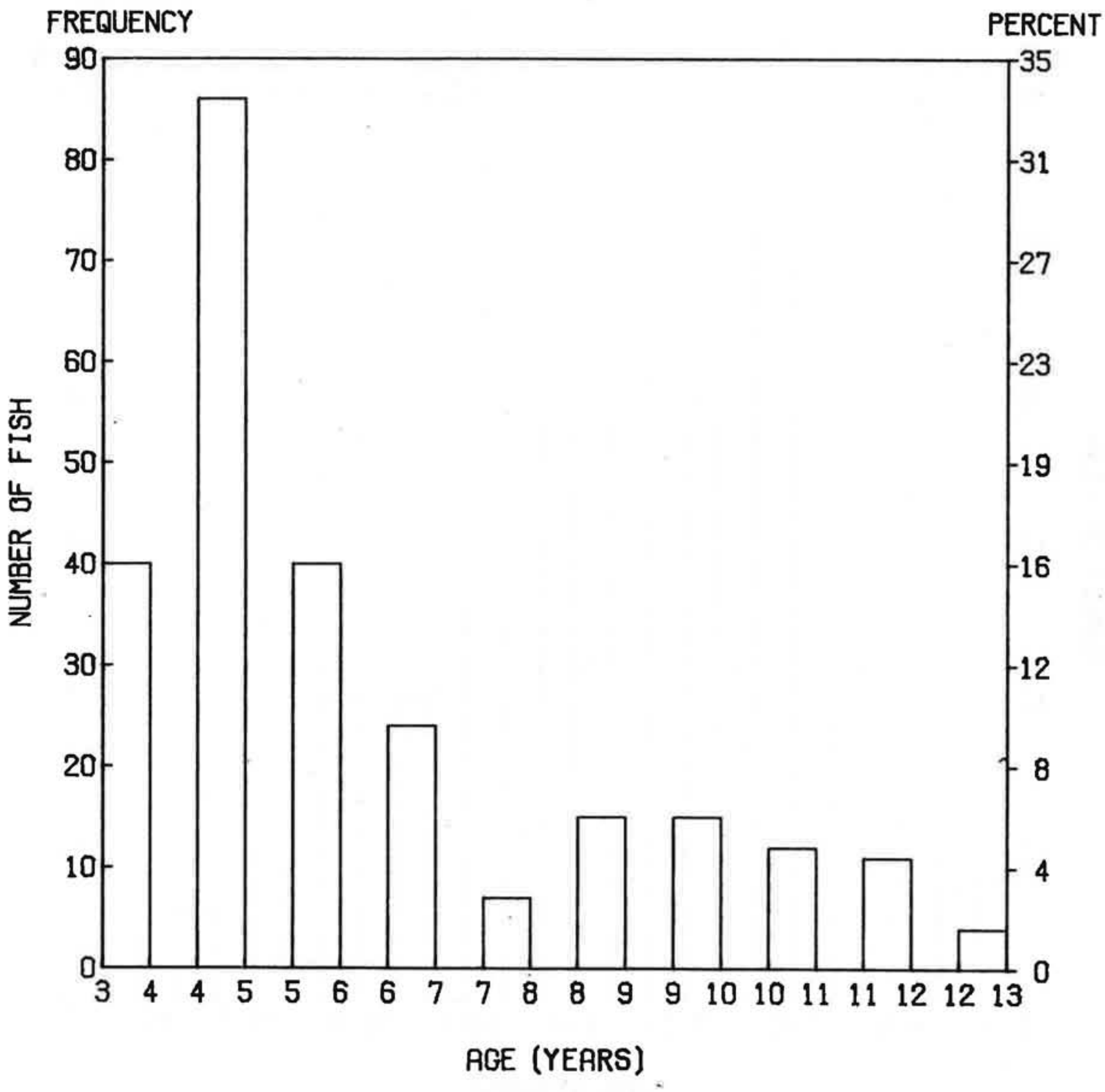


Figure 6.--Age frequency histogram of black rockfish (males and females combined) collected in Puget Sound, 1973-76.

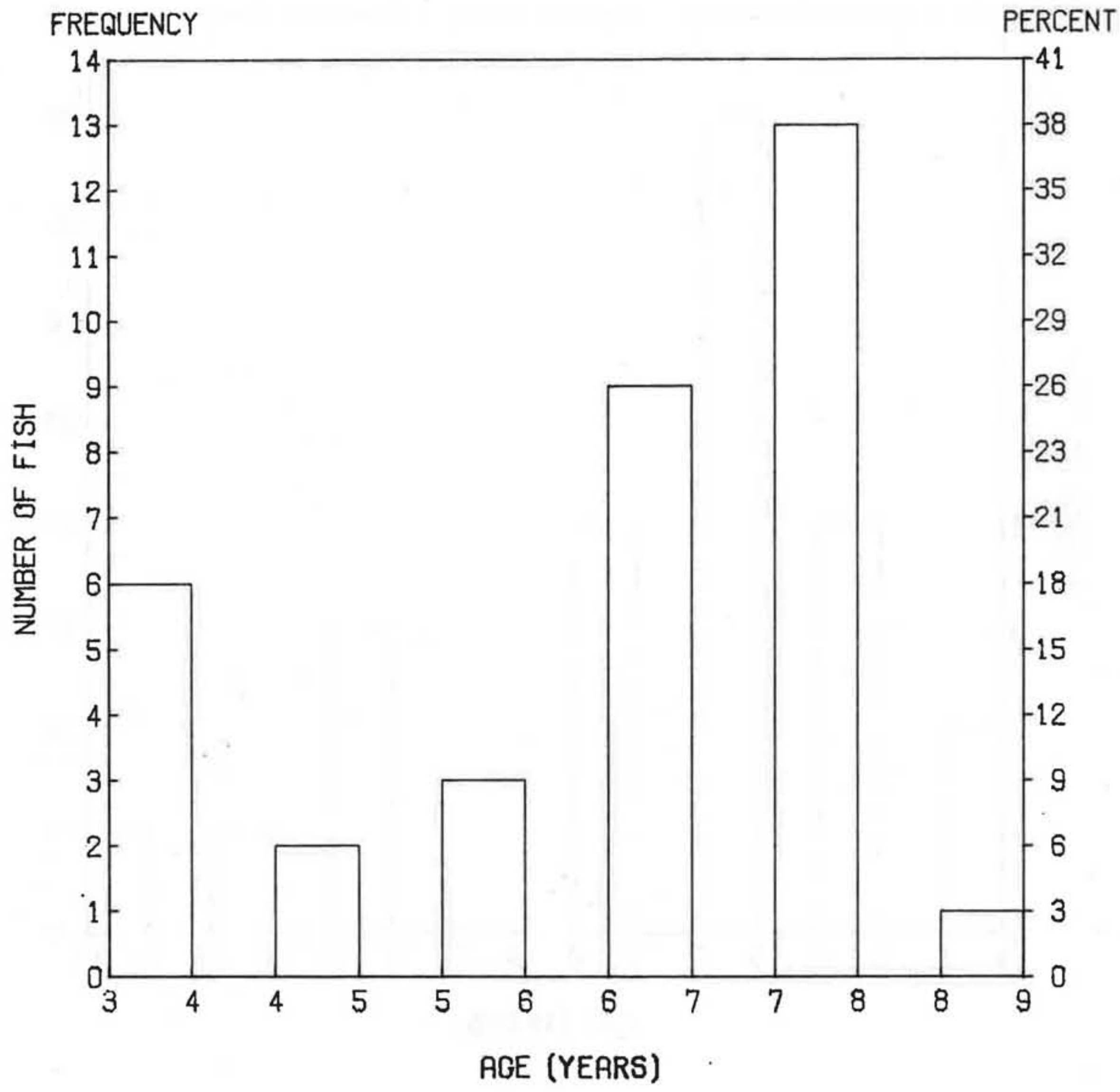


Figure 7.--Age frequency histogram of yellowtail rockfish (males and females combined) collected in Puget Sound, 1973-76.

