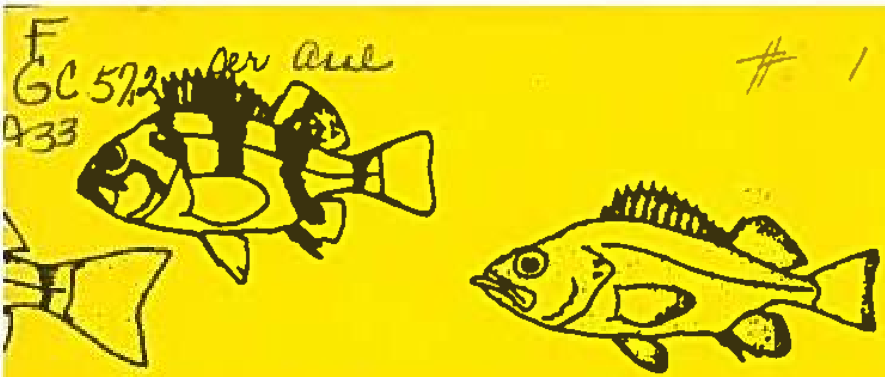
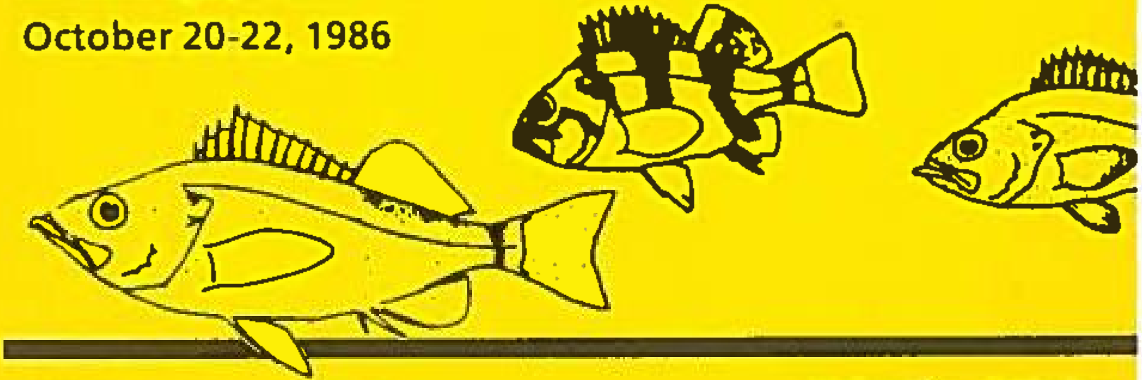


Lowell Wakefield
Fisheries Symposium

Proceedings of the International Rockfish Symposium

Anchorage, Alaska USA
October 20-22, 1986



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Acknowledgements

The International Rockfish Symposium, the fifth in the Lowell Wakefield Fisheries Symposium Series, was planned to bring together scientists and managers involved with biology and management of *Sebastes* species to provide information for use in developing management strategies for the rockfish complex.

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Sponsors of the International Rockfish Symposium are the Alaska Department of Fish and Game, the National Marine Fisheries Service Northwest and Alaska Fisheries Center, the North Pacific Fishery Management Council, and the University of Alaska Sea Grant College Program.

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Session I -- History of the Fisheries

Session II -- Life History and Reproduction

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Session VI -- Workshop on future rockfish research needs

24. Westrheim, S.J., W.R. Harling, and D. Davenport.
1968. Preliminary report on maturity, spawning season, and larval identification of rockfishes (*Sebastodes*) collected off British Columbia in 1967. Fish. Res. Board Can., Manuscr. Rep. Ser. 951, 23 p.

25. Westrheim, S.J., W.R. Harling, D. Davenport, and M.S. Smith.
1968. Preliminary report on maturity, spawning season, and larval identification of rockfishes (*Sebastodes*) collected off British Columbia in 1968. Fish. Res. Board Can., Manuscr. Rep. Ser. 1005, 28 p.

Wiens, J.A., and J.M. Scott.
1975. Model estimation of energy flow in Oregon coastal seabird populations. Condor 77:439-452.

