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# SHARKS AREN'T THE ONLY FISH TO BE AFRAID OF... A Survey of Serranidae Species of Genus *Aethaloperca*, *Anyperodon*, *Cephalopholis*, *Epinephelus*, and *Plectropomus* on Chumbe Island, Zanzibar, Tanzania

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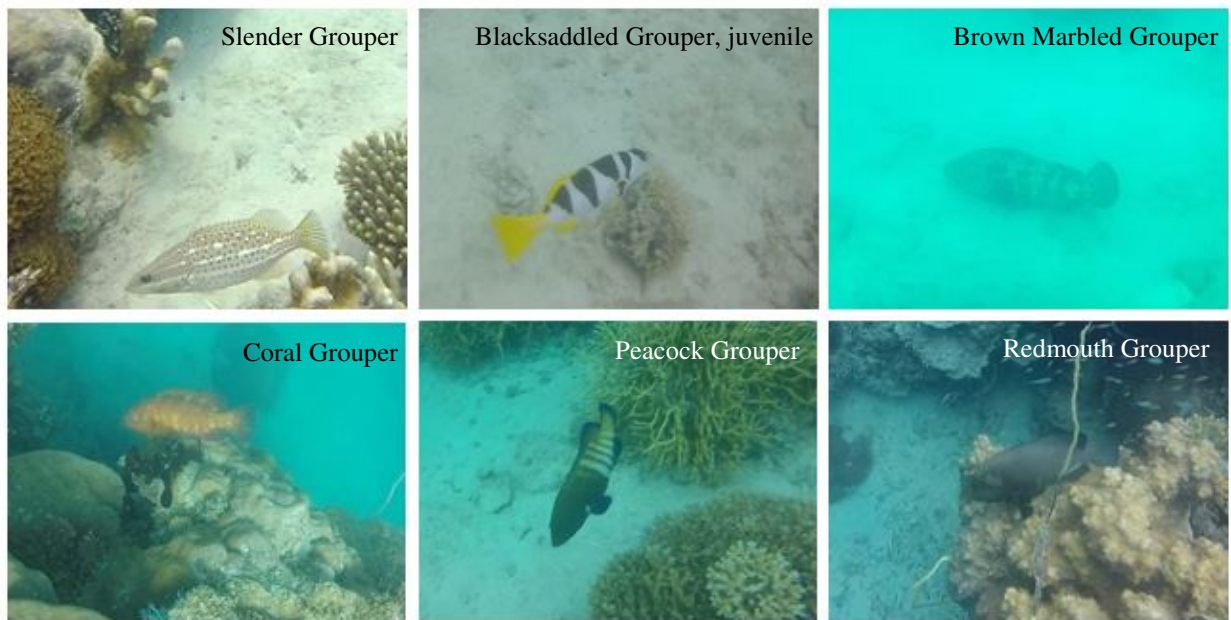
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## SHARKS AREN'T THE ONLY FISH TO BE AFRAID OF...

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A Survey of Serranidae Species of Genus *Aethaloperca*, *Anyperodon*, *Cephalopholis*, *Epinephelus*, and *Plectropomus* on Chumbe Island, Zanzibar, Tanzania



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Fall 2014

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The Chumbe staff was phenomenal in every way possible; I will never be able to repay them for how much they did for me. First, Vera, who made my stay on Chumbe extremely comfortable and was always watching out for me and my mental and physical health. Second, to Bakari and Juma who came out snorkeling with me to help me find my groupers. And third, to Fatuma and the rest of the kitchen staff for keeping me extremely well-fed with delicious food during my stay.

And lastly, I would like to thank Olivia McGrath for helping me find my groupers and photographing them when I couldn't (Brown Marbled Grouper photo on cover page).



**Abstract:**

A census as well as behavioral analysis of six grouper (Serranidae) species was conducted on Chumbe Island off the coast of Unguja, Zanzibar, Tanzania during October and November 2014. The six species were counted, divided into size classes, and behavioral notes were taken on the individuals observed on both the western drop-off of Chumbe Island's reef as well as the back, shallower reef. Results showed that larger individuals, as well as species that grow larger, inhabit the deeper waters of the drop-off, while smaller species and juveniles inhabit the shallower back reef. The Brown Marbled (*Epinephelus fuscoguttatus*) and Blacksaddled (*Plectropomus laevis*) Groupers were determined to be two of the largest fish on the reef, and the numbers of large *E. fuscoguttatus* are higher than originally believed, a sign of a healthy, complex ecosystem. Biomass of all species was determined to be 9.240g/m<sup>2</sup>, highly concentrated at the drop-off of the fringing reef. Juvenile percentage of each species was determined, overall suggesting a high probability of success for future generations of these species. Active hunters were determined to be Peacock (*Cephalopholis argus*) and Redmouth (*Aethaloperca rogae*) Groupers, while *E. fuscoguttatus* and Slender (*Anyperodon leucogrammicus*) Groupers spent most of their time concealing themselves in coral. Most of the species were found to have very specific habitats on the reef, especially the large individuals.

**Introduction:**

A powerhouse of biological diversity, the world's coral reefs are home to at least four thousand species of fish and possibly over twenty-five percent of marine life (Lieske, 2002, p. 6). Pristine reefs are examples of a checks-and-balances system that has existed for millions of years. While a reef grows, an important aspect of the system is the abundance of predators on a reef. Large predators include reef sharks, barracudas, octopi, and groupers. By keeping the numbers of their respective prey stable, these predators keep the reef ecosystem in balance. The fringing coral reef of Chumbe Island, off the coast of Unguja, Zanzibar, Tanzania, is an example of one of these pristine systems where all the components of the food chain are well represented.

Chumbe Island Coral Park houses all of the aforementioned predators and the Marine Protected Area (MPA) has been recognized since 1994. An MPA is defined as “an area of the ocean where there are limits on human activity” (Chumbe). Multiple species of grouper reside in the protected Western side of the reef, including Blacksaddled (*Plectropomus laevis*), Peacock (*Cephalopholis argus*), Redmouth (*Aethaloperca rogaa*), Coral or Jewel (*Cephalopholis miniata*), Slender (*Anypserodon leucogrammicus*) and Brown Marbled (*Epinephelus fuscoguttatus*) Groupers, all within sight by snorkeling and free diving. These six species are listed on the International Union for the Conservation of Nature's (IUCN) Red List, and they range from Data Deficient to Vulnerable. All these species are members of the Family Serranidae, composing of Anthias, Basslets, and Groupers (Richmond, 2002, p. 358). Table 1 in Appendix describes each species in more detail, including local names.

Biomass is a key indicator of reef health and determining the biomass of a common predator is important for understanding the food chain dynamics of the ecosystem. Large

predators like sharks and groupers can account for over fifty percent of the total biomass of a large, deep reef, but is most likely a smaller percent for a shallower reef (Friedlander et al. 2002).

This study had five main goals. First, to establish a baseline census in terms of numbers and biomass for these six grouper species so that a comparison study may be done in a few years to see if populations of these species change and how the presence of these predators indicates the health of the reef. Secondly, to determine how these fish behave on the reef including individual behavior and social behavior within the species. Third, to establish the average size of the six Serranid species and the ratio of juveniles to adults. The fourth was to determine the general and specific habitats of the six species. And lastly, to create educational material for the guests of CHICOP on all the main reef predators to assist in understanding why predators are important members of coral reef ecosystems.

**Species Descriptions:**

*P. laevis* is listed by the IUCN as Vulnerable (VU) since the species is relatively widespread throughout the Indo-Pacific, but very concentrated on coral reefs while having almost no individuals outside the reefs. Diet consists of larger reef fishes, including other groupers, as well as occasional crustaceans. There is a strong chance they may be overfished, but the data on this is not sufficient. Their populations have been shown to be decreasing by as much as thirty percent of the mature individuals since 2008. Valuable members of the Live Reef Food Fish Trade (LRFFT), a trade mostly in China that involves the consumption of live fish, *P. laevis* faces many threats to their continued existence. Part of this may be due to the distinct coloration patterns on the juveniles that make them relatively easy to find. The juvenile stage is where the fish earns its name, and the mature adult stage is named the blue spot phase (Choat, et al. 2008). A drastic transition between the two can occur anytime between one to twelve years of age, while the average age at maturity is 10.1 years (Pianka 1978).

*C. argus* is listed by the IUCN as Least Concern (LC) since they are the most widespread of all groupers and common on coral reefs. The species is a common catch of artisanal fishermen and is caught widely over the Indo-Pacific. A smaller species, they have a tendency to stay in shallower waters and more towards the inner section of reefs (Liu et al. 2008). Over ninety-seven percent of their diet consists of smaller fish (Dierking et al. 2009).

*A. rogaea* is listed by the IUCN as Data Deficient (DD) since they are naturally scarce and not caught by fishermen. Their range is down the East coast of Africa and expands to the Indo-Pacific and they are found in caves and holes from one to sixty meters below the surface. Diet consists mainly of small fish, but also includes stomatopods and crustaceans (Heemstra, Samoilys et al. 2008).

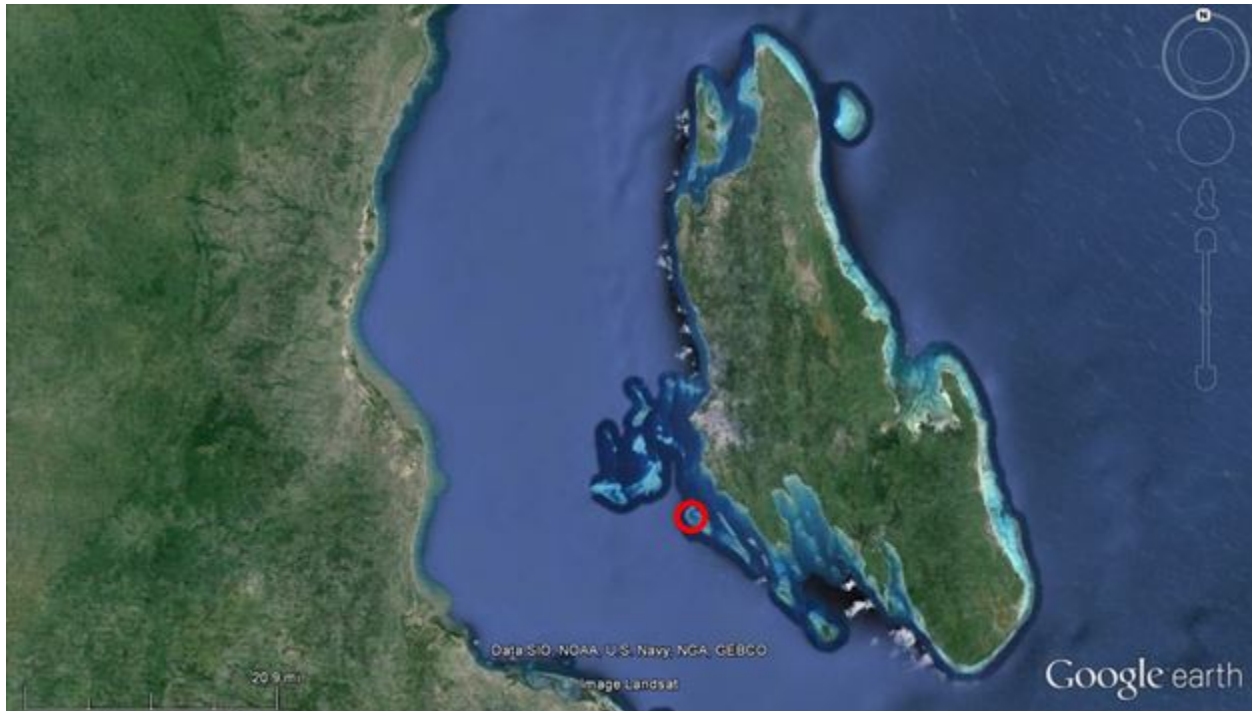
*C. miniata* is listed by the IUCN as LC since they are fairly widespread and common in well-protected MPAs, but their population is listed as decreasing due to habitat loss and overfishing. They are common both in artisanal fisheries as well as the LRFFT. Diet consists of small fish and crustaceans. Their preferred habitat includes coral caves on the outer areas of coral reefs (Cabanban et al. 2008).

