Distribution of the Blackeye goby, *Rhinogobiops nicholsi*, around temperate reefs along the central coast of California

A Capstone Project
Presented to the Faculty of Science and Environmental Policy
in the
College of Science, Media Arts, and Technology
at
California State University, Monterey Bay
in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science
by
Megan Kelly

May 12, 2010

Abstract

A clear understanding of how species interact with each other as well as their habitat is necessary for successful management of marine ecosystems. *Rhinogobiops nicholsi* is an abundant, small, prey species that frequents the sand/rock interface along the edge of temperate reefs from southern Alaska to Baja, and is ideal for a habitat interaction study. To quantify the extent to which the blackeye goby utilizes this sand/rock ecotone, video transects collected by a towed camera sled in 2007 and 2008 were analyzed for the presence of blackeye gobies and their spatial relationship to temperate reefs. Data were collected at several locations within the Monterey Bay National Marine Sanctuary including: Soquel/North Monterey Bay, Point Lobos, Point Sur and Piedras Blancas. A pair of 10 cm sizing lasers were used to calculate the distance between individual gobies and the nearest hard substrate. A mean distance of 0.40 m from hard substrate was calculated, indicating that the utilization of this ecotone is critical for this species. During the data analysis, a green color morph was observed, which is distinctively different than the typical beige. This color morph is hypothesized to be associated with substrate, with green individuals occurring over rock and beige over sand. Corresponding with this, there was also a statistical difference in the distance that the two colors were observed from hard substrate: green 0.14 m and beige 0.44 m. This study has enhanced the knowledge about how blackeye gobies are distributed throughout their habitat, as well as provided baseline information on the ecotones surrounding temperate rocky reefs.

Introduction

Fish-habitat associations

A clear understanding of how species interact with each other as well as their habitat is necessary for successful management of marine ecosystems (Bell et al. 1990, Syms 1995). Recognizing how fish communities are organized can provide important information for conservation and management agencies (Chittaro 2004) because understanding the nature of fish distributions can provide valuable insight into the types of processes that drive assemblage structure, or what fish are where, when and why (Syms 1995). Habitat is commonly used to explain assemblage structure. Williams and Bax (2001) describe fish habitat, as "the structural component of the environment that attracts organisms and serves as a center of biological activity." One important component of fish habitat is the structural complexity of the substrate (relief). Relief is a vital component of fish habitat, especially at finer scales (centimeters to meters), because it provides shelter from predators, nesting areas as well as food resources (Syms 1995; Williams & Bax 2001). Furthermore, the interface of two habitats creates a transition zone where species commonly overlap. While much is known about these interfaces or ecotone habitats terrestrially, there is still much to be discovered in the marine environment (Anderson 2009).

Previous studies on fish-habitat associations have shown that in temperate waters, moderate to high relief hard substrate as well as the surrounding soft sediment ecotones are important for many fish species (Auster & Lindholm 2005; Lindholm et al. 2007). These studies were based on the East Coast of the United States and incorporated many different fish species. Auster and Lindholm (2005) found that deep boulder reefs played a key role in many species lives as refuge from predators and strong currents as well as for reproduction. They also served as platforms for zooplanktivorous fishes to access the water column and for scan and pick fishes to feed on hard substrate invertebrates. The behaviors and habitat utilization characteristics that Auster and Lindholm found in 2005 can be applied to similar ecosystems off central California. Both areas have a similar make-up of substrate, rocky outcrops surrounded by soft sediment, as well as representatives from the same trophic guilds. Because these systems are so similar in substrate composition, rocky outcrops surrounded by a ring of soft sediment, the importance of these rocky outcrops can be applied to this study as well.

Ecology of blackeye gobies

The blackeye goby, *Rhinogobiops nicholsi,* is a common member of temperate rocky reef fish communities (Stephens et al. 1981; Cole 1984; Lenihan & Brooks 2006; Anderson 2009). Although considered a hard substrate associated species, blackeye gobies are often observed at the sand-rock interface surrounding reef systems, indicating that they are clearly using this ecotone (Cole 1982; Cole 1983; Cole 1984; Csepp & Wing 1999; Steele & Forrester 2002; Pondella II et al. 2005; Anderson 2009). The observations in these studies however, do not go into detail about how blackeye gobies were using the habitat, but rather state that they were observed there. Hence, the full extent to which blackeye gobies utilize this ecotone is unknown. This information could provide important insights into about the ecology of this species and ultimately the greater reef fish community. By understanding how blackeye gobies are distributed across their habitat, it is possible to extrapolate to both their predators and prey.

Distribution of blackeye gobies is related to the social structure of this species (Cole 1984). Blackeye gobies display strong site fidelity; both males and females defend territories throughout the year and territory size is strongly correlated with fish size (Cole 1984; Kroon et al. 1998; Forrester & Steele 2000; Andrews & Anderson 2004). Although, individuals compete with conspecifics, it is not uncommon for a dominant fish's territory to have smaller size class or young of the year residents (Cole 1984; Kroon et al. 1998). Individual goby territories are often randomly distributed across a landscape and are comprised of multiple shelter rocks, surrounded by an area defended by an individual fish (Cole 1984; Kroon et al. 1998). The limiting factor in the distribution and abundance of blackeye gobies appears to be the availability of shelter rocks (Kroon et al. 2000). Areas with more shelter rocks available generally have higher densities of blackeye gobies associated with them. Since larger individuals often have multiple shelter rocks within their territories, they are limiting the amount of available habitat even further (Kroon et al 2000). Although limited by available shelter rocks, blackeye gobies tend to densely populate areas in which they are found. Cole (1984) found that as many as 6 gobies (SD= 0.6) populated a square meter in some areas.

Blackeye gobies, like other small benthic fish species, are a key component of reef food webs, serving as both predators and prey (Kroon et al. 1998; Froeschke et al. 2005; Lenihan & Brooks 2006). Several larger fish species, including Kelp bass (*Paralabrax clathratus),* barred sand bass (*Paralabrax nebulifer),* copper rockfish *(Sebastes carnatus)* and olive rockfish *(Sebastes serranoides*), as well as kelp greenling (*Hexagrammos decagrammus)*, painted greenling (*Oxylebus pictus)*, have been observed feeding on blackeye gobies, or gobies were found in stomach contents (Love & Westphal 1981; Murie 1995; Love et al. 1996; Kroon et al. 1998; Parker et al. 2000; Froeschke et al. 2005; Lenihan & Brooks 2006;). However, the extent to which blackeye gobies are incorporated in these species' diets is unknown. All of these species, except the greenlings, are key components of recreational fishing throughout nearshore California waters (Love & Westphal 1981; Love et al. 1996; Parker et al. 2000). Through understanding where blackeye gobies are, we can extrapolate that information onto where these larger predators may also reside, or at least feed.

Gobies also play a predatory role in reef ecosystems, feeding on small benthic invertebrates, like amphipods and polychaete worms, as well as zooplankton (Kroon et al. 1998; Lenihan & Brooks 2006). Because of their role in the food web, as well as their relative abundance, blackeye gobies have been used as a model reef fish in studies conducted in the Santa Barbra Channel to determine the impact of removing oil platforms on the surrounding fish communities (Lenihan & Brooks 2006). They have also been ranked in the top third with respect to community importance because of their relative abundance by Stephens and Zerba (1981). For these reasons, blackeye gobies were a perfect organism for this habitat interaction study.

Divergent color morphology among individuals of the same species has been documented in many marine reef fishes (DeMartini and Donaldson 1996). In some cases, the divergence is a result of genetic isolation, sexual dimorphism or habitat type (DeMartini and Donaldson 1996; Planes and Doherty 1997). Until the mid-1980s, blackeye gobies were not believed to be a species that demonstrated divergence with respect to color morph. In 1984, Cole commented on blackeye gobies having the capability of rapidly changing from the usual pale tan to a pale orange or dark brown. This color morph was documented in Vancouver British Columbia at depths from 3 to 20 m, but no further investigations were conducted to investigate the reasoning behind the color.

