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[Article]

Essential Habitat Identification for Age-0 Rockfish along the Central Oregon Coast

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Abstract.—The habitat needs of nearshore juvenile rockfish *Sebastes* spp. have rarely been studied but are an essential component of habitat identification for management. We investigated the relationships between habitat type, species composition, and growth of juvenile rockfish after settlement into nearshore reefs and estuaries in central Oregon. We identify and prioritize essential fish habitat (EFH) for blue rockfish *S. mystinus* and black rockfish *S. melanops* caught by minnow traps and by scuba divers with hand nets. Species were confirmed through genetic analysis. Our nearshore samples were dominated by blue rockfish, while estuary samples contained almost exclusively black rockfish. Settlement patterns suggest that black rockfish had a strong preference for anthropogenic habitat (docks, pilings, jetties) within the Yaquina Bay estuary. Growth was not significantly different among habitats or sampling years for either black rockfish or blue rockfish. We identify estuaries as EFH for black rockfish juveniles along the central Oregon coast and confirm nearshore reef areas as EFH for blue rockfish juveniles. Small sample sizes of juvenile yellowtail rockfish *S. flavidus* and widow rockfish *S. entomelas* suggest that estuaries are also important for these species.

All marine fishes require healthy habitats for feeding, growth to maturity, and reproductive success. Identification of critical habitat for commercially exploited fish species and understanding the role of habitat in recruitment processes are essential to successful management of marine fisheries. In spite of this significant need, critical habitat requirements for many temperate marine species are still poorly known. Protection and monitoring of critical habitats require an understanding of the role habitat plays in population dynamics and ecosystem function. However, before critical habitat can be designated and protected, it must first be accurately identified.

On the U.S. West Coast, concerns about the status of rockfish *Sebastes* spp. have prompted investigations of habitat requirements for commercially important species. The 1996 amendments to the Magnuson–Stevens Fishery Conservation and Management Act define essential fish habitat (EFH) as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity" (National Oceanic and Atmospheric Administration 2006). This broad definition means that habitat used by all life stages of all managed species must be identified. Prioritization of habitats is needed given limited management resources and identification of critical areas for additional spatial management. Only a few managed groundfish species have been studied sufficiently to fully identify EFH, largely due to a lack of basic biological information on juvenile life history stages (Love et al. 2002). At least 62 species of rockfish inhabit the coastal waters of Pacific North America (Eschmeyer and Herald 1983; Love et al. 2002), and many of these species are important in both commercial and recreational fisheries. Insufficient data on the habitat needs of these species need to be addressed (PFMC 2005). Identification of nursery habitat for declining rockfish stocks is a critical step to conserving and rebuilding overexploited populations.

In an effort to streamline the process of EFH description and identification, the National Marine Fisheries Service has adopted a four-level system based on a hierarchy of biological detail originally proposed by Minello (1999) and Able (1999). The first requirement for the establishment and description of EFH is presence–absence data (level 1). This classification simply allows elimination of areas that are not serving as habitat for species under investigation. Inference about the importance of habitat from level 1 data is limited in that it only describes the geographical distribution of a species in relation to habitat. Level 2 data include the habitat-specific densities of fish. This

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assumes that increased abundances (measured generally as catch per unit effort [CPUE] in fisheries data and fisheries-independent surveys) in a habitat reflect increased habitat quality. In level 1 and level 2 assessments, it is necessary to account for gear biases and other factors that may influence presence–absence or density calculations. With data limited to these two levels for most of the 82 groundfish species in its groundfish management plan, the Pacific Fisheries Management Council has identified the entire continental shelf of the U.S. West Coast as EFH (PFMC 2005). Level 3 information includes habitat-specific vital rates, such as growth, reproduction, and survival. Vital rate information is difficult to obtain for many species, but it provides a measure of habitat quality. Level 4 includes habitat-specific production estimates, or the contribution of a habitat to the spawning stock biomass of a species. Data at this level are rarely available for marine species.

Although this classification scheme has been used for identification of adult rockfish habitat, very few efforts to describe the distribution and habitat of juvenile rockfish have been conducted along the Pacific Northwest coast. This is at least partly due to adverse conditions for regular sampling, as well as species identification issues for age-0 fish. Juvenile habitats play a significant role in many of the processes that regulate postsettlement population dynamics, such as growth, competition, and predation. Ultimately, studies investigating the carrying capacity and quality of nursery habitats will be needed to evaluate and possibly restore habitats that are crucial to fisheries resources.

To address this important research gap, we set out to describe and define EFH for Oregon's nearshore juvenile rockfish species. While estuaries have received considerable attention as nursery habitats for a number of marine species (Butler and Jernakoff 1999; Beck et al. 2001; Akin et al. 2005), few studies have investigated juvenile rockfish recruitment to northeastern Pacific estuaries. Historic studies have shown that juvenile rockfish recruit to eelgrass *Zostera marina* and subtidal kelp *Laminaria saccharina* habitats within estuarine and inshore environments (Leaman 1976; Bayer 1981; Murphy et al. 2000), but no studies have delineated estuarine habitats from more oceanic, nearshore rocky reef habitats. Early pilot projects conducted along the Oregon coast during summer in 2002 and 2003 (T. Hart, Oregon State University, and S. Heppell, unpublished data) indicated that juvenile rockfish were abundant in both nearshore and estuarine habitats. This led us to question (1) whether estuaries are providing high-quality habitat for age-0 rockfish and (2) how the differential contributions of nearshore reef habitat versus estuarine habitat affect early ontogeny.

The major objectives for this study were to (1) describe species composition of juvenile rockfish within nearshore rocky reef and estuarine habitats, (2) examine differences in spatial and temporal abundance of rockfish among habitats, and (3) quantify habitat quality by comparing habitat-specific rockfish growth rates among sites. We utilized the existing four-level framework to identify EFH for two of the most abundant nearshore species of juvenile rockfish on the central Oregon coast: black rockfish *Sebastes melanops* and blue rockfish *Sebastes mystinus*. Our analysis of recruitment, seasonal abundance, and growth rates by habitat contributes to a growing body of literature on juvenile rockfish habitat associations throughout the species' range.