*A. leucogrammicus* is listed by the IUCN as LC due to their wide range and that there is no evidence to show any decline in their numbers. Range is throughout the Indo-Pacific Ocean. The species is thought to be naturally uncommon, but there is very little information since they are not caught by fishermen and usually hide within corals, so they are not seen often. They occasionally appear on the LRFFT (Heemstra, Pollard et al. 2008).

*E. fuscoguttatus* is listed by the IUCN as Near Threatened (NT) since they are caught in both artisanal fisheries and for the LRFFT. Range is throughout the Indo-Pacific Ocean. There is very little monitoring of species populations or behavior, but the species prefers the outer banks of coral reefs for areas to hide. Population trends are unknown (Cornish, 2004). This species is known to travel away from their home on a coral reef to form spawning aggregations in deeper waters (Brown Marbled Grouper 2013).

**Study Area:**

Off the coast of Tanzania in East Africa is a small archipelago. Two main islands make up the Zanzibar archipelago, Unguja (South) and Pemba (North). Eight kilometers Southwest of Zanzibar Town, Unguja, lies the small island of Chumbe. Under the Western waters of Chumbe lies one of the Africa's most diverse and colorful protected reef areas (Chumbe). Zanzibar has ninety square kilometers of coral reefs with few protected and fewer protected well. The MPA of Chumbe Island Coral Park (CHICOP) has an area of 0.33 km<sup>2</sup>, and is highly protected by a private organization that runs an eco-tourism operation (Nordlund, et al. 2013). The reef boasts over 200 species of hard coral, which is ninety percent of the coral species in all of East Africa, and at least 435 species of fish. When the park was recognized in 1994, it was the world's first private MPA, and it remains the only private MPA in East Africa (Chumbe).



**Figure 1:** Unguja, Zanzibar archipelago showing major islands and reefs with Chumbe Island circled in red



**Figure 2:** Chumbe Island with MPA outlined in red, according to Google Earth. Information slightly inaccurate as to extension of MPA, accurate GPS coordinates currently being acquired.

**Methodology:**

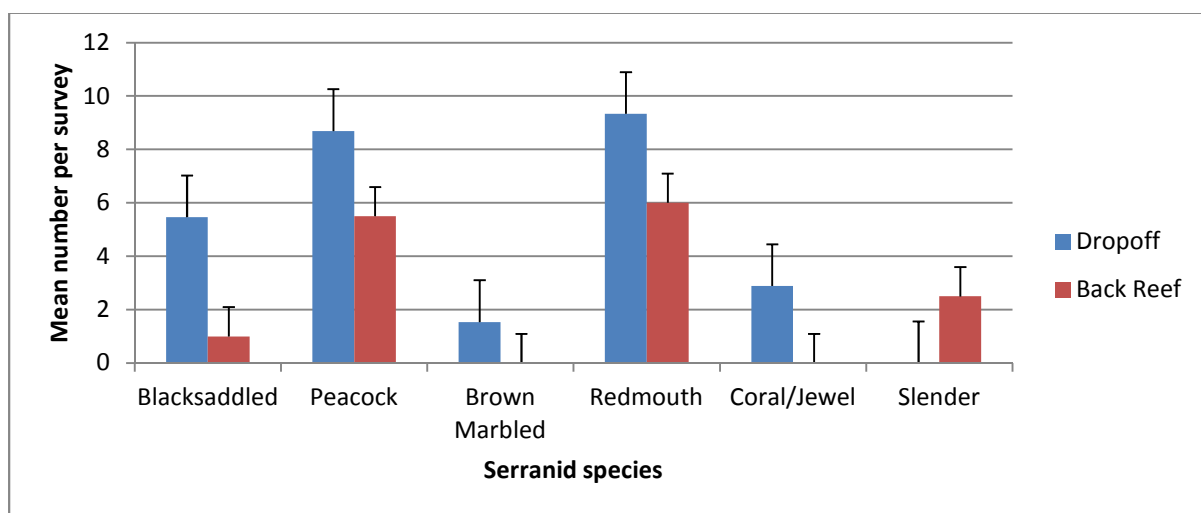
The length of the CHICOP MPA reef was surveyed along the Western drop-off region from October 10-13, 2014, and from November 4-14, 2014, and the internal reef was surveyed from November 16-22, 2014. Survey is defined as an underwater visual census swim either along the entire drop-off region or a serpentine swim through the shallow back reef. The North end of the survey was at 6°16'28.00" S, 39°10'29.85" E, and the South end of the survey was at 6°16'15.48" S, 39°10'33.80" E. The currents and tides were followed: North to South when the tide was going out and South to North as the tide was coming in. The six species of grouper observed were divided into size categories where every individual was noted for every survey (Table 2). Size was determined by the length of the fish from nose to the end of the caudal fin. Observational data was taken including a tally of the number of times that more than one grouper of the same species were seen together, notes on behavior, whether or not the individual was under shelter (Table 3). Hunting behavior was categorized as perched on coral for *C. argus* and *C. miniata*, and swimming through schools of small fish for *A. rogae* (Shpigel, et al. 1989). Hunting behavior could not be defined for the other species during literature review. Surveys were timed and ranged between 1.25 and 1.5 hours, either following the Western drop-off line of the reef or crossing the internal, shallow reef and occurred between 0800 and 1600 hours. The tides for the surveys were averaged between spring and neap and when the tide was coming in or going out. While in the water, data was recorded on a slate and then transferred to an Excel Workbook to be analyzed. Data on biomass was taken from Fishbase.org (November 2014) in a 95% range. To ensure accuracy of behavior, video was taken of individuals with an underwater camera, a GoPro Hero 3+ Silver Edition. Note was taken as to where the individual species were concentrated on the reef. An educational pamphlet was created for the guests of CHICOP



detailing about the different predators on the MPA reef, and an educational video with similar information will be created in January 2015 to be sent to CHICOP.

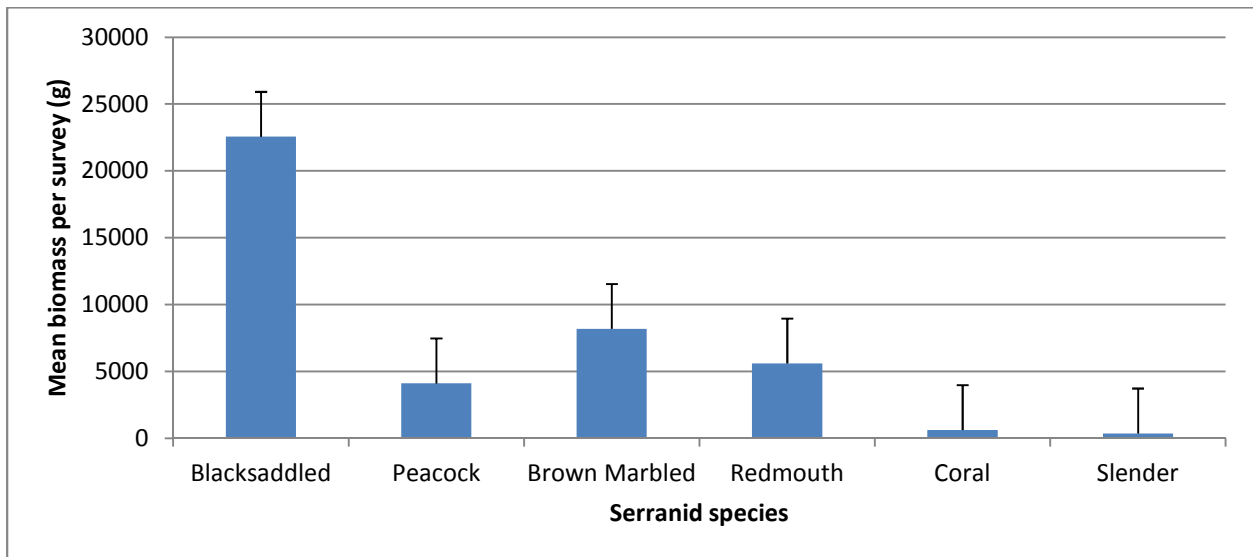
### Results:

Over the course of the month-long survey during October and November 2014, the Western drop-off was surveyed thirteen times, and the inner reef was surveyed four times. Along the 1,000 m of fringing coral reef and back reef, representing an area of approximately 50,000 m<sup>2</sup>, a total of 378 Serranid species were observed: 75 *P. laevis*, 139 *C. argus*, 20 *E. fuscoguttatus*, 108 *A. rogae*, 26 *C. miniata*, and 10 *A. leucogrammicus*. A total of 318 were observed on the drop-off (71 *P. laevis*, 117 *C. argus*, 20 *E. fuscoguttatus*, 84 *A. rogae*, and 26 *C. miniata*) with an average per survey of 24, and 60 were observed on the inner reef (4 *P. laevis*, 22 *C. argus*, 24 *A. rogae*, and 10 *A. leucogrammicus*) with an average per survey of 15 (Chart 1). Generally, the larger individuals of each species were observed on the deeper drop-off of the fringing reef, while more juveniles and smaller individuals were observed in the shallower back reef. *A. leucogrammicus* was not observed on the drop-off, and no individuals of *E. fuscoguttatus*, *C. miniata*, and adult *P. laevis* were observed on the inner reef.

