Identification of critical habitat for all life stages of commercially exploited fish populations is critical for effective management. Despite a clear need for basic biological information on juvenile rockfish life history, there have been very few efforts to describe distribution and habitat of this life stage, particularly along the Oregon coast. This study investigated the relationships between habitat-type, species composition and growth of juvenile rockfishes following settlement into nearshore reefs and estuaries. By using a four-level classification system to prioritize and identify Essential Fish Habitat, results of this study refine scientific knowledge of EFH for Oregon’s nearshore rockfish species.

Four species of rockfish were collected during the summers of 2004 and 2005: blue rockfish (S. mystinus), black rockfish (S. melanops), yellowtail rockfish (S. flavidus) and widow rockfish (S. entomelas). Nearshore hand net samples were dominated by blue rockfish. Estuary samples were almost exclusively black rockfish, indicating that this species is common in Yaquina Bay. No black rockfish were
collected from our nearshore sampling sites in either 2004 or 2005, although this habitat is listed as common for juveniles of this species.

Blue rockfish settlement was detected from April thru July in 2004, and from May thru June in 2005. Peak settlement timing was in June of both years. Settlement for black rockfish ranged from March thru July both years, with peak settlement timing occurring in mid-May. Yellowtail and widow rockfish juveniles were rarely encountered, with settlement occurring in April and July respectively.

Abundance, as estimated from catch per unit effort (CPUE) calculations, varied among years and habitats. Black rockfish were more abundant in 2004 than in 2005. Some of the highest densities were found around pilings, docks and other anthropogenic structures: CPUE decreased within rock, eelgrass, and sand habitats respectively.

Growth was not significantly different among habitats for either black or blue rockfish. Growth rate differences were not significant among years for either black or blue rockfish. However, growth differences were significant between species (black 0.50 mm d\(^{-1}\) and blue 0.54 mm d\(^{-1}\) (two sample-t test, T stat = -3.19, df = 133 P-value <.002).

Additionally, this thesis presents a tank validation experiment that investigated the validity of traps as a quantitative measure of habitat quality. This trap validation study showed that as habitat complexity increases, trap efficiency decreases. Trap attractiveness is an important source of bias when used for juvenile rockfish abundance estimation. This study demonstrates abundance estimates may be inflated
in areas of low habitat complexity in the natural environment, or under-estimate the relative abundance of rockfishes within complex habitats.

This study identifies estuaries as Essential Fish Habitat for black rockfish juveniles along the central Oregon coast, and nearshore reef as EFH for blue rockfish juveniles. Results of this study also provide specific information on spatial and temporal patterns of recruitment, habitat selection and growth, previously unknown for Oregon's nearshore Sebastes species.
Growth Rates and Species Composition of Juvenile Rockfish (Sebastes spp.) in Oregon’s Nearshore and Estuarine Habitats

by
M. Brett Gallagher

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degree of
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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.

__________________________________________________________

M. Brett Gallagher, Author
ACKNOWLEDGEMENTS

This project was successfully completed with the help of many people. I would like to take this opportunity to thank the following people for their support in one capacity or another. First I’d like to thank my committee members Selina Heppell, Michael Banks and Hal Weeks for agreeing to guide me through the Master’s process. Funding for this project was provided by Oregon SeaGrant. Special thanks to Bob Malouf, Eric Dickey and Evelyn Paret for making this project a reality. Additionally, I’d like to thank Scott Heppell for providing me an excellent research experience in the Cayman Islands, and for continued financial support through the completion of my Master’s work. More thanks to the following for help with my field sampling: Ted Hart, Marlene Bellman, Todd Miller, Tad Schwager, Craig Tinus, Jay Vaughan, Matt Hawkyard, Raquel Sosa, and Curt Gault. Thank you all for getting out on the water with me.

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# TABLE OF CONTENTS

| CHAPTER 1: GENERAL INTRODUCTION ................................................................. | 1 |
| Background ........................................................................................................ | 2 |
| Where is EFH for groundfish? .......................................................................... | 5 |
| Literature Cited ............................................................................................... | 8 |
| CHAPTER 2: HABITAT UTILIZATION BY YOUNG-OF-THE-YEAR .............................. | 10 |
| ROCKFISHES ALONG THE CENTRAL OREGON COAST: A CASE STUDY IN ................ | 10 |
| ESSENTIAL FISH HABITAT IDENTIFICATION ....................................................... | 10 |
| Introduction ..................................................................................................... | 13 |
| Materials and Methods .................................................................................... | 13 |
| Nearshore sampling ......................................................................................... | 15 |
| Estuarine sampling ......................................................................................... | 17 |
| Species identification ..................................................................................... | 19 |
| Age and Growth Analysis ............................................................................... | 20 |
| Analytical Methods ......................................................................................... | 22 |
| Results ............................................................................................................ | 23 |
| Species composition by habitat ...................................................................... | 24 |
| Settlement timing ............................................................................................ | 24 |
| Discussion ....................................................................................................... | 31 |
| Conclusion ...................................................................................................... | 34 |
| Literature Cited .............................................................................................. | 35 |
| CHAPTER 3: TANK VALIDATION OF TRAPPING METHODS USED IN .................. | 39 |
| COLLECTION OF YOUNG-OF-THE-YEAR BLACK ROCKFISH (SEBASTES ................ | 39 |
| MELANOPS) ....................................................................................................... | 40 |
| Introduction .................................................................................................... | 40 |
| Materials and Methods ................................................................................... | 41 |
| Results ............................................................................................................ | 41 |
| Discussion ...................................................................................................... | 45 |
| Literature Cited ............................................................................................. | 46 |
| CHAPTER 4: RESEARCH RECOMMENDATIONS ................................................... | 47 |
| Rockfish Trapping ............................................................................................ | 47 |
| Expansion of study area ................................................................................... | 48 |
| Extension of Sampling Period ........................................................................ | 49 |
| Level 4 data- production by habitat ................................................................ | 50 |
| Literature Cited .............................................................................................. | 51 |
| BIBLIOGRAPHY ............................................................................................... | 53 |
| Appendix 1: Otolith Consistency Analysis ...................................................... | 59 |
| Literature Cited .............................................................................................. | 63 |
| Appendix 2: Information tables ....................................................................... | 64 |
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trends in exploitable biomass for four west coast rockfish stocks: canary (<em>S. pinniger</em>), Pacific Ocean perch (<em>S. alutus</em>), bocaccio (<em>S. paucispinis</em>) and widow (<em>S. entomelas</em>) Data derived from Pacific Fishery Management Council stock assessments (Hamel 2007; He et al. 2007; MacCall 2007; Stewart 2007) and provided by Steve Ralston-NOAA, Southwest Fisheries Science Center.</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Estuarine Habitat Areas of Particular Concern (HAPCs) for the US west coast (From PFMC Groundfish Fishery Management Plan).</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Study area along the central Oregon coast, including estuarine and nearshore sampling sites. Four estuarine study sites were located within Yaquina Bay, OR. Two nearshore sites were located 4km (South Yaquina reef) and 8km (Margarita reef) South of Yaquina Bay and were both over 2km offshore. Depth contours are shown at 10m intervals.</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Schematic of analytical method procedure for age, length, birth date, settlement date and growth analysis.</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>Black rockfish length, collection date and habitat distribution 2004-2005.</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Species composition, length and collection date within nearshore sampling sites 2004-2005.</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>Proportional contributions of each species within estuarine and nearshore sampling locations, 2004 &amp; 2005.</td>
<td>24</td>
</tr>
<tr>
<td>8a, b</td>
<td>Estimated settlement timing of young-of-the-year black and blue rockfishes, April-July 2004-2005.</td>
<td>25</td>
</tr>
<tr>
<td>9</td>
<td>Habitat specific abundance as estimated from catch per unit effort (CPUE) for black rockfish within estuarine habitats 2004-2005. Dock pilings were consistently areas of highest abundance.</td>
<td>27</td>
</tr>
<tr>
<td>10 a, b</td>
<td>Temporal patterns of abundance as estimated from catch per unit effort (CPUE) for black rockfish within estuarine habitats during 2004 (a) and 2005 (b).</td>
<td>28</td>
</tr>
<tr>
<td>11</td>
<td>Estimated daily growth rates (mean) for black and blue rockfish 2004 and 2005.</td>
<td>31</td>
</tr>
<tr>
<td>12</td>
<td>Fish retention within McBride trap design per fish density.</td>
<td>41</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>13:</td>
<td>Proportion of fish caught within tanks (for all 4 replicates) of four different densities of fish (4, 7, 14, and 28 fish) over all three different habitat types (rock, eelgrass, and sand-mud) over a 24hr period.</td>
<td>42</td>
</tr>
<tr>
<td>14 (a-c):</td>
<td>Proportion of fish trapped over time for tanks of four different densities of fish (4, 7, 14, and 28 fish) and 3 substrates. Proportions are pooled totals for 4 replicates. A. Sand-mud habitat type. B. Eelgrass habitat type. C. Rock habitat type.</td>
<td>44</td>
</tr>
<tr>
<td>15:</td>
<td>Minnow trap capture density as distance from piling habitat increased.</td>
<td>45</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Comparison of HAPC size and percentage of US west coast Exclusive Economic Zone (From PFMC Groundfish Fishery Management Plan)</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Biological parameter comparison among habitats using single factor ANOVA and two sample t-tests.</td>
<td>30</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>A 1:</td>
<td>Count 1 VS Mean: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.</td>
<td>60</td>
</tr>
<tr>
<td>A 2:</td>
<td>Count 2 VS Mean: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.</td>
<td>60</td>
</tr>
<tr>
<td>A 3:</td>
<td>Count 3 VS Mean: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.</td>
<td>61</td>
</tr>
<tr>
<td>A 4:</td>
<td>Count 1 minus Count 2: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.</td>
<td>61</td>
</tr>
<tr>
<td>A 5:</td>
<td>Count 1 minus count 3: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.</td>
<td>62</td>
</tr>
<tr>
<td>A 6:</td>
<td>Count 2 minus count 3: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.</td>
<td>62</td>
</tr>
<tr>
<td>A 7:</td>
<td>Regression of black rockfish age on growth rate. X-axis denotes estimated daily age of each fish, Y-axis represents growth rate (mm/day).</td>
<td>63</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>A 1: Sampling dates, species composition, total number and collection method</td>
<td>64</td>
<td></td>
</tr>
</tbody>
</table>
DEDICATION