The information provided by this study focus on the fine-scale movements of a small temperate reef fish. However, the movements and habitat utilization of this one species has implications both up and down the food chain. Understanding patterns such as the ones observed in this study are key to effective marine spatial planning because they provide information on where fish are and how they are using their habitat. This information is essential in determining what areas to protect as well as how much protection they should have. An example of this can be seen in the Monterey Bay National Marine Sanctuary (MBNMS). The MBNMS was established in 1992 and is currently mandated by the 2000 reauthorization of the Sanctuaries Act to conduct a complete site characterization by 2010 (MBNMS 2008). A site characterization is a way to classify all species and habitat types represented within a given area, in this case the MBNMS. The Act includes funding for each sanctuary to conduct a site characterization, which includes information on all species and habitat types within the sanctuary (MBNMS 2008). This Act recognizes how important information about both the biological and habitat components is in order to get a complete picture of what is being protected.

The main goals of this study were to 1. Describe the distribution of blackeye gobies in central California, 2. Quantify the distance the blackeye gobies travel away from hard substrate into surrounding ecotones and 3. Explore the relationship between the observed color morph and substrate. The information resulting from this study has added knowledge about this species and will also be incorporated into the MBNMS's site characterization, adding information about one of the species that is resident throughout the sanctuary. By understanding how *R. nicholsi* are distributed across temperate reefs as well as the surrounding sandy substrate within the MBNMS, both scientists and policy makers can better understand the reef system as a whole.

Methodology

Study Sites

Data on the distribution of blackeye gobies were collected in 2007 and 2008 at four locations along the continental shelf of central California (Figure 1). The first study site is Soquel/North Monterey Bay. This area encompasses both shallow and deep soft sediment habitat that is dotted with rock ridges and low terraces (CDFG 2007; Starr & Yolkavich 2007). The second study site, Pt. Lobos, is dominated by high relief granitic outcrops and pinnacles with lower relief cobble and sand fields (CDFG 2007; Starr & Yolkavich 2007) Pt. Sur is the third study site. This site is comprised of high relief rocky outcrops surrounded by sand or cobble bottom (Starr & Yolkavich 2007). Piedras Blancas, the fourth study site, is made up of high relief rock outcrops and jagged pinnacles reaching into the water column, as well as shallow soft substrate (CDFG 2007) . For all four sites, data were collected over moderate-relief rocky substrates and adjacent low-relief sand habitats from the 30m to 100 m isobaths, encompassing much of the depth range of blackeye gobies.

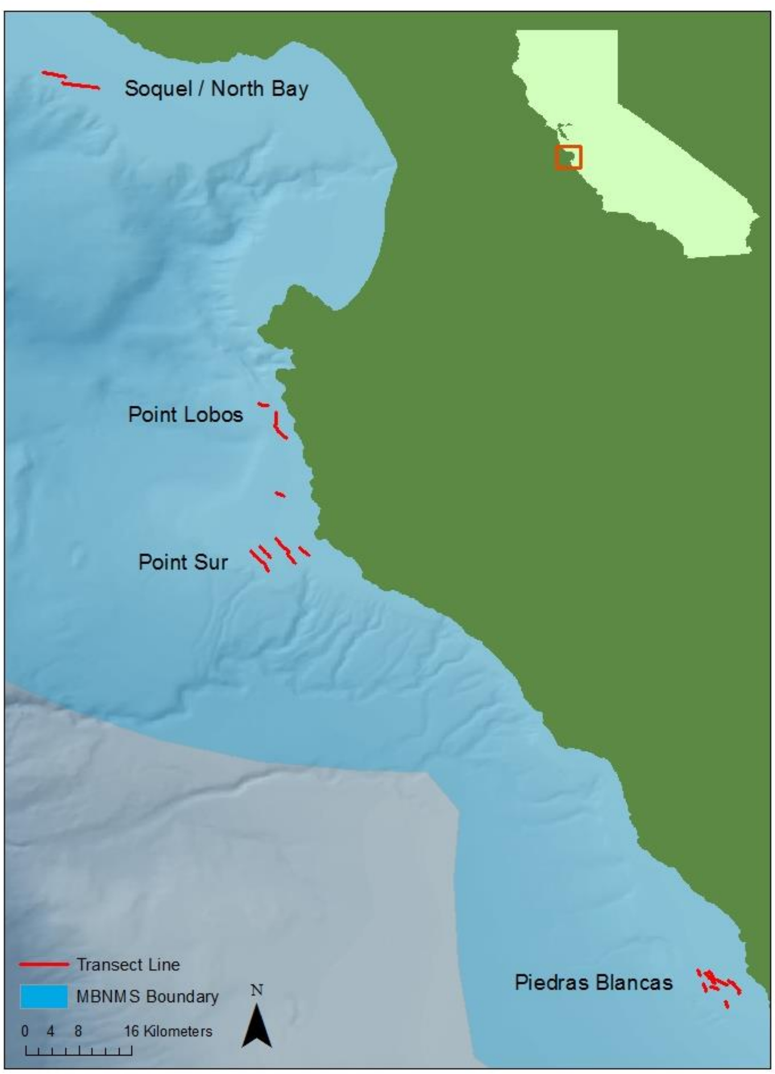

Figure 1: Map of the study areas within the MBNMS, including the transect lines and the boundaries of the MBNMS.

Towed Camera Sled

Continuous video imagery was collected using a towed camera sled (Figure 2) deployed from the *RV Fulmar* (owned and operated by the MBNMS; Figure 2 inset). The towed camera sled consists of an aluminum frame protecting a video camera, lights, sizing lasers, and navigational equipment. The sled is connected to the boat via a winch wire, which is used to control the altitude of the sled off the bottom. There is also a 300 meter armored coaxial cable that feeds live footage topside to the winch operator and data collectors. Towed camera sleds provide scientists with a non-extractive method of collecting information about the seafloor and are able to go beyond depths safe for SCUBA (Stein et al. 1992; Calliet et al. 1999; Barker et al. 1999). This platform can be used to ground truth or validate habitat types as well as species-habitat associations (Stein et al. 1992; Calliet et al. 1999; Barker et al. 1999).

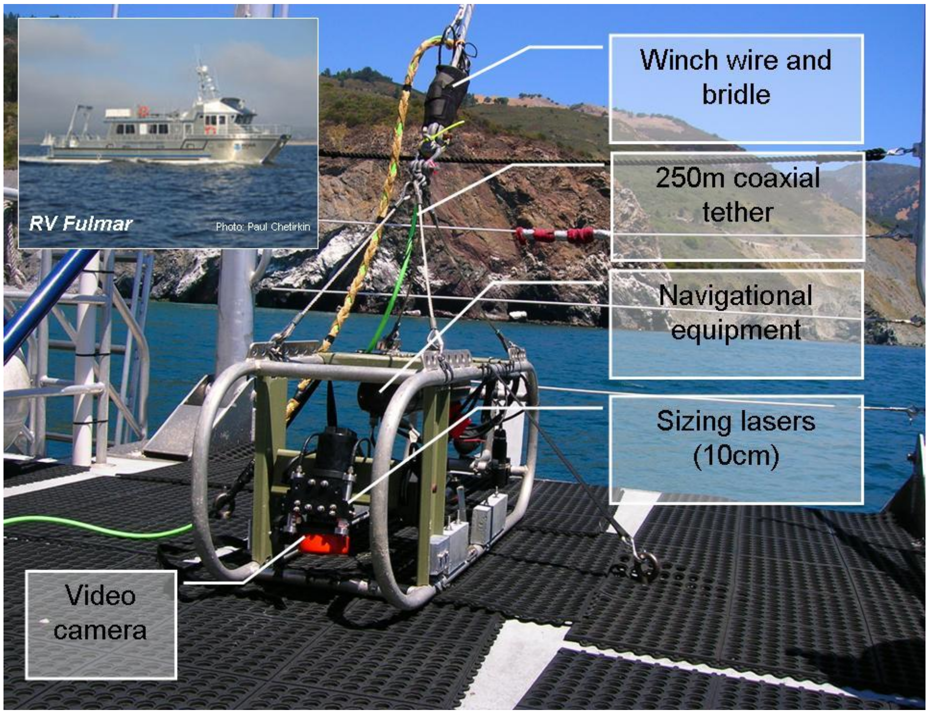

Figure 2: Towed Camera Sled, Inset: *RV Fulmar* (Photo: Ashley Knight)