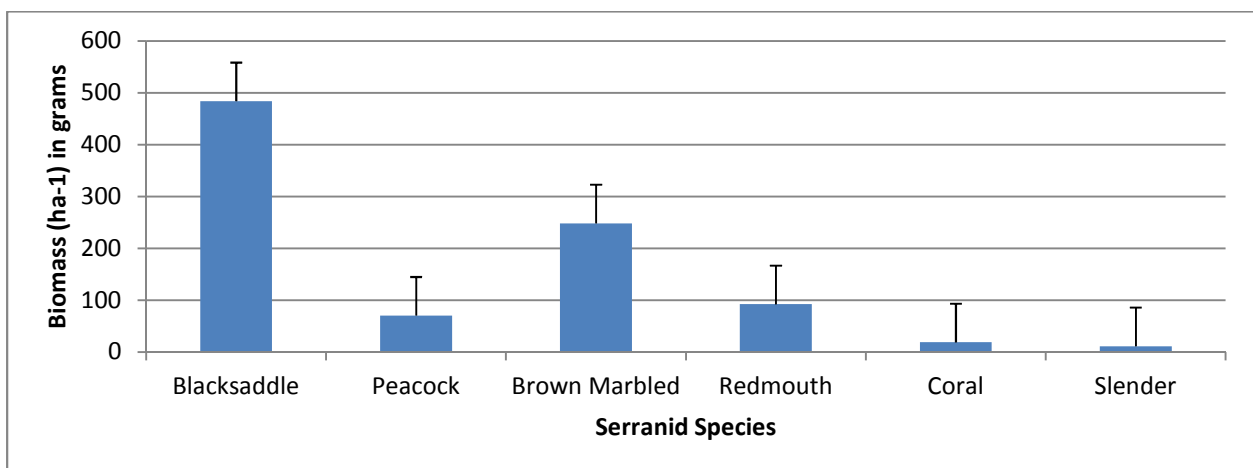


**Chart 1:** Day-time abundance of six grouper (Serranidae) species on Chumbe Island's fringing and back reef based on timed visual surveys, n=13, n=4, respectively

The average biomass per survey of all species was 36.9 kilograms on the drop-off and 3.9 kilograms on the inner reef, with the combined average of 29.1 kilograms (Chart 2). The average biomass was determined per hectare of each species with a total biomass of all species of 0.924 kilograms per hectare. *P. laevis* were the highest percentage of the total biomass per hectare, with almost 0.5 kilograms per hectare, and *A. leucogrammicus* was the smallest percentage at 0.01 kilograms per hectare (Chart 3).

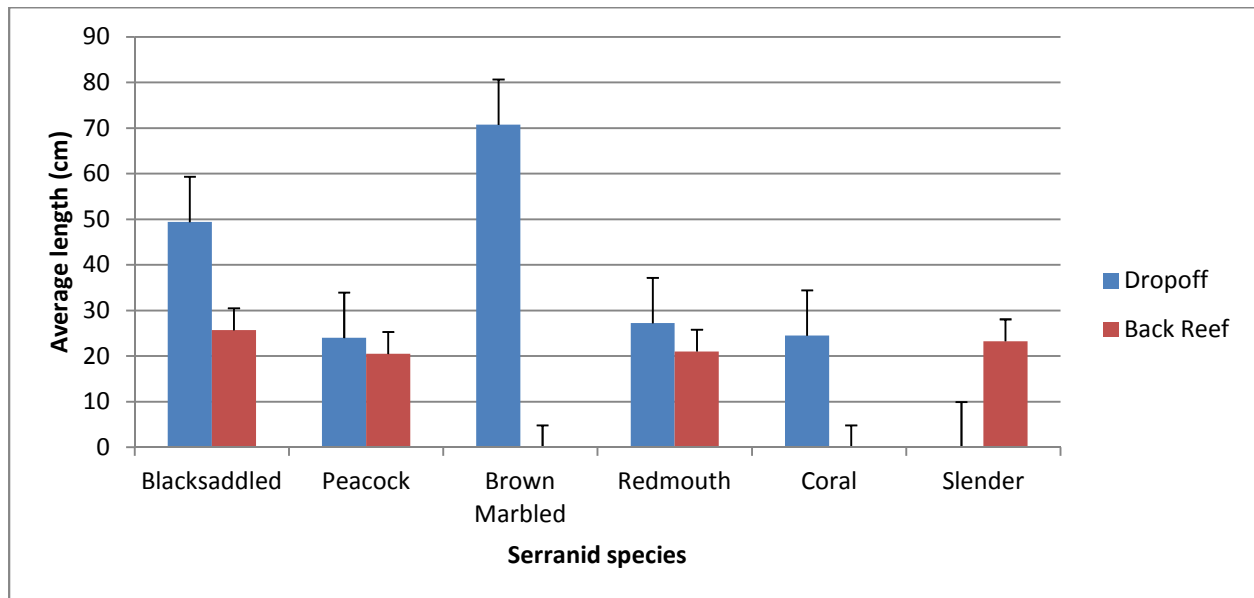


**Chart 2:** Day-time biomass of six grouper (Serranidae) species on Chumbe Island's fringing and back reef based on timed visual surveys, n=17



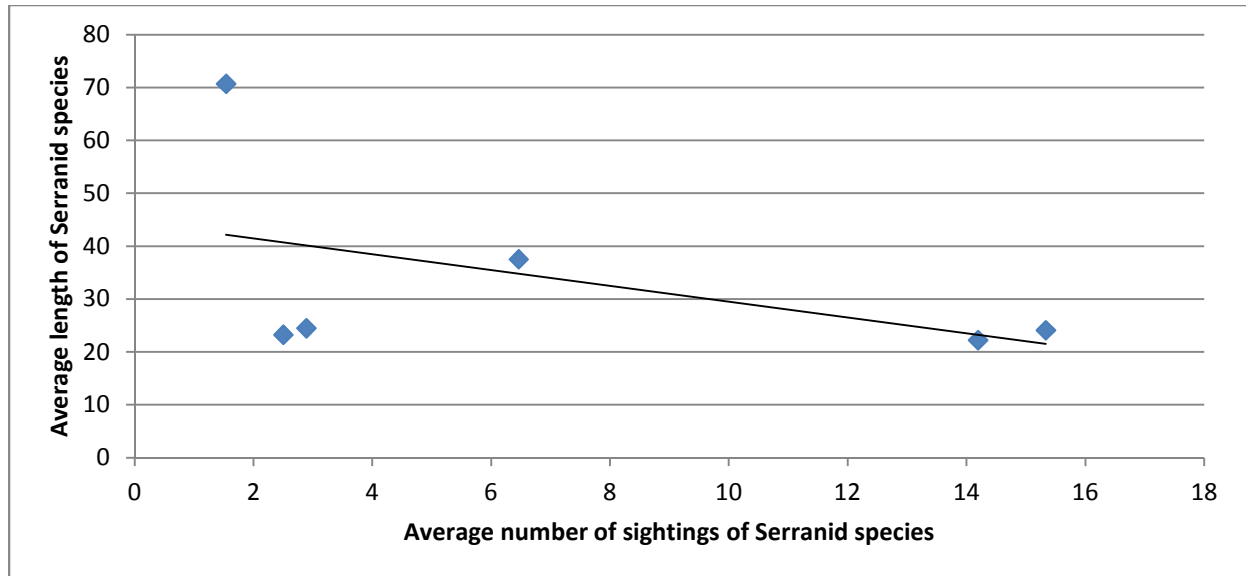
**Chart 3:** Day-time average biomass per ha of six grouper (Serranidae) species on Chumbe Island's fringing and back reef based on timed visual surveys, n=17

Average length in centimeters for all species was 39 for the drop-off and 23 for the inner reef, with an average of the whole reef at 34 cm (Chart 4).



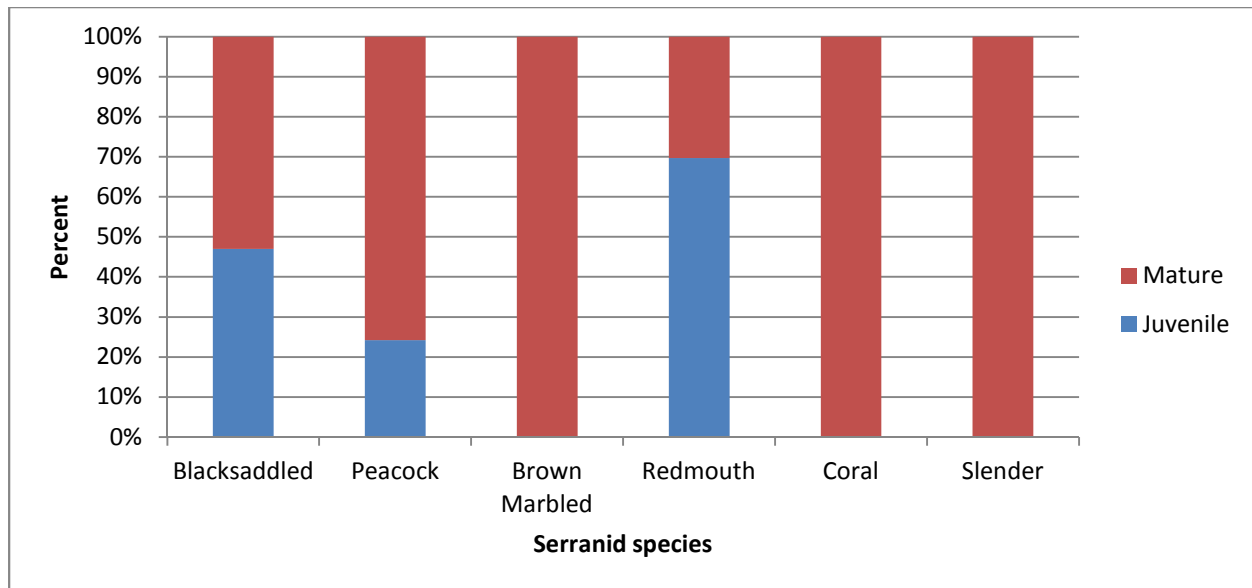
**Chart 4:** Day-time average lengths (cm) of six grouper (Serranidae) species on Chumbe Island's fringing and back reef based on timed visual surveys, n=17, n=4

The largest fish, *P. laevis* and *E. fuscoguttatus*, were not seen as often as smaller species such as *C. argus* and *A. rogae*. *C. miniata* and *A. leucogrammicus*, however, are neither large fish nor were seen often (Chart 5).

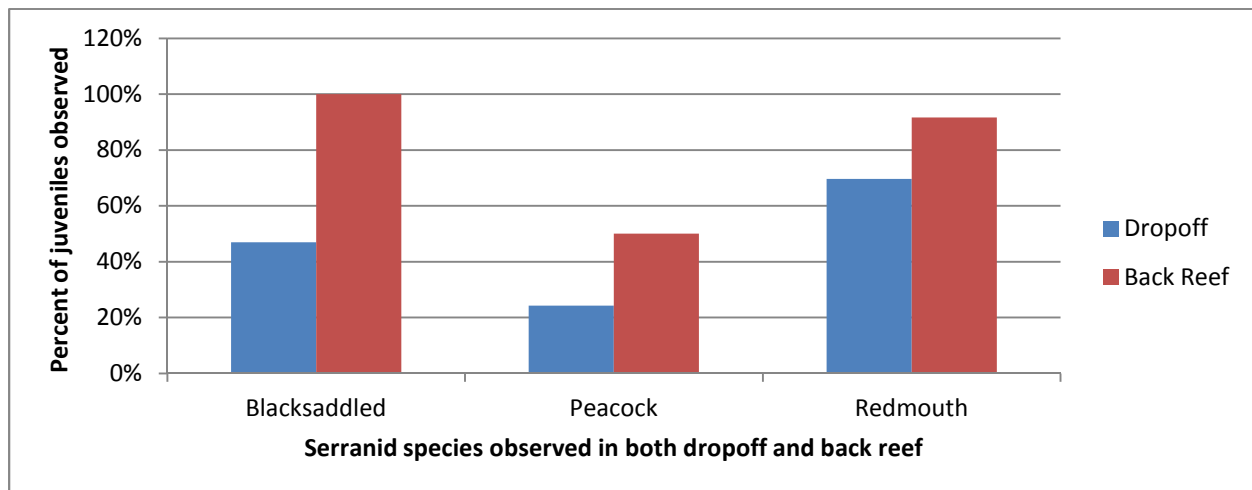


**Chart 5:** Day-time average number of sightings of Serranid species compared to average lengths, drawn with a linear line-of-best-fit, n=17

On the drop-off, a smaller percentage of juveniles were observed, with the greatest difference in *E. fuscoguttatus* and *C. miniata*, where no juveniles were observed. The largest percentage of juveniles observed was of *A. rogae* with over 90%. *P. laevis* was almost evenly split between juveniles and adults, but over 80% of *C. argus* observed were mature (Chart 6). Also, a higher percentage of juveniles were observed in the back reef than on the drop-off for the species seen in both areas (Chart 7). Distinction between juvenile and adult information found in Table 4 in Appendix.



