Depth and Substrate Preferences of Preadult Cabezon (Scorpaenichthys marmoratus) in Point Lobos Marine Reserve

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Abstract

With the recent boom in the live-fish industry, nearshore ecosystems that were once relatively unfished are now experiencing heavy fishing pressure. From 1994 to 1998, live-fishery landings for the state of California went from estimated values of 408 metric tons (MT) to 670 MT, an increase of 64%. The cabezon (Scorpaenichthys marmoratus) was first targeted by live-fishermen in 1994. Since then fishing pressure has been on the rise. From 1996 to 1997 there was a 115% increase in cabezon landings. In 1998 the cabezon became the number one catch in the live-fishery, totaling 152 MT at a value of approximately $1 million. In response to the live-fishery, the Nearshore Fisheries Management Act was passed in 1998, instituting a minimum size limit for cabezon of 356 mm that became effective in January 1999. At this time there is only minimal management of the live-fishery and cabezon in particular. This is due in part to insufficient knowledge of species habitat associations and how they change with age. Without understanding the abundance of the species in its preferred habitat it is difficult to make management decisions. This study sought to quantify the depth and substrate preferences of sexually immature, preadult cabezon. Twenty-four 60 m video transects were run using SCUBA across three depth zones (0-6 m, 6-12 m, 12-18 m) at Point Lobos Marine Reserve near Monterey California. A total of five fish were observed, with the deepest and largest being a 558 mm fish at 7.3 m depth. The other four fish were at slightly shallower depths, and ranged in size from 352 to 391 mm in length. The data was analyzed using the Kruskal-Wallis nonparametric statistical test and no clear distinction of depth preferences was revealed. A second set of data collected by a Carmel High School class in the Spring of 1999 was also analyzed using Kruskal-Wallis. These data did show a difference in depth strata but there was no stratification for depth during sampling, and thus the samples are extremely unbalanced. There is no indication from these data sets that preadult and adult cabezon are segregated by depth. In addition to the field study, an examination of fisheries management policies was conducted to address knowledge of cabezon life history traits learned from the literature, and from the observations and results of this study.

Background and Goals

Fishing has always been important to the economy of California's central coast. The central coast fishery traditionally sees changes in target species as populations rise and fall and as consumer demand varies. In recent years, one of these changes has been taking place within the nearshore fishery. Market demand for live fish has resulted in a lucrative new segment of the fishing industry that specifically targets shallow nearshore areas for species such as cabezon (Scorpaenichthys marmoratus), California sheepshead (Semicossyphus pulcher), greenlings

(Hexagrammos spp., Ophiodon elongatus) and rockfish (Sebastes spp.) (California Department of Fish and Game (CDF&G), 1995; Chambers, 1998).

The live-fish fishery got its start when it became apparent that the consumer's willingness to pay for live fish was significantly higher than for dead fish. At the time, dead fish from the nearshore area fetched about $0.30 per pound and it was simply not profitable to risk fishing that dangerous, rocky area. However, in the Asian fish markets of large west coast cities, live fish were selling for between $2.50 and $9.00 per pound depending on species and region (Griffith, 1998). For the consumer, live fish represent the freshest catch possible since they are chosen live from tanks at the markets. All of a sudden the profit became worth the risks. The fishery first came to the attention of CDF&G in 1989 when 52,000 pounds of fish were landed at a value of $146,000. By 1997 landings had reached 1.4 million pounds with a value of $3.9 million (Griffith, 1998). From field observations it is believed that the documented landings underestimate the true size of the fishery (CDF&G, 1998). This is due to the mobility of the operations involved, and the rugged and vast nature of the nearshore coastal area where the fishery operates. Typically the people involved with the live-fishery are working as small teams in skiffs that are launched from relatively inaccessible locations. They fish the nearshore kelp beds using hook and line gear, or traps, and they can easily go unnoticed in their work. Many fishers act as the middleman as well, delivering and selling their own catch, which further complicates data collection (CDF&G, 1999). The profits associated with the fishery, declining catches in other fisheries, and the fact that entry into the fishery costs only $125 has made it an attractive proposition for anglers of all kinds (Lea et al., 1999; Griffith, 1998). Finally consumer demand for live fish remains strong and in the live-fish market it is the dinner-plate-sized fish that bring the highest price, (A large dinner plate is about 300 mm in diameter). The preference of the consumer for conveniently sized fish and the industry's willingness to supply them indicate that relevant research is needed to produce policy that will sustain both the fishery and the populations of target species.

In the past, cabezon was generally sought after only by a small segment of recreational anglers, particularly spearfishers (Lauth, 1988), and only showed up in the commercial catch incidentally (O'Connell, 1953). For this reason there were essentially no regulations governing the catch of cabezon until very recently. With the rapid expansion of the live-fishery, the California Legislature passed the Nearshore Marine Fisheries Act (NMFA) in 1998, establishing commercial size limits for ten nearshore fish species. For the cabezon this limit was set at 356 mm, and it went into effect in January 1999. It does not apply to fish caught in trawls or brought to market dead (NMFA, 1998). Data collected by CDF&G previous to the size limit shows that from 36-54% of the catch in two selected areas was below this limit (VenTresca, 1999; Pattison, 2000). The new size limit will likely reduce these numbers, but with the rapid expansion of the live-fishery along the entire coast of California other measures may be needed as well.

Cabezon reach sexual maturity at different rates and sizes for each sex (O'Connell, 1953). It is not clear what these sizes are at maturity. Until recently it was believed that males first began to mature at a size of approximately 339 mm, and that all were mature by the time they reached 427 mm. For females the range was 445 mm to 524 mm (O'Connell, 1953; Lauth, 1988). However the data used to calculate these sizes were not conclusive due to small sample sizes. Recent data collected by CDF&G in Morro Bay have been inconsistent with these size ranges (Pattison, 2000). The work in Morro Bay found an average size within their samples of 358 mm with only 7% above this size being immature, and 13% below being mature (Pattison, 2000). These data represent the average for both males and females, though females represented 91% of the sample population in which maturity was determined. This suggests that most of the female fish are reaching maturity by 358 mm in length, even though this is nearly 100 mm shorter than the other data suggested for maturation size. Although this is an ongoing study, the results were used to set the commercial limit for cabezon, and also to determine maturity for this project.