Methods

Study sites.—Nearshore sampling took place at two sites along the central Oregon coast (Figure 1): South Yaquina Reef (44.584′N, 124.101′W) and Margarita Reef (44.521′N, 124.105′W). Nearshore rocky patch reef sites ranged in depth from 10 to 35 m. Large boulders (>2 m), kelp fronds, abundant plumose anemones *Metridium* spp., and various sponges (Porifera) provide ample refugia for newly settled juvenile fishes at these sites, which range in patch size from 50 to 500 m^2. Estuarine sampling was conducted within Yaquina Bay, Oregon (44.62°N, 124.03°W), at four separate habitat types: eelgrass beds; sandy areas; rock or boulder outcroppings; and dock pilings (two replicates per habitat; eight total sites). Yaquina Bay is located on the central Oregon coast in Lincoln County. It is the fourth-largest estuary in the state, encompassing a total area of 20.5 km^2 at high tide. Tidal influence extends to about 42 km upriver (Pearcy and Myers 1974). The mean depth of Yaquina Bay is 2.6 m (Hickey and Banas 2003). Tides in Yaquina Bay are of the mixed-semidiurnal type, with spring-neap amplitude variation on the order of 50% (Emmett et al. 2000; Hickey and Banas 2003).

Collection methods.—We collected fish from nearshore and estuarine sites along the Oregon coast from 18 June to 24 September 2004 and from 25 June to 15 August 2005 by using hand nets and minnow traps. Collection periods were monthly for our nearshore sites and biweekly for estuarine sites, enabling us to quantify the following: (1) species composition among sites; (2) spatial and temporal differences in abundance; and (3) growth rates. Nearshore sites were sampled throughout both summers (two dives per month) for a total of 14 sampling events (eight dives in 2004 and six dives in 2005). All sampling in these areas utilized

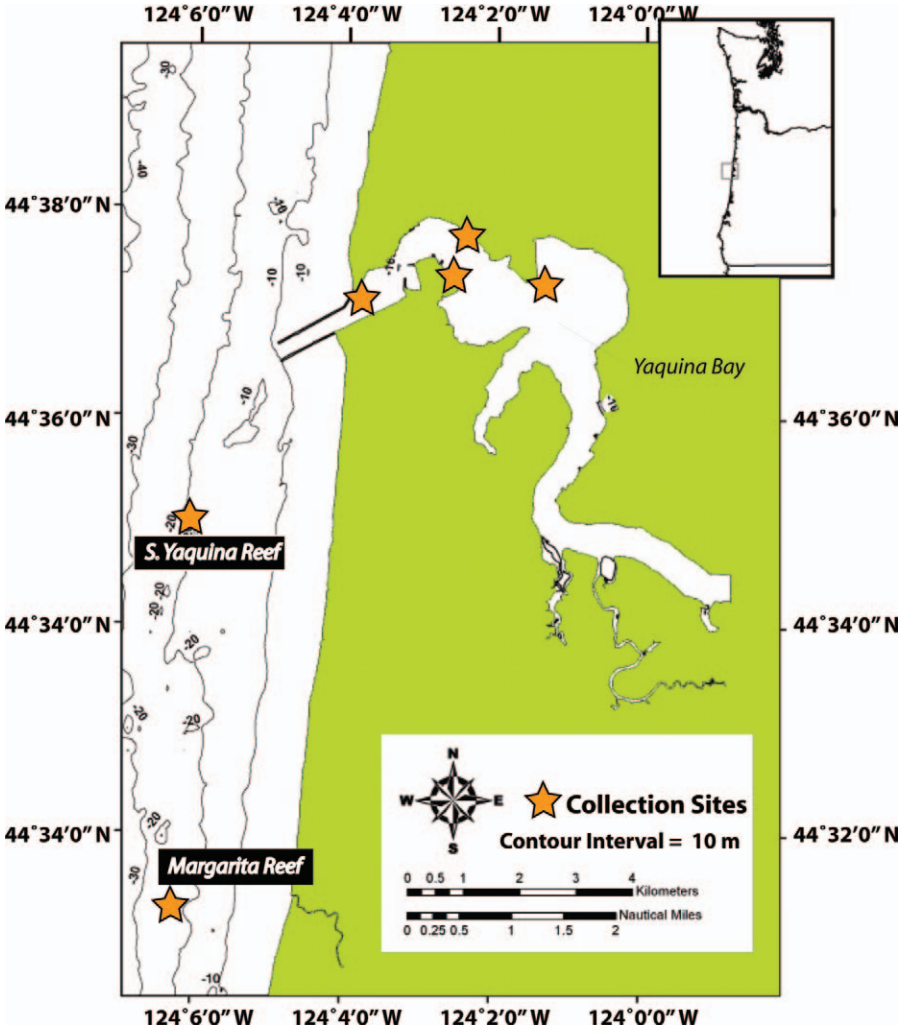

FIGURE 1.—Study area along the central Oregon coast, including estuarine and nearshore sites where juvenile rockfish were sampled. Depth contours are shown at 10-m intervals.

scuba, with divers working in pairs. Dive time was limited by air consumption and averaged 45 min; thus, the CPUE for all dive surveys was standardized as the number of fish captured per 45 min of dive time. Estuarine CPUE was standardized as number of fish captured per hour of trap soak time.

Our diving platform consisted of a 21-ft (6.3-m) Boston whaler, so sampling was limited to days where ocean conditions were less than 3-m combined seas for diver safety. Targeted depth during all dive surveys was 20–25 m. This depth was frequently inhabited by age-0 rockfish and provided shelter from strong current and surge. Two divers worked a benthic icthyofaunal net for kelp environments (BINKE net design sensu Anderson and Carr 1998) to capture age-0 rockfish. Net dimensions were 80 × 90 cm on a foldable polyvinyl chloride frame; net mesh size was 3 mm. All collected fish were transferred to plastic bags and brought to the surface for identification. Fish were measured to the nearest millimeter standard length (SL), sacrificed with tricaine methanesulfonate (MS-222) anesthesia, and frozen for later processing. We also attempted to catch age-0 rockfish in weighted minnow traps; this capture method was unsuccessful in nearshore habitat, in part due to adverse conditions (wave action) and possibly due to avoidance that we observed when traps were set in highly structured habitats (Gallagher 2007).