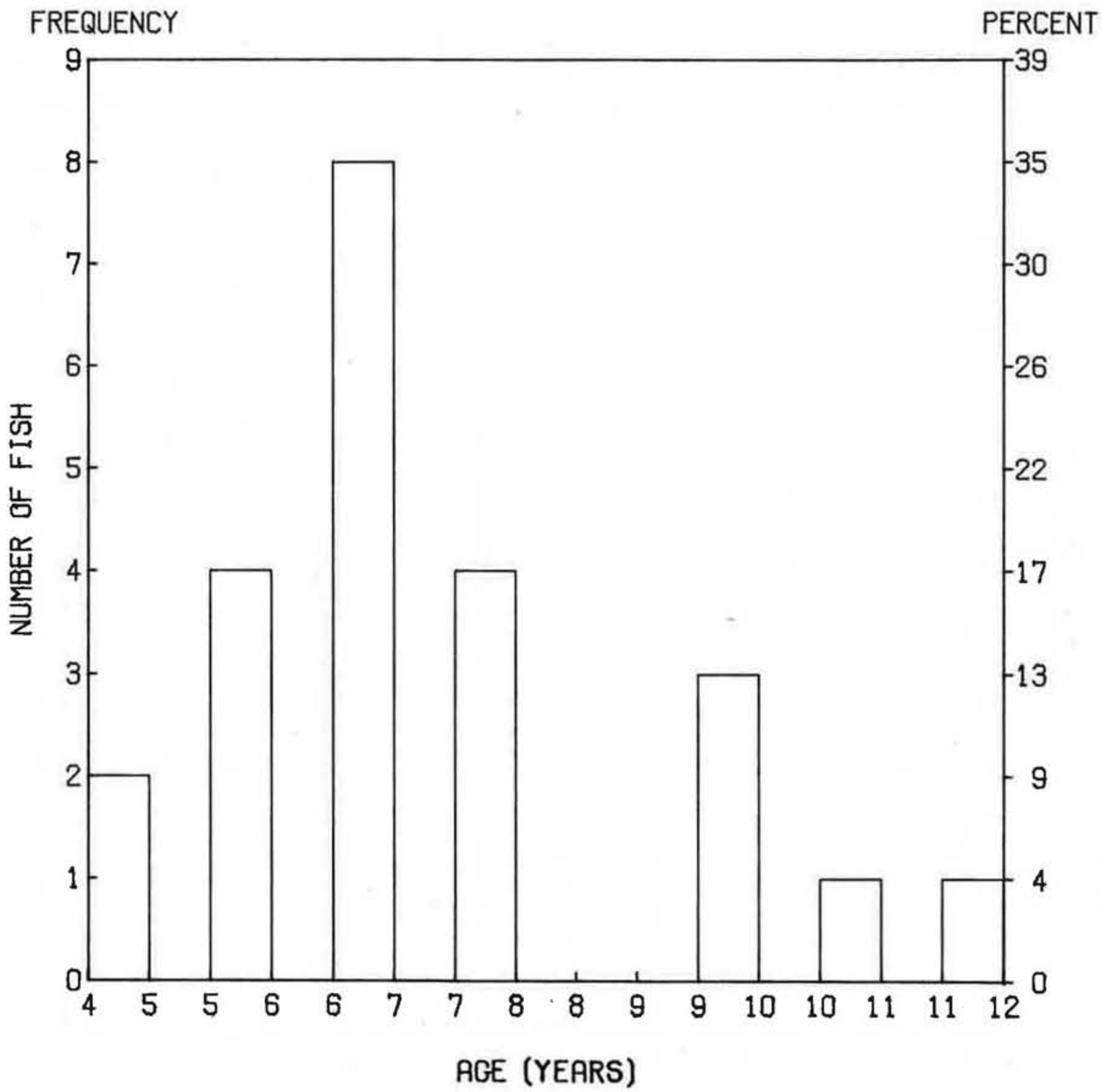


Figure 8.--Age frequency histogram of bocaccio rockfish (males and females combined) collected in Puget Sound, 1973-76.

