AN ABSTRACT OF THE THESIS OF

RICHARD GEORGE STEINER for the degree of MASTER OF SCIENCE

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Title: FOOD HABITS AND SPECIES COMPOSITION OF NERITIC REEF FISHES OFF DEPOE BAY, OREGON

Abstract approved: Redacted for Privacy

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The distribution and trophic ecology of neritic reef fishes was studied to provide biological information useful in conserving these stocks. Hook and line fishing was conducted from July 1976 to July 1977 on neritic reefs within 5 km of the Oregon coast adjacent to Depoe Bay. Sampling was designed to determine the seasonal and depth variations in species composition of nearshore reef-fish communities, and to determine the trophic relationships within these species.

The species composition of fish communities on reefs shoreward of the 20 m depth contour was markedly different from that on deeper (20-50 m) reefs. While fish communities on shallow reefs were dominated by black rockfish (*Sebastes melanops*), those on deeper reefs were dominated collectively by lingcod (*Ophiodon elongatus*), yelloweye rockfish (*Sebastes ruberrimus*), and black rockfish. The mean lengths of the two most abundant species, black rockfish and lingcod, were decidedly longer on the deep reefs than on the

shallow reefs. Several neritic reef fish species were seldom found shoreward of the 20-30 m depth interval, suggesting that this zone constitutes a functional boundary to the distribution of these species.

The catch per unit of effort for black rockfish was significantly ($p = .01$) greater on shallow reefs (10-20 m) during summer and winter than it was during spring and fall. The species composition of catches in all reef areas changed seasonally due mainly to a significant ($p = .10$) increase in lingcod abundance in reef areas during their winter spawning period.

Analysis of stomach contents of the five principal species using Bray-Curtis dissimilarity indices revealed that these nearshore reef fish communities are relatively uncoupled trophic systems. This suggests that the principal species do not exclude one another from reef areas through competition for food, and thus, for purposes of conservation, can probably be considered separately.

Because of the continuing increase in sport and commercial fishing effort on neritic reef fishes, it is increasingly possible that these stocks could be overexploited. Restriction of the lingcod fishery during their winter spawning period and a maximum size limit for lingcod are possible strategies to help insure adequate recruitment of these species. However, before such restrictions are considered, the role of offshore stocks of lingcod with regard to spawning and recruitment needs to be better understood.

Food Habits and Species Composition of Neritic Reef Fishes off Depoe Bay, Oregon

by

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INTRODUCTION

This thesis reports on a study of the ecological relationships among neritic reef fishes off the central Oregon coast. The research was initiated to help develop biological criteria for use in managing these stocks. The study was conducted from July, 1976 through July, 1977 in the marine area between Government Point and Cascade Head, near Depoe Bay, Oregon, between the 10 and 50 m depth contours.

Neritic reef fishes support a sizeable sport fishery and are marketed as commercial fishes in Oregon. Several experienced charter boat operators and commercial fishermen expressed concern that these stocks have been seriously reduced as a result of the rapid increase in fishing pressure during the past 10 years. Resource managers, recognizing the dependence of local economies on a viable neritic reef fishery, were concerned with the maintenance and equitable allocation of this resource.

The initial establishment of catch regulations on the sport fishery for neritic reef fishes was based mainly on intuition and industry demand (personal communication, Jack Robinson and Jerry Butler, Oregon Department of Fish and Wildlife [ODFW]), as is historically the case with many fisheries. To overcome the insufficient biological information on which to base critical decisions regarding these stocks, reliable data are needed on catch and effort characteristics, the biology of individual fish species, and the behavioral and trophic interactions between these species.

In conjunction with these needs, the objectives of the research reported here were:

1. To determine if the species composition of neritic reef fees communities adjacent to Depoe Bay, Oregon varies with water depth.
2. To determine if there are seasonal trends in the species composition of neritic reef fish communities adjacent to Depoe Bay, Oregon.
3. To determine the degree of food resource partitioning among the principal species of neritic reef fishes caught by recreational and charter boat fishermen adjacent to Depoe Bay, Oregon.

Information on the spatial and temporal variations in species composition (objectives 1 and 2) should provide resource managers with a preliminary basis for establishing specific catch regulations by season and/or area. The nature of food resource partitioning (objective 3) between fishes comprising a multispecies fishery is necessary (but not sufficient) information for understanding the degree to which the productivity of one species will affect the productivity of coexisting species. More specifically, with regard to neritic reef fishes, it is of prime importance to establish how individuals of one species might exclude individuals of other species from a reef area either by feeding or behavioral competition. Also, in addition to being relevant to the development of an optimal management strategy, this information will supplement an accumulating body of knowledge on the spatially and temporally dynamic processes that influence the distribution and abundance of organisms off the coast of Oregon.

The ecology of neritic reef fishes has been investigated in California, but preliminary studies farther north indicate that Oregon reef fish communities differ markedly from those in California. Barker (1974) reported the species composition of the catch by five different gear types used on neritic reefs adjacent to Newport, Oregon. His data indicate that the fishing gear conventionally used in the sport fishery (the jig) captured primarily black rockfish (Sebastes melanops), followed by lingcod (Ophiodon elongatus), kelp greenling (Hexagrammos decagrammus), yelloweye rockfish (S. ruberrimus), blue rockfish (S. mystinus), and cabezon (Scorpaenicthys marmoratus), in order of numerical importance.

By contrast, the charter boat catch on California reefs, using similar fishing methods, was dominated by blue rockfish, followed by yellowtail rockfish (S. flavidus), olive rockfish (S. serranoides), bocaccio (S. paucispinus), canary rockfish (S. pinniger), vermillion rockfish (S. miniatus), lingcod, and copper rockfish (S. caurinus) (Miller and Gotshall, 1965). The two most dominant species in the

Oregon catch, black rockfish and lingcod, were ranked 11th and 7th, respectively, in the California fishery, and the two most dominant species in the California fishery, blue rockfish and yellowtail rockfish, were ranked 5th and 12th, respectively, in the Oregon catch. This evidence points to the possibility for considerable geographic variation in the species composition of neritic reef fish communities along the Pacific Coast of North America.

Miller and Geibel (1973), Wilby (1937), and Hart (1943) reported a shoreward migration of lingcod during their winter spawning period. These migrations induce significant seasonal variations in neritic reef fish communities.

The food habits of several neritic reef fish species have been determined. The lingcod has been characterized as a voracious and opportunistic carnivore, feeding primarily on fishes; including Pacific sand lance (Ammodytes hexapterus), Pacific herring (Clupea harengus pallasi), and many bottom forms such as flounders (Pleuronectidae), Pacific hake (Merluccius productus), walleye pollock (Theragra chalcogramma), Pacific cod (Gadus macrocephalus), and rockfishes (Sebastes spp.); crustaceans; and octopus (Octopus sp.) (Wilby, 1937). Miller and Geibel (1973) reported that 70% or more of the lingcod diet is fish, including mostly juvenile rockfishes (73% by number), shortbelly rockfish (S. jordani), northern anchovy (Engraulis mordax), Pacific staghorn sculpin (Leptocottus armatus), blackeye goby

(Coryphopterus nicholsi), spotted cusk-eel (Octophidium taylori), sanddab (Citharicthys sp.), Pacific saury (Cololabis lucioceps), and Pacific viperfish (Chauliodus macouni). The remainder of their diet consisted of cephalopods (half Octopus bimaculatus and half Loligo opalescens), gastropods (Calliostoma, Tegula, and Nassarius), and a few decapods (Cancer sp. and Spirontocarid shrimp). Gotshall et al. (1965) reported that the food of blue rockfish collected in California consisted mainly of tunicates, scyphozoans, hydroids, crustaceans, fishes, and algae, in order of importance. O'Connell (1953) reported that the food of cabezon consisted mainly of crustacea (Cancer, Loxorynchus, Pugettia, Phyllolithodes, Scyra, Mimulus, Pagurus, Cryptolithodes, Hemigrapsus, and Pentidotea), molluscs (cephalopods, abalone, limpets, chitons, and clams), and fishes (Cottidae, Gibbonsia, Sebastes, and Citharicthys). Hart (1973) mentioned that yellow-eye rockfish are known to eat crustaceans and lingcod spawn, but he made no reference to any more specific studies on this species nor to any studies on black rockfish or China rockfish (S. nebulosus) food habits. To my knowledge, there are no published accounts concerning the feeding interrelationships among the fishes comprising the neritic reef fish communities off the Pacific Coast of North America.

METHODS AND MATERIALS

Study Area

The study area was located immediately north of Depoe Bay, Oregon and extended from Government Point north to Cascade Head and offshore to the 50 m depth contour (Fig. 1). Reefs in this area were classified as either Type I--those between the 10 and 20 m depth contours, Type II--those between 20 and 30 m, or Type III--those between 30 and 50 m. Figure 2 illustrates the bathymetric stratification along a typical inshore-offshore transect reconstructed from fathometer recordings taken in the study area.

Hydrography

Surface sediments from the shoreline to a water depth of about 100 m (55 fm) are predominantly sands consisting of detrital quartz and feldspar (Bourke et al., 1971), and these sediments vary in thickness from 0-30 m (MacKay, 1969). Neritic reefs are formed where barren rock is exposed to the overlying ocean. The size and configuration of these rock outcroppings varies from small, jagged pinnacles less than .001 km^2 in surface area, to large, relatively smooth rock surfaces in excess of 1.0 km^2. The amount of exposed rock changes seasonally with variations in sand transport (personal communication, Capt. Fred Robison, Depoe Bay, Oregon). During

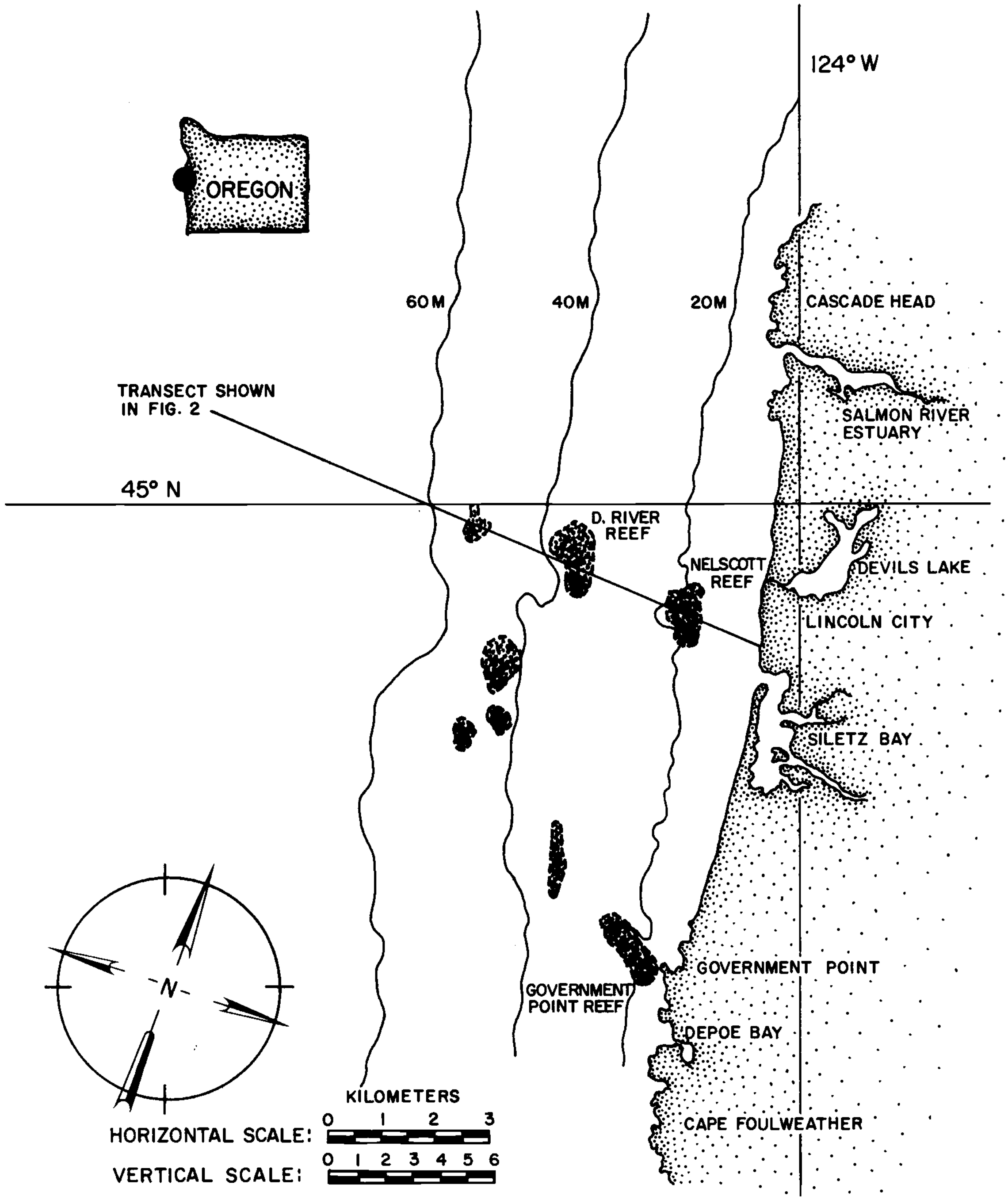

Figure 1. Map of the area from Government Point to Cascade Head, Oregon, in which the ecological relationships of neritic reef fishes were studied during 1976-77. (Horizontal scale west of the coastline is enlarged 2x.)

the winter, the onshore-offshore rate of transport of sand is greatest, moving sand from littoral areas to greater depths. The longshore transport of sand is to the north during the winter and to the south during the summer, and varies by area (Kulm et al., 1968). The bottom slope of the first 1/2-mile from shore is significantly greater than the slope farther offshore, varying from 1:100 to 1:35 nearshore, and from 1:100 to 1:600 at distances greater than 1/2-mile from shore (Fig. 2).