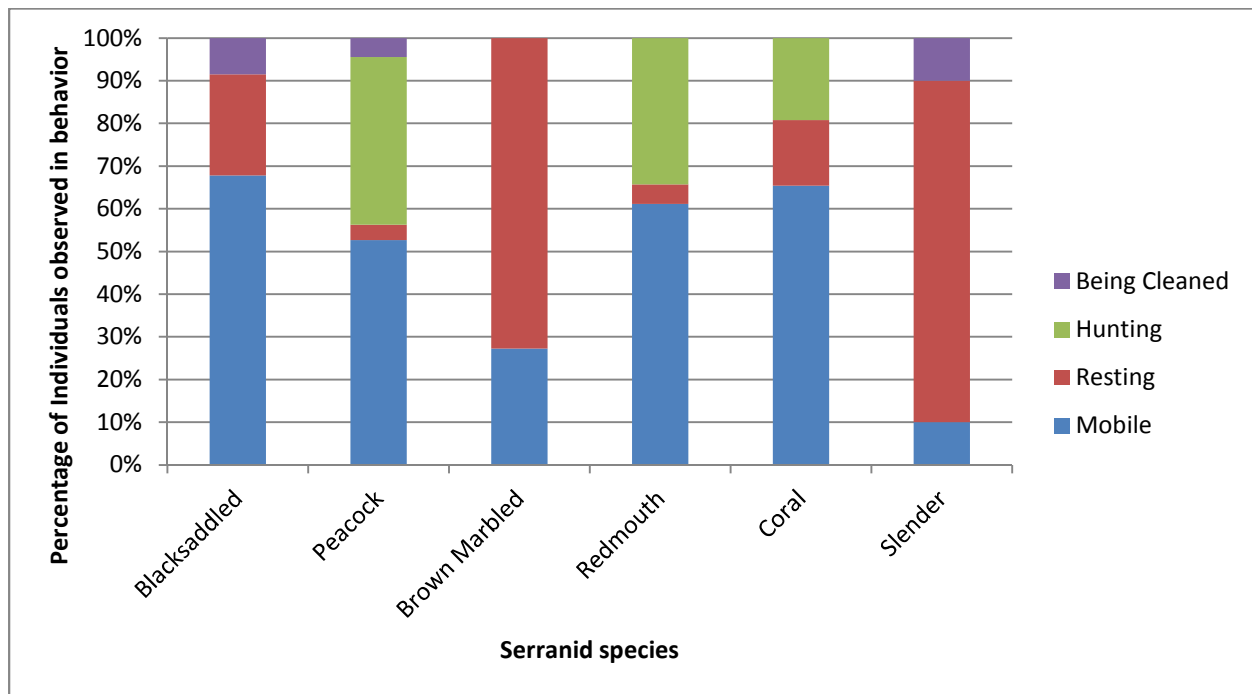
**Chart 6:** Day-time percentage of juveniles to sexually mature adults of six grouper (Serranidae) species on Chumbe Island's fringing and back reef based on timed visual surveys, n=17



**Chart 7:** Day-time percent of juveniles observed on drop-off and back reef of three grouper (Serranidae) species on Chumbe Island's fringing reef and back reef based on timed visual surveys, n=13, n=4, respectively

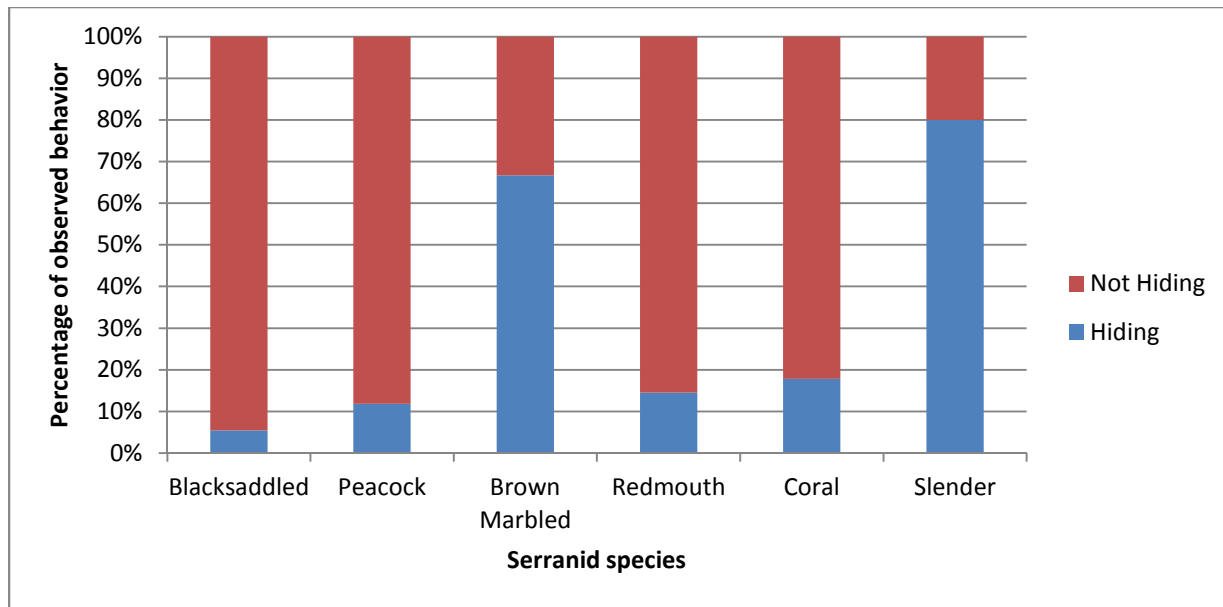
Four different behaviors were observed over the course of the study: mobile, resting, hunting, and being cleaned by Cleaner Wrasse (*Labroides dimidiatus*). *E. fuscoguttatus* was observed at rest, under shelter, over 70% of the time, while *C. miniata* and *P. laevis* were the most active, both observed mobile around 65% of the time. *C. argus* and *A. rogae* were observed hunting more often than the other species, both observed to be hunting over 40% of the

time. Only three species were observed being cleaned, *P. laevis*, *A. leucogrammicus*, and *C. argus*, and one *P. laevis* was observed rubbing its body against the sand multiple times, so this behavior was marked as self-cleaning. *A. leucogrammicus* was almost always observed under shelter, and almost always at rest (Chart 8).



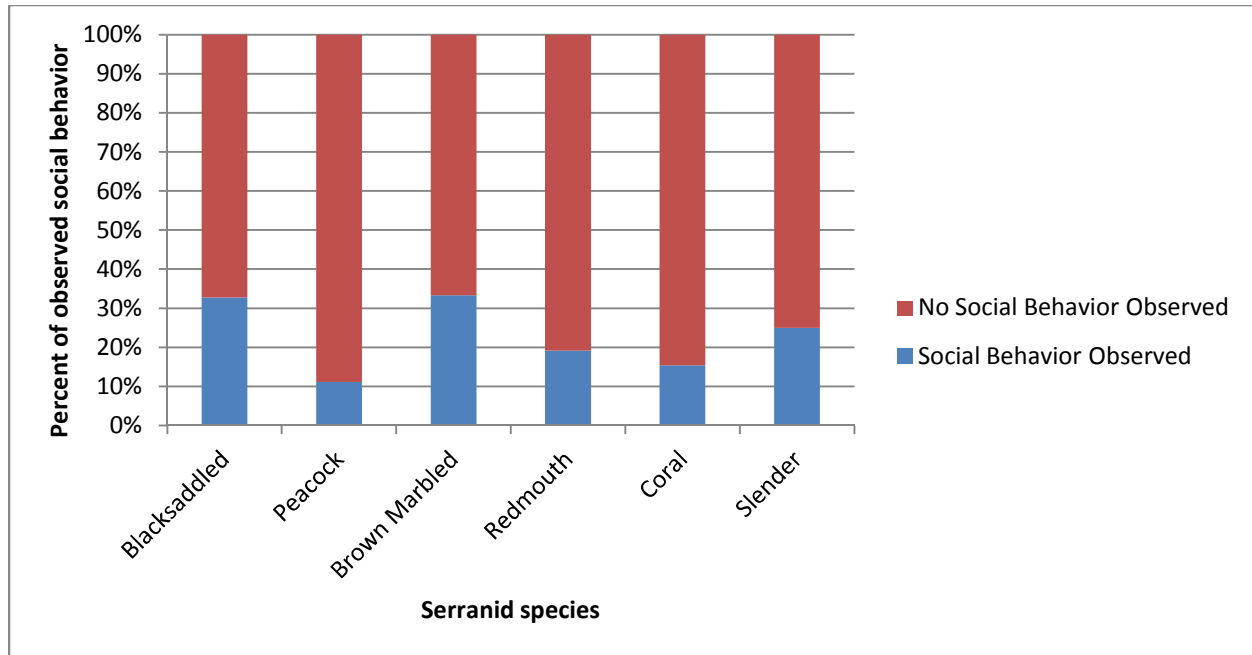
**Chart 8:** Day-time distribution of behavior of six grouper (Serranidae) species on Chumbe Island's fringing and back reef based on timed visual surveys, n=17

Note was taken whenever an individual was observed concealing itself, which was most common with *A. leucogrammicus*, which was almost always observed under shelter, usually stacks of table coral (*Acropora hyacinthus*). *E. fuscoguttatus* was also commonly observed concealing itself and were observed doing this over 65% of the time. *C. argus* and *P. laevis* were observed in this behavior the least, only about 15% and 5%, respectively. The other two species, *A. rogae* and *C. miniata*, were not observed to be concealing themselves often, both under 20% of the time (Chart 9).