Estuarine sites were sampled biweekly with traps deployed for 25-h soak periods (14 total sampling

events: eight dates in 2004 and six sample dates in 2005). Wood and galvanized stainless-steel minnow traps measuring $65 \times 65 \times 45$ cm (Aquatic Ecosystems, Inc.) were used for fish collection within the estuary. These traps include a concave entry that allows fish to enter easily through a narrow panel. Trap validation experiments were conducted within a 700-gal tank under laboratory conditions to document capture efficiency. No fish escaped the traps during laboratory testing (Gallagher 2007). Samples were collected during daylight hours, with traps set approximately 0.5 h before the high tide and soaked for two full tidal cycles (25 h). Two traps were set in each habitat type and were anchored with 4.5-kg mushroom anchors at depths ranging from 2 to 7 m. Upon retrieval of the traps, all fish were measured to the nearest millimeter SL, sacrificed with MS-222, and frozen for later processing.

We utilized two different collection methods (fish traps and BINKE nets) due to the logistical issue of sampling in different environments (trap removal was uncertain in heavy seas in coastal areas; scuba is prohibitively time consuming and labor intensive for estuaries). However, to test for gear bias in fish length and species captured, we collected a subset of samples in the estuary by using both gear types. Black rockfish were the only species collected during subsampling, and differences in length were not statistically significant between gear types (t-test: df = 26, P = 0.53).

Species identification.—Age-0 rockfish are extremely difficult to classify to species based on morphological characteristics (Laidig and Adams 1991; Moser 1996; Rocha-Olivares 1998; Love et al. 2002). The 14 rockfish species of the subgenus *Sebastomus* (including blue rockfish, black rockfish, and yellowtail rockfish *Sebastes flavidus*) are particularly difficult to separate by usual morphometric methods (Li et al. 2006). Alternative methods of classification, such as biochemical assays or molecular techniques, are currently the most accurate and favored means of identifying species (Gray et al. 2006; Zhuozhuo et al. 2006). For our samples, caudal fin clips from all individuals were DNA sequenced to confirm species. All tissue samples were preserved in a 95% solution of ethanol and sent to the Southwest Fisheries Science Center (National Oceanic and Atmospheric Administration, La Jolla, California) for analysis. The DNA was extracted by use of a Chelex (BioRad Laboratories) boiling technique (Hyde et al. 2005). Briefly, a portion ($\sim 1 \times 1$ mm) of caudal fin was placed into a 0.2-mL polymerase chain reaction (PCR) tube containing 150 μL of a 10% (weight/volume [w/v]) Chelex solution. Samples were heated in a PTC200 DNA Engine (MJ Research) to 65°C for 20 min and then 103°C for 25 min. Extractions were stored at −20°C pending further analyses.

The mitochondrial cytochrome *b* (cyt*b*) gene was used to amplify DNA by using primers GluRF2 (5′-AAC CAT CGT TGT TAT TCA ACT ACA AGA ACC-3′; Hyde and Vetter 2007) and CB3RF2 (5′-CGA ACA GGA ART ATC AYT CTG G-3′; J. R. Hyde, Southwest Fisheries Science Center, unpublished data) in a 10-μL reaction volume containing 67-mM tris-HCl (pH 8.8), 16.6-mM $(NH_4)_2SO_4$, 10-mM beta-mercaptoethanol, 2-mM $MgCl_2$, 800-μM deoxynucleotide triphosphates, 0.4 μM for each primer, 0.5 units of *Taq* DNA polymerase (New England Biolabs), and 50–100 ng of DNA template. The DNA was amplified by using the following temperature profile in a PTC200 DNA Engine (MJ Research): 94°C for 2 min; 35 cycles of 94°C for 0.5 min, 59°C for 1 min, and 72°C for 1 min; followed by 3 min at 72°C. All PCR batches contained at least one no-template negative control to monitor for possible DNA contamination. Products were electrophoresed through a 2% (w/v) agarose gel in 1× tris-borate-EDTA buffer, stained with ethidium bromide, and visualized via an ultraviolet transilluminator. Reactions were digested by using ExoSAP-IT (USB Corp.) to remove unincorporated primers and deoxynucleotides before cycle sequencing. Products were cycle sequenced with the internal primer CBinR3 (5′-ATG AGA ART AGG GGT GGA AGC T-3′) by using BigDye Terminator version 3.1 and were analyzed on an ABI 3130XL automated capillary sequencer (Applied Biosystems). The DNA sequences were edited by using Sequencher version 4.5 (GeneCodes, Inc.).

The obtained sequences were combined with a data set of reference sequences representing multiple individuals of all species of *Sebastes* found in the northeast Pacific (Hyde and Vetter 2007; J. R. Hyde, unpublished data). The resultant sequence alignment was subjected to phylogenetic analysis by using a simple measure of genetic distance (Kimura two-parameter model) within PAUP* (version 4.b10; Swofford 2001). To assess statistical support values for the nodes, a nonparametric bootstrap resampling scheme was applied. Species identifications were determined by assessing the degree of bootstrap support for groupings of sequences of the unknowns against the reference data set. All groupings that had more than 80% bootstrap support were taken as valid for species identifications.