Wyllie Echeverria, T.
In press. Thirty-four species of California rockfishes: maturity and seasonality of reproduction. U.S. Natl. Mar. Fish. Serv., Fish. Bull.

Addendum

MacGregor, J. S.
1986. Relative abundance of four species of *Sebastes* off California and Baja California. Calif. Coop. Oceanic *Fish.* Invest. Rep. 26: 121-135.

This paper was published too late to be included in our review. It contains an analysis of occurrences of rockfish larvae collected in the CalCOFI program, and discusses distributions of *S. jordani*, *S. paucispinis*, *S. macdonaldi*, and *S. levis* specifically.

Proc. Int. Rockfish Symp.
Oct. 1986, Anchorage, Alaska

Post-larval copper rockfish in the Strait of Georgia: Habitat use, feeding, and growth in the first year

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Nanaimo, British Columbia

Many demersal marine fishes have pelagic larvae which subsequently settle into benthic habitats. The pelagic-demersal transition is a critical event for these young fishes, as many have specific habitat requirements. Some of these species are able to discriminate among micro-habitats at the time of the pelagic-demersal transition (Marliave 1977). After initial settlement, young-of-the-year (YOY) fishes may select habitats based on factors such as food availability (Jones 1984), shelter availability (Shulman 1984, 1985, Ebeling and Laur 1985), predator density (Shulman 1985) and presence of conspecifics (Sweatman 1983). The pelagic-demersal transition may result in high mortality, depending on the success with which the young fish locate suitable shelter and appropriate prey.

Copper rockfish (*Sebastes caurinus*) is found in shallow rocky-reef habitats from California to Alaska (Hart 1973). It release pelagic larvae, which subsequently recruit to shallow reef environments (Carr 1983). Throughout most of its range, copper rockfish is one of a number of rockfish species found in nearshore waters. However, in the Strait of Georgia, British Columbia, rockfish diversity is low, and copper rockfish is the most common shallow water (< 20 m) species. As a result, copper rockfish is an important component of nearshore reef communities of the Strait of Georgia, and is exploited by both recreational and commercial fisheries (Richards 1986).

The process of recruitment is poorly understood for most rockfishes; although, for temperate reef fishes, macrophytes apparently are important features in post-larval habitats. In the Labrid species *Pseudolabrus celidotus*, for example, recruitment was consistently higher in certain habitats, defined principally by macrophyte type (Jones 1984). In California, several post-settlement rockfishes first appear in kelp canopies, followed by ontogenetic shifts to more benthic habitats (Carr 1983); similarily, Boehlert (1977) found that pre-juvenile splitnose rockfish (S. diploproa) frequent patches of floating kelp prior to their demersal transition. In the study reported here, we examined patterns of habitat use by post-larval YOY copper rockfish in the Strait of Georgia, including changes in density, size distributions, and feeding habits over time. The primary objective was to identify which shallow reef environments might be especially valuable to copper rockfish in their first year.

Study Area

The study was conducted off Snake Island, a small island (0.52 km by 0.24 km) located in the Strait of Georgia on the east coast of Vancouver Island (Fig. 1). This site was chosen because of the diversity of benthic habitats available, and becasue of its relative isolation. The nearest land mass is a small island 2.3 km away, which is separated from Snake Island by a channel with depths over 100 m. The nearest headland is 2.4 km distant, with deep intervening channels.

Habitats were categorized on the basis of the presence or absence of dominant macrophytes. They are: kelp forest (KF), Agarum slope (AG), eelgrass bed (EG), or sand (SN) (Table 1). In the following sections we identify habitats by their two letter designators, and, in the case of the KF habitat, the bottom and canopy are separately identified as KF-bottom and KF-canopy.