Data Collection

A total of 29 video transects were analyzed from 2007 and 2008. All video transects were approximately 65 minutes in length, conducted at an average speed of 1 knot and covered a distance of approximately 1 kilometer. Data were extracted from video imagery as individual fish were encountered. When an individual goby was observed, the time, color morphology of fish, substrate type, relief, and water depth were recorded. Substrate type was characterized as hard or soft sediment. To differentiate from a pebble or a rock wall, relief was recorded as low, medium or high for hard substrate and flat or moderate for soft substrate using Green et al.'s classification method (1999). Water depth was recorded by a depth sensor on the sled and was provided on the video screen overlay. If gobies were observed on soft substrate, the approximate distance from the individual to the nearest hard substrate was measured using the 10 cm paired sizing lasers. If hard substrate was not in the paused frame, the time from the individual to the nearest hard substrate on the transect was recorded and converted into distance using the approximate speed of the boat.

Data Analyses

Two hypotheses were investigated:

H01: The distance that blackeye gobies span from hard substrate is consistent among study sites.

Alternative: The distance that blackeye gobies span from hard substrate varies with among study sites.

H02: Fish color morph is associated with the substrate on which the individual is observed, with green individuals occurring over hard, rocky substrate and beige individuals occurring over soft, sandy substrate.

Alternative: There is no association between fish color and substrate.

Hypothesis 1: Distance from hard substrate

First, a Mann-Whitney U test was used to evaluate whether the distance that each color morph was observed from hard substrate was statistically different between study sites. Non-parametric Mann-Whitney U tests had to be performed because the data did not meet all of the assumptions of normality.

Then, all data were complied by color and a second Mann-Whitney U test was run to see if there was any difference in the distances from hard substrate for each color morph among sites. The Point Lobos study site was excluded from all of the Mann-Whitney U analyses due to a low sample size.

Hypothesis 2: Color-habitat associations

Data were analyzed to quantify any association between observed color morph and substrate. The Chi-square test was used to evaluate any association. First, the test was used to see if there was an association with all study sites combined. This first Chi-square determined if there is an association between color morph and substrate, and if this association is seen in all study sites.

Sites were then separated and analyzed for associations individually. Finally, the Chi-square test was conducted using both relief and substrate, to determine the driver behind any associations at a finer scale; relief and substrate or just substrate.

Results

Hypothesis 1: Distance from hard substrate

When the distance that blackeye gobies traveled from hard substrate were compared, Soquel (mean= 0.13; SD= 0.13) was statistically different from Point Sur (mean= 0.42; SD= 0.95) (p= 0.020) and Piedras Blancas (mean= 0.39; SD= 0.82) (p= 0.001). Point Sur and Piedras Blancas were not significantly different (p= 0.303) (Figure 3).

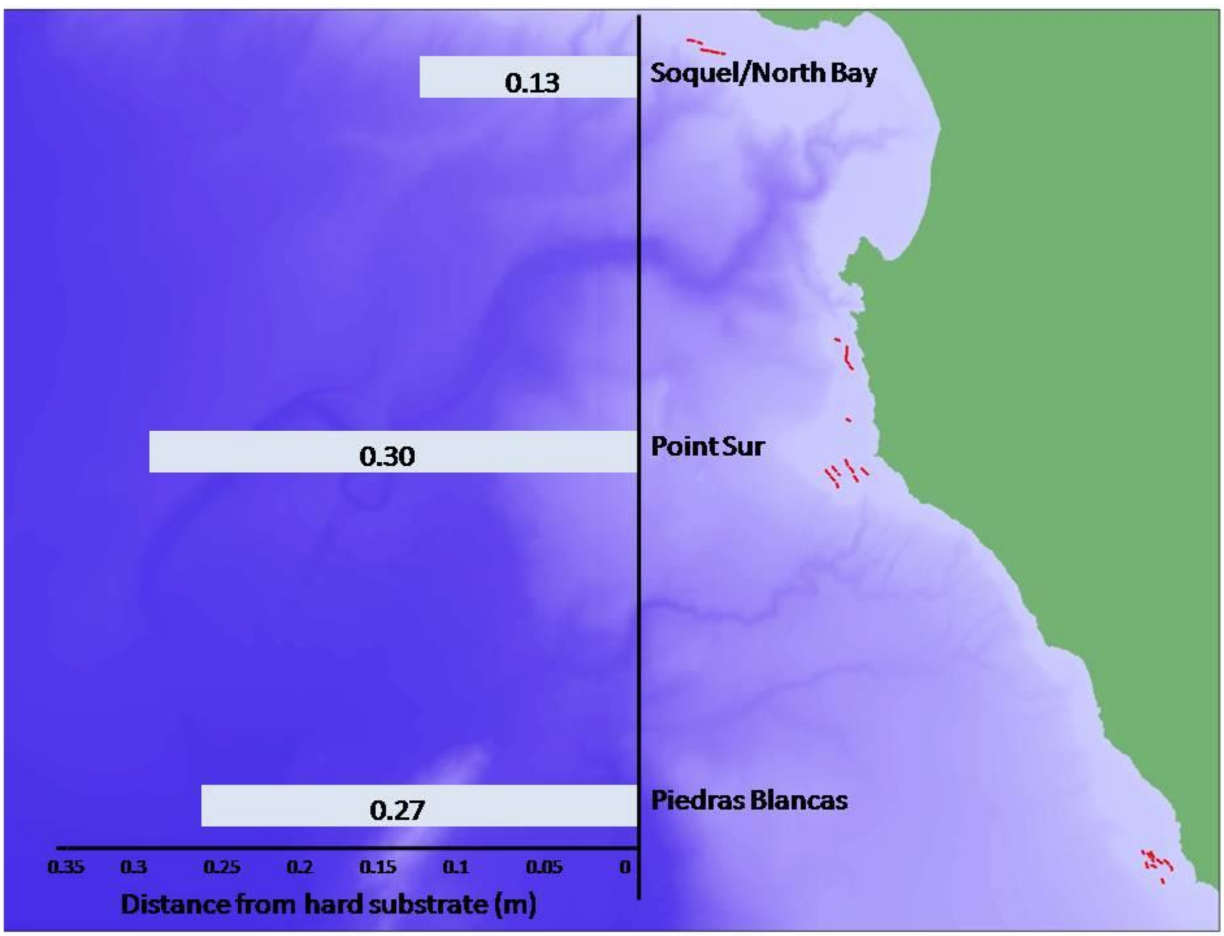

Figure 3: Mean distance gobies traveled from hard substrate for Soquel, Point Sur and Piedras Blancas.

The two color morphologies were observed over different habitat types (Figure 4).

Figure 4: Two observed color morphs observed in this study. The typical beige color can be seen in the left picture, while the new observed green color can be seen in picture on the right.

The mean distance that each color morph was observed from hard substrate, for the entire study region, is shown in Figure 5. Beige gobies were observed a mean distance of 0.44 m (SD= 1.0) from hard substrate, while green gobies were observed a mean distance of 0.14 m (SD= 0.2) from hard substrate.

