AN ABSTRACT OF THE THESIS OF

Alison D. Dauble for the degree of Master of Science in Fisheries Science presented on June 8, 2010

Title: Young-of-the-year Rockfish (*Sebastes* spp.) Settlement Dynamics in Oregon Estuaries

Abstract approved:

Scott A. Heppell

In the Pacific Northwest, several species of rockfishes (*Sebastes* spp.) are under extreme conservation measures due to low population levels. Although currently at healthy population levels, one species of interest is the black rockfish (*S. melanops*), which has been shown to utilize estuarine habitat during its early life history stages. Black rockfish constitute a large portion of the recreational harvest in the Pacific Northwest, and are also a commercially fished species along the majority of the west coast. Annual recruitment in rockfishes has been shown to be extremely variable, and a better understanding of the factors behind successful recruitment and the subsequent settlement process would assist in prioritizing management and conservation efforts for this and other species. The overall goal of my study was to investigate the role that natural and anthropogenic influences play in the estuarine settlement dynamics of northeast Pacific rockfishes, using black rockfish as the

primary study species. Genetic identifications confirmed that the majority of the young-of-the-year (YOY) rockfish captured during this study were *S. melanops*, with small numbers of *S. caurinus* and *S. emphaeus* present as well. Results from trapping surveys indicated that YOY black rockfish utilize multiple estuaries on the Oregon coast from spring through late fall, and may be present in highly developed estuaries through their first winter before moving to deeper habitats, as shown by late season increases in catch-per-unit-effort (CPUEs) and the capture of multiple age-1 juveniles in the estuary. Catches were higher in the more developed estuaries on the coast, suggesting that the presence of structure is an extremely important component to the settlement process in this species and that the continued development of Oregon estuaries may not adversely affect YOY rockfish settlement. Two years of dive surveys on a standardized set of artificial reef structures in Yaquina Bay showed that a settlement index of YOY rockfish within the estuary could reflect larger trends in the YOY population and suggest that habitat saturation is not a factor that affects the settlement process of YOY rockfish in estuaries. This study provides strong evidence of widespread use of estuarine habitat on the Oregon coast by black rockfish during their first year of life, and provides additional support that structure is an important component to the settlement process, and has set the groundwork for investigating inter-annual variation in the estuarine settlement of rockfish.

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Young-of-the-year Rockfish (*Sebastes* spp.) Settlement Dynamics in Oregon Estuaries

by
Alison D. Dauble

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APPROVED:

Major Professor, representing Fisheries Science

Head of the Department of Fisheries and Wildlife

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Alison D. Dauble, Author

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CONTRIBUTION OF AUTHORS

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DEDICATION

I would like to dedicate this thesis to my grandmother, Violet, and my grandfather, Ken, both of whom passed away while I was a member of this lab, I will always miss you, and also to my grandmother, Priscilla, for always inspiring me, even when I didn't want to go on a walk.

Young-of-the-year Rockfish (*Sebastes* spp.) Settlement Dynamics in Oregon Estuaries

CHAPTER 1: INTRODUCTION

General Background

Estuaries rank among the most productive habitats on earth, yet they are also one of the most highly human-impacted habitat types (Edgar et al. 2000). There is a growing concern that environmental protections for estuaries need to be stronger, as anthropogenic modifications of west coast estuaries have increased dramatically over the last several decades (Huppert et al. 2003). Estuaries in the Pacific Northwest (PNW) are physically structured by large-scale ocean forcing, such as the annual upwelling regime, and their biological characteristics are highly influenced by oceanic processes (Hickey and Banas 2003; Miller and Shanks 2004). Coastal plain estuaries, typical to the Oregon coast, are relatively small and geologically young, and so they are not thought to contribute greatly to annual marine fish recruitment (Emmett et al. 2000; Hickey and Banas 2003).

There is recent evidence indicating that certain west coast estuaries may in fact play a significant role in local recruitment of certain species. The larvae and juveniles of some species of marine fishes have been shown to be present in PNW estuaries (Pearcy and Myers 1974; Monaco et al. 1992; Miller and Shanks 2005; Reum and Essington 2008). Recent studies have demonstrated that specific habitats within estuaries may be functioning as nursery grounds for flatfishes, such as English sole (*Pleuronectes vetulus*) and Pacific sanddab (*Citharichthys sordidus*) (Rooper et al. 2006; Brown 2006), and for rockfishes (*Sebastes* spp.) (Appy and Collson 2000;

Miller and Shanks 2004; Gallagher and Heppell 2010). Although there is value in PNW estuaries that lies outside of their contributions of recruits to fish populations, if their relative importance to specific harvested species is established, it may provide additional incentives for expanded conservation efforts (Brown 2006).

Rockfishes are a long-lived, slow growing group of demersal marine fishes that give birth to live young (Love et al. 2002). Following a pelagic larval stage of three to six months, young-of-the-year (YOY) rockfish move to a benthic environment and become strongly associated with structure, a process called settlement (Love et al. 1991; Love et al. 2002). Benthic settlement of many rockfish species occurs with seasonal regularity (Moser and Boehlert 1991), prior to progressively moving to deeper habitats as they mature (Love et al. 2002). Spatial distribution patterns of YOY rockfish during both pre- and post-settlement stages are highly complex, and are most likely related to variability within the wind-driven coastal upwelling system on the west coast (Larson et al. 1994; Laidig et al. 2007; Wilson et al. 2008). Many different types of habitats are utilized during the post-settlement stage, and YOY rockfishes are common in nearshore rocky reefs, kelp beds, and other shallow environments along the west coast (Love et al. 2002).

Rockfishes also utilize anthropogenically-altered environments during their first year, such as the offshore oil platforms in California (Love et al 2000; Caselle et al. 2002; Love and York 2005), where YOY rockfish of multiple species dominate the mid-water column surrounding the platforms. It appears that these large structures

allow YOY rockfish to aggregate and the presence of these platforms could possibly enhance production of certain species, including various overfished rockfish species (Love et al. 2000; Emery et al. 2004; Love et al. 2005). Variation in settlement structure complexity can influence post-settlement stage mortality rates in YOY rockfish (Johnson 2006), probably by affecting a predator's ability to detect YOY rockfishes at low densities (Hobson et al. 2001; Johnson 2006). Local population sizes can be strongly affected by post-settlement dynamics (Hixon and Jones 2005; Johnson and Hixon 2010) and understanding how structure affects the settlement process in rockfishes could be as important as understanding what drives the variability observed in the pelagic recruitment phase (Johnson 2007).

The settling of YOY rockfishes within estuarine environments on the Oregon coast has been documented previously (Appy and Collson 2000; Miller and Shanks 2004a; Gallagher and Heppell 2010), but many questions remain as to the relative importance of these habitats to their early life history. Habitat-specific studies have the potential to further answer questions concerning the processes that can affect mortality during a marine fish's early life history (Able 1999). By evaluating the role of structure to rockfish settlement specifically within estuaries, the relative value of the habitat, with regards to variation in the settlement process, could be clarified for management and conservation purposes (Heck et al. 2003).

Off the west coast, several species of rockfishes are under extreme conservation measures due to low population levels (Parker et al. 2000) and a low level

productivity that does not allow for high levels of fishing pressure (Hilborn et al. 2002). In 2000, after several decades of rapid industry growth and the subsequent collapse of rockfish populations, the west coast groundfish fishery was declared an economic disaster and much of the continental shelf was closed to bottom trawling (Shaw and Conway 2007). Scientific uncertainty in the predictions for rockfish population levels and incoming recruitment was cited as a major motivation for the initial closures (Shaw and Conway 2007). The National Marine Fisheries Service (NMFS) has declared seven species of rockfish to be overfished within the last decade (NMFS 2010) and has established multiple depth-based "rockfish conservation areas" in order to reduce fishing pressure (NMFS 2009). Information on the early life history of rockfishes is still patchy and incomplete (Boehlert and Yamada 1991; Parker et al. 2000), however, incorporating information on vulnerable life stages into a holistic stock assessment approach could reduce uncertainty in rockfish population predictions and provide more detailed information for fisheries management (Botsford et al. 1997; Shaw and Conway 2007).

The black rockfish (*S. melanops*) is a dominant nearshore species that constitutes over half of the total recreational groundfish harvest in Oregon and is currently estimated to be at healthy population levels (Sampson 2007). It is also a commercially fished species over the entire west coast (Parker et al. 2000; Love et al. 2002). Although not previously known to settle in estuarine environments (Pearcy and Myers 1974), recent evidence has demonstrated that this species

utilizes habitats within Oregon estuaries during their first year (Miller and Shanks 2004; Gallagher and Heppell 2010). Despite the large number of estuaries on the Oregon coast, the total estuarine surface area is relatively small when compared to the Columbia River estuary or Grey's Harbor in Washington, and many of the larger estuaries have been substantially altered by anthropogenic development such as dredging and port construction during the last four decades (DLCD 1987). A better understanding of the factors affecting variability in the estuarine settlement process would be valuable in both the prioritization of conservation efforts and for future fisheries management (Boehlert et al. 1991; Beck et al. 2001; Gillanders 2005).

The overall goal of this study was to investigate natural and anthropogenic influences in the estuarine settlement dynamics of rockfish, using black rockfish as the primary study species. The primary objectives were to (1) evaluate the settlement variability of black rockfish in Oregon estuaries experiencing different levels of anthropogenic development and (2) develop an index using artificial settlement structures within an Oregon estuary, upon which year class strength can be assessed to further evaluate the role that structure and natural variability play in settlement. These objectives were evaluated over two years (2008 and 2009), providing the groundwork for exploring interannual variation in the settlement dynamics of black rockfish within estuaries on the Oregon coast.

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CHAPTER 2: YOUNG-OF-THE-YEAR ROCKFISH (*SEBASTES* SPP.) SETTLEMENT PATTERNS AMONG SIX OREGON ESTUARIES WITH DIFFERENT LEVELS OF HUMAN DEVELOPMENT

Introduction

Estuaries rank among the most productive habitats on earth; unfortunately, they are also one of the most degraded by human activities (Edgar et al. 2000). Despite the large number (> 20) of estuaries along the Oregon coast, the total estuarine surface area is extremely small (excepting the Columbia River estuary), and many of the larger estuaries on the coast have been substantially altered by anthropogenic development activities, such as dredging or port construction (DLCD 1987). The estuaries of the Pacific Northwest are highly influenced by the biological and physical characteristics of the nearshore environment (Hickey and Banas 2003; Miller and Shanks 2004a). The larvae and juveniles of numerous fish species have been shown to be present in Pacific Northwest estuaries (Pearcy and Myers 1974; Monaco et al. 1992; Miller and Shanks 2004a) and recent studies have demonstrated the use of specific habitats within estuaries as possible nursery grounds for flatfishes, particularly English sole (*Pleuronectes vetulus*) (Rooper et al. 2006; Brown 2006), and rockfishes of the genus *Sebastes* (Appy and Collson 2000; Miller and Shanks 2004a; Gallagher and Heppell 2010).

Rockfishes are a group of long-lived, slow-growing demersal fishes that give birth to live young (Love et al. 2002). There are over 60 species of rockfishes in the North Pacific ocean (Love et al. 2002), and along the West coast of North America, several species of rockfishes are under extreme conservation measures due to low

population levels (Parker et al 2000; Love et al. 2002). The National Marine Fisheries Service (NMFS) has declared seven species of rockfish to be overfished within the last decade (NMFS 2010).

Information on the early life history stages of many rockfish species is patchy and incomplete (Boehlert and Yamada, 1991; Parker et al. 2000; Love et al. 2002). After a pelagic larval stage of three to six months, young-of-the-year (YOY) rockfish move to a benthic environment, a process called settlement (Love et al. 2002). Spatial distribution patterns of YOY rockfishes at this stage have been shown to be highly complex, possibly related to oceanographic conditions (Larson et al. 1994; Wilson et al. 2008), and post-settlement mortality may be subject to both the number of new recruits and the ecological setting (Johnson 2007).

The black rockfish (*S. melanops*), although not currently on the overfished species list, constitutes over half of the total recreational groundfish harvest in Oregon (Sampson 2007), as well as being a commercially fished species over the entire west coast (Parker et al. 2000; Love et al. 2002). Although black rockfish are not traditionally thought to be found in estuaries (Pearcy and Myers 1974), recent evidence has demonstrated that this species utilizes the estuarine environment during its early life history stages (Miller and Shanks 2004a; Gallagher and Heppell 2010). A better understanding of the factors that affect variability in settlement dynamics, and the role that estuaries play in this process, would be valuable in both

the prioritization of conservation efforts and for enhancing the effectiveness of fisheries management (Boehlert et al. 1991; Beck et al. 2001; Gillanders 2005).

The overall goal of this study was to investigate the estuarine settlement dynamics of black rockfish, including natural and anthropogenic influences on that process. The objectives were to (1) evaluate the settlement variability of black rockfish in Oregon estuaries that are experiencing different levels of anthropogenic development, (2) describe settlement patterns in multiple estuaries to further understand factors that could affect the settlement process, and (3) estimate the length of time YOY rockfish are present within estuaries and the timing of the initial estuarine settlement pulse. These three objectives were evaluated over two years (2008 and 2009), to provide the groundwork for exploring interannual variation in the estuarine settlement dynamics of black rockfish.

Materials and Methods

***Study Site*.** Two estuaries were chosen from each of three development levels, as defined by the Oregon Department of Land Conservation and Development (DLCD) in the Oregon Estuary Plan Book (DLCD 1987), and trap surveys were conducted in the following six estuaries: Nehalem, Siletz, Yaquina, Alsea, and Coos, and Coquille bays (Figure 2.1). Alsea and Siletz bays are "conservation" estuaries that lack jetties and have minimal development. Nehalem Bay and the Coquille River estuary are considered "shallow-draft development" estuaries that have jetties and a moderate amount of development, but are not dredged regularly. Yaquina and Coos bays are

"deep-draft development" estuaries that have jetties, a substantial amount of shoreline development, and are dredged regularly to admit deep-draft boat traffic.

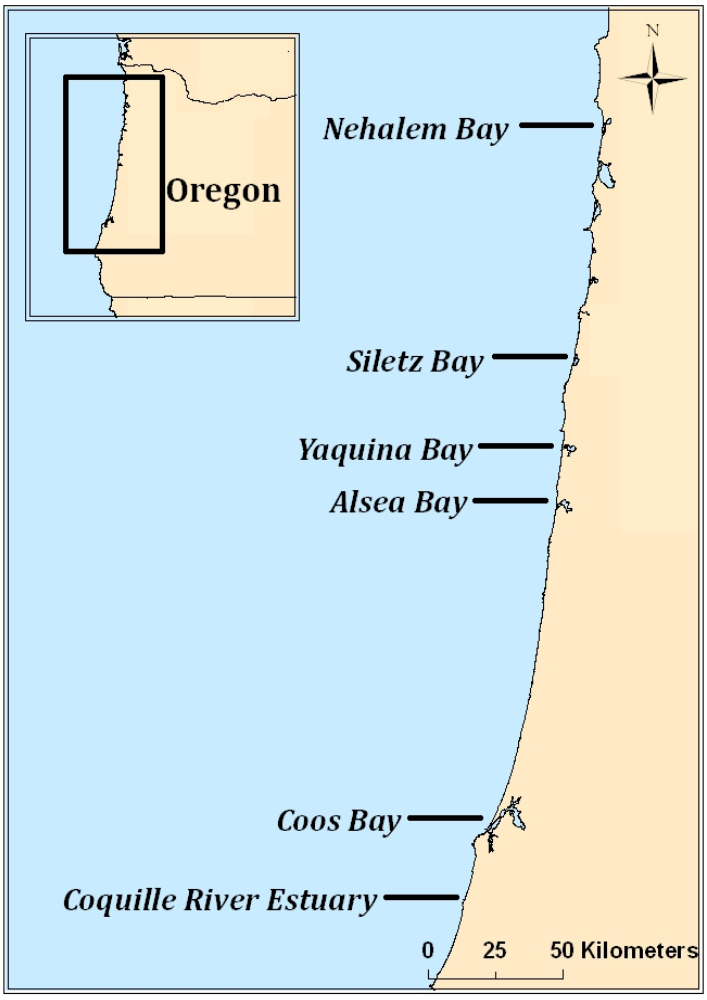

Figure 2.1: Locations of the estuaries on the Oregon coast where trap surveys were conducted.

Traps were placed adjacent to existing artificial structure (docks or pilings) or natural structure (rock). Specific trap sites were chosen based on distance from the estuary mouth, accessibility (several sites were on private property), and the depth of the water at low tide. In four of the estuaries (Nehalem, Alsea, Coos, and

Coquille), there were two sites chosen, an "estuary mouth" site (Site 1), located as close to the mouth of the bay as possible, and an "upriver" site (Site 2). In Siletz, there was only one site chosen because of the lack of available hard structure upriver at low tide. In Yaquina Bay, three sites were chosen, the additional site replicating a location from a previous study (Gallagher and Heppell 2010).

Methodology. Trapping sessions occurred approximately every three to four weeks, from May to November 2008 and April to October 2009. For each trapping session, two large, square minnow traps (Model MT-10, Aquatic Eco-Systems Inc., Apopka, FL*),* approximately 45 centimeters (cm) square on the base and 30 cm tall, were fitted with additional weights to prevent movement, and placed at the base of the structure at the trapping site. Depth of the traps varied with the tidal cycle and ranged between approximately one to seven meters. The traps were set, unbaited, for approximately 24 hours to encompass an entire daily tidal cycle.