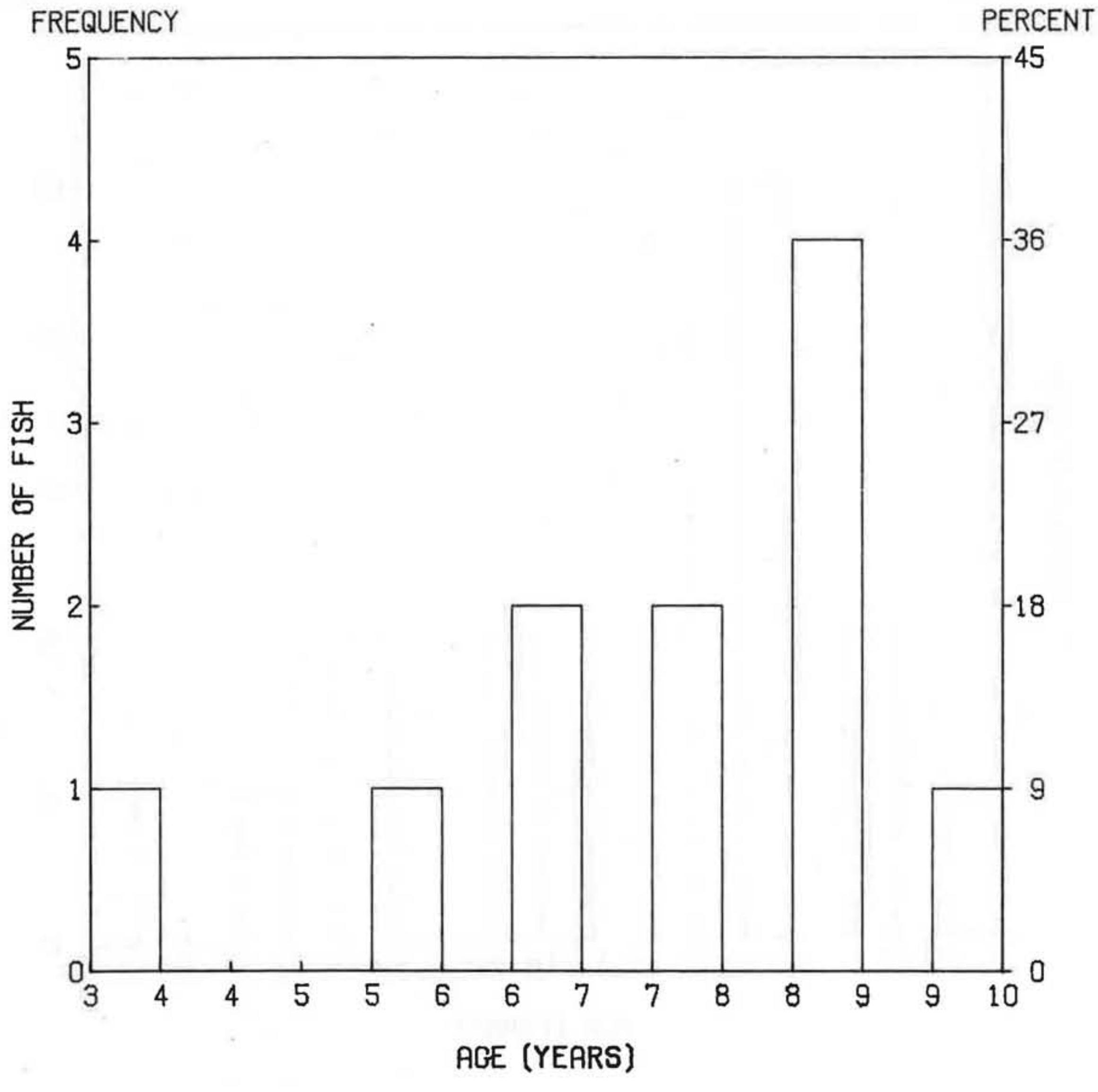


Figure 9.--Age frequency histogram of canary rockfish (males and females combined) collected in Puget Sound, 1973-76.

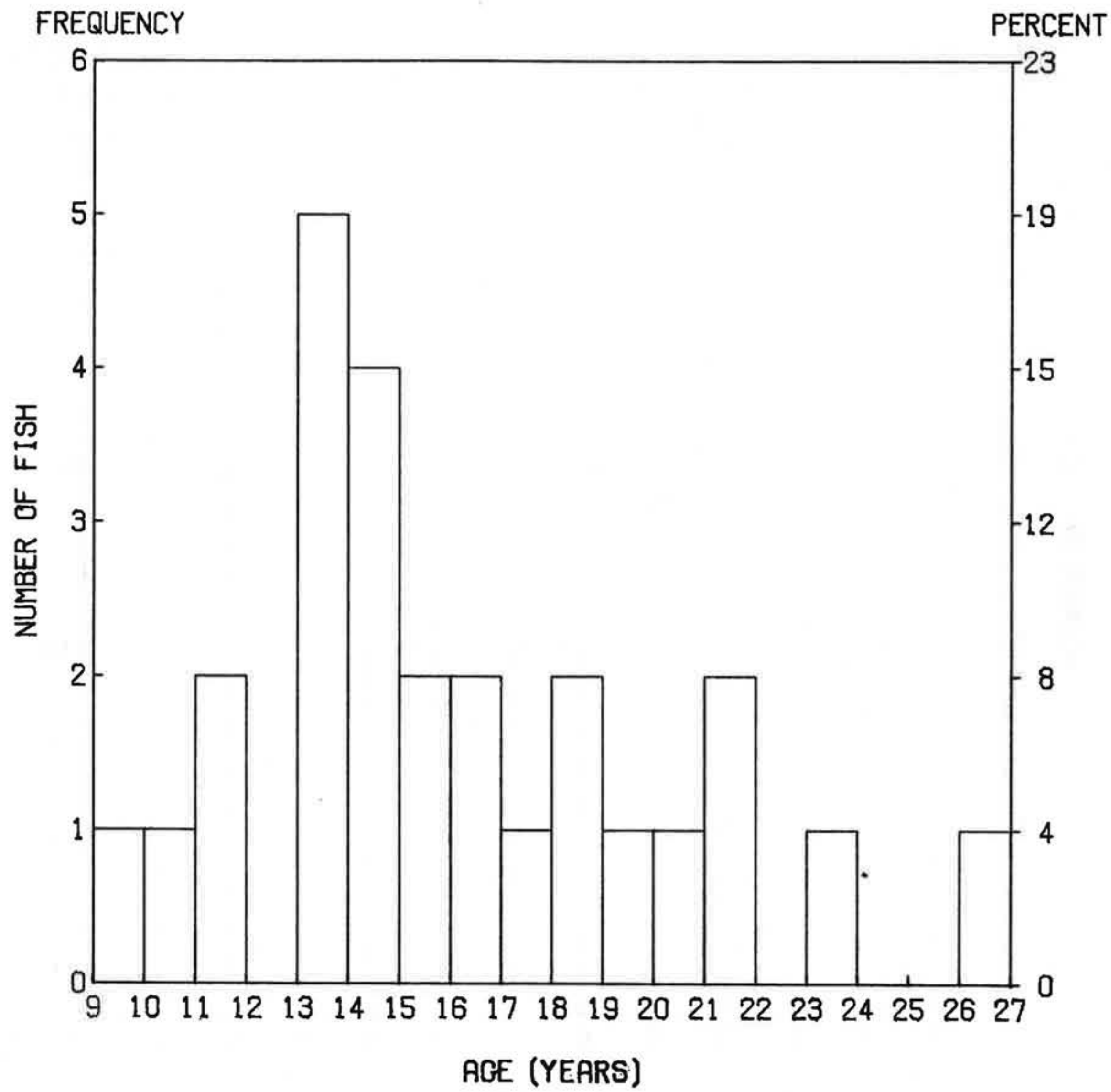


Figure 10.--Age frequency histogram of yelloweye rockfish (males and females combined) collected in Puget Sound, 1973-76.

exception of yelloweye rockfish all fish are fully recruited at age 8-9 (recruitment is used in the context of exploitable numbers). With the age frequencies obtained it is possible to estimate annual mortality rates for those species for which sufficient samples were collected.

The method chosen was Heincke's method (Ricker 1975) which is more reliable than when determination of age for older specimens is unreliable. The formula for Heincke's method is:

$$\text{Survival Rate} = \frac{\sum_{t=1}^{n} N_t}{\sum_{t=o}^{n} N_t}$$

and

$$\text{annual mortality rate} = \ln\left(\frac{1}{\text{survival rate}}\right)$$

The mortality rates obtained are shown in Table 10. The rates for copper and brown rockfish were similar (.23287 vs. 27444) which is expected since they are similar in habitat distribution. Yellowtail rockfish show a high mortality which is deceptive. Yellowtail rockfish in Puget Sound are mostly juveniles which appear to migrate at age 5-7 (M. Baker, College of Fisheries, University of Washington, Seattle, pers. comm.) to the coastal area. The high mortality rate obtained for black rockfish is probably due to gear bias since the capture methods tended to select younger fish. The mortality rate of quillback rockfish also appears to be high but it is not known whether it reflects gear bias or an actual representation of the population. The mortality rates shown should be considered provisional until enough samples are collected by alternate methods to construct more realistic age frequency tables.

Table 10.--Mortality rates for six species of rockfish, using Heincke's method.

