Morphology and Distribution Patterns of Several Important Species of Rockfish (Genus *Sebastes*)

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ABSTRACT—This paper investigates some aspects of the relationship between morphology and distribution of some of the commercially important species of rockfish (genus Sebastes*). On the basis of morphometrics, several species pairs of rockfish are suggested. Members of the species pairs are found to be spatially segregated. It is suggested that certain types of adaptive strategies are very important in terms of species that can support commercial fisheries.*

Introduction

In central California, commercial catches of rockfish (genus *Sebastes*) are dominated by bocaccio, *Sebastes paucispinis*, and chilipepper, *S. goodei*. As one moves northward, composition of the commercial catch gradually changes, and in northern Washington, the catch is dominated by Pacific ocean perch, *S. alutus;* silvergray rockfish, *S. brevispinis;* yellowtail rockfish, *S. flavidus;* and canary rockfish, *S. pinniger*. Because of the possibility of a fishery for smaller rockfish species, shortbelly rockfish, *S. jordani*, can also be included in this north-south grouping of commercial species (Table 1).

Table 1.—Commercial rockfish species.

Southern species	Northern species
Chilipepper	Pacific ocean perch
Bocaccio	Silvergray rockfish
Shortbelly rockfish	Yellowtail rockfish
—	Canary rockfish

Several of these commercially important species are very similar in appearance, particularly the Pacific ocean perch and chilipepper and the silvergray rockfish and bocaccio. This similarity in appearance is significant since studies on habitat utilization of fishes with similar feeding morphologies suggest that spatial segregation is probably one of the most important means of niche separation (Werner and Hall, 1977). It is also important because similarity in feeding morphology suggests a similarity in the basic adaptive strategy of these species.

Morphological Relationships

Morphological measurements for these species were taken from Phillips (1957). Variables were chosen which were characteristic of a species' basic adaptive strategy. They include length of head, length of upper jaw, orbit diameter, least depth of caudal peduncle (all as ratios to standard length), the ratio of body height/body width, both at pectoral fins, and maximum recorded length (Table 2).

The first three variables will strongly affect a species' feeding behavior. A species' height/width ratio and depth of caudal peduncle are measures of the hydrodynamic qualities of a fish. The fusiform body, moderately elliptical in cross section, is physically the most efficient for movement through a liquid medium, and therefore is characteristic of species that swim more or less continuously. Species that are in constant motion are also characterized by a narrow caudal peduncle and deeply incised caudal fin (Alexander, 1967). Maximum length was included both because of its effect on movement and because of the effect of absolute size on predation dynamics (Wilson, 1975). The species were clustered using a phi-squared distance coefficient (Sneath and Sokal, 1973). The dendrogram (Fig. 1) shows that species are grouped into a number of species pairs.

Silvergray rockfish and bocaccio are relatively large fish with a large head size and a large jaw size. They also have, relative to the other species, a much smaller orbit. Their body shapes are compressed fusiform and they have moderately incised caudal fins. Bocaccio is primarily piscivorous (Phillips, 1964), and the morphologies of these two species are strongly adapted for

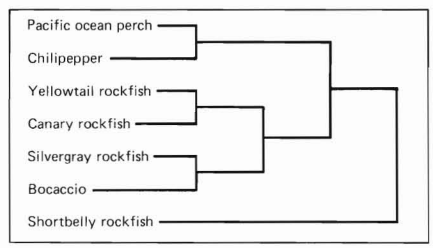

Figure 1.—Cluster analysis of morphological similarity of rockfish species.

Table 2.—Morphological variables for rockfish species (genus *Sebastes*).

Species	Length of head[1]	Length of upper jaw[1]	Orbit diameter[1]	Height/Width	Least depth of caudal peduncle[1]	Maximum length (cm)
Pacific ocean perch	0.370	0.169	0.103	1.97	0.086	50.4
Silvergray rockfish	0.370	0.189	0.080	2.00	0.090	71.1
Yellowtail rockfish	0.357	0.167	0.089	1.67	0.108	66.0
Chilipepper	0.357	0.159	0.085	1.97	0.084	55.9
Shortbelly rockfish	0.344	0.139	0.088	1.88	0.078	30.5
Bocaccio	0.370	0.200	0.074	2.00	0.086	91.1
Canary rockfish	0.357	0.178	0.091	1.97	0.114	76.4

[1]Ratio to standard length.

taking large mobile prey. The large body and mouth size are obvious adaptations for increased prey size. The smaller orbit diameter suggests a reduction in the importance of visual recognition. The large mouth also increases the angle at which a prey item can be taken by allowing the fish to grasp the prey at the side of its jaw (Alexander, 1967). In this way the fish does not have to be directly in front of a prey item for capture. The compressed fusiform body shape and the moderately incised caudal fin suggest an increase in acceleration at the cost of some efficiency in swimming. All of these characteristics show a high level of adaptation for the capture of large mobile prey items.