**Chart 9:** Day-time hiding tendencies of six grouper (Serranidae) species on Chumbe Island's fringing and back reef based on timed visual surveys, n=17

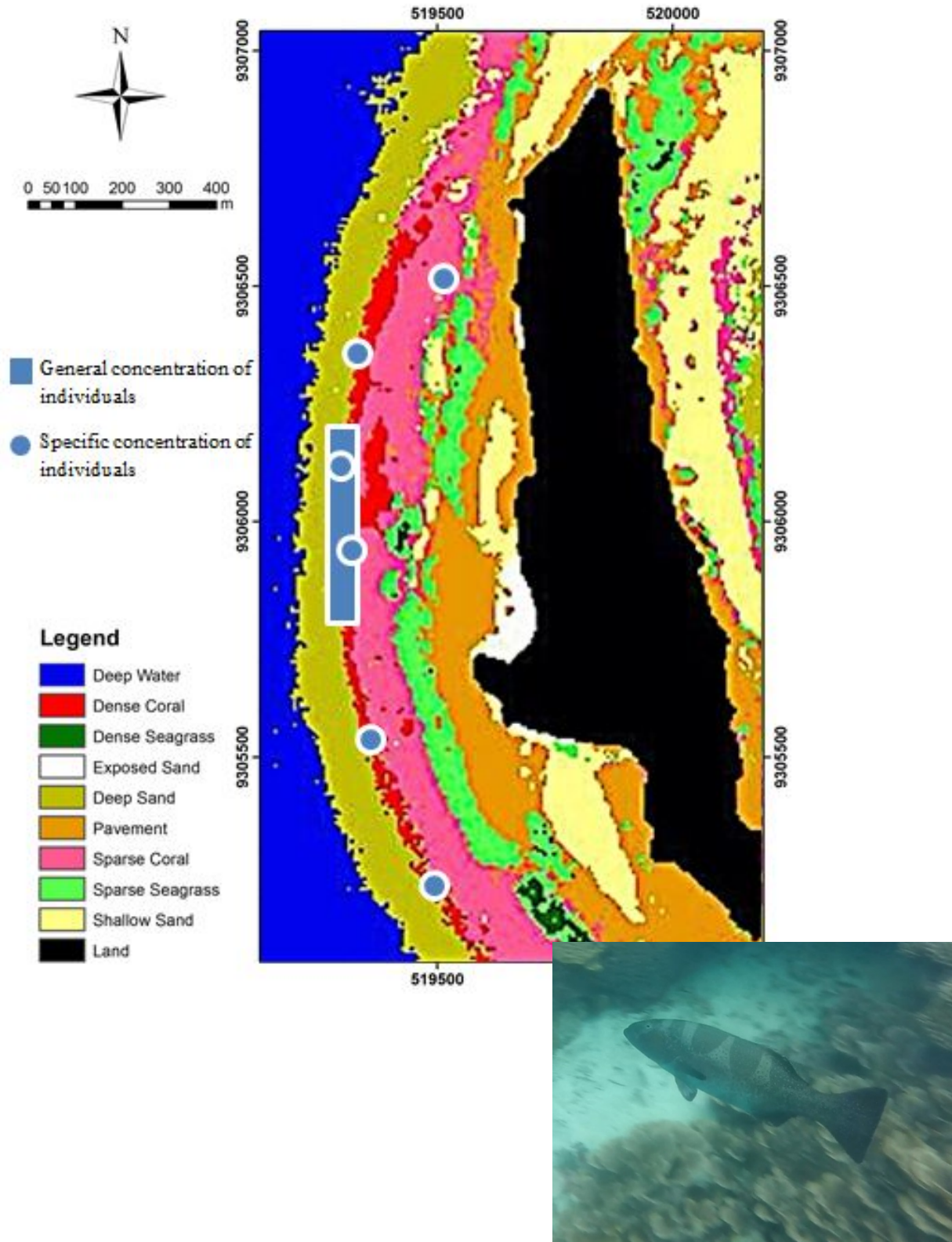
While it was uncommon to see any Serranid species in groups, the average for all species at 25%, instances were recorded where there was more than one observed with others of the same species. The most social behavior was shown in *P. laevis* and *E. fuscoguttatus*, with just over 30% of individuals in groups of two or more. *P. laevis* was the only species seen in a group larger than two, with two instances of three seen together. Less than 19% of *C. argus* and *C. miniata* were seen in groups, and *A. leucogrammicus* was almost never seen with any other members of the same species (Chart 10), however, they were commonly seen in the coral with schools of Red Soldierfish (*Myripristis murdjan*).



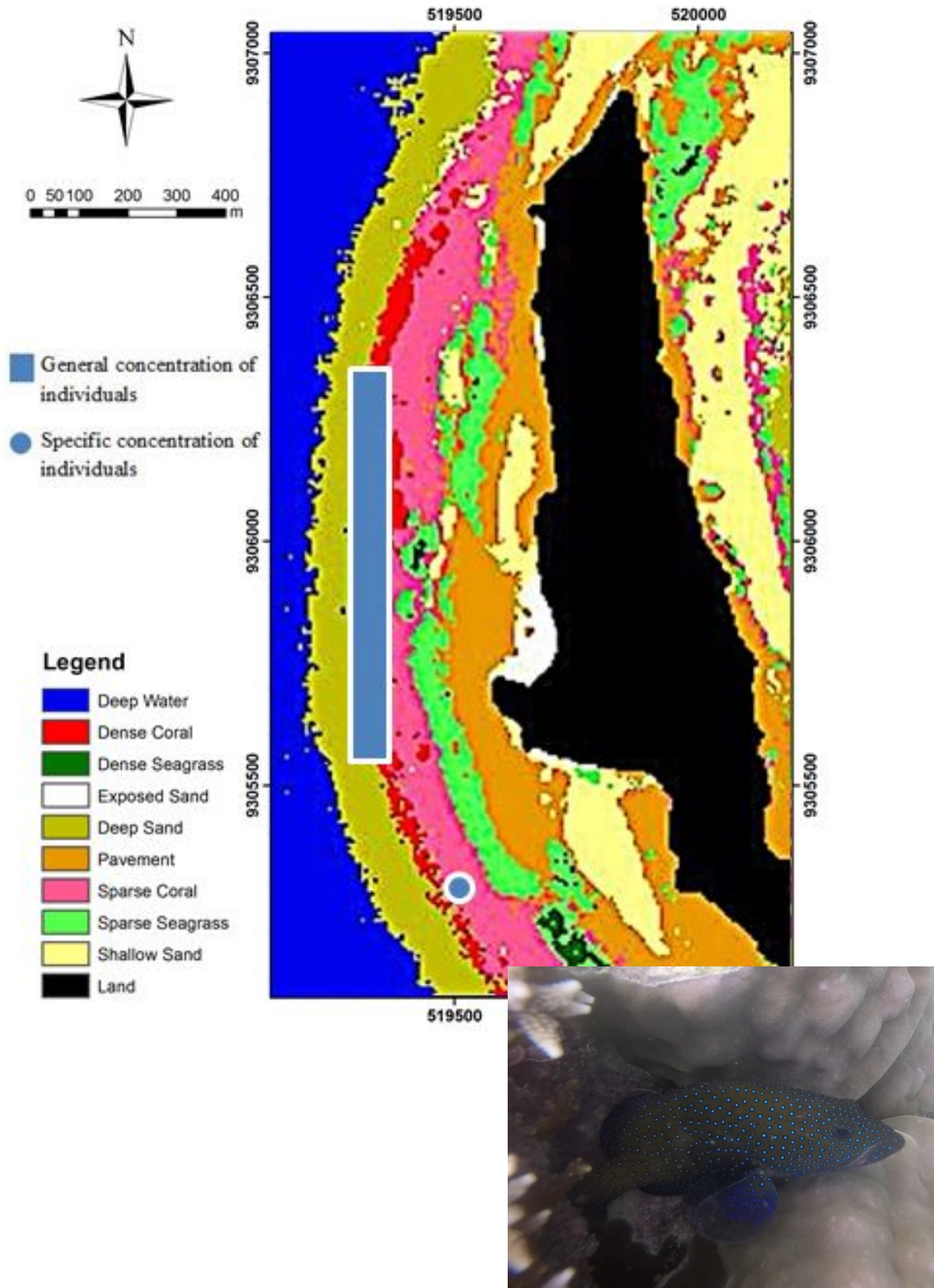
**Chart 10:** Day-time social behavior tendencies of six grouper (Serranidae) species by percentage on Chumbe Island's fringing and back reef based on timed visual surveys, n=17

It was noted where concentrations of each species were found, and Figures 3-8 detail where their concentrations were on the reef. Overall, most species were found in higher densities of coral, closer to or on the drop-off, between  $6^{\circ}16'334.69''$  S,  $39^{\circ}10'29.17''$  E and  $6^{\circ}16'48.89''$  S,  $39^{\circ}10'29.46''$  E from North to South. Some species had entire areas where they had higher concentrations, while some were in very specific areas.



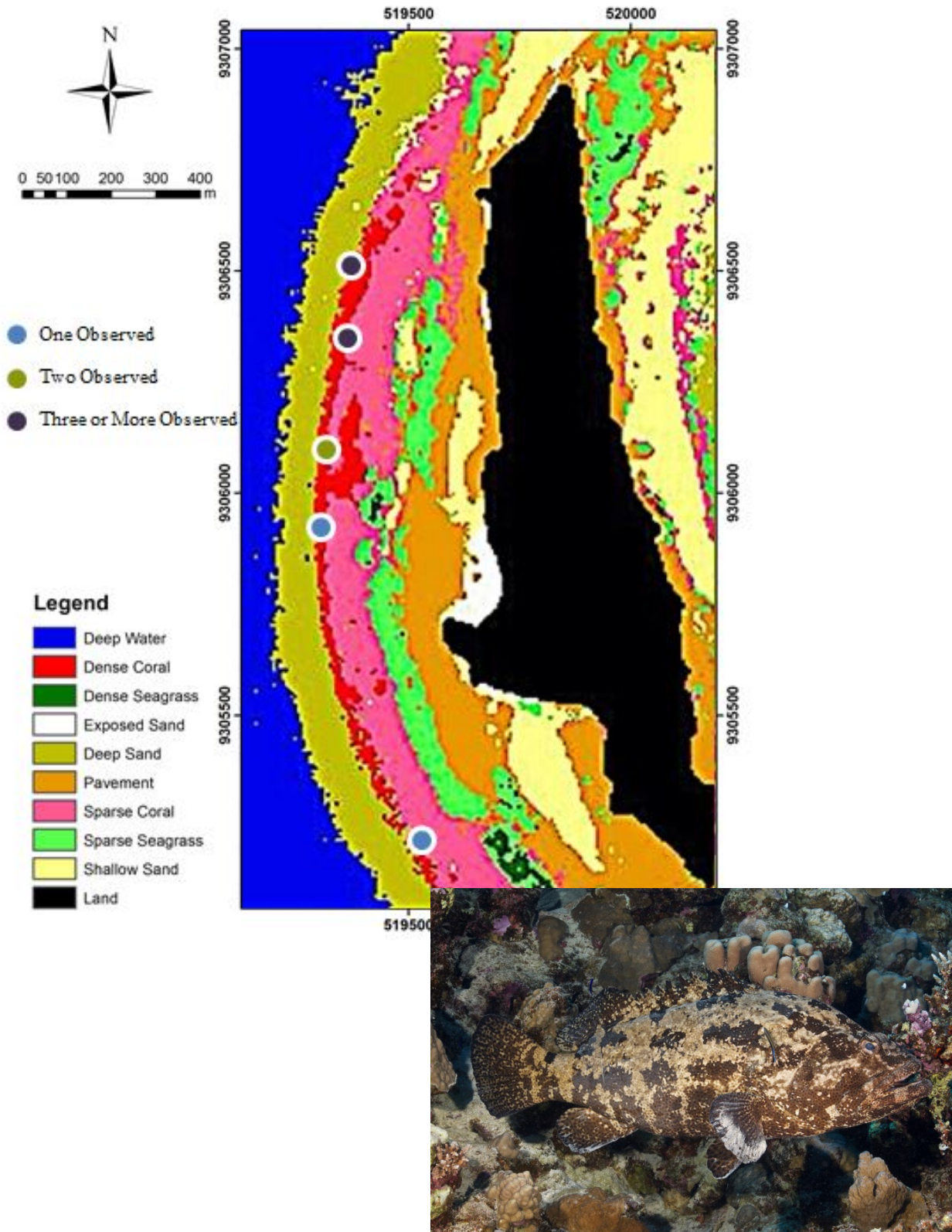


**Figure 3:** Chumbe Island MPA reef with concentrations of *P. laevis* based on average sightings per survey with photo of adult individual, n=13