Age and growth analysis.—Numerous studies have validated daily otolith increment formation in age-0 rockfish (Boehlert and Yoklavich 1987; Laidig and Adams 1991; Woodbury and Ralston 1991; Kokita

and Omori 1998; Kokita and Michio 1999; Johnson et al. 2001; Plaza et al. 2001). Sagittal otoliths were removed and dried by using standard techniques (Campana 1984a, 1984b; Laidig et al. 1991). All unclear, abnormally shaped otoliths were discarded from the original sample of 322 fish, and the left sagittal otolith from each fish was used for birth and settlement date determination. We used standard protocols (Secor and Dean 1992; Laidig and Ralston 1995) to enumerate increments along the anterior dorsal portion of the otolith from the core to settlement and subsequently to the outer edge (capture date). Parturition (larval extrusion) dates were calculated by subtracting total estimated age from capture date. Timing of settlement was subsequently determined by adding the number of increments between the parturition check mark and the settlement check mark. Back-calculated birthdates and settlement dates were only determined for otoliths with distinct extrusion and settlement checks ($N = 140$); this subsample spanned the entire size range of fish collected (49–81 mm SL). All otolith daily increment counts were conducted by the primary author. We conducted a consistency analysis to determine the level of agreement among three repeated otolith reads. Two separate statistical indices were used to determine the validity of the interpretation: the coefficient of variation (CV; Chang 1982) and the average percent error estimation (Beamish and Fournier 1981). Because a major disadvantage of the average percent error index is that it fails to take into account the standard deviation of the range of ages within the aging analysis, we feel more confident using the CV as our measure of precision. The CV for this analysis was 3.5%. There is no threshold value for accepting or rejecting readings, although Laine et al. (1991) suggested a maximum CV of 5% for acceptable readings.

Growth (mm/d) was estimated by dividing each fish's SL by its age in days. This provides a metric that includes all phases of growth from parturition through postsettlement. Given that only 10–15% of the variability in growth occurs in the larval and pelagic life stages in rockfish (Laidig et al. 1991; S. Ralston, National Oceanic and Atmospheric Administration, personal communication), this metric captures the portion of postsettlement variability that is most interesting for the investigation of habitat-specific growth rates.

Analytical methods.—Analyses of abundance were based on CPUE calculations (standardized as number of fish captured per 45-min dive time for nearshore samples and number of fish captured per 25-h trap soak period for estuarine samples). For both black rockfish and blue rockfish, differences in mean CPUE between years were analyzed by using *t*-tests. Analysis of variance (ANOVA) was used to evaluate differences in CPUE of black rockfish among habitats and to analyze growth rate differences between (1) species and (2) years nested within species. For black rockfish, data for growth rates within eelgrass, rock, pilings, and sand habitats were combined after *t*-tests showed no differences in replicate sites sampled.

Results

Over two summer seasons of sampling (2004–2005), we collected a total of 322 rockfish of four different species: 205 black rockfish, 104 blue rockfish, 9 yellowtail rockfish, and 4 widow rockfish *Sebastes entomelas*. The average size of fish increased through the sampling season during both years, indicating that we were following a cohort of postsettlement juveniles through time (Figure 2).

Level 1 Assessment: Presence–Absence Data

The presence or absence of a target species is the simplest way to define habitat and can be useful when investigating species' range boundaries. Most of the fish captured were black rockfish from the estuary traps (Figure 3). No black rockfish were collected from our nearshore sampling site in either 2004 or 2005. Estuary samples were also almost exclusively black rockfish, indicating that this species is common in Yaquina Bay or is particularly attracted to minnow traps. Nearshore BINKE net samples were dominated by blue rockfish. Surprisingly, there were no black rockfish in the nearshore samples, although the depth of our scuba sampling may have been beyond their habitat preference (Stein and Hassler 1989).

Settlement Timing

Settlement dates for all species based on otolith examination ranged from 29 March to 11 July in 2004 ($N = 68$) and from 6 April to 9 July in 2005 ($N = 39$). In both years, peak settlement of blue rockfish in the nearshore habitat was later than black rockfish settlement in the estuary (Figure 4). Only two yellowtail rockfish had settlement checks on the otoliths that enabled their inclusion in the settlement analysis. Settlement dates for those fish were 11 and 24 April 2005. The solitary widow rockfish within the otolith sample settled out on 2 July 2004.

Settlement dates of black rockfish were unimodal during both sampling years, while blue rockfish settlement was more variable, at least in 2004 (Figure 4). This may indicate sampling of multiple recruitment pulses within the nearshore habitat, but sample sizes were small (2004: $N = 31$; 2005 $N = 8$).