Pacific ocean perch and chilipepper are smaller fish with smaller mouth sizes. However, their orbit diameter, particularly Pacific ocean perch, is larger. Their body shape is also a compressed fusiform one, but with a more deeply incised caudal fin. These species feed primarily on pelagic crustaceans, particularly on euphausids (Phillips, 1964; Skalkin, 1964). The reduced mouth size is a reflection of the smaller prey size. It also reduces the angle at which the fish can take a prey. The more deeply incised caudal fin suggest a fish which is more efficient at cruising with some sacrifice in acceleration. The increased orbit diameter could imply that a smaller prey size increases the difficulty of visual recognition.

The shortbelly rockfish is the smallest of the species with by far the smallest mouth size. The body shape is a more rounded fusiform one with the smallest height/width ratio. The species also has the narrowest caudal peduncle and is the only species with a deeply incised caudal fin. The shortbelly rockfish feeds primarily on macroplankton (Phillips, 1964). The small mouth size is accompanied by a large orbit diameter. This suggests that prey items are small and even more difficult to see. The body shape is the most strongly adapted for efficient cruising. The shortbelly rockfish has no direct replacement as the other species pairs.

Yellowtail and canary rockfish were paired together primarily because they both have a much thicker caudal peduncle than the other species. However, they are not really similar species except for the fact that they are very different than the other species so far discussed. Also both of these species are members of the northern group of commercial species and have no apparent replacement in the southern group of commercially important species. Since these species represent a fundamentally different line of adaptive strategies, they will not be discussed further.

These species, except for yellowtail and canary rockfish, represent a morphological trend from a large fish with a larger mouth size to a small fish with a smaller mouth size. It is probable that the species also represent to some degree a trend in feeding types. The interesting point is the degree of apparent replacement of species in the transition from the southern to the northern complex.

Distributional Analysis

The similarity of the morphometrics of these species pairs implies that they should show some degree of spatial segregation (Werner and Hall, 1977). The data for this analysis came from the 1977 Rockfish Survey (Gunderson and Sample, 1980). Species densities (in pounds per nautical miles trawled) were calculated in 30-minute blocks of latitude. The data, by species, are shown in Table 3. Histograms were also constructed for the major species for densities combined over all depths (Fig. 2,3).

Association between species was measured from presence-absence data using the binary correlation coefficient, V. Sampling properties and test of significance are given in Pielou (1969). Table 4 gives values of V and their significance.

The histograms of Pacific ocean perch and chilipepper show a trend of a peak of abundance of the southern species, an area of overlap with reduced abundance of both species, and then a peak of abundance in the northern species. The correlation analysis between the species pair shows a strong negative association. The histograms of bocaccio and silvergray rockfish show an area of abundance of the southern species and an area of overlap. The correlation analysis shows a nonsignificant result. This probably is the result of using a presence-absence correlation technique. Use of the abundance

Table 3.—Rockfish species density (pounds per nautical mile) per 30-minute block.