Species	Ages used to calculate Z	N	Z
Brown rockfish	6-15	175	.2744
Copper rockfish	9-18	284	.2329
Yellowtail rockfish	6-12	27	.52325
Quillbakc rockfish	9-16	161	.49644
Black rockfish	4-12	214	.51395

Von Bertalanffy Growth Curves

Length-age frequency were fit to the Von Bertalanffy function for six species of rockfish (Figures 11-15). The equation fit was the standard form:

$$lt = L\infty(1-e^{-k(t-t\ )})$$

with a variance weighing factor calculated using GROWFIT, a production program by Somerton (1977). The assumption was made that the variability of length increases non-linearly with age and the function describing the variance as:

$$\text{Var (Length)} = Ae^{Bt}$$

$e = 2.71828......$
A, B are constants
t = age
$L\infty$= theoretical maximum length for the sample population

The fish analyzed were measured in total length to the nearest mm. Otoliths were used to determine age of fish and ages were estimated to the nearest year. Sufficient data was available to derive separate growth curves by sex for four species of rockfish, and a common curve was derived for the remaining two species.

The results obtained were inconsistent when compared with observed lengths. The extreme variability of age with length is graphically illustrated by Figures 11 to 15 and is more extreme than would be expected; Table 11 shows predicted versus observed lengths, and Table 12 illustrates the coefficients of the relationships. Two probably causes of the variability are inconsistent otolith age data and dependency of fish growth on location (i.e., sampling area).

It is difficult to determine the age of slow growing rockfish from their otoliths. As the fish age, the rings in the otoliths get closer and tend to collapse into each other. A tagging experiment is presently underway in Puget Sound which will provide an alternate method of estimating annual growth.

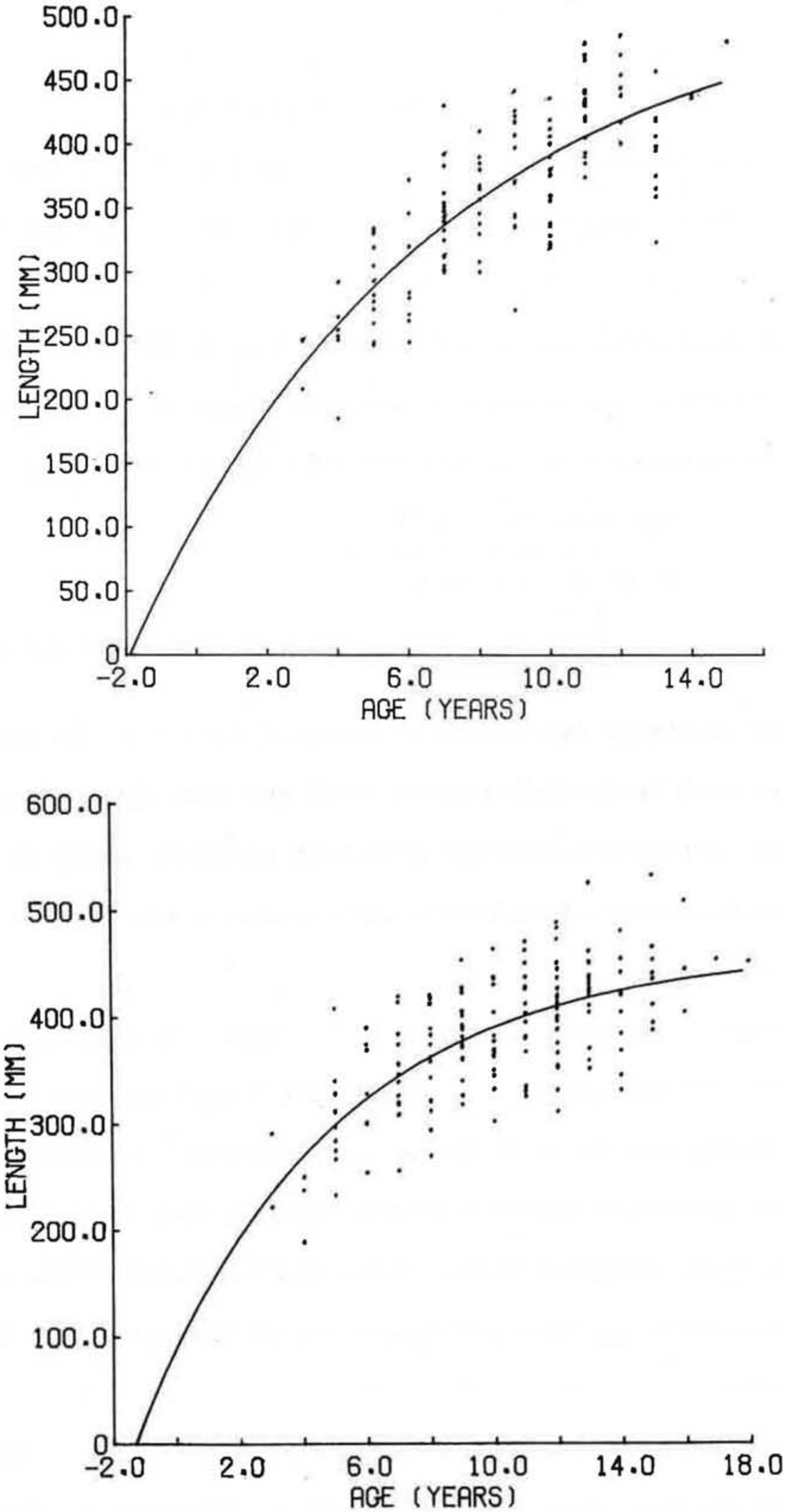


Figure 11.--Age length relationship using the Von Bertalanffy function for male and female copper rockfish collected in Puget Sound, 1973-76.