Temperature (°C), salinity (parts per thousand, ppt), and dissolved oxygen (milligrams per liter, mg/L) were measured when each pair of traps was deployed and retrieved, using a model YSI-85 multi-meter (YSI, Inc., Yellow Springs, OH). Measurements were taken as close to the traps as possible and the two readings were averaged for analysis.

The total catch from both traps for each session was combined. In 2008, all fish caught in the traps were identified to species and then measured to the nearest

millimeter (mm) standard length. In 2009, all fish were identified, but only YOY or juvenile rockfish were measured. A fin clip was taken from the second dorsal fin of all captured rockfish, which was used for subsequent genetic identification to species. Fin clips were stored in ethanol until processed for genetic identification. All live fish were released unharmed, and any in-trap mortalities were recorded. YOY or juvenile rockfish that died in the traps were kept and preserved in ethanol for later analysis.

Species Identification. All fish collected were identified visually to species, but because of some difficulty in identifying YOY rockfish, the visual determinations were confirmed by genetic analysis, which was performed at the Oregon State University Marine Fisheries Genetics Laboratory in Newport, OR, as follows:

Total genomic DNA was extracted from the dorsal fin tissue using a glass fiber plate extraction protocol (Ivanova et al. 2006). Polymerase chain reaction (PCR) was used to amplify a 782-base pair (bp) fragment of the mitochondrial DNA (mtDNA) cytochrome b (cytb) gene using previously published GluRF and CB3RF primers (Rocha-Olivares et al. 1999). Thermal cycling conditions included an initial denaturation at 94 °C for 2:30 minutes (min), followed by 35 cycles of 94 °C for 45 seconds (sec), 56 °C for 1:30 min, and 72 °C for 1:30 min. Final extension was carried out at 72 °C for 3 min. The PCR products were cleaned using a standard ExoSap procedure (USB Corporation, Cleveland, OH) and were cycle sequenced using BigDye kits (Applied Biosystems, Foster City, CA) and internal primers CBInf2

(5' – TRA GKG TTG CAT TGT CTA CTG AGA A – 3') and CBInr2 (5' – GGR CTT TAC TAC GGY TCR TAC CT – 3') (J Hyde, pers. comm.). Sequencing products were cleaned using a Sephadex filtration protocol (Millipore, Billerica, MA) and visualized on an ABI 3730XL capillary sequencer. Sequence data were aligned and edited using Sequencer v4.7 (Gene Codes, Ann Arbor, MI) software.

Using an iterative approach, YOY rockfish genetic sequences were compared to a reference dataset of 374 independent haplotypes from 67 species of morphologically identified adult *Sebastes* spp. Comparisons were performed using the program PAUP* v4b10 (Sinauer Associates, Sunderland, MA) with the optimality criterion set to distance (number of bp differences divided by total sequence length in bp). Species included in the reference dataset are listed in Taylor et al. (2004).

Nonparametric bootstrapping (1000 replicates) was used to cluster each unknown haplotype within the reference dataset of 374 known adult haplotypes. If a YOY clustered within a monophyletic single-species clade with a bootstrap value >70%, this was accepted as positive identification of the individual. If a YOY clustered with a monophyletic clade with a bootstrap <70%, a secondary analysis was performed that included haplotypes of the three nearest (in uncorrected "p" genetic distance) species to the unknown rockfish haplotype to confirm the identification. Some species in the reference dataset (*S. wilsoni* / *emphaeus* / *variegatus* / *zacentrus*, or WEVZ complex, and *S. melanops* / *flavidus,* or the MF complex) failed to form monophyletic clades. YOYs falling within these multispecies clades were classified

as belonging to the WEVZ complex or the MF complex, rather than to a specific species.

Analysis. Data were maintained in Excel™ (Microsoft Corp.) and converted for analysis in R (http://www.r-project.org) and S-Plus™ (TIBCO Software Inc.) software packages. Catch-per-unit-effort (CPUE) measurements were calculated by using the total number of rockfish captured in both traps of each trapping session, and dividing it by the total trapping time (two traps times approximately 24 hours), yielding a measurement of number of rockfish per trap hour. This particular effort measurement was chosen because of the slightly variable length of each trap session. Catches among estuaries and sites were compared using a Tukey's multiple comparison procedure. A multiple regression analysis was used to determine the extent of the relationship between the CPUEs and the three environmental variables measured. Catch per unit efforts were $\log_{10}$-transformed for the multiple comparison procedure, for any t-tests, and for all regressions, due to the order of magnitude differences observed in the catches of YOY rockfish across estuaries. For the early and late season CPUE comparisons, a small value was added to the zero catches in order to allow for comparisons of the $\log_{10}$-transformed data. The division between early and late season for these comparisons was approximately halfway (mid-July) through the seasonal timeframe when YOY rockfish were present. A two-sample comparison test (Welch's t-test) was utilized when variances were unequal, otherwise, a two-sample t-test was used to evaluate early and late season catches. Size comparisons between years excluded YOYs captured after 30

September in 2008 and 03 October in 2009 in order to standardize the sampling season between years.

Two proxies for estuary development level were created to use in separate linear regression analyses, called “hardened linear shoreline” and “mouth cross-sectional area” (Table 2.1). These two measurements attempt to describe the amount of available structure, the size of the estuaries, the presence of jetties, dredging, and river flow rates. They are not, however, independent variables and were therefore not used in a multiple regression analysis. Average total hardened linear shoreline (in kilometers, km) was estimated using the “ruler” measurement tool in Google Earth™ (Google, Inc.). A series of bank edge, linear segments with hardened shoreline or structure were estimated three times per estuary, and then averaged for each estuary. Measurements were made from the estuary mouth to approximately one kilometer past the upriver trapping site for that particular estuary. Mouth cross sectional areas were estimated using the maximum depth from National Oceanic and Atmospheric Administration nautical charts (Office of Coast Survey, U.S. Department of Commerce, http://www.charts.noaa.gov) closest to the mouth itself. The width of the mouth was estimated using the Google Earth™ “ruler” tool, and the two measurements were multiplied to get a cross sectional area (in meters squared, m^2).

Table 2.1: Qualitative and quantitative characteristics of each of the six estuaries from the central Oregon coast sampled during this study.

Estuary	Development Classification Level*	Size of Estuary (km^2)**	Presence of Jetties	Dredged Channel	Avg. Hardened Linear Shoreline (km)	Mouth Cross Sectional Area (m^2)
Yaquina	Deep Draft	15.82	Yes	Yes	8.93	3475.2
Coos	Deep Draft	44.4	Yes	Yes	6.02	8482.0
Coquille	Shallow Draft	3.31	Yes	No	3.18	898.7
Nehalem	Shallow Draft	9.34	Yes	No	2.35	1100.3
Siletz	Conservation	4.8	No	No	0.025	232.4
Alsea	Conservation	8.68	No	No	1.14	1019.0

*DLCD 1987 **Pearcy and Myers 1974

Results

A total of 621 YOY and juvenile rockfish were captured in 2008 in 103 individual trapping sessions, and 455 were captured in 2009 in 89 individual trapping sessions (Table 2.2). In 2008, YOY rockfish were captured in all six estuaries, whereas in 2009, rockfish were captured in all estuaries but Siletz Bay.

Genetic Identification. A total of 298 fin clip samples were processed for genetic identification during this study; 248 samples from 2008 and 50 from 2009. Fin clips were separated by estuary and randomly subsampled for genetic analysis in proportion to the number of rockfish caught in each estuary. In 2008 (Figure 2.2a), 95.2% (236) of the samples were identified to *S. melanops* and in 2009 (Figure 2.2b), 86.0% (43) were *S. melanops*.

Several individuals of the WEVZ complex were identified in both 2008 (1.6%, 4) and 2009 (6.0%, 3). Three of these species (*S. wilsoni / variegatus / zacentrus*) have never been previously reported in estuaries at any life stage (Love et al. 2002) and ecological characteristics suggest that the most likely candidate from these four is *S. emphaeus*, the Puget Sound rockfish, as the other three species are deepwater rockfishes that are much rarer in shallow waters (Love et al. 2002). In 2008, three of the four WEVZ samples were from Yaquina Bay (captured from July – November)

Table 2.2: The number of rockfish captured, number of trap sessions with rockfish captured (of the total number of trap sessions), date of initial capture, the minimum time present within each estuary based on the trap surveys, and the date of the peak in catch-per-unit-effort for each estuary in 2008 and 2009.

		2008					2009				
Estuary	**Development Classification Level***	**No. Rockfish Caught**	**No. Sessions Rockfish Captured (of total)**	**Date of Initial Capture**	**Minimum Time Present**	**Peak CPUE**	**No. Rockfish Caught**	**No. Sessions Rockfish Captured (of total)**	**Date of Initial Capture**	**Minimum Time Present**	**Peak CPUE**
Yaquina	Deep Draft	170	23 (38)	09 June	09 June – 19 Nov	15 Oct	337	37 (49)	09 Apr	09 Apr – 27 Aug	06 July
Coos	Deep Draft	237	12 (14)	24 May	24 May – 22 Nov	22 Nov	86	8 (10)	17 Apr	17 Apr – 02 Oct	03 Aug
Coquille	Shallow Draft	177	11 (16)	24 June	24 June – 22 Nov	24 June	24	7 (10)	29 May	29 May – 02 Oct	22 June
Nehalem	Shallow Draft	21	6 (14)	06 July	06 July – 13 Nov	07 Sept	4	2 (8)	01 July	01 July – 25 Aug	01 July
Alsea	Conservation	5	4 (13)	07 July	07 July – 25 Sept	25 Sept	4	2 (5)	09 June	09 June – 27 Aug	09 June
Siletz	Conservation	11	4 (8)	30 June	30 June – 26 Aug	16 July	0	0 (7)	No rockfish captured in Siletz 2009		

*DLCD 1987

and one was from Coquille (June). In 2009, all three samples were from Yaquina Bay (May to July).

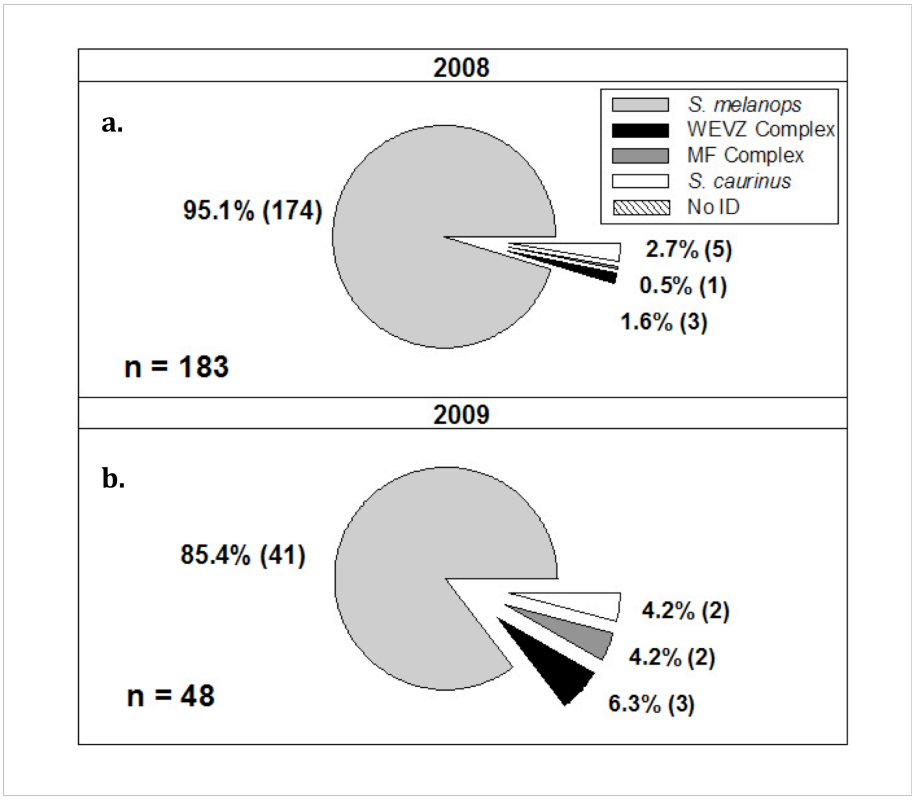

Figure 2.2: Proportions of the different young-of-the-year rockfishes genetically identified from dorsal fin clip samples in 2008 (a) and 2009 (b).

Of the remaining samples, one sample in each year (Nehalem 2008 and Yaquina 2009) was identified to the MF complex and was therefore indistinguishable between *S. melanops* and *S. flavidus*, the yellowtail rockfish, which has been previously reported in Yaquina Bay (Gallagher and Heppell 2010). One sample in 2009 was indistinguishable among *S. melanops*, *S. flavidus*, or *S. serranoides*, the olive rockfish. The latter species has not been found off the Oregon coast (Love et al. 2002), so it is unlikely the sample is from an olive rockfish, and is more likely either

S. melanops or *S. flavidus*. In June 2009, two samples (4.0%) of *S. caurinus*, the copper rockfish were collected from Yaquina Bay. This species has not previously been reported in this estuary. Finally, in 2008, seven samples (2.8%) failed to sequence properly, but none failed in 2009.

Development Level. There was a positive relationship between the seasonal mean CPUE by estuary and the hardened linear shoreline estimates (linear regression, F = 10.87, p = 0.008; Figure 2.3a), with a doubling of CPUE occurring for every 1.46-fold (95% CI: 1.30 to 1.63) increase in the median of hardened linear shoreline. Over 50% of the variation in CPUE was explained by the log-log linear regression of CPUE and hardened linear shoreline (R^2 = 0.5207; Figure 2.3a).

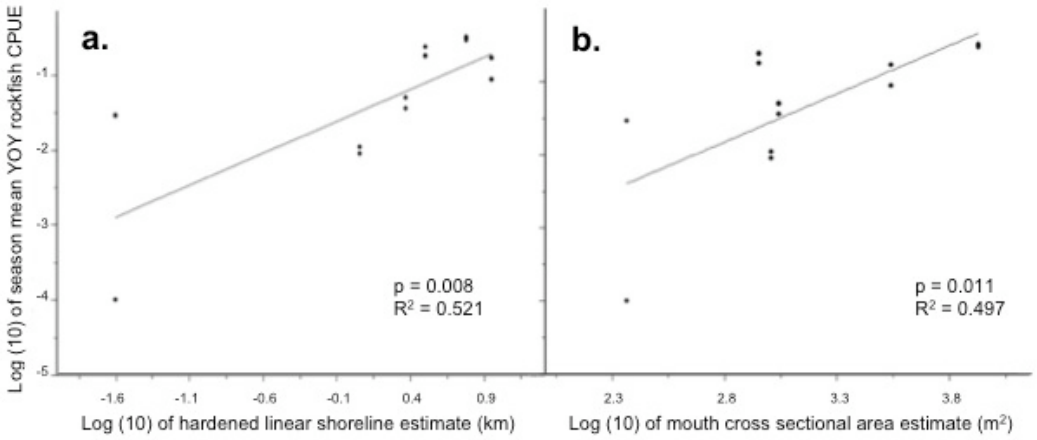

Figure 2.3: Linear regressions of the log_{10}-transformed season mean young-of-the-year catch-per-unit-effort in each estuary for 2008 and 2009 and hardened linear shoreline estimates (a) and mouth cross sectional area (b).

Similar to the relationship found for hardened linear shoreline, there was a positive linear relationship between mean estuary CPUE and estuary mouth cross-sectional area (F = 9.89, p-value: 0.01; Figure 2.3b), with CPUE doubling with every 1.88-fold

(95% CI: 1.54 to 2.30) increase in the median of mouth cross-sectional area. Approximately 50% of the variation in CPUE was explained by the log-log linear regression of mouth cross-sectional area ($R^2 = 0.4973$; Figure 2.3b).

CPUE Comparisons. In 2008, there were no statistically significant differences found in CPUE across estuaries (one-way ANOVA, $p = 0.09$). In 2009, there were significant differences in CPUE across estuaries (one-way ANOVA, $p = 0.02$). Follow up with the Tukey analysis demonstrated differences in the mean CPUE among the following estuary pairs: Coos > Siletz, Nehalem > Siletz, and Yaquina > Siletz.

Early and Late Season Differences in CPUE. In 2008, at the two upriver Yaquina sites, the late season CPUE was greater than the early season CPUE at both Site 2 (Welch's t-test; $p = 0.02$) and at Site 3 (Welch's t-test; $p = 0.04$). While there was no statistical difference in the upriver site early and late season CPUEs at Coos (Welch's t-test; $p = 0.14$), the general pattern of increased CPUE later in the season holds true in this estuary as well, with the highest CPUE found in late October at Site 2 (upriver site). There were no differences found between early and late season CPUEs at Site 1 (estuary mouth) in either Yaquina (Welch's t-test; $p = 0.36$) or Coos (two-sample t-test; two-sided $p = 0.92$).

Just as in 2008, there were no differences between the 2009 early and late season CPUEs at Site 1 in Yaquina (Welch's t-test; $p = 0.75$). Late season CPUE, however, was again greater than the early season CPUE at both Site 2 (Welch's t-test; p-value

< 0.001) and Site 3 (Welch's t-test; p-value = 0.03). In 2009, the number of trap surveys was substantially smaller at both sites in Coos, limiting statistical power, but followed the general pattern of greater abundance during the late season at the upriver site. Late season CPUE at Site 2 in Coos Bay was greater than early season (Welch's t-test; p = 0.02), however, there were not enough completed surveys to run a comparison test at Site 1. This general pattern was also observed in YOY rockfish capture rates on artificial reef structures placed in Yaquina Bay (see Chapter 3, *this thesis*). Catches did not differ between early and late season CPUEs in the other four estuaries (Welch's and two-sample t-tests; all p-values > 0.05).