Latitude		Pacific						
Deg.	Min.	ocean perch	Silvergray rockfish	Yellowtail rockfish	Chili-pepper	Shortbelly rockfish	Bocaccio	Canary rockfish
34	0	0	0	0	1.7	4.4	5.6	0.3
	30	0	0	0.1	5.5	13.4	23.6	1.0
35	0	0	0	0	0.5	4.9	5.0	0
	30	0	0	0	20.2	31.0	3.2	0.1
36	0	0	0	26.4	0.1	7.4	28.6	0.2
	30	0	0	0	13.1	435.2	15.2	0.8
37	0	0	0	0	15.4	487.1	15.3	0.2
	30	0	0	0	118.5	0.9	269.2	11.9
38	0	0	0	0	99.6	55.0	14.4	0.3
	30	0	0	2.9	53.7	9.5	13.1	1.1
39	0	0.2	0	0.5	92.3	14.4	8.4	0.7
	30	0.1	0	4.2	78.7	1.2	7.6	1.0
40	0	0	0	0	10.7	0.1	1.8	21.5
	30	6.8	0	0	4.6	0	0.5	0
41	0	0.7	0	0.2	0	0	0	0.2
	30	1.1	0	0	0	0	0	0.4
42	0	2.6	0	0.3	0	0	0	0
	30	21.1	0	25.0	0.1	0	1.2	0.8
43	0	6.3	0	1.9	0	0	0.7	5.9
	30	10.9	0	2.2	0	0.1	0.8	0.3
44	0	15.5	1.0	0.2	0	0.7	2.6	3.8
	30	8.8	0	24.6	0	0	0.9	0.1
45	0	13.9	0.2	0.2	0	0	0.2	0.2
	30	23.9	0.3	1.5	0	0.1	1.6	28.8
46	0	101.6	8.6	75.6	0	0	17.9	48.8
	30	133.3	0	80.9	0	0	0.7	60.5
47	0	70.6	15.3	115.6	0	0	7.0	22.3
	30	33.5	10.2	26.1	0	0	0.7	1.1
48	0	180.6	193.3	141.1	0	0	22.8	276.9

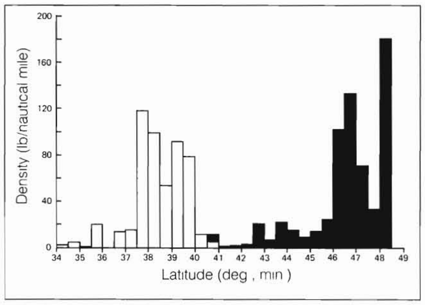

Figure 2.—Pacific ocean perch density (dark bar) and chilipepper density (clear bar) in pounds per nautical mile.

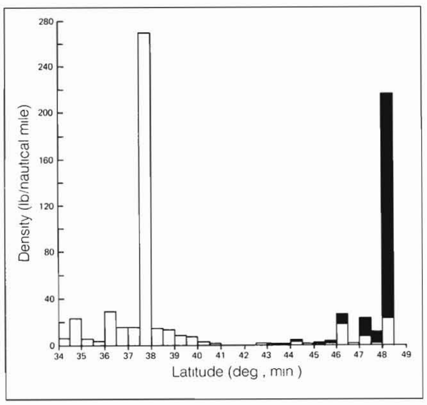

Figure 3.—Silvergray rockfish density (dark bar) and bocaccio density (clear bar) in pounds per nautical mile.

data would have required extensive data editing. However, Figure 3 suggests an inverse relationship between abundances of these two species.

Members of the southern and northern groups of commercially important species appear as distinct entities in the correlation analysis. Members of both the northern and southern groups of species show weak positive association. Between members of the two groups, there is stong negative association.

Table 4.—Binary correlation coefficients for rockfish species.

Species	Pacific ocean perch	Silvergray rockfish	Yellowtail rockfish	Chili-pepper	Shortbelly rockfish	Bocaccio	Canary rockfish
Pacific ocean perch	1.0	.057	−.052	−.316***	−.286***	−.244***	−.095**
Silvergray rockfish	—	1.0	.150***	−.109***	−.101**	.091**	.191***
Yellowtail rockfish	—	—	1.0	−.185***	−.180***	−.013	.289***
Chilipepper	—	—	—	1.0	.045	.022	−.162***
Shortbelly rockfish	—	—	—	—	1.0	.058	−.111***
Bocaccio	—	—	—	—	—	1.0	.065
Canary rockfish	—	—	—	—	—	—	1.0

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Discussion

Among the northern and southern groups of commercially important rockfishes, several species can be paired together on the basis of similar morphologies. These species pairs also tend to be spatially segregated. This, in turn, suggests similarities in the basic adaptive strategy of these species pairs. This sort of apparent equivalence between organisms of different regions has long been noted by biogeographers (Levins, 1968).

For a rockfish species to support a commercial fishery, the species must have a large enough body size to provide a marketable fillet, be relatively abundant, and be sufficiently aggregated to provide a profitable catch per unit of effort for the fisherman. Of the approximately 70 species of rockfish off the northeastern Pacific coast, only a few rockfish species have the necessary requirements to support a commercial fishery. The fact that, within the group of commercially exploitable rockfish, certain species show strong similarity in their functional adaptive strategies, points out the importance of these particular adaptive strategies.

Acknowledgments

This paper benefited from critical readings by M. E. Adams, E. S. Hobson, W. H. Lenarz, and H. Li.

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