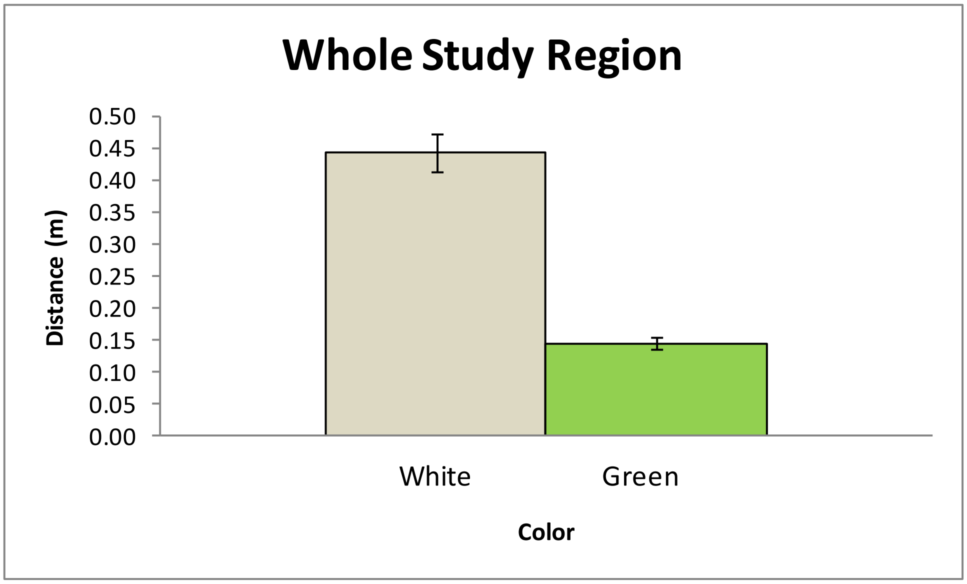

Figure 5: Mean distance from hard substrate for green and beige gobies for entire study region with standard error bars.

When the observations were separated by the four study sites, this same general trend of beige gobies further from hard substrate was true for all sites except Point Lobos (Figure 6). For Point Lobos, green gobies had a greater mean distance (mean= 1.5 m) than beige gobies (mean=0.78 m; SD=1.6), but there was only one recorded green goby over soft sediment in Point Lobos.

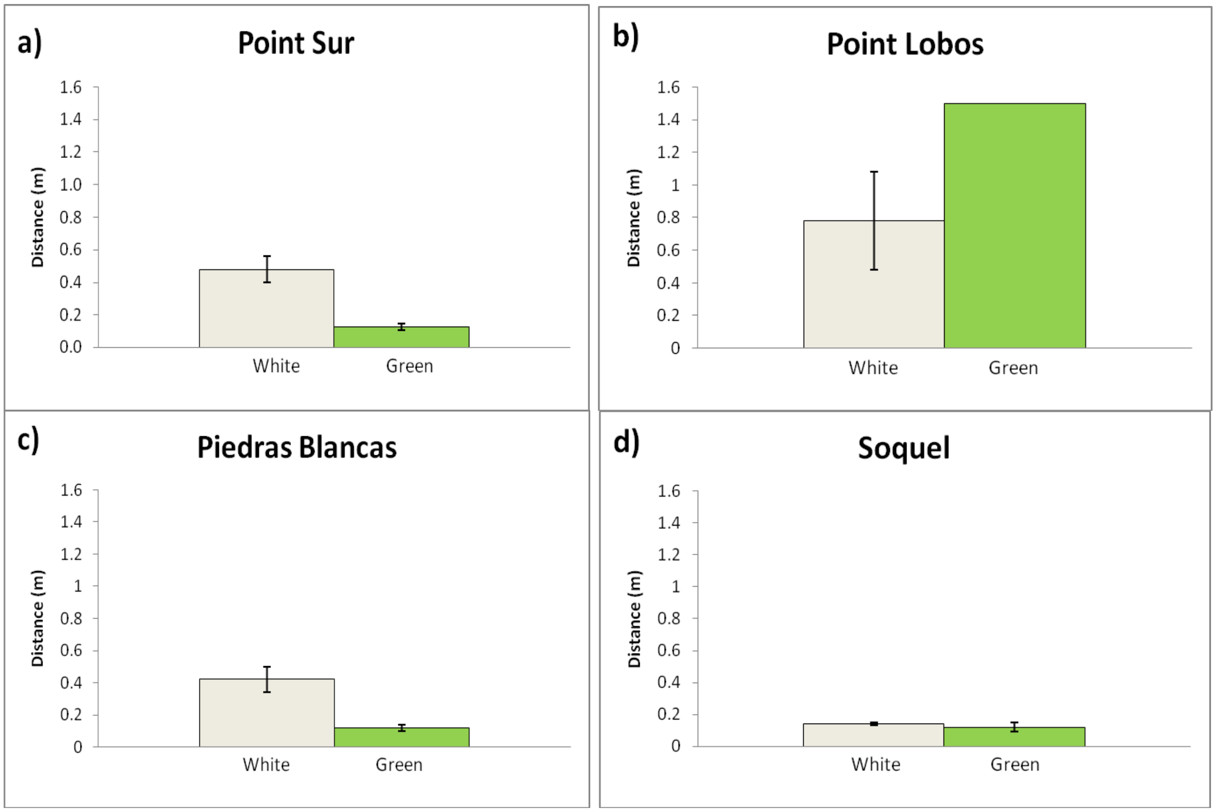

Figure 6: Mean distance in meters with standard error bars for green and beige gobies from hard substrate (a) Point Sur, (b) Point Lobos, (c) Piedras Blancas and (d) Soquel. Note that Point Lobos only had one green goby observed and therefore no standard error could be calculated.

The results from the Mann-Whitney U test indicated that the distances beige gobies travelled from hard substrate in Point Sur (mean= 0.48 m; SD = 1.0) and Soquel (mean = 0.14 m; SD = 0.13) were significantly different (p= 0.000). This was also true for beige gobies in Piedras Blancas (mean= 0.42 m; SD= 0.88) and Soquel (p= 0.000). There was no difference in the distance of beige gobies when Point Sur and Piedras Blancas were compared (p= 0.227). The distance for green gobies was not statistically different for any of the sites. Point Lobos was omitted from the Mann-Whitney U analysis due to a low sample size.

Hypothesis 2: Color-habitat associations

Green gobies were observed more over hard/rocky substrate, while beige gobies were observed more over soft/sandy substrate. The distribution of individuals of both color morphs over the two substrate types for the entire study region can be seen in Figure 7. Here, it is clear that the proportion of beige gobies over sand substrate is greater than the proportion of green over soft sediment. On the other hand, the proportion of both colors was similar over rock substrate. A Chi-square showed that there was a significant association between color and substrate (p= 0.000).

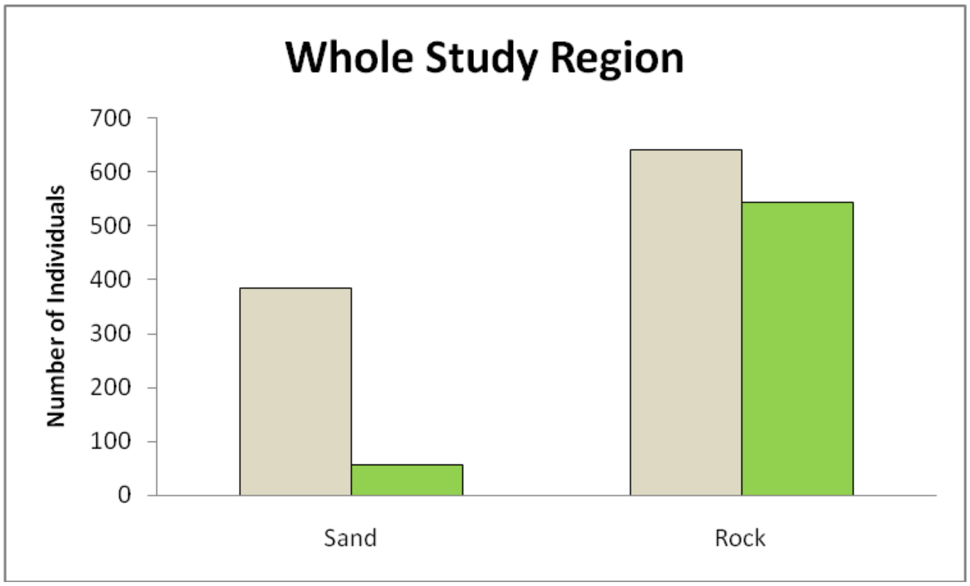

Figure 7: Number of individual green and beige gobies over sand and rock substrate for the entire study region.