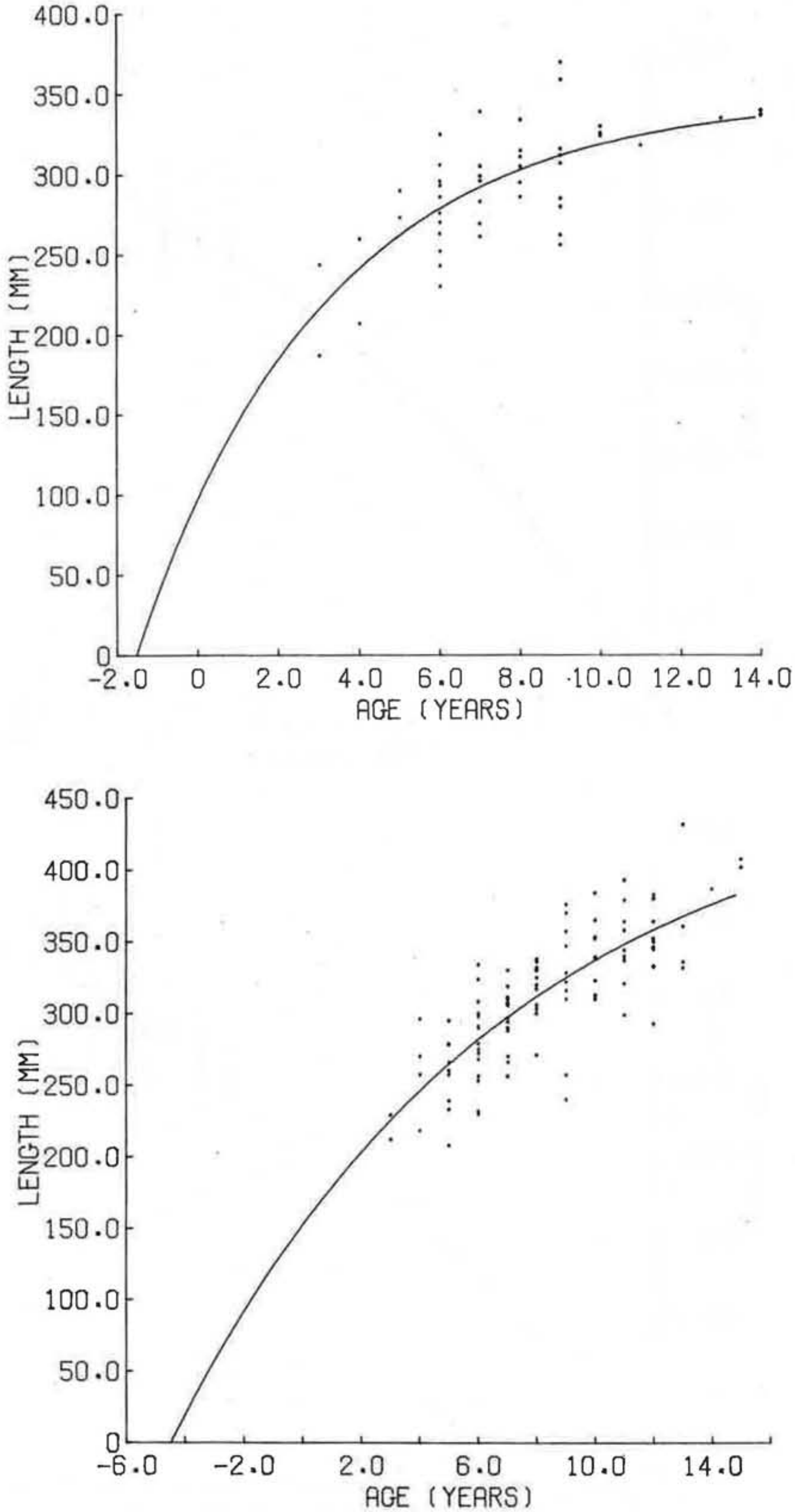
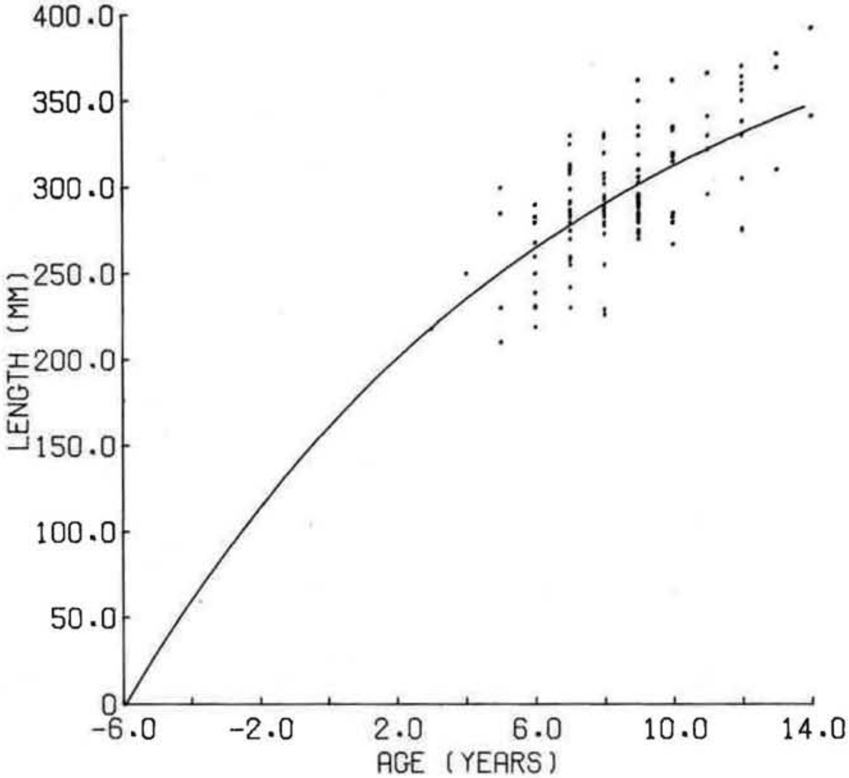


Figure 12.--Age length relationship using the Von Bertalanffy function for male and female brown rockfish collected in Puget Sound, 1973-76.



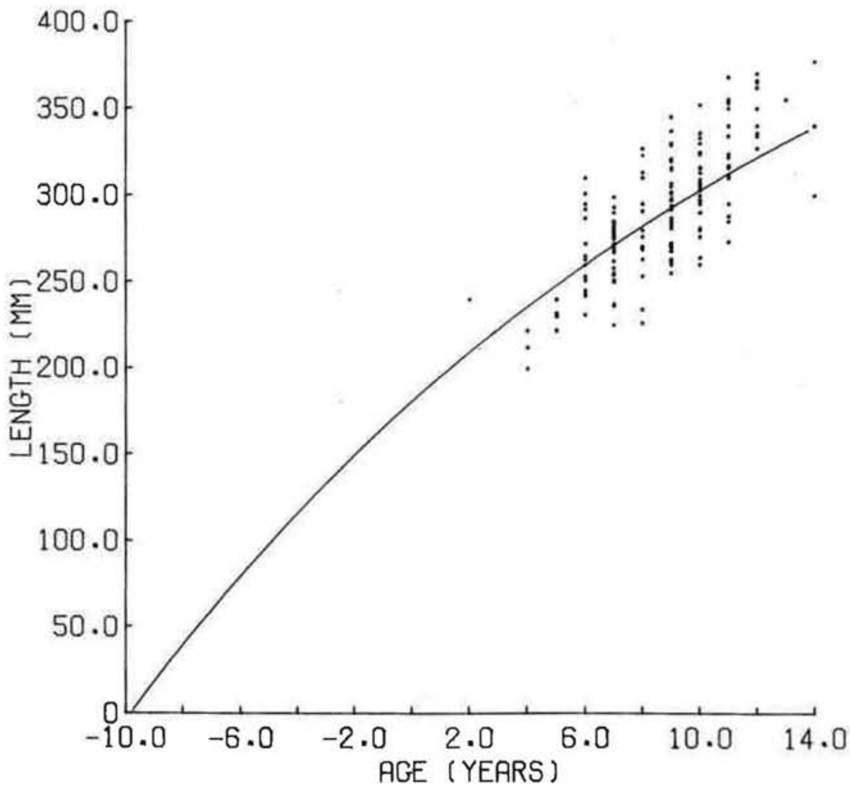


Figure 13.--Age length relationship using the Von Bertalanffy function for male and female quillback rockfish collected in Puget Sound, 1973-76.

