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An Assessment of Icthyofauna and Artisanal Fishing From the Port of Pedregal in the Golfo de Chiriquí.

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Acknowledgements

Este proyecto no fue realizado sin la ayuda de mucha gente en David y en Pedregal. Los pescadores artesanales, con quien yo pase mucho tiempo, y toda la gente de Marisqueria Sari, tienen mi gratitud por introducirme al parte del Golfo de Chiriquí muy especial y me incluyeron en sus vidas diarios. También, la Señora en la ciudad de David, con el que yo viví durante mi proyecto, tuvo un excelente cuidado de mí todo el tiempo y le debo mi salud! Mis padres y mi hermano me apoyaron durante este tiempo y comprendieron todo para ayudarme a terminar. Nuestro director y la coordinador de estudiantes en David, Ruben Gonzalez y Analisse Staff fueron amable también. ¡Yo agradezco el tiempo de todos porque compartiendo con ustedes ha influido me mucho!

Abbreviations and Acronyms

TEP=Tropical Eastern Pacific

H’=Shannon’s Index of Community Diversity

S’=Simpson’s Reciprocal Index of Diversity

J’= The Evenness Component of Diversity

CPUE=Catch Per Unit Effort

UNK#=Species of fish for which the common Spanish name is not known by the author

Rel. Ab.=Relative Abundance

Freq. Oc.=Frequency of Occurrence

ANAM=Autoridad Nacional Ambiente, National Environmental Authority

ARAP=Autoridad de los Recursos Aquaticós de Panamá, Authority of Marine Resources of Panama

MarViva=Non-Governmental Organization dealing with marine resource protection

PNMGCH=Parque Nacional Marino Golfo de Chiriquí, Golfo de Chiriquí National Marine Park

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Figure 2. The cumulative species curve shows the total number of species encountered over the length of the study.

Table 1. This chart lists the Spanish common name, family name and species code for each species encountered. The total number of individuals of that species, its relative abundance, the number of catches in which it was present and the frequency of occurrence is also listed for each species.

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Executive Summary:

The artisanal fishery based out of Pedregal, on the Pacific Coast of Panama in the Chiriqui Province was studied to analyze the biodiversity and community structure of the icthyofaunal population and investigate the practices and opinions of the fishermen there. The study area is located in the Gulf of Chiriqui, and is heavily influenced by freshwater runoff from anthropogenically influenced rivers during. This is especially relevant during the rainy season.

During two weeks in November, at the end of the rainy season, fishermen from one port in Pedregal were accompanied for the purposes of data collection and interviewing. The data collected on the fish community were analyzed in terms of biodiversity measurements including Shannon's Index of Community Diversity and Simpson's Reciprocal Index of Community Diversity as well as species and family richness and family composition, evenness and length frequency. This data for a cross-section in time can provide basic data about the icthyofauna of the community and comments on the possible health of the ecosystem studied. Additionally, investigating these measurements over a variety of habitat types can add to the dearth of knowledge of species-habitat interactions in mangrove habitats. The fishermen that made this study possible depend on this fish community for their livelihood and culture. Their long-term understanding of the area is a source of knowledge that should be recorded as well. For these reasons, understanding their methods and opinions will help to preserve the biodiversity of the region and its unique culture.

The results of this study showed that the artisanal fishery of this region does include a diverse and dynamic fish community inhabiting a variety of habitat types. The fishermen are informed on the trends of the fish populations and practice their work on a small-scale. However, competition and possible habitat degradation due to a variety of environmental

issues could currently pose a threat to the fish community that supports the artisanal fisheries of Pedregal.

Resumen Ejecutivo:

La pesca artesanal con base in Pedregal, en la costa del Pacífo de Panamá en la provincia de Chiriqui se ha estudiado para analizar la estructura de la biodiversidad y de la comunidad de la población icthyofaunal e investigar las prácticas y las opiniones de los Pescadores allí. El área de estudio se encuentra en el Golfo de Chiriqui, y está fuertemente influenciado por la escorrentía de agua dulce de los ríos antropogénicament influenciado durante la estación de lluvia. Esto es especialmente relevante durante la estación de lluvia.

Durante dos semanas en Noviembre, al final de la estación de lluvia, los pescadores de un puerto de Pedregal fueron acompañados a los efectos de la recopilación de datos y entrevistas. Los datos recogidos en la comunidad de peces fueron analizadas en términos de medición de la biodiversidad incluyendo el índice de Shannon de diversidad comunitaria y el índice de Simpson reciproco de la diversidad de la Comunidad, así como las especies y la riqueza de la familia y la composición familiar, la regularidad y frecuencia de tallas. Estos datos de una sección transversal en el tiempo puede proporcionar datos básicos sobre la ictiofauna de la comunidad y los comentarios sobre la salud posibles del ecosistema estudiado. Además, la investigación de estas mediciones en una variedad de tipos de hábitat puede agregar a la falta de conocimiento de las interacciones de los hábitats de especies en los manglares. Los pescadores que hicieron posible este estudio dependen de esta comunidad de peces para su subsistencia y la cultura. A largo plazo la compresión de la zona es una fuente de conocimiento que deben ser registrados también. Por estas razones, la comprensión de sus métodos y opiniones ayudara a preservar la biodiversidad de la región y su cultura única.

Los resultados de este estudio mostraron que la pesca artesanal de esta región incluye una comunidad de peces diversa y dinámica que habitan una gran variedad de tipos de hábitat. Los pescadores se les informa sobre las tendencias de las poblaciones de peces y la práctica de su trabajo en una pequeña escala. Sin embargo, la competencia y la degradación del hábitat es posible debido a una variedad de temas ambientales en la actualidad podría representar una amenaza para la comunidad de peces que apoya la pesca artesanal del pedregal.

1. Introduction

1.1. Location in the TEP

This study was conducted in the artisanal fisheries of the Gulf of Chiriquí out of the port of Pedregal on the Pacific Coast of Western Panama. Sampling was carried out primarily in the mangrove habitat of the river delta of Rio Chiriquí and on the rocky and sandy shores of the Gulf near Pedregal and the nearby fishing town of Boca Chica. The Gulf of Chiriquí, although close in proximity to the Gulf of Panama to the East, has different oceanographic properties (Kwiecinski and Chial 1982). The mountains of interior Panama tend to act as a barrier to the wind currents experienced by the Gulf of Panama. This is evidenced by the decreased Northerly wind stress index, especially in the dry season, in the Gulf of Chiriquí reported by Kwiecinski and Chial (1982). The result is a lack of upwelling phenomenon in the area indicated by elevated temperature and decreased salinity in the dry season as well as depressed levels of dissolved phosphates at both 20 and 40 meters of depth (Kwiecinski and Chial 1982). However, a recent study done by Camilli et al. (2007) found evidence of upwelling in the inter-island region to the East of Pedregal and Boca Chica, further from shore, while the areas near Pedregal and Boca Chica experience increased seasonal fresh water discharge as a result of the rivers that empty into the ocean, especially during the rainy season (Camilli et al. 2007). The Gulf of Chiriquí has a wetter climate that the Gulf of Panama and this increases turbidity, limiting coral reef growth at greater depths (Dominici-Arosemena and Wolff 2006). Additionally, the tides in the Gulf of Chiriquí can alter the water level by up to 3-4 meters (Dominici-Arosemena and Wolff 2006).