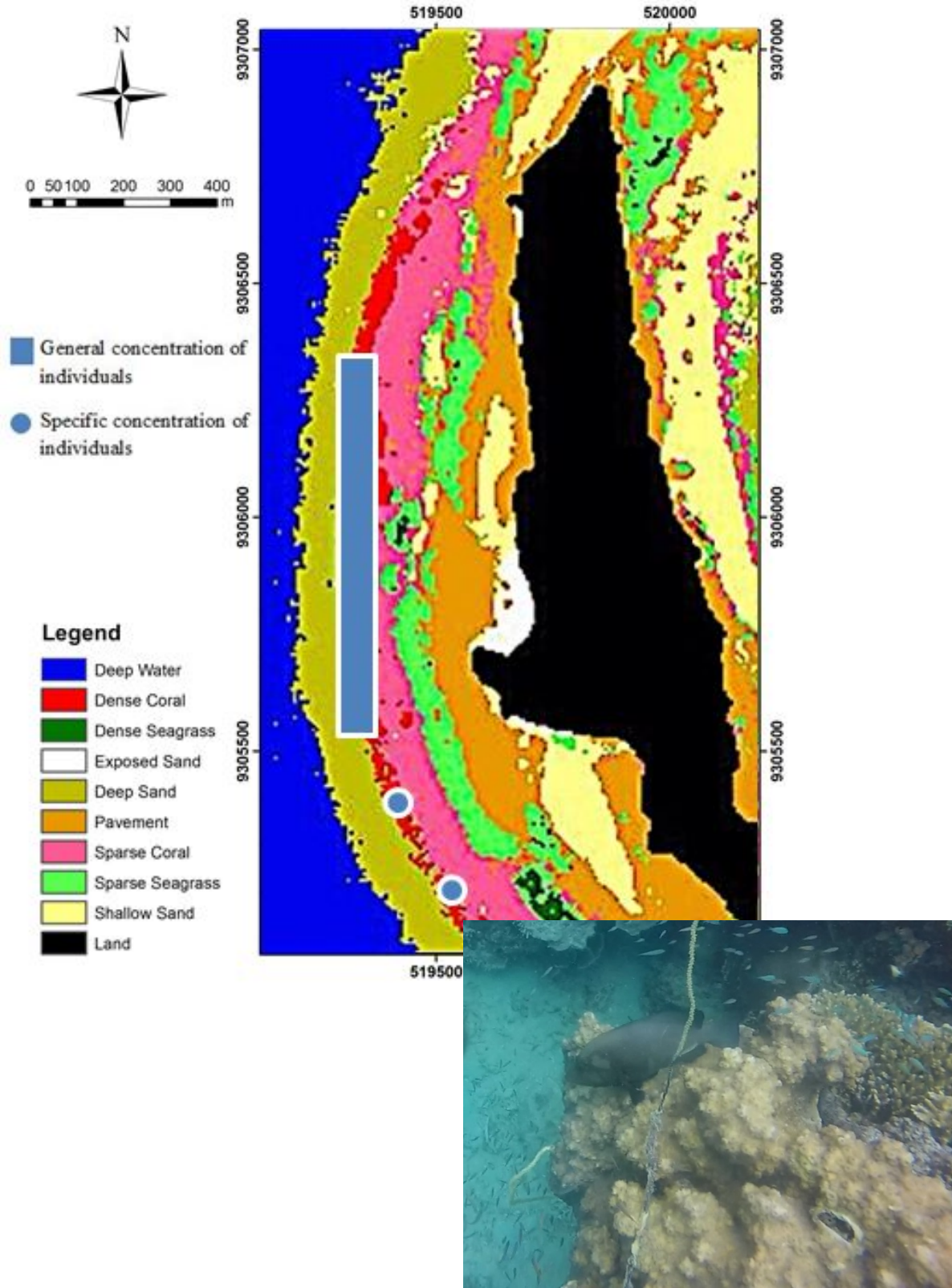


**Figure 4:** Chumbe Island MPA reef with concentrations of *C. argus* based on average sightings per survey with photo of individual, n=13



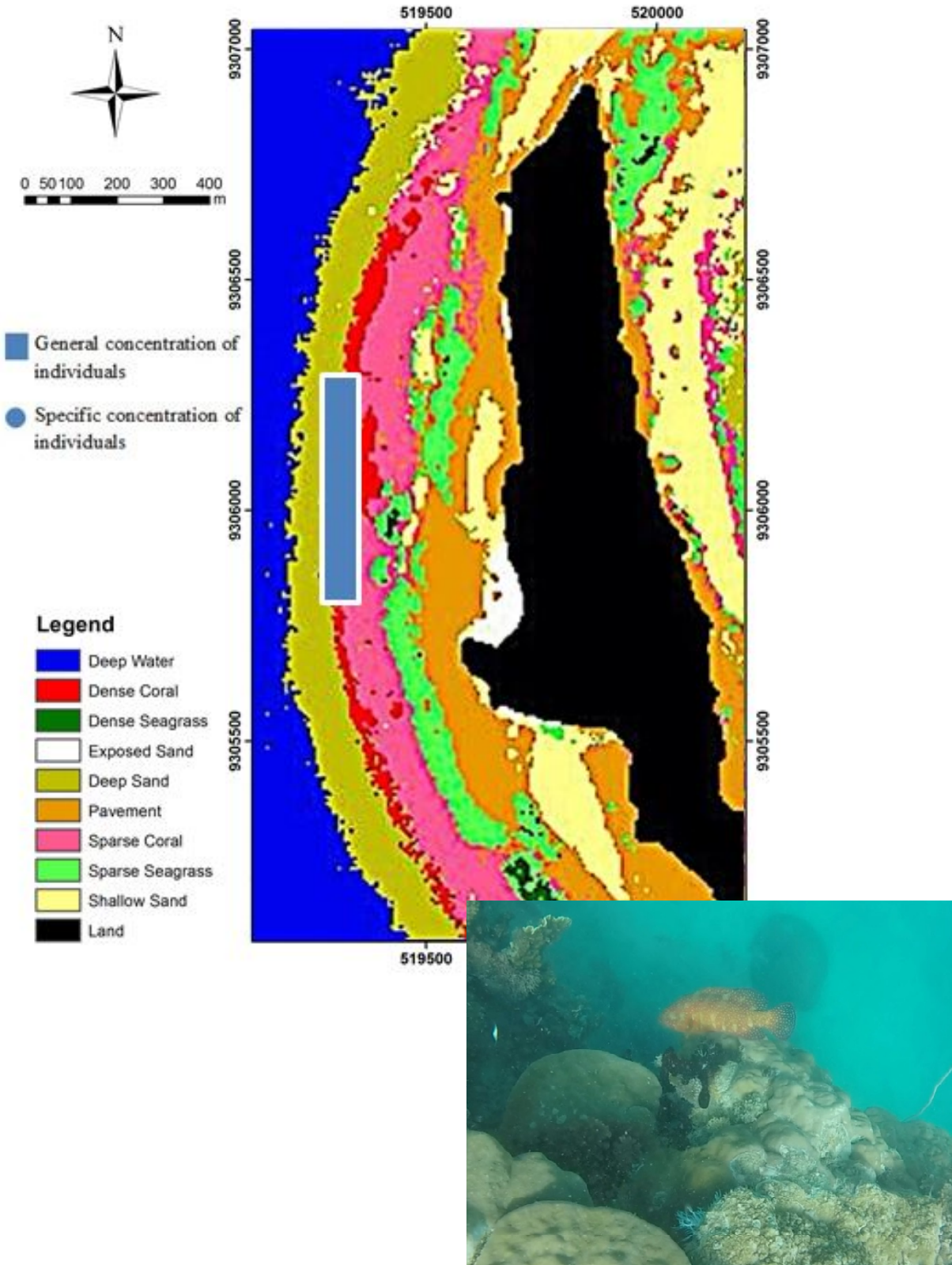


**Figure 5:** Chumbe Island MPA reef with concentrations of *E. fuscoguttatus* based on average sightings per survey with photo of individual (Photo Credit: Wikipedia.org), n=13

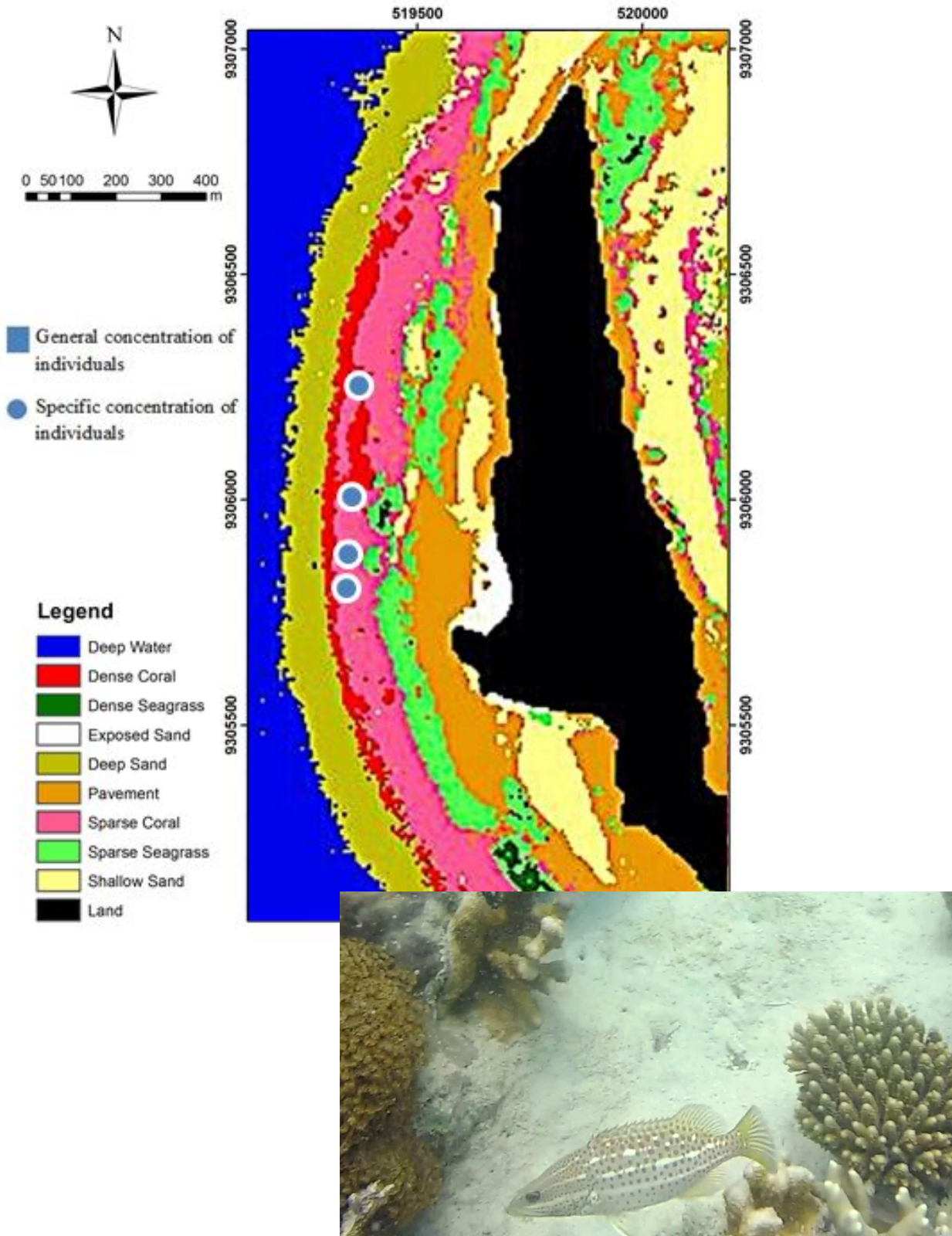


**Figure 6:** Chumbe Island MPA reef with concentrations of *A. rogae* based on average sightings per survey with photo of individual, n=13