A similar pattern is seen when the distribution of color is seperated by study site (Figure 8). For all study sites, proportion of beige gobies was much higher than green over sand substrate, while they were distrubuted more uniformly over rock substrate. Chi-square results for individual sites varied in significance, with Point Sur, Point Lobos and Piedras Blancas all having significant associations (p= 0.000). Soquel however, did not have a significant association between color and substrate (p= 0.190).

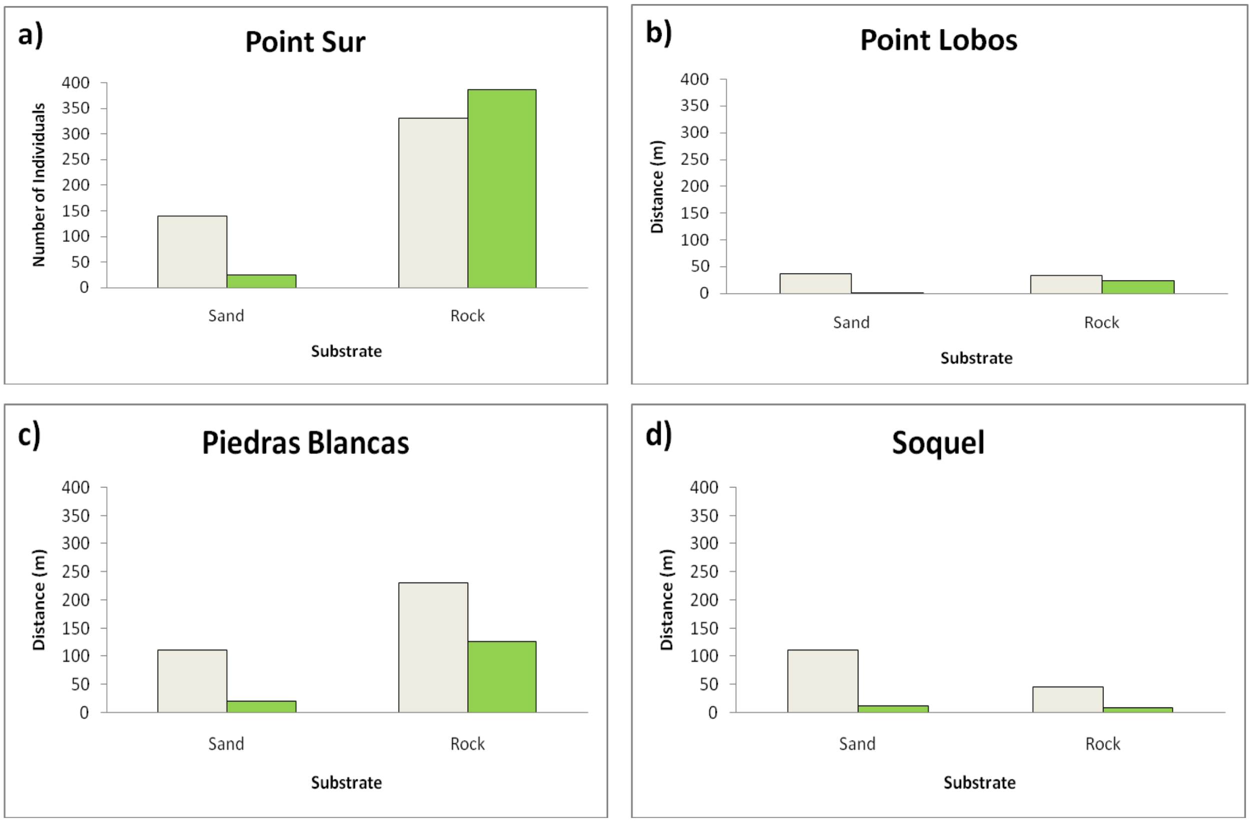

Figure 8: Number of individual green and beige gobies over sand and rock substrate for (a) Point Sur, (b) Point Lobos, (c) Piedras Blancas and (d) Soquel.

The percentage of beige to green gobies over both substrate and relief show that as high-relief rock substrate transitions into lower-relief sand, the relative abundance of beige gobies increases (Figure 9). The inverse is true for green gobies, their relative abundance increases as sand substrate turns into rock and the relief increases. The association between color and substrate was still significant when relief was added to the Chi-square analysis of the whole study region ($p = 0.000$).

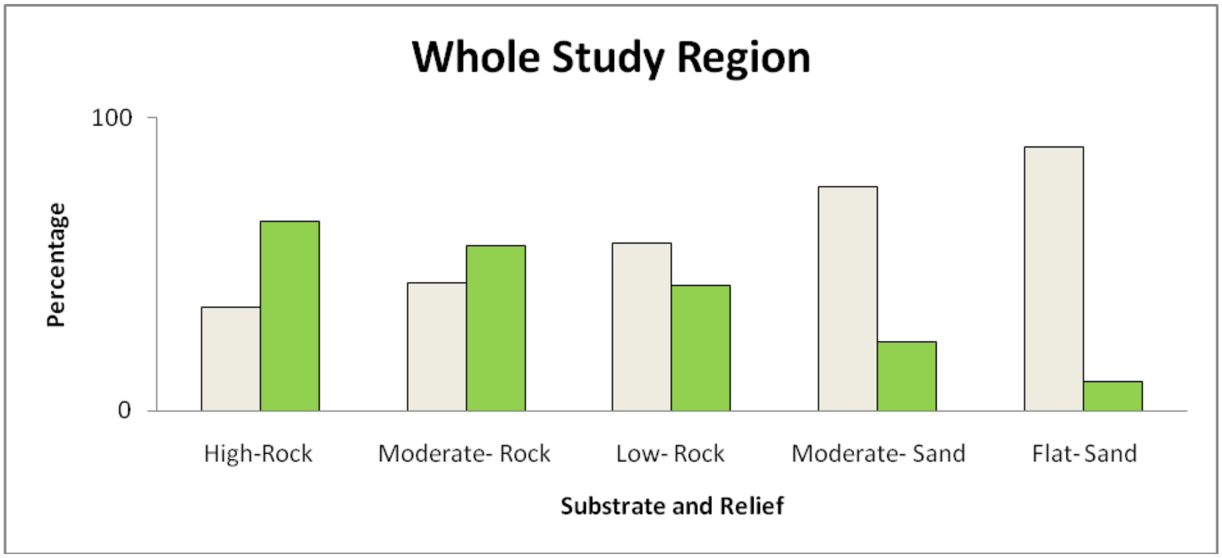

Figure 9: Combined proportion of green and beige gobies over different relief for all four study sites.

When observations were apportioned by study site, the pattern of green gobies decreasing in relative abundance as substrate changes to low relief soft sediment and beige gobies increasing with this change in substrate was only observed in Point Sur and Piedras Blancas (Figure 10). However, the Chi-square analysis showed that there was an association between color and substrate/relief for Point Sur, Soquel and Piedras Blancas (p= 0.000). Point Lobos did not have a significant association between color and substrate with relief (p= 0.094).