Methods

Fish densities were estimated while SCUBA diving. Visual counts were made by swimming along randomly placed 25-m transect lines in each of the four habitats in each of three time periods. Ten replicate transects comprised each habitat/time sample. Fish were recorded if they were observed in the water column within 1 m of either side of the transect line. In areas with dense algal cover, such as rocky slopes covered with Agarum, divers searched the algae to flush any hidden individuals. In the KF habitat, where stands of Nereocystis formed an extensive canopy, initial counts were made within 1.5 m of the bottom, followed by a second count in the kelp canopy. The two counts were combined for the KF transect total. Copper rockfish were identified as YOY, juvenile or adult, based on size.

Transect counts were conducted August 15-22, September 24-27, and October 17-22, 1985. Transects in each habitat were surveyed on at least two different days in each time period. All dives were performed between 0900 and 1300. Algal cover in each habitat was estimated in August and September from four randomly placed 15-m transects. In addition, while counting fish in the KF habitat, divers recorded the number of Nereocystis stipes within the 2-m wide transect band.

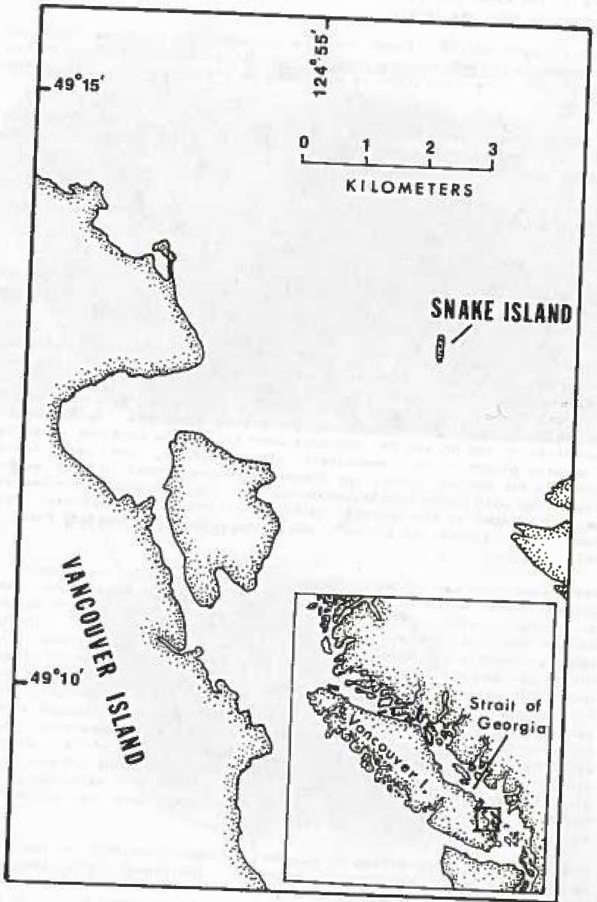

Figure 1. The Snake Island study site in the Strait of Georgia, British Columbia, Canada.

Table 1. The major habitats at the Snake Island study site. Depths are relative to mean sea level.

1. Kelp Forest (KF) 5 - 11 m. An area characterized by dense stands of the giant kelp *Nereocystis leutkeana*, with a canopy extending to the sea surface. The understory is dominated by the kelp *Agarum fimbriatum* (75% cover).

2. Agarum Slope (AG) 6 - 14 m. Rocky slopes dominated by the understory kelp *Agarum fimbriatum* (86% cover). Occasional broken rocks provide additional vertical relief.

3. Eelgrass Bed (EG) 7 - 11 m. Areas where the perennial eelgrass *Zostera marina* occurs in dense stands, rooted in sandy substrate. Individual plants reach a height of 1.6 m. The bottom is gently sloping. Algal drift material is common.

4. Sand (SN) 8 - 30 m. Areas of sandy substrate with no rooted macrophytes. The bottom is sparsely covered with algal drift dispersed from the rocky areas (31% cover with drift algae, mostly *Agarum*).

YOY copper rockfish were collected after density counts had been completed in each time period. Divers armed with small-mesh hand nets captured fish in the order in which they were encountered, selecting no more than a few fish from a single school. In August, fish from the KF habitat were collected from canopy and bottom locations. By September, densities in the KF and SN habitats were too low to continue sampling. Fish were placed on ice immediately after capture, and were frozen within a few hours. Later, the frozen fish were thawed in ice water, damp-dried with paper towels, measured for fork length to the nearest mm, and weighed to the nearest centigram. Otoliths (saggitae) were removed and stored in alcohol, and stomachs were removed and fixed in 10% formalin.