Size at Capture Comparisons. In 2008, YOY and juvenile rockfishes ranged from 22 to 90 mm standard length (n = 609, average size 60.2 mm), and in 2009, from 20 to 113 mm (n = 459, average size 54.2 mm) (Figure 2.4). There were multiple larger individuals caught in April to June of 2009, and one in 2008 (82 – 113 mm); these were most likely age-1 juveniles from the previous year's recruitment. After discarding the late season captures in 2008 and excluding probable age-1 individuals, the average size of YOY rockfishes in 2009 was found to be 1.51 mm smaller than the 2008 average (two-sample t-test; one-sided p-value: 0.0018, 95% CI: 0.49 to 2.53). However, this value is probably biologically insignificant, given that the black rockfish growth rates in Yaquina Bay have been measured at approximately 0.5 mm/day from Yaquina Bay (Gallagher and Heppell 2010). Approximate size at settlement for *S. melanops* has been estimated at 46mm (Matarese et al. 1989), which was consistent with what was found in this study. A

large number of pre-settlement size YOY rockfish (67 individuals ≤ 45 mm) were caught in 2009, but only nine were captured in 2008.

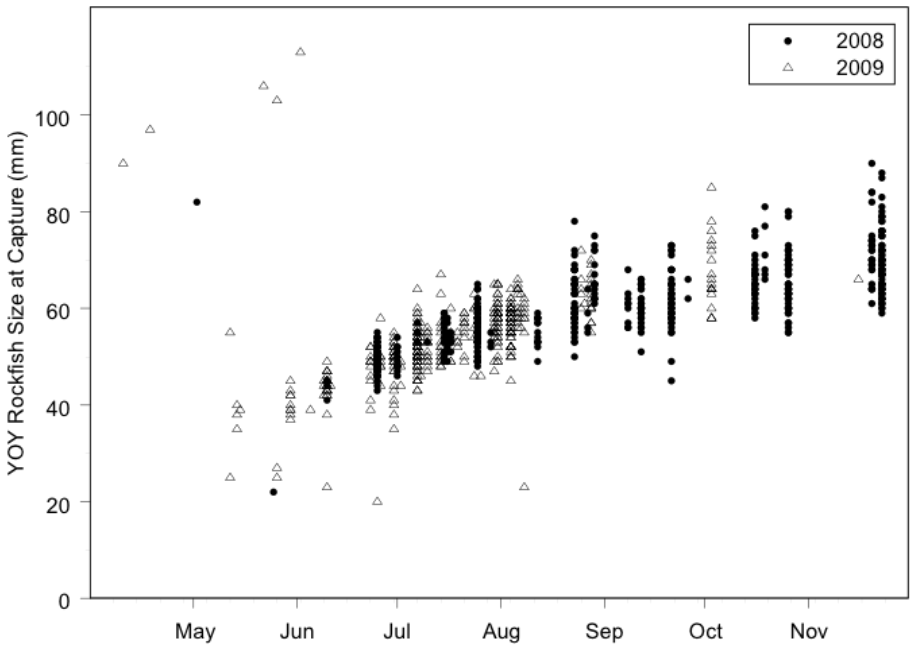

Figure 2.4: Size distributions of YOY rockfish from all estuaries in 2008 (closed circles) and 2009 (open triangles).

Environmental Variables. There was no linear relationship between CPUE and temperature (p-value: 0.89), salinity (p-value: 0.42), or dissolved oxygen (p-value: 0.33); the three variables combined explained less than 5% of the variation in CPUE (R^2 = 0.04). Temperature (range: 8.5 – 16.9 °C), salinity (13.8 – 33.6 ppt), and dissolved oxygen (5.6 – 12.9 mg/L) varied spatially according to the estuary and the depth of the trap site, but not necessarily on a temporal basis.

Settlement Patterns: Deep Draft Estuaries. During 2008 in Yaquina Bay, YOY rockfish were captured consistently from early May (Site 1, estuary mouth site) or

early June (Sites 2 and 3, upriver sites) until trapping surveys were discontinued in mid-November (Figure 2.5a). Catches were consistently low throughout the season at Site 1, with a slight peak in July, but CPUEs increased slightly through the final trap session of the season at Sites 2 and 3, in October and November. In 2009, rockfish were captured from May or June to late September, when trap surveys were finished for the year (Figure 2.5b). Catch-per-unit-effort peaked in 2009 in either July (Sites 1 and 3) or August (Site 2).

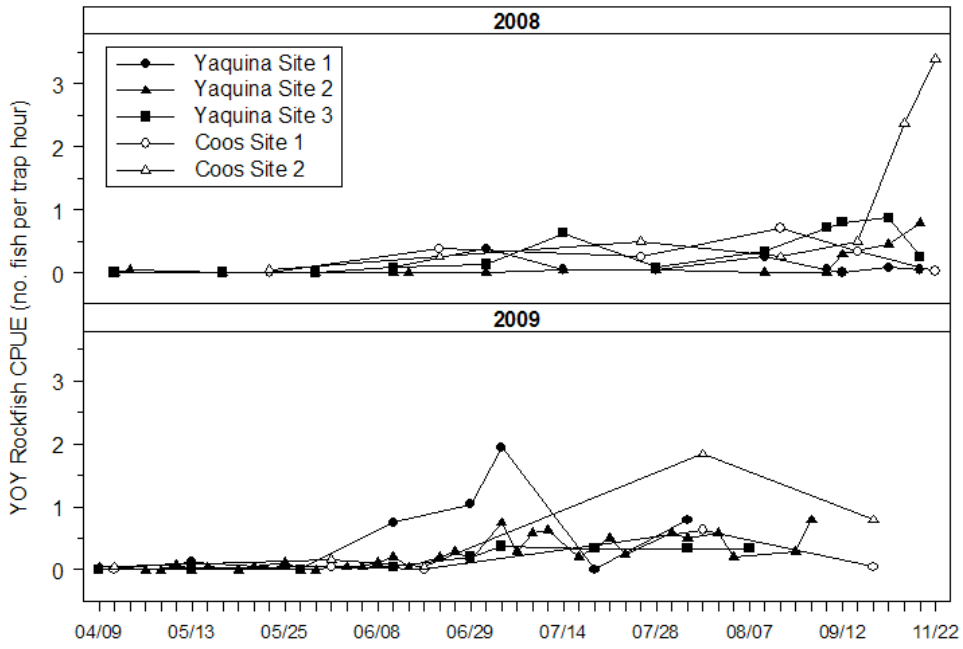

Figure 2.5: Time series of young-of-the-year rockfish catch-per-unit-effort in the deep draft estuaries, Yaquina and Coos bays, by site in 2008 (a) and 2009 (b).

In 2008 in Coos Bay, YOYs were initially captured in late May, at Site 2, and in late-June at Site 1 (Figure 2.5a). Rockfish were captured from May or June into November in 2008, when trapping finished for the winter. Catches peaked in late

August at Site 1, and in late October at Site 2. In 2009, YOYs were captured slightly earlier, in mid-April (Site 2) and in late May (Site 1) and were captured until the last trapping session of the year in early October (Figure 2.5b). Catches peaked at both sites in early August in 2009.

Settlement Patterns: Shallow Draft Estuaries. In 2008, YOY rockfish were initially captured in late June at both sites in the Coquille River estuary. No rockfish had been captured 14 days earlier, during the previous trap session (Figure 2.6a). Catches for the year peaked at this first trap session, but YOYs continued to be captured in smaller, consistent numbers at both sites until trapping discontinued in mid-November. In 2009, YOYs were captured initially in late May at both sites. In 2009 the CPUE again peaked in June at both sites, with captures continuing until September (Figure 2.6b). There were no rockfish captured during the October trapping sessions.

In 2008 in Nehalem Bay, YOY rockfish were first captured at both sites in early July (Figure 2.6a). As with other estuaries in 2008, rockfish were captured until mid-November. The CPUE at Site 2 (upriver) peaked in September; however, due to low overall capture rates there was no defined peak in CPUE at Site 1 (estuary mouth). In 2009, YOYs were only captured at a single trapping session at each site, in late August at Site 1 and early July at Site 2 (Figure 2.6b).

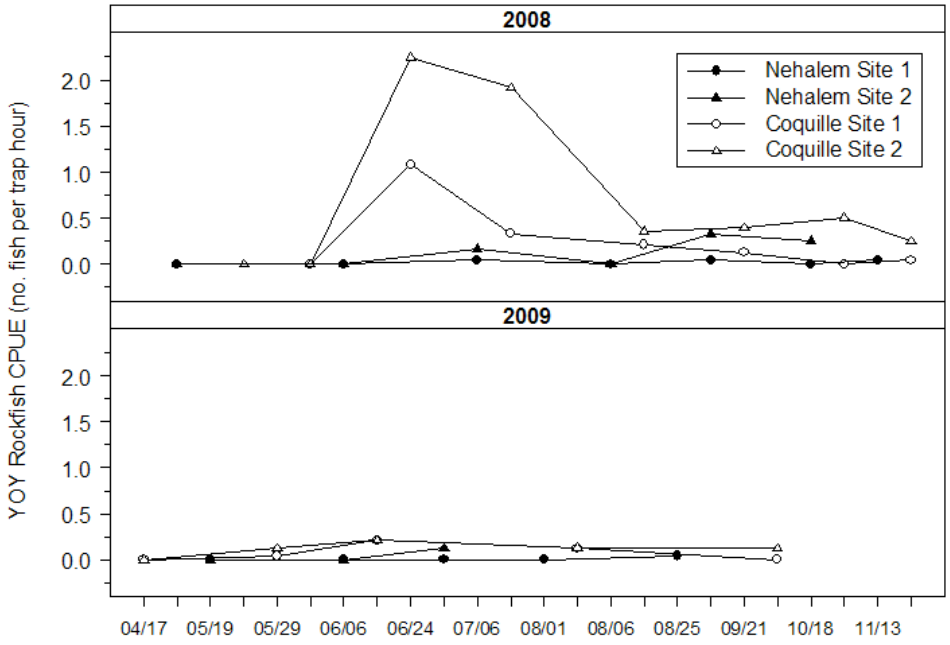

Figure 2.6: Time series of young-of-the-year rockfish catch-per-unit-effort in the shallow draft estuaries, Nehalem Bay and the Coquille River estuary, by site in 2008 (a) and 2009 (b).

Settlement Patterns: Conservation Estuaries. In 2008 in Alsea Bay, rockfish were captured first in early July at Site 2 (upriver) and in late August at Site 1 (estuary mouth) (Figure 2.7a). At both sites, YOYs were only captured over two trapping sessions (approximately two months), and due to low capture levels, there were no defined peaks in CPUE in 2008. In 2009, however, YOY rockfish were first captured in early June at Site 1, and CPUE peaked at this time. Rockfish were captured once more in July, again, over approximately two months. In 2009 no trapping occurred at Site 2, as heavy silting during the 2008/2009 winter season inundated that trapping site.

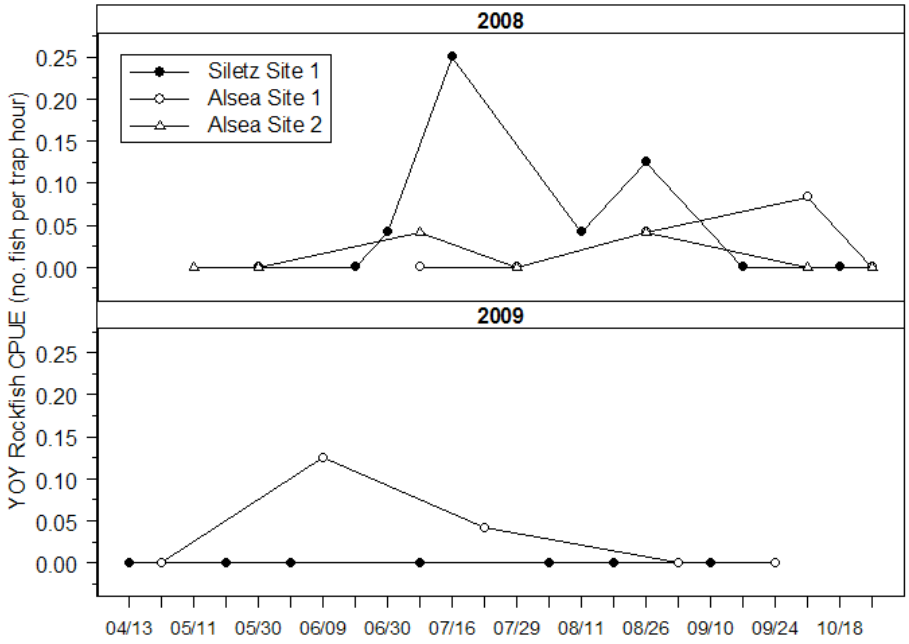

Figure 2.7: Time series of young-of-the-year rockfish catch-per-unit-effort in the conservation estuaries, Alsea and Siletz bays, by site in 2008 (a) and 2009 (b).

In Siletz in 2008, YOYs were captured initially in late June. No rockfish were captured on the previous trap session 10 days earlier (Figure 2.7a). Rockfish continued to be captured until August, and CPUE peaked in mid-July. No rockfish were captured in Siletz in 2009 (Figure 2.7b).

Discussion

This study documents to my knowledge the first captures of YOY rockfish in Nehalem, Siletz, and Alsea Bays, and the Coquille River estuary, in addition to continued documentation of YOY rockfish presence in Coos and Yaquina bays. Young-of-the-year rockfish have been previously captured in Yaquina (Appy and

Collson 2000; Schlosser and Bloeser 2006; Gallagher and Heppell 2010), Coos (Miller and Shanks 2004a; Schlosser and Bloeser 2006), Winchester, and Tillamook Bays (Appy and Collson 2000) on the Oregon coast. Given the small amount of estuarine habitat available on the Oregon coast, the presence of YOY black rockfish within these estuaries suggests that these environments could be vital habitat during a black rockfish's first, and possibly, second year. Young-of-the-year black rockfish show a strong association with shallow depths (Hallacher 1977; Stein and Hassler 1989; Merems 2003), and co-occur in multiple shallow-depth environments on the Oregon coast, including shallow rocky relief shorelines (Miller and Shanks 2004a) and tidepools (Studebaker and Mulligan 2008).

The dominant species found in this study was *S. melanops*, which has also been reported as the dominant YOY rockfish species in tidepools along the Oregon and northern California coasts (Studebaker and Mulligan 2008), and in shallow nearshore rocky relief areas (Merems 2003; Miller and Shanks 2004a). In a comparison between Yaquina Bay and adjacent nearshore habitats, black rockfish were the dominant species within the estuary but were not captured at nearby nearshore reefs, most likely due to the depth of the reef (Gallagher and Heppell 2010).

Sebastes caurinus, the copper rockfish, was found in Yaquina Bay in 2000 (Appy and Collson 2000), and again in 2003-2005 (Schlosser and Bloeser 2006), but was not found in 2004 or 2005 by Gallagher and Heppell (2010), when genetic methods

were used to identify specimens. Neither Appy and Collson (2000) nor Schlosser and Bloeser (2006) used genetic methods to identify the YOY and juveniles collected, and admitted to some uncertainty as to the exact species identification. Copper rockfish have also been captured in light traps in Coos Bay (Miller and Shanks 2004a). Despite multiple trapping locations in several estuaries, copper rockfish were only captured in Yaquina Bay during this study. The lack of copper rockfish caught in Coos Bay could be accounted for by differences in sampling frequency (once every three weeks versus every other day in Miller and Shanks 2004a), because of differences in the trap style (minnow trap versus light trap), or because YOY copper rockfish were not present in Coos Bay in 2008 or 2009. Given the small numbers of copper rockfish found during this study, it seems likely that they are utilizing estuarine habitats more sporadically than black rockfish.

Small numbers of samples from Yaquina Bay were identified to the *Sebastes melanops / flavidus* clade. *Sebastes flavidus,* the yellowtail rockfish, has also been documented in Yaquina Bay (Gallagher and Heppell 2010), where a small number (< 10) were captured in 2004, but none were captured in 2005. This may be another case of sporadic use of estuarine habitat, as with *S. caurinus*.

As mentioned previously, the fish from this study identified to the WEVZ complex (*Sebastes wilsoni* / *emphaeus* / *variegatus* / *zacentrus*) are most likely the Puget Sound rockfish, due to the shallow depth of the estuary sites sampled. If these samples are indeed Puget Sound rockfish, this is to my knowledge the first

documentation of estuarine habitat use by this species outside the Puget Sound (Love et al. 2002). In addition, large schools (> 40 individuals) of unidentifiable juvenile rockfishes were frequently observed near trapping locations; both Puget Sound and pygmy rockfish (*S. wilsoni*) have strong schooling behaviors (Love et al. 2002). Little is known about the harlequin (*S. variegatus*) and sharpchin (*S. zacentrus*) rockfish, and although these species have been observed to aggregate in small schools, they are considered to be rare in shallow environments, such as estuaries, while the Puget Sound rockfish is common in the Oregon nearshore (Love et al. 2002).