To my family, principally to the memory of my grandmother Anita Prokop, for always supporting and encouraging my dreams. To my father and mother, Clark and Kim Gallagher, thank you for the years of guidance you have given me. Mom, you instilled in me a yearning for knowledge and always encouraged my earliest scientific exploits. Thank you for teaching me that science can be cool. Dad, thanks for showing me the value of dedication and preparedness, for your unconditional acceptance and for allowing me to stand on your shoulders. To my sister Tiffany for unwavering support and comic relief, thanks for reminding me not to take myself too seriously. These past years have been full of adversity, and I dedicate this project to all of you as a token of my appreciation for your unconditional encouragement, support and love. Thank you for being there for me during some of my biggest challenges.
CHAPTER 1: GENERAL INTRODUCTION

Rockfishes (Scorpaenidae: Sebastinae), are in one of the 14 families of viviparous fishes. The 388 species within this large family are found in all tropical and temperate seas, but occur mostly in the Indian and Pacific ocean basins (Helfman et al. 1997). Nearly all of the 68 species within the genus *Sebastes* are found in the North Pacific, with highest concentrations off the west coast of the United States and Canada. These species are mostly demersal, of intermediate size (25-70cm), and aggregate in areas of high habitat complexity, such as rocky reefs, coral reefs, oil platforms and kelp beds (Love et al. 2002).

Rockfishes are long-lived (30-200 years maximum age (Love et al. 2002)), iteroparous and highly fecund. Although they give birth to live young, rockfish fecundity is similar to like-sized oviparous fishes; for example, fecundity can reach maximum values of 2.3 million in bocaccio rockfish (*S. paucispinis*) and 5.6 million in vermillion rockfish (*S. miniatus*) (Love et al. 2002). Most *Sebastes* species have a single annual reproductive cycle. Members of this genus are primitively viviparous, with fertilization occurring internally. Embryos develop within paired ovaries, and larvae are extruded into the water column 1-2 months after fertilization (Boehlert and Yoklavich 1983, Eldridge et al. 1991, Moser and Boehlert 1991). Following parturition, all larvae experience a pelagic phase, which varies in both duration and vertical placement within the water column (Love et al. 2002). Some species have very short pelagic juvenile stages, while others can remain in the pelagic realm for up to one year before settling to a demersal existence. This settlement into the demersal habitat is referred to as “recruitment” for the purpose of this research and thesis.
Furthermore, this thesis concentrates specifically on the early settlement and post-settlement stages of rockfish early life history.

**Background**

Globally, we are experiencing a crisis in world fisheries. In 1997 the Food and Agriculture Organization (FAO) of the United Nations, reported that the majority of fish stocks harvested from wild populations can be assigned fully exploited or overexploited status. World catches (total landings) of fish have declined steadily since 1989 (FAO Marine Resource Service, 2005) and catch sizes have also decreased (Blanchard et al. 2005, Sibert et al. 2006). One recent study predicts a “global fisheries collapse” in the year 2048 if current trends continue (Worm et al. 2006). Furthermore, fishing interests are sequentially exploiting lower and lower trophic levels, a phenomenon known as “fishing down the food web” (Pauley et al. 1998). By consistently depleting the apex predator populations within food webs, harvest pressure is altering the trophic dynamics of many marine ecosystems (Frank et al. 2005).

Many rockfish populations exhibited drastic declines in the 1970’s, if not earlier, leading to the current “crisis” in US groundfish fisheries (Bloeser 1999). In 2000, former U.S. Secretary of Commerce William M. Daley declared west coast groundfish management a “fisheries failure” and economic disaster. Harvest levels continued to decline and large areas of the shelf and slope were closed to fishing. In 2003, the Pacific Fisheries Management Council (PFMC) declared 7 species of pacific rockfish as overfished (Figure 1; (50 CFR 660, 2003)).
Figure 1: Trends in exploitable biomass for four west coast rockfish stocks: canary (*S. pinniger*), Pacific Ocean perch (*S. alutus*), bocaccio (*S. paucispinis*) and widow (*S. entomelas*) Data derived from Pacific Fishery Management Council stock assessments (Hamel 2007; He et al. 2007; MacCall 2007; Stewart 2007) and provided by Steve Ralston-NOAA, Southwest Fisheries Science Center.

The culmination of these events prompted the implementation of several conservation plans. These rebuilding plans include: 1) Efforts to reduce fishing capacity (boat buyback programs, reduced harvest quotas, shortened fishing seasons), 2) Appropriations of funding for scientific study of EFH (Essential Fish Habitat), 3) Marine Protected Area (MPA) design and implementation, 4) Inclusion of large areas of trawlable seafloor habitat into Rockfish Conservation Areas (RCAs), and 5) In-season management changes, including emergency closures to the fishery (for example, in summer 2007, surpassing the harvest cap for widow rockfish (*S. entomelas*) drove the closure of the Pacific whiting fishery with 240,000,000 pounds remaining un-harvested (Federal Register website2)).
Spatial management and marine protected areas have the potential to help ameliorate the effects of overfishing on many groundfish species (Lauck et al. 1998), but only if they are designed properly. Successful MPA design requires an understanding of critical habitat requirements and basic life history characteristics of target species, but is not the only reason for investigation of essential fish habitat. Legal mandates within the 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act require the description and identification of habitat requirements for all life stages of commercially endangered or critically protected groundfish species. US Congress defined essential fish habitat as: “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (16 U.S.C. 1802(10)). EFH guidelines were further elaborated in 2002 under 50 CFR 600.10:

Waters include areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species’ contribution to a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity: covers a species’ full life cycle.