**Figure 7:** Chumbe Island MPA reef with concentrations of *C. miniata* based on average sightings per survey with photo of individual, n=13



**Figure 8:** Chumbe Island MPA reef with concentrations of *A. leucogrammicus* based on average sightings per survey with photo of individual, n=13

**DISCUSSION:**

Both the dense coral of the drop-off and the sparse coral of the back reef of CHICOP were surveyed to get a full census of the Serranid species inhabiting all areas of the MPA reef. Serranid species were observed during every survey. Larger individuals were observed on the drop-off, while smaller individuals were observed on the back reef, and this trend was explicit for all species, to the point where the species that grow the largest were not observed at all on the back reef. The largest individual (in terms of both length and girth) seen on the reef was an *E. fuscoguttatus* over ninety centimeters long, and along with other *E. fuscoguttatus* and *P. laevis*, these large predators are all indicative of a healthy reef ecosystem with a complex and dynamic food web.

**Biomass & Size:**

Since the collected data is setting a baseline for future study at CHICOP, there is no comparison to make to previous studies of the same methodology. The numbers of Serranid species have a range that somewhat correlates to average size, indicating that the numbers of larger fish are most likely much smaller than smaller fish. The largest fish, notably *P. laevis* and *E. fuscoguttatus*, were seen much less than the smaller species including *C. argus* and *A. roga*. *C. miniata* and *A. leucogrammicus* are outliers since they have very specific habitats, coral caves and in between corals respectively, that make them difficult to find via underwater visual census. The habitat of these two species normally consisted of deeper water and inside stacks of coral, respectively, so it is very probable that some individuals were not counted. The average biomass of all species was 9.240 g/m<sup>2</sup>, which is much higher than a study done ten years ago, which came to a biomass of all Serranid species of 1.236g/m<sup>2</sup>, but methodology was different and less time was spent on the drop-off, where the larger fish are. However, this could also be indicative of

the effectiveness of CHICOP in conservation of a well-developed food web in the past ten years. However, the study found ten Serranid species, while this study only found six of the seven that have been identified on Chumbe in the last ten years after the previous study was done (Lanshammar, 2004, p. 11-12).

In terms of biomass, the combination of a more commonly seen fish and a larger fish contributed to high biomass, like *P. laevis*. This species was also numerous in juveniles, which can grow to be adult-size before changing color, and the adults were never observed concealing themselves since their bodies have such good camouflage, so the individuals were likely to be found. *E. fuscoguttatus* had the largest biomass per fish due to their large length and girth, but they were much less numerous than all the other species, hence the lower biomass. *A. leucogrammicus* had the smallest biomass due to individuals being relatively difficult to find, and they are smaller fish with a small girth, so they do not have much weight to them either. *E. fuscoguttatus* had the largest average size, and individuals were observed on multiple occasions that were over 90 centimeters long. Originally it was known that two large *E. fuscoguttatus* inhabited the drop-off of the reef, but with average sightings and distinction between individuals, there are most likely four large individuals, possibly five, another indicator of a healthy reef ecosystem (Friedlander, et al. 2002). *E. fuscoguttatus* and *P. laevis* are two of the largest fish on the reef, along with the Blacktip Reef Sharks (*Carcharhinus melanopterus*) that come to the reef at dawn and dusk to hunt. But the groupers make their home on the reef, while the sharks just pass through.

There was also a stark difference in average sizes between the drop-off and the back reef, with every species having a smaller average size in the back reef. This indicates that the fish stay in the shallower, back reef until they grow large enough to compete on the drop-off. And



the difference in average sizes between all species was over 16 centimeters between the drop-off and the reef. This also correlates well with the percentage of juveniles observed of each species.

### **Juvenile Population:**

*A. rogae* and *P. laevis* had the highest juvenile percentage, most likely due to the large size of maturity and that the color change can occur anywhere from 1-10 years, respectively (Choat, et al 2008). Some very large *P. laevis* juveniles were observed. Of the six species, three were observed on both the drop-off and the back reef, and all three species had a higher percentage of juveniles on the back reef than on the drop-off. This correlates well with data that shows many species of grouper grow up in seagrass beds, move to a shallow reef, and once large enough, can move to deeper waters (Brown Marbled Grouper, 2013). And since there were no adult *P. laevis* or *E. fuscoguttatus* in the back reef, this further accentuates where these species grow up. Also, once the large species reach a certain size, they can no longer hide well in shallow water to ambush their prey, so they must move to deeper water.

### **Behavior:**

The two species observed at rest most often, *E. fuscoguttatus* and *A. leucogrammicus*, were also the species observed to be concealing themselves behind or within coral the most often. And the species most often observed to be hunting rarely concealed themselves, but rather relied on camouflage to ambush prey, since when *C. argus* and *C. miniata* were perched and hunting, they were often difficult to see. No actual feeding of any species was observed. Highly mobile species included *P. laevis*, where the juveniles accounted for a large portion of the percentage, as well as *A. rogae* and *C. miniata*. This could mean that many individuals of these species, especially the juvenile *P. laevis*, do not have a specific territory they stay in, but rather move about the coral reef, while species like *C. argus* have specific territories where the females

stay in one area, usually hunting, and the male is mobile, visiting the females in his territory (Liu, et al. 2008).

Groupers are known for being ambush predators, so they must have some way of concealing themselves from potential prey (Dierking, et al. 2009). Some species are heavily reliant on camouflage, like adult *P. laevis*, *C. argus*, *A. rogaea*, and *C. miniata*, while others rely on a shelter to hide in, like *E. fuscoguttatus* and *A. leucogrammicus*. *E. fuscoguttatus*, however, has a well-designed camouflage, especially in deeper water, while *A. leucogrammicus* does not, so they are heavily reliant on the table coral they hide in for ambush.

None of the six species were commonly observed in groups, they were often observed to be solitary fish, and the most common instances in which groups were seen were either hunting in the same area (*C. argus*, *A. rogaea*, and *C. miniata*) or hiding in the same area (*A. leucogrammicus* and *E. fuscoguttatus*). However, the numbers of social behavior in *E. fuscoguttatus* is rather high compared to the other species. This is due to two instances of two individuals seen together, one very large individual (over 90 cm long) and one smaller individual (about 45 cm long) were together in the Northern end of the reef, and it is fairly certain that these two individuals were seen together twice since they were seen in the same area on consecutive days and the two fish were similar sizes to the previous sighting. Other than these two occurrences, all *E. fuscoguttatus* were observed alone. As for *P. laevis*, three large adults were seen together twice, and were believed to be the same group due to the sizes of the individuals and that one of them was turning coloration to an adult. This was the largest group of *P. laevis* observed and accounts for a significant percentage of the observed social behavior for the species. *P. laevis* was the most social of all species, and showed the smallest percentage of hiding tendencies, a trend not strictly followed by other species since *C. argus* was the least

social and showed a small percentage of hiding tendencies, so these two behaviors may not be closely related.

**Habitat:**

*P. laevis* had both a general habitat as well as specific areas of concentration, indicating that some individuals move about the reef, while others stayed in the same general area. This wide dispersion of habitat is most likely due to the high number of juveniles, which were very mobile and seen in more areas of the reef than the adults. The large adults were seen at the bottom of the drop-off, approximately six to eight meters deep, while the juveniles were seen in shallower water, approximately two to five meters deep. No mature adults were observed on the back reef.

*C. argus* had a habitat dispersed throughout the reef, but were more concentrated on and around the drop-off, and were not seen at depths beneath six meters. They were mostly seen in the middle of the reef, but had a specific concentration at the southernmost point of the reef. Mature adults were observed all around the reef, but with the maximum size of *C. argus* at 50 centimeters (although the largest observed on the reef was approximately 40 centimeters), these fish are not hindered by size and can make their home in many different areas of the reef.

*E. fuscoguttatus* was seen the least of all the Serranid species, and their positions were noted with more precision than other species. Specific concentrations were observed, showing tendencies to favorite a particular area of the reef, and on one occasion, a specific coral head in the North was a preferable habitat for one smaller individual (approximately 60 cm long) that was observed in the same area three times over consecutive days (Figure 9). The areas of highest concentration were the northernmost area of the reef, where the coral becomes sparser, and there were two instances of two *E. fuscoguttatus* seen together in a very similar area, out in the open,

and three instances of observing the previously mentioned smaller individual. Other areas, always the drop-off, had slightly smaller concentrations of *E. fuscoguttatus*, but always in a specific area.



**Figure 9:** Day-time coral head used for concealment for one *E. fuscoguttatus* that was observed here three times over consecutive days

*A. rogaea* had a wide distribution that covered both the drop-off as well as the back reef where larger individuals and smaller ones were observed, respectively. This suggests that *A. rogaea* grows up in shallower waters, then move to the drop-off when they have achieved a certain size. They had a large general concentration in the middle of the reef, more along the dense coral of the drop-off than the sparse coral of the back reef, but were still numerous in all areas surveyed, showing that they most likely do not keep to specific territories, but rather move about the entire reef. Two specific concentrations of *A. rogaea* were observed at the southern end of the reef, and almost none were observed at the northernmost area of the reef, suggesting that this species prefers denser areas of coral. Generally, individuals were observed between two and five meters deep, this species preferring shallower water compared to others.

*C. miniata* had a relatively specific distribution on the reef. Individuals were never seen above four meters, and kept close to the shelf of the drop-off. They were concentrated where the

drop-off was steepest, which correlates with their preference for deeper waters and concealing themselves in coral caves (Cabanban et al. 2008). Most likely, this species has a specific territory on the reef since individuals were only observed in a very small, approximately 350 meter length of reef.

*A. leucogrammicus* also had very specific concentrations, but these were on the back reef. This species seemed to prefer specific areas of coral cover, with individuals observed in very similar areas over the course of the study, suggesting that this species keeps to a certain area of coral, which becomes its home since they were never observed far from shelter. And this would be why *A. leucogrammicus* is not seen on the drop-off, since there are no areas of Table Coral for the individuals to hide under.