One implication of this limit is the reproductive output of fish at this size. Batch fecundity for cabezon increases with size and age (O'Connell, 1953). Fish caught near the limit will have been mature for one season at most. These inexperienced fish will have contributed very little of their potential to the population. Thus, this limit may not be set at a beneficial size for population stability.

Fisheries management seeks to sustain productive fisheries in terms of both harvest and species health. This is done by trying to prevent two kinds of excessive fishing. The first is called "growth overfishing," and occurs when fish are caught at too young an age, so that they do not reproduce and the benefits of their future growth are lost. This type of fishing has also been shown to decrease the average size of a species as the fish evolve towards earlier maturation to compensate for the harvest pressure. However, this hasn't been demonstrated as true for all fish (Heino, 1998). The second type of excessive fishing is called "recruitment overfishing," and occurs when the spawning stock is so heavily exploited that reproduction and recruitment drop to levels that can't support the fishery (Carr and Reed, 1993; Berman et al., 1997). For cabezon the focus on fish around 356 mm means it's possible that both immature and mature fish could be overfished. So, potentially, cabezon are at risk of both growth and recruitment overfishing. Species that face largely unregulated fishing pressures on even their most remote populations will see declines in population health (Boreman et al., 1997; Heino, 1998). Cabezon have never faced the current level of harvesting pressure and it is difficult to predict how they will respond. To better understand the potential impacts of this new harvesting activity it is necessary to understand the population structure of the cabezon and how they are distributed within their environment.

There has been limited research on cabezon. They are the largest members of the family Cottidae, attaining a maximum length of 990 mm and a maximum weight of 11.4 kg, and they range from Sitka, Alaska to Point Abrejos, Baja California (Feder, 1974; Gotshall, 1989; Leet, 1992). They are benthic, ambush predators that display opportunistic feeding behavior and are found to depths of approximately 76 m (O'Connell, 1953; Leet, 1992). A CDF&G bulletin from 1953 on the life history of the cabezon established initial findings related to age and growth, diet, larval development and dispersal, size at sexual maturity, batch fecundity, and morphology (O'Connell, 1953). Postlarvae were observed to appear in tide pools at a minimum length of about 40 mm and there was even one adult of 488 mm taken there. However specimens of this size were rare. Only 15 of 53 fish taken from the tide pools were over 300 mm in length. Inferences were made about the fish moving to deeper water as they increase in size and also about the types of habitat they could be associated with but there was no substantiating data for these ideas. By the author's own admission there were a lack of juvenile and adult samples within the study. It is possible to find other sources that make the same habitat predictions but again there is no supporting data (Feder et al., 1974; Lauth, 1988; Gotshall, 1989; Leet et al., 1992). A recent study conducted by CDF&G on biological aspects of rockfishes looked at site fidelity or movement among the species (Lea et al., 1999). During this study preliminary data on cabezon was also recorded, and it was found that cabezon showed no movement and were considered highly residential to their home reefs (Lea et al., 1999). These data raise the question of territoriality and habitat preferences. If the species is territorial then it would make sense that the larger, mature fish would occupy the prime habitat, and that there might be segregation within the species' habitat among the different sized fish. Confirmation of this hypothesis could prove beneficial in trying to manage the fishery.

The cabezon's position as the number one species in the live-fishery, and the desire within the fishery for smaller fish, along with the fact that maturity at the minimum size limit is in question, make the species of central interest. Preliminary catch data representing a sample of the total catch from Pfeiffer Point to Salmon Cove along the Big Sur coast shows an average depth range for fishing of between 3 and 10 m (VenTresca, 1999). If it can be shown that sexually immature cabezon reside within specific depth ranges then it should be possible to convert this information into effective policy for zonal management of the fishery. Determining the preference for substrate type is also crucial for management because it allows prediction of available habitat and indirectly, population sizes. The driving question for this study is then: Do sexually immature preadult cabezon display preferences for depth and substrate that differ from those of adults, and if so can these preferences be used to make fisheries management policy recommendations? I attempted to test the hypothesis that preadult cabezon abundance would differ according to depth strata and substrate. Based on the generalizations found in the literature I expected to find that preadult cabezon would show preferences for depths less than 10 m and for rocky substrate.

Methods

To test my hypotheses I reviewed the literature and found that the most common sampling techniques for observing fish involved using line transects of varying lengths depending on study area (Ebeling et al., 1985; Lauth, 1988; Holbrook et al., 1990; Carr, 1991; Lara and Gonzalez, 1998; Ornellas and Coutinho, 1998). For this study, there were ten transects in three different depth ranges, each measuring 60 x 4.0 m. These transects were randomly placed along depth contours within the diving area of Point Lobos Marine Reserve, Monterey County, CA, and run using SCUBA equipment at headings that kept them within distinct depth strata. These depth strata were set at 0-6, 6-12, and 12-18 m in order to encompass the average range found in the Big Sur data (VenTresca, 1999). The sampling was performed by a pair of divers. One diver used underwater video gear to record each fish seen along the transect while the second diver set the route with a 60 m transect tape and compass heading. In several cases the heading we followed varied along the length of the transect in order to maintain our position within the depth contour. Each time a fish was observed the second diver recorded substrate type, algal presence, location along the transect, coloration, and the presence or absence of a nest. Substrate relief was estimated for the area of each positive contact, immediately following the dives. The classification for relief was: 0- 1m for low, 1- 3 m for medium, and over 3 m for high. The underwater video gear was equipped with laser pointers mounted 10 cm apart that were recorded as red dots on the video image. By recording these laser dots in the same frame as the fish it was possible to estimate sizes during later analysis (Gingras et al., 1998). Fish were classified as immature if they were under the minimum limit of 356 mm, and mature if they were over the limit.