This definition has led to the PFMC’s designation of the entire continental shelf as essential fish habitat for the 82 groundfish species under its jurisdiction (PFMC EFH Environmental impact Statement (EIS), 2005). Thus, by itself the groundfish EFH designation does not facilitate prioritization of the most critical habitat areas.
**Where is EFH for groundfish?**

Of the 82 species of groundfish managed by the Pacific Fishery Management Council, only a small proportion has been studied adequately to assess population status. Many species of rockfish are not formally assessed due to a lack of basic biological information, particularly regarding juvenile life history stages (Love et al. 2002). At least sixty-two species of rockfishes inhabit the coastal waters of Pacific North America, (Eschmeyer and Herald 1983) and many of these species are important in both commercial and recreational fisheries. Insufficient data on the habitat needs of these species needs to be addressed (PFMC 2005). Identification of nursery habitat for declining rockfish stocks is a critical step to conserving and rebuilding over-exploited populations. Estuarine environments play a critical role in providing nursery habitats for many fish species throughout the world, however, the contribution of estuarine habitats to rockfish population dynamics remains unknown.

Recently, work has been conducted to identify and designate Habitat Areas of Particular Concern (HAPCs) for many marine species (Reed, 2000; Reed, 2002; PFMC EFH document, 2003). HAPCs are an attempt to more specifically identify EFH, and have been hypothesized to focus the application of protective measures to the most sensitive habitat areas. HAPCs are defined as areas with particularly large numbers of species and life stages, habitat that is particularly rare, and/or habitat that is stressed or vulnerable, and include nearshore rocky reefs and estuaries (Table 1). HAPCs are usually focused on areas of high biodiversity, but do not account for vital rates of species found within these habitats. While this is a more effective approach than designating the entire ocean as essential fish habitat, the “particular” component driving designations for many of these areas is the overall physical structure of the
habitat, not the ecological interactions occurring within. Furthermore, HAPCs do not give us enough information to quantitatively assess habitat for particular species. Although HAPCs in Oregon include estuaries and nearshore rocky reefs (Figure 2, Table 1), questions remaining unanswered include: 1) How do these habitats contribute to food availability, shelter from predation and access to mates for reproduction? 2) How do these habitats contribute to the sustainability of the fishery? and 3) Specifically, which rockfish species depend on estuarine habitats?

Figure 2: Estuarine Habitat Areas of Particular Concern (HAPCs) for the US west coast (From PFMC Groundfish Fishery Management Plan).
Table 1: Comparison of HAPC size and percentage of US west coast Exclusive Economic Zone (From PFMC Groundfish Fishery Management Plan).

<table>
<thead>
<tr>
<th>Description</th>
<th>% of EEZ</th>
<th>Area (ha)</th>
<th>Area (square nautical miles)</th>
</tr>
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<tbody>
<tr>
<td>Estuaries</td>
<td>0.68%</td>
<td>560,738</td>
<td>1635</td>
</tr>
<tr>
<td>Canopy Kelp</td>
<td>0.03%</td>
<td>26,347</td>
<td>77</td>
</tr>
<tr>
<td>Seagrass</td>
<td>0.09%</td>
<td>77,613</td>
<td>226</td>
</tr>
<tr>
<td>Core Habitat</td>
<td>6.18%</td>
<td>5,088,479</td>
<td>14,835</td>
</tr>
<tr>
<td>Rocky Reefs</td>
<td>2.55%</td>
<td>2,101,009</td>
<td>6125</td>
</tr>
<tr>
<td>Oil Production</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platforms</td>
<td>3.67%</td>
<td>3,017,148</td>
<td>7896</td>
</tr>
</tbody>
</table>

In an attempt both to simplify and to provide levels of certainty for EFH definitions, a new approach has been implemented by NOAA-Fisheries, adapted from previous work identifying four levels of useful information for habitat classification (Able 1999, Minello 1999). Level 1 data is based on the presence or absence of a target species. Level 2 data includes habitat-specific densities of fish. Level 3 information concerns habitat-specific vital rates such as growth, reproduction or survival. Level 4 data incorporates estimates of fish production per habitat. Level 3 and Level 4 information are difficult and time-consuming to collect, and are usually absent from EFH studies and designations. However, to assure accurate and specific designation of habitat for protection and/or restoration, this higher level of information should be the goal if EFH is to be used for MPA design or other management activities.

Ideally, new marine reserve designs will be based on the best available science, including species-specific habitat information (Beck et al. 2001). My thesis work includes Level 1, 2 and 3 data for two species of juvenile rockfish (*S.melanops* & *S.mystinus*) on the Central Oregon Coast. Species identification, settlement timing,
abundance and growth results are presented in Chapter 2. Chapter 3 presents a rockfish trap efficiency study. Chapter 4 includes a discussion of knowledge gained while undertaking these projects, and presents research recommendations for future juvenile rockfish studies. It is my hope that this work will further the basic biological knowledge of Oregon’s juvenile rockfishes, and ultimately contribute to the sustainability of Oregon’s fishery resources.

Footnotes:


Literature Cited


CHAPTER 2: HABITAT UTILIZATION BY YOUNG-OF-THE-YEAR ROCKFISHES ALONG THE CENTRAL OREGON COAST: A CASE STUDY IN ESSENTIAL FISH HABITAT IDENTIFICATION

Introduction

All marine fishes require healthy habitats for feeding, growth to maturity and reproductive success. Identification of critical habitat for commercially exploited fish species and understanding the role of habitat in recruitment processes is essential to successful management of marine fisheries. In spite of this significant need, critical habitat requirements for many temperate marine species remain unknown. Marine habitat destruction and degradation are occurring at an alarming rate (Hughes et al. 2003, Pandolfi et al. 2005, Wheeler et al. 2005, Lan et al. 2006), and may be a substantial barrier to the long-term sustainability of ocean fisheries. In highly populated coastal areas, habitat destruction and modification are pronounced; common examples include conversion of estuarine and mangrove habitats into commercial use zones, dredging of estuarine habitats, and nutrient-induced eutrophication and pollution. While conservation may be generally important to many individuals, changes in human behavior to avoid negative impacts are more likely if the consequences of habitat conversion or loss can be related to the loss of ecosystem services, such as fisheries production and flood control (Wigand, et al. 2001, Tockner and Stanford 2002, Chan et al. 2006).

One question currently concerning many ocean resource managers is “How can we most effectively protect fish habitat?” This may be accomplished through protected area designation, fishing gear restrictions, or both (Pew Ocean Commission 2003; U.S. Commission on Ocean Policy, 2004). Setting aside critical habitats
protects these areas from unnatural degradation and resource extraction, and provides a forum for scientific inquiry into the role habitat plays in ecosystem function. However, before critical habitat can be designated and protected, it must first be accurately identified.

On the U.S. West Coast, concerns about rockfish (Genus *Sebastes*) management have prompted investigations of habitat requirements for critically protected or commercially endangered groundfish species. The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act define Essential Fish Habitat (EFH) as, “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (16 U.S.C. 1802(10)). This broad collection of terms means that habitat used by all life stages of all species must be identified; with 82 groundfish species in its management plan, the Pacific Fisheries Management Council (PFMC) has identified the entire continental shelf of the U.S. West Coast as essential fish habitat (PFMC, EFH Environmental Impact Statement (EIS) document, 2005). Although this rough categorization does not prioritize quality habitats, prioritization is essential given limited management resources.