#### **Sources of Error:**

Sources of error in this study include weather, the short duration, and the tide tables, among others. This study was conducted during the lesser monsoon season in East Africa, and with rain comes murky water, which sometimes made it especially difficult to find the well-camouflaged individuals. And since so many of these species rely on hiding and camouflage to hunt, surely not all the individuals were observed that were present. Hunting behavior may not have been determined accurately due to lack of literature on the subject. Limits on free-diving depth were also an issue since some of the species can live at depths not able to be reached by free-diving. It was attempted to spread out surveys over all times of the day while dividing the tides between coming in and going out, but it was not a completely even distribution. Pertaining to *A. rogaea*, there was a noticeably high juvenile population, which may be due to the lack of information on this species, so the length that divides juveniles and adults in this study may be higher than the actual differentiating length.

**Conclusion:**

With the conclusion of this study, a baseline of Serranid species has been established and future studies can compare their results to this information. A baseline of numbers of the six species, their biomass per hectare, their size, and multiple facets of their behavior, so changes, if any, can be observed in the future. The number of large *E. fuscoguttatus* individuals inhabiting the reef was raised from what was previously believed. The spread of the behavior of these species was also established for future comparison and to show how these species spend their time on the reef. A ratio of juveniles to adults was shown as well that showed a healthy balance of juveniles to adults to support future generations of Serranid species.

Presence of large predators is indicative of a healthy reef ecosystem, and understanding their role on the reef is key to furthering conservation efforts, and a pristine reef ecosystem such as CHICOP can be used as a model for conservation efforts to be compared to (Lanshammar, et al. 2004). Along with these six Serranid species, multiple other predators were observed on the reef including: Blacktip Reef Sharks (*Carcharhinus melanopterus*), Common Reef Octopi (*Octopus cyanea*), Bluespotted Ribbontail Stingrays (*Taeniura lymma*), as well as multiple snapper and eel species. An educational pamphlet for CHICOP guests was created, and an educational video will be made in January 2015 detailing about groupers and other predators on the reef including where they are situated on the reef, how to find them, and their diet.

**Recommendations & Suggestions for Further Study:**

Based on the data taken over this month-long study, further study of the predators at CHICOP is recommended. Since the area is already well-protected and remains the only private MPA in East Africa, in-depth cataloging and research should be conducted to show what a model coral reef ecosystem looks like. This can assist less protected areas in helping them to know what to look for in signs of a healthy reef and what differentiates the other West Indian Ocean reefs from Chumbe in terms of fish density and size. To further this study, it is recommended that egg production capacities of each species be researched so as to determine the value of CHICOP in terms of larvae export. It is also recommended that this study be repeated every few years to establish trends in the large predators, and possibly expanding the study to include all predators on the reef. Including size categories, numbers, and behavior would continue to be helpful in the next few years to track changes in any of the above. A total biomass calculation of Chumbe's reef would be beneficial, and then the numbers could be compared to the biomass of predators and those percentages compared to studies conducted in the Pacific islands.

Further understanding of the movements of these large fish would be beneficial. A study on the movements of *E. fuscoguttatus* combined with a photo-identification of individuals would help better establish the territories of these fish. However, this must be done with an underwater camera with zoom to photograph the individuals that get startled and quickly swim away from their hiding spots. The fish are very shy, so getting close to them is difficult.

Always interesting are comparisons between the protected and unprotected sides of Chumbe (the West side and East side, respectively). A comparison study can be conducted on the size and diversity of predators on each side of the reef to further accentuate the value and effectiveness of MPAs.

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**Appendix:**

<b>Scientific Name</b>	<b>English Name</b>	<b>Kiswahili Name</b>	<b>IUCN Red List Category</b>	<b>Max. Length (cm)</b>	<b>Lifespan (years)</b>	<b>Habitat</b>
<i>Plectropomus laevis</i>	Blacksaddled Grouper	Chewa mjombo	Vulnerable (VU)	110	18	Coral reefs and lagoons
<i>Cephalopholis argus</i>	Peacock Grouper	Chewa kichogo/ shembaru au Tewa mraba	Least Concern (LC)	50	8-12	Coral and rocky reefs
<i>Epinephelus fuscoguttatus</i>	Brown Marbled Grouper	Chewa kubwa (no real name obtained)	Near Threatened (NT)	100	40	Coral reefs, close to shelter
<i>Aethaloperca rogae</i>	Redmouth Grouper	Chewa	Data Deficient (DD)	40	Unknown	Coastal reefs and lagoons
<i>Cephalopholis miniata</i>	Coral or Jewel Grouper	Chewa ndudu	Least Concern (LC)	40	25	Coral reefs, close to shelter
<i>Anyperodon leucogrammicus</i>	Slender or White-Lined Grouper	Chewa	Least Concern (LC)	52	Unknown	Coral-abundant areas

**Table 1:** Grouper Species Specifications. Information obtained from (Brown Marbled Grouper, 2013), (Richmond, 2002), and IUCN Red List

<b>Name</b>	<b>Juvenile to 15 cm</b>	<b>16-30 cm</b>	<b>31-45 cm</b>	<b>Larger than 45 cm</b>
Redmouth				
Blacksaddled juvenile				
Blacksaddled adult				
Peacock				
Brown Marbled				
Coral/Jewel				
Slender				

**Table 2:** Table Used for Size Distribution of Four Grouper Species

Name	Tally the # of times there was more than 1	Activities Observed	Hiding/Not Hiding
Redmouth			
Blacksaddled juvenile			
Blacksaddled adult			
Peacock			
Brown Marbled			
Coral/Jewel			
Slender			

**Table 3:** Table Used for Behavioral Observations of Serranid Species

Serranid Species	Distinction of Sexual Maturity
Redmouth	Reaches 34 cm
Blacksaddled	Color change
Peacock	Reaches 22 cm
Brown Marbled	Reaches 50 cm
Coral/Jewel	Reaches 26 cm
Slender	Color change

**Table 4:** Distinction of Sexual Maturity of Serranid Species. Information obtained from FishBase.org and (Debelius 1999, 77-82).

Educational Pamphlet on Predators of CHICOP on the following pages.

## *The Predators of Chumbe Island Coral Park*

Predators are vital components of any ecosystem, and their presence is indicative of a very healthy one. On coral reefs such as Chumbe, there are numerous predators you can see around the reef, including Blacktip Reef Sharks, groupers, octopi, barracudas, stingrays, snappers, and eels. But these predators tend to be very shy and swim away from humans, so there's nothing to fear! The species listed have their English names as well as their local Kiswahili name. The best time to snorkel the reef for a diversity of fish is the early morning or late evening, that's when the fish are most active (including predators). If you want to see them, though, here's where you have to look:

### *Blacktip Reef Sharks (Papa):*

- Be on the lookout at dawn and dusk. They like to swim around the south lagoon near the seagrass beds and can often be seen there after 5pm. They have also been seen on the reef very early in the morning.
- They are piscivores, eating fish including some of the other species on this list!
- Not a danger to humans, they are very shy and will swim away quickly when close to humans, which is why they are hard to find. And they only grow to about 1.3 meters long.

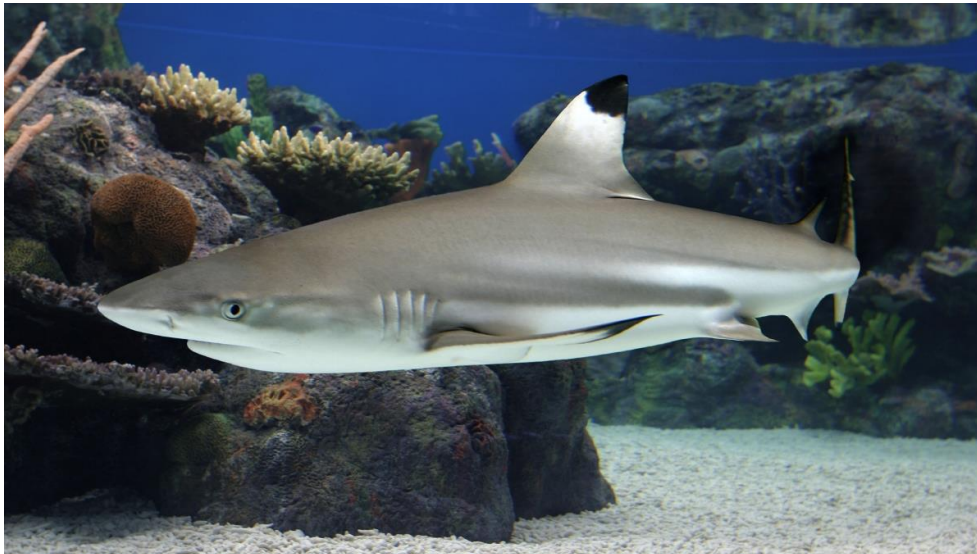


Photo credit: Monterey Bay Aquarium

### *Groupers (Chewa):*

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- Numerous on the reef, at least seven different species on Chumbe, and they can be seen in almost all areas of the reef. The most common place to see them, though, is the drop-off on the Western edge. There are many places for the big groupers to hide, and they are pretty well camouflaged so you have to be looking for them.
- Some larger species like the Brown Marbled (which can grow to one meter long) like to hide behind coral, but are startled easily. One of them is named Oscar!
- Smaller species like the Peacock Grouper are dispersed throughout the reef
- Looking in stacks of Table Coral, you might find a Slender Grouper hiding
- Coral Groupers are found in the deeper waters of the drop-off, and they are a beautiful red and yellow fish!
- Juvenile Blacksaddled Groupers like to swim about the reef and are easy to find, while the adults, which are almost completely black, live in the deeper water of the drop-off



**Top row from left to right:** Peacock Grouper, Slender Grouper, Brown Marbled Grouper  
**Bottom row from left to right:** Coral Grouper, Redmouth Grouper, Blacksaddled Grouper (juvenile)

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### *Octopi (Pweza):*

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- There are plenty of octopi on Chumbe's reef, but are very hard to see since they are so well camouflaged. The rangers are good at finding them!
- Octopi eat mostly crustaceans with their strong beak under their head (it looks very similar to a bird's beak)
- They like to hide on and inside coral crevasses, camouflaging themselves to blend in, but will change color when disturbed
- Commonly seen sold at markets (just the tentacles)



### *Barracudas (Tengezi):*

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- Barracudas can grow very large, over 125 cm, and are often seen at fish markets in Zanzibar, since their meat is sought after in many hotels
- They tend to hang out on the deeper areas of the reef and come to the reef to feed on medium-sized fish and squid
- Have been known to attack humans, but is a case of mistaken identity (shiny jewelry can look like a fish's scales in the water), but no instances of this in Chumbe!



Photo credit: silber.com

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***Stingrays (Pungu):***

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- Very close relatives of sharks, they feed on invertebrates and small fish
- They have a poisonous barb about halfway down the end of their tail, to hovering directly over them is not a good idea
- They stick to the sandy bottoms of the reef, sometimes under coral and sometimes buried under the sand, but you can often see a few swimming close to the bottom



***Soldierfish & Squirrelfish (Kifuu):***

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- Many species in the Western Indian Ocean, they feed on small fish and crustaceans and have poisonous spines on their backs
- Can find them in coral caves and in-between stacks of coral





### *Eels (Mkungu):*

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- There are many species of eels on Chumbe, and you can find them in coral crevasses, sticking their heads out, looking for prey
- Juvenile eels grow up in seagrass beds



Photo Credit: Alex Cheston



Photo Credit: Olivia McGrath

### *Trumpetfish (Mzu-moshi):*

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- Two colors: yellow or brown
- Commonly seen swimming around the reef
- Uses ambush technique to attack small fish on the reef