The increased catch rates of YOY and juvenile rockfishes within the more developed estuaries lends support to the argument that structure is an important component of the settlement process (Love et al. 1991; Buckley 1997; Love et al. 2002), and indicates that increased development projected for the Oregon coast (Kline et al. 2003) would not necessarily lead to increased mortality, at least during the post-settlement period. In general, structure can reduce post-settlement mortality by providing refuge from predation (Hixon and Beets 1989; Johnson 2007) and can affect other demographic measurements, such as individual size and community assemblages (Crowder and Cooper 1982; Hixon and Beets 1989). The presence of structure perhaps even triggers the initiation of the settlement process in rockfish species (Carr et al. 2003; Plaza et al. 2003). Anthropogenic modification can increase available estuarine structure through the construction of jetties, piers, groins, docks, and the like. Indeed, human development within estuaries could

potentially serve as a mechanism to increase initial recruitment of rockfishes, although population-level effects would be difficult to quantify as there are currently very few established links between abundance of post-settlement rockfishes and overall population trends (Sakuma et al. 2006; Wilson et al. 2008).

It should be noted that an increase in the amount of underwater structure isn't the only result from increased development of estuaries. Other anthropogenic impacts, such as pollution, introduction of invasive species, and loss and degradation of existing natural habitats within estuaries, have caused fundamental alterations to estuarine species compositions and habitat quality (Lotze et al. 2006). In addition, dependence on estuarine environments has been identified as a significant risk factor for extinction and species that utilize these environments at any life stage are considered to be highly vulnerable (Roberts and Hawkins 1999).

The proxies created to describe "development level" could be applied to other studies examining human impacts on estuarine inhabitants. However, it is important to note that the proxies combine several aspects that may be important for explaining the differences between the catch rates in multiple estuaries. They do not address specific factors such as overall size of the estuary, river flow rates, tidal exchanges, or the types of structure available, but rather attempt to combine these multiple factors into one quantifiable variable. As such, the impact of each of these factors *individually* cannot be assessed using these proxies. However, they do

provide a useful starting point for many potential avenues of research on human impacts on estuarine ecosystems.

There are multiple possible explanations for the late-season increases observed in YOY rockfish CPUEs in the upper portions of Coos and Yaquina bays, the more developed estuaries. The increases could indicate a late summer-fall movement of YOY rockfish up the bay or there could be a second influx of previously settled individuals from nearshore environments moving into the bays to these upriver sites. It is also possible that the increase represents a movement of YOY rockfish from even higher up the bay, as they head downstream and into the nearshore environment at the end of their first summer of life. The general size distribution of rockfish did not change at this point in the season, indicating that a second recruitment event is unlikely. The physical parameters measured (temperature, salinity, dissolved oxygen) did not substantially alter over time at these sites, and so factors such as decreased salinity from increased fall river flow should not have affected the spatial distributions of YOY rockfishes. This late season increase in CPUEs is most likely to be indicative of movement up or down the estuary, possibly to a more sheltered location within the estuary prior to the winter storm season or as a stopover point on their way out of the bay. If this is the case, it is possible that this phenomenon is a function of the size of the estuary rather than the level of development, as the Coos and Yaquina bays are two of the largest estuaries on the Oregon coast and no differences were found in the other four estuaries sampled. Although the minnow traps employed were fairly size selective (with an opening of

approximately 3 cm by 30 cm), there were a number of probable age-1 rockfishes captured at the beginning of the season in 2009, suggesting that some portion of the YOY rockfishes do stay in the estuary over their first winter or, at least, move into the estuary from the nearshore environment in the early spring. In either case, it appears that in addition to the YOYs, older juveniles do utilize habitats within certain estuaries.

The lack of correlation between rockfish catches and the measured environmental variables indicate that the conditions observed on this study were likely not driving the relative abundance of YOY rockfish in Oregon estuaries. This was expected, given the number of studies confirming the presence of YOY rockfish within these locations and the fact that this study did not encounter environmental conditions atypical to estuarine environments. Results may have differed if environmental conditions were measured on a continuous basis throughout the trap session, as opposed to only at the deployment and recovery of the traps.

Settlement patterns suggest that YOY rockfish are present for a larger portion of the year in Yaquina and Coos bays, for over six months, when compared to two or three months in other estuaries. Abundances of YOY rockfish in Yaquina Bay were similar to those of Gallagher and Heppell (2010), indicating that YOY rockfish utilize the estuarine habitat in this bay consistently over multiple years (2004-2005 in Gallagher and Heppell 2010; 2008-2009 in this study). Although using different trapping methods, it is also clear that estuarine habitat within Coos Bay is utilized

by YOY rockfishes on a consistent interannual basis as well (2001-2002, Miller and Shanks 2004a; 1999 – 2010, JA Miller, pers. comm.). No information exists on the interannual consistency of YOY rockfish presence within other estuaries on the Oregon coast. Statistical results from 2009 suggest that YOY rockfish may not use the Siletz estuary as consistently as other estuaries, which is not surprising given that Siletz has a very limited amount of structure at low tide and is extremely shallow. As biological assemblages in Oregon estuaries are highly influenced by the nearshore ocean (Hickey and Banas 2003; Miller and Shanks 2004a), this location may have been subject to a spillover effect of YOYs from the nearshore environment during the strong recruitment year reported in 2008 (K Sakuma, pers. comm.; JA Miller, pers. comm.). The trap surveys conducted in this study have established a baseline for both exploring interannual variation in estuarine settlement and for spatial comparisons across a large portion of the Oregon coast.

Overall, this study explored the estuarine settlement patterns of rockfishes on the Oregon coast during a life stage for which little information exists, and provides additional support for the importance of structure during the settlement process. Other studies of North Pacific rockfishes have shown that settlement can be an active process under behavioral control and activated by certain environmental cues (Plaza et al. 2003), and that habitat complexity could be as important a factor as the initial supply of recruits in post-settlement mortality (Johnson 2007). Although it is widely recognized that annual recruitment in rockfishes is extremely variable (Love et al. 1991; Ralston and Howard 1995; Wilson et al. 2008), a recent

study in California showed positive correlations between abundances of newly settled rockfishes and year class strength in adult populations (Laidig et al. 2007). This study has provided evidence supporting the widespread use of estuarine habitat by rockfishes, particularly *S. melanops*, on the Oregon coast during their early life history and suggests that the continued development of these habitats could both positively and negatively affect population dynamics of marine fish species on the West coast.

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CHAPTER 3: DEVELOPMENT OF A YOUNG-OF-THE-YEAR ROCKFISH (*SEBASTES* SPP.) SETTLEMENT INDEX ON ARTIFICIAL STRUCTURES IN AN OREGON ESTUARY

Introduction

Estuaries on the Pacific Northwest (PNW) coast of North America are physically influenced by large-scale ocean forcing, such as the annual upwelling regime (Hickey and Banas 2003; Brown and Ozretich 2009) and their biological characteristics are highly influenced by oceanic processes (Miller and Shanks 2004a; Reum and Essington 2008). Coastal plain estuaries, typical to the Oregon coast, are relatively small and geologically young, and so they are not thought to contribute greatly to annual marine fish recruitment (Emmett et al. 2000; Hickey and Banas 2003). However, the larvae and juveniles of numerous marine fishes have been shown to be present in PNW estuaries (Monaco et al. 1992; Miller and Shanks 2005; Reum and Essington 2008), and recent studies have suggested that specific estuarine habitats could be used as nursery grounds for various flatfishes (Rooper et al. 2006; Brown 2006) and rockfishes (*Sebastes* spp.) (Appy and Collson 2000; Miller and Shanks 2004a; Gallagher and Heppell 2010). While valuable for other reasons, if PNW estuaries contribute to the recruitment in marine fish populations, and if their relative importance to harvested species is established, it may provide additional incentives for expanded conservation efforts (Kennedy 1990; Brown 2006).

Rockfishes are a long lived and slow growing demersal group of species that give birth to live young (Love et al. 2002). After a pelagic larval stage of three to six

months, young-of-the-year (YOY) rockfish move to a benthic environment and become strongly associated with structure (Love et al. 1991; Love et al. 2002), a process called settlement. Benthic settlement of many species of rockfish occurs with seasonal regularity (Moser and Boehlert 1991), prior to progressively moving to deeper habitats as they mature (Love et al. 2002). Many different types of shallow habitats are utilized during the post-settlement stage, and YOY rockfishes are common in nearshore rocky reefs (Merems 2003; Gallagher and Heppell 2010), kelp beds (Love et al. 2002; Laidig et al. 2007), and rocky intertidal pools (Studebaker and Mulligan 2009).

YOY rockfishes also utilize anthropogenically altered environments during their first year, such as the decommissioned oil platforms in California, where mid-waters surrounding the platforms are dominated by YOY rockfish of multiple species (Love et al 2000), on the oil/gas pipelines connecting those platforms to shore (Love and York 2005), and even on the debris fields surrounding the oil platforms (Caselle et al. 2002). It appears that the presence of large artificial structures allow YOY rockfish to aggregate and could enhance production of certain species, including several overfished rockfish species (Love et al. 2000; Emery et al. 2004; Love et al. 2005). Variation in structure complexity has been shown to alter post-settlement stage mortality rates of multiple marine fish species (Beukers and Jones 1997; Andrews and Anderson 2004; Doherty et al. 2004), including YOY rockfish assemblages (Hobson et al. 2001; Johnson 2007), and it has been suggested that understanding how structure affects the settlement process in rockfishes is as

important as understanding variability during the pelagic pre-settlement phase (Johnson 2007).

Spatial distribution patterns of YOY rockfishes during the pelagic pre-settlement stage are highly complex, and are most likely related to variability within the wind-driven coastal upwelling system on the West coast (Larson et al. 1994; Wilson et al. 2008); however, less is known about their distributions during their first year, following settlement. The settling of YOY rockfishes within estuarine environments on the Oregon coast has been documented previously (Appy and Collson 2000; Miller and Shanks 2004a; Gallagher and Heppell 2010), but many questions remain as to the importance of these habitats to their early life history. By evaluating the role of structure to rockfish settlement within estuaries, the value of the habitat with regards to settlement variability could be clarified (Heck Jr. et al. 2003).

The overall goal of this study was to investigate natural and anthropogenic influences in the estuarine settlement dynamics of rockfish, using black rockfish (*Sebastes melanops*) as the focal species. The primary objective was to develop a novel recruitment index using artificial settlement structures within an Oregon estuary, upon which year class strength can be assessed to further evaluate the role that structure and natural variability play in settlement. A secondary objective was to determine if habitat saturation could play a role in estuarine settlement of YOY rockfish. Settlement to artificial structures was evaluated over two years (2008 and

2009), and provides the basis for exploring inter-annual variation in the estuarine settlement dynamics of black rockfish.

Materials and Methods

Study Site. Dive surveys were conducted on six artificial reef structures that were deployed in February 2008 in Yaquina Bay on the central Oregon coast. These six structures were constructed of standard cinderblocks (approximately 20 x 20 x 40 cm each with two square holes) mortared together in a pyramid shape (Figure 3.1), and set inside welded steel frames. Each structure consisted of 45 cinderblocks, weighed approximately 770 kilograms (kg), and had a total volume of 0.65 cubic meters (m^3). The structures were put out in pairs, two in each of three locations throughout the bay, and were placed a significant distance (greater than 100 m) from any existing natural or artificial structures.

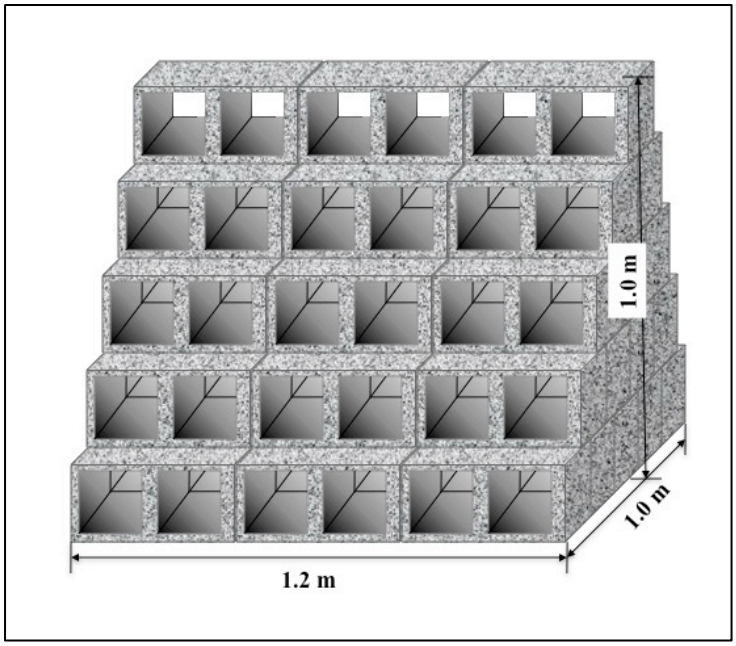

Figure 3.1: Schematic of cinderblock artificial reef structure with approximate dimensions.

Structures one and two were located between two finger jetties immediately inshore from the mouth of the estuary (Figure 3.2), structures three and four were located near the Hatfield Marine Science Center seawater pumphouse docks at approximately channel marker 12, and structures five and six were upriver near Idaho Point, in proximity to channel marker 14. Within each pair, structures were placed approximately 100 m apart. This was close enough to facilitate diving, but far enough apart to assume no between-structure effects within the pair. All the structures were between 4 and 8 m deep at high tides and were deliberately placed outside the main navigation channel of the bay. Dive surveys were conducted from February to November 2008 and from April to October 2009. Surveys were conducted on a bi-weekly basis, subject to the weather conditions and the availability of the dive crew.

Survey and Collection Methods. All dive surveys were conducted from a 21' Boston Whaler center console boat. A single dive survey would consist of a visual survey followed by a sampling event. Two divers would descend on the structure mooring line, and once within sight of the structure (within approximately 1 to 2m), if the visibility was satisfactory, the divers would pause for two minutes in order to allow the fish to acclimate to the presence of the divers (Graham 1992). Divers would separate, one to each side of the structure and each diver would identify and count any fish seen within the interior of the structure and any associated fish up to 1 m distance from the structure. The divers would then rotate sides and repeat,

counting fish on all sides of the structure, to obtain a total-structure count for each diver. These data were reported to a data recorder on the boat as soon as the divers reached the surface. If visibility was less than one meter, the dive survey would be canceled.

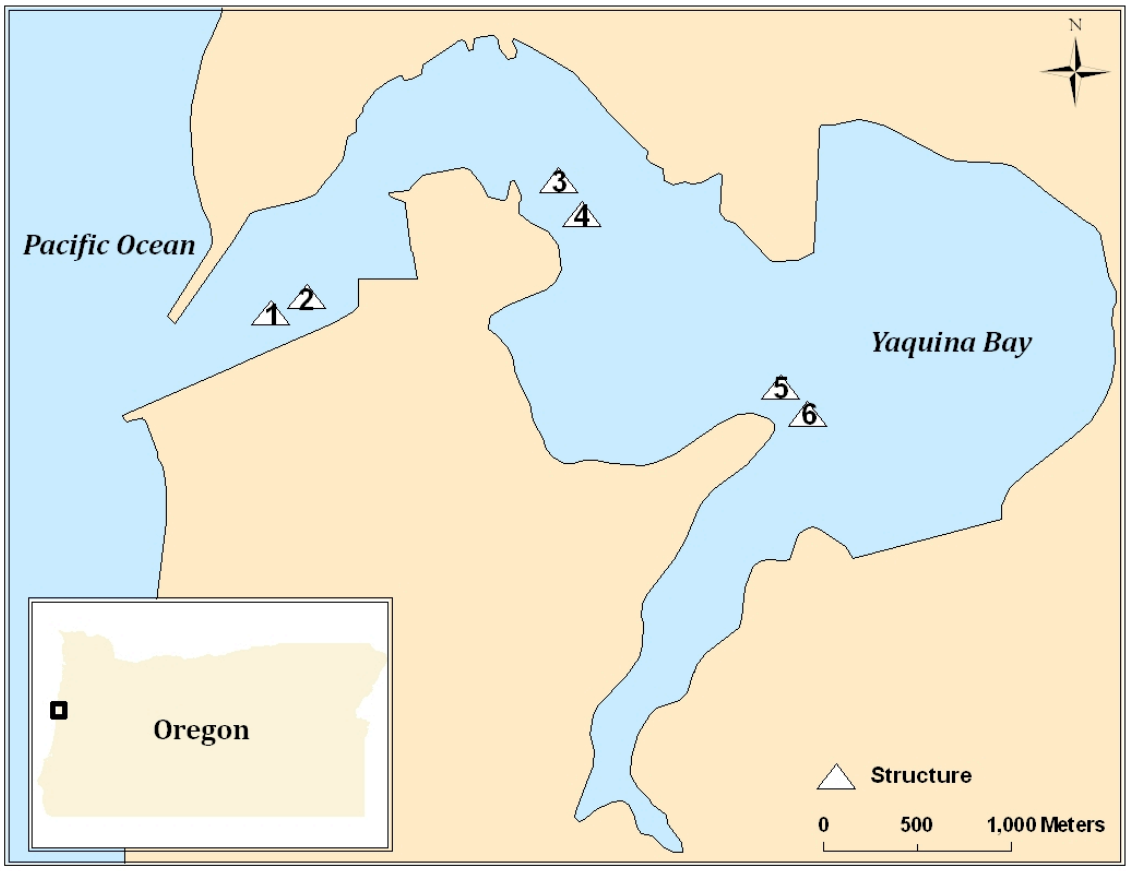

Figure 3.2: Locations of the artificial reef structures deployed in Yaquina Bay on the central Oregon coast to quantify settlement rates of young-of-the-year rockfish.