Settlement date was estimated by counting daily otolith increments. A distinct mark, which is structurally identical to the metamorphic mark documented by Victor (1983), occurred in most otoliths, and is assumed to mark the time of the pelagic-demersal transition (Figure 2). In July 1986, a recently metamorphosed YOY copper rockfish was collected in the Strait of Georgia, near Nanaimo. The otoliths from that fish clearly show a recently formed clear area with no peripheral increments (Figure 2). We regard this as a provisional validation of the metamorphic mark, pending further studies. Otoliths were mounted on microscope slides and viewed at 400x magnification through an oil immersion lens. Otoliths from specimens collected in August were read whole, whereas otoliths from later specimens were mounted on microscope slides with clear fingernail hardener and ground down on 600 grit sandpaper. The number of increments peripheral to the metamorphic mark was assumed to equal the number of days since settlement.

Food habits were quantified by examining stomach contents of each fish under a binocular dissecting microscope. Individual prey items were sorted into homogeneous taxonomic groups, and counted. Percent volume of each prey group was estimated by spreading prey items to a uniform thickness over a background grid of 1 mm squares, then counting the area covered. In the case of larger prey items, such as shrimp, the area covered was multiplied by their estimated thickness relative to

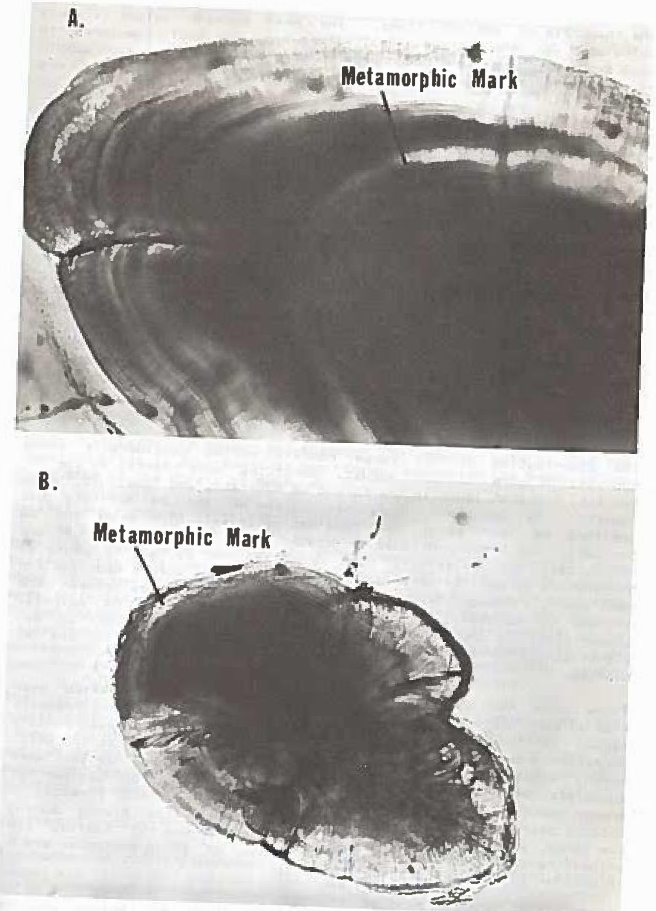

Figure 2. A. Otolith from a fish collected in September 1985, showing metamorphic mark. B. Otolith from a fish collected in July 1986 showing recently formed metamorphic mark.

the thickness of smaller items. The mean percent volume (%V) was calculated as the average of all values for individual specimens in each sample. The percent occurrence of prey catagories in each sample is the percent of specimen stomachs in which the prey catagory was found.

Transformations of density and size data did not produce distributions with homoscedastic variances. Hence we used a nonparametric test (Kruskal-Wallis) to compare densities and sizes among habitats within a time period, and among time periods within a habitat. We used the Wilcoxon two-sample test in all cases where there were only two medians to compare.