The Gulf of Chiriquí contains several habitat types including coral reef, rocky shores and mangrove which provide a variety of niches to support the high faunal biodiversity observed (Dominici-Arosemena and Wolff 2006). The primary habitat of the larger Tropical Eastern Pacific (TEP) region is rocky shores and the Gulf of Chiriquí has the largest archipelago of rocky islands in the region (Dominici-Arosemena and Wolff 2006). It has been suggested that this type of habitat provided the source of icthyofauna from which today's coral reef fish evolved and may still be used in similar ways. A study by Dominici-Arosemena and Wolff (2006) was carried out in Bahía Honda, Eastern Golf of Chiriquí, to analyze the value of the physical structure including corals, rocks and benthic sessile organisms, to the reef fish community structure. It was found that this area had the highest species richness in the TEP region. The coral reef habitat present is believed to be the oldest in the TEP. Overall, coral reefs in the TEP have been drastically reduced due to geologic changes (Dominici-Arosemena and Wolff 2006). This was noted in the 80's and 90's and the Golf of Chiriquí was identified as one of two critical areas vulnerable to anthropogenic disturbance and pollution (Camilli et al. 2007).

Mangrove habitat is the major habitat type sampled in this study that is present in the Golfo de Chiriquí. Mangrove ecosystems are a unique habitat type that provide a broad array of ecosystem services and have not been thoroughly studied (Faunce and Serafy 2006). Mangrove forest ecosystems play a role in essential ecological, physical, biological and biogeochemical processes such as filtering land derived materials in freshwater reaching the ocean, stabilizing the shoreline and providing nutrients for the fauna of the region (Fuetry et al. 2010, Shervette et al. 2007). They also function as habitat for a variety of wildlife at different ontogenetic stages by serving as spawning grounds and nurseries (Fuetry et al. 2010). Additionally, mangroves participate in the surrounding economic environment through their role as artisanal fishing grounds as well (Fuetry et al. 2010).

1.2. Environmental Threats and Assessment

The part of the TEP that makes up the coast of the Pacific marine provinces in Panama is in a precarious position in terms of conservation for several reasons. The mouths of these rivers are downstream of agriculture areas including cattle farms. Land use upstream is also in transition. As these areas experience rapid population growth, there is unregulated construction and land development and an increase in septic waste (Camilli et al. 2007). Although comparatively little research has been done in this region of the tropical Pacific to date, further study to characterize the oceanographic properties of the region with sophisticated 3-D imaging and feature classification, *in*-situ chemical sensing and acoustic mapping was carried out by Camilli et al. (2007). This study showed increased levels of Methane and Carbon Dioxide content in the marine region off the coast of the fishing town, Boca Chica, South of Pedregal. It was determined that this region is primarily influenced by the freshwater input from watersheds during the wet season and is therefore most likely affected by the contents of anthropogenically altered runoff that may contain chemical pollution and cause sediment loading and eutrophication (Camilli et al. 2007).

Mangrove habitat specifically, is threatened by coastal development and resource extraction for products such as wood, tannins, conchs and fish. Mangroves support regional fisheries and their connection to fish diversity is recognized but the interactions involved have not been well studied (Fuetry et al. 2010, Faunce and Serafy 2007). Like all instances of habitat loss, reduction of mangrove cover has ecological consequences and, specifically, alters the fish community (Shervette et al. 2007). Based on the understood functions of a healthy mangrove habitat, a mangrove fish community can be assessed to draw conclusions on the overall ecosystem health based on the principles described on a study by Shervette et al. (2007). The principles of such an assessment include 1) the species diversity and composition 2) the relative abundance and evenness of the species 3) the nursery function of the habitat and 4) the trophic integrity of the fish community (Shervette et al. 2007). Nursery function is indicated by the presence of juveniles of estuarine dependent species (Shervette et al. 2007). Biotic stress on an ecosystem decreases biodiversity (Shervette et al. 2007). Biotic stress would also decrease the evenness of the distribution of species abundance and disrupt the nursery function of the habitat.

Habitat use by juveniles is identified by the presence of fish of a smaller length class (Shervette et al. 2007). Body size or length is a determining feature of fish because it affects the animal’s ability to navigate especially in habitats such as mangroves with high structural complexity (Petitgas et al. 2011). Marine fish often utilize a variety of habitats during the stages of a complex life cycle, with individuals making ontogenetic shifts in habitat as the length class changes. The frequency of a given length class in a population is affected by factors such as rates of reproduction, recruitment, growth and mortality (Anderson and Neumann 1996). Length frequency data contributes to understanding of population structure and lifecycle patterns and can be very useful for designing management plans for marine areas (Petitgas et al. 2011).

Faunce and Serafy have reviewed the worldwide literature published between 1955 and 2005 on mangrove habitats. Although there have been very few studies done on mangrove habitat in general, the mangroves of North, Central and South America are comparatively better understood than other regions. The Americas contain only 27% of the world's mangrove cover while almost 50% of the studies reviewed by Faunce and Serafy (2006) were located there. Despite this apparent preference for American mangroves, the mangroves of Pacific Panama are still identified as an area lacking in research. Additionally, Faunce and Serafy (2006) identify fish–habitat correlation as a theme that is in need of investigation. Therefore, it is valuable to explore the relationship between the fish community and habitat types in the artisanal fishery out of the port of Pedregal by investigating the diversity of the fish caught in this region.

1.3 Measuring Biodiversity

Measuring diversity is possible for a variety of biological collections as detailed in Pielou (1966a). According to Pielou (1966b), diversity is affected by two aspects of a population; the number of species in that population and how many individuals represent each species. Alternatively, Pielou (1966b) describes biodiversity as the amount of uncertainty that exists concerning the species of an individual selected randomly from a population. The more species represented in the population and the more evenly they are represented, the greater the uncertainty, and therefore, diversity of the population (Pielou 1966b). Too measure this uncertainty, and assign a value for diversity, equations that identify "information content" can be utilized.

For a discrete population for which every species and the number of individuals of each species is known, the information content can be measured exactly using Brillouin's formula

(Pielou 1966b). More often, the information content must be estimated based on a random sample of a larger, or infinitely large, population whose individual members are not countable. In this case, a random sample is used containing *s* species consisting of proportions of each species $p_1, p_2, \ldots p_s$. The formula Shannon Index of Community Diversity measures the information content or population value of diversity per individual for the sample.