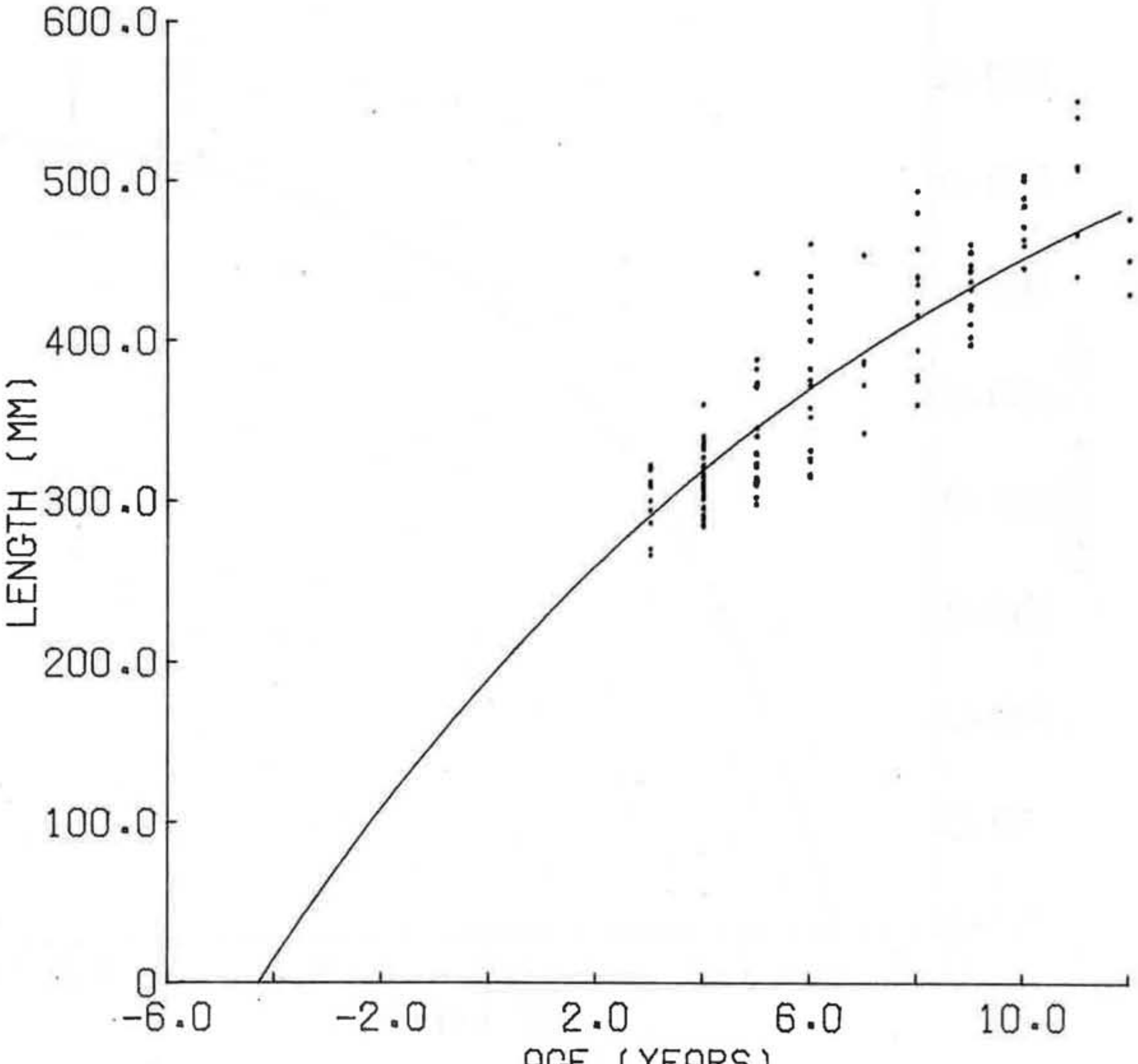


Figure 14.--Age length relationship using the Von Bertalanffy function for black rockfish (male and female combined) collected in Puget Sound, 1973-76.

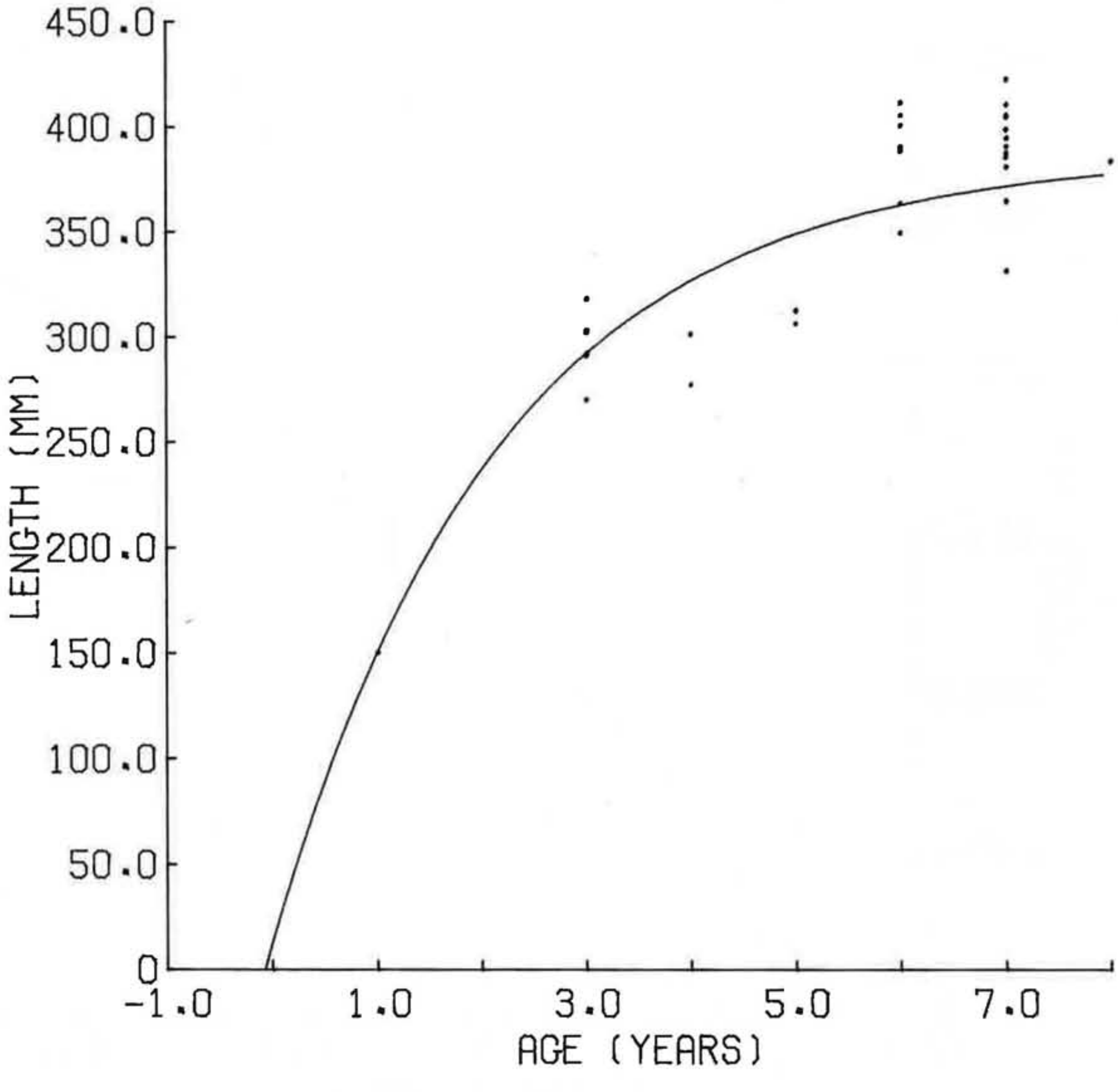


Figure 15.--Age length relationship using the Von Bertalanffy function for yellowtail rockfish collected in Puget Sound, 1973-76.