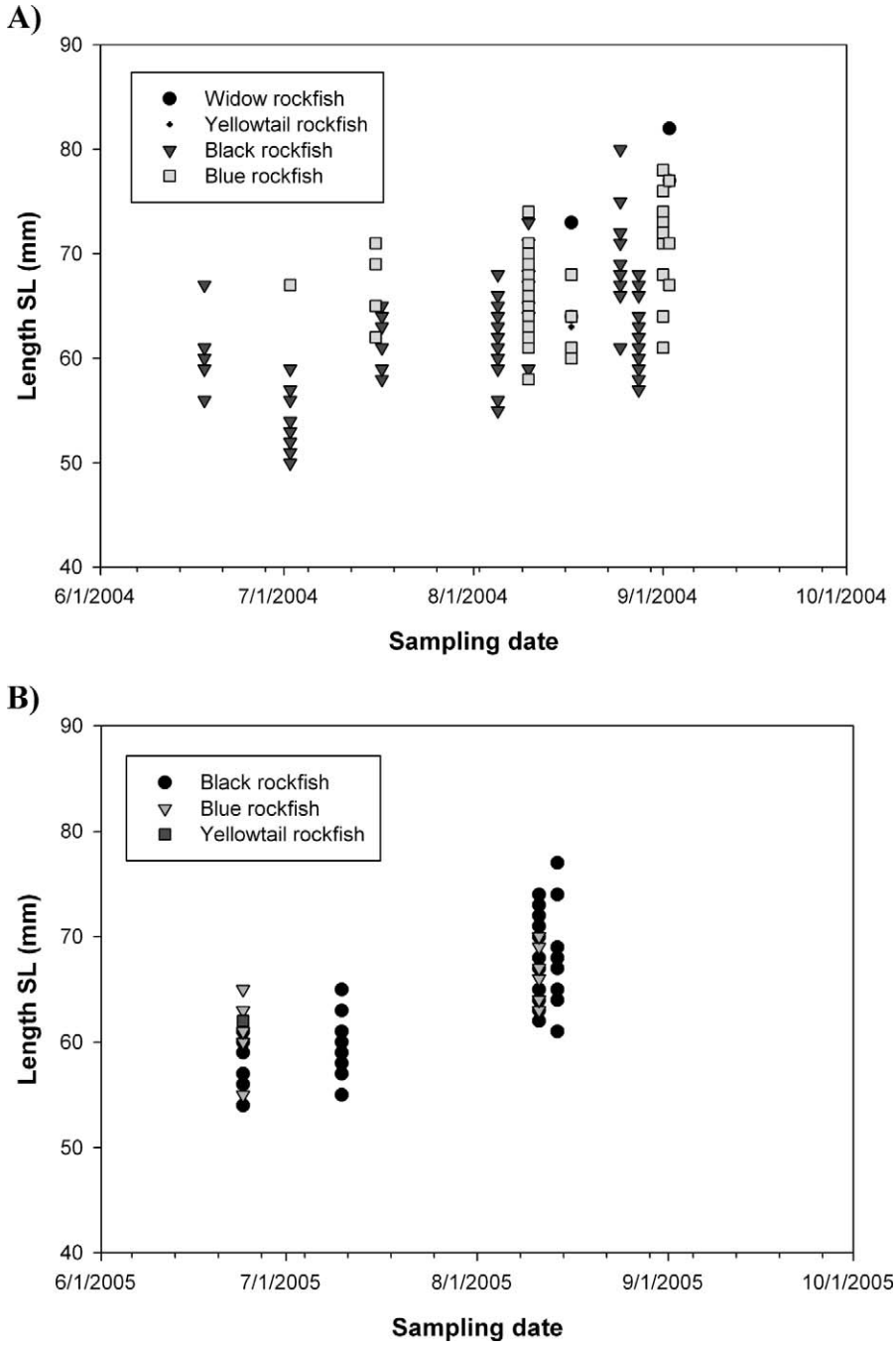

FIGURE 2.—Standard length (SL) of all rockfish species captured along the central Oregon coast versus sampling date during **(A)** 2004 and **(B)** 2005. Yellowtail rockfish, black rockfish, and blue rockfish were captured in both years; widow rockfish were captured in 2004 only.

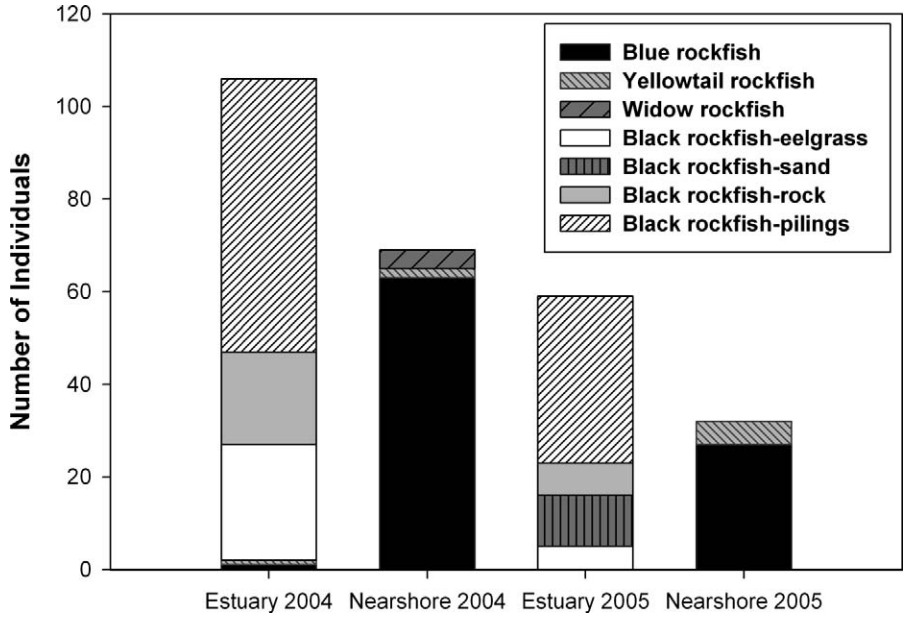

FIGURE 3.—Rockfish species composition in estuarine and nearshore sampling sites along the central Oregon coast during 2004 and 2005. For estuary sites, the proportional distribution of black rockfish within eelgrass, rock, piling, and sand habitats is shown.

Level 2 Assessment: Relative Abundance

Relative abundance as estimated from CPUE varied among years and habitats. Although absolute abundance of black rockfish was higher in 2004 than in 2005 (mean ± SE = 0.49 ± 0.16 and 0.32 ± 0.11, respectively), statistical tests showed that this was not a significant trend (*t*-test: df = 50, $P = 0.51$). However, differences in species abundances between habitats were statistically significant, with highest densities found around pilings, docks, and other anthropogenic structures (ANOVA: $F_{3,51} = 10.44$, $P < 0.001$). Catch per unit effort was much lower within rock, eelgrass, and sand habitats, respectively (Figure 5), indicating a habitat preference for anthropogenic structure. The greatest catch rates occurred at our dock piling station, which was immediately adjacent to a 20- × 20-ft oyster dock with nets of oysters hanging 6–7 ft from the surface of the water. The station with the lowest catch rate was over sand, with only 19 total fish; captures in this area were probably due to the fish's use of the traps themselves as habitat. Rock habitat stations demonstrated the greatest variability in fish abundance between stations of a consistent habitat type.

Blue rockfish CPUE was not significantly higher in 2004 than in 2005 (mean ± SE = 4.92 ± 1.3 and 4.83 ± 1.16 fish/45-min dive time, respectively; *t*-test: df = 5, $P = 0.97$). Both sampling sites in the nearshore were of a consistent habitat type, allowing only for examination of CPUE differences between years. Due to extremely low sample sizes, yellowtail rockfish and

TABLE 1.—Biological parameters estimated from otolith analysis of black rockfish and blue rockfish collected along the central Oregon coast during April through September 2004 and 2005. Numbers in parentheses denote the range.