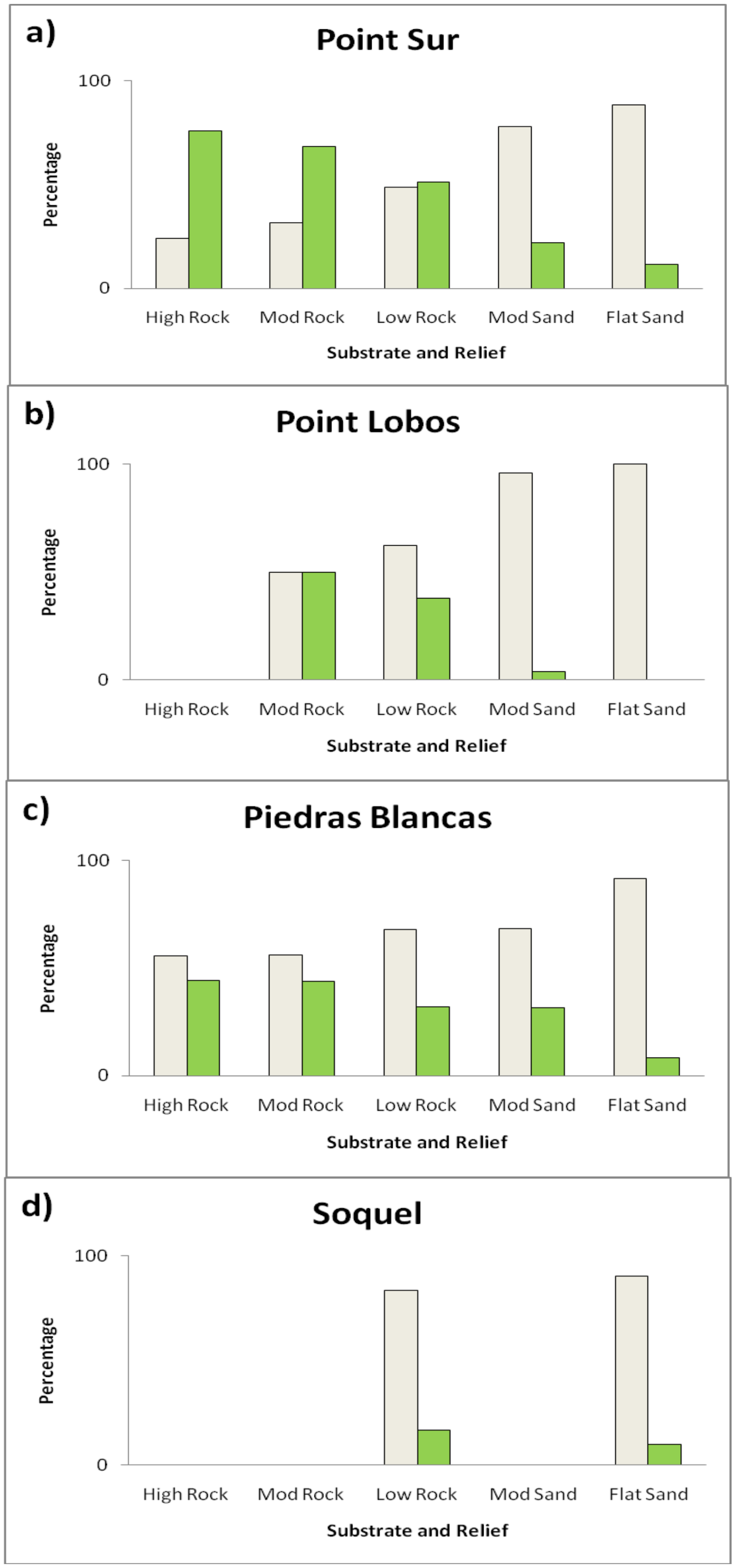

Figure 10: Proportion of green and beige gobies over different relief for all four study sites (a) Point Sur, (b) Point Lobos, (c) Piedras Blancas and (d) Soquel.

Discussion

There appears to be a difference in the distance that gobies span from hard substrate among study sites, with blackeye gobies sticking closer to hard substrate in Soquel and going further in both Point Sur and Piedras Blancas. The current project has observed blackeye gobies at depths from 35 to 104 m; far deeper than earlier studies where the color morph was first described (Cole 1984). This study was also conducted in a different region, the central coast of California compared to Vancouver B.C. Along with these differences, the observed color morph is also different. Instead of pale orange or dark brown, observed by Cole (1984), gobies in this study were observed displaying a bright green color as well as the typical beige. This study also found that there is significant variation in the distance that the color morphs span onto soft substrate, with beige gobies venturing out almost four times further than green gobies. The observed color morph also has an association with habitat type, with green gobies associated with hard/rocky substrate and beige gobies associated with soft/sandy substrate. Although different blackeye goby color morphs have been observed previously, there have been no prior habitat association analyses conducted to see if there is a possible association.

Hypothesis 1: Distance from hard substrate

The variation among study sites in the distance that gobies traveled from hard substrate can be attributed to numerous factors (Figure 4). One possible driver that emerged in this study is the observed color morph. Beige gobies appear to be the main drivers behind this difference among study sites. When the dominant habitat types of the study sites are compared, a difference in the distance the gobies span onto sandy substrate was observed. Soquel, which is significantly different from both Point Sur and Piedras Blancas, is dominated by low relief soft sediment. The rocky substrate that is there is also lower relief. Because of this, gobies are sticking closer to the little rocky substrate that is there. However, in both Point Sur and Piedras Blancas, rocky substrate is prevalent and mainly higher relief. Here, gobies ventured out onto sandy substrate almost four times further than Soquel. In these areas, hard substrate is everywhere, there are more escape routes that a goby in Point Sur or Piedras Blancas could take to avoid predation; there are more options. Green gobies stayed closer to rocky substrate because they are very conspicuous over sand and most likely attract predators. The mean distance that green gobies were observed from hard substrate for all study sites was approximately 0.12 m, or roughly one body length. This distance is critical for a prey fish that stands out against sandy substrate. One body length away from shelter is a large contrast to three or four body lengths observed for beige gobies. Because beige gobies are more camouflaged against the sandy substrate, they are more suited to live there with little chance of being spotted by visual predators, such as kelp bass, barred sand bass, copper rockfish and olive rockfish; all of which are key components of recreational fishing throughout nearshore California waters (Love & Westphal 1981; Love et al. 1996; Parker et al. 2000). Understanding where blackeye gobies are and what habitats they are associated with can provide managers with insight on where these recreationally important species may be located. These data provide a starting point for future studies on these predator species. They all have been observed feeding on blackeye gobies (Kroon et al. 1998; Lenihan & Brooks 2006), and therefore must also be utilizing the sand/rock ecotone to some extent.

It is important to understand how species are utilizing these ecotone habitats because they are an integral part of the landscape (Risser 1990). Ecotones have been predominantly described for terrestrial scenarios, but their definition can easily be translated into the marine environment. These areas are unique in that they combine attributes from their neighboring habitats, while adding their own traits and qualities (Risser 1990; Gosz 1993). Because these ecotone habitats are unique in their composition and accommodate such rich assemblages of species, great attention should be paid to protecting their integrity (Smith et al. 1997). The mean distance that beige gobies were observed was approximately 0.45 m from hard substrate, when all study sites were combined (Figure 5), indicating that the ecotone between the sand and rock substrates is well utilized by blackeye gobies. When study sites were separated, the mean distance varied among sites dramatically, from 0.14 m in Soquel to 0.48 m in Point Sur (Figure 6). Although the mean distance for beige gobies was variable, the mean distance for green gobies was fairly stable; approximately 0.12 m for all sites (Figure 6).

Hypothesis 2: Color-habitat associations

There is an association between fish color and substrate for the entire study region (Figure 7), and this same association is seen when the sites were analyzed individually, excluding Soquel (Figure 8). Associations between animal color morphs and their habitat have been well documented both terrestrially and in the marine environment (Lindquist 1980; Brodie 1992; Chang & Emlen 1993; Kohda & Hori 1993). These associations are often displayed in a polymorphic population, where factors such as sexual selection and predation shape the community structure (Caine & Sheppard 1954; Lindquist 1980; Brodie 1992; Chang & Emlen 1993; Kohda & Hori 1993; Forsman & Appleqvist 1999). Along with substrate type (soft or hard), relief is also a main component of habitat type because it allows for a more accurate depiction of the landscape. There was an association between color when substrate and relief were combined, except for Point Lobos (Figures 9 & 10). Phelan et al. (2001) found that with newly settled winter flounder (*Pseudopleuronectes americanus*), sand grain size had an effect on their distribution, indicating the importance of relief, even at very fine scales. In the case of the flounder, relief was associated with particular prey types, where as with blackeye gobies, relief is important for prey capture, predator avoidance and reproduction (Phelan et al. 2001).