For a population of fish in a large area such as this study site, the population is too large to measure but can be sampled and the Shannon Index of Community Diversity can be used to estimate the average diversity (Pielou 1966a). This is an approximation rather than a true measure because all of the species in the sample may be identified and counted but it is not assumed that every species in the entire population was included in the sample (Pielou 1966a). The Shannon's Index of Community Diversity is therefore an estimation of diversity in average conditions for large populations (Pielou 1966b). Shannon's Index of Community Diversity can also be used to compare populations to determine which is more diverse. This value is sensitive to changes in rare species (Myers et al. 2011). Therefore, when comparing this value for two groups, it is more likely to be significantly different between two groups when the populations of the rare species changed dramatically.

Other measures of diversity include Simpson's Reciprocal Index of Diversity (Myers et al. 2011). According to Myers et al. (2011) this measure is instead sensitive to changes in the population of abundant species. Thus, this measure will be more likely to be significantly different between two groups if there are large variations in the populations of the most abundant species.

The Evenness Component of Diversity (J') can also be used to measure diversity according to Pielou (1966a). This is based on the fact that higher diversity results from a more even distribution of individuals of a population across the represented species (Pielou 1966a). The maximum possible diversity for a given number of species, *s*, is calculable. If every species present was represented by a single individual, maximum evenness and diversity would be achieved. Calculating Shannon's Index of Diversity for this theoretical population leaves:

$$H'_{max} = -\sum_{i=1}^{s}\left(\frac{1}{s} * ln\left(\frac{1}{s}\right)\right) = ln(s)$$

Therefore, to express the evenness of a sample population, the ratio of observed evenness to maximum evenness can be used by dividing Shannon's Index of Community Diversity by the maximum possible diversity calculated.

$$J' = \frac{H'}{H'_{max}} = \frac{H'}{ln(s)}$$

These measures of biodiversity and evenness as well as species and family richness data provide a variety of information on the species that make up a specific population and aid in the assessment of that population. When applied to communities such as the fish community of an artisanal fishery it may be possible to draw conservation related conclusions about the fishery.

1.4. Artisanal Fisheries

Changes in a fish community would also affect artisanal fishing grounds that the fishery would normally support. The FAO Tech Guidelines for Responsible Fishers, offers a definition of small-scale fisheries as a "dynamic and evolving sector employing labor-intensive harvesting, processing and distribution technology to exploit marine and inland fishery resources". The products of these enterprises are sold in local and domestic markets or are used for subsistence consumption. Fish is important from a health standpoint because it provides a source of micronutrients, fatty acids and animal proteins in the diet. Since 1973, the global consumption of fish has doubled but has not kept up with population increases. Almost all fish from small-scale fisheries is sold for human consumption, and makes up half of the fish consumed by humans world-wide. There is a large variety of organization of the operation of artisanal fisheries and the methods used vary from port to port (FAO Tech Guidelines). The primary locations for artisanal fisheries in Panama include the Golfo de Panama, Golfo de Chiriquí, Golfo de Montijos and Golfo de Paritas (Aguera 1992). Protecting these fishing grounds is important for the health of the unique ecosystems and for the cultural heritage and livelihood of the people of the region.

2. Objectives

1. Assess icthyofaunal diversity in the Rio Chiriquí delta mangroves and near-shore inter-island habitat in terms of species richness and evenness.
2. Compare icthyofaunal diversity and community structure of the dominant species over variations in habitat type to test for ontogenetic shifts in habitat use and niche utilization.
3. Describe the methods and opinions of artisanal fishermen in the port of Pedregal in the context of conservation.

3. Materials and Methods

3.1. Study Site:

Pedregal is a fishing town on the Pacific Coast of Panama located at N 8º21’44” W 82º26’16”. The town is at the top of the wide river delta for the Rio Chiriquí which opens into the Golf of Chiriquí. There are several ports in the town for both commercial and artisanal fishing. La Marisqueria Sari is the port for several artisanal fishermen who work together in a cooperative. Some of the fishermen who work here were accompanied for the purpose of data collection.

2.2. Icthyofauna:

Data were collected on six fishing trips during the end of the rainy season between the 13th and 26th of November 2011. During these trips, the coordinates of each fishing effort or catch (n=75 catches) were recorded and the species and fate (kept or thrown back) of each fish caught was recorded. When possible, the surrounding habitat type was noted (n=40 catches) and the Maximum Standard Length (MSL) as shown in Figure 1. of each fish kept for sale was measured and recorded (n=29 catches). Length measurements were taken using a wooden ruler with a headboard. The fish was laid on its right side with the mouth held to the headboard with light pressure and all measurements were rounded up to the nearest centimeter. Photographs of each new fish species were taken upon capture for identification purposes in order to avoid interference in the fishing process. Fish species were identified to the family level and to the species level if possible at the Universidad Autonoma de Chiriquí (UNACHI) according to *Peces Demersales y Pelagicos Costeros del Pacifico de Centro America Meridional, Guia Illustrada* by William A. Bussing and Myrna I. Lopez S.

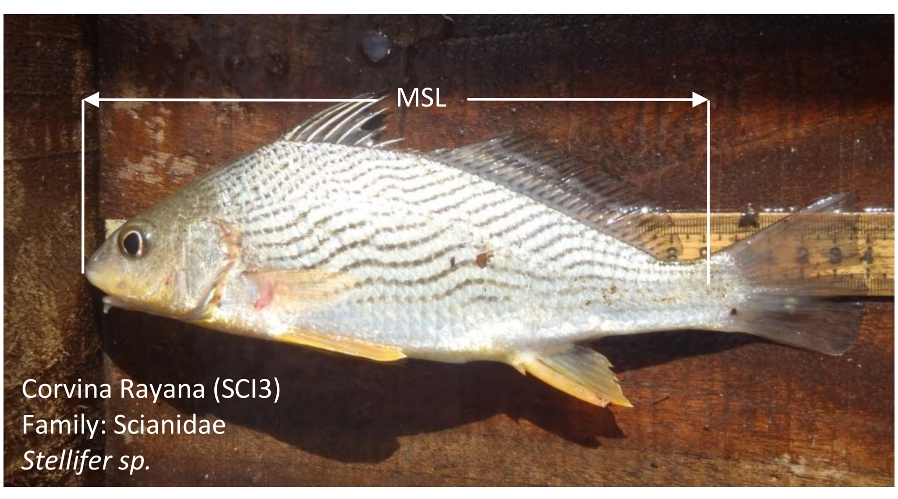


Figure 1. The measurement of Maximum Standard Length (MSL) as listed by Anderson and Nuemann (1996).