Temperatures recorded at the Yaquina Bay sensor during the study period by the School of Oceanography at Oregon State University and surface temperatures taken from the M/V Tooshqua are shown in Figure 3. Intense turbulent mixing during the winter often leads to isothermal conditions over the nearshore area, and occassionally a weak thermocline becomes established at depths less than 20 m during the summer (Bourke et al., 1971).

The currents in the nearshore regions are a complex function of winds, main ocean currents, tides, and bottom topography. These currents vary in force and direction on time scales as short as one hour and at times the flow in one area is in a direction opposite to that of another nearby area (Neal et al., 1969). This variability is supported by personal observations. During an upwelling event recorded in August and September, 1966, Mooers et al. (1968) found the near bottom currents 8, 16, and 24 km off Depoe Bay to be

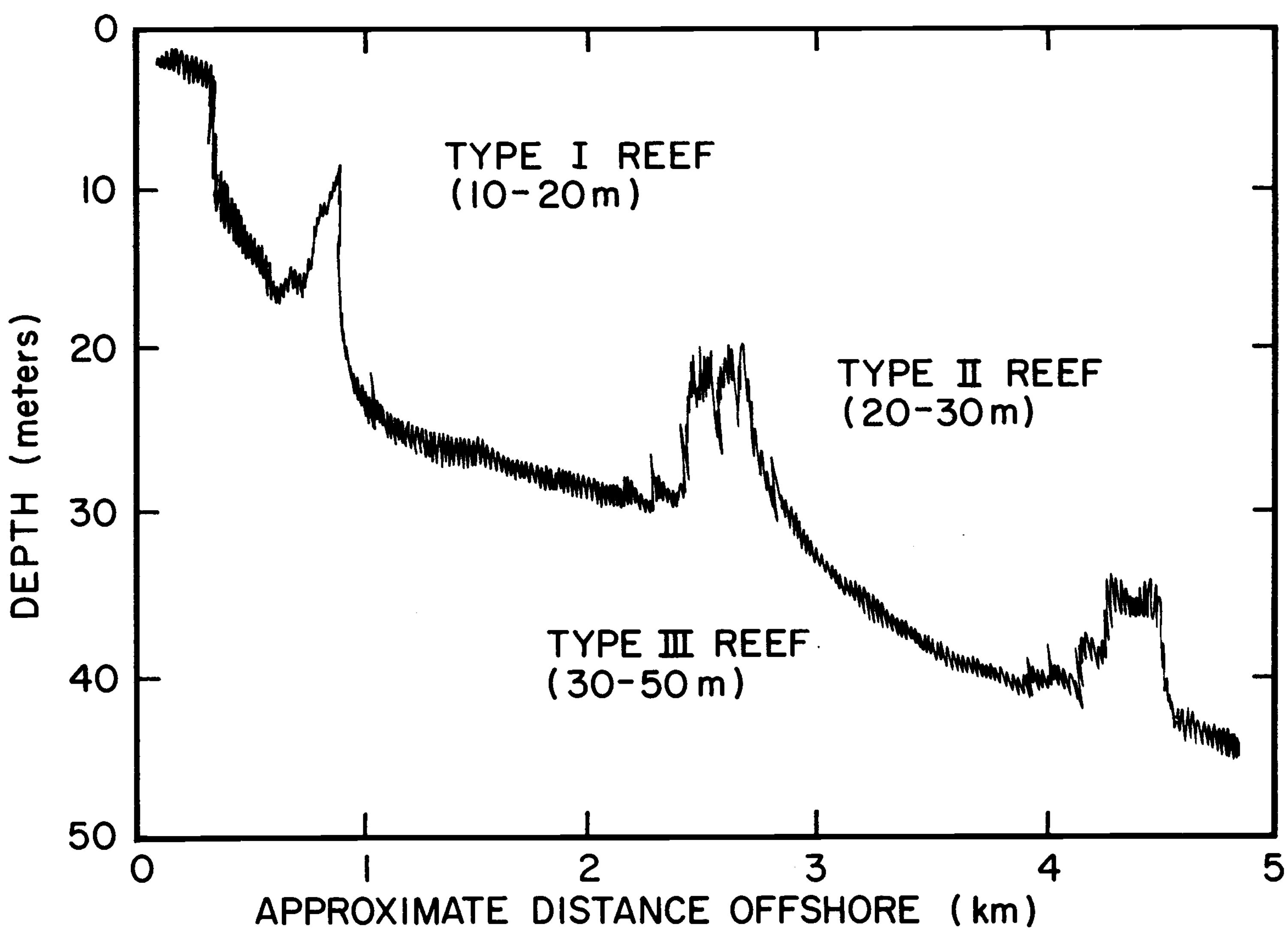

Figure 2. Bathymetry of a typical onshore-offshore transect (Fig. 1) reconstructed from echo sounder recordings made on the study area showing reef types stratified by depth.

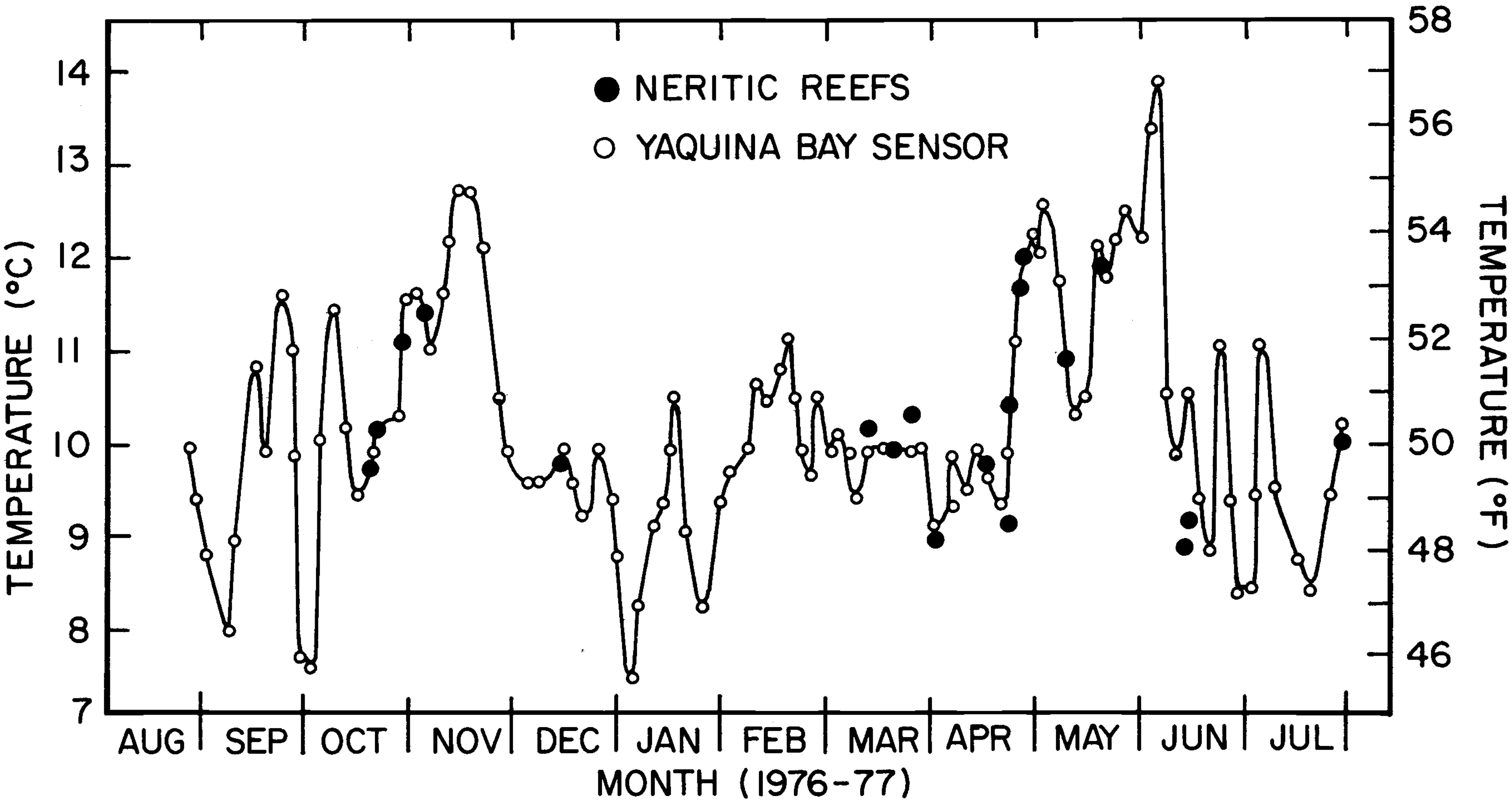

Figure 3. Sea surface temperature measured over neritic reefs adjacent to Depoe Bay, Oregon, and 3-day mean temperature at Yaquina Bay sensor during study period.

directed toward the north and onshore, while the near surface currents were directed toward the south and offshore. They stated that it was uncertain how the upwelling event affected the region within 8 km of the shore, but believed mixing was dominant. Brown (1967) reported that when current velocities are of appreciable magnitude, the bottom sediment may become loosely compacted with considerable material in suspension. This is supported by personal observation. These conditions might lead to severe scouring and sedimentation around neritic reefs (Brown, 1967). Wave heights during the study period were observed to vary from <1 m to >8 m, with both the mean height and variability being greatest during the winter.

Sampling Methods

Fishing was conducted from the M/V Tooshqua, a 26-foot Newport dory. Reefs were located using LORAN A and a continuously recording depth sounder, on the basis of position information provided by Capt. Fred Robison. The M/V Tooshqua was fished on the Government Point reef and the inshore Nelscott reef to sample Type I reefs, and on the D River reef to sample Type II reefs. The charter boat catch on reefs from 30-50 m deep was used to sample Type III reefs (Fig. 1). The fishing gear and methods used in this study were those conventionally used to catch reef fishes by charter boat fishermen. A 12- to 16-oz piece of molded lead with a terminal treble hook, or occasionally a single hook baited with whole herring or eulachon (smelt) (Thaleicthys pacificus) was fished by rod and reel using 30-lb test monofilament line. Whereas the charter boats used only a terminal jig or baited hook, I added a small plastic lure (hootchie) and a hook about 1-m above the jig. To fish, the gear was gently moved up and down while keeping it as close to the bottom as possible. The number of rods used each day was multiplied by the number of hours fished to obtain an estimate of fishing effort in gear hours per day. While fishing, the boat was allowed to drift, as a result of current and wind stress, from one side of the reef to the other.

The fish were identified to species, weighed, measured for fork length, and identified to sex whenever possible; then they were either released as part of a tagging study or retained for stomach analyses. Most stomachs were collected by dissection from those fish not released, but occasionally, before tagged fish were released, a partial stomach sample was obtained by pressing the fish's abdomen in a direction toward their mouth which caused the fish to regurgitate. Also stomachs often became everted during ascent to the surface due to air bladder expansion and other reasons, and the regurgitated food items were collected whenever possible. Charter boat catches were sampled periodically throughout the year, and stomach samples were collected along with information on relative abundance, length, and weights of species in the catch.