The lack of association in Soquel (Figure 8) may be attributed to a low sample of green gobies in comparison to beige. Soquel is predominately soft substrate with small outcrops of hard bottom. Although there is no statistical significance, Soquel is dominated by beige gobies and soft substrate, alluding to a connection. For Point Lobos (Figure 10), only a one green goby was observed over sandy substrate. In both cases, a low sample size is most likely the driver behind the lack of association.

Although sexual selection, predation and habitat are often the main drivers behind polymorphism, other physical factors such as depth or geographic location may also have an effect (Lindquist 1980; DeMartini & Donaldson 1996) and were taken into account in this study. Depth was immediately ruled out because both color morphs were observed at all depths encompassed by this study, 35 m-104 m. Proportionally, there were more green gobies observed in the southernmost study areas, Piedras Blancas and Point Sur, indicating the possibility of a latitudinal difference in the color morph distribution. Although there were more green gobies observed in these areas, the substrate composition is very different in the southern regions from the northernmost study site, Soquel. Because there was no site with comparable habitat to Point Sur or Piedras Blancas, in the north, this pattern could be an artifact of the study.

Another factor governing the differences in the distribution of the two color morphs is natural selection through predation. Kohda and Hori (1993) described some of the selective advantages of different color morphs, which included camouflage against prey, against predators, and against food stealing organisms. Camouflage against prey consists of a predator disguising itself from potential prey items. This is most likely not the case for blackeye gobies because their diets consist mainly of zooplankton, polychaete worms, isopod and amphipod crustaceans, along with other benthic invertebrates (Lenihan & Brooks 2006). Their prey is relatively diverse and abundant in marine ecosystems, so focusing on camouflaging from each prey type is not the best usage of energy. However, it is logical for blackeye gobies to focus energy on camouflaging from visual predators (Lindquist 1980; Forsman & Appelqvist 1999; Munday et al. 2003). Gobies that blend in with their habitat are likely to have a higher survivorship and ultimately higher fitness than individuals that are not camouflaged (Chang & Emlen 1993; Munday et al. 2003). However, a more detailed study, oriented towards predator/prey interactions would be necessary to fully make these connections. Munday et al. (2003) stress in their study, that to detect the drivers behind color variants within a population, a detailed understanding of the ecology of the species is necessary.

In addition to being a prey species for recreationally important fishes, blackeye gobies are an abundant temperate reef community member. The baseline data collected in this study improves the knowledge about how blackeye gobies are distributed across temperate reef systems and their surrounding soft sediment. Numerous studies have been conducted on blackeye gobies, but they failed to explore how gobies are distributed across different habitat types. The ecotone used by blackeye gobies has potential to be important for many other species as well, both up and down the food chain. The management implications of data like these are limitless, mainly because sound data on the movement and habitat utilization of temperate reef fishes is scarce.

The demand for marine protected areas (MPAs) as conservation tools has been steadily increasing over time with the degradation of the world's oceans (Halpern 2003; Lubchenco et al. 2003). However, the design and implementation of these reserves has been largely based on social needs and political will, instead of scientific knowledge (McNeill 1994; Halpern 2003). This lack of scientific input is partly due to the lack of scientific research that is necessary for the effective placement of marine reserves (Halpern 2003; Mark Carr, personal communication). Information on where species are and what habitats they use throughout different life stages, dispersal of geographic features and substrate, as well as oceanographic processes are all necessary to make marine reserves effective, both in size and placement (Lubchenco et al. 2003; Neigel 2003). An example of this need for scientific knowledge can be seen in implementation of the Marine Life Protection Act (MLPA).

One of the goals of the MLPA is to "protect the natural diversity and abundance of marine life, and the structure, function, and integrity of the marine ecosystem" (CDFG 2007). To accomplish this, the stakeholders and science advisory team were challenged with using the best available science in the creation of the network of MPAs (CDFG 2007). Through this process however, both the stakeholders and the science advisory team quickly realized that the science needed for this process, in many cases, has not even been conducted (Mark Carr, personal communication). This was especially true for species movement throughout different life stages and their corresponding habitat utilization. The science that was available for this process was taken from all over the globe, and only a small fraction actually came from the temperate waters off the West Coast of the U.S. (Mark Carr, personal communication). This occurrence is not new to the MLPA process; many attempts at designing MPAs have concluded that there are significant gaps in the available science and our understanding of marine ecosystems (NRC 2001).

This study, although focusing on one species, is adding to the knowledge of temperate reef communities. Through this study, I was able to identify that blackeye gobies were in fact utilizing the sand/rock ecotone surrounding temperate reefs to a great extent. By identifying that this ecotone is important habitat for blackeye gobies, this study has also provided key insights on how other species may also use this area. This is important baseline data that can be used in future studies on how larger predatory fishes are also distributed across temperate reefs and their surrounding ecotones. Blackeye gobies are a prey for many larger fish species, and are abundant in the temperate waters ranging from southern Alaska to Baja (Csepp & Wing 1999), therefore it is important for scientists and managers to understand how they are distributed with respect to specific habitat types.

These data will also be provided to the MBNMS as part of their mandatory site characterization efforts. Part of the MBNMS's management plan is to "Identify key ecological interactions, including predator-prey relationships, migratory patterns, life history stages, and the role of biogenic habitat" (MBNMS 2008). This study demonstrated which habitat blackeye gobies are distributed across as well as sparked new questions for future studies on this species within the MBNMS. Through a partnership between the MBNMS and the Institute for Applied Marine Ecology (IfAME), at CSU Monterey Bay, the results from this study, as well as others, are provided directly to resource managers. This aspect of the current project is critical because managers are being provided with data on a species that is abundant throughout their Sanctuary. Aside from contributing to the mandated site characterization, the results from this study also provide baseline data that can be expanded on in the future to encompass different individual species or complete fish assemblages over temperate reefs and the adjacent ecotone. Solid baseline data is necessary because it sets the foundation for future studies to build upon. Over the years, conservation efforts have shifted from the traditional one species management plans to protecting entire ecosystems (Halpern 2003). Both scientists and managers realized that managing an entire ecosystem rather than a single species was a better solution because traditional management strategies have failed in many cases, fishery collapse (Halpern 2003). This study has provided information about a key member of temperate reef communities and ultimately added to the knowledge of temperate reef communities as a whole.

Although this study met the stated objectives, more questions presented themselves throughout the process. A more detailed study on diet, predation and reproduction is necessary to determine the specific drivers of the observed color morph. Also an experimental study on color-habitat associations would be useful to determine how strong this association is, using similar methods to Steele et al. (1998) could prove to be useful. To validate the distance results, a study encompassing a wider geographical range, which includes more comparable study areas, would be necessary.

Acknowledgements:

I wish to thank my advisor and mentor Dr. James Lindholm for all of his support and guidance throughout my undergraduate experience and for providing some amazing opportunities for me to explore the ocean; my parents, for getting me outside and sparking an interest in nature that has turned into a true passion; Ryan Bassett, for his unconditional support and love throughout this entire process; Ashley Knight and Donna Kline, for the numerous impromptu project discussions; everyone else in the IfAME Lab for all of their insights and help; as well as the crew of the RV *Fulmar*, for key support in the field during data collection and getting us home safely every day. I would also like to thank Dr. Suzy Worcester for assistance in post-processing and data analyses and Dr. Susan Alexander for providing invaluable feedback. This project would not have been possible without the support of Dr. James Lindholm and financial support from the Monterey Bay National Marine Sanctuary Program's Sanctuary Integrated Monitoring Network as well as Dr. Bill Head, director of the Undergraduate Research Opportunities Center and the McNair Scholars Program.

References

Anderson TJ ,Syms C, Roberts DA, Howard DF. 2009. Multi-scale fish-habitat associations and the use of habitat surrogates to predict the organization and abundance of deep-water fish assemblages. Journal of Experimental Marine Biology and Ecology 379:34-42.

Andrews KS, Anderson TW. 2004. Habitat-dependent recruitment of two temperate reef fishes at multiple spatial scales. Marine Ecology Progress Series 277:231-244.