2.3. Analysis:

Shannon's Index of Community Diversity (H') and Simpson's Reciprocal Index of Diversity (S') were calculated for the total catch and for specific groupings of catches based on location and habitat type.

$$H' = -\sum_{i=1}^{s}(p_i * \ln(p_i))$$

$$S' = \left(\sum_{i=1}^{s}(p_i)^2\right)^{-1}$$

$$p_i = proportion\ of\ total\ catch\ made\ up\ of\ the\ ith\ species = \frac{n_i}{N}$$

The Evenness Component of Diversity (J') was calculated to determine how close each location or habitat type came to ideal fish species diversity.

$$J' = \frac{H'}{\ln(S)}$$

$$S = Total\ number\ of\ species$$

To judge the effectiveness of the equipment used to test the species present, a cumulative species curve was plotted. In order to group fish species as dominant, common, uncommon or rare, the relative abundance was compared to the frequency of occurrence.

$$Relative\ Abundance = 100 * \left(\frac{n_i}{N}\right) = 100 * p_i$$

$$n_i = number\ of\ individuals\ of\ the\ ith\ species \qquad N = Total\ number\ of\ individuals$$

$$Frequency\ of\ Occurence = 100 * \left(\frac{c_i}{C}\right)$$

$$c_i = number\ of\ catches\ in\ which\ the\ ith\ species\ was\ present$$

$$C = Total\ number\ of\ catches$$

2.4. Artisanal Fishing Methods and Fishery Conservation:

During the process of preparing boats for fishing and while fishing, un-structured interviews were held with two boat captains and four workers. Semi-structured interviews were held with fishermen with several years of experience including 5 boat captains and 1 worker on land. Based on some of the answers received during interviews, the analysis of the data was expanded to include a comparison of two distinct regions; the coasts near the mouth of Rio Chiriquí and Pedregal and the coast of Isla Boca Brava, near Boca Chica. As an additional method of analyzing the artisanal fishing process in Pedregal, the Catch Per Unit Effort (CPUE) was calculated.

$$CPUE = \frac{N}{C}$$

$$N = Total\ number\ of\ fish\ caught$$

$$C = Total\ number\ of\ catches$$

4. Results

4.1. Icthyofauna:

There were a total of 36 species of fish in 20 families encountered in the total study area which are presented in Table 1. The most diverse family was Carangidae (6 species) followed by Scianidae, Lutjanidae and Haemulidae (4 species each). These four families together make up 50% of the total number of species encountered and 25% of the total fish caught. A total of 90% of the total species were first encountered in the first two thirds of the catches. The cumulative species curve (Figure 2.) shows that the number of new species does begin to reach an asymptote at the end of the study.

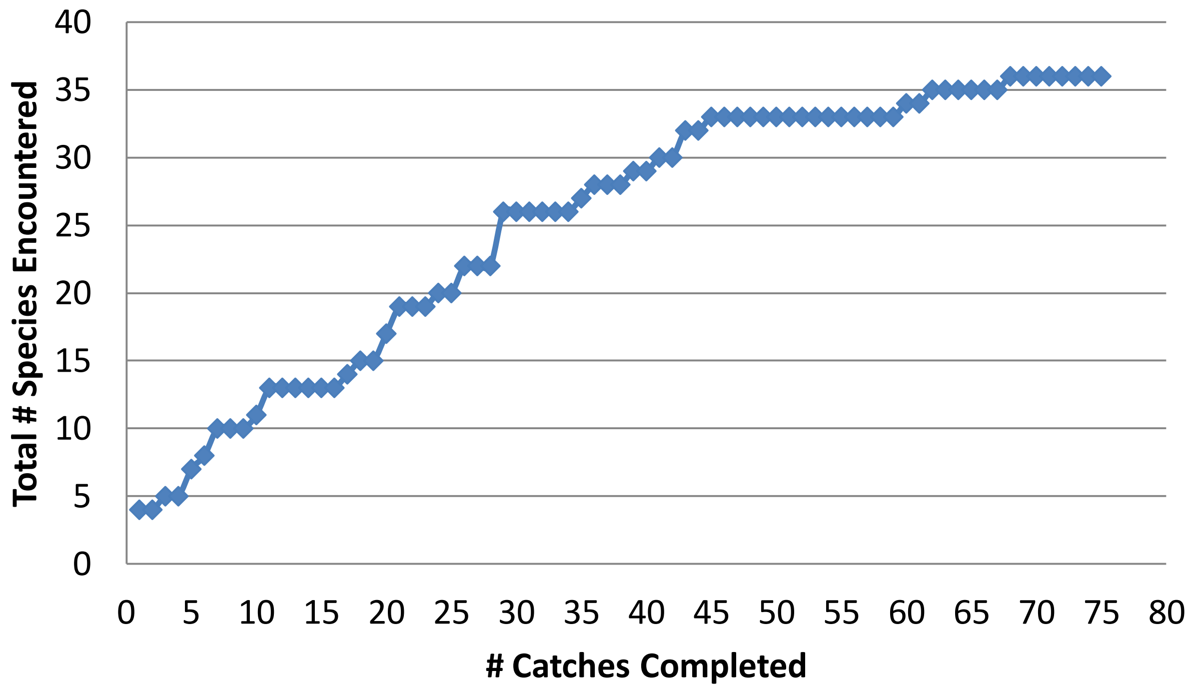


Figure 2. The cumulative species curve shows the total number of species encountered over the length of the study.

Common Name	Family	Species Code	# Ind.	Rel. Ab.	c_i	Freq. Oc.
*Lisa	Mugilidae	Mugi	843	51.69	53	70.67
†Vieja	Haemulidae	Hae1	101	6.19	39	52.00
†Brillantina	Gerreidae	Ger2	177	10.85	32	42.67
†Jurel	Carangidae	Car1	111	6.81	28	37.33
†Longineo	Carangidae	Car2	53	3.25	25	33.33
‡Robalo	Centropomidae	Cent	45	2.76	18	24.00
‡Luneta	Carangidae	Car3	21	1.29	16	21.33
‡Congo	Ariidae	Ari1	58	3.56	14	18.67
‡Pargo Rojo	Lutjanidae	Lut2	25	1.53	12	16.00
Pajarita	Carangidae	Car4	2	0.12	1	1.33
Pampano	Carangidae	Car5	3	0.18	3	4.00
Coginua	Carangidae	Car6	11	0.67	5	6.67
Corvina de Piedra	Scianidae	Sci1	3	0.18	3	4.00
Corvina Plateada	Scianidae	Sci2	16	0.98	4	5.33
Corvina Rayana	Scianidae	Sci3	3	0.18	1	1.33
Bocancha	Scianidae	Sci4	2	0.12	1	1.33
Pargo Mancha	Lutjanidae	Lut1	5	0.31	5	6.67
Pargo Amarillo	Lutjanidae	Lut3	3	0.18	2	2.67