Habitat	Sample size (*N*)	Mean age (d)	Mean date of birth	Mean settlement date	Mean standard length (mm)	Mean growth rate (mm/d)
Black rockfish						
Eelgrass	16	144.25 (112–192)	26 Mar (28 Feb–25 Mar)	16 May (25 Apr–11 Jun)	63.5 (58–68)	0.46 (0.38–0.86)
Dock pilings	55	130 (90–188)	28 Mar (18 Feb–9 May)	22 May (12 Apr–7 Jul)	65.02 (54–77)	0.51 (0.38–0.68)
Rock or boulder	15	129.9 (108–165)	24 Mar (27 Mar–18 Apr)	15 May (27 Apr–13 Jun)	63.4 (55–74)	0.49 (0.41–0.57)
Blue rockfish						
South Yaquina Reef	14	127.89 (100–167)	7 Apr (24 Feb–1 May)	23 May (19 Apr–10 Jun)	66.14 (61–69)	0.527 (0.41–0.66)
Margarita Reef	35	125.8 (99–163)	4 Apr (25 Feb–22 May)	2 Jun (11 Apr–6 Jul)	67.4 (60–78)	0.544 (0.41–0.66)

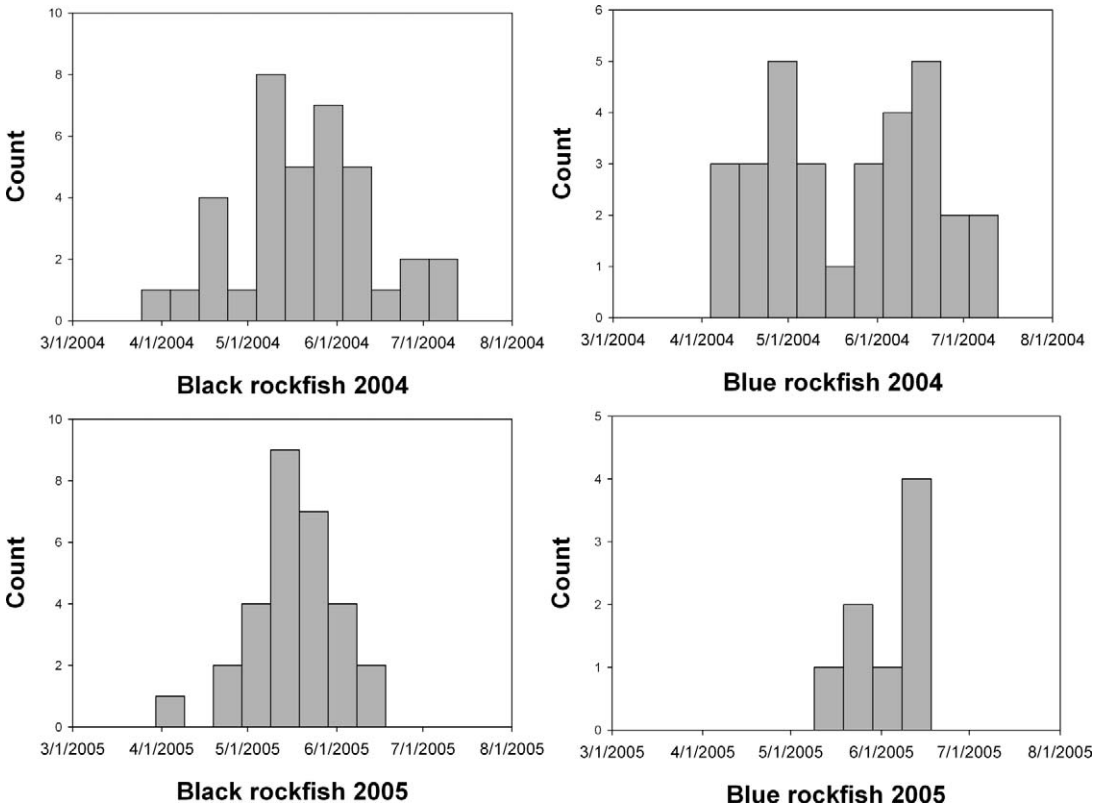

FIGURE 4.—Histograms of settlement timing (estimated from otolith increment analysis) for age-0 black rockfish and blue rockfish along the central Oregon coast during March through August 2004–2005.

widow rockfish were excluded from the abundance analyses.

Level 3 Assessment: Growth Rates

Growth rate differences were not significant between years for either black rockfish or blue rockfish (Tables 1, 2), and growth rate did not differ among habitat types for black rockfish within the estuary (ANOVA: $F_{3,53} = 1.423$, $P = 0.25$). However, mean growth rate differences were significant between species (Figure 6; Table 2). The lack of growth rate differences in black rockfish among estuary habitat types suggests either that (1) growth in the environments we sampled was not habitat dependent or (2) fish moved around the estuary and were not tied to a specific habitat type (Figure 7).

Discussion

Based on three levels of EFH classification, this study identifies estuaries as EFH for black rockfish juveniles along the central Oregon coast and identifies nearshore reef at 15–25-m depth as EFH for blue rockfish juveniles. This is valuable information for management as black rockfish and blue rockfish form the backbone of Oregon's recreational groundfish fishery (Conway and Opsommer 2007). This is the first study to examine nearshore rocky reef and estuarine habitat usage by postsettlement juvenile rockfish. Level 1 EFH assessment was sufficient for our general conclusion: the absence of age-0 black rockfish from nearshore rocky reefs sites narrows the focus of nursery habitat to subtidal kelp beds and estuaries. However, our study did not survey subtidal habitats. Previous studies have revealed juvenile rockfish within subtidal habitats, most commonly tidepools and kelp beds (Johnson et al. 2005; Studebaker and Mulligan 2008). This habitat was not sampled in our study due to our focus on the delineation of estuarine versus nearshore oceanic reef habitats. We recommend that future sampling should include subtidal, intertidal, estuarine, and nearshore reef habitats. Work conducted by Studebaker and Mulligan (2008) showed high abundances of juvenile black rockfish within tidepool habitats in northern