In an effort to streamline the process of EFH description and identification, the National Marine Fisheries Service has adopted a 4-level classification system, originally proposed by Thomas Minello (1999) and Kenneth Able (1999). The first requirement for the establishment and description of EFH is presence/absence data (Level 1). This classification simply allows elimination of areas that are not serving as habitat for species under investigation. Inference about the importance of habitat from level 1 data is limited, in that it only describes the geographical distribution of a
species in relation to habitat. Level 2 data includes the habitat-specific densities of fish. This assumes that increased abundances in a habitat reflect increased habitat quality. While two separate habitats may be used by the same species, one habitat may contribute disproportionately to the abundance of the species. In both level 1 and level 2 assessments, it is necessary to account for gear biases and other factors that may influence presence/absence or density calculations. Level 3 information includes habitat-specific vital rates, such as growth, reproduction or survival. Vital rate information is difficult to obtain for many species, but it provides a quantitative measure of habitat quality. Level 4 relies on habitat specific production estimates, or the contribution of a habitat to the spawning stock biomass of a species. By knowing how habitats function in relation to the adult reproductive population, fisheries managers may be able to protect habitats critical for continued reproductive success and resilience of the species.

While this classification scheme has proven to be an effective tool for field investigations of adult rockfish habitat, very few efforts to describe the distribution and habitat of juvenile rockfish have been conducted off the Oregon coast. My study used the 4-level framework to identify EFH for two species of juvenile rockfish along the Oregon coast. Identification of essential habitat and its importance for juvenile rockfish growth is the first step to understanding how different areas of the coast serve as nursery habitat, thereby contributing to our efforts to understand recruitment variability in these important commercial species.
Materials and Methods

Fish were collected from nearshore and estuarine sites along the Oregon coast from June-September 2004 and 2005. All fish were captured using either hand nets or traps.

Nearshore sampling

All sampling within the nearshore occurred at two separate sites along the central Oregon Coast: South Yaquina Reef (44.584’ N, 124.101’ W) and Margarita Reef (44, 5.21’ W, 124.1.05’ W)(Figure 3.)
Figure 3: Study area along the central Oregon coast, including estuarine and nearshore sampling sites. Four estuarine study sites were located within Yaquina Bay, OR. Two nearshore sites were located 4km (South Yaquina reef) and 8km (Margarita reef) South of Yaquina Bay and were both over 2km offshore. Depth contours are shown at 10m intervals.
These nearshore rocky patch reefs range in depth from 10m to 35m. Nearshore reefs are basaltic rock formations and provide extremely complex habitat. Large boulders (>2m), kelp fronds (*P. palmaeformis*), abundant plumose anemones (*Metridium spp.*) and various sponges (Phylum *Porifera*), provide ample refugia for YOY fishes at these sites, which range in patch size from 50 - 500 m². All sampling in these areas utilized SCUBA, with divers working in pairs. Our diving platform consisted of a 21 ft Boston whaler, so sampling was limited to days where ocean conditions were less than 3m combined seas for diver safety. Targeted depth during all dive surveys was 20-25 m. This depth was frequently inhabited by young-of-the-year (YOY) rockfishes and provided shelter from strong current and surge.

My hand net, originally developed by the Carr Lab-UC Santa Cruz, was constructed of PVC pipe and fine mesh netting that allowed us to capture YOY rockfish while using SCUBA. Net dimensions were 80cm x 90cm, with 3mm mesh size. Two divers utilized the hand net to capture YOY rockfish. Dive time was limited by air consumption, with all dives averaging 45 minutes. All fish collected underwater within nets were then transferred to plastic bags and brought to the surface for identification. Fish were measured to the nearest mm standard length (SL), then transported to the lab and frozen for later processing.

**Estuarine sampling**

All estuarine fish were collected within Yaquina Bay, Oregon (44, 37.3’ N., 124, 2.8’W.) (Figure 3). Fish were collected from four separate habitats within Yaquina Bay, eelgrass beds, sandy areas, rock/boulder outcroppings, and dock pilings. Wood and galvanized stainless steel minnow traps (Aquatic Ecosystems Inc.) were used for fish collection within the estuary. These traps include an elongated funnel
design that allows fish to enter easily through a narrow panel. Trap validation experiments were conducted within a 700 gallon tank under laboratory conditions to document capture efficiency. No fish escaped the traps during laboratory testing (see Ch 3).

Traps were deployed for 24-hour soak periods. Sampling was conducted during daylight hours, wherein traps were set approximately one-half hour before the high tide and soaked for two full tidal cycles (24hrs). Two traps were set in each habitat type, anchored with 4.5kg mushroom anchors in areas where depth ranged from 2-7m. Upon retrieval of the traps all fish were measured to the nearest mm SL. All fish were then transported to the lab and frozen for later processing.

I utilized two different collection methods (fish traps and hand nets) within my sampling protocol; this was to account for the logistical difficulty of gear retrieval in the nearshore environment. Inclement weather and heavy seas prevented me from leaving trap gear unattended on the nearshore reefs, as I found it unethical to deploy traps that had a high likelihood of ghost-fishing should I not be able to retrieve them. Furthermore, because my traps needed to have a surface buoy attached to them, wave action kept the traps bouncing up and down off the bottom, and became more of a fish deterrent rather than a collection device.

Hand nets were not used in the estuary for most collections, as this method required SCUBA divers to be in the water. I deemed this logistically unnecessary, as my fish traps were an effective and efficient way of collecting fish within estuarine sampling sites. However, tests for sampling gear bias were conducted. To investigate whether fish length, age or species differed between methods, I collected samples
using both gear types within the estuary. Two separate, two sample T-tests were conducted to examine differences between length and age of fish captured among gear types. Neither result was statistically significant (p=0.29,0.53 respectively).

*Species identification*

Young-of-the-year (YOY) rockfishes are extremely difficult to classify to species using morphological characteristics (Laidig and Adams 1991, Love et al. 2002, Moser 1996, Rocha-Olivares 1998). The 14 rockfish species of the subgenus *sebastomus* (including blue, black and yellowtail rockfishes) are particularly difficult to separate by usual taxonomic methods (Li et al. 2006). Alternative methods of classification such as biochemical assays or molecular techniques are currently the most accurate and favored means of identifying species (Gray et al. 2006, Zhuozhuo et al. 2006). DNA sequencing was utilized to successfully determine species identification of all individuals within our sample. Genetic analysis was conducted by John Hyde at the National Oceanic and Atmospheric Administration-Southwest Fisheries Science Center, La Jolla, CA.

Tissue samples were taken from the caudal fin. All tissue samples were subsequently preserved in 95% ethanol and shipped to the Southwest Fisheries Science Center for analysis. DNA was extracted from YOY rockfish samples by use of a Chelex (BioRad Laboratories) boiling technique (Hyde et al. 2005). Briefly, a portion (~1mm x 1mm) of caudal fin was placed into a 0.2ml PCR tube containing 150µL of a 10% (w/v) Chelex solution. Samples were heated in a PTC200 DNA Engine (MJ Research) to 65°C for 20 minutes and then 103°C for 25 minutes. Extractions were stored at –20°C pending further analyses.
The mitochondrial cytochrome b (cytb) gene was used to amplify DNA, using primers GluRF2 5’ AAC CAT CGT TGT TAT TCA ACT ACA AGA ACC (Hyde and Vetter, 2007) and CB3RF2 5’ CGA ACA GGA ART ATC AYT CTG G (J. Hyde unpublished) in a 10µL reaction volume containing (67mM Tris-HCl pH 8.8, 16.6mM (NH₄)₂SO₄, 10mM β-mercapto-ethanol, 2mM MgCl₂, 800µM dNTPs, 0.4µM each primer, 0.5 units Taq DNA polymerase (New England Biolabs), and 50-100ng of DNA template) and amplified using the following temperature profile in a PTC200 DNA Engine (MJ Research); 94ºC (2:00), 35 cycles of [94ºC(0:30), 59ºC(1:00), 72ºC(1:00)], followed by three minutes at 72ºC. All PCR batches contained at least one no template negative control to monitor for possible DNA contamination. Products were electrophoresed through a 2% (w/v) agarose gel in 1 X Tris-Borate-EDTA buffer, stained with ethidium bromide and visualized via an UV-transilluminator. Reactions were digested using ExoSAP-IT (USB Corp.) to remove unincorporated primers and deoxynucleotides prior to cycle sequencing. Products were cycle sequenced with the internal primer CBinR3 5’ ATG AGA ART AGG GGT GGA AGC T, using BigDye v.3.1 Dye Terminators and analyzed on an ABI 3130XL automated capillary sequencer (Applied Biosystems). DNA sequences were edited using Sequencher v4.5 (GeneCodes, Inc).