The Point Lobos Reserve was chosen as the sample site for several reasons. First, a habitat map based on substrates, and a map of depth contours were both created recently from a seafloor survey done in May and June of 1999 by the Seafloor Mapping Lab at California State University Monterey Bay (CSUMB). The habitat map proved unsuitable for my project because there was only one identifiable habitat within the survey area. However, I was able to use the bathymetric map for stratification of my samples. Another advantage of Point Lobos is its status as a marine reserve. The waters around Point Lobos have been protected since 1973, so it should be possible to observe undepleted populations there. Point Lobos is located in the middle of an area of strong upwelling along California's Central Coast and is known locally as being rich in marine life.

Geographic Information System (GIS) software and Global Positioning System (GPS) technology were used extensively throughout the study. The GIS software ArcView was used to generate geo-referenced polygons representing the three depth strata as they occurred within the designated diving area at Point Lobos. A total of thirty random sample sites were then generated from these polygons so that there were ten in each strata. These sites were converted to waypoints, and along with a map of the dive area, downloaded into a portable Trimble GPS data logger. The GPS received differential corrections from a Coast Guard beacon and worked very well except for the final sampling day when we were only able to get accurate positions for two of the six sites. The only potential problem associated with losing positional accuracy was that we would miss the intended depth strata. Luckily we were able to see where the sites were supposed to be on the map and approximate their real world positions accordingly. On that final day, one of the sites was found to be in a turbulent zone between several wash rocks, so it was relocated to the nearest safe location. In all I was able to sample twenty-four (Fig. 1) of the original thirty sites over the period of January 17th to February 26th, 2000. Eight samples were collected within each strata.

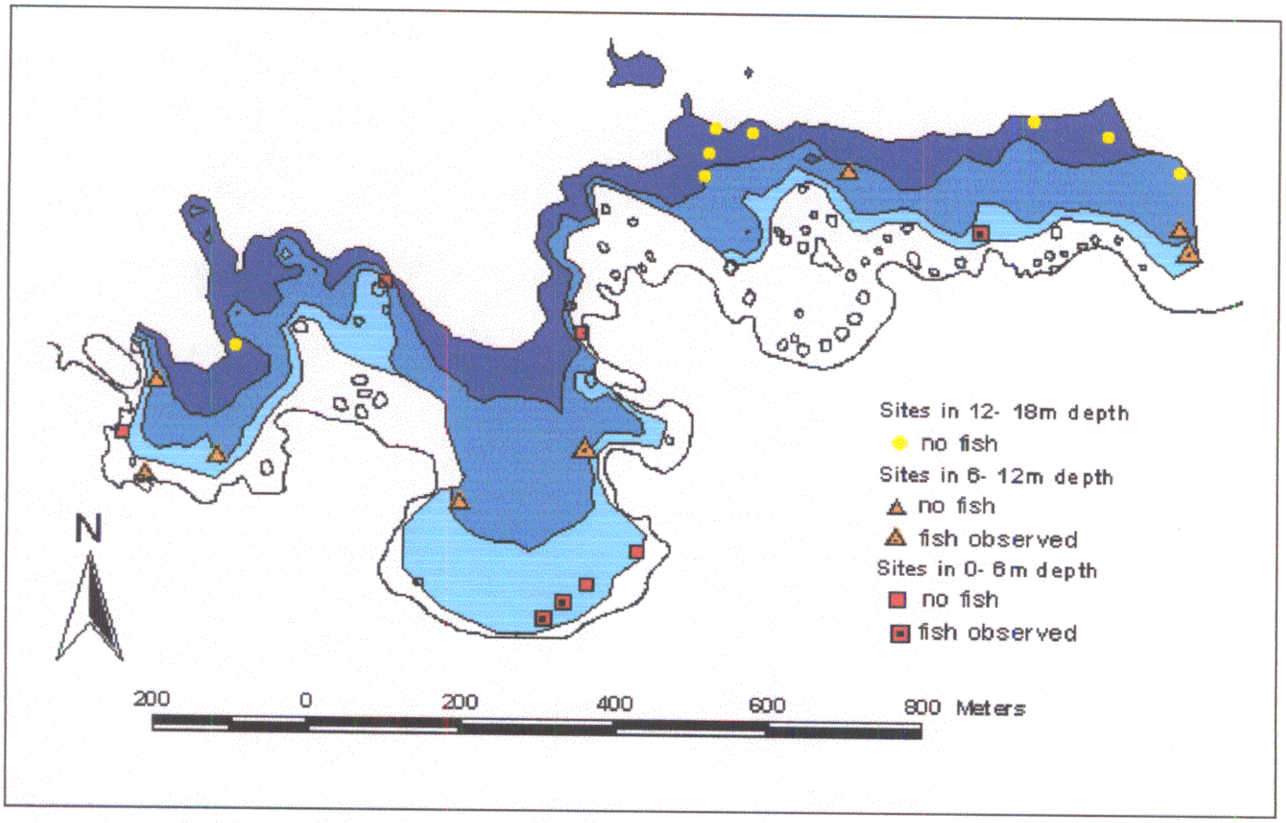

Figure 1. Northeast section of Point Lobos Marine Reserve. The blue polygons represent the different depth levels with the lightest representing the shallowest depth and the darkest representing the deepest depth. The total survey area is represented by all three depth polygons combined. The red squares represent sample sites in the 0-6 m range. The orange triangles represent sites in the 6-12 m range, and the yellow points represent sites in the 12-18 m range. Symbols with a dot in the center represent sites where fish were observed.