The fish collection method utilized for this work was developed specifically for these structures. The primary diver held a hand-made double opening net, designed to cover both holes of an individual cinderblock, against one side of the structure. The secondary diver used a "fish flusher", which was a large, round house-cleaning

brush on a long handle, to push the fish through the holes from the opposite side of the structure into the net. The cinderblock structure was "flushed" in an "S" pattern, beginning at the top left corner of the structure and moving across the row to the right, then down to the second row, across to the left and so on until every hole had been "flushed". Once this operation was complete, both divers returned to the surface to process the catch. It should be noted that on occasion the lowest row of the cinderblock structure could not be physically sampled because of intermittent heavy sedimentation.

Collected fish were brought in the net to the surface, transferred to a 20-liter bucket with ambient seawater, sorted by species and counted. In addition to the above data, any YOY or juvenile rockfishes were measured (mm SL), and a clip from their second dorsal was collected for subsequent genetic analysis. All fish were then released in one of two ways, according to the structure from which they were collected. Fish captured from the odd numbered structure in each pair were held on board the boat until operations at that structure were completed, then released a substantial distance (> 300 m) from any other sampling sites. Fish captured from the even numbered structures were released directly above the structure, with the intention that they would directly re-colonize the structure. This removal treatment serves as a mechanism to assess the possibility of these structures becoming fully utilized, or saturated, with individuals. This direct re-colonization was observed by divers and verified periodically through the season.

During the dive operation, an assistant on the boat collected temperature (degrees °C), salinity (ppt), and dissolved oxygen (milligrams per liter, mg/L) data using a YSI-85 multi-meter (YSI, Inc., Yellow Springs, OH). Environmental variables were measured as close to the structure as possible.

Species Identification. All fish collected were identified visually to species, but because of some difficulty in identifying YOY rockfish, the visual determinations were confirmed by genetic analysis, which was performed at the Oregon State University Marine Fisheries Genetics Laboratory in Newport, OR, as follows:

Total genomic DNA was extracted from the dorsal fin tissue using a glass fiber plate extraction protocol (Ivanova et al. 2006). Polymerase chain reaction (PCR) was used to amplify a 782-base pair (bp) fragment of the mitochondrial DNA (mtDNA) cytochrome b (cytb) gene using previously published GluRF and CB3RF primers (Rocha-Olivares et al. 1999). Thermal cycling conditions included an initial denaturation at 94 °C for 2:30 minutes (min), followed by 35 cycles of 94 °C for 45 seconds (sec), 56 °C for 1:30 min, and 72 °C for 1:30 min. Final extension was carried out at 72 °C for 3 min. The PCR products were cleaned using a standard ExoSap procedure (USB Corporation, Cleveland, OH) and were cycle sequenced using BigDye kits (Applied Biosystems, Foster City, CA) and internal primers CBInf2 (5' – TRA GKG TTG CAT TGT CTA CTG AGA A – 3') and CBInr2 (5' – GGR CTT TAC TAC GGY TCR TAC CT – 3') (J Hyde, pers. comm.). Sequencing products were cleaned using a Sephadex filtration protocol (Millipore, Billerica, MA) and visualized

on an ABI 3730XL capillary sequencer. Sequence data were aligned and edited using Sequencer v4.7 (Gene Codes, Ann Arbor, MI) software.

Using an iterative approach, YOY rockfish genetic sequences were compared to a reference dataset of 374 independent haplotypes from 67 species of morphologically identified adult *Sebastes* spp. Comparisons were performed using the program PAUP* v4b10 (Sinauer Associates, Sunderland, MA) with the optimality criterion set to distance (number of bp differences divided by total sequence length in bp). Species included in the reference dataset are listed in Taylor et al. (2004).

Nonparametric bootstrapping (1000 replicates) was used to cluster each unknown haplotype within the reference dataset of 374 known adult haplotypes. If a juvenile clustered within a monophyletic single-species clade with a bootstrap value >70%, this was accepted as positive identification of the individual. If a YOY clustered with a monophyletic clade with a bootstrap <70%, a secondary analysis was performed that included haplotypes of the three nearest (in uncorrected "p" genetic distance) species to the unknown rockfish haplotype to confirm the identification. Some species in the reference dataset (*S. wilsoni* / *emphaeus* / *variegatus* / *zacentrus*, or WEVZ complex) failed to form monophyletic clades. YOY rockfish falling within these multispecies clades were classified as belonging to the WEVZ complex, rather than to a specific species.

Analysis. Data were maintained in Excel™ (Microsoft Corp.) and converted for analysis in R (http://www.r-project.org) and S-Plus™ (TIBCO Software Inc.) software packages. Densities of YOY rockfish were calculated using both the captured number of fish and the visual assessment survey. For the capture method, density was calculated by dividing the number of rockfish captured by the volume of the structure sampled. On occasions where the bottom row was not sampled due to sedimentation on the structure, the volume used for density estimates was adjusted accordingly. Visual densities were calculated by dividing the number of rockfish seen by the volume of the structure plus 1m on each side of the structure. ANOVAs and Tukey's multiple comparison procedures were used to assess differences between both the catch densities and the visual densities among the structures. A multiple regression was used to determine the relationship between YOY rockfish density and environmental parameters. This regression only included dive sessions where environmental variables were collected (96 surveys of 127 in 2008 and 36 of 37 in 2009).

Results

A total of 127 dive surveys were conducted in 2008, during which time a total of 2565 individual fish of 17 different species were observed associated with the structures (Table 3.1). In 2009, a total of 529 fish of 10 different species (Table 3.1) were observed on 37 dive surveys. In 2008, 55.9% (1434) and in 2009, 46.7% (247) of fish observed were YOY or juvenile rockfishes. In 2008, a total of 926 fish were captured, and 191 (20.6%) were YOY rockfish. A total of 283 fish were

Table 3.1: The number of all fish species captured and observed on the artificial structures in 2008 and 2009.

Common Name (*Scientific Name)*	2008		2009		Total
	Captured	Observed	Captured	Observed	
Bay Pipefish (*Sygnathus leptorhynchus*)	0	1	0	0	**1**
Buffalo Sculpin (*Enophrys bison*)	9	31	13	9	**62**
Cabezon (*Scorpaenichthys mamaratus*)	169	53	24	0	**246**
English sole(*Pleuronectes vetulus*)	1	45	0	0	**46**
Kelp Greenling (*Hexagrammos decagrammus*)	173	376	72	89	**710**
Lingcod (*Ophiodon elongatus*)	0	3	0	0	**3**
Monkeyface Prickleback (*Cebidichthys violaceus*)	1	0	2	0	**3**
Northern Clingfish (*Gobiesox maeandrices*)	0	2	0	0	**2**
Red Irish Lord (*Hemilepidotus hemilepidotus*)	0	2	0	2	**4**
Rockfish (*Sebastes* spp.)	191	1434	11	247	**1883**
Saddleback Gunnel (*Pholis ornata*)	165	167	77	95	**504**
Sailfin Sculpin (*Nautichthys oculofasciatus*)	6	3	17	0	**26**
Shiner Perch (*Cymatogaster aggregata*)	1	10	0	18	**29**
Staghorn Sculpin (*Leptocottus armatus*)	78	43	25	5	**151**
Three-spined Stickleback (*Gasterosteus aculeatus*)	0	8	0	0	**8**
Unidentified Flatfishes	0	77	0	0	**77**
Unidentified Sculpins	132	310	42	64	**548**
Total	**926**	**2565**	**283**	**529**	**4303**

captured in 2009, including 11 YOY rockfish (3.8%). In 2008, YOY rockfish were observed and captured on all six of the structures (Table 3.2). In 2009, YOY rockfish were only captured on even-numbered structures, but were observed on five of six structures at least once. The number of dive surveys was substantially lower in 2009 due to unusual weather conditions and the occasional loss of the structure mooring buoys on the structures that were used to locate the structures and facilitate diving. Only one survey in the two years sampled was canceled due to low visibility (< 1 m); this occurred in June 2009.

Table 3.2: The number of young-of-the-year rockfish captured and observed, and the number of dive surveys conducted for each structure in 2008 and 2009.

	2008			2009		
Structure No.	**No. Rockfish Caught**	**No. Rockfish Observed**	**No. Dive Surveys**	**No. Rockfish Caught**	**No. Rockfish Observed**	**No. Dive Surveys**
1	18	114	23	0	42	7
2	80	535	22	2	51	7
3	6	188	21	0	24	7
4	55	127	21	5	122	7
5	26	232	20	0	0	3
6	6	238	20	4	8	6
TOTAL	**191**	**1434**	**127**	**11**	**247**	**37**

Genetic Identifications. In 2008, 65 samples were processed for genetic identification. A total of 92.5% (62) of the samples from the dive surveys were identified as *S. melanops* (Figure 3.3a). In 2009, there were only two samples that were randomly chosen from the dive surveys and both samples were identified as *S. melanops*. Overall in Yaquina Bay, including samples from the trap surveys (Chapter 2), 96.1% (149 of 155) of all YOY rockfish in 2008 and 84.2% (32 of 38) of all YOY

rockfish in 2009 were *S. melanops* (Figure 3.3b). One fish (representing 1.5% of the total), collected from Structure 2 in July 2008, was from the WEVZ complex. None of

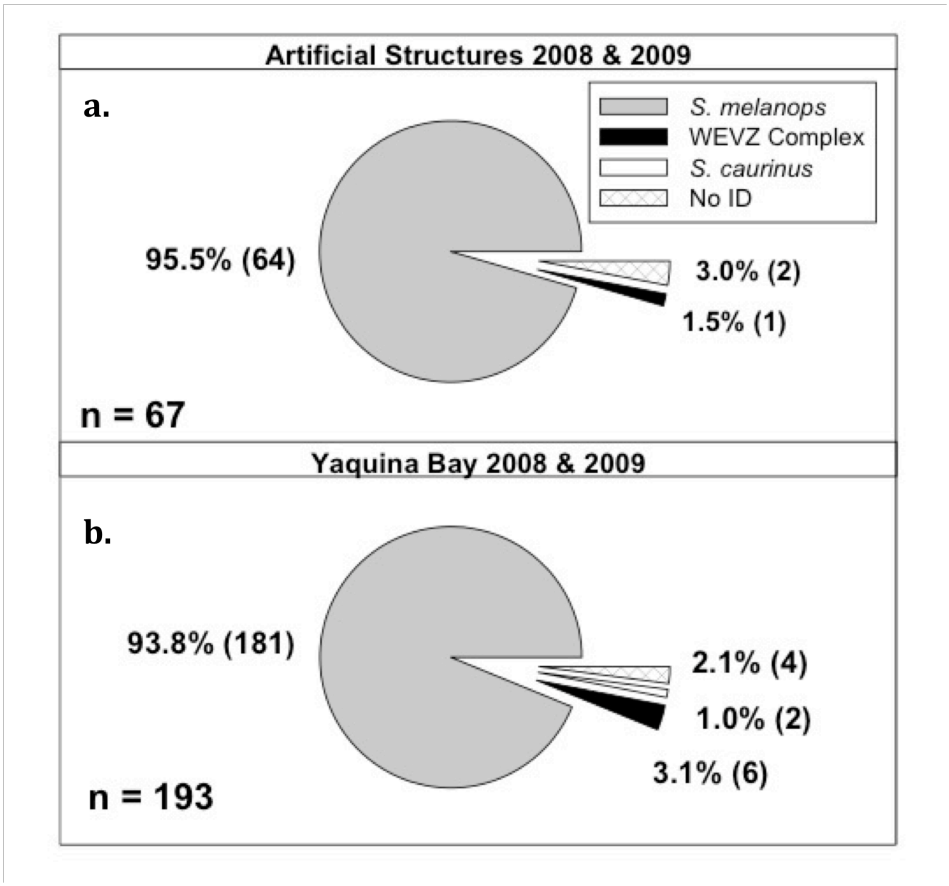

Figure 3.3: Proportions of genetically identified young-of-the-year rockfish from dorsal fin clip samples, years combined, on the artificial reef structures (a) and in Yaquina Bay (b) from both the dive surveys (Chapter 3, *this thesis*) and the trap surveys (Chapter 2, *this thesis*).

these four species in this complex have been previously reported in Oregon estuaries (Love et al. 2003), however, ecological characteristics suggest that the most likely candidate from these four is *S. emphaeus*, the Puget Sound rockfish, as the other three species are deepwater rockfishes that rarely occur in shallow water. There were also two fish (2.0%) identified as copper rockfish, *S. caurinus*, from Yaquina Bay, however, there were no copper rockfish collected from the structures.

Two samples from the structures (3.1%) in 2008 failed to sequence properly, but none failed in 2009.

Size at Capture. Approximate size at settlement for black rockfish is 45 mm (Matarese et al. 1989), and the results of this study are consistent with this estimate. Average size for the YOYs caught on the structures in 2008 was 60.4 mm (range: 46

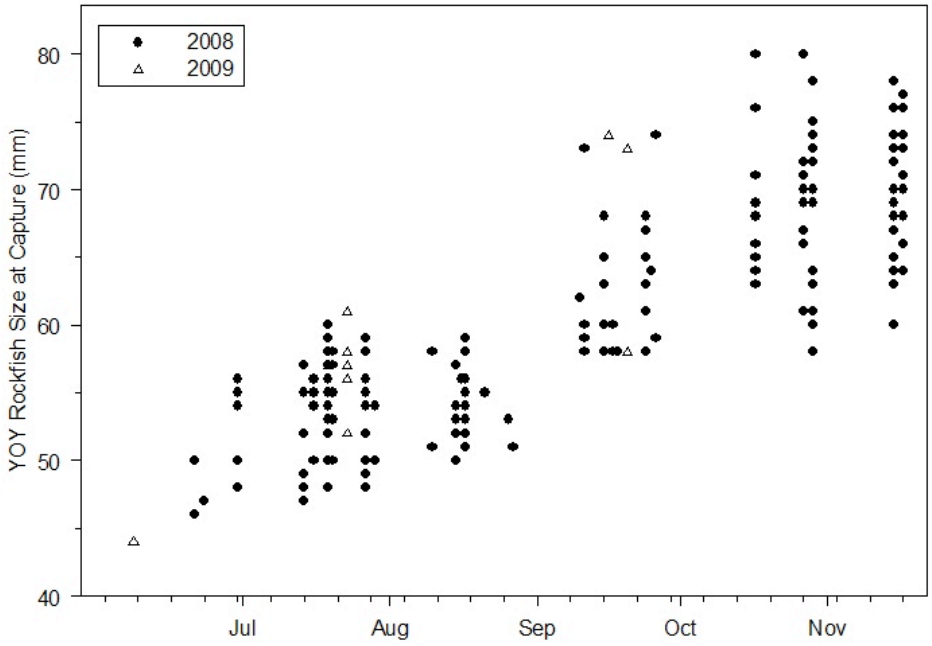

Figure 3.4: Size distributions of YOY rockfish on artificial structures in 2008 (closed circles) and 2009 (open triangles).

to 80 mm, n = 191) and the average size of YOYs caught in 2009 was 59.0 mm (44 to 74mm, n = 10) (Figure 3.4). One 224 mm juvenile rockfish was captured in 2009. Even including this large individual, there was no difference in size between years (Welch's t-test; p = 0.39). There was no difference in the average size of the YOY rockfish captured in these dive surveys or in trap surveys conducted elsewhere in

the bay (Chapter 2) (2-sample t-test; p = 0.70) in 2008 or in 2009 (Welch's t-test; p = 0.22).

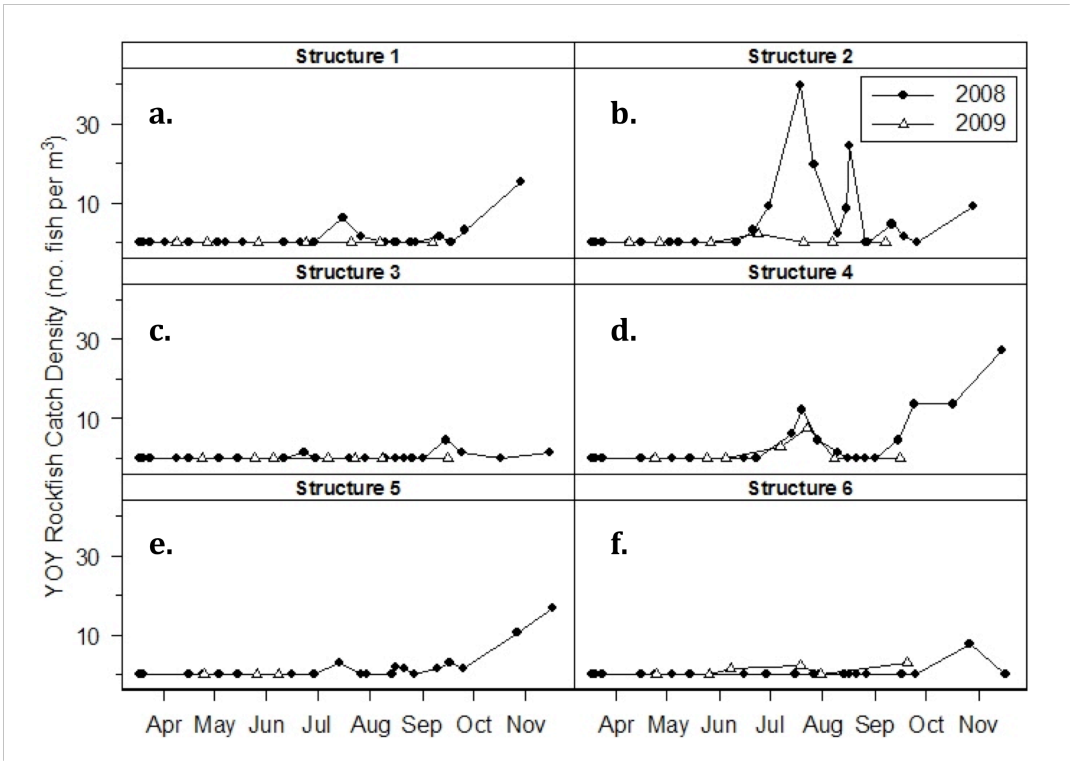

Figure 3.5: Time series of young-of-the-year rockfish catch densities at each structure (panels a – f are structures 1 - 6 respectively) in 2008 and 2009.