Cabezon	Lutjanidae	Lut4	17	1.04	8	10.67
Frijolio	Haemulidae	Hae2	8	0.49	2	2.67
Roncador	Haemulidae	Hae3	1	0.06	1	1.33
Toliva	Haemulidae	Hae4	22	1.35	3	4.00
Bagre	Ariidae	Ari2	6	0.37	5	6.67
Tamboril sin espina	Tetraodontidae	Tetra	26	1.59	7	9.33
Tamboril con espina	Diodontidae	Diod	17	1.04	9	12.00
Cochu Sapo	Batrachoididae	Batr	1	0.06	1	1.33
Borugati	Lobotidae	Lobo	2	0.12	2	2.67
Aguja	Belonidae	Belo	4	0.25	4	5.33
Barracuda	Sphyraenidae	Sphy	1	0.06	1	1.33
Sardina	Engraulidae	Engr	16	0.98	7	9.33
Arenque	Pristigasteridae	Pristi	2	0.12	2	2.67
Pez Hoja	Paralichthyidae	Para	7	0.43	6	8.00
Pez Bobo	Polynemidae	Poly	1	0.06	1	1.33
Boriguero	Synodontidae	Syno	3	0.18	3	4.00
UNK 1	Gerreidae	Ger1	1	0.06	1	1.33
UNK 2	Ephippididae	Ephi	1	0.06	1	1.33
Total			1616			
**Dominant Species*	*†Common Species*	*‡Uncommon Species*				
Rare species are unmarked						

Table 1. This chart shows the Spanish common name, family name and species code for each species encountered. The total number of individuals of that species, its relative abundance, the number of catches in which it was present and the frequency of occurrence is also listed for each species.

All of the species were grouped as dominant, common, uncommon or rare based on their placement on the plot of relative abundance versus frequency of occurrence according to Myers et al. (2011) (Figure 2.). Only one species was categorized as dominant, the species *Mugil curema*, the only member of the Mugilidae family, which made up 51.8% of the total fish caught. Common species include two species of the Carangidae family and one species each of the Haemulidae and Gerreidae families and together make up 27.1% of the total fish caught. They had relative abundances between 3.25 and 10.85 and a frequency of occurrence between 33.33 and 52.00. Uncommon species include one member each of the Carangidae, Lutjanidae, Ariidae and Centropomidae families and make up 9.1% of the total fish caught. This group had relative abundance between 1.29 and 3.56 and frequency of occurrence between 16.00 and 24.00. The rare species included members of 18 different families and a total of 11.2% of the total fish caught. The relative abundance of rare species ranged from .06, for species of which only one individual was caught, to 1.59. The frequency of occurrence of the rare species ranged between 1.33, for species caught only once, and 12.00.

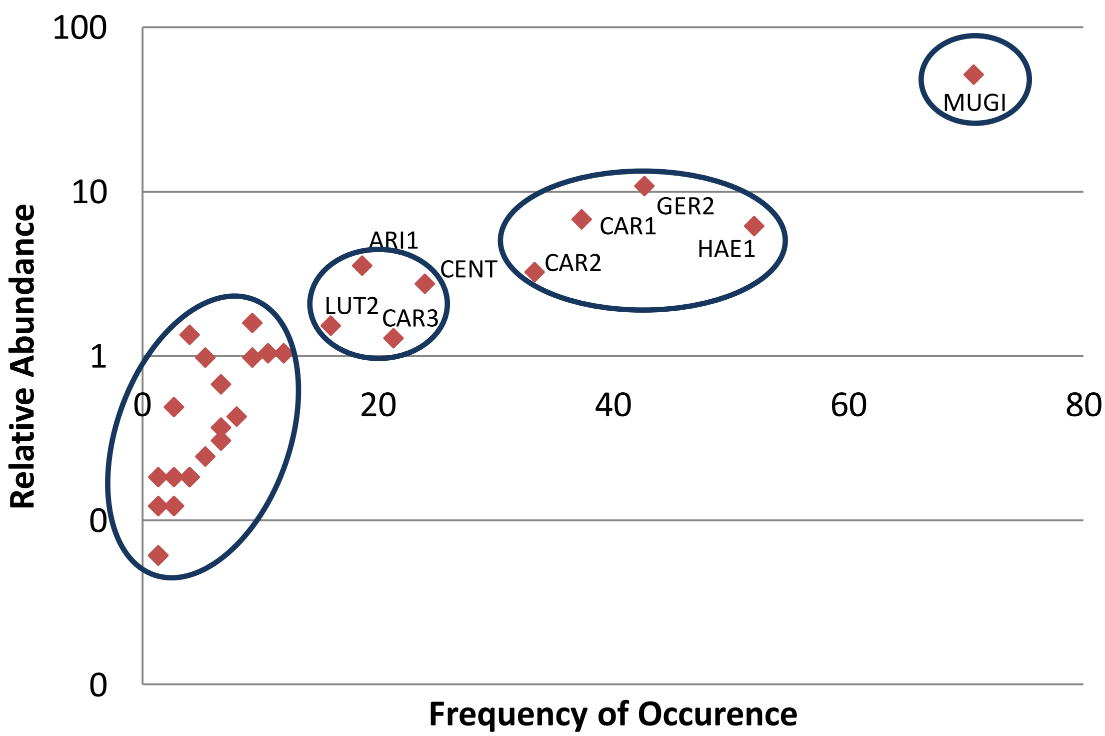


Figure 3. Plot of relative abundance versus frequency of occurrence of all fish species encountered in the artisanal fishing grounds of Pedregal, Golfo de Chiriquí. The groups of dominant, common, uncommon, and rare species are identifiable.

	Total Fish Caught (n=75 catches)	Pedregal Region (n=66)	Boca Chica Region (n=8)	Mangrove Habitat (n=23)	Mangrove/ Rocky Shore Habitat (n=3)	Rocky Shore Habitat (n=3)	Sandy Beach Habitat (n=11)
H’	1.958	2.111	1.133	1.706	0.614	1.812	2.187
S’	3.372	4.229	1.999	3.250	1.283	12.771	5.384
J’	0.546	0.683	0.429	0.580	0.247	0.706	0.757
sr	36	22	14	19	12	13	18
fr	20	18	11	13	10	10	12
CPUE	21.56	56.25	17.42	-	-	-	-
f1	MUGI (0.521)	MUGI (0.447)	MUGI (0.713)	MUGI (0.519)	MUGI (0.882)	HAE (0.306)	GER (0.365)
f2	CAR (0.124)	GER (0.147)	CAR (0.156)	GER (0.142)	CAR (0.047)	MUGI (0.143)	MUGI (0.186)
f3	GER (0.110)	CAR (0.112)	HAE (0.049)	CAR (0.139)	HAE,GER (0.018)	CAR (0.122)	CAR (0.115)

Table 2. The calculated values of Shannon’s Index of Community Diversity (H’), Simpson’s Reciprocal Index of Diversity (S’) and The Evenness Component of Diversity (J’) are presented here for the total study and for study groups broken down by fishing area (Pedregal vs. Boca Chica) and habitat (Mangrove, Mangrove/Rocky Shore, Rocky Shore and Sandy Beach). The species richness (sr) and family richness (fr) are presented as well, followed by the first three families (f1, f2, f3) with the highest proportion of individuals in each set of catches.