Table 11.--Comparison of computed and observed mean length at age for 7 species of rockfish collected in Puget Sound.

	Brown rockfish						Copper rockfish					
	Males			Females			Males			Females		
Age	Number of observations	Mean length	Fitted length	Number of observations	Mean length	Fitted length	Number of observations	Mean length	Fitted length	Number of observations	Mean length	Fitted length
3	2	215.00	213.96	2	220.50	225.25	5	242.80	226.11	3	256.50	228.81
4	2	233.50	239.73	4	260.26	245.64	9	241.22	262.17	6	225.67	263.00
5	2	281.50	260.62	9	257.22	264.34	23	299.00	292.90	13	305.50	292.12
6	11	276.36	277.55	15	280.67	281.47	15	312.80	319.08	8	330.86	316.95
7	7	293.14	291.27	13	295.69	297.18	36	342.64	341.40	21	342.80	338.10
8	6	307.67	302.40	16	316.38	311.58	27	358.85	360.41	14	358.08	356.12
9	9	305.22	311.41	10	322.30	324.78	34	384.22	376.61	14	388.25	371.48
10	5	339.00	318.72	8	342.38	336.88	31	377.06	390.42	17	382.50	384.57
11	1	318.00	324.65	9	348.33	347.97	32	410.78	402.19	16	395.75	395.72
12			329.45	10	352.60	358.14	30	415.73	412.21	7	407.13	405.23
13	1	335.00	333.34	4	365.25	367.46	27	412.22	420.76	10	424.35	413.32
14	2	338.50	336.50	1	387.00	376.01	12	437.50	442.84	10	404.90	420.23
15			339.05	2	405.00	383.84	2	480.00	451.57	8	439.63	426.11
16							1		459.31	3	452.00	431.12
17									466.17	1	453.00	435.39
18									472.26	1	451.00	439.03

	Quillback rockfish						Black rockfish					
	Males			Females			Males			Females		
Age	Number of observations	Mean length	Fitted length	Number of observations	Mean length	Fitted length	Number of observations	Mean length	Fitted length	Number of observations	Mean length	Fitted length
2			201.18	1	240.00	207.12						
3	1	218.00	219.15			220.50	8	302.87	287.21	4	298.75	1/
4	1	250.00	235.83	3	211.33	233.33	18	306.83	316.59	16	318.88	
5	4	256.25	251.31	5	231.00	245.65	14	340.64	343.92	9	342.22	
6	13	252.38	265.67	16	269.06	257.47	9	374.89	369.55	7	377.43	
7	22	285.27	278.99	29	266.59	268.82	4	371.50	393.01	1	453.00	
8	24	289.42	291.34	17	281.76	279.72	9	421.56	415.03	3	432.33	
9	26	300.62	302.81	35	294.94	296.17	11	432.55	435.52	2	433.00	
10	11	310.64	313.44	26	302.81	300.21	7	473.00	454.59	1	503.00	
11	5	331.00	323.31	19	325.84	309.84	4	488.25	472.33	3	522.33	
12	10	332.40	332.46	9	350.00	319.03	3	451.67	488.84			
13	3	352.00	340.96	1	355.00	327.96						
14	2	366.50	348.84	3	339.00	336.48						

1/ Data for black rockfish is too variable to derive Von Bertalanffy parameters.

Table 11.--Comparison of computed and observed mean length at age for 7 species of rockfish collected in Puget Sound--continued.

	Canary rockfish sexes combined2/		Yelloweye rockfish sexes combined2/		Bocaccio rockfish sexes combined2/	
Age	Number of observations	Mean length	Number of observations	Mean length	Number of observations	Mean length
4					2	550.50
5	1	302.00			4	585.25
6	2	375.50			8	611.88
7	2	405.50			4	609.75
8	4	434.50				
9	1	401.00	1	430.00	3	678.33
10			1	465.00	1	696.00
11			2	392.50	1	730.00
12						
13			5	561.40		
14			4	529.75		
15			2	527.50		
16			2	587.50		
17			1	580.00		
18			2	653.00		
19			1	717.00		
20			1	675.00		
21			2	655.00		
22						
23			1	685.00		
24						
25						
26			1	707.00		

2/ Insufficient data for Von Bertalanffy analysis.

Table 12.--Parameter estimates of the Von Bertalanffy growth function for six species of rockfish collected in Puget Sound, 1973-76.

Species	N	L_∞	K	t_0
Copper rockfish				
Males	132	520	.12	-1.90
Females	163	460	.16	-1.3
Brown rockfish				
Males	46	350	.21	-1.5
Females	103	470	.087	-4.5
Quillback rockfish				
Males	87	450	.075	-5.9
Females	164	540	.041	-9.8
Black rockfish 1/	133	680	.076	-4.3
Yellowtail rockfish 1/	35	390	.43	- .14
Canary rockfish 1/	11	460	.071	-22.0

1/ Insufficient data for analysis by sex.

The second cause of variability in growth appears to be the high dependency of growth on location. Miller (1967) felt that it was impossible to construct a common regional curve for blue rockfish due to the variability of growth due to location. It is not known if this applies to Puget Sound specimens, and an experiment is currently being conducted to determine the effect of location on growth for copper rockfish.

As more specimens are collected, cohort analysis will be possible and the assumption of no difference in annual growth patterns can be tested as well as seasonal groupings of the data rather than the annual grouping used in this study. Although the results obtained show high variability, they are accurate enough to describe the general growth pattern for the population in Puget Sound.

Summary and Conclusions

The qualitative food study data presented was limited by the high percentage of stomach content losses due to regurgiation. From the usable data there is evidence of opportunism in the feeding habits of those species investigated. Definite differences in organisms utilized by the various species were thought to be a result of differences in those species' habitat and depth preferences and, hence, organism availability.

Our investigations of the timing of maturation and reproduction of rockfish showed Puget Sound rockfish schedules to be in line with those of DeLacy, Hitz, and Dryfoos 1964, for brown and copper rockfish (brown rockfish "spawn" in June, copper rockfish spawn in April). Evidence, although sparse, indicates the lack of adult yellowtail rockfish in Puget Sound, hence no spawning occurs there. The ubiquitous presence of the juveniles comes as a possible result of large numbers of larvae being brought into Puget Sound by tidal current. Spawning of quillback rockfish occurred in May, while data from yelloweye rockfish collections indicate an annual double spawning (February and August).

Adult black rockfish were seldom captured during the December to April period in areas where accessibility is normally good in Puget Sound. Three spent males were captured in shallow inshore area in early January 1977 and later that month a spent female was collected from deep water in central Puget Sound by a commercial fisherman. This would seem to indicate a late January, early February spawning period which is not too different from the findings of Dunn and Hitz (1968) and Westrheim (1975).

Little can be said about the spawning of bocaccio other than males in ripe condition have been collected in late January from central Puget Sound, which would imply a late winter to early spring spawning. Westrheim (1975) gave February as the month of spawning along the coast from Oregon northward to British Columbia.