Results

Spatial and temporary variation in density.

YOY copper rockfish were the most abundant fish encountered on transects. Older juvenile and adult copper rockfish also occurred, but at a maximum density of 1.8 fish/transect (AG habitat in September). No other rockfish species occurred on transects. Lingcod, probably the major predator on YOY copper rockfish, had a maximum density of 0.8 fish/transect in the AG habitat in September and in the EG habitat in October.

The distribution of YOY copper rockfish varied considerably among habitats (Figure 3). In August, densities were highest in the KF habitat, somewhat lower in the EG and AG habitats, and lowest in the SN habitat. By September, densities in the KF and SN habitats had declined to near zero, but remained relatively high in EG and AG habitats. The trend continued in October, with low densities in KF and SN habitats, and relatively high densities in EG and Ag habitats. Differences in density were significant ($p<.001$) across habitats for each month, although there were no significant differences between the AG and EG habitats in August and October, based on pairwise comparisons. In September, the density of YOY copper rockfish was significantly greater ($p<.008$) in the EG habitat than in the AG habitat.

There were also significant changes in density of YOY rockfish over time in each habitat, with the exception of the AG habitat. Density peaked in the EG habitat in September ($p<.05$), whereas density decreased dramatically in the KF and SN habitats after August ($p<.001$). During August, most YOY copper rockfish in the KF habitat were associated with the kelp canopy. However, in September and October YOY copper rockfish were only found on the floor of the kelp forest. A notable decrease occurred in the density of *Nereocystis* plants during the study, as the mean number of stipes in the KF habitat (in stipes/transect) decreased from 29 in August, to 17 in September and 8 in October ($p<.001$, Kruskal-Wallis test).

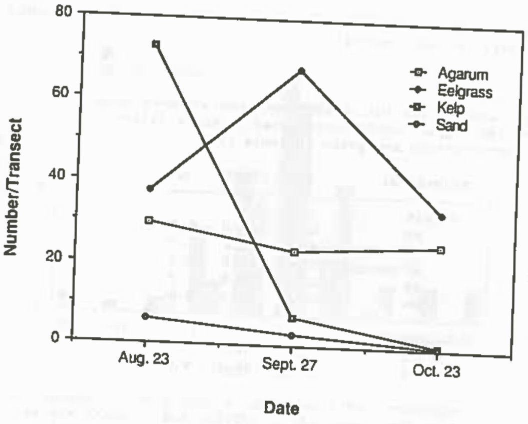

Figure 3. Density, in number per transect (50 square meters), of YOY copper rockfish in four habitats over three months at the Snake Island study site in the Strait of Georgia.

Spatial and temporal variation in size.

Size differences were apparent for YOY copper rockfish collected from different habitats in each time period ($p<.001$, Table 2). In August, when YOY copper rockfish occupied all four habitats, the largest fish were collected from the KF-bottom habitat, followed by EG, KF-canopy, SN and AG habitats. Fish in the KF-bottom habitat were significantly larger than fish in other habitats by pairwise comparison tests. In September and October fish in the EG habitat were marginally larger than fish in the AG habitat ($p<.05$ and $p=.05$, respectively).

The largest size increase for YOY copper rockfish occurred over the August - September period ($p<.001$ for both EG and AG habitats). Size increases between September and October were significant for the EG habitat ($p<.01$), but not for the AG habitat. Growth rates between August and October averaged 0.15 and 0.16 mm/day in the AG and EG habitats, respectively.

Settlement Date.

The number of otolith increments peripheral to the metamorphic mark in August and September specimens provided the distribution of settlement dates in Figure 4. Settlement appears to have occurred in one major episode during the first week of August. The daily nature of the otolith increments is verified by comparison of settlement dates from August and September specimens. The distributions of settlement dates back-calculated from the two sampling periods are virtually identical (Figure 4); thus, the number of increments added between the collection dates in August and September is approximately equal to the number of calendar days in that interval.