In the entire study area, an H’ value of 1.958, S’ value of 3.372 and J’ value of 0.546 is reported (Table 2.). The family Mugilidae made up 52% of the total fish caught in the study region.

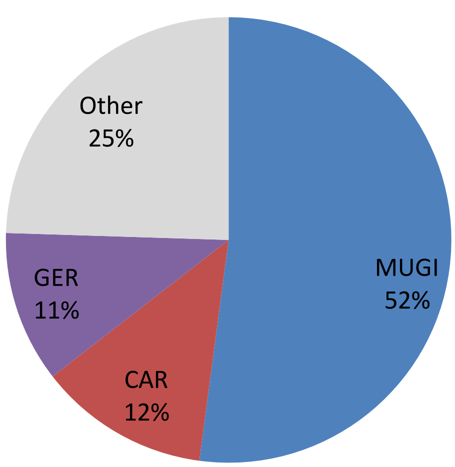


Figure 4. Chart of family composition of total fish caught in the study region over all six trips. Reported values are the total relative abundance of all species in the given Family expressed as a percentage of the total catch for the region. Other is used to indicate all Families with percentages less than the values presented.

Pedregal region showed higher values for all three measures of diversity in comparison to the Boca Chica region (H'=2.111, 1.133; S'=4.229, 1.999; J'=0.683, 0.429 respectively) (Table 2.). The CPUE value for the Boca Chica region was elevated in comparison to that of the entire study region as well as the Pedregal region specifically. The family composition was also altered between the regions. *Mugil curema* made up a much larger portion of the population in the Boca Chica region compared to both the total and the Pedregal region (Figure 5.).

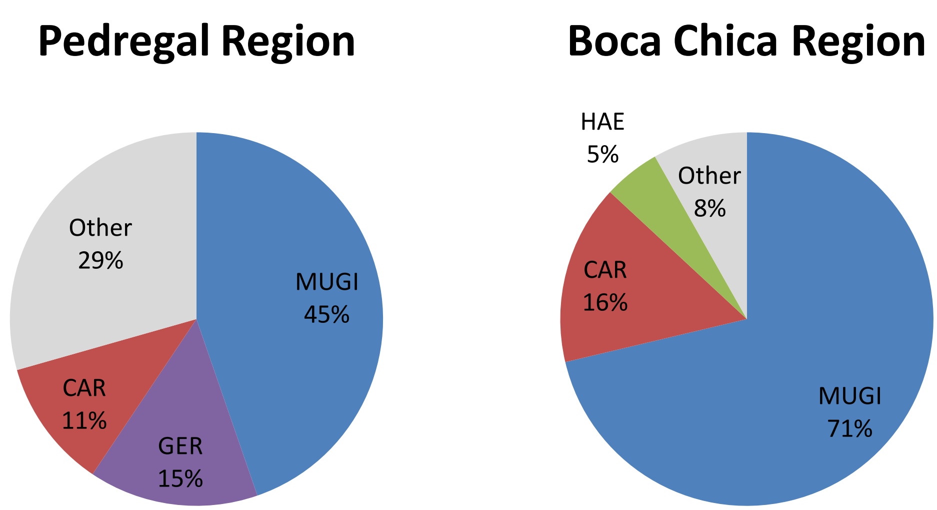
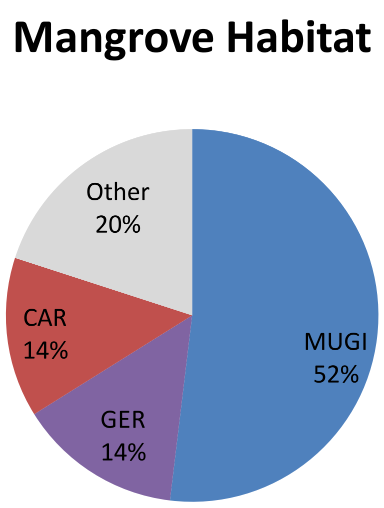
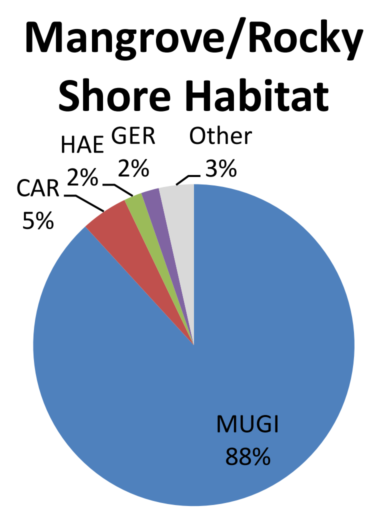


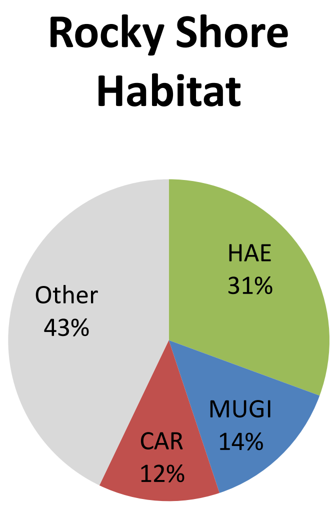
Figure 5. Comparison of the family composition of the Pedregal versus Boca Chica regions.

Values of diversity varied across habitat types. The highest H' value was reported in the sandy beach habitat, followed by the rocky shore, mangrove and, finally, the mangrove/rocky shore mixed habitat (Table 2.). The rocky shore habitat exhibited an S' value almost double that of the second highest habitat, sandy beach, which was followed by mangrove and, lastly, mangrove/rocky shore. The J' value was highest for sandy beach, followed by rocky shore and then mangrove habitat while mangrove/rocky shore habitat had the lowest value by far.

Mangrove and mangrove rocky shore habitat were dominated by the Mugilidae family, species *Mugil curema* (Figure 6.). This family made up a similar proportion of the family composition in the mangrove habitat as the total region while in the mangrove/rocky shore habitat, it made up a comparatively larger proportion. In the mangrove habitat the Gerreidae and Carangidae families made up the second and third largest proportions of the family composition, respectively. In the mangrove/rocky shore habitat, these two families were switched and the family Haemulidae made up the same proportion as the third largest family Gerreidae. Mugilidae was not dominant in the rocky shore and sandy beach habitats but made up the second largest proportion of the family composition of both. The largest proportion of the family composition was Haemulidae in the rocky shore habitat and Gerreidae in the sandy beach habitat. In both types of habitat, Carangidae made up the third largest proportion of the family composition.