The stomachs and food items were preserved in 10% buffered Formalin, and later washed with fresh water and placed into 40% isopropyl alcohol. The food items were identified to the lowest taxonomic category deemed necessary (usually as far as possible), and weighed to the nearest gram with an electronic balance. Entire fishes were identified with "Guide to the Coastal Marine Fishes of California" (Miller and Lea, 1972), and partially digested fishes were identified on the basis of vertebral characteristics using "A Key to Some Southern California Fishes Based on Vertebral Characters" (Clothier, 1950). Fish remains not identifiable by either of the above methods were identified occasionally by comparing them to skeletal structures taken from fishes collected during the R/V Cayuse cruise of January 7-9, 1978. A reference collection of all prey items was made and the identification of all food items was verified by specialists at Oregon State University.

RESULTS

Species Composition

Tables 1, 2, and 3 show the species composition of the catch from the M/V Tooshqua on Type I and II reefs and the charter boat catch on Type III reefs. Five principal species--black rockfish, lingcod, blue rockfish, yelloweye rockfish, and cabezon--together constituted from 92-99% of the weight of each seasonal catch (Fig. 4). Two of these species--lingcod and black rockfish--comprised the majority (52.1-90.4%) of the weight of each seasonal catch. The percent of the biomass of the catch represented by each of these two species is shown in Figures 5 and 6. For lingcod, the relative percentage of the catch was consistently greater on Type III reefs than on Type II reefs, and consistently greater on Type II reefs than on Type I reefs. Also, the relative percentage of lingcod in the catch was consistently greater during the winter than during the summer for all three areas. For black rockfish, an opposite trend is observed. The percent of the total biomass of the catch comprised by black rockfish was consistently greater on Type I reefs than on Type II reefs, and was greater on Type II reefs than on Type III reefs, and was lower in the winter than in the summer for all three areas.

The mean daily catch per unit effort (CPUE) for lingcod was consistently greater in Type II catches than in Type I catches for all

Table 1. Species composition of the catch of neritic reef fishes on Type I reefs (10-20 m) during 1976-1977.

Species	Summer			Fall			Winter			Spring		
	No.	kg	kg%	No.	kg	kg%	No.	kg	kg%	No.	kg	kg%
Sebastes melanops	200	300.4	76.9	176	229.1	55.6	70	90.4	39.4	152	231.7	58.1
Ophiodon elongatus	15	52.9	13.5	26	110.9	26.9	29	108.0	47.1	27	94.5	23.7
Scorpaenicthys	7	17.6	4.5	12	39.3	9.5	7	18.2	7.9	9	32.0	8.0
Sebastes mystinus	6	5.5	1.4	24	18.7	4.5	14	10.8	4.7	44	32.6	8.2
Sebastes nebulosus	4	6.3	1.6	5	5.7	1.4	-	-	-	-	-	-
Sebastes pinniger	1	1.1	0.3	3	3.1	0.8	-	-	-	1	1.3	0.3
Hexagrammos decagrammus	5	4.9	1.3	3	3.0	0.7	2	1.8	0.8	6	4.5	1.1
Hexagrammos lagocephalus	1	1.1	*	-	-	-	-	-	-	1	1.1	0.3
Hemilepidotus hemilepidotus	1	0.8	0.2	1	1.0	0.2	-	-	-	-	-	-
Sebastes flavidus	-	-	-	2	0.9	0.2	-	-	-	2	1.0	0.3
Totals	240	390.6		252	411.7		124	229.2		241	398.7	
Gear hours		134			140			69			133	
Days fished		26			19			13			25	

*Trace amount

Table 2. Species composition of the catch of neritic reef fishes on Type II reefs (20-30 m) during 1976-1977.

Species	Summer			Fall			Winter			Spring		
	No.	kg	kg%	No.	kg	kg%	No.	kg	kg%	No.	kg	kg%
Sebastes melanops	81	139.5	30.7	104	172.4	45.4	8	13.3	6.2	39	67.6	33.6
Ophiodon elongatus	21	116.7	25.7	25	127.9	33.7	30	141.3	66.1	18	78.5	39.0
Scorpaenicthys	10	45.5	10.0	1	5.7	1.5	1	8.2	3.8	3	14.4	7.2
Sebastes ruberrimus	16	83.0	18.3	5	20.8	5.5	7	39.1	18.3	4	22.6	11.3
Sebastes mystinus	39	40.0	8.8	31	34.9	9.2	3	3.3	1.5	7	9.6	4.8
Sebastes nebulosus	7	11.2	2.5	1	1.3	0.3	1	1.9	0.9	5	8.5	4.3
Sebastes flavidus	3	1.3	0.3	12	5.8	1.5	1	0.1	*	-	-	-
Sebastes pinniger	4	10.4	2.3	5	10.7	2.8	2	6.6	3.1	-	-	-
Sebastes rubrivinctus	1	2.6	0.6	-	-	-	-	-	-	-	-	-
Hexagrammos decagrammus	4	4.5	1.0	1	0.2	*	-	-	-	-	-	-
Totals	186	454.7	-	185	379.7	-	53	213.8	-	76	201.2	-
Gear hours		136			100			32			45	
Days fished		18			10			5			8	

* Trace amount

Table 3. Species composition of the catch of neritic reef fishes on Type III reefs (30-50 m) during 1976-1977.

Species	Summer No.	Summer kg	Summer kg%	Winter No.	Winter kg	Winter kg%
Sebastes melanops	337	539.0	23.4	17	27.0	1.6
Ophiodon elongatus	107	663.0	28.7	204	1265.0	74.5
Scorpaenicthys	46	147.0	6.4	32	102.4	6.0
Sebastes ruberrimus	143	744.0	32.2	48	250.0	14.7
Sebastes mystinus	26	34.0	1.5	8	10.4	0.6
Sebastes nebulosus	57	74.0	3.2	3	4.0	0.2
Sebastes flavidus	4	6.0	0.2	-	-	-
Sebastes pinniger	39	78.0	3.4	16	32.0	1.9
Sebastes maliger	1	1.0	*	-	-	-
Hexagrammos decagrammus	29	29.0	1.3	7	7.0	0.4
Hexagrammos lagocephalus	1	1.0	*	-	-	-
Hydrolagus	1	+	*	-	-	-
Platichthys	1	+	*	-	-	-
Hemilepidotus	4	+	*	-	-	-
Sebastes miniatus	1	+	*	-	-	-
Sebastes nigrocinctus	1	+	*	-	-	-
Sebastes rosaceus	1	+	*	-	-	-
Totals	799	2,308.0	*	335	1,697.0	

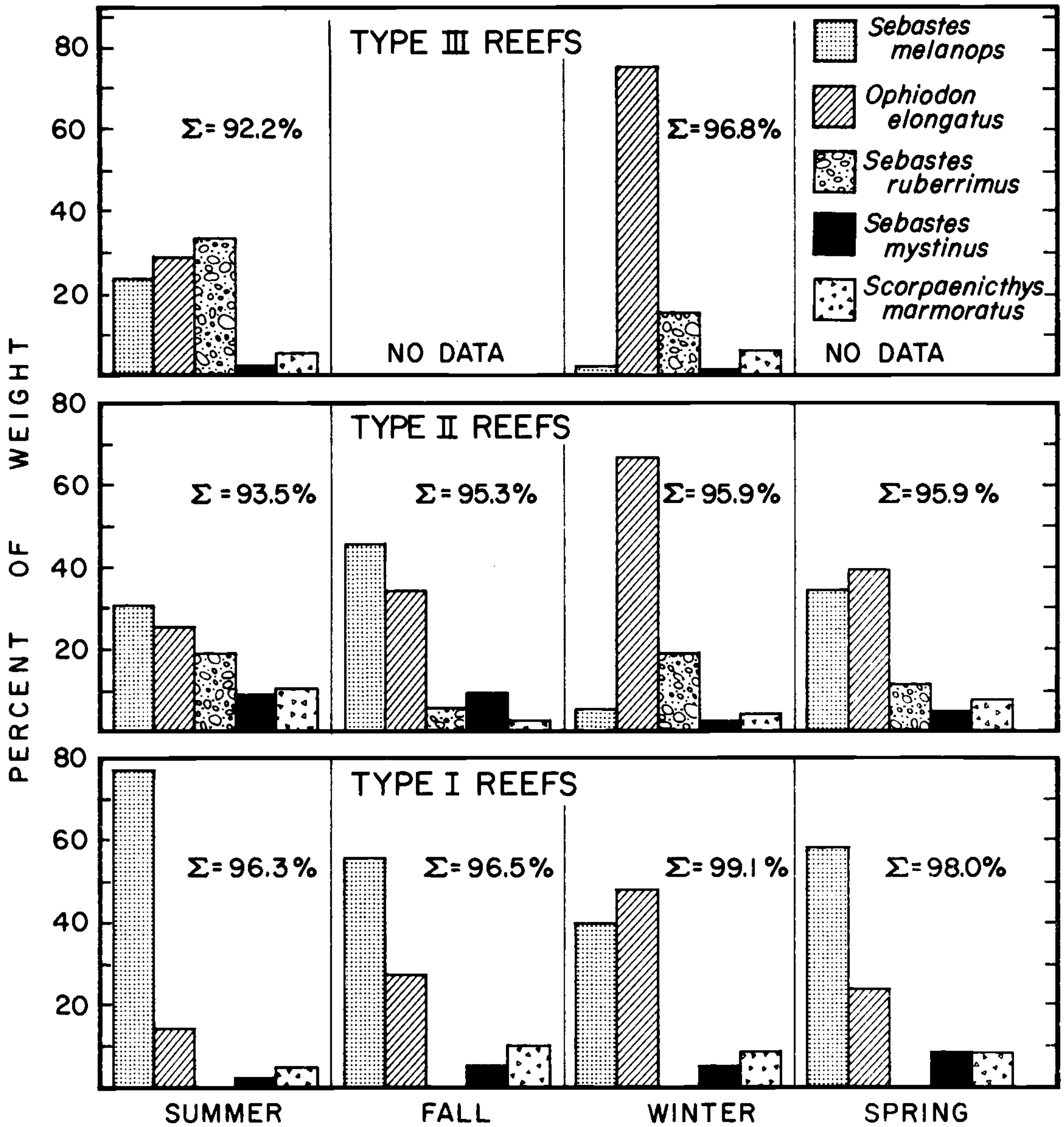

Figure 4. Percent of weight of the seasonal catch comprised by the five principal species captured on Type I (10-20 m), Type II (20-30 m), and Type III (30-50 m) reefs near Depoe Bay, Oregon, during 1976-1977.