Temporal Patterns. In 2008, YOY rockfish were first observed in mid-June at structures one (Figure 3.5a) and two (Figure 3.5b), and were seen on the majority of the surveys through the final dive of the season in late October (Table 3.3). Rockfish were captured first in mid-June (structure one) or mid-July (structure two) and were captured on most of the subsequent surveys including the final survey. In 2009, no YOY rockfish were captured on structure one and YOYs were only captured on one survey in late June on structure two. However, on structure one, YOYs were seen on multiple surveys from mid-July to early September (the final survey of

2009), and on structure two, YOYs were consistently observed from early April to early September. In 2008, YOY rockfish were first seen on structures three (Figure 3.5c) and four (Figure 3.5d) in mid-May and mid-June, respectively, and were observed on the majority of subsequent surveys, including the last dive of the year in mid-November. Rockfish were captured on approximately half of the surveys on both structures beginning in mid-June and through the final dive in mid-November. In 2009, no rockfish were captured on structure three and were only observed on the last two surveys of that year. On structure four, YOYs were first observed in early July and were seen on all subsequent surveys that year, but were only captured on two surveys, in early and late-July.

In 2008, YOY rockfish were first observed in mid-June on structure five (Figure 3.5e) and in mid-July on structure six (Figure 3.5f), and were seen on the majority of surveys through the final dive in mid-November. Rockfish were captured on roughly half of the subsequent surveys on structure five; however, on structure six, YOYs were only captured on the final dive, in mid-November. In 2009, no rockfish were seen or captured on structure five and were only seen twice on structure six. In spite of not being seen, YOY rockfish were captured from early June through mid-September on the majority of 2009 surveys on structure six.

Spatial Differences within the Estuary. There was no difference among the structures in either 2008 or 2009 with regard to the YOY rockfish catch density (One-way ANOVA; $p = 0.68$ and $p = 0.26$, respectively). There were also no

Table 3.3: Period of observation and captures for young-of-the-year rockfish, and the number of surveys where young-of-the-year rockfish were observed and captured (with total number of dive surveys) in 2008 and 2009.

	2008				2009			
Structure No.	**Observation Period**	**No. Surveys Rockfish Observed (of total)**	**Capture Period**	**No. Surveys Rockfish Captured (of total)**	**Observation Period**	**No. Surveys Rockfish Observed (of total)**	**Capture Period**	**No. Surveys Rockfish Captured (of total)**
1	21 June – 29 Oct	10 (23)	16 July – 29 Oct	5 (23)	21 July – 7 Sept	3 (7)	0	0 (7)
2	21 June – 29 Oct	13 (22)	21 June – 29 Oct	10 (22)	9 Apr – 7 Sept	5 (7)	24 June	1 (7)
3	15 May – 15 Nov	10 (21)	23 June – 15 Nov	4 (21)	8 Aug – 16 Sept	2 (7)	0	0 (7)
4	16 June – 15 Nov	10 (21)	14 July – 15 Nov	8 (21)	7 July – 16 Sept	7 (7)	7 – 23 July	2 (7)
5	16 June – 17 Nov	10 (20)	14 July – 17 Nov	8 (20)	0	0 (3)	0	0 (3)
6	16 July – 17 Nov	9 (20)	27 Oct	1 (20)	19 July – 20 Sept	2 (6)	8 June – 20 Sept	4 (6)

difference in density among the odd (n = 3) or even numbered (n = 3) structures (Tukey's multiple comparison analysis) indicating that there were no detectable spatial differences in YOY rockfish catch densities throughout Yaquina Bay, even with the removal of all captured rockfish during each dive at the odd-numbered structures.

Similar results were found with the visual rockfish density measurements. There was no difference in density among the structures in 2008 or 2009 (One-way ANOVA; $p = 0.60$ and $p = 0.05$, respectively), nor was there any difference between the pairs of structures throughout the bay (Tukey's multiple comparison test). As there were no differences within each pair of structures in either 2008 or 2009, this indicates that the removal treatment did not affect the densities of YOY rockfish captured or observed on the structures.

Environmental Variables. Rockfish catch densities on the structures were not linearly correlated with temperature, salinity, or dissolved oxygen (Multiple regression; $p = 0.57$) and all three variables combined explained less than 1.5% of the variability in the densities ($R^2 = 0.015$).

Discussion

As shown by two years of dive surveys, the cinderblock structures deployed to study rockfish settlement were successful at recruiting newly settled fishes, including a large number of YOY rockfishes. Although studies have shown that rockfish year-

class strength is established during the pelagic stages prior to settlement (Ralston and Howard 1995; Sakuma et al. 2006), local population sizes, such as those of black rockfish with potentially limited (<150km) dispersal distances (Miller and Shanks 2004b), have been shown to be strongly influenced by factors affecting post-settlement mortality (Hobson et al. 2001; Hixon and Jones 2005; Johnson 2007) and abundances of newly settled YOY rockfish have recently been correlated with year class strength of adults in California (Laidig et al. 2007).

The rockfish species compositions and size ranges found on these structures were similar to the compositions found in other studies within estuarine environments (Miller and Shanks 2004a; Gallagher and Heppell 2010; Chapter 2, *this thesis*), indicating that the structures did attract individuals from the general population of nearshore, shallow-water YOY rockfishes, and not a specific subset. Variation in habitat complexity has been shown to explain the differences in rockfish species compositions on artificial habitats (Love and York 2006). However, with the high percentages of *S. melanops* on these structures and in estuarine environments in general (Miller and Shanks 2004a; Gallagher and Heppell 2010; Chapter 2), it is more likely that the rockfish species compositions are determined at a larger scale, as opposed to complexity at the level of the structures themselves or even within the overall estuary. The black rockfish has also been reported as the dominant YOY rockfish species in rocky intertidal tidepools along the Oregon and northern California coasts (Studebaker and Mulligan 2008), and in shallow nearshore rocky relief areas (Merems 2003; Miller and Shanks 2004a). In a study that compared

rockfish settlement by habitat type, black rockfish were the dominant species within Yaquina Bay, but no black rockfish were captured at nearshore rocky reefs adjacent to the estuary mouth, most likely due to the depth of the reef (Gallagher and Heppell 2010).

Many studies in both tropical and temperate systems have utilized artificial structures to evaluate demographic rates within marine fish populations (e.g. Buckley 1997; Carr and Hixon 1997; Love et al. 2000; Caselle et al. 2002) and the presence of structure, natural or artificial, has been shown to directly influence post-settlement dynamics in rockfishes (Buckley 1997; Hobson et al. 2001; Johnson 2007). For example, decommissioned oil platforms and their associated pipeline structures off the southern California coast have been shown to not only aggregate rockfish of multiple life stages (Love et al. 2000; Love and York 2005), but also to enhance production of rockfishes through increased growth (Love et al. 2007) and by providing nursery habitat during the more vulnerable early life stages (Love et al. 2000; Carr et al. 2003; Emery et al. 2004). The presence of these platforms does not appear to reduce YOY rockfish recruits to nearby natural reefs (Emery et al. 2004), and this is likely the case as well with the small artificial structures used in the current study. The structures used in this study might serve as a refuge from predation, as the size of the holes of a cinderblock are not very large (approximately 10 cm^2) and may not admit the large predators that normally prey on YOY rockfishes in these environments (Hobson et al. 2001). The structures are also located some distance from any other structured habitat, suggesting that a predator

would have to accidentally locate the individual structures, rather than following the contours of a larger block of habitat, in order to encounter potential prey items on the structure. Given the fact that the relationship between large predatory fish and small prey fish is influenced by shelter availability of specific sizes (Hixon and Beets 1989), and given that large juvenile or adult fish of any species were not commonly seen or captured during the surveys, it might be reasonable to assume that predation rates on these structures are low, although predation and mortality rates should be assessed on these structures to provide support to this hypothesis.

There were no spatial differences found in YOY rockfish catch or visual densities on the structures within the estuary, although nearly significant values were found on the visual surveys in 2009, when YOY rockfish densities were lower, relative to 2008. Gallagher and Heppell (2010) found no significant differences in YOY rockfish catch-per-unit-efforts (CPUEs) among multiple trapping sites in different habitats within Yaquina Bay. However, the lack of spatial differences throughout the bay is in contrast with the large observed interannual differences in YOY rockfish catch and visual densities on the structures. Large variation in both the pelagic stages (Larson et al. 1994; Sakuma et al. 2006; Wilson et al. 2008) and the post-settlement stage (Hobson et al. 2001; Laidig et al. 2007) of rockfishes has been documented at multiple spatial scales. Large portions of this interannual variability are shared among specific complexes of rockfish coast-wide, with a smaller percentage attributable to finer geographic scales (Field and Ralston 2005).

There were also no discernable habitat saturation effects, based on the lack of difference in visual and catch density between structures for which fish were removed and structures on which captured fish were returned. It is possible that there weren't enough YOY rockfish to saturate the habitats, and/or that the structures were complex enough to become saturated. However, given the high densities observed on the dive surveys (> 50 YOY rockfish observed in less than $5m^3$ total volume), it is more likely that the treatment itself was unsuccessful. Densities of YOY rockfishes in excess of 115 fish/$100m^2$ have been recorded on other artificial structures, such as the decommissioned oil platforms in California, where YOY and juvenile rockfishes are extremely abundant in the mid-waters around these platforms (Love et al. 2000), although it should be noted that these schools were of mixed species compositions. It is possible that the highly developed nature of Yaquina Bay (DLCD 1987), including large jetties and port construction, provided enough habitat, both natural and artificial, for YOY rockfish to settle in many locations throughout the estuary, and that spatial differences might have been detected if the structures had been placed within another estuary, where structure was a limiting factor.

In terms of intra-annual temporal patterns of YOY densities on the structures, density at all six structures (with the exception of structure five in 2009) displayed a peak in density during the first half of the season (April to June) (Figure 3.5), or an initial settlement pulse, followed by another less pronounced peak during the second half of the season (September to October/November). This second increase

in YOY density, as well as the presence of age-1 juveniles on the structures early in the 2009 season, is suggestive of an over-wintering behavior not previously documented in estuarine environments. This late season increase has also been shown at particular sites in Yaquina Bay with trapping surveys carried out congruently with these dive surveys (Chapter 2, *this thesis*). Increased counts of YOY rockfishes on nearshore scuba surveys on the northern California coast during September and October, when compared to June or July, have been attributed to a substantial decrease in predation (Hobson et al. 2001). Results from the current study could be confounded by the fact that there is typically an increase in water clarity in the fall, potentially resulting in an increased sighting frequency of individuals that were previously present.

As with any field study, multiple sources of bias were inherent within the study design. For safety reasons, the dive surveys were restricted to daytime high slack tides, which therefore present a very narrow range of environmental conditions that would be encountered. It is not surprising that none of the environmental variables measured are correlated with rockfish densities on the structures, and it appears that more extreme ranges of conditions would have to be encountered before affecting YOY rockfish spatial distributions and densities. Additionally, while the lead author was the primary diver on this study, the multiple volunteer dive buddies had variable experience levels both in terms of the dive conditions and fish identification. It was also difficult to accurately count the large schools of YOY rockfish encountered on the structures, although having two independent estimates

helps to decrease the uncertainty in the counts. Perhaps the bias with the largest possible impact was visibility, which was often less than 3 to 4 m. As mentioned previously, this was monitored on every survey and surveys were to be canceled if visibility was less than one meter, or approximately the length of the structure. However, this would only affect the visual counts.

This study did not attempt to assess growth or the increased input of recruits to the black rockfish fishery. Growth rates could easily be assessed for fish on these structures using otolith growth ring back calculations or tagging methodologies, and results could be compared to both natural and anthropogenically modified habitats in the area. There is evidence of increased rockfish growth on artificial structures (Love et al. 2007) and the presence of structure has been shown to increase survival during the post-settlement phase of certain species of rockfish, such as the cowcod (*S. levis*) (Emery et al 2004). While the structures utilized in this study provide a relatively easy method to study post-settlement rockfish dynamics, the establishment of a connection between these structures and the adult rockfish population could provide a method to evaluate the long-term importance of estuaries to overall population size (Carr and Hixon 1997). Otolith microchemistry (Gillanders 2005), for example, could be used to determine whether estuarine-origin rockfish recruit to the nearshore, fished population of black rockfish, although this might not be possible due to the similarities in the water masses in the lower estuary and the nearshore environment.

Overall, the estuary-based results from this study seem to reflect the larger differences in rockfish recruitment seen within the same two-year period. There was a strong recruitment season in 2008; however, this was not the case in 2009 (K Sakuma, pers. comm.; JA Miller, pers. comm.). The advantages of using these structures to establish a long-term settlement index include consistent quantification of settlement on the structures and the fact that their estuarine location means that they are more easily accessible than the nearshore Oregon coast during the majority of the year. In order to attempt to correlate this index with other large-scale rockfish recruitment surveys elsewhere on the west coast, these surveys must continue for multiple years in a consistent manner. A recent study has shown that abundances of juveniles can be related to year class strength in another nearshore rockfish species (Laidig et al. 2007). Together with the differences reflected during the two year period of this study, there is evidence that this index could be a useful alternative to expensive, large-scale pelagic surveys, and that YOY black rockfish utilize estuarine environments on a consistent, if variable, interannual basis.

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CHAPTER 4: GENERAL CONCLUSIONS

There is strong evidence that rockfish are utilizing estuarine habitat during their first year of life on a consistent interannual basis (Appy and Collson 2000; Miller and Shanks 2004a; Gallagher and Heppell 2010; Chapters 2 and 3, *this thesis*). This phenomenon is apparent in a large number of the estuaries on the Oregon coast, and while this study definitely shows the use of estuaries by YOY rockfish, the relative importance of these habitats and whether they are functioning as nursery habitats cannot be accurately assessed without more information, such as growth, survival, and movement (Beck et al. 2001). Nonetheless, the presence of YOY black rockfish within these habitats will need to be considered when addressing conservation needs and making management decisions for Oregon estuaries in addition to other species also inhabiting these bays.

While some studies have shown that the overall strength of recruitment in some nearshore rockfishes is established prior to the settlement phase (Larson et al. 1994; Sakuma et al. 2006; Wilson et al. 2008), the presence and quality of structure that YOY rockfish experience post-settlement could have a large effect on the local population sizes of adult rockfish (Hixon and Jones 2005; Johnson 2007). These local populations provide the basis for the extremely important recreational and commercial groundfish fishery in the Pacific Northwest. Most recreational fishing is primarily in proximity to the various ports, the majority of which are located within estuaries on the highly exposed Oregon coast. While black rockfish are not

currently listed as overfished (NMFS 2010), with the increased development projected for the coast (Huppert et al. 2003) and the recent salmon closures on the West coast (PFMC 2010), fishing pressure on these nearshore rockfish populations may increase as a result of potentially shifted or increased effort. Rockfish species do not support a large amount of fishing pressure, due to a natural low productivity level (Parker et al. 2000; Hilborn et al. 2002), and factors that could potentially affect survival at the post-settlement stages should be investigated further in order to clarify their role in local population sizes.

Young-of-the-year black rockfish appear to not differentiate between natural and anthropogenically modified habitat (Love et al. 2005; Love et al. 2007), rather it appears to be overall habitat complexity, by affecting density-dependent factors such as predation and intraspecific competition, that determines the proportion of the population that survives their first year (Hobson et al. 2001; Hixon and Jones 2005; Johnson 2007). Among other things, this concept has implications for the projected wave energy developments underway on the Oregon coast. Wave energy parks are currently in the testing phase on the Oregon coast (OWET 2010) and could also provide an opportunity to learn more about YOY rockfish post-settlement dynamics because they will offer an considerable amount of underwater hard structure, similar to the decommissioned oil rigs in southern California that serve as a settling ground for YOY rockfish (i.e. Love et al. 2000; Caselle et al. 2002; Love and York 2005).

The framework has been established to continue the dive surveys on the artificial structures in Yaquina Bay, which will, with time, provide a long-term picture of rockfish settlement dynamics, and additional manipulative studies could be conducted to assess both growth and survival on these structures. Although a recent study showed no differences in growth in YOY black rockfish in Yaquina Bay between multiple anthropogenic and natural habitats within Yaquina Bay (Gallagher and Heppell 2010), YOY blue rockfish (*S. mystinus*) growth rates on artificial structures is similar to and perhaps even faster than when they are in natural reefs in southern California (Love et al. 2007), suggesting that YOYs from the artificial structures could perform better. By tagging individual YOY rockfish (e.g. Johnson and Hixon 2010), movement patterns could potentially be documented as well.