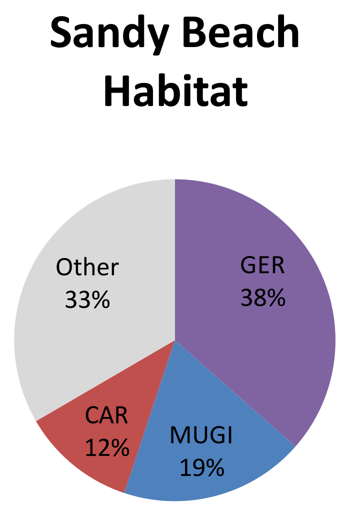
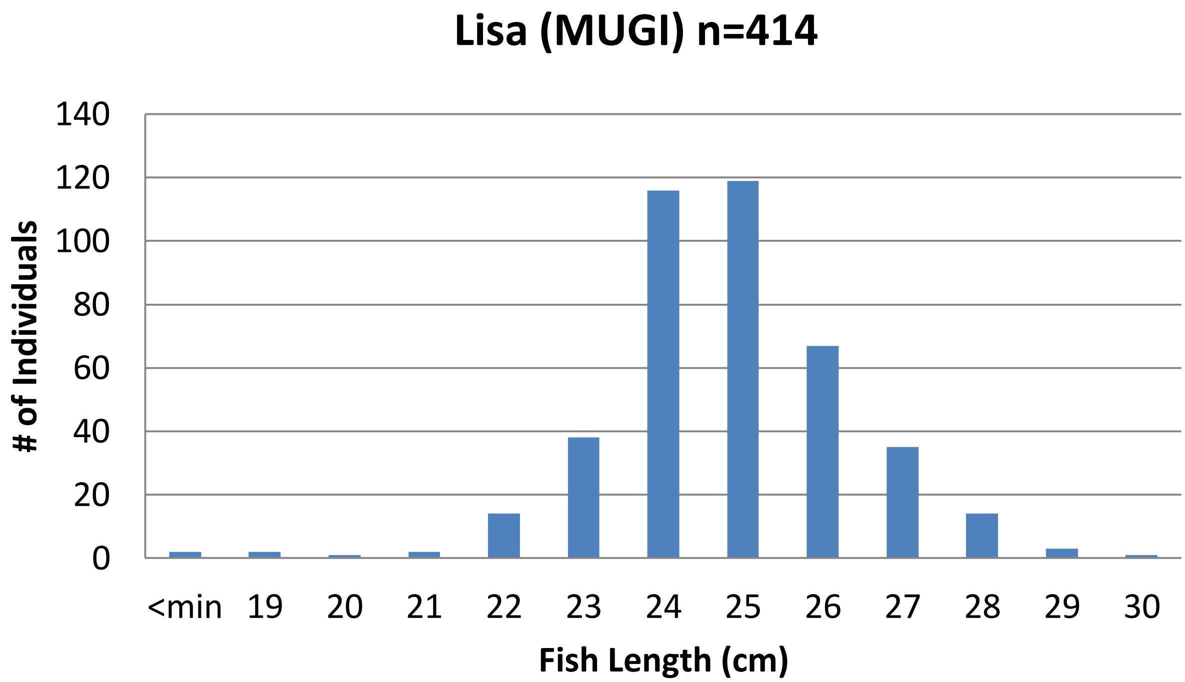
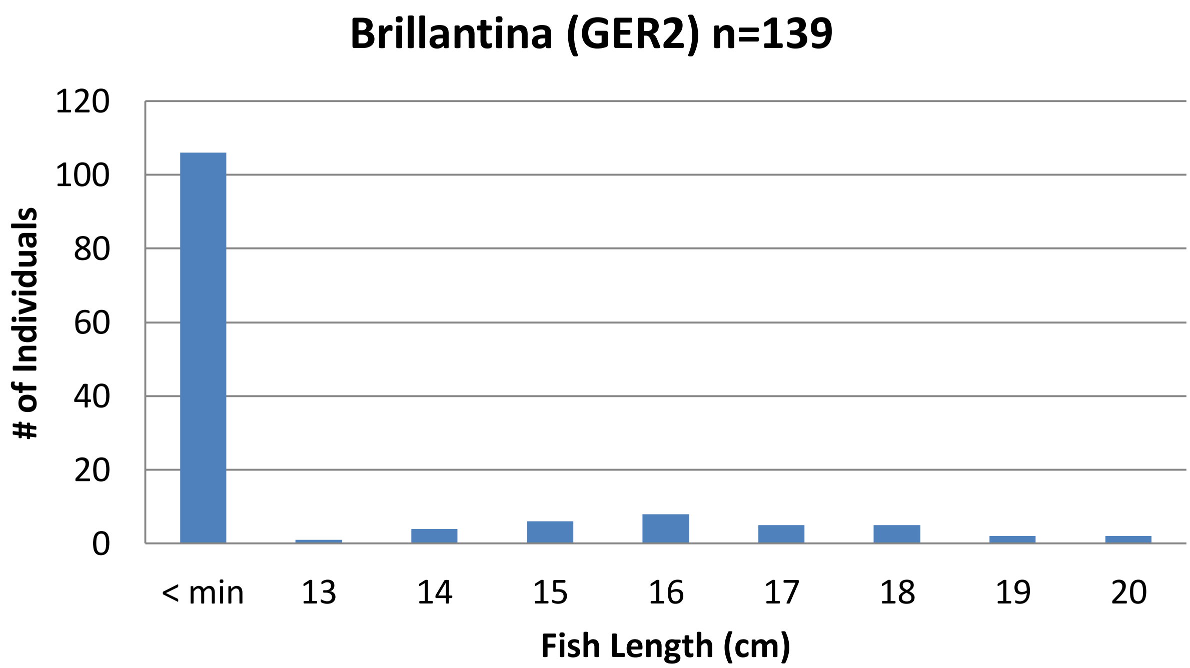
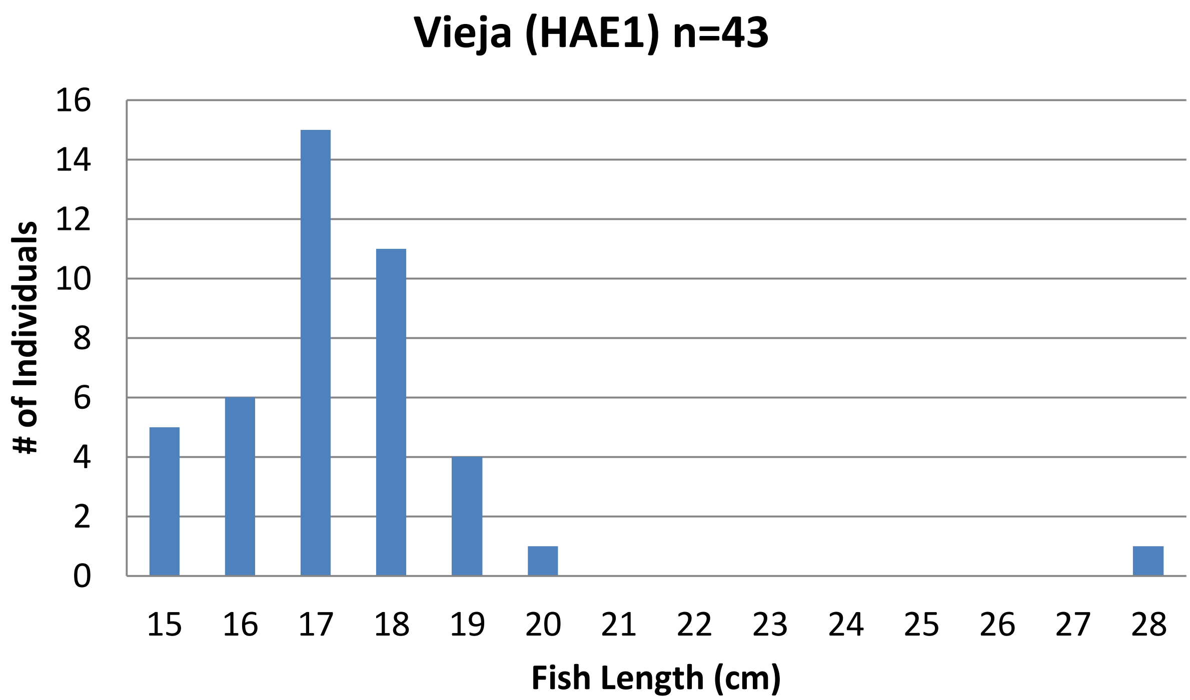