Table 2. Sample sizes (N), mean length and standard error (SE) in mm for YOY copper rockfish collected at Snake Island. Habitat abbreviations are given in Table 1.

TIME/HABITAT	N	LENGTH	SE
August			
AG	89	36.5	0.4
KF-bottom	49	42.2	0.7
KF-canopy	99	38.2	0.3
EG	61	38.8	0.7
SN	66	37.3	0.6
September			
AG	59	44.6	0.7
EG	83	46.4	0.6
October			
AG	29	45.6	1.2
EG	57	48.4	0.6

Food habits.

Recently settled copper rockfish juveniles fed on a variety of planktonic zooplankton, epi-benthic crustaceans, and benthos- or macrophyte-associated mobile invertebrates (Tables 3 and 4). Harpacticoid copepods, gammerid amphipods, caprellid amphipods, mysids and shrimp were especially important prey groups. Generally they appear to feed opportunistically.

In August, pelagic planktonic prey were an important component of the diet of fish in KF (calanoid copepods) and AG (crab zoea) habitats. With those exceptions, prey were predominately epibenthic or demersal. Harpacticoid copepods were the most commonly found prey in the diet in August, especially in habitats outside the kelp forest; and were the most important (in %V) single prey group in AG and SN habitats.

Time series of diet compositions were available for fish from AG and EG habitats. Some prey groups were consistently used, but there also were some ontogenetic shifts in feeding habits (Tables 3 and 4). In the AG habitat, harpacticoid copepods remained important prey in September (11 %V) and October (19 %V), although a shift to larger prey was evident by the increase in shrimp in September (31 %V) and October (18 %V), and mysids in October (28 %V). In the EG habitat, shrimp were a main diet component in August (26 %V), and continued to be important in September (30 %V) and October (45 %V). After August, fish in the EG habitat were feeding almost exclusively on large epi-benthic or benthic crustaceans (shrimp, gammerid amphipods and mysids).

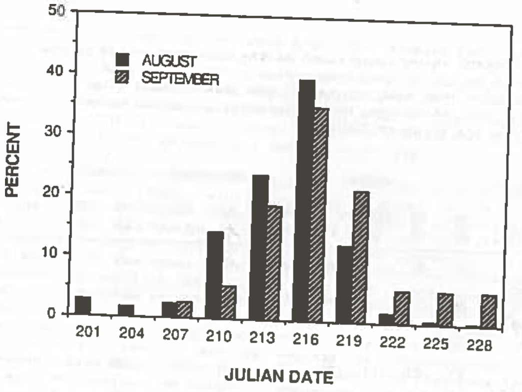

Figure 4. Back-calculated date of settlement for YOY copper rockfish at the Snake Island study site collected in August (n=348) and September (n = 37), based on number of otolith increments. Distributions shown are based on total numbers in each three day interval, beginning on Julian Day 200 (July 20). Maximum settlement is in the interval beginning August 4.

Table 3. Frequency of occurrence of major taxonomic groups of prey found in YOY copper rockfish stomachs. KFB: KF-bottom habitat, KFC: KF-canopy habitat; other habitat abbreviations are given in Table 1.

PREY GROUP	AUGUST					SEPTEMBER		OCTOBER	
SAMPLE SIZE	AG 32	EG 32	KFB 32	KFC 31	SN 32	AG 43	EG 41	AG 28	EG 34
Calanoid Copepod	.16	.11	.13	.80	.03	.10		.15	
Harpacticoid Copepod	.93	.93	.58	.52	.96	.50	.06	.63	.25
Crab Zoea	.16								
Gammerid Amphipod	.13	.14	.29	.16	.31	.26	.70	.44	.33
Caprellid Amphipod	.06	.29	.45	.42	.37	.03		.07	.04
Stomatopod	.03	.04		.03	.03			.04	.08
Mysid	.19	.11	.19	.06	.10			.37	.54
Shrimp	.03	.18	.13		.10	.38	.42	.22	.54
Polychaete		.11	.29	.10	.21	.06	.18		.04

Table 4. Percent volume, expressed as the mean proportion of the total stomach volume in each prey catagory, for YOY copper rockfish sampled from each habitat at the Snake Island site in each month. KFB: KF-bottom, KFC: KF-canopy; all other habitat abbreviations are given in Table 1.