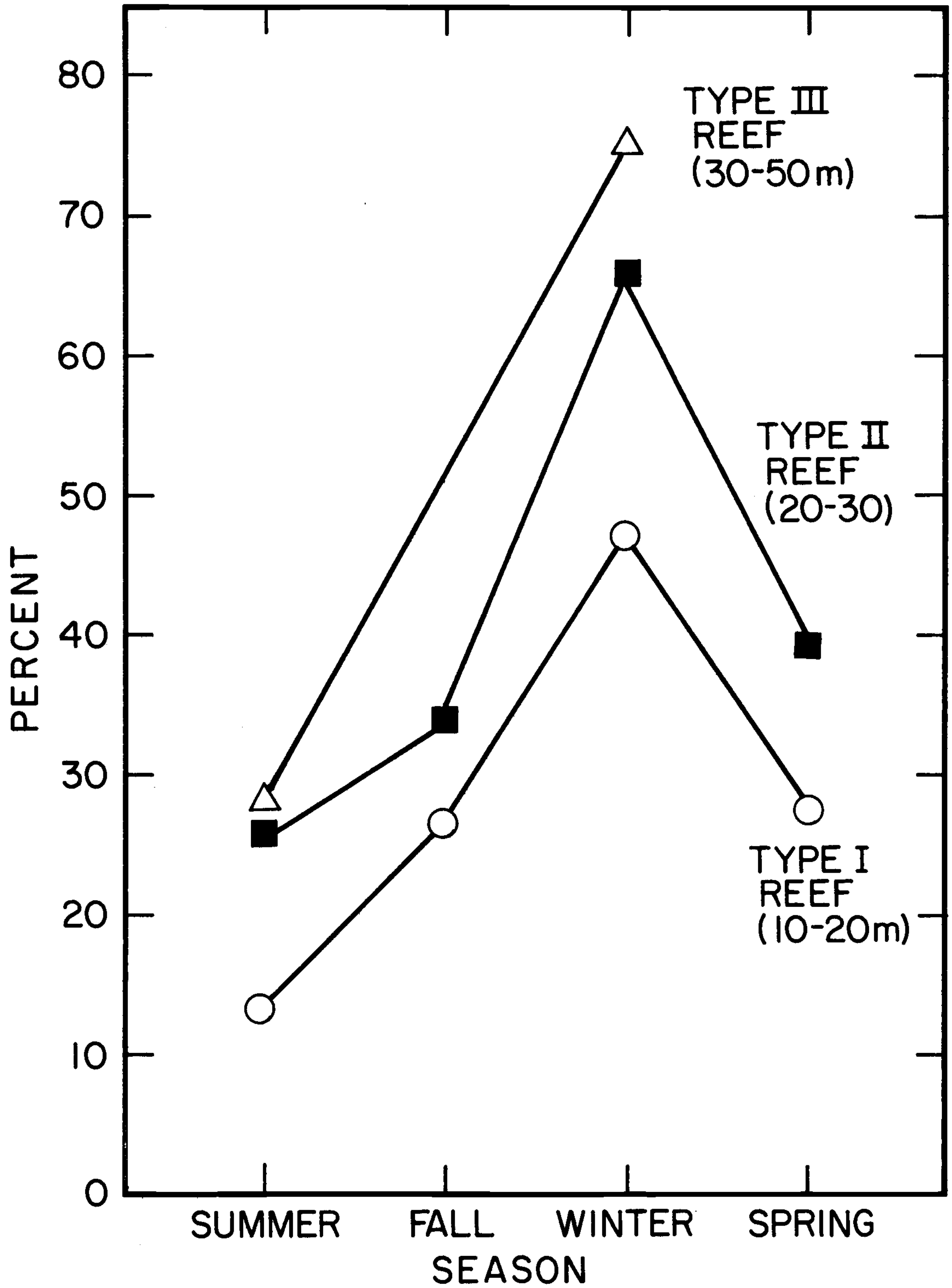

Figure 5. Percent of weight of the total catch comprised by lingcod by reef type and season near Depoe Bay, Oregon during 1976-1977.

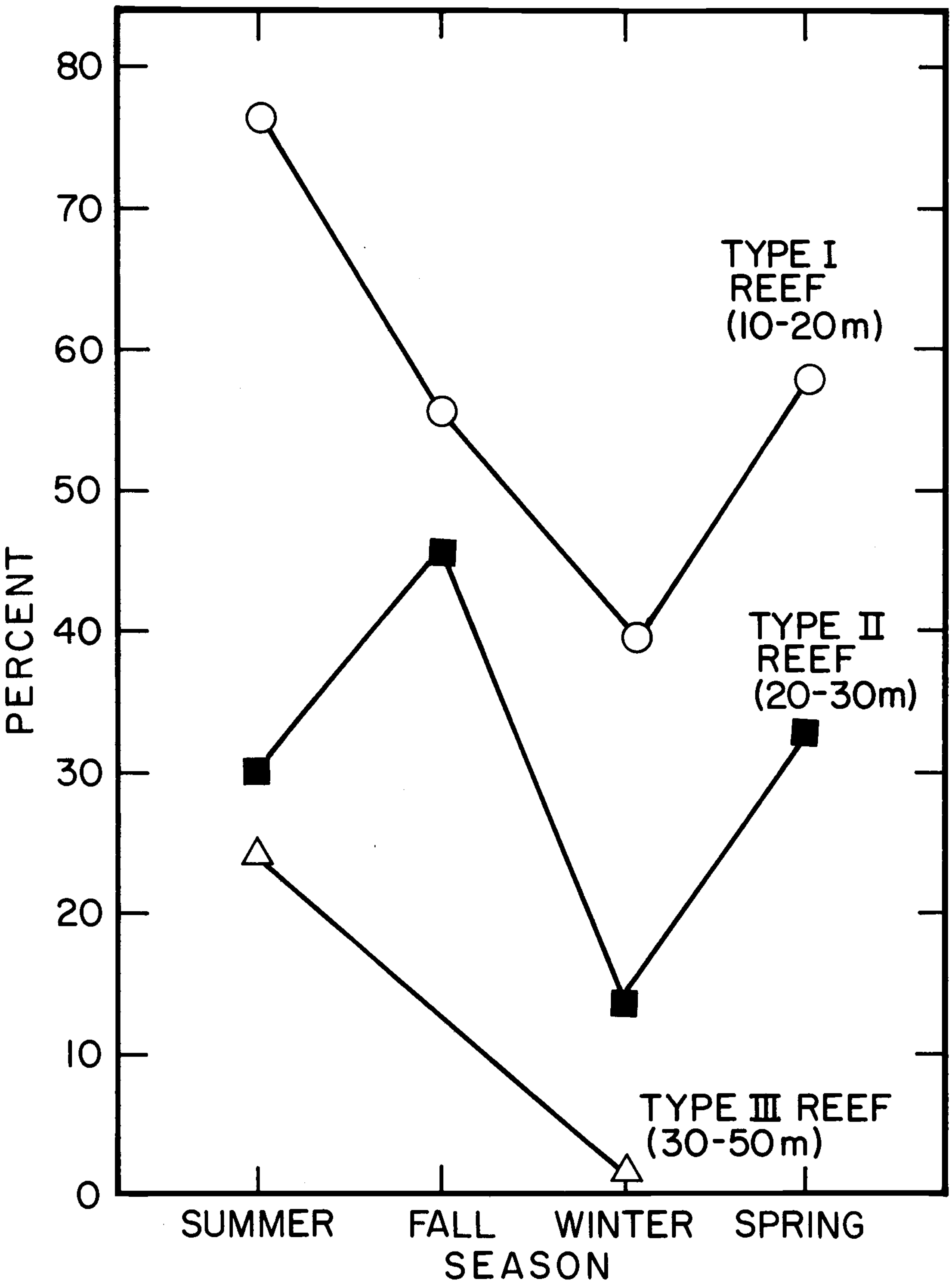

Figure 6. Percent of weight of the total catch comprised by black rockfish by reef type and season near Depoe Bay, Oregon during 1976-1977.

seasons and was greater during the winter for both reef types (Fig. 7). The mean daily CPUE for black rockfish was consistently greater in Type I catches than in Type II catches, and there was no apparent seasonal trend (Fig. 8).

To analyze the effect of season and depth on the CPUE of lingcod and black rockfish, a Wilcoxon Z test was applied, where

$$Z = \frac{T_x - \frac{N_1(N_1 + N_2)}{4}}{\sqrt{\frac{N_1 N_2(N_1 + N_2 + 1)}{12}}}$$

and N_1 = smaller sized sample

N_2 = larger sized sample

T_x = the smaller sum of the ranks (either T or T') of N_1

Table 4 shows the calculated significance levels of the differences between Type I and II reef areas for CPUE for lingcod and black rockfish in each season. The only highly significant result is that the CPUE for black rockfish was greater on Type I reefs than on Type II reefs during the summer and winter. The bias of multiple inference can be ignored because $\frac{.08}{8}$ (or 1%) of the comparisons are expected to be significant at $p \leq .01$ by chance alone, while in Table 4, $\frac{2}{8}$ (25%) of the comparisons are significant beyond this level.

Table 5 shows the calculated significance levels of seasonal differences in the CPUE for lingcod and black rockfish by reef type.

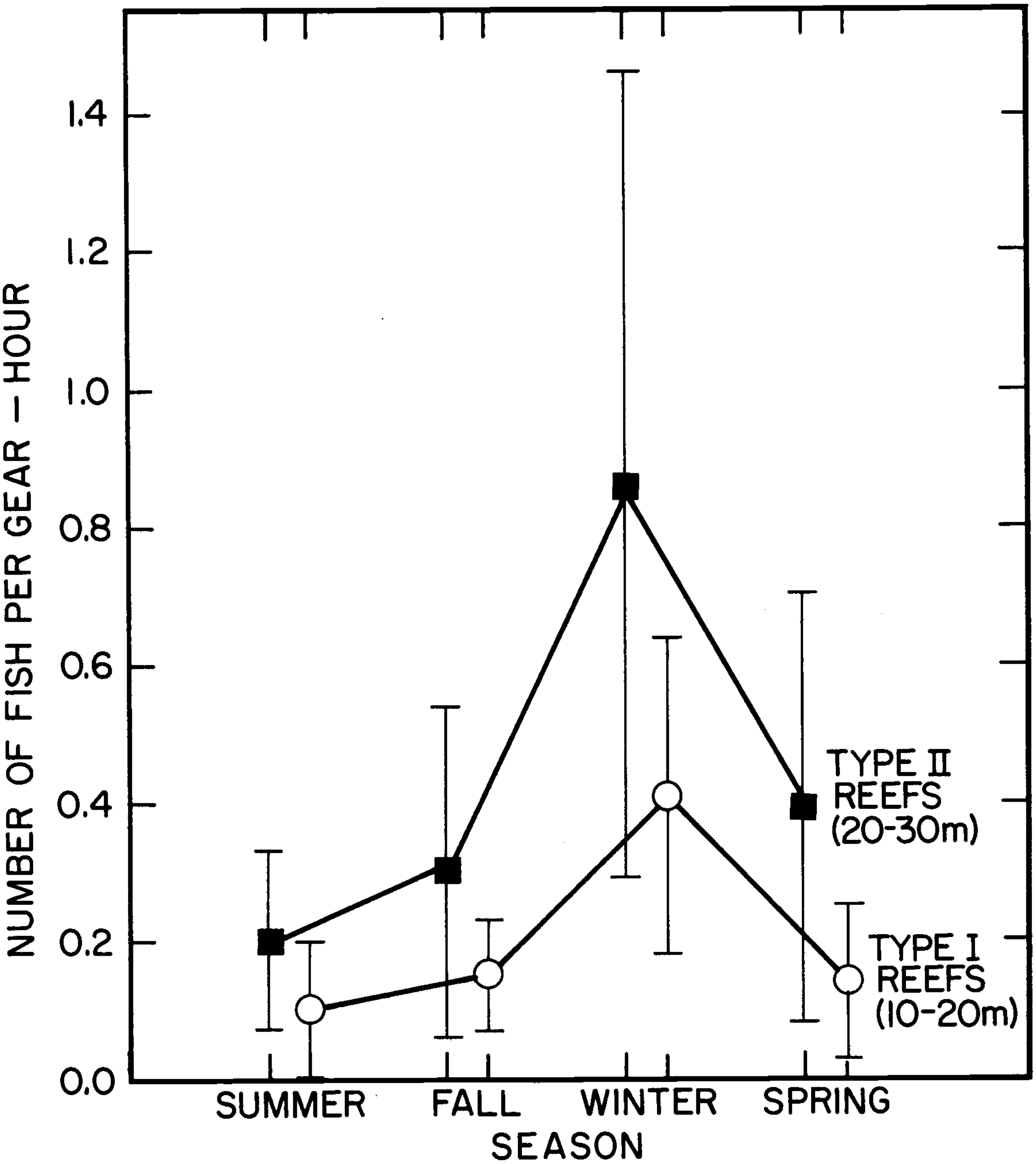

Figure 7. Mean daily catch per unit effort for lingcod by reef area and season near Depoe Bay, Oregon during 1976-1977.

Table 4. Significance levels (calculated by Wilcoxon Z test) of the differences in the catch per unit of effort (CPUE) for lingcod and black rockfish on Type I and II reef areas.

Season	Lingcod I x II[a]	Black Rockfish I x II
Summer	+.3472[b]	-.0030[c]
Fall	+.2302	-.8104
Winter	+.2040	-.0044[c]
Spring	+.4902	-.5286

[a] I x II = CPUE in Type I reef area (10-20 m) compared to CPUE in Type II reef area (20-30 m).

[b] + or - indicates whether CPUE increased or decreased from Type I to Type II reef areas.

[c] considered highly significant.

Table 5. Significance levels (calculated by Wilcoxon Z test) of seasonal differences in catch per unit of effort (CPUE) for lingcod and black rockfish by reef type.