The obtained sequences were combined with a data set of reference sequences representing multiple individuals of all species of Sebastes found in the northeast Pacific (Hyde and Vetter 2007, J. Hyde unpublished data). The resultant sequence alignment was subjected to phylogenetic analysis using a simple measure of genetic distance (Kimura 2-parameter) within the PAUP*(v4.b10) (Swofford 2001)
framework. To assess statistical support values for the nodes, a nonparametric bootstrap resampling scheme was applied. Species identifications were determined by assessing the degree of bootstrap support for groupings of sequences of the unknowns against the reference dataset. All groupings that had >80 bootstrap support were taken as valid for species identifications.

**Age and Growth Analysis**

Numerous studies have validated daily otolith increment formation in YOY rockfishes: (Boehlert and Yoklavich 1987, Johnson et al. 2001, Kokita and Michio 1999, Kokita and Omori 1998, Laidig and Adams 1991, Plaza et al. 2001, Woodbury and Ralston 1991). Back-calculated birthdates and settlement dates were determined for juveniles spanning the entire size range collected. Sagittal otoliths were removed and dried using standard techniques (Campana 1984a, b, Laidig et al. 1991). All unclear, abnormally shaped otoliths were discarded from the sample and the left sagittal otolith from each fish was used for birth and settlement date determination. All otoliths were mounted in Crystal-Bond™ mounting epoxy and sanded using 1200 grit CrossFIRE™ sand paper. Otoliths were then polished using Buehler Gamma micropolish II™ and buffed for ease of reading. Otolith reading was then conducted following standard protocols (Laidig and Ralston 1995, Secor and Dean 1992). Otoliths were examined using a Micromaster I Fisher Scientific™ digital microscope connected to Image Pro Express™ software. All otoliths were viewed using a 100X magnification oil-immersion lens. Using the Image-Pro image™ analysis system, I enumerated increments along the anterior dorsal portion of the otolith from the core to settlement, and subsequently to the outer edge (capture date). Extrusion dates were calculated by subtracting total estimated age from capture date. Timing of settlement
was subsequently determined by adding the number of increments between the extrusion check mark and the settlement check mark. Otoliths were collected from all fish within the sample, however only otoliths with distinct extrusion and settlement checks were included in the growth analysis (N=140).

**Analytical Methods**

I conducted consistency analyses to determine the level of agreement between repeated otolith reads. Two separate statistical indexes were used to determine the validity of the interpretation. The coefficient of variation (CV) (Chang, 1982) for this analysis was 3.5%. There is no threshold value for accepting or rejecting readings, though Laine et al. (1991) suggests a maximum CV value of 5% for acceptable readings. For a thorough description of my consistency analysis, refer to Appendix 1 of this thesis.

Growth was estimated by dividing each fish’s standard length by its age in days (mm d\(^{-1}\)). This provides a metric that includes all phases of growth from parturition through post-settlement. Giving that only 10-15% of the variability in growth occurs in the larval and pelagic life stages in rockfish ((Laidig et al. 1991); Stephen Ralston NOAA, *personal. comm.*), this metric captures the portion of post-settlement variability that is most interesting for the investigation of habitat-specific growth rates. I utilized the two sample t-test to test the hypothesis that mean growth did not significantly differ among species and among years, and ANOVA to test the hypothesis that mean age, birth date, settlement date, length and growth did not differ among habitats.
Figure 4: Schematic of analytical method procedure for age, length, birth date, settlement date and growth analysis.
Results

Over two years of sampling (2004-2005), I collected a total of 323 rockfish of 4 different species: 205 black, 104 blue, 5 yellowtail and 4 widow. Collection dates ranged from 18 June until 24 September 2004, and between 25 June and 15 August 2005. Average size of fish increased through the sampling season during both years, indicating that I was following a cohort of post-settlement juveniles through time (Figures 5 & 6).

Figure 5: Black rockfish length, collection date and habitat distribution 2004-2005
Species composition, length and collection date within nearshore sampling sites 2004-2005.

**Species composition by habitat**

The presence or absence of a target species is the simplest way to define habitat, and can be useful when investigating species’ range boundaries. Most of the fish captured were black rockfish from the estuary traps (Figures 5,7). No black rockfish were collected from our nearshore sampling site in either 2004 or 2005. Estuary samples were also almost exclusively black rockfish, indicating that this species is common in Yaquina Bay or is particularly attracted to minnow traps. Trap catches were highest in dock/piling and rock/boulder habitats (Figure 9.) Nearshore hand net samples were dominated by blue rockfish but had much more variability in species composition. Surprisingly, there were no black rockfish in the nearshore samples, although this habitat is listed as common for juveniles of this species (Love et al. 2002).
Figure 7: Proportional contributions of each species within estuarine and nearshore sampling locations, 2004 & 2005.

Settlement timing

Settlement dates for all species based on otolith examination ranged from March 29th to July 11th in 2004 (N= 68) and from April 6th to July 9th in 2005 (N=39). Settlement in the nearshore habitat was later than it was in the estuary in both years. Black rockfish settlement ranged from 29 March to 11 July in 2004 (N=37), and from 5 April until 17 June in 2005 (N=29). Blue rockfish settlement ranged from 6
April until 9 July in 2004 (N=31) and from 13 May until 17 June 2005 (N=8). Only two yellowtail rockfish had settlement checks on the otoliths that enabled their inclusion in the settlement analysis. Settlement dates for those fish were 11 and 24 April, 2005. The solitary widow rockfish within the otolith sample settled out on July 2 2004.

Figure 8a, b: Estimated settlement timing of young-of-the-year black and blue rockfishes, April-July 2004-2005.
Settlement dates of black rockfish were normally distributed during both sampling years, indicating that I was sampling one distinct cohort through time (Figure 8a). Blue rockfish settlement dates had a bimodal distribution for 2004, and a skewed distribution for 2005 (Figure 8b). This may indicate that I was sampling two separate recruitment pulses within the nearshore; however this is more likely a consequence of small sample sizes (N=31, 2004 and N=8, 2005)(Figure 6.).

Abundance, as estimated from catch per unit effort (CPUE) calculations, varied among years and habitats. Black rockfish were more abundant in 2004 than in 2005. Some of the highest densities were found around pilings, docks and other anthropogenic structures: CPUE decreased within rock, eelgrass, and sand habitats respectively (Figure 9). The greatest catch rates occurred at our dock piling station, which was immediately adjacent to a 20x20 foot oyster dock with nets of oysters hanging 6-7 feet from the surface of the water. The station with the lowest catch rate was over sand with only 19 total fish; captures in this area were likely due to use of the traps themselves as habitat (CH 3). Rock habitat stations demonstrated the greatest variability in fish abundance between stations of a consistent habitat type.
Figure 9: Habitat specific abundance as estimated from catch per unit effort (CPUE) for black rockfish within estuarine habitats 2004-2005. Dock pilings were consistently areas of highest abundance.
Figure 10 a, b: Temporal patterns of abundance as estimated from catch per unit effort (CPUE) for black rockfish within estuarine habitats during 2004 (a) and 2005 (b).
Blue rockfish abundance was also higher in 2004 than in 2005 (22.14 and 13.56 (fish collected per hour sampling), respectively). Both sampling sites in the nearshore were of a consistent habitat type, allowing only for examination of abundance differences between years. The synchrony of abundance differences between these two species may indicate recruitment of Oregon’s nearshore rockfishes was less successful in 2005 than in 2004. Due to extremely low sample sizes, yellowtail and widow rockfishes were excluded from the abundance and growth analyses.