For this study, two sets of data were analyzed. The first data set was the one collected by my dive partners and myself. The second data set was collected by the Subtidal Marine Research Class from Carmel High School (CHS), over the period of April 8th to May 3rd, 1999. The CHS data was collected along 20 x 4 m transects, on a reef in Whaler's Cove, Point Lobos Marine Reserve. The CHS transects were selected haphazardly without depth stratification, and the cabezon were categorized as being either above the 356 mm limit or below it. Sizes were estimated by in situ comparison of each fish to dive slates which measured 356 mm. There were a total of 291 transects sampled in Whaler's Cove by CHS during their study. Since their sampling was not stratified by depth, the data was severely unbalanced when placed into the three depth levels necessary to test my hypothesis. They sampled 6 sites in the 0-6 m range, 220 sites in the 6-12 m range, and 65 sites in the 12-18 m range. The Kruskal-Wallis nonparametric statistical test was used to analyze both data sets.

Results

At the twenty-four sites that I sampled, a total of five fish were observed. Only one of these fish, a 352 mm specimen, was classified as immature. The other four fish ranged from 359 to 558 mm. Two fish were observed at a depth of 6.1 m, during transects designed to be in the 0-6 m level, but each was classified within a different depth zone. The depths along the transect at site 9 were in the range of 0-6 m, and the transect was classified as such. The transect at site 10 was in the range of 6-12 m, therefore that fish was placed in the deeper strata. For the most part the transects were at the expected depths, however, one transect from the shallow range was reclassified upon completion as being a mid-range depth, and one transect from the mid-range level was reclassified as a deep range site. There were 3 fish observed in the 0-6 m level, and 2 fish observed in the 6-12 m (Fig. 2).

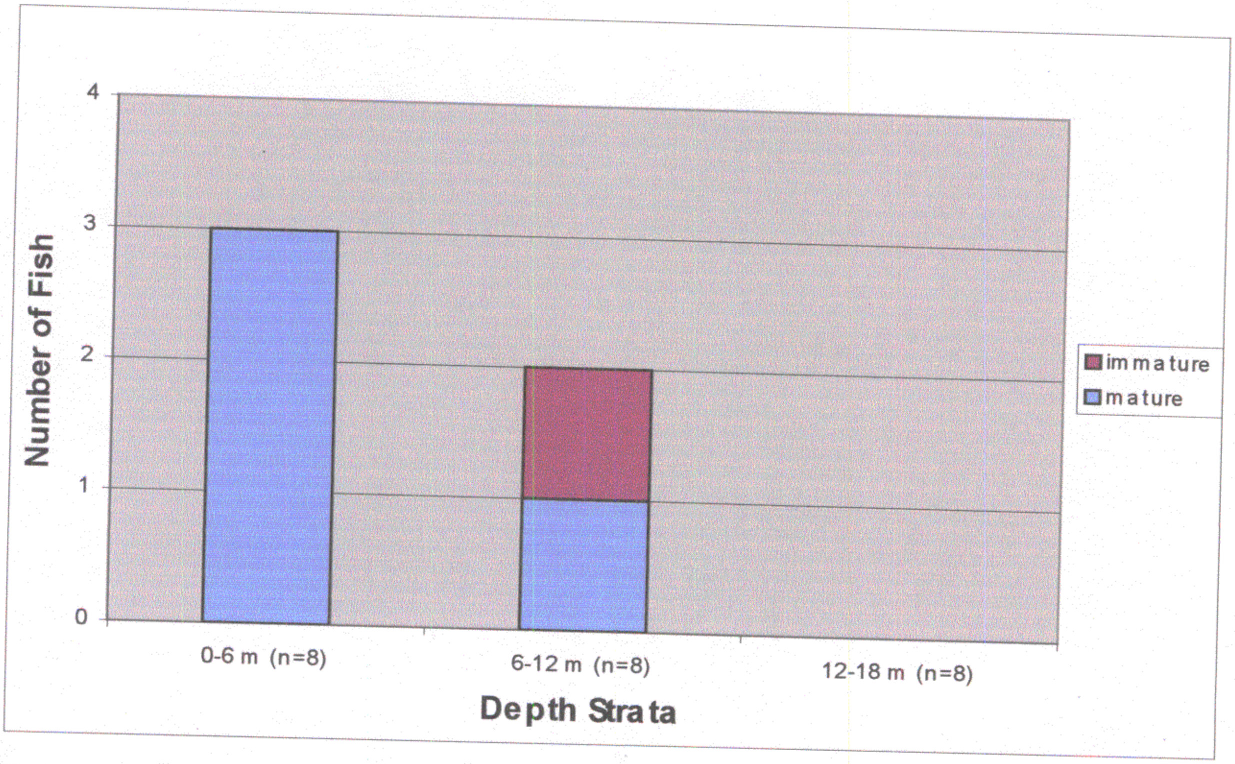

Figure 2. Castleton sampling results from Point Lobos Reserve. A total of five fish were observed in the shallower levels. Only one of these fish was classified as immature. No fish were observed in the deepest level. Eight transects were run at each level.

Sampling took place under relatively calm conditions. The swell averaged 0.5– 1.8 m and horizontal visibility averaged approximately 6– 7.5 m's. Only one dive, at site 22, was performed under rougher conditions with the swell near 3 m, but even on that dive the visibility was still approximately 4.5 m. The sampling density for my data was calculated as 0.21/240 m^2.

My original null hypothesis was that there would be no difference in distribution of immature and mature fish between depth strata. Because of a lack of data I was only able to test for a difference in distribution of the species as a whole. A Kruskal-Wallis test found no significant difference between depth zones (H_c= 3.389, N= 24, $p > 0.05$).

The results of the CHS study were somewhat different.