Seasons	LC/I	LC/II	BK/I	BK/II[a]
Summer x Fall	+.1188[b]	+.1164	-.4180	+.0818
Summer x Winter	+.0308[c]	+.0168[c]	-.5092	-.8728
Summer x Spring	+.4066	+.7040	-.2003	+.3078
Fall x Winter	+.0750[c]	+.0718[c]	+.6600	-.2340
Fall x Spring	-.8026	+.9522	+.7948	-.9602
Winter x Spring	-.0750	-.2040	-.6966	+.1738

[a] LC/I = lingcod, Type I reef (10-20 m), LC/II = lingcod, Type II reef (20-30 m), BK/I = black rockfish, Type I reef, and BK/II = black rockfish, Type II reef

[b] + or - indicates whether CPUE increased from season 1 to season 2.

[c] considered significant.

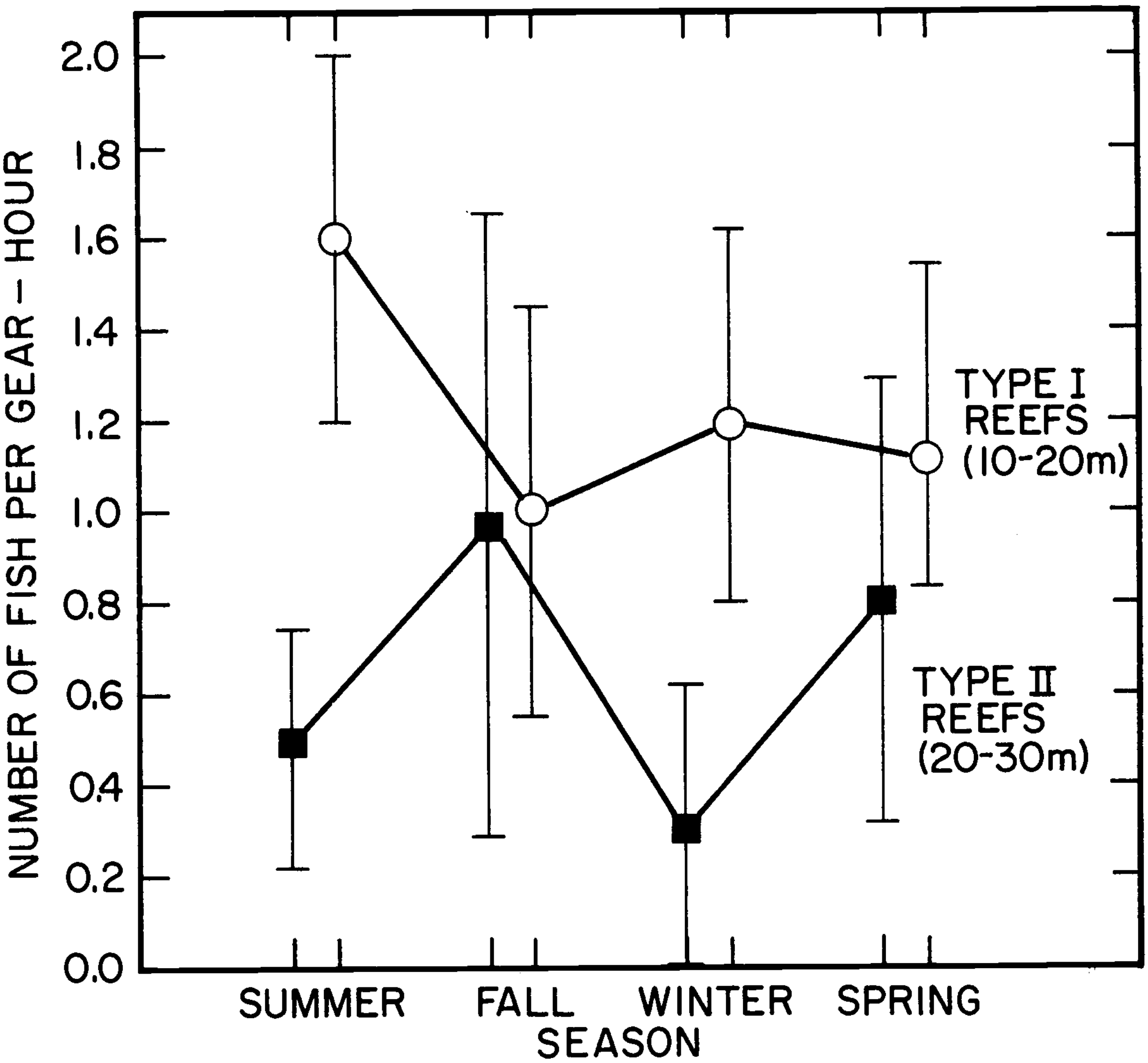

Figure 8. Mean daily catch per unit effort for black rockfish by reef type and season near Depoe Bay, Oregon during 1976-1977.

Ten percent ($\frac{2.4}{24}$) of the comparisons could be significant at the $p \leq .10$ level due to chance alone, but because $\frac{6}{24}$ of the comparisons are significant beyond this level, it is probable that 4 of these represent actual differences in the seasonal CPUE. The four most significant differences were the increase in CPUE for lingcod from summer to winter and fall to winter in both reef areas.

Figure 9 indicates that generally the lingcod inhabiting Type III reefs are larger (and probably older) than those inhabiting Type II reefs, and those on Type II reefs tend to be larger than those on Type I reefs. Although it was not quantified, there seemed to be very few immature lingcod caught in any of the reef areas.

The length-frequency diagram for black rockfish caught on Type I and II reefs is shown in Figure 10. The insufficient number of length measurements for black rockfish caught on Type III reefs made it impossible to compare them with the catch on Type I and II reefs. The trend in black rockfish size with depth was similar to that for lingcod, being generally larger in the deeper reef areas. Thirty-seven percent of the black rockfish caught on the Type I reefs were smaller than the estimated size at 50% maturity (taken from data collected by Jerry Butler, ODFW, on reefs adjacent to Newport, OR), while only 12% of those caught on Type II reefs were smaller than this size.

Table 6 shows the winter and summer sex ratios for lingcod

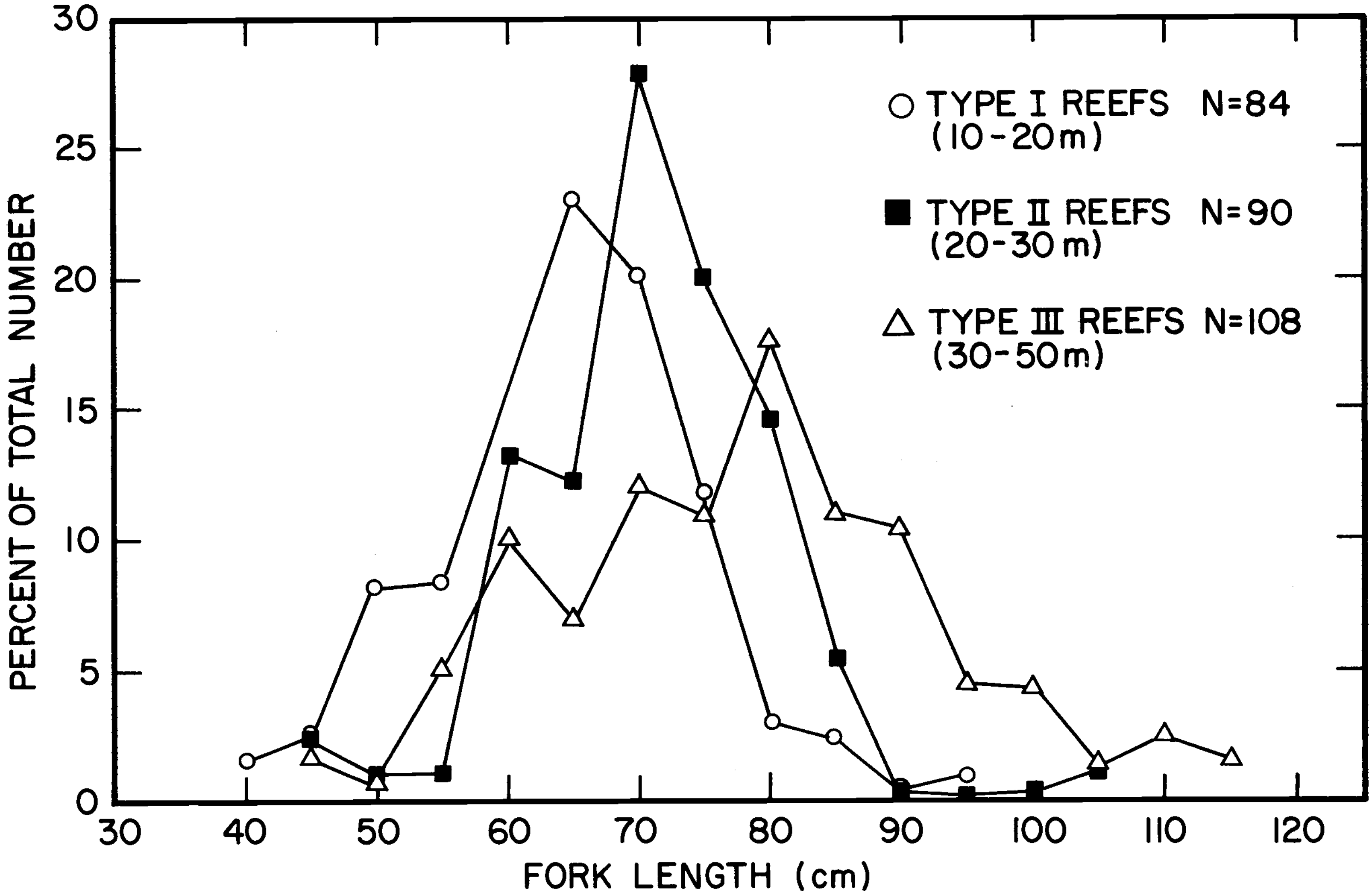

Figure 9. Length-frequency (by 5 cm increments) of lingcod caught on Type I, II, and II reefs near Depoe Bay, Oregon during 1976-1977.

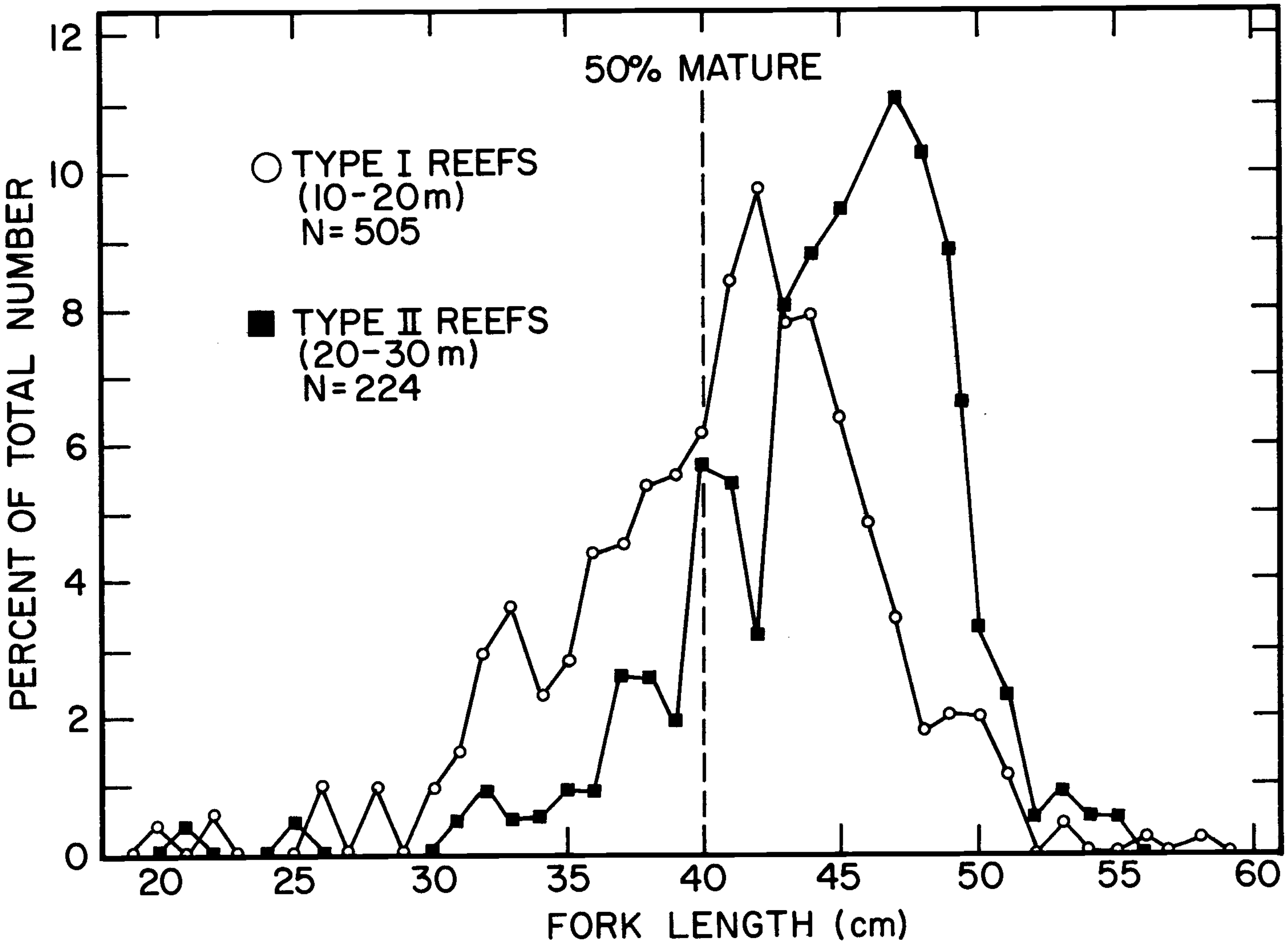

Figure 10. Length-frequency of black rockfish caught on Type I and Type II reefs near Depoe Bay, Oregon during 1976-1977, showing length at which 50% are estimated to be mature.

caught in all three reef areas combined. During the summer, the ratio of females to males was 1:5.3, and during the winter the ratio was 1:1.1. The ratio of female to male black rockfish caught in all reef areas for all seasons combined was 1:1.1 (47% females and 53% males) for 149 fish.