Comparisons to natural habitat are essential when assessing the effectiveness of artificial reefs (Hixon and Beets 1989) and should be conducted in representative samples of all the habitats that YOY black rockfish occupy (Beck et al. 2001) in order to gain insights into the potential for estuaries acting as nursery grounds for this species. Although not directly assessed within this study, artificial structures and the continued development of Oregon's estuaries could increase rockfish recruitment on the Oregon coast, by providing additional structure for increased settlement (e.g. Emery et al. 2004). Interstitial spaces, such as those in the artificial structures utilized in this study, have been shown to provide refuge from predation (Hixon and Beets 1989), and a reduction in predation during the initial post-

settlement phase has been shown to increase local juvenile population sizes in rockfishes (Hobson et al. 2001).

While there is a positive relationship between the level of estuary development and YOY rockfish population size (as measured by CPUE), it is important to distinguish between what may be beneficial for YOY black rockfish settlement and what may be beneficial for the nearshore ecosystem as a whole. Not all the factors involved with determining YOY rockfish spatial distributions at this stage have been identified, and if habitat utilized by YOY rockfish becomes unsuitable due to other alterations of estuary habitat, such as pollution or increased dredging, local populations of adult rockfish could suffer as a result. Young-of-the-year rockfish estuarine settlement could possibly be an ecological "dead-end" with little or no contribution to the adult rockfish population, so that while increased development in estuaries on the Oregon coast may lead to increased settlement of YOY black rockfish, this increase may not have any impact on the overall population and therefore, development cannot be directly inferred to be beneficial to rockfish populations. It is important to note that the size of the estuary is a major confounding factor in this study, and that YOY black rockfish utilize multiple types of habitats on the Oregon coast and not only estuaries. It is possible that rockfish utilizing estuary habitat is a more recent phenomenon, as a study in the 1970's in Yaquina Bay did not find any evidence of YOY rockfish utilizing estuarine habitat (Pearcy and Myers 1974). Balancing the increasing development and human population size on the Oregon coast with the

ecological needs for the multitude of species utilizing estuarine habitats, now including rockfish, will continue to be a challenge in the future.

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Appendix A

Appendix Table 1: Trap Survey Data 2008

Trap ID No.	Date	Estuary	Site	Total Trap Time	Average Temperature (°C)	Average Salnity (ppt)	Average Dissolved Oxygen (mg/L)	No. Rockfish Captured	Total Rockfish CPUE
2008-01	04/17/08	YAQUINA	1	24.00	n/a	n/a	n/a	0	0.000
2008-02	04/17/08	YAQUINA	2	23.99	n/a	n/a	n/a	0	0.000
2008-03	04/17/08	YAQUINA	3	24.01	n/a	n/a	n/a	0	0.000
2008-04	05/01/08	YAQUINA	2	24.00	12.3	25.8	7.7	1	0.042
2008-05	05/09/08	NEHALEM	1	24.00	10.4	27.6	8.9	0	0.000
2008-06	05/09/08	NEHALEM	2	24.00	11.9	4.4	9.9	0	0.000
2008-07	05/11/08	ALSEA	2	24.00	13.2	14.6	8.8	0	0.000
2008-08	05/15/08	YAQUINA	1	24.01	13.8	29.8	9.3	0	0.000
2008-09	05/15/08	YAQUINA	2	24.00	13.5	30.4	7.6	0	0.000
2008-10	05/15/08	YAQUINA	3	24.00	10.1	25.8	9.5	0	0.000
2008-11	05/24/08	COOS	1	23.99	10.5	32.2	9.5	0	0.000
2008-12	05/24/08	COOS	2	23.99	11.2	31.1	7.5	1	0.042
2008-13	05/24/08	COQUILLE	2	23.99	14.4	17.8	10.2	0	0.000
2008-14	05/28/08	YAQUINA	1	24.00	11.4	31.0	7.0	0	0.000
2008-15	05/28/08	YAQUINA	2	23.99	10.2	32.3	5.8	0	0.000
2008-16	05/28/08	YAQUINA	3	24.00	13.7	26.2	8.2	0	0.000
2008-17	05/30/08	ALSEA	2	24.00	12.7	22.3	8.3	0	0.000
2008-18	05/30/08	SILETZ	1	24.00	14.0	24.2	1.2	0	0.000
2008-19	06/02/08	COQUILLE	1	23.99	9.3	32.9	7.9	0	0.000
2008-20	06/02/08	COQUILLE	2	23.99	9.4	32.2	7.4	0	0.000
2008-21	06/06/08	NEHALEM	1	24.00	11.9	7.7	8.9	0	0.000
2008-22	06/06/08	NEHALEM	2	23.99	11.7	6.0	9.0	0	0.000
2008-23	06/09/08	YAQUINA	1	23.99	11.1	31.7	8.1	2	0.083
2008-24	06/09/08	YAQUINA	2	24.00	11.8	29.7	7.4	0	0.000
2008-25	06/09/08	YAQUINA	3	24.00	13.0	25.5	7.9	2	0.083
2008-26	06/10/08	YAQUINA	2	23.99	12.2	27.7	6.4	0	0.000
2008-27	06/17/08	SILETZ	1	24.00	14.8	19.7	9.3	0	0.000
2008-28	06/24/08	COOS	1	24.06	12.7	31.4	9.8	9	0.374
2008-29	06/24/08	COOS	2	24.07	14.3	29.3	7.8	6	0.249
2008-30	06/24/08	COQUILLE	1	24.03	13.5	22.7	12.1	26	1.082
2008-31	06/24/08	COQUILLE	2	24.00	13.2	23.2	11.0	54	2.250
2008-32	06/30/08	SILETZ	1	23.99	15.4	29.6	10.9	1	0.042
2008-33	06/30/08	YAQUINA	1	24.00	12.4	32.7	6.8	9	0.375
2008-34	06/30/08	YAQUINA	2	23.99	12.2	33.0	9.5	0	0.000
2008-35	06/30/08	YAQUINA	3	24.01	12.2	32.8	9.0	3	0.125
2008-36	07/06/08	NEHALEM	1	24.00	16.7	18.5	6.4	1	0.042
2008-37	07/06/08	NEHALEM	2	23.99	16.9	18.0	7.1	4	0.167
2008-38	07/09/08	ALSEA	1	24.00	14.9	26.7	7.1	0	0.000
2008-39	07/09/08	ALSEA	2	23.99	14.5	26.7	6.7	1	0.042
2008-40	07/14/08	YAQUINA	1	23.99	9.7	33.4	6.1	1	0.042
2008-42	07/14/08	YAQUINA	3	24.00	9.1	33.3	5.9	15	0.625
2008-43	07/16/08	SILETZ	1	24.01	13.5	14.2	8.8	6	0.250
2008-44	07/24/08	COOS	1	24.01	11.0	33.2	8.6	6	0.250

Trap ID No. Cont.	Date	Estuary	Site	Total Trap Time	Average Temperature (°C)	Average Salnity (ppt)	Average Dissolved Oxygen (mg/L)	No. Rockfish Captured	Total Rockfish CPUE
2008-46	07/24/08	COQUILLE	1	24.03	13.1	28.2	8.5	8	0.333
2008-47	07/24/08	COQUILLE	2	24.02	11.9	29.8	9.3	46	1.915
2008-48	07/28/08	YAQUINA	1	23.99	11.3	33.3	9.0	1	0.042
2008-49	07/28/08	YAQUINA	2	24.00	10.5	33.5	8.6	1	0.042
2008-50	07/28/08	YAQUINA	3	23.99	12.2	33.3	11.4	2	0.083
2008-51	07/29/08	ALSEA	1	23.99	11.5	33.0	9.3	0	0.000
2008-52	07/29/08	ALSEA	2	24.00	15.4	22.5	7.7	0	0.000
2008-53	08/06/08	NEHALEM	1	24.00	13.1	28.8	7.0	0	0.000
2008-54	08/06/08	NEHALEM	2	24.00	12.2	30.5	6.4	0	0.000
2008-55	08/11/08	SILETZ	1	24.00	16.7	29.4	10.7	1	0.042
2008-56	08/11/08	YAQUINA	1	24.01	14.1	32.9	7.6	6	0.250
2008-57	08/11/08	YAQUINA	2	24.02	13.7	33.2	9.0	0	0.000
2008-58	08/11/08	YAQUINA	3	24.02	13.5	32.2	9.0	8	0.333
2008-59	08/22/08	COOS	1	24.07	15.5	32.3	9.0	17	0.706
2008-60	08/22/08	COOS	2	24.09	15.1	32.4	7.9	6	0.249
2008-61	08/22/08	COQUILLE	1	24.06	15.4	32.4	8.1	5	0.208
2008-62	08/22/08	COQUILLE	2	24.03	15.5	32.0	7.8	17	0.354
2008-63	08/26/08	ALSEA	1	24.02	15.4	31.7	8.0	1	0.042
2008-64	08/26/08	ALSEA	2	24.01	15.1	31.7	8.8	1	0.042
2008-65	08/26/08	SILETZ	1	24.04	20.4	26.2	13.0	3	0.125
2008-66	08/28/08	YAQUINA	1	24.00	14.8	32.3	7.2	1	0.042
2008-67	08/28/08	YAQUINA	2	24.00	15.2	32.3	9.2	0	0.000
2008-68	08/28/08	YAQUINA	3	24.01	14.2	32.3	8.8	17	0.708
2008-69	09/07/08	NEHALEM	1	24.00	10.1	33.1	8.8	1	0.042
2008-70	09/07/08	NEHALEM	2	24.01	10.0	33.3	8.8	8	0.333
2008-71	09/12/08	YAQUINA	1	24.00	10.5	33.2	7.7	0	0.000
2008-72	09/12/08	YAQUINA	2	24.00	10.8	33.4	8.1	7	0.292
2008-73	09/12/08	YAQUINA	3	23.99	9.9	33.3	7.1	19	0.792
2008-74	09/17/08	SILETZ	1	24.03	12.3	23.2	8.2	0	0.000
2008-75	09/21/08	COOS	1	24.02	11.9	33.4	8.8	8	0.333
2008-76	09/21/08	COOS	2	24.01	13.2	32.9	7.5	12	0.500
2008-77	09/21/08	COQUILLE	1	24.07	12.1	33.6	8.4	3	0.125
2008-78	09/21/08	COQUILLE	2	24.06	12.3	33.4	8.5	19	0.395
2008-79	09/25/08	ALSEA	1	24.05	12.7	32.5	8.6	2	0.083
2008-80	09/25/08	ALSEA	2	24.04	12.5	32.7	8.5	0	0.000
2008-81	10/15/08	YAQUINA	1	24.14	12.3	32.7	7.1	2	0.083
2008-82	10/15/08	YAQUINA	2	24.14	12.2	32.9	7.7	11	0.456
2008-83	10/15/08	YAQUINA	3	24.13	12.4	32.1	8.1	21	0.870
2008-84	10/18/08	NEHALEM	1	23.98	11.4	32.3	8.1	0	0.000
2008-85	10/18/08	NEHALEM	2	23.97	11.4	31.8	8.5	6	0.250
2008-88	10/25/08	COQUILLE	1	24.03	9.1	33.5	9.5	0	0.000
2008-89	10/25/08	COQUILLE	2	23.98	9.0	33.7	9.5	12	0.500
2008-90	10/29/08	ALSEA	1	24.28	10.2	33.1	9.3	0	0.000
2008-91	10/29/08	ALSEA	2	24.28	10.3	32.7	9.1	0	0.000
2008-92	11/13/08	NEHALEM	1	24.08	10.4	13.9	9.1	1	0.042
2008-93	11/19/08	YAQUINA	1	24.06	12.2	29.0	7.2	1	0.042
2008-94	11/19/08	YAQUINA	2	24.20	12.0	29.3	6.7	19	0.785

Trap ID No. Cont.	Date	Estuary	Site	Total Trap Time	Average Temperature (°C)	Average Salnity (ppt)	Average Dissolved Oxygen (mg/L)	No. Rockfish Captured	Total Rockfish CPUE
2008-96	11/22/08	COOS	1	24.04	11.8	29.5	7.9	1	0.021
2008-97	11/22/08	COOS	2	24.13	12.1	26.9	6.9	82	3.399
2008-98	11/22/08	COQUILLE	1	24.21	11.6	30.8	8.3	1	0.041
2008-99	11/22/08	COQUILLE	2	24.20	11.9	24.4	8.7	6	0.248

Appendix Table 2: Trap Survey Data 2009

Trap ID. No.	Date	Estuary	Site	Total Trap Time	Average Temperature (°C)	Average Salinity (ppt)	Average Dissolved Oxygen (mg/L)	No. Rockfish Captured	Total Rockfish CPUE
2009-1	04/09/09	YAQUINA	1	23.90	10.0	28.5	8.3	0	0.000
2009-2	04/09/09	YAQUINA	2	23.96	10.1	31.4	9.1	1	0.042
2009-3	04/09/09	YAQUINA	3	23.90	9.8	31.0	10.3	0	0.000
2009-4	04/13/09	SILETZ	1	24.01	9.2	3.9	10.0	0	0.000
2009-5	04/17/09	COOS	1	24.01	10.4	29.4	8.9	0	0.000
2009-6	04/17/09	COOS	2	24.02	10.6	27.9	8.0	1	0.042
2009-7	04/17/09	COQUILLE	1	24.02	9.8	31.5	8.9	0	0.000
2009-8	04/17/09	COQUILLE	2	24.02	9.8	31.6	9.0	0	0.000
2009-9	04/29/09	ALSEA	1	24.00	11.2	30.7	10.1	0	0.000
2009-10	05/04/09	YAQUINA	2	24.01	12.1	30.3	7.6	0	0.000
2009-11	05/07/09	YAQUINA	2	24.00	10.9	30.7	8.3	0	0.000
2009-12	05/11/09	YAQUINA	2	24.01	11.5	29.6	7.3	2	0.083
2009-13	05/13/09	SILETZ	1	24.03	10.6	2.4	9.9	0	0.000
2009-14	05/13/09	YAQUINA	1	24.01	12.0	23.3	7.3	3	0.125
2009-15	05/13/09	YAQUINA	2	24.03	12.4	23.0	7.1	0	0.000
2009-16	05/13/09	YAQUINA	3	24.12	12.4	23.3	8.1	0	0.000
2009-17	05/14/09	YAQUINA	2	24.13	12.0	27.6	7.1	1	0.041
2009-18	05/18/09	YAQUINA	2	24.00	12.0	29.2	6.4	0	0.000
2009-19	05/19/09	NEHALEM	1	23.88	12.6	16.0	9.1	0	0.000
2009-20	05/19/09	NEHALEM	2	23.86	12.5	16.6	8.6	0	0.000
2009-21	05/21/09	YAQUINA	2	24.00	9.3	32.7	3.9	1	0.042
2009-22	05/25/09	YAQUINA	2	24.05	10.0	33.3	4.9	3	0.125
2009-23	05/27/09	YAQUINA	1	23.93	9.2	33.7	3.7	0	0.000
2009-24	05/27/09	YAQUINA	2	23.92	10.3	18.0	5.2	0	0.000
2009-25	05/27/09	YAQUINA	3	23.86	11.0	33.4	4.4	0	0.000
2009-26	05/28/09	YAQUINA	2	24.02	10.0	3.0	4.8	0	0.000
2009-28	05/29/09	COOS	2	24.04	10.0	33.2	6.5	4	0.166
2009-29	05/29/09	COQUILLE	1	24.03	10.2	33.0	6.8	1	0.042
2009-30	05/29/09	COQUILLE	2	24.02	10.3	33.0	6.4	3	0.125
2009-31	06/01/09	YAQUINA	2	24.01	11.3	32.5	7.1	1	0.042
2009-32	06/02/09	SILETZ	1	24.08	16.9	2.0	13.4	0	0.000
2009-33	06/04/09	YAQUINA	2	24.06	11.8	33.1	11.9	1	0.042
2009-34	06/06/09	NEHALEM	1	23.98	13.9	28.6	9.0	0	0.000
2009-35	06/06/09	NEHALEM	2	23.97	13.9	28.5	8.8	0	0.000
2009-36	06/08/09	YAQUINA	2	24.00	13.5	30.7	9.2	3	0.125
2009-37	06/09/09	ALSEA	1	23.99	14.9	28.6	8.9	3	0.125
2009-38	06/09/09	YAQUINA	1	23.96	13.9	30.1	8.4	18	0.751
2009-39	06/09/09	YAQUINA	2	23.93	13.9	30.2	8.8	5	0.209