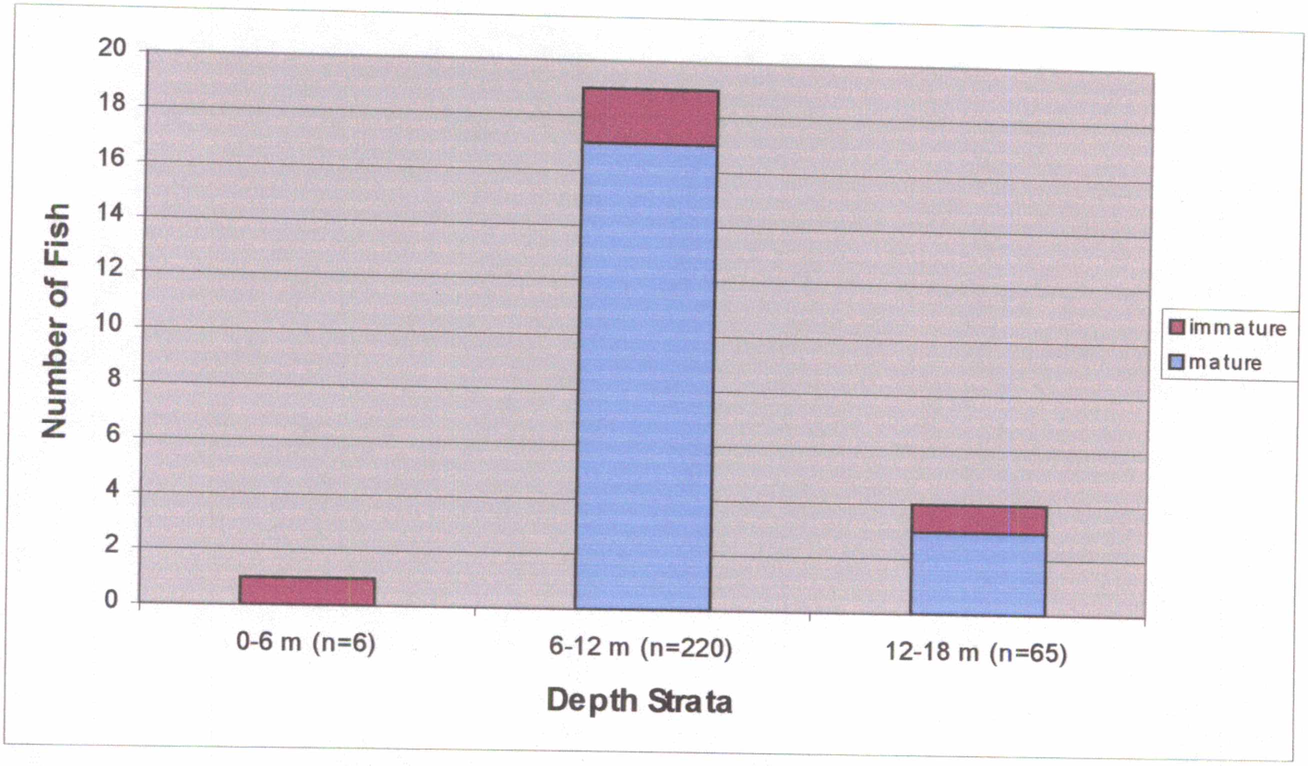

Figure 3. Carmel High School sampling results from Point Lobos Reserve. There were a total of twenty-four cabezon observed during this study. Only four of these fish were classified as immature.

There was much more data from this survey, however, only 4 of the 24 fish observed were classified as <356 mm (Fig. 3). Thus once again I was unable to test for distribution of immature fish. A Kruskal-Wallis test on depth distribution for all the observed fish found a significant difference between levels (H_c= 475.74, N= 291, $p< 0.05$). These results seem to indicate that cabezon prefer the mid-level depth strata, however, there were 220 transects run at this level versus 6 transects at the shallow level and 65 transects at the deeper level. This imbalance in sampling could be responsible for the difference between depth levels. The sampling density for the CHS data was calculated as 0.25/240 m^2.

Complete results of both statistical tests, as well as observations from my sampling can be found in the Appendix.

Discussion of Results

The hypothesis for this study was that there would be stratification by depth of preadult cabezon. Data was collected randomly among depth strata within the diving area of Point Lobos Marine Reserve to test this hypothesis. There were not enough fish observed to test for differences between preadult and adult fish, so stratification by depth was tested using all observed fish. A Kruskal-Wallis test found no stratification among the levels, even though we didn't observe any fish in the deepest level. A fish density of 0.21/240 m^2, or 875 fish per km^2, was calculated from the observations. The five fish observed in my survey were all found on rock with algal turf. These findings are not surprising due to the cabezon's coloration, demersal existence and ambush style hunting tactics. A link between cabezon and rocky substrates has also been suggested in the literature (O'Connell, 1953; Feder et al., 1974; Lauth, 1988; Gotshall, 1989; Leet et al., 1992). Four of the transects from my study were conducted entirely on sediment. Removing these from the calculations increases the fish density to 0.25/240 m^2, or 1042 fish per km^2, which might be more accurate if rocky substrate is indeed the preferred habitat.

Because I was sampling during spawning season I expected to observe some nesting behavior. Among cabezon, the males maintain nest sites that commonly contain several batches of eggs from different females (Lauth, 1988). The males are known to be determined guards of their nests (Feder et al., 1974; Leet et al., 1992). The base color of adult cabezon has been shown to be highly indicative of sex. Males tend to be reddish in color and females greenish. For immature fish both sexes are more commonly red (O'Connell, 1953). All of the fish I observed were reddish in color, so they might all have been male. However, only the 558 mm fish displayed behavior indicative of an adult nesting male. It showed no fear of us and never moved though we lingered in its area for several minutes filming and looking for a nest. Classifying the fish as male due to its color could have been supported by the fish's behavior if either my dive partner or myself had observed a nest. All nests found by Lauth (1988) were on exposed surfaces in depths to 17 m, and O'Connell (1953) claims that the species is not known for hiding its eggs. Thus it seems that we were sampling in the right places to see nests, but none were observed.