Age at first maturity was determined for three species of rockfish using spawning checks in otoliths (Table 13). Copper and brown rockfish females began maturing at age 3, 50% were mature at age 4, and all were mature at age 7. Female quillback rockfish were similar except that one fish was mature at age 2. The preceding on age at first maturity should be considered provisional as further study is needed to corroborate the existence of spawning checks for Sebastes otoliths.

In the copper rockfish fecundity study of DeLacy et al. (1964), a discrepancy was found between the published and recalculated regression equation, and this discrepancy was probably the result of a typographical or computational error.

In our study fecundity was found to increase at a rate proportional to approximately the fifth power of the total length ($F = 2.7404 \times 10^{-8} L^{4.9567}$).

Table 13.--Age of first maturity for three species of rockfish females.

Species	Age (years)	Percentage	No. fish
Brown rockfish	3	3.1	2
	4	75.4	49
	5	17.0	11
	6	4.6	3
			65
Copper rockfish	3	11.5	79
	4	51.0	84
	5	23.6	39
	6	12.7	21
	7	.1	1
			164
Quillback rockfish	2	3.5	1
	3	10.3	3
	4	44.8	13
	5	31.0	9
	6	3.5	1
	7	6.9	2
			29

An analysis of covariance test was used to justify a common line ($F = 5.8157 \times 10^{-9} L^{5.2156}$) for the combined length-fecundity data (this study plus DeLacy et al. 1964).

Length-weight relationships for six species of rockfish were computed and fitted in log-linear form to the standard allometric equation ($W = aL^b$) e.g., logW = logn a x b logL. The relationships are valid only within the range of lengths given. Four species (brown, copper, quillback, and black rockfish were the only species with large enough sample sizes to allow statistical tests of different length-weight relationships by sex) of rockfish were found to have different legnth-weight ratios by sex.

Age frequencies and mortality rates were based on ages determined by otolith readings. The frequencies are in absolute numbers and reflect bias due to capture method and varying recruitment. Recruitment into the sport fishery for rockfish begins at sexual maturity--approximately age 4. The age frequency distribution was the basis of the estimates of annual mortality rates for those species with sufficient sample sizes (brown, copper, yellowtail, quillback, and black rockfish, and bocaccio). Heincke's method (Ricker 1975) was used to derive annual mortality rates--the inverse of the survival rate. Mortality rates presented in this paper should be considered as provisional until better age frequency data is available.

Age-length data were fit to the Von Bertalanffy function for six species of rockfish. The results showed extreme variability of age by length and calculated values were inconsistent when compared with observed lengths. The two probable causes of the differences between the expected and observed values are differences in growth as a function of local productivity variation and inconsistencies in age data based on otoliths. Although the results show a high variability, they are accurate enough to describe the growth patterns for the various rockfish populations in Puget Sound.

Literature Cited

Bargmann, G. G.

1977. Instances of copper rockfish consuming a spiny dogfish shark. Calif. Fish Game 63(3):192.

Browning, R. J.

1974. Fisheries of the North Pacific. Alaska Northwest Publ. Co., Alaska 97.

Buckley, R. M.

1967. 1965 Bottom sport fishery. Wash. Dep. Fish., Suppl. Prog. Rep., 40 p.

1968. 1966 Bottom sport fishery occurring in Washington marine punch card Area 2 through 12. Wash. Dep. Fish., Suppl. Prog. Rep., 41 p.

Buckley, R. M., and K. Satterthwaite.

1970. 1967 Bottom sport fishery. Wash. Dep. Fish., Suppl. Prog. Rep., 53 p.

DeLacy, A. C., C. R. Hitz, and R. L. Dryfoos.

1964. Maturation, gestation, and birth of rockfish (Sebastodes) from Washington and adjacent waters. Wash. Dep. Fish., Fish. Res. Pap. 2:51-67.

DeLacy, A. C., B. Miller, and S. F. Borton.

1972. Checklist of Puget Sound fishes. Univ. Wash., Seattle, Div. Mar. Resources, Wash. Sea Grant WSG 72-3 43 p.

Gunderson, D. R.

1976. Population biology of Pacific ocean perch (Sebastes alutus) stocks in Washington-Queen Charlotte Sound region and their response to fishing. Ph.D. Thesis Univ. Washington, Seattle, 140 p.

Gunderson, D. R.

1977. Population biology of Pacific ocean perch (Sebastes alutus) stocks in Washington-Queen Charlotte Sound region, and their response to fishing. J. Fish. Res. Board Can. 75:369-403.

MacGregor, J. S.

1970. Fecundity, multiple spawning, and description of the gonads in Sebastodes. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 596, 12 p.

Miller, D. J., M. W. Odemar, and D. Gotshall.

1967. Life history and catch analysis of the blue rockfish (Sebastodes mystinus off central California, 1961-1965. Calif. Dep. Fish Game, Resources Agcy. Marine Resources Operations, MRO reference No. 67-14.

Moser, H. G., E. H. Ahlstrom, and E. M. Sandknop.

1977. Guide to the identification of scorpion fish larvae (family Scorpaenidae) in the Eastern Pacific with comparative notes on species of Sebastes and Helicolenus from other oceans. U.S. Dep. Commer. NOAA Tech. Rep. NMFS CIRC-402, 71 p.

Patten, B. G.

1973. Biological information on copper rockfish in Puget Sound, Washington. Trans. Am. Fish. Soc. 102:412-416.

Prince, E. D., and D. W. Gotshall.

1976. Food of the copper rockfish, Sebastes caurinus Richardson, associated with an artificial reef in south Humboldt Bay, California. Calif. Fish Game 62(4):274-285.

Raitt, D. S.

1933. The fecundity of the haddock. Fish. Board Scotl., Sci. Invest., 1932, 1:3-42.

Ricker, W. E.

1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can., Bull. 191, 382 p.

Skillman, R. A. and M. Y. Y. Yong.

1974. Length-weight relationships for six species of billfishes in the central Pacific Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972. Part 2. Review and contributed papers, p. 226-237. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Somerton, D.

1977. Growfit - A program for fitting growth curves to size-age or weight-age data. Univ. Wash., Seattle, Center for Quantitative Science in Fisheries, Forestry and Wildlife. Unpubl. manuscr. 8 p.

Simpson, A. C.

1951. The fecundity of the plaice. U.K. Min. Agric. Fish., Fish. Invest., Ser. 2, 17(5):1-27.

Tesch, F. W.

1968. Age and growth. In W. E. Ricker (editor), Methods for assessment of fish production in fresh waters, p. 93-123. International Biological Programme Handbook 3. Blackwell Sci. Publ., Oxford.

Washington, P. M.

1976. How to Use Artificial Lures. In Proceedings of a Seminar "Bottom Sport Fisheries of Puget Sound" (ed. Marjorie Day) Kitsap Extension Service and Cooperative Extention Service of Washington State Univ. p. 64-69.

Westrheim, S. J.

1975. Reproduction, maturation, and identification of larvae of some Sebastes (Scorpaenidae) species in the northeastern Pacific Ocean. J. Fish. Res. Board Can. 32:2399-2411.

Zar, J. H.

1974. Biostatistical analysis. Prentice-Hall, Inc., N.J. 620 p.

grn
blu
blk