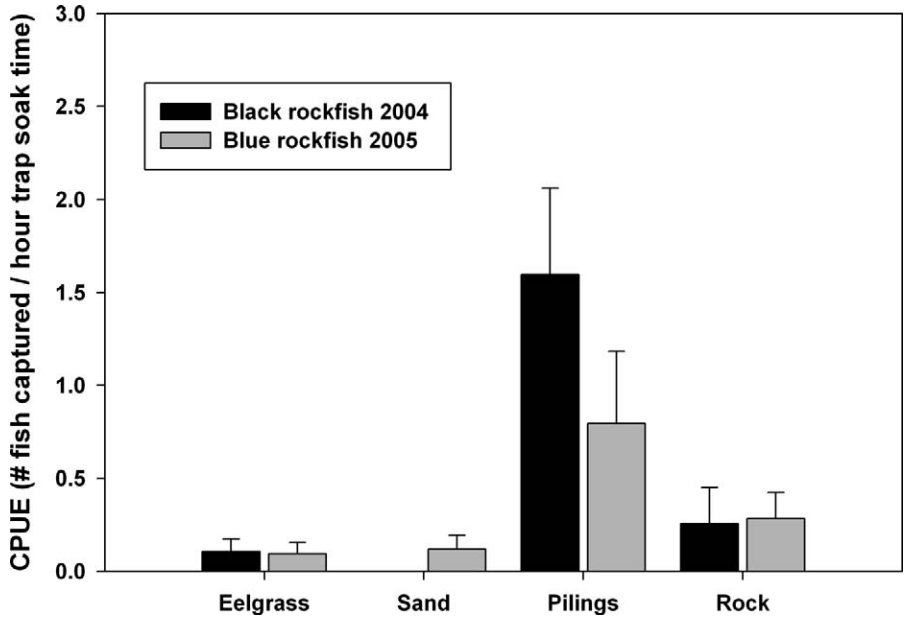

FIGURE 5.—Age-0 black rockfish catch per unit effort (number of fish per hour of trap soak time; mean + SE) in eelgrass, sand, piling, and rock habitats along the central Oregon coast.

California, although this habitat type remains understudied along the Oregon coast. Incidentally, we believe this omission does not color the importance of our inferences. Our work indicates that habitat partitioning is occurring at a very early life stage, and although black rockfish have consistently been found in the estuary, the question remains whether they are "estuarine dependent," a designation that has been demonstrated for a number of flatfish species (Yamashita et al. 2001; Brown 2003).

While several authors (Bayer 1981; Love et al. 1991; Shaffer et al. 1995; Buckley 1997) have observed juvenile rockfish strongly associated with various types of habitat (eelgrass, kelp, and drift vegetation), this work shows a general gradient wherein a greater abundance of age-0 black rockfish occurs within complex anthropogenic habitat (docks, seawalls, and jetties), leading us to question how continued estuarine development might affect rockfish populations. Within the estuary, minnow traps consistently captured the largest numbers of rockfish within areas of high habitat complexity (docks and pilings). While previous work shows that the presence of giant kelp *Macrocystis pyrifera* attached to rocky banks in the nearshore strongly influences the abundance and species composition of juvenile rockfish local recruitment (Carr 1991), the similar vertical morphology of pilings may act as an attractive substitute for natural habitat within the estuarine environment. The larger depth range of pilings that had continual contact with the surface provided a distinctive morphology that black rockfish may have been more attracted to than comparable refugia, such as rock. The oyster dock, adjacent to one of our piling habitat sites, undoubtedly provided shelter for juvenile fish and may have been a factor contributing to the large abundances found at that station. Furthermore, CPUE estimates for traps in habitats without structure may actually be biased high due to the traps themselves functioning as structural refugia. We conducted a number of tank experiments to test trap efficiency in various substrates and found that in highly complex habitats (dock pilings and rock),

TABLE 2.—Results of analysis of variance on estimated daily growth rates of black rockfish and blue rockfish in 2004 and 2005 for all habitats sampled along the central Oregon Coast (df = degrees of freedom).

Source	df	Sum of squares	Mean square	*F*	*P*
Black rockfish					
Model	3	0.6335	0.0211	3.74	0.0127
Error	131	0.7388	0.0056	—	—
Corrected total	134	0.8021	—	—	—
Blue rockfish					
Species	1	0.0365	0.0365	6.47	0.012
Year	1	0.0006	0.0006	0.11	0.737
Species × year	1	0.0064	0.0064	1.14	0.288

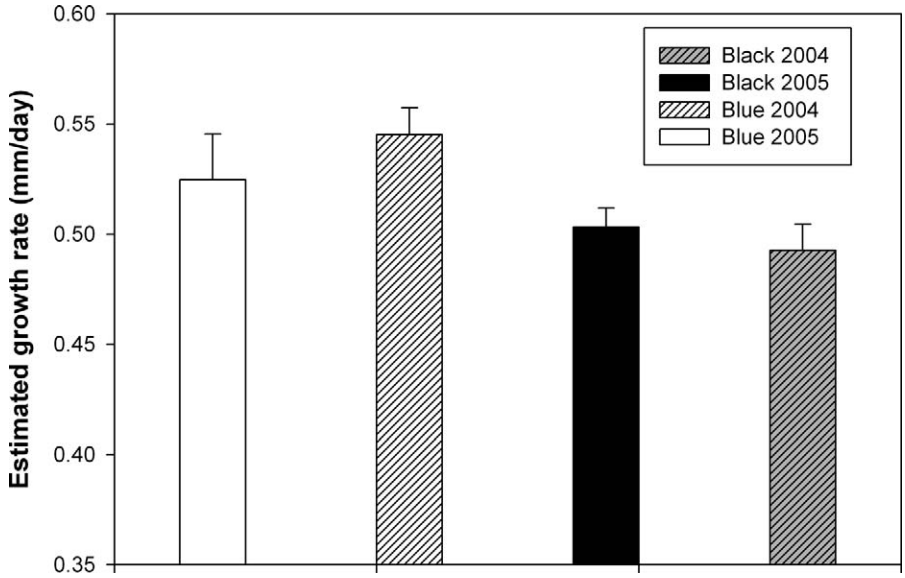

FIGURE 6.—Mean (+SE) daily growth rates in standard length (mm/d; estimated from otolith increment analysis) for black rockfish and blue rockfish sampled along the central Oregon coast in 2004 and 2005.

minnow traps may be underestimating the total abundance of fish within a habitat (Gallagher 2007).