Growth was not significantly different among habitats for either black or blue rockfish. (Table 2). Growth rate differences were not significant among years for either black or blue rockfish, however, growth differences were significant between species (black 0.50 mm d$^{-1}$ and blue .54 mm d$^{-1}$ (two sample-t test, T stat = -3.19, df = 133 P-value <.002).
Table 2: Biological parameter comparison among habitats using single factor ANOVA and two sample t-tests.

### Black Rockfish

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Sample Size (N)</th>
<th>Mean Age (days)</th>
<th>Mean Date of Birth</th>
<th>Mean Length (SL mm)</th>
<th>Mean Growth (mm/d)</th>
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<tr>
<td>Eelgrass</td>
<td>16</td>
<td>144.25</td>
<td>26-Mar</td>
<td>16-May</td>
<td>63.5</td>
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<tr>
<td>Max.-Min.</td>
<td>(70-181)</td>
<td>(28-Feb-25-Mar)</td>
<td>(25-Apr-11-Jun)</td>
<td>(58-68)</td>
<td>(0.38-0.86)</td>
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<tr>
<td>Dock Pilings</td>
<td>55</td>
<td>130</td>
<td>28-Mar</td>
<td>22-May</td>
<td>65.02</td>
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<tr>
<td>Max.-Min.</td>
<td>(90-188)</td>
<td>(18-Feb-9-May)</td>
<td>(12-Apr-7-Jul)</td>
<td>(54-77)</td>
<td>(0.38-0.68)</td>
</tr>
<tr>
<td>Rock/Boulder</td>
<td>15</td>
<td>129.9</td>
<td>24-Mar</td>
<td>15-May</td>
<td>63.4</td>
</tr>
<tr>
<td>Max.-Min.</td>
<td>(108-165)</td>
<td>(27-Mar-18-Apr)</td>
<td>(27-Apr-13-Jun)</td>
<td>(55-74)</td>
<td>(0.41-0.57)</td>
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<tr>
<td>F-stat</td>
<td>2.38</td>
<td>0.233</td>
<td>1.296</td>
<td>0.8361</td>
<td>2.317</td>
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<tr>
<td>DF</td>
<td>85</td>
<td>85</td>
<td>74</td>
<td>85</td>
<td>85</td>
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<tr>
<td>P-value &lt;0.05</td>
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<td>0.792</td>
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### Blue Rockfish

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<th>Habitat</th>
<th>Sample Size (N)</th>
<th>Mean Age (days)</th>
<th>Mean Date of Birth</th>
<th>Mean Length (SL mm)</th>
<th>Mean Growth (mm/d)</th>
</tr>
</thead>
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<tr>
<td>South Yaq.</td>
<td>14</td>
<td>127.89</td>
<td>7-Apr</td>
<td>23-May</td>
<td>66.14</td>
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<tr>
<td>Max.-Min.</td>
<td>(100-167)</td>
<td>(24-Feb-1-May)</td>
<td>(19-Apr-10-Jun)</td>
<td>(61-69)</td>
<td>(0.41-0.66)</td>
</tr>
<tr>
<td>Marg. Reef</td>
<td>35</td>
<td>125.8</td>
<td>4-Apr</td>
<td>2-Jun</td>
<td>67.4</td>
</tr>
<tr>
<td>Max.-Min.</td>
<td>(99-163)</td>
<td>(25-Feb-22-May)</td>
<td>(11-Apr-6-Jul)</td>
<td>(60-78)</td>
<td>(0.41-0.66)</td>
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<tr>
<td>T-stat</td>
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<td>0.455</td>
<td>1.43</td>
<td>-0.975</td>
<td>0.701</td>
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<td>DF</td>
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<td>47</td>
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<td>47</td>
<td>47</td>
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<tr>
<td>P-value &lt;0.05</td>
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<td>no</td>
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</tbody>
</table>
Figure 11: Estimated daily growth rates (mean) for black and blue rockfish 2004 and 2005.

Discussion

This study identifies estuaries as Essential Fish Habitat for black rockfish juveniles along the central Oregon coast, and nearshore reef as EFH for blue rockfish juveniles. This is valuable information for management, as black and blue rockfish form the backbone of Oregon’s recreational groundfish fishery (Conway and Opsommer 2007). This is the first study to contrast and compare nearshore rocky reef and estuarine habitat usage by post-settlement juveniles and presence/absence was an extremely useful indicator of essential fish habitat. The absence of YOY black rockfish from nearshore rocky reefs sites narrows the focus of nursery habitat to subtidal kelp beds and estuaries, challenging the currently held belief that the majority of black rockfish settlement occurs in rocky reef habitats. Although black rockfish
have been consistently found in the estuary, the question remains whether they are “estuarine dependent”, a designation that has been demonstrated for a number of flatfish species that also use estuaries (Yamashita et al. 2001, Brown 2003).

Habitat-specific densities (measured as CPUE) vary greatly among habitats within the estuary. Highly complex anthropogenic habitats within the estuary provide habitat for various species of juvenile rockfishes. Minnow traps consistently captured the largest numbers of rockfishes within areas of high habitat complexity. The larger depth range of pilings with continual contact with the surface provided a distinctive morphology that black rockfish may have been more attracted to than comparable refugia such as rock. Additionally, piling habitats offered slightly greater maximum depths (1-2m) in comparison to all other stations. It is possible that this small difference allowed juvenile rockfish to reduce the stress induced by rapid fluctuations in salinity and temperature, while remaining close to a habitat that facilitated predator avoidance. The oyster dock, next to station P2, undoubtedly provided shelter for juvenile fish, and may have been a factor contributing to the large abundances found at that station. Furthermore, CPUE estimates may be biased due to their potential to function as refugia in marginal habitat such as sand or mud. To examine this bias I conducted a number of tank experiments to testing my collection methods in differing habitat substrate (Chapter 3 of this thesis). Tank studies suggested that in highly complex habitats (dock pilings, rock), minnow traps may be underestimating the total abundance of fish within a habitat.

While previous work shows that the presence of *Macrocystis pyrifera* attached to rocky banks in the nearshore strongly influences the abundance and species
composition of local recruitment of juvenile rockfishes (Carr 1991), the similar vertical morphology of pilings may act as an attractive substitute for natural habitat within the estuarine environment. Although several studies (Buckley 1997, Love et al. 1991, Shaffer et al. 1995) have observed that juvenile rockfish strongly associate with various types of habitat (eelgrass, kelp, drift vegetation), this work shows a general gradient of greater abundance of young-of-the-year black rockfish within habitat of higher complexity and larger structure within Yaquina Bay (Fig. 4).

Growth rates of YOY rockfish in my study were slightly higher than those presented in other studies (0.50 mm d^{-1} for blacks and 0.54 mm d^{-1} for blues). Love et al. reported blue rockfish growth rates ranging from .31 to .38 mm d^{-1} from fish collected at various oil platforms and natural reefs in the Santa Barbara Channel region of California, and 0.29 mm d-1 in field studies and 0.27 mm d-1 in laboratory experiments (Love et al. 2007, Love et al. 1991). The only other published study that examines growth rates of YOY rockfishes integrated from parturition to post settlement was Johnson et al. (2001). Reported growth rates were 0.17 mm d-1 in greenstriped rockfish (S. elongatus), 0.25 mm d^{-1} in cowcod (S. levis), and 0.32 mm d^{-1} in stripetail rockfish (S. saxicola).

This work is the first to present growth rates of black rockfish in a field study. The higher growth rates seen in my study could be attributable to increased food availability provided by the highly productive upwelling off of the Oregon coast. Sampling biases associated with the timing and methods used in this study may also exist. I collected fish early in their ontogenetic development, but would expect post-settlement growth to slow as fish age to maturity. Furthermore, as fish grow they
become less susceptible to certain collection methods, thereby potentially biasing growth results. However, tests of age and sampling method effects on growth were not significant in my study, though caution should be applied when comparing my results with fish captured under different sampling protocols.