A second data set collected by CHS in Whaler's Cove, Point Lobos Marine Reserve was also analyzed. A total of 24 fish were observed in this study, but only four were immature. As a result, the entire data set was tested for differences in depth stratification. The results of this test found a difference among depth strata that is very obvious when looking at a graph representing observed fish per depth level. The graph in Fig. 2 shows the majority of the fish were found in the 6-12 m depth range. What the graph does not show is that the CHS study was not designed to be analyzed by depth strata, so the sampling was very unbalanced when the numbers were placed into the different levels. This limits the usefulness of the stratification results. The observed fish density for this study was found to be 0.25/240 m^2, which matches up with the adjusted density from my observations. However, it is probably not appropriate to use the CHS density as an approximation of fish density for my sampling area because it was collected entirely on one reef in Whaler's Cove, and could thus be interpreted as lacking replication. Despite this problem, the observed densities are the most interesting results from this study.

There is very little information in the literature on densities of commercial groundfish species of the West Coast. The only numbers I could find to compare with cabezon come from the yelloweye rockfish (Sebastes ruberrimus) fishery in the Eastern Gulf of Alaska. The yelloweye is a benthic predator that inhabits the deep reefs, filling a similar niche to cabezon in the shallow reefs (McConnaughey and McConnaughey, 1994). The average yelloweye density over three years of surveying was 2432 fish per km^2 (O'Connell et al., 1998). Without knowing the specifics of the yelloweye fishery, i.e., harvest pressure and management of the fishery, it is interesting to note that the density of yelloweye in harvest areas is more than twice the observed density of cabezon within a no-take zone. This could be an indication of cabezon's vulnerability to overfishing, and at the very least it shows that the question of cabezon density needs to be resolved.

To determine a sample size necessary to adequately detect the mean density for cabezon in a future study, I used the formula

$$n \approx \left(\frac{200\mathbf{CV}}{r}\right)^2$$

where r = Desired relative error (width of confidence interval as percentage of the mean)
CV = Coefficient of variation = Standard deviation/Observed mean (Krebs, 1989).

This formula assumes a confidence interval of 95%. For $r = 10$, the necessary sample size was 1,592. Collecting 1,592 samples didn't seem very realistic so I bumped the relative error up to 25%, and calculated a new sample size of 255. This number still seems relatively large, and the fact that so many samples would be necessary, confirms for me the feeling that the observed densities were low. Without more data it is impossible to say whether or not the observed numbers accurately reflect cabezon density or if they represent problems in methodology. Experience gained while collecting my data, combined with information from the literature suggests a few possible answers.

Cabezon are very cryptic in appearance and it's possible that we simply missed seeing some of them. In the deeper transects we were commonly sampling in boulder fields where there were numerous cracks and crevices for the fish to hide in. I made an effort to inspect all of these areas as I came upon them, but I'm sure that some of the more hidden areas went unobserved. In particular, if the crevices, caves or passages were particularly deep or curved out of sight then it's likely that they were not completely sampled. The total absence of any observed fish at the deepest depth level could be reflective of the different habitats that we encountered. It follows that shifts in habitat would be reflected by shifts in foraging behavior.

As cabezon mature into adults the composition of their diet changes. By analyzing stomach contents, O'Connell (1953) was able to show that the adult diet consists of 59.8% crustaceans, 27.4% molluscs, 8.5% fish, and the rest are egg masses and annelids. The shift in the diet from juvenile to adult is expressed in fish dropping from a frequency of 25% to 8.5%, crustaceans dropping about 15%, and the molluscs essentially making up this difference. Thus the change in dietary composition could be reflective of a move to deeper waters with increased age, and an accompanying shift in hunting tactics. Once in deeper water cabezon would probably spend less time waiting in ambush on exposed rocky surfaces for passing fish to swim by. They are definitely not going to wait in ambush for an abalone (Haliotis spp.). This indicates they must be searching for prey at least part of the time, and if their prey tends to be concealed among the crevices then it is logical that the cabezon will be as well.

Another explanation for the low number of fish observed could be that my sampling area, the northeast section of Point Lobos Marine Reserve, is not capable of supporting a larger population of cabezon. It might be that prevailing winds and swell, which are commonly out of the northwest during the spawning season, limit the dispersal of larvae, adversely affecting recruitment success. Localized currents can also be important factors in larval recruitment (Carr and Reed, 1993).

There are several options for trying to improve on the methods of this study. Sampling could be conducted in several geographically distinct sites with conditions ranging from extreme exposure to current and swell, to protected bays. This would theoretically eliminate the possibility of studying a population that is unrepresentative of the species in general, and would also potentially show variations in population structure among different habitats. The other important factor is detecting the fish. It was surprising that we came up with such low numbers with the relatively good sampling conditions we experienced. It could be that for cabezon, changing the scale of the sampling unit would make sense. I believe that intensively searching a smaller area for each sample site would give a higher confidence in locating the fish present.

Another way to detect the fish could be to take advantage of the fact that they are relatively easy to catch, which is attested to by their place in the live-fishery. Ideally the fish could be caught with baited traps, causing as little physical harm to the fish as possible. The traps could be placed randomly at different depth levels, and all fish tagged to avoid counting specimens multiple times. This would theoretically address the issue of fish that are otherwise hidden to sight observation. Being able to roust fish from within hidden areas, and include them in sampling will be essential for getting a more accurate measure of density, as well as establishing more definite habitat associations and distributions. Finally, establishing a study period of at least one-year, and collecting data regularly throughout that time, should allow for a more complete picture of cabezon ecology, by accounting for seasonal variability and increasing sample size.