Table 6. Seasonal sex ratios for lingcod caught on neritic reefs adjacent to Depoe Bay, Oregon during 1976-1977.

Season	Male	Female	N
Summer	84%	16%	88
Winter	58%	42%	76

Food Habits

Table 7 shows the percentage of the biomass of all food items in each principal species represented by each food item. I estimated the dissimilarity of the diets of the five principal species and one non-principal species, China rockfish, using the Bray-Curtis dissimilarity measure (Clifford and Stephenson, 1976). This index, here referred to as BC is:

$$BC = \frac{\sum_{1}^{N} \left| X_j - Y_j \right|}{\sum_{1}^{N} (X_j + Y_j)}$$

where X_j and Y_j are measures of the proportion of the biomass of

Table 7. Food items found in the stomachs of six neritic reef fish species during 1976-77, expressed as the percent of the total biomass of the stomach contents of the species.

Foot Item	Species[1]					
	LC	BK	BU	YE	CBZ	CH
Pelagic Nekton						
Allosmerus (juv.)	0.3	19.0	---	---	---	1.0
Allosmerus (adult)	7.1	32.5	5.8	0.4	---	---
Engraulis	0.2	8.5	5.4	---	---	---
Clupea	1.1	5.0	---	---	---	---
Sebastes (juv.)	0.4	2.6	---	2.4	0.5	---
Demersal Nekton						
Sebastes (adult)	3.0	---	---	9.1	---	---
Cottidae (UNID)[2]	0.6	---	---	6.2	4.8	---
Leptocottus	7.1	---	---	---	---	---
Artedius	---	0.7	---	19.8	---	---
Clinocottus	0.4	---	---	1.2	---	---
Hemilepidotus	1.7	1.7	---	---	2.8	---
Gibbonsia	---	---	---	---	1.8	---
Hexagrammos eggs	*[3]	---	---	1.2	---	---
Ophiodon eggs	3.9	*	---	4.2	8.0	---
Pleuronectidae (UNID)	2.2	---	---	11.7	---	---
Isopsetta	2.2	1.7	---	---	---	---
Glyptocephalus	2.2	---	---	---	---	---
Lepidopsetta	1.2	---	---	---	---	---
Parophrys	12.1	---	---	---	---	---
Microstomus	---	*	---	---	---	---
Citharicthys	1.2	---	---	---	---	---
Microgadus	11.4	0.8	---	---	---	---
Merluccius	10.6	---	---	---	---	---
Anoplopoma	2.7	---	---	---	---	---
Ocella verrucosa	0.6	---	---	---	---	---
Trichodon	2.7	---	---	---	---	---
Ronquilus	0.6	---	---	---	---	---
Octopus	19.2	---	---	1.2	0.9	---

continued on next page

Table 7. (continued)

Food Item	Species					
	LC	BK	BU	YE	CBZ	CH
Zooplankton						
GZP[4] (UNID)	---	---	23.3	---	---	---
Pleurobrachia	---	0.2	3.8	---	---	---
Megalopa	---	9.5	4.4	---	---	---
Scyphozoa	---	---	21.7	---	---	---
Salp	---	4.0	---	---	---	---
Clione	---	---	0.8	---	---	---
Limacina	---	2.4	---	---	---	---
Mysid	---	3.8	0.8	---	---	---
Zoea	---	0.6	---	---	---	---
Hydromedusae	---	---	11.6	---	---	---
Benthic Invertebrates						
Gastropoda	*	---	---	---	1.0	---
Chiton	---	---	---	---	9.8	9.6
Pandalus	0.3	---	---	7.5	0.3	---
Heptacarpus	---	---	---	1.2	---	---
Crangon	---	---	2.3	---	---	1.9
Cumacea	---	---	*	---	---	---
Oxyrhyncha	---	---	---	---	28.8	29.8
Brachyryncha (UNID)	---	---	---	---	1.7	5.8
Cancer oregonensis	---	---	---	---	32.5	51.9
Cancer (UNID)	0.3	---	---	33.1	5.6	---
Annelida	---	0.2	1.2	---	---	---
Isopoda	---	0.1	---	---	---	---
UNID Fish	---	3.8	5.4	0.4	0.3	---
UNID organic matter	---	2.7	13.5	---	---	---
Number of stomachs	148	156	51	28	39	11

[1] LC - lingcod, BK = black rockfish, BU = blue rockfish, YE = yellow eye rockfish; CBZ = cabezon, CH = china rockfish

[2] Unidentified   [3] * = trace amount   [4] Gelatinous zooplankton

all food items in species X and Y that are represented by food item j. BC values range from .00 when all of the food items consumed by species X are consumed in equal amounts by species Y, to 1.00 when none of the food items consumed by species X are consumed by species Y. The calculated values are shown in Table 8. The only predator pair with a low BC value (high similarity) was cabezon-China rockfish. All BC values for principal species pairs were $\geq .80$, indicating very low similarity in their diets.

To determine if any prey item represented a significant food resource for more than one principal species, a food partition plot (Table 9) was constructed similar to that used by Tyler (1972). All food items which represented 7% or more of the diet of a species were considered significant food resources. Only two food resources were significant components of the diets of more than one principal predator, these were adult whitebait smelt (Allosmerus elongatus) for black rockfish and lingcod, and Pleuronectidae for lingcod and yelloweye rockfish.

Tables 10 and 11 show the itemized stomach contents by season and the percentage of empty stomachs by season for black rockfish and lingcod, respectively. The percent of black rockfish and lingcod stomachs that were empty was greatest during the winter for each species (Fig. 11). However, Table 12 shows that the average amount of food in all non-empty stomachs was greatest for lingcod during the

Table 8. Bray-Curtis (Bray and Curtis, 1957) measures of dissimilarity between the stomach contents of fishes caught on neritic reefs adjacent to Depoe Bay, Oregon during 1976-1977. Values vary from .00 for complete similarity to 1.00 for complete dissimilarity.

Species[1]	BK	BU	YE	CBZ	CH
LC	.86	.93	.87	.92	1.00
BK	-	.80	.96	.98	.99
BU	-	-	1.00	1.00	.98
YE	-	-	-	.84	1.00
CBZ	-	-	-	-	.27

[1] LC = lingcod, BK = black rockfish, BU = blue rockfish, YE = yellow-eye rockfish, CBZ = cabezon, CH = China rockfish.

Table 9. Principal prey items taken by the five principal fish species caught off Depoe Bay, Oregon during 1976-1977, expressed as percent of the total biomass of the stomach contents of the species.

Food Items	Species[1]				
	LC	BK	BU	YE	CBZ
Allosmerus (juv.)		19.0			
Allosmerus (adult)	7.1	32.5			
Engraulis		8.5			
Sebastes				11.5	
Leptocottus	7.1				
Artedius				19.8	
Pleuronectidae	19.9			11.7	
Microgadus	11.4				
Merluccius	10.6				
Octopus	19.2				
GZP[2]			56.6		
Megalopa		9.5			
Chiton					9.8
Pandalus				7.5	
Oxyryncha					28.8
Cancer oregonensis					32.5
Other *Cancer* spp.				33.1	
Total	75.3	69.5	56.6	83.6	71.1

1 BK = black rockfish, LC = lingcod, BU = blue rockfish, YE = yellow rockfish, CBZ = cabezon.

2 Gelatinous zookplankton.

Table 10. Seasonal stomach contents of black rockfish caught on neritic reefs adjacent to Depoe Bay, Oregon during 1976-1977.

Food Item	Summer		Fall		Winter		Spring	
	g	%	g	%	g	%	g	%
Allosmerus	132.5	73.7	140.4	51.8	7.0	*	195.3	53.6
Isopsetta	15.2	33.5	-	-	-	-	-	-
Mysid	19.0	10.6	14.8	5.5	-	-	2.2	0.6
Shrimp	15.0	0.8	1.5	0.6	0.5	*	-	-
Megalopa	1.0	0.5	-	-	-	-	87.9	24.1
Pleurobrachia	0.2	0.1	-	-	-	-	-	-
Sebastes	4.0	2.2	2.0	0.7	-	-	17.0	4.7
Artedius	6.3	3.5	-	-	-	-	-	-
Engraulis	-	-	50.7	18.7	-	-	25.8	7.1
Clupea	-	-	43.7	16.1	-	-	-	-
Microgadus	-	-	8.6	3.2	-	-	-	-
GZP[1]	-	-	0.4	-	-	-	-	-
Isopoda	-	-	1.2	0.4	-	-	-	-
Zoea	-	-	2.0	0.7	-	-	-	-
Hydrozoa	-	-	5.5	2.0	-	-	-	-
Salp	-	-	-	-	35.0	*	-	-
Hemilepidotus	-	-	-	-	-	-	15.0	4.1
Limacina	-	-	-	-	-	-	21.0	5.8
Totals	193.2		280.8		42.5		364.2	
Stomachs		34		52		19		36
Empty Stomachs		8 (23%)		21 (40%)		14 (74%)		13 (36%)

[1] Gelatinous zooplankton.

*Not calculated due to inadequate sample size.

Table 11. Seasonal stomach contents of lingcod caught on neritic reefs adjacent to Depoe Bay, Oregon during 1976-1977.