**Conclusion**

This study raises important questions about how estuarine habitats are functioning for nearshore rockfishes of the Pacific Northwest. Future studies need to investigate the proportional contribution of these habitats to the sustainability of the fishery (level 4). While black rockfish are present, abundant and growing well in estuarine habitats, proportional recruitment to the adult population remains unknown. New approaches need to examine how habitats alter vital rates, and ensure habitats are not functioning as ecological sinks. Not only does the conservation of habitats depend on protecting sites where organisms are present, it depends on protecting the ecological process occurring in these sites. This is one of the first studies to describe level 1, 2 & 3 habitat data for juvenile rockfishes, and establishes a protocol for examining EFH for commercially important nearshore species.

Footnotes:


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CHAPTER 3: TANK VALIDATION OF TRAPPING METHODS USED IN COLLECTION OF YOUNG-OF-THE-YEAR BLACK ROCKFISH (SEBASTES MELANOPS)

Introduction

Many pilot studies have used fish traps to sample juvenile groundfish. However, no previous work has investigated how the presence of these traps affects juvenile fish behavior or how adequately trap catches represent populations being sampled. More specifically, it is important to evaluate potential biases that may be caused by factors such as the size of area that traps accurately sample, whether fish caught in a trap actually remain in the trap, and whether the ability of a trap to capture juvenile groundfish varies depending on the habitat or time of day. These are important questions to consider when examining presence/absence (level 1) or habitat-specific density (level 2) inferences, as gear biases could substantially effect both qualitative and quantitative assessments of fish habitat (Able 1999).

Before beginning an intensive habitat sampling project, I thought it imperative to test for biases of two separate gear types I was preparing to use in the collection of YOY black rockfish (S. melanops) in Oregon’s estuarine and nearshore habitats.

My testable hypotheses in order of importance were:

1) Juvenile rockfish can be caught and retained in traps.
2) Capture probability is a linear function of fish density.
3) Juvenile rockfish do not show any selection preference between trap designs.
4) Habitat complexity does not affect individual capture probability.
5) Individual capture probability does not differ during the night vs. day.
By examining the performance of two trap designs in differing habitat types and fish densities, I was able to gain insight into the accuracy of my sampling devices to describe the natural system under investigation.

**Materials and Methods**

To assess the catch rate and retention of fish in different habitats, I conducted a series of tank trials with differing fish densities and substrate. Four green, 700 gallon plastic tanks (3m diameter) with approximately 1 meter of water depth were used in an open courtyard at Hatfield Marine Science Center in Newport, Oregon. Seawater was fed directly from Yaquina Bay at a constant flow with temperature ranging from 9 to 15 degrees C. Only *S. melanops* were used for the tank trials, and were the same size as individuals captured during the Yaquina Bay field trapping study, thereby matching the size and developmental stage of wild fish. I procured fish for the tank trials using hook and line, trawl, and seine to avoid fish with prior trap experience. All fish were allowed to acclimate three days before commencement of tank trials, and were placed on a euphausid diet 24 hours before the commencement of the lab experiments.

Two separate minnow traps were used in this analysis: one designed by Susan McBride (UC-Irvine), and another distributed by Aquatic Ecosystems Inc. My first set of trials demonstrated that the McBride traps did not effectively retain rockfish of the size most commonly found in Yaquina Bay, and I therefore excluded these traps from further studies (Figure 12).
For the remainder of my tank study, four adjacent tanks with different fish densities (4, 7, 14, or 28 fish) were used for each trial. A total of three trials of 4 replicates each were conducted using sand-mud, eelgrass, and rock substrate in the tanks, for a total of 4 tank x 3 habitat treatment x 4 fish density combinations. All trials were conducted for 24 hours starting at 12 pm.

**Results**

For all habitat types, catch per-unit effort markedly decreased in tanks with greater than 14 black rockfish. Trap efficiency also decreased with increasing substrate size and complexity (Figure 14 a-c). For sand-mud habitat, an average of 80% of the *S. melanops* were retained within traps for all four fish densities, while the average percent of black rockfish retained for all fish densities was lower around eelgrass (71%) and rock (53%). Black juvenile rockfish entered the traps most often.
during the evening and night periods (Fig.14) consistent with diel settlement patterns that other studies have found (Love 1991). The greatest percent of fish captured were over sand-mud habitat in comparison to rock and eelgrass, indicating that in the absence of larger size substrate, juvenile rockfish are more susceptible to the sampling device. Retention of *S. melanops* ranged from 61% to 95% in densities of 4 to 14 fish over all habitat types, while 26% to 66% of black rockfish were captured in traps with densities of 28 fish over all habitat types.

![Figure 13: Proportion of fish caught within tanks (for all 4 replicates) of four different densities of fish (4, 7, 14, and 28 fish) over all three different habitat types (rock, eelgrass, and sand-mud) over a 24hr period.](image)
A.

B.
C.

Figure 14 (a-c): Proportion of fish trapped over time for tanks of four different densities of fish (4, 7, 14, and 28 fish) and 3 substrates. Proportions are pooled totals for 4 replicates. A. Sand-mud habitat type. B. Eelgrass habitat type. C. Rock habitat type.

During July of 2004, I placed a transect of minnow traps adjacent to my piling habitat station, to test whether catch rates decrease as distance from complex structure increases. This transect began directly underneath the dock, with minnow traps spaced at 2 meter intervals from the dock pilings into the mud-sand habitat. As the distance from complex habitat increased, rockfish captures decreased markedly (Figure 15).
Figure 15: Minnow trap capture density as distance from piling habitat increased.

**Discussion**

This trap validation study shows that as habitat complexity increases, trap efficiency decreases. This may be due to the fact that in areas of low habitat complexity traps are utilized by juvenile rockfishes as a partial prey refuge, whereas in areas of high habitat complexity, juvenile rockfishes have settled in the structure already present, and do not seek out additional refugia. In addition, tank studies suggest that trapping efficiency is inversely related to habitat complexity. Continued trap efficiency studies conducted during the summer of 2005 suggest that modifications to the trap may reduce this effect; traps painted black did not show a strong reduction in trap success with increased habitat complexity and were more...
attractive to fish overall. Nevertheless, trap attractiveness is an important source of bias when used for juvenile rockfish abundance estimation (Level 2 data). Abundance estimates may be inflated in areas of low habitat complexity in the natural environment, or under-estimate the relative abundance of rockfishes within complex habitats. The reduction in catch with distance from known habitat provides some hope for this method; at least for identification of habitat boundaries. Likewise, my pilot studies of rockfish trapping in nearshore environments achieved zero catch unless traps were located precisely on rocky substrate (CH 4).

Overall, trapping is an effective sampling tool that allows researchers to capture fishes in complex environments where beach seining, trawling or direct observation is not feasible. However, future juvenile groundfish trapping investigations should carefully consider the effects of habitat on sampling efficiency and evaluate bias through controlled, replicated experiments.

**Literature Cited**


CHAPTER 4: RESEARCH RECOMMENDATIONS

During the course of my studies at Oregon State University, I have been involved in numerous research projects concerning Oregon’s coastal ocean resources. It is my sincere hope that the observations and conclusions I’ve made as a student will help fisheries managers more effectively conserve ocean resources for future generations. I believe this is an important time for refining and expanding our knowledge of how ecosystems function, and hope my studies will inspire others to continue where I’ve left off. As a new graduate student, I was amazed at the lack of information available regarding the early ontogeny of many rockfish species. I found a niche for my research, designing an intensive field project to refine the understanding of Oregon’s juvenile rockfish life history. As I became a more efficient and knowledgeable student, I was able to recognize a number of ways I could have improved my study. Study designs were not organized as efficiently as possible, and the difficult working environment of the Oregon coast certainly added to the limited scope of this project. This being said, I would like to present some recommendations for future research, in the hopes that I can keep future researchers from “re-inventing the wheel”, so to speak.