Discussion of Policy

In order to begin addressing policy issues surrounding the cabezon and the live-fishery this study was designed to help fill an important gap in ecological knowledge of the species. Regardless of the results of this study there are traditional as well as newer management practices that deserve attention as possible methods of sustaining cabezon populations.

Traditional fisheries management has commonly been based on quotas, seasons, and size limits and gear restrictions. These methods have been largely ineffective at managing fisheries as evidenced by a general state of worldwide overfishing (Roughgarden and Smith, 1996). The reasons for this failure are often political and social in nature (Botsford, 1997). There is constant and intense pressure from these arenas to raise quotas, extend seasons and relax gear restrictions. Governments that are ostensibly trying to serve the people then push for limits that are based on economic theory instead of ecological knowledge (Roughgarden and Smith, 1996).

There are indications that fisheries management in California has a good chance of improving on past failures. The NMFA (1998) has given management power directly to CDF&G and declared that research and conservation of nearshore species and their habitats is necessary. Many of the traditional management tools will find a place in implementing these policies and they have the potential to be more effective if their use is based on sound biological knowledge. The institution of the minimum size limit for cabezon is a good example.

Previous knowledge of cabezon maturity was inconclusive, leading CDF&G to conduct an ongoing study to better understand this important factor. The sample size used to set the limit was much larger than in previous studies and it's planned to continue collecting data so that CDF&G can be confident that the size has been set such that it minimizes the taking of immature fish (Pattison, 2000). An important issue not addressed by the current size limit is the fact that fecundity increases with size and age (O'Connell, 1953; Lauth, 1988). Fish taken at the limit will have been mature for no more than one season and will therefore have contributed at levels far below their potential. It seems unlikely that these relatively inexperienced fish would show the spawning success of older fish either. This is especially relevant for the males since they are responsible for guarding the nests. Thus it could be argued that fish being taken at the age of maturation or even a season beyond it, represents a potential problem in the current management policy. This issue could be addressed with a revised size limit or by other management techniques.

Another potential tool that addresses the catch of immature fish is gear limitations within the live-fishery. Cabezon are known in the fishery as being aggressive feeders that are sometimes killed by swallowing the hook (Chambers, 1998). Besides resulting in a substantial drop in price for the catch, this can also lead to the indiscriminant death of immature fish. The benefits of traps address both these problems. Immature fish can be set free and the legal catch will fetch the highest price. There are a couple of potential drawbacks. According to Chambers (1998) fishermen find that sometimes traps are more effective while at other times hook and line methods work best. It's unlikely that fishermen would support an effort to make traps the only allowable method. Perhaps a future study could try and identify any temporal patterns associated with catching immature cabezon as well as other target species. If any correlations were established then it would make sense to use the traps during the times when the preadults are at their highest risk. In 1998 line gear of all types was used to take 72% of the fish compared to 22% for traps (CDF&G, 1999). This means that many fishermen would have to buy traps in order to continue fishing. An average trap costs from $45 to $65, which could represent a significant investment for some fishermen if they had to buy a whole set of traps. Perhaps some sort of incentives, like low-interest loans, would be appropriate.

Looking at potential seasonal restrictions for cabezon it is tempting to say that spawning season is a logical time to protect the species, however, Heino (1998) found that a fish stock can sustain much higher harvest rates if fished only at their spawning grounds, as long as reproduction occurs prior to harvest. This knowledge is difficult to apply for cabezon. It is known that in the northern part of their range cabezon have an extended spawning season that runs from late November until early the following September, and that they can spawn twice during this season (Lauth, 1988). In California the season starts at about the same time but only lasts until March, and although the data were not conclusive it appears that they may spawn twice here as well (O'Connell, 1953). Thus there is no coordinated spawning effort by the fish that could be monitored and used to set the timing of a closure. Trying to institute a seasonal closure for cabezon that addressed the vulnerability of the spawning stock prior to spawning would necessarily span many months, and be difficult to justify unless populations start to crash.

The use of quotas is inextricably linked with stock assessment. Without some knowledge of stock size, quotas cannot be set. Two methods of quotas style management have been shown to be effective at achieving maximum sustainable yield, which is the highest possible long-term average yield. A constant harvest rate strategy takes a constant fraction of the stock each year, and a constant stock size strategy sets a target stock that is always maintained (Heino, 1998). Both of these strategies are obviously reliant on accurate stock assessment for their efficacy. For cabezon the only means of stock assessment currently available is catch data, which without some knowledge of species density and habitat area doesn't really mean much except that either there are fish or there aren't. It is also flawed in that it's giving you the information after the point at which any corrective actions can be taken. The first steps in effectively addressing stock assessment are determining density, habitat associations and habitat area.

My study was trying to answer some of the questions necessary for accurate stock assessment but not with the idea of quotas in mind. Rather it was aimed more at being able to identify discrete areas of habitat along the coastline that might be closed to fishing in order to protect immature stock. This idea is more closely aligned with the idea of marine protected areas (MPA).

These harvest refuges are becoming increasingly advocated as a means to protect and ideally enhance stock sizes (Carr and Reed, 1993). Considerations for establishing an MPA that can satisfy these goals are specific to the biological and ecological characteristics of the target species as well as oceanographic conditions and the willingness of the local fishing industries to cooperate in the design and maintenance of its boundaries. The central idea behind the MPA as a management tool is that refuge populations will supplement harvest populations through larval recruitment (Carr and Reed, 1993). This is the one management option that addresses the relationship between size and batch fecundity, allowing at least some populations to reach full size and fecundity. I believe that MPA's are an important option for management of the live-fishery.