Growth rates of age-0 rockfish in this study were slightly higher than those reported previously. Love et al. (1991, 2007) reported blue rockfish growth rates of 0.31 to 0.38 mm/d for fish collected at various oil platforms and natural reefs in the Santa Barbara Channel region, California; 0.29 mm/d in field studies; and 0.27 mm/d in laboratory experiments. The only other published study in which the authors examined age-0 rockfish growth rates integrated from parturition to postsettlement was that by Johnson et al. (2001), who reported growth rates of 0.17 mm/d in greenstriped rockfish *Sebastes elongatus*, 0.25 mm/d in cowcod *Sebastes levis*, and 0.32 mm/d in stripetail rockfish *Sebastes saxicola*. The high growth rates for black rockfish and blue rockfish (0.50 and 0.54 mm/d, respectively) in our study could be attributable to increased food availability provided by the highly productive upwelling off the Oregon coast.

Sampling biases associated with the timing and methods used in this study may also exist. We collected fish early in their ontogenetic development but would expect postsettlement growth to slow as the proportion of energy required for increased mass and volume increases exponentially with length. Furthermore, as fish grow they become less susceptible to certain collection methods, thereby potentially biasing growth results. Within this study, subsampling of fish with different collection methods showed no species or length bias; however, caution should be applied when comparing our results with those describing fish captured under different sampling protocols. Additionally, our calculations of habitat-specific growth rates assumed that individuals did not move between habitat sites. We believe these assumptions are valid for these species because they are very strongly associated with complex habitat and do not seem to make ontogenetic habitat shifts in until later in their ontogeny. Nonetheless, very little is know about ontogenetic habitat shifts in juvenile rockfish, and this is a fertile avenue for further study. A combination of mark–recapture surveys, deployment of passive integrated transponder devices, and molecular methods could help elucidate these movement patterns.

This study raises important questions about current and historical patterns of estuarine habitat usage by nearshore juvenile rockfish. Future studies should investigate the proportional contribution to these fisheries and their roles in governing long-term sustainable use (EFH assessment level 4). Although black rockfish are present, abundant, and growing well in estuarine habitats, proportional recruitment to the adult population remains unknown. In the quest to describe, define, and possibly conserve EFH, new approaches are needed for examining how habitats alter vital rates and for ensuring that habitats are not functioning as ecological sinks. The conservation of habitats depends not only on protecting sites where

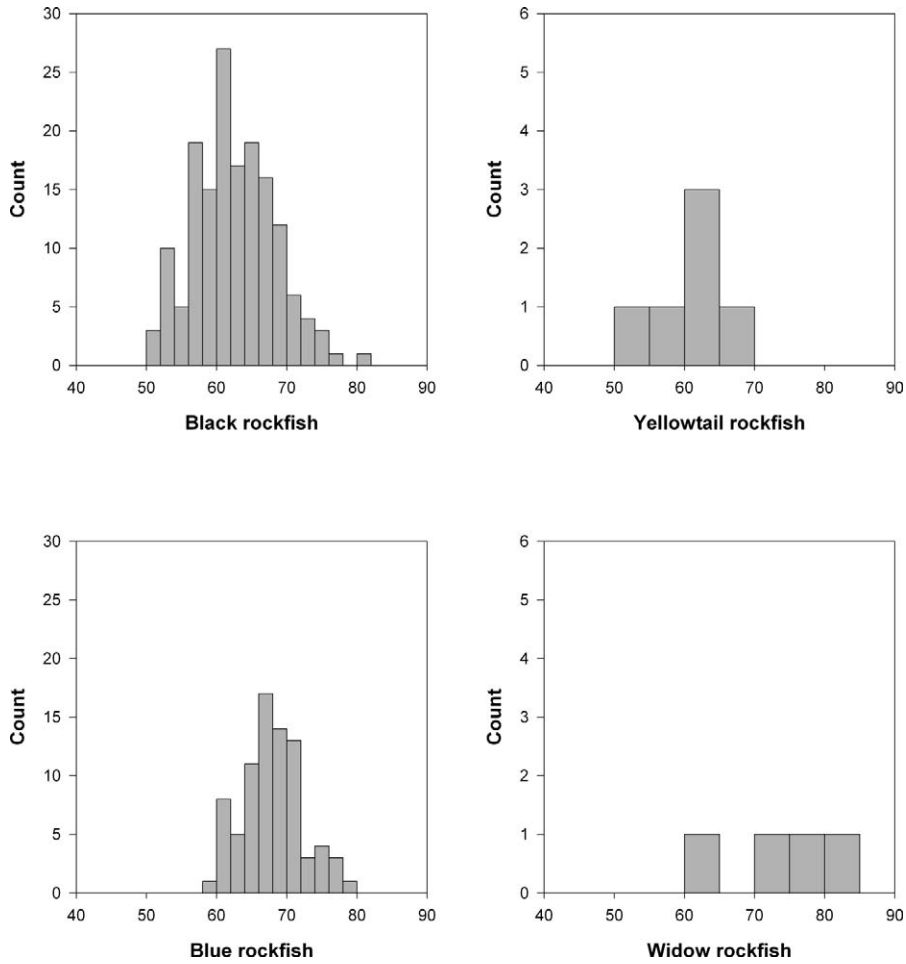

FIGURE 7.—Length frequency distributions (*x*-axis shows standard length, mm) for four rockfish species captured along the central Oregon coast during March through September 2004–2005.

organisms are present but also on protecting the ecological processes occurring at these sites. This is one of the first studies to describe habitat data at assessment levels 1–3 for juvenile rockfish, and our study establishes a protocol for examining the EFH of commercially important nearshore species.

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