Rockfish Trapping

Through trial and error and a number of lost and broken traps, I believe we’ve established an efficient and reliable way of collecting YOY rockfishes within subtidal and estuarine environments. We tried utilizing our minnow traps in nearshore sampling sites, however, the combination of heavy seas, poor visibility and the
deployment of traps using SCUBA proved to be a logistically unfeasible way to collect data. Because our traps needed to have surface buoys attached to them, wave action kept the traps bouncing up and down off the bottom, and became more of a fish dispersion device rather than a collection device. Furthermore, it is very difficult to accurately predict the ocean conditions along the Oregon Coast, and we could not be assured of retrieving our traps in a timely fashion. Therefore, we consistently used hand nets to collect our nearshore specimens, and would recommend this method for future nearshore studies.

Expansion of study area

While my findings refine the way critical habitat is considered for nearshore rockfishes, this work is only the first step in a longer journey. Given the surprising result of absentia of black rockfish from nearshore rocky reef habitats, it is imperative that future studies confirm this pattern up and down the Oregon coast. Additionally, I am not aware of any habitat studies on nearshore rockfishes along the outer Washington coast, as all focus has been concentrated on the relatively calm inshore environment of Puget Sound. Washington’s outer coastal environment is a prime candidate for future EFH studies that utilize the methods developed during my thesis work.

While the amount of estuarine habitat available to nearshore species is limited and patchily distributed, I would submit that nearshore rocky reef habitats are almost as rare. No previous studies have been conducted on Oregon’s nearshore rocky reefs, however, other studies have collected YOY black rockfish within Oregon’s subtidal and estuarine habitats (Bloeser 1999, Bobko and Berkely 2004, Miller 2004, Miller...
and Shanks 2005, Moser and Boehlert 1991). I believe it is essential to differentiate between these habitats, as the physical, chemical and biological processes operating within each environment are extremely different. Estuaries may, in fact, be the more “essential” habitat for *S. melanops* (CH 2), and this species may even be “estuarine dependent” on Oregon’s central coast.

This research also raises interesting questions about historic habitat usage patterns of YOY black rockfish. The Yaquina Bay estuary has been modified and altered substantially. A comparison with another, more pristine estuary such as Alsea Bay, could perhaps shed some light on the historical role of estuaries as nursery habitat. Fish collected in our study were found in the highest densities near anthropogenic habitat, begging the question of whether human impacts have actually created habitats for nearshore species. This certainly seems to be the case for a number of rockfish species utilizing oil platforms along the California coast (Love et al., 2007).

**Extension of Sampling Period**

Work conducted in 2004 showed that black rockfish continue to reside in the estuary at least through September. One sampling date (9-24-04) yielded 114 rockfish within 1 trap at the dock-piling habitat for only 24 hours of soak time. Higher catch rates late in the season indicates these YOY fish are persisting in estuarine habitats well into the fall transition, and future work needs to investigate temporal usage patterns on a yearly time scale.
Level 4 data - production by habitat

Level 4 data is extremely rare in EFH description and identification studies. This useful data remains the “Holy Grail” of habitat studies, and gives specific predictions of how habitats contribute to sustainable fisheries. I believe it is possible to gather this level of information for YOY black rockfish that utilize estuaries, and linking fish recruitment within the estuary and the consequent contribution of the estuarine population to adult spawning stock biomass is essential. One way this could be accomplished is by PIT tagging a substantial number of YOY rockfish within Yaquina Bay. PIT (Passive Integrated Transponder) tags are an effective tool for monitoring fish populations of many marine species (Achord et al. 1996, Downing et al. 2001, Kern et al. 2001), including black rockfish (Parker and Rankin 2003).

The Oregon Department of Fisheries and Wildlife’s Marine Resources Program has been employing Port samplers at various coastal locations along the Oregon coast (Astoria, Garibaldi, Pacific City, Depoe Bay, Winchester Bay, Charleston, Bandon, Gold Beach and Brookings), and conduct field interviews with recreational and commercial fishermen while collecting fishery effort counts. Observers also collect other biological data on the catch; species identification, catch location, size-frequency data are all collected by port samplers. Currently, ODFW is conducting a long-term project to evaluate whether PIT tags can be used to estimate exploitation rates of black rockfish (ODFW website). Several adult fish are tagged each spring, and PIT tag scanning is conducted by port samplers at the dock to search for recovered fish. This data is then used to model population demographics, and determine whether exploitation rates are sustainable. Incorporating a juvenile demographics study into this work would be a cost-effective way to capitalize on the
sampling effort already underway, and could provide managers with insightful information about recruitment variability for this target species. I would advise to start this project soon, as we would expect to see a few years’ time-lag between when juvenile fish are tagged and when they start showing up in the PIT tag scanning data.

The goal of this thesis project was to refine essential habitat information for Oregon’s nearshore juvenile rockfishes and hopefully contribute to the prevention of substantial population declines seen in other commercially important rockfish species. It is my greatest wish that the work I’ve conducted during the completion of this thesis will help scientists continue to effectively investigate critical marine habitats, and will provide information useful for marine protected area design and implementation.

**Literature Cited**


BIBLIOGRAPHY


Brown, J.A. 2003. An evaluation of the nursery role of estuaries for flatfish populations in central California, Biology (ecology and evolutionary biology), University of California Santa Cruz, Santa Cruz, CA.


Campana, S.E. 1992. Analysis of otolith microstructure data. In Otolith microstructure examination and analysis. Edited by D.K. Stevenson and S.E. Campana. Canadian Special Publication of Fisheries and Aquatic Sciences, Ottawa, Canada. pp. 73-100.


Appendix 1: Otolith Consistency Analysis

There are many methods to test the reproducibility of results from otolith readings that determine fish age. Early work by Beamish and Fournier (1981) developed an APE index, or Average Percent Error estimation. This technique has one major disadvantage, in that it fails to take into account the standard deviation of the range of fish within the ageing analysis. Further work by Chang (1982) suggested incorporating standard deviation as a proportion of the mean age estimation, with the Coefficient of Variation (CV) method. As stated previously (CH 2), there is no threshold CV value for acceptable readings, however work by Laine et al. (1991) suggests 5% to be an acceptable threshold value.

A second index of precision developed by Chang (1982), is denoted as (D), which is simply the Coefficient of Variation divided by the square root of the number of repeated readings. D is then used to show the percent error contributed by each observation to the averaged age determination for each individual fish within the sample.

Because I had no prior experience with daily otolith ageing, I decided to conduct a pilot analysis before I rigorously conducted repeated otolith reads. My first attempt was fairly rough and computed CV and D values for otolith readings were 7.48% and 5.6%, respectively. Though these numbers are not unacceptable, I plotted accuracy agreement graphs to determine whether I should exclude this first read from my age analysis (Appendix Figure 1. a-f). Values for this first reading departed substantially from both the mean for all three readings, and the other two readings. Therefore I chose to proceed by using reads #2 and #3 for my ageing analysis. Two
separate studies support this approach for daily otolith analysis (Campana 1992, Campana and Jones 1992), and computed CV and D values for these final reads were 3.5% and 2.65% respectively.

Appendix Figure 1: Count 1 VS Mean: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.

Appendix Figure 2: Count 2 vs Mean: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.
Appendix Figure 3: Count 3 VS Mean: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.

Appendix Figure 4: Count 1 minus Count 2: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.
Appendix Figure 5: Count 1 minus count 3: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.

Appendix Figure 6: Count 2 minus count 3: Plot of consistency of otolith reads over the entire size range of fish within the sample. X-axis denotes age of fish in days, Y-axis is the departure from mean estimated age.
Appendix Figure 7: Regression of black rockfish age on growth rate. X-axis denotes estimated daily age of each fish, Y-axis represents growth rate (mm/day).

**Literature Cited**


Campana, S.E. 1992. Analysis of otolith microstructure data. *In* Otolith microstructure examination and analysis. Edited by D.K. Stevenson and S.E. Campana. Canadian Special Publication of Fisheries and Aquatic Sciences, Ottawa, Canada. pp. 73-100.

### Appendix 2: Information tables

Appendix Table 1: Sampling dates, species composition, total number and collection method

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