Food Items	Summer			Fall			Winter			Spring		
	N	g	%	N	g	%	N	g	%	N	g	%
Allosmerus	38	157	7.0	4	9	2.0	34	263	16.9	7	10	0.6
Clupea	4	74	3.3	-	-	-	-	-	-	-	-	-
Pleuronectid	4	258	11.5	3	220	48.1	7	674	43.3	5	315	18.2
Microgadus	4	224	10.0	2	92	20.1	3	91	5.8	13	283	16.3
Sebastes	12	19	0.8	1	45	9.8	-	-	-	9	150	8.7
Leptocottus	2	263	11.7	1	68	14.9	1	81	5.2	1	47	2.7
Octopus	3	680	30.3	1	2	0.4	-	-	-	1	539	31.1
Merluccius	1	533	23.7	-	-	-	-	-	-	1	152	8.8
Engraulis	-	-	-	-	-	-	-	-	-	2	4	0.2
Agonid	-	-	-	2	13	2.8	1	24	1.5	-	-	-
Cottid	1	38	1.7	-	-	-	-	-	-	-	-	-
Ophiodon eggs	-	-	-	-	-	-	*	239	15.4	*	10	0.6
Trichodon	-	-	-	-	-	-	1	89	5.7	1	85	4.8
Margarites	-	-	-	-	-	-	*	12	0.8	-	-	-
Clinocottus	-	-	-	-	-	-	2	22	1.4	-	-	-
Hemilepidotus	-	-	-	-	-	-	2	47	3.0	2	79	4.6
Pandalus	-	-	-	-	-	-	1	14	9.0	1	6	0.3
Ronquilus	-	-	-	-	-	-	-	-	-	1	37	2.1
Cancer	-	-	-	-	-	-	-	-	-	2	17	1.0
Totals	69	2246		16	457		52	1556		49	1734	
Stomachs		27			21			33			46	
Empty Stomachs		5 (19%)			13 (54%)			24 (73%)			17 (37%)	

* Not counted

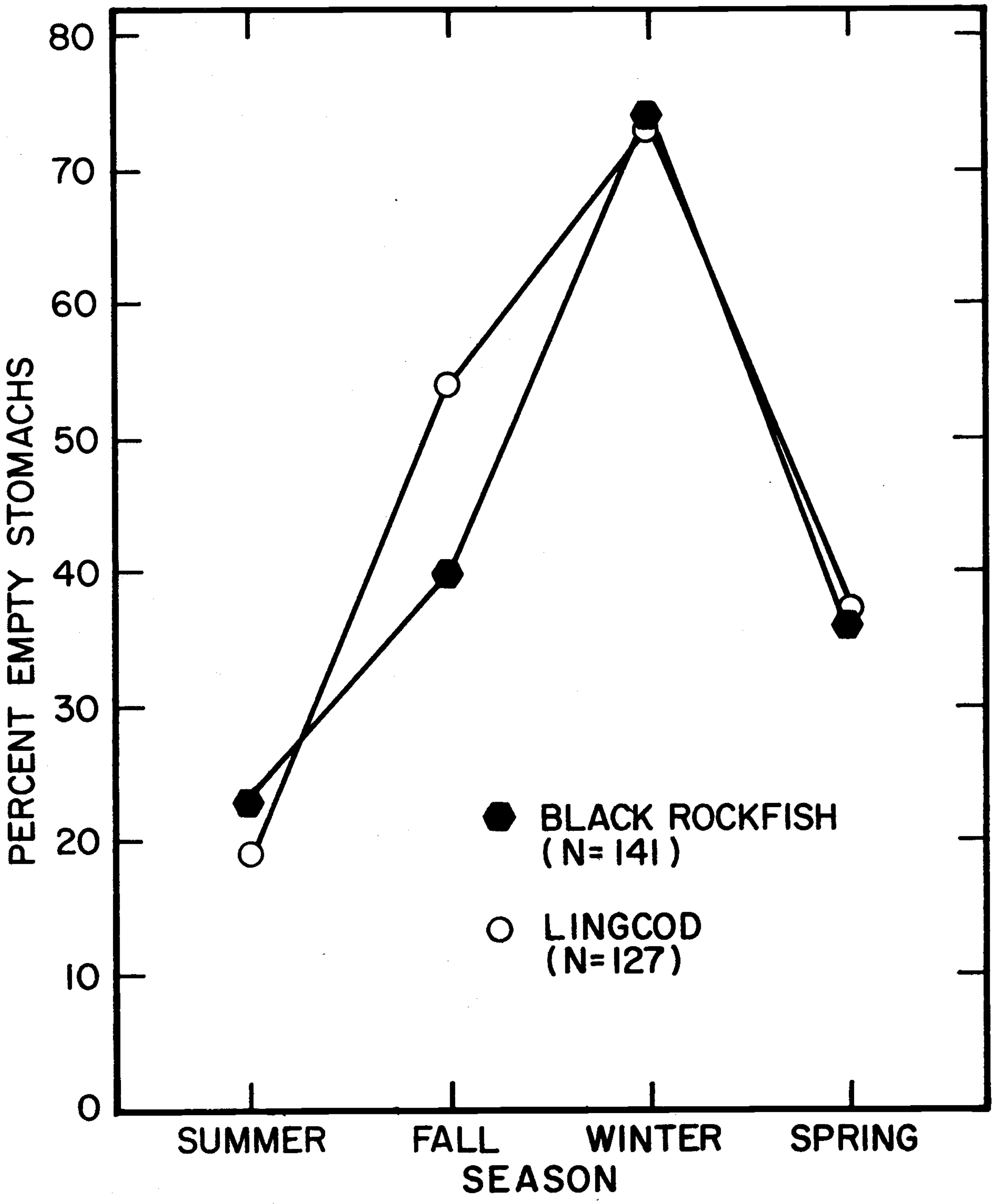

Figure 11. Percent of empty stomachs by season for black rockfish and lingcod caught over neritic reefs adjacent to Depoe Bay, Oregon during 1976-1977.

winter and for black rockfish during the spring.

Table 12. Mean number and weight of food items in all non-empty lingcod and black rockfish stomachs for each season during 1976-77.

Season	Lingcod			Black Rockfish*	
	Stomachs (no.)	Food Items (mean)	Weight (g) (mean)	Stomachs (no.)	Weight (g) (mean)
Summer	27	3.1	102.0	34	7.4
Fall	21	2.0	57.0	52	9.0
Winter	33	5.8	173.0	19	8.5
Spring	46	1.7	60.0	36	11.3

*The number of food items in black rockfish stomachs was not recorded.

DISCUSSION

Because catchability cannot be assumed to be equal for each fish in a reef area (Append. 1), catch characteristics cannot be assumed to represent absolute community structure. However, assuming that there is no systematic difference in catchability from one season to another or from one area to another, then certain depth and seasonal trends in the structure of fish communities on nearshore neritic reefs (those within 5 km of the coast) can be inferred from the results of this study.

Depth Trends

The portion of fish biomass comprised by black rockfish is consistently greater on the shallow-inshore reefs than on the deeper-offshore reefs, and the portion comprised by lingcod is consistently greater on the deeper-offshore reefs than on the shallow-inshore reefs. The Type III reef sample is biased in this respect in that charter boats fished without using hootchies, which I found very effective for catching black rockfish. Nevertheless, this general trend is observed between catches on Type I and Type II reefs using hootchies, and is supported by the contentions of fishermen and divers (Append. 2).

From daily CPUE data it can be inferred that the abundance of black rockfish is greater on the shallow-inshore reefs than on the deeper-offshore reefs during the summer and winter. For lingcod, although the seasonal means of daily CPUE values were consistently greater offshore than inshore, this difference was statistically insignificant due to a large amount of variance in daily CPUE values. This suggests that there is no significant difference between the number of lingcod on the 10-20 m reefs and the number on the 20-30 m reefs.

The mean length of both lingcod and black rockfish is significantly greater (at $p \leq .01$) on the deeper offshore reefs than on the shallow-inshore reefs. This indicates that the mean age of the fish found on deeper reefs is probably greater than that of those on the shallower reefs. Thirty-seven percent of the black rockfish caught on Type I reefs were estimated to be immature, while only 12% of those caught on Type II reefs were immature. Also, the few black rockfish that I have seen from deep water trawl catches were very large in comparison to nearshore reef fish. This information is consistent with the idea that estuaries and nearshore reefs may form nursery areas for the juveniles and young adults of certain fish species. Preliminary studies indicate that the majority of juvenile rockfish found in Yaquina Bay, Oregon, are black rockfish, while comparatively few are taken farther offshore (personal communication with Wayne LaRoche, School of Oceanography, O.S.U.). Several phenomena might play a role in this increased abundance of young black rockfish in inshore areas. First, if black rockfish larvae are dispersed offshore by currents they might undertake an active shoreward migration. Second, if the extrusion of black rockfish larvae during the late winter or early spring corresponds to strong onshore currents, as is often the case during this period (Bourke et al., 1971), then many larvae would be swept close to shore. Third, the survival rate of black rockfish juveniles might be proportionately higher in inshore areas than in offshore areas, possibly as a result of reduced predator pressure or increased availability of food.

Very few immature lingcod are taken in the neritic reef fishery. This probably results in part from large lingcod feeding on smaller ones and thereby effectively excluding them from reef areas (Wilby, 1937), and in part from the fact that juvenile lingcod feed primarily on custaceans (Phillips and Barraclough, 1977), and therefore are not very susceptible to hook and line gear. Phillips and Barraclough (1977) reported an active shoreward migration of recently metamorphosed juvenile lingcod, and this, together with the length-frequency information presented above, indicates that the distribution of lingcod juveniles might follow a pattern resembling that of black rockfish.

Yelloweye rockfish, canary rockfish, yellowtail rockfish, quillback rockfish (S. maliger), and several relatively infrequent species such as boccacio, flag rockfish (S. rubrivinctus), and tiger rockfish (S. nigrocinctus) are taken almost exclusively from reef areas deeper than 25 m. This, together with the information presented above, indicates that the 20-30 m depth interval is a boundary to the distribution of several neritic reef fish species.

Seasonal Trends

There was no statistically significant seasonal difference in the number of black rockfish (inferred from CPUE) in nearshore reef areas. The biological significance of seasonal variations in the lingcod CPUE data remains indeterminate due to the bias of possibly increased catchability during winter nest protection (Append. 1). However, if these data actually represent an increase in lingcod abundance in nearshore reef areas from summer to winter, as this and other studies suggest (Wilby, 1937; Hart, 1943; Miller and Geibel, 1973), then there must be a significant reapportionment of the relative importance of principal species in these fish communities. The winter increase in lingcod importance relative to black rockfish importance is consistent with this notion. Also, the ratio of female to male lingcod increased from about 1:5 in the summer to about 1:1 in the winter. This information on the seasonality of species composition in neritic reef fish communities is entirely consistent with the hypothesis suggested by Miller and Geibel (1973), that there is a shoreward spawning migration mainly by female lingcod, while males remain more residential in nearshore areas throughout the year.

Food Habits

Results of stomach analyses show that the diets of the principal species caught in the neritic reef fishery are highly dissimilar and that, except in two cases, there is no intraspecific overlap in principal energy sources. All BC values between the diets of the five principal species were $\geq .80$, and only 2% $(\frac{2}{85})$ of the possible reoccurrences of principal food items actually occurred. Table 13 shows the percent of the stomach contents of each principal predator that was comprised by each functional prey category. The only principal predator that preyed predominantly on pelagic nekton was black rockfish. During the spring, however, 25% of their food came from feeding on dense aggregations of planktonic crab megalopa. Blue rockfish was the only principal predator that preyed predominantly on zooplankton. Eighty-two percent of the lingcod food and 50% of the yelloweye rockfish food came from demersal nekton. Both species fed occasionally on pleuronectids and lingcod eggs, but they usually fed on different prey items, causing their BC value to be .87. Eighty-eight percent of the food of cabezon and 46% of the food of yelloweye rockfish came from benthic invertebrates, but because they fed predominantly on different food items, their BC value was .84. Also, the scale of food partitioning differs within these communities. The partitioning between black rockfish and blue rockfish food resources occurs on a rather broad functional level, i. e., pelagic nekton vs. zooplankton. By contrast, the partitioning between lingcod and yelloweye rockfish and yelloweye rockfish and cabezon food resources occurs on a finer taxonomic scale within functional feeding categories, often to genus or species (i. e., Leptocottus vs. Artedius between lingcod and yelloweye rockfish, and Cancer oregonensis vs. other Cancer spp. between cabezon and yelloweye rockfish).

Table 13. Percent biomass of the stomach contents that was comprised by each functional prey category for the five principal species caught on neritic reefs adjacent to Depoe Bay, Oregon during 1976-1977.

Prey	Predator[1]				
	LC	BK	BU	YE	CBZ
Pelagic Nekton	9.1	67.6	11.2	2.8	0.5
Zooplankton	-	20.5	66.4	-	-
Demersal Nekton	81.7	3.2	-	50.4	10.8
Benthic Invertebrates	4.5	0.3	1.2	46.0	87.7

[1] LC = lingcod, BK = black rockfish, BU = blue rockfish, YE = yellow rockfish, CBZ = cabezon

The high degree of food resource partitioning among the principal species in neritic reef fish communities is in accordance with the feeding specializations in other boreal marine fish communities reported by Tyler (1972). The feeding specialization among neritic reef fishes is not surprising considering that their functional feeding morphologies differ so drastically.

The high BC values and low overlap of principal energy sources indicate that these fishes do not compete directly for food resources. However, it is possible that there is considerably more trophic competition between certain species than is indicated by Tables 8 and 9. Black rockfish fed heavily on unidentified crab magalopa and cabezon fed primarily on adult crabs, indicating that they might be feeding on different developmental stages of the same species. Also, the observation that lingcod will occasionally attack other principal species and other lingcod being pulled to the surface by hook and line gear suggests that this might be an infrequent but possibly significant means of competition. However, if there is little direct trophic competition, as is suggested by the calculated dissimilarity measures and low principal prey overlap, then it can be tentatively concluded that the presence of a principal species on a reef area does not significantly inhibit the presence of another. Because the larval and juvenile stages of the principal species might compete for food, it remains theoretically possible, and perhaps probable, that the productivity of one of these species might significantly affect that of another.