PREY CATAGORY	AUGUST					SEPTEMBER		OCTOBER	
	AG	EG	KFB	KFC	SN	AG	EG	AG	EG
SAMPLE SIZE	32	32	32	31	32	43	41	28	34
Calanoid copepod	.02	.01	-	.25	-	.02		.01	
Harpacticoid copepod	.28	.14	.11	.08	.28	.11	-	.19	.01
Crab zoea	.13								
Gammerid amphipod	.04	.03	.11	.05	.06	.21	.29	.09	.16
Caprellid amphipod	.04	.12	.23	.25	.21	.01		.02	-
Stomatopod	-	.02		-	-			-	.01
Mysid	.07	.06	.19	.01	.04			.28	.15
Shrimp	.02	.26	.15		.10	.31	.30	.18	.45
Polychaete		.11	.08	.05	.01	.06	.05		.06
Unident.	.39	.25	.12	.30	.27	.28	.33	.22	.14

Discussion

There was probably little mixing of YOY copper rockfish among habitats during the initial post-larval summer period, as there were significant among-habitat differences in mean fish size in August. Subsequent changes in density could result from additional recruitment from plankton, migration of post-larval juveniles from nearby sites, dispersion among habitats, mortality, or any combination of these factors. It is unlikely that settlement from the plankton continued at Snake Island after the start of the study, as the otolith ages and length frequencies of the samples give no indication of new settlement. It is also unlikely that densities were affected by migration from other reef areas, because of the relative isolation of Snake Island. Therefore, we assume that all density changes reflected movements among habitats and/or mortality.

Ontogenetic shifts in habitat use occur in response to changing resource values, such as shelter from predation or prey availability (Werner and Gilliam 1984). Bluegill sunfish switch foraging habitats when the relative food values of the habitats change (Werner et al. 1983a), although these fish may forage in less prey-rich habitats with more shelter when in the presence of predators (Werner et al. 1983b). Jones (1984) found that post-larvae of a temperate reef fish preferentially used habitats with high algal biomass and increased prey density, although he recognized the difficulty in separating the effects of food availability and protection from predators. Predation is undoubtedly a factor in habitat resource value in the Strait of Georgia. Potential predators in the study area include lingcod (Miller and Geibel 1973) and adult copper rockfish (Prince and Gotshall 1976, Moulton 1977), and various bird species (Carr 1983).

Post-larval rockfish juveniles have been observed to shift habitats as they grow (Carr 1983), with associated changes in feeding habits (Singer 1985). Copper rockfish in the Strait of Georgia follow a similar pattern, although we observed them to initially occupy a greater diversity of habitats than observed in California (Carr 1983). The scope of our study did not allow the controlled field experiments necessary to quantify the relative importance of prey vs. predators as factors in habitat selection. However, we did examine prey use by habitat, over time. During the three months of this study, YOY copper rockfish consistently exploited certain prey types within a habitat. For example, fish in the AG habitat ate harpacticoid copepods throughout the study, even though in October the fish were larger than in earlier samples. We suspect, therefore, that the reduction in use of kelp forest habitats between August and September was a result of reduced shelter availability and/or reduced density of all prey types, and was not a result of changing preferences by growing fish.

In the Strait of Georgia, post-larval copper rockfish initially utilize a variety of reef-associated habitats. Kelp forests are an especially important habitat during this phase. However, the relative food and shelter values of shallow reef habitats change seasonally with the production cycles of the dominant macrophytes and their associated invertebrate populations. Within the first few months of settlement YOY copper rockfish shift to demersal habitats with perennial macrophytes. For YOY copper rockfish the availability of reef areas with both summer kelp forests and winter perennial macrophytes is a feature that potentially enhances first year survival. Such areas may, therefore, be especially valuable as nursery areas, and could possibly contribute disproportionately large numbers of individuals to older age classes.

Acknowledgements

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