Auster PJ, Lindholm J. 2005. The ecology of fishes on deep boulder reefs in the western Gulf of Maine (NW Atlantic). Diving for Science 2005 Proceedings of the American Academy of Underwater Sciences p. 91-105.

Breitburg DL. 1987. Interspecific competition and the abundance of nest sites: factors affecting sexual selection. Ecology 86(6):1844-4855.
Brodie EDI.1992.Correlational selection for colour pattern and antipredator behaviour in the garter snake *Thannophis ordinoides*. Evolution 46:1284–1298.
Cain AJ, Sheppard PM.1954. Natural selection in *Cepaea*. Genetics 39:89–116.
[CDFG] California Department of Fish and Game. 2007. California Marine Life Protection Act Master plan for marine protected areas p.33.
Chang H, Emlen JM. 1993. Seasonal variation of microhabitat distribution of the polymorphic land snail *Cepaea nemoralis*. Oecologia 93:501–507.
Chittaro PM. 2004. Fish-habitat associations across multiple spatial scales. Coral Reefs (23):235-244.
Cole KS. 1982. Male reproductive behavior and spawning success in the temperate goby *Coryphopterus nicholsi*. Canadian Journal of Zoology 60:2309-2316.
Cole KS. 1983. Protogynous hermaphroditism in a temperate territorial marine goby, *Coryphopterus nicholsi*. Copeia 1983:809-812.
Cole KS. 1984. Social spacing in a temperate territorial marine goby, *Coryphopterus nicholsi*. Marine Biology 80:307-314.
Csepp DJ, Wing BL. 1999. Northern range extensions and habitat observations for blackeye goby *Rhinogobiops nicholsii* and kelp perch *Brachyistius frenatus* in Southeastern Alaska. Alaska Fishery Research Bulletin 6(2):78-82.
DeMartini ED, Donaldson TJ. 1996. Color morph-habitat relations in the arc-eye hawkfish *Paracirrhites aractus* (Pisces: Cirrhitidae). Copeia 2:362-371.
Forrester GE, Steele MA. 2000.Variation in the presence and cause of density-dependent mortality in three species of reef fishes. Ecology 80(9):2416-2427.
Forsman A, Appelqvist S.1999. Experimental manipulation reveals differential effects of color pattern on survival in male and female pygmy grasshoppers. Journal of Evolution Biology 12:391–401.
Froeschke JT, Allen LG, Pondella II DJ. 2005. The reef fish assemblage of the outer Los Angeles Federal Breakwater, 2002-2003. Bulletin Southern California Academy of Science 104(2):63-74.
Gosz JR. 1993. Ecotone Hierarchies. Ecological Applications 3(3): 370-376.
Halpern BS. 2003. The impact of marine reserves: do reserves work and does reserve size matter.Ecological Applications 13(1):S117-S137.
Kohda M, Hori M.1993. Dichromatism in relation to trophic biology of predatory cichlid fishes in Lake Tanganyika, East Africa. Journal of Zoology 229:447–455
Kroon FJ, de Graaf M, Liley RN. 1998. Social organization and competition for refuges and nest sites in *Coryphopterus nicholsii* (Gobiidae), a temperate protogynous reef fish. Environmental Biology of Fishes 57:401-411.
Lenihan HS, Kay MC, Brooks AJ. 2006. Relative contribution of POCS oil platforms to regional population dynamics of a model reef fish, the blackeye goby *Rhinogobiops nicholsii*, in the Eastern Santa Barbra Channel Final Technical Summary Final StudyReport. U.S. Department of the Interior Minerals Management Service Pacific OCS Region.
Lindholm J, Auster PJ, Knight A. 2007. Site fidelity and movement of adult Atlantic cod *Gadus*

morhua at deep boulder reefs in the western Gulf of Maine, USA. Marine Ecology Progress Series 342: 239-247.

Lindquist DG. 1980. Aspects of the Polychromatism in populations of the Gulf of California Browncheek Blenny, *Acanthemblemaria crockeri* (Blennioidea: Chaenopsidae). Copeia 1: 137-141.

Love M. 1991. Probably more than you want to know about the fishes of the Pacific Coast. Santa Barbra, CA: Really Big Press; p.166-167.

Lubchenco J, Palumbi SR, Gaines SD, Andelman S. 2003. Plugging a hole in the ocean: the Emerging science of marine reserves. Ecological Applications 13(1):S3-S7.

McNeill SE. 1994.The selection and design of marine protected areas: Australia as a case study. Biodiversity and Conservation 3:586-605.

[MBNMS] Monterey Bay National Marine Sanctuary. 2008. Monterey Bay National Marine Sanctuary Final Management Plan prepared as part of the joint management plan review (JMPR) Volume III of IV. U.S. Department of Commerce National Oceanic and Atmospheric Administration National Ocean Services Office of National Marine Sanctuaries.

Munday PL, Evre PJ, Jones GP.2003. Ecological mechanisms for coexistence of colour polymorphism in coral-reef fish: an experimental evaluation. Population Ecology (137):519-526.

Murie DJ. 1995. Comparative feeding ecology of two sympatric rockfish congeners, *Sebastes caurinus* (copper rockfish) and *S. malinger* (quillback rockfish). Marine Biology 124:341-353.

[NRC] National Research Council. 2001. Marine protected areas tools for sustaining ocean Ecosystems. Washington DC: National Academy Press.

Neigel JE. 2003. Species-area relationships and marine conservation. Ecological Applications 13(1):S138-S145.

Parker SJ, Berkeley SA, Golden JT, Gunderson DR, Heifetz J, Hixon MA, Larson R, Leaman BM, Love MS, Musick JA, O'Connell VM, Ralston S, Weeks HJ, Yoklavich MM. 2000. management of Pacific rockfish. Fisheries 25(3):22-29.

Phelan BA, Manderson JP, Stoner AW, Bejda AJ. 2001. Size-related shifts in the habitat associations of young-of-the-year winter flounder (*Pseudopleuronectes americanus*): field observations and laboratory experiments with sediments and prey. Journal of Experimental Marine Biology and Ecology 257: 297-315.

Planes S, Doherty PJ. 1997. Genetic and color interactions at a contact zone of *Ancanthochromis polyacanthus*: a marine fish lacking pelagic larvae. Evolution 51(4):1232-1243.

Pondella II DJ, Ginter BS, Cobb JR, Allen LG. 2005. Biogeography of the nearshore rocky-reef fishes at the southern and Baja California islands. Journal of Biogeography 32:187-201.

Powledge F. 2003. Island biogeography’s lasting impact. BioScience 53(11):1032- 1038.

Risser PG. 1990. The Ecological Importance of Land-water ecotones. In: Naiman RJ, Decamps H.The Ecology and management of aquatic-terrestrial ecotones. United Nations Educational, Scientific and Cultural Organization; p. 7-17.

Smith TB, Wayne RK, Girman DJ, Bruford MW. 1997. A role for ecotones in generating rainforest biodiversity. Science 276(5320):1855-1857.

Starr, R. & Yoklavich, M. 2007. Monitoring MPAs in deep water off central California 2007 IMPACT Submersible Baseline Survey.

Steele MA, Forrester GE. 2002. Early postsettlement on three reef fishes: effects on spatial patterns of recruitment. Ecology 83(4):1076-1091.

Steele MA, Forrester GE, Almany GR. 1998. Influences of predators and conspecifics on recruitment of a tropical and temperate reef fish. Marine Ecology Progress Series 172:115-125.

Syms C. 1995. Multi-scale analysis of habitat association in a guild of blennioid fishes. Marine Ecology Progress Series 125:31-43.

Tertreault I, Ambrose RF. 2007. Temperate marine reserves enhance targeted by not untargeted fish in multiple no-take MPAs. Ecological Applications 17(8):2251-2267.

Williams A, Bax NJ. 2001. Delineating fish-habitat association for spatially based management: an example from the south-eastern Australian continental shelf. Marine Freshwater Research 52:513-536.