Trap ID. No. Cont.	Date	Estuary	Site	Total Trap Time	Average Temperature (°C)	Average Salinity (ppt)	Average Dissolved Oxygen (mg/L)	No. Rockfish Captured	Total Rockfish CPUE
2009-41	06/10/09	YAQUINA	2	23.97	13.5	30.7	8.6	1	0.042
2009-42	06/22/09	COOS	1	23.90	13.1	32.9	8.8	0	0.000
2009-43	06/22/09	COOS	2	23.94	14.2	31.9	8.2	1	0.042
2009-44	06/22/09	COQUILLE	1	23.90	12.0	33.0	8.4	5	0.209
2009-45	06/22/09	COQUILLE	2	23.84	11.8	32.8	8.1	5	0.210
2009-46	06/24/09	YAQUINA	2	24.01	11.6	32.2	7.1	5	0.208
2009-47	06/25/09	YAQUINA	2	24.00	13.2	31.2	6.4	7	0.292
2009-48	06/29/09	YAQUINA	1	24.01	10.9	32.8	7.4	25	1.041
2009-49	06/29/09	YAQUINA	2	24.04	11.3	32.6	6.9	4	0.166
2009-50	06/29/09	YAQUINA	3	24.00	14.6	29.9	7.9	5	0.208
2009-51	07/01/09	NEHALEM	1	24.02	8.4	33.6	8.7	0	0.000
2009-52	07/01/09	NEHALEM	2	23.99	8.6	33.6	8.3	3	0.125
2009-53	07/06/09	YAQUINA	1	24.16	11.4	33.0	10.6	47	1.946
2009-54	07/06/09	YAQUINA	2	24.00	11.2	33.2	11.3	18	0.750
2009-55	07/06/09	YAQUINA	3	24.10	11.7	25.9	10.1	9	0.373
2009-56	07/07/09	YAQUINA	2	24.21	12.3	33.0	12.2	7	0.289
2009-57	07/09/09	SILETZ	1	24.00	15.2	10.7	12.6	0	0.000
2009-58	07/09/09	YAQUINA	2	23.99	14.7	31.6	6.7	14	0.584
2009-59	07/13/09	YAQUINA	2	23.98	14.6	31.7	6.4	15	0.626
2009-60	07/16/09	YAQUINA	2	24.00	12.9	32.4	5.0	5	0.208
2009-61	07/18/09	YAQUINA	1	24.02	9.8	33.4	4.8	0	0.000
2009-62	07/18/09	YAQUINA	3	24.01	9.9	33.4	5.7	8	0.333
2009-63	07/20/09	YAQUINA	2	24.02	9.6	33.4	5.8	12	0.499
2009-64	07/23/09	YAQUINA	2	24.00	13.0	32.4	5.0	6	0.250
2009-65	07/25/09	ALSEA	1	24.03	9.7	33.2	9.2	1	0.042
2009-66	07/29/09	YAQUINA	2	24.00	10.2	33.5	4.9	14	0.583
2009-67	07/30/09	YAQUINA	1	23.99	12.0	33.6	6.4	19	0.792
2009-68	07/30/09	YAQUINA	2	23.98	10.9	33.6	6.9	12	0.500
2009-69	07/30/09	YAQUINA	3	24.01	11.0	33.5	7.7	8	0.333
2009-70	08/01/09	NEHALEM	1	23.94	11.4	32.9	8.6	0	0.000
2009-71	08/03/09	COOS	1	23.88	13.1	33.1	10.4	15	0.628
2009-74	08/03/09	COQUILLE	2	23.41	13.5	33.4	9.6	3	0.128
2009-75	08/05/09	YAQUINA	2	24.03	13.5	33.3	10.6	14	0.583
2009-76	08/06/09	SILETZ	1	23.85	14.9	17.0	10.5	0	0.000
2009-77	08/06/09	YAQUINA	2	24.32	13.9	33.3	10.5	5	0.206
2009-78	08/07/09	YAQUINA	3	23.99	14.4	33.3	11.3	8	0.333
2009-79	08/24/09	YAQUINA	2	24.17	11.5	33.2	7.3	7	0.290
2009-80	08/25/09	NEHALEM	1	24.03	11.3	32.1	8.1	1	0.042
2009-81	08/25/09	SILETZ	1	24.03	14.3	19.2	10.0	0	0.000
2009-82	08/27/09	ALSEA	1	24.00	11.7	32.9	7.8	0	0.000
2009-83	08/27/09	YAQUINA	2	23.91	11.9	33.4	7.1	19	0.795
2009-84	09/10/09	SILETZ	1	24.01	n/a	n/a	n/a	0	0.000
2009-85	09/24/09	ALSEA	1	24.01	n/a	n/a	n/a	0	0.000
2009-86	10/02/09	COOS	1	24.03	n/a	n/a	n/a	1	0.042
2009-87	10/02/09	COOS	2	24.01	n/a	n/a	n/a	19	0.791
2009-88	10/02/09	COQUILLE	1	24.06	n/a	n/a	n/a	0	0.000
2009-89	10/02/09	COQUILLE	2	24.05	n/a	n/a	n/a	3	0.125

Appendix B

Appendix Table 1: Dive Survey Data 2008

Date of Survey	Structure No.	Average Rockfish Visual Estimate	No. Rockfish Collected	Rockfish Catch Density	Rockfish Visual Density	Water Temperature (°C)	Water Salinity (ppt)	Dissolved Oxygen (mg/L)
03/18/08	1	0	0	0.00	0.00	n/a	n/a	n/a
03/20/08	1	0	0	0.00	0.00	n/a	n/a	n/a
03/24/08	1	0	0	0.00	0.00	n/a	n/a	n/a
04/02/08	1	0	0	0.00	0.00	n/a	n/a	n/a
04/09/08	1	0	0	0.00	0.00	n/a	n/a	n/a
04/16/08	1	0	0	0.00	0.00	n/a	n/a	n/a
05/03/08	1	0	0	0.00	0.00	10.4	29.8	9.6
05/08/08	1	0	0	0.00	0.00	9.0	32.8	6.1
05/18/08	1	0	0	0.00	0.00	11.8	32.4	10.6
06/11/08	1	0	0	0.00	0.00	9.0	33.1	4.3
06/21/08	1	1	0	0.00	0.21	9.7	33.2	6.5
06/29/08	1	0	0	0.00	0.00	9.7	33.7	7.3
07/16/08	1	5	4	6.09	1.07	9.0	33.6	7.0
07/27/08	1	1.5	1	1.52	0.32	9.1	33.7	7.2
08/10/08	1	8.5	0	0.00	1.83	12.4	33.1	9.9
08/15/08	1	0	0	0.00	0.00	10.0	33.3	6.1
08/17/08	1	16	0	0.00	3.44	9.5	33.3	4.3
08/25/08	1	5.5	0	0.00	1.18	14.2	32.3	8.0
08/28/08	1	4.5	0	0.00	0.97	14.5	32.4	8.6
09/11/08	1	7	1	1.52	1.50	9.1	33.4	6.1
09/18/08	1	2	0	0.00	0.43	10.5	33.3	9.8
09/26/08	1	4	2	3.04	0.86	11.5	33.0	8.9
10/29/08	1	2	10	15.22	0.43	10.4	33.2	7.2
03/18/08	2	0	0	0.00	0.00	n/a	n/a	n/a
03/20/08	2	0	0	0.00	0.00	n/a	n/a	n/a
03/24/08	2	0	0	0.00	0.00	n/a	n/a	n/a
04/09/08	2	0	0	0.00	0.00	n/a	n/a	n/a
04/16/08	2	0	0	0.00	0.00	n/a	n/a	n/a
05/03/08	2	0	0	0.00	0.00	10.4	29.9	9.3
05/08/08	2	0	0	0.00	0.00	8.9	33.0	6.1
05/18/08	2	0	0	0.00	0.00	11.4	32.5	10.3
06/11/08	2	0	0	0.00	0.00	8.9	27.5	4.5
06/21/08	2	1.5	2	3.04	0.32	9.6	33.2	6.8
06/30/08	2	2	6	9.13	0.43	11.0	32.6	8.4
07/19/08	2	4.5	26	39.57	0.97	8.9	33.6	7.1
07/27/08	2	14	13	19.79	3.01	9.2	33.7	8.0
08/10/08	2	25	1	2.28	5.37	12.2	33.4	9.7
08/15/08	2	27.5	5	8.56	5.91	9.8	33.3	6.0
08/17/08	2	34	16	24.35	7.30	9.5	33.5	5.2
08/26/08	2	27.5	0	0.00	5.91	14.4	32.4	8.1
08/28/08	2	27.5	0	0.00	5.91	14.5	32.4	8.5
09/11/08	2	26.5	3	4.57	5.69	9.0	33.6	6.4
09/18/08	2	30.5	1	1.52	6.55	10.5	33.3	9.7
09/26/08	2	27	0	0.00	5.80	11.4	33.2	9.1
10/29/08	2	18.5	6	9.13	3.97	10.5	33.0	8.1
03/18/08	3	0	0	0.00	0.00	n/a	n/a	n/a
03/20/08	3	0	0	0.00	0.00	n/a	n/a	n/a
03/24/08	3	0	0	0.00	0.00	n/a	n/a	n/a
04/09/08	3	0	0	0.00	0.00	n/a	n/a	n/a
04/16/08	3	0	0	0.00	0.00	n/a	n/a	n/a
05/04/08	3	0	0	0.00	0.00	8.8	31.8	7.5
05/15/08	3	0.5	0	0.00	0.11	9.1	32.7	6.6
06/23/08	3	0	1	1.52	0.00	9.9	33.1	7.6
06/30/08	3	0	0	0.00	0.00	10.9	33.2	8.5

Date of Survey cont.	Structure No.	Average Rockfish Visual Estimate	No. Rockfish Collected	Rockfish Catch Density	Rockfish Visual Density	Water Temperature (°C)	Water Salinity (ppt)	Dissolved Oxygen (mg/L)
07/29/08	3	0	0	0.00	0.00	10.1	33.5	9.4
08/10/08	3	2	0	0.00	0.43	12.4	33.4	10.0
08/16/08	3	1	0	0.00	0.21	10.0	33.2	6.3
08/21/08	3	0	0	0.00	0.00	13.9	32.5	9.0
08/26/08	3	4	0	0.00	0.86	14.4	32.3	8.0
09/01/08	3	8.5	0	0.00	1.83	11.7	32.8	7.9
09/15/08	3	5.5	3	4.57	1.18	9.3	33.4	5.5
09/24/08	3	4	1	1.52	0.86	9.9	33.4	9.1
10/17/08	3	27.5	0	0.00	5.91	12.6	32.7	8.0
11/15/08	3	41	1	1.52	8.80	13.0	31.4	8.2
03/18/08	4	0	0	0.00	0.00	n/a	n/a	n/a
03/20/08	4	0	0	0.00	0.00	n/a	n/a	n/a
03/24/08	4	0	0	0.00	0.00	n/a	n/a	n/a
04/16/08	4	0	0	0.00	0.00	n/a	n/a	n/a
04/24/08	4	0	0	0.00	0.00	n/a	n/a	n/a
05/04/08	4	0	0	0.00	0.00	8.9	31.9	7.4
05/15/08	4	0	0	0.00	0.00	9.3	32.7	6.6
06/16/08	4	0.5	0	0.00	0.11	8.0	32.5	4.2
06/23/08	4	0	0	0.00	0.00	9.9	33.3	7.4
07/14/08	4	2.5	4	6.09	0.54	8.2	33.4	4.8
07/20/08	4	0.5	8	12.18	0.11	8.9	33.6	5.6
07/29/08	4	0	3	4.57	0.00	10.3	33.5	8.8
08/10/08	4	2	1	1.52	0.43	12.4	33.3	10.4
08/16/08	4	4	0	0.00	0.86	9.9	33.4	5.9
08/21/08	4	1	0	0.00	0.21	14.1	32.6	9.1
08/26/08	4	2	0	0.00	0.43	13.9	32.3	7.3
09/01/08	4	0	0	0.00	0.00	11.8	32.7	8.0
09/15/08	4	4	3	4.57	0.86	9.3	33.6	5.7
09/24/08	4	4	9	13.70	0.86	10.0	33.5	7.8
10/17/08	4	19.5	9	13.70	4.19	12.5	32.8	8.5
11/15/08	4	23.5	18	27.40	5.05	n/a	n/a	n/a
03/18/08	5	0	0	0.00	0.00	n/a	n/a	n/a
03/20/08	5	0	0	0.00	0.00	n/a	n/a	n/a
04/16/08	5	0	0	0.00	0.00	n/a	n/a	n/a
04/24/08	5	0	0	0.00	0.00	n/a	n/a	n/a
05/04/08	5	0	0	0.00	0.00	9.1	31.7	7.1
05/15/08	5	0	0	0.00	0.00	9.6	32.4	6.4
06/16/08	5	1	0	0.00	0.21	8.2	33.4	5.4
06/29/08	5	0	0	0.00	0.00	10.0	33.4	8.3
07/14/08	5	2.5	2	3.04	0.54	8.8	33.3	4.1
07/27/08	5	0.5	0	0.00	0.11	9.7	33.6	8.0
07/30/08	5	0	0	0.00	0.00	11.0	32.6	8.8
08/14/08	5	0.5	0	0.00	0.11	10.2	33.2	5.8
08/16/08	5	0.5	1	1.83	0.11	9.8	33.3	6.1
08/21/08	5	1	1	1.52	0.21	13.9	32.7	8.5
08/27/08	5	0	0	0.00	0.00	13.9	32.5	7.1
09/10/08	5	0	1	1.52	0.00	9.3	33.4	8.7
09/17/08	5	6.5	2	3.04	1.40	10.0	33.3	11.9
09/25/08	5	18.5	1	1.52	3.97	11.2	33.3	7.5
10/27/08	5	46	7	10.65	9.88	9.9	32.8	7.4
11/17/08	5	39	11	16.74	8.37	12.6	30.2	5.4
03/18/08	6	0	0	0.00	0.00	n/a	n/a	n/a
03/20/08	6	0	0	0.00	0.00	n/a	n/a	n/a
03/24/08	6	0	0	0.00	0.00	n/a	n/a	n/a
04/16/08	6	0	0	0.00	0.00	n/a	n/a	n/a
05/04/08	6	0	0	0.00	0.00	9.2	31.7	7.8
05/15/08	6	0	0	0.00	0.00	9.4	32.8	6.4
06/16/08	6	0	0	0.00	0.00	8.4	33.3	5.6
06/29/08	6	0	0	0.00	0.00	9.9	33.5	8.2
07/16/08	6	1	0	0.00	0.21	9.4	33.3	7.0
07/27/08	6	0	0	0.00	0.00	9.7	33.7	8.0

Date of Survey cont.	Structure No.	Average Rockfish Visual Estimate	No. Rockfish Collected	Rockfish Catch Density	Rockfish Visual Density	Water Temperature (°C)	Water Salinity (ppt)	Dissolved Oxygen (mg/L)
08/14/08	6	0	0	0.00	0.00	10.2	33.3	5.7
08/17/08	6	0.5	0	0.00	0.11	9.9	33.5	6.2
08/21/08	6	1	0	0.00	0.21	13.9	32.7	9.0
08/27/08	6	2	0	0.00	0.43	14.0	32.4	7.0
09/17/08	6	1	0	0.00	0.21	9.9	33.4	11.6
09/25/08	6	5	0	0.00	1.07	11.1	33.3	8.7
10/27/08	6	57.5	5	7.61	12.35	9.9	32.2	7.3
11/17/08	6	51	0	0.00	10.95	12.7	30.3	5.3

Appendix Table 2: Dive Survey Data 2009

Date of Survey	Structure No.	Average Rockfish Visual Estimate	No. Rockfish Collected	Rockfish Catch Density	Rockfish Visual Density	Water Temperature (°C)	Water Salinity (ppt)	Dissolved Oxygen (mg/L)
04/09/09	1	0	0	0.00	0.00	9.9	31.5	9.8
04/27/09	1	0	0	0.00	0.00	8.8	33.1	5.6
05/27/09	1	0	0	0.00	0.00	9.3	33.5	4.5
06/24/09	1	0	0	0.00	0.00	9.6	32.8	6.5
07/21/09	1	1.5	0	0.00	0.32	8.9	33.6	4.6
08/07/09	1	14	0	0.00	2.97	14.3	33.2	10.7
09/07/09	1	5.5	0	0.00	1.17	13.5	32.4	8.5
04/09/09	2	0.5	0	0.00	0.11	9.7	31.5	10.0
04/27/09	2	0	0	0.00	0.00	8.7	33.6	5.4
05/27/09	2	0	0	0.00	0.00	9.1	33.6	4.6
06/24/09	2	5	1	2.28	1.06	9.8	32.9	8.1
07/21/09	2	6	0	0.00	1.27	9.1	33.4	5.1
08/07/09	2	10.5	0	0.00	2.22	14.1	33.4	10.8
09/07/09	2	3.5	0	0.00	0.74	13.7	33.2	8.3
04/24/09	3	0	0	0.00	0.00	8.8	33.3	3.8
05/25/09	3	0	0	0.00	0.00	9.9	33.1	5.1
06/05/09	3	0	0	0.00	0.00	11.6	32.9	11.4
07/07/09	3	0	0	0.00	0.00	11.2	33.2	12.3
07/23/09	3	0	0	0.00	0.00	9.3	33.5	5.1
08/08/09	3	4.5	0	0.00	0.95	15.2	33.0	10.6
09/16/09	3	7.5	0	0.00	1.59	15.6	32.5	7.5
04/24/09	4	0	0	0.00	0.00	8.6	33.5	4.2
05/25/09	4	0	0	0.00	0.00	9.9	33.1	5.1
06/05/09	4	0	0	0.00	0.00	11.4	32.9	11.6
07/07/09	4	13	2	3.04	2.75	11.1	33.2	12.5
07/23/09	4	16.5	5	7.61	3.50	9.4	33.6	5.6
08/08/09	4	19	0	0.00	4.03	14.0	33.2	11.3
09/16/09	4	12.5	0	0.00	2.65	15.8	32.7	7.7
04/25/09	5	0	0	0.00	0.00	8.8	33.2	5.2
05/26/09	5	0	0	0.00	0.00	9.5	33.3	4.6
06/08/09	5	0	0	0.00	0.00	13.0	30.9	9.9
04/25/09	6	0	0	0.00	0.00	8.6	33.5	5.0
05/26/09	6	0	0	0.00	0.00	9.5	33.3	4.5
06/08/09	6	0	1	1.52	0.00	13.0	30.8	10.3
07/19/09	6	2	1	2.28	0.42	9.1	33.4	5.1
07/31/09	6	0	0	0.00	0.00	11.2	33.6	9.2
09/20/09	6	2	2	3.04	0.42	n/a	n/a	n/a