Implementation of MPA's aimed at preserving the cabezon fishery have to address a few issues. Even though cabezon have become the number one catch in the industry they are not the only target species, therefore trying to design a refuge without consideration of the other species and the ecological health of the nearshore ecosystem as a whole would almost certainly result in failure. Understanding recruitment methods of the target fish and what type of replenishment patterns these result in can allow for grouping of species with similar traits for refuge design consideration. Cabezon spawn demersal larvae that immediately enter the plankton for a period of three to four months (O'Connell, 1953). Depending on local currents this could lead to geographically isolated breeding populations contributing to a large common pool of larvae that are dispersed over a wide area, or to a situation where dispersal is limited to replenishment of only localized neighboring populations (Carr and Reed, 1993). Small refuges covering several kilometers of coastline that are interspersed at regular intervals depending on habitat would address either one of these recruitment outcomes, especially where dispersal occurs over a large area. Populations of fish that are dependent on local replenishment are more vulnerable to overfishing in general, thus when identified should maybe be protected regardless of location. Lastly it would be difficult to design an effective MPA without population estimates for the refuge and harvest populations. So once again determining density and habitat area are of central importance.

Also crucial to the success of an MPA and fisheries management in general is the involvement and cooperation of the effected fishing industry. Rather than just dictating rules and fostering no relationship with the fishermen, establishment of new refuges should take place with input from all sides. The more involved fishermen are in the decision-making process the more likely they will be to comply with the resulting rules (Pomeroy, 1999). Making fishermen co-managers of a refuge with responsibilities for collecting catch data and monitoring fishing activity are potentially more feasible on a local scale, where the people are more likely to have a personal attachment to their local ecosystem. This supports the establishment of smaller, localized MPAs.

Depending on which policy methods are used the issue of maturity will remain important. A part of this issue that I haven't found information on is the possibility that size at maturity varies by geographic region. So far, data has been collected from Puget Sound, Monterey Bay and Morro Bay, with agreement existing between the former two. Certainly it would make sense to look at populations in the north, central and southern portions of the state to test this possibility.

It is clear that policy decisions need to be made on cabezon and the live-fishery. In some cases, more data is necessary before any action can be taken. However, there are issues that can be addressed with existing information. A move towards the use of more traps would allow for the safe release of under-sized fish, and probably the bringing to market of a higher percentage of live cabezon. A reevaluation of the minimum size limit also seems to be in order. If there are no geographic differences in maturation rates then the current limit is set such that the majority of fish caught over the limit will be mature. But the fact that a fish might be mature at 356 mm doesn't address its spawning benefit to the population if the fish is caught at or near this size. If the goal of the minimum size limit is allowing fish to reproduce before being caught, then giving the fish at least one more season to grow and mature would be more effective. This would mean increasing the minimum size limit by 75 to 100 mm (O'Connell, 1953). The fact that the observed densities from this study appear to be relatively low, supports reexamination of the minimum limit.

Future efforts at collecting data on cabezon should focus on information that will be useful in designing MPAs, which I believe will be crucial as a management tool for cabezon and the live-fishery in general. The results of this study were not able to show any clear depth distribution for cabezon, however, I was able to calculate densities which seem low for a commercially targeted species. Future studies need to analyze the issue of density further, and then use this information along with habitat associations to design MPAs which can support both refuge and harvest populations. With the continued study of cabezon and the nearshore ecosystem, and the inclusion of the effected fishermen in the decision making process, it should be possible to maintain the species and its associated fishery.

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Appendix

Table 1. Sample Results for Observed Fish

Site	Date	Size[1] (mm)	Depth (m)	Color	Substrate	Algal Turf	Nest	Relief
16	1/17/00	558	7.3	Red	Rock	Yes	No	Medium
4	1/18/00	359	2.7	Red	Rock	Yes	No	Low
5	1/18/00	391	2.1	Deep red	Rock	Yes	No	Medium
10	1/22/00	352	6.1	Brown	Rock	Yes	No	Low
9	1/22/00	380[2]	6.1	Red	Rock	Yes	No	Low

[1] Fish sizes were calculated by determining the on-screen distance between the laser points, using that value with the known distance between points to calculate a scale factor, and then multiplying the on-screen fish size by the scale factor.

[2] The final fish was not recorded to video with the lasers due to the failure of one laser. As I struggled with the dying laser my dive partner was able to place the length of his forearm close enough to the fish for an approximation of size. By determining that the fish ran from his elbow to the end of his fist and then measuring that distance I was able to estimate the size of the fish at approximately 380 mm, +/- 20 mm.

Table 2. Kruskal-Wallis Statistical Results for CSUMB Samples

Depth Levels		
0-6 m	**6-12 m**	**12-18 m**
0 (10)	1 (22)	0 (10)
0 (10)	0 (10)	0 (10)
1 (22)	0 (10)	0 (10)
1 (22)	0 (10)	0 (10)
0 (10)	0 (10)	0 (10)
0 (10)	1 (22)	0 (10)
0 (10)	0 (10)	0 (10)
1 (22)	0 (10)	0 (10)
n_1=8	n_2=8	n_3=8
R_1=116	R_2=104	R_3=80

H_0= All levels are the same.
H_A= All levels are not the same.

N= 24
H_C= 3.389
$H_{0.05,8,8,8}$= 5.805

Accept H_0

Table 3. Kruskal-Wallis Statistical Results for CHS Samples

Depth Levels		
0-6 m	**6-12 m**	**12-18 m**
5 x 0 (134.5)	202 x 0 (134.5)	61 x 0 (134.5)
1 x 1 (279.5)	17 x 1 (279.5)	4 x 1 (279.5)
	1 x 2 (291)	
n_1= 6	n_2= 220	n_3= 65
R_1= 952	R_2= 34632.5	R_3= 9322.5

H_0= All levels are the same.
H_A= All levels are not the same.

N= 291
k= 3
H_C= 475.74
$\chi^2_{0.05,2}$= 5.991

Reject H_0