The only high degree of dietary similarity was found between cabezon and China rockfish, and this raises the question of whether or not these two species compete for food. Cabezon averaged 6.5% of the total biomass of each catch and China rockfish averaged only 1.4% of each catch. Although it was not quantified, it seemed that cabezon and China rockfish were not caught together frequently, and usually that most China rockfish were caught in very localized areas with other China rockfish. Cabezon are very aggressive fish (diver reports) and if they constitute a greater portion of the community biomass, it seems logical to speculate that they might competitively exclude China rockfish from certain reef areas.

Of the stomach contents of lingcod caught in reef areas, about 30% by weight was comprised by fishes that are thought normally to inhabit sandy areas, such as flatfishes, Pacific sandfish (*Trichodon trichodon*), and staghorn sculpin (*Leptocottus armatus*). Divers reported never having observed these fishes on rocky reefs (Append. 2). This suggests that lingcod occasionally leave rocky areas to feed over sand bottom. The fact that lingcod are frequently encountered over sand (Append. 2) lends support to this hypothesis. This might reduce competition for food in reef areas.

The data also indicate that, although lingcod fed least frequently during the winter, the amount of food consumed during each feeding was greater then than during other seasons. This might mean that their spawning behavior prohibits feeding as frequently as during the summer, but when they feed they eat more than during other seasons. Black rockfish fed least frequently during the winter also, but the amount of food consumed in each feeding was greatest in the spring. This probably was a result of the high availability of dense aggregations of whitebait smelt (Allosmerus elongatus) and crab megalopa during the spring.

It can be concluded on the basis of this study that there are significant seasonal and depth variations in the fish communities on neritic reefs within 5 km of the Oregon coast. The data presented here support the hypothesis of a shoreward spawning migration of lingcod during the winter. These data also indicate that the 20-30 m depth interval represents a significant distributional boundary to many neritic reef fish species--the species composition of the deeper reefs being markedly different from that of the shallower reefs.

The establishment of catch restrictions in a multispecies fishery should entail some consideration of the distribution of constituent stocks. If the lingcod caught in the neritic reef fishery are part of a much larger stock that is distributed broadly across the continental shelf (which seems to be an acceptable hypothesis), then the impact of the nearshore fishery must be considered in relation to the impact of the offshore trawl fishery on the stock.

The spawning migration of lingcod from offshore to nearshore reefs (suggested by Miller and Geibel (1973) and supported by data presented in this thesis) is probably the cause of the formation of dense aggregations of lingcod on nearshore reefs during the winter. If moderate weather makes feasible an intense sport and/or commercial fishery during the winter, then these aggregations of spawning lingcod might be vulnerable to overexploitation, leading to a reduced recruitment to both nearshore and offshore stocks. If signs of overexploitation become apparent (some fishermen believe they already have), then a winter restriction or closure of the neritic reef fishery should increase future recruitment. However, there is a theoretical density above which any increase in the number of lingcod in a reef area will not increase the number of eggs spawned in the area, due to density-dependent effects of food and space limitation on fecundity. Hart (1967) provided some quantitative evidence for this crowding effect on lingcod in the Strait of Georgia. Before optimal yields can be adequately estimated, therefore, the dependence of lingcod fecundity on their density in reef areas needs to be more adequately elucidated. This could be investigated by comparing fecundity of lingcod in heavily fished areas to that of lingcod in lightly fished areas, much as Hart (1967) did.

Another consideration with regard to conserving these stocks is the food habits of these principal species. The adults of the principal species probably do not compete significantly for food resources, and thus the presence of one species in a reef area probably does not inhibit the presence of another, assuming there is little behavioral competition. Thus, this can be considered a trophically uncoupled system and each species can be managed separately. It should be kept in mind though, that it is theoretically possible that the productivity of a principal species might affect the productivity of another, particularly through possible dietary overlap of their larvae.

There was probably some indirect predator-prey effects of lingcod and black rockfish on other economically important fishery resources off the Oregon coast. Pleuronectids constitute a significant part of the diet of lingcod in nearshore reef areas, and if this is assumed to be equally true for the offshore lingcod, then there might be competitive effects between lingcod and pleuronectid production. Also, black rockfish feed heavily on crab larvae during the spring, and since Dungeness crab (Cancer magister) larvae are an important component of the crab larvae in nearshore waters off Oregon (Lough, 1975), black rockfish might compete significantly with the Dungeness crab fishery. However, before any management decision is made regarding this competitive effect, the impact of black rockfish on Dungeness crab stocks should be quantitatively estimated.

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APPENDICES

APPENDIX 1

Catchability

The term catchability is used here to represent how inclined a particular fish is to strike a jig or hootchie. The catchability of neritic reef fish is a function of how hungry they are, where they are, what food items they are hungry for, how large they are, their functional feeding morphologies, and possibly their defense inclinations.

The results of stomach analyses, though suggestive, cannot lead to any precise determination as to how inclined a fish is to strike a jig or hootchie. For example, blue rockfish and cabezon each constitute a significant portion of the catch on hook and line gear using jigs that imitate fish. However, analyses of stomach contents of these species indicate that, in a natural situation, they don't prey heavily on fish. This paradox can be resolved in one of two ways--either there is a proportionately great abundance of the species in a reef area or, although the majority of its food comes from non-fish items, it might readily attack a fish (jig) when available. Observations by divers suggest that the first alternative might be more adequate for blue rockfish, and the second alternative might be more adequate for cabezon.

Another consideration with regard to catchability is the location of the fish in relation to the reef fishery. It is reasonable to assume that, because most fishing is done with the gear as close to a reef as possible, any vertical or horizontal movement of fish away from the reef surface will temporarily reduce their catchability. All five principal species are occasionally caught away from reef surfaces by commercial crab pots, salmon (Oncorhynchus) troll gear, longline, gillnet (Barker, 1975 and Append. 2). It is generally agreed by fishermen and divers (Append. 2) that excessive turbulence causes fish to leave reef areas, temporarily removing them from the reef fishery. Also, it is apparent that blue rockfish frequent the water column more so than black rockfish, and thus it is logical to assume that blue rockfish are less susceptible than black rockfish to the reef fishery.

Other observations suggest that the catchabilities of these fish might vary. The temporal variability in feeding intensity suggested by divers, fishermen and data on percent of stomachs found to be empty might induce variations in catchability. At times when black rockfish were observed feeding intensively on densely aggregated food items they seemed much more inclined to strike a jig than at other times. Also, the observation by divers that male lingcod will maliciously attack anything that threatens their nest suggests they may be more catchable during the period of nest protection than at other times, even though they don't feed as often.

All of the cases presented above attest to the potential for variation in the catchability and thus the catch characteristics of the principal species in the neritic reef fishery. These should be born in mine when attempting to derive biological significance from catch characteristics.

APPENDIX 2

Summary of Local Knowledge

In most scientific studies, researchers are faced with the task of deriving conclusions based solely on their own data. In many fisheries investigations, however, researchers have access not only to their own data but also to the knowledge and opinions of fishermen who have had considerably more experience with particular situations than researchers could ever hope to gain in just a few years. I have been exceptionally fortunate during my study to have had access to first-hand information from fishermen and SCUBA divers with many years of experience with neritic reef fishes off Oregon. The method by which these fishermen and divers collect, analyze, and interpret data is fundamentally identical to the scientific method, and thus these beliefs should prove valuable in understanding neritic reef fish behavior and relationships. The method of justification of these beliefs probably varies from one person to another and from time to time. Although I consider many of these beliefs to be unacceptable for purposes of scientific investigation, I do consider the results of the extensive, methodical inquiries made by certain persons to be particularly relevant to this discussion. The purpose of this section is to synthesize the knowledge of local fishermen and divers in an attempt to elucidate certain trends which they have noticed during their many years of experience.

The fishermen interviewed for this section were Fred Robison, Depoe Bay, with 31 years of experience; Fred Robison, Jr., Depoe Bay, with 15 years of experience; Morry Notz, Depoe Bay, with 7 years of experience; Ralph Wansel, Newport, with 5 years of experience; and Betsy Wisner, Newport, with 15 years of experience. The SCUBA divers interviewed were Freeman Button, O.S.U. Marine Science Center, Newport; Bill Herder, "Deep Sea Bills," Newport; and Hugh Rackliff, ODFW, Newport, each with more than 20 years of diving experience on Oregon reefs.

The fishermen notice that CPUE and catch composition vary daily and at times hourly. They attribute this to actual changes in the distributions, abundances and activity levels of the fish species in reef areas, and to changes in physical conditions affecting fishing, such as current and wind velocity, tidal currents, turbidity, etc. Divers also observe temporal variations in the distributions, abundances, and activity levels of fishes in reef areas. Sometimes they observe high densities and low activity levels, and sometimes low densities of fish in reef areas. Divers and fishermen agree that the distributions, abundances, and activity levels of fishes in these reef areas are affected in some complex manner by wave height, water temperature, direction and intensity of wind driven and tidal currents, turbidity, distribution and abundance of prey organisms, spawning behavior, and fishing pressure. It is generally believed by fishermen and divers that excessive turbulence (i.e. large waves and/or strong currents) will cause many of the fishes to leave the reef areas for deeper, calmer water. There are times when commercial dungeness crab fishermen catch many lingcod in their crab pots distributed on sand bottom, and times when they catch very few (personal communication with commercial crabbers Bob Budson, Depoe Bay, Ted Herford, Depoe Bay, and Ron Hegge, Newport). Also divers usually see significantly fewer fish in reef areas after turbulent conditions, and fishermen find that CPUE is very much reduced after turbulent conditions.

Fishermen have noticed occasionally that they can fish a reef area intensively for several hours with low CPUE, but when the tidal current changes, CPUE will greatly increase. They also notice the reverse effect of transitions from high to low CPUE in very short time periods similarly correlated with tidal current direction and intensity. Divers also notice a similar correlation between direction and velocity of tidal current and activity levels of fishes.

Divers have speared large lingcod up to 27 kg (60 lb) on the groins between the jetties at Newport, but report that this is rare and that usually the lingcod that frequent the shallow inshore areas are much smaller than the ones seen on deeper reefs. Similarly, fishermen say that they catch relatively few smaller lingcod on the shallow reefs. Divers and fishermen report that black rockfish are much more dominant on the shallow, inshore reefs than on the deeper, offshore reefs. Ralph Wansel and other Newport fishermen report that they seldom catch black rockfish while bottom fishing on Stonewall Bank, a large reef area about 24 km (15 miles) offshore. Divers report that, at times, blue rockfish are very abundant in reef areas, and that this species is seen in the water column more often than near the reef surface; whereas black rockfish are seen more often near the reef surface than in the water column, although occasionally they are observed schooling near the surface while feeding on dense aggregations of prey. The divers have not seen yelloweye rockfish in shallow, inshore areas and fishermen very rarely catch this species on or near shallow, inshore reefs. Sometimes no yelloweye rockfish are caught on the deep reefs although normally a few are caught, and occasionally very many are caught. Fishermen and divers agree that reef edges display distributional phenomena very different from the tops of the reefs. While exploring sandy areas away from reefs, divers occasionally encounter lingcod, wolfeel (Anarrhichthys oscellatus), kelp greenling, cabezon, black rockfish, and blue rockfish. Copper rockfish are seen mainly in the very nearshore and estuarine areas.

Fishermen report that they have found the stomachs of lingcod to contain large and small octopus, squid (Loligo sp.), coho salmon (Oncorhynchus kisutch), wolfeel, pleuronectids, Pacific tomcod

(*Microgradus proximus*), staghorn sculpin, whitebait smelt, spiny dogfish sharks (*Squalus acanthias*), small lingcod, dungeness crabs, shrimp, and snails. They also report that the contents of lingcod stomachs vary from year to year and from place to place. Fishermen and divers report that there are times when reef fish feed intensively and other times when they are relatively docile. The following lingcod food items have not been seen on reefs by the divers: flatfish, staghorn sculpin, Pacific tomcod, dungeness crab, and spiny dogfish sharks. These organisms are seen frequently over sand.