Figure 6. The family compositions of the catch in four habitat types including mangrove, rocky shore/mangrove, rocky shore and sandy beach with the percentage of the total composition reported for each family.

Length data was collected for four economically important species caught during the study period (Figure 7.). These included Jurel (n=18), Vieja (n=43), Brillantina (n=139) and Lisa (n=414). The length frequency histograms for the dominant species in the total study area, *Mugil curema*, or Lisa, (Figure 5.) shows that the mode of fish length is 25 cm. The median length of saleable *Mugil curema* was 24.7 cm. Fish less than 19 cm were not saleable and were not measured. They made up .48% of the catch. Mean length of saleable Brillantina (GER2) was 16.36 cm and the mode was 16 cm. Fish less than 13 cm were not kept and these made up 76.26% of the total Brillantina caught. The mean length of Vieja (HAE1) was 17 cm and the median length of saleable Vieja was 17.40 cm. All of the Vieja caught were considered saleable. The mean length of Jurel (CAR1) was 16.73 cm and the mode was 16.5 cm. Jurel less than 14cm were not considered saleable and these made up 38.89% of the catch.


Lisa (MUGI) n=414
# of Individuals
140
120
100
80
60
40
20
0
<min
19
20
21
22
23
24
25
26
27
28
29
30
Fish Length (cm)


Brillantina (GER2) n=139
# of Individuals
120
100
80
60
40
20
0
< min
13
14
15
16
17
18
19
20
Fish Length (cm)



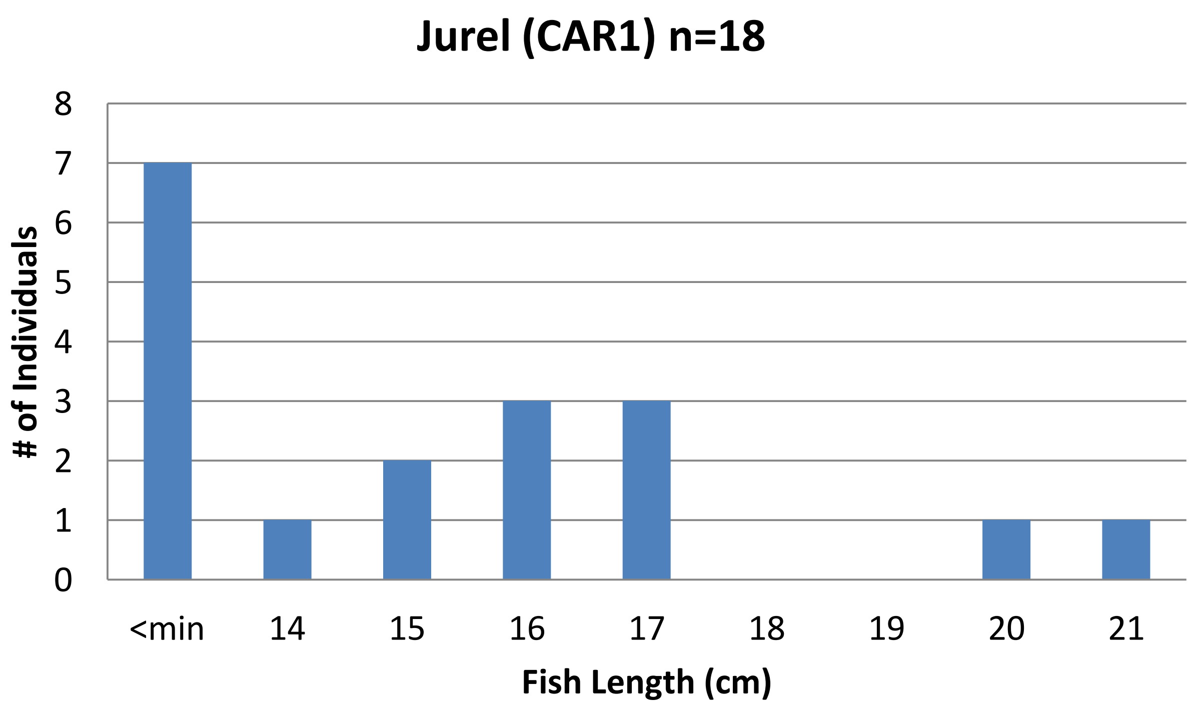


Figure 7. Fish length frequency histograms for four economically important species of fish caught in the artisanal fishing grounds of the Pedregal region of the Golfo de Chiriquí.

Length was also compared across two distinct habitat types for the dominant species, *Mugil curema*, including mangrove habitat (n=262 fish), closer to the port and within the Rio Chiriquí delta, and sandy beach habitat (n=162 fish) which was further from port and closer to the Golfo de Chiriquí (Figure 8.). The mean length of Lisa was 24.77 cm in mangrove habitat and 24.97 cm in sandy beach habitat. The mode in mangrove habitat was 25 cm and the mode in sandy beach habitat was 24 cm. None of the Lisa caught in the sandy beach habitat were not considered saleable and only 0.8% of the Lisa caught in the mangrove habitat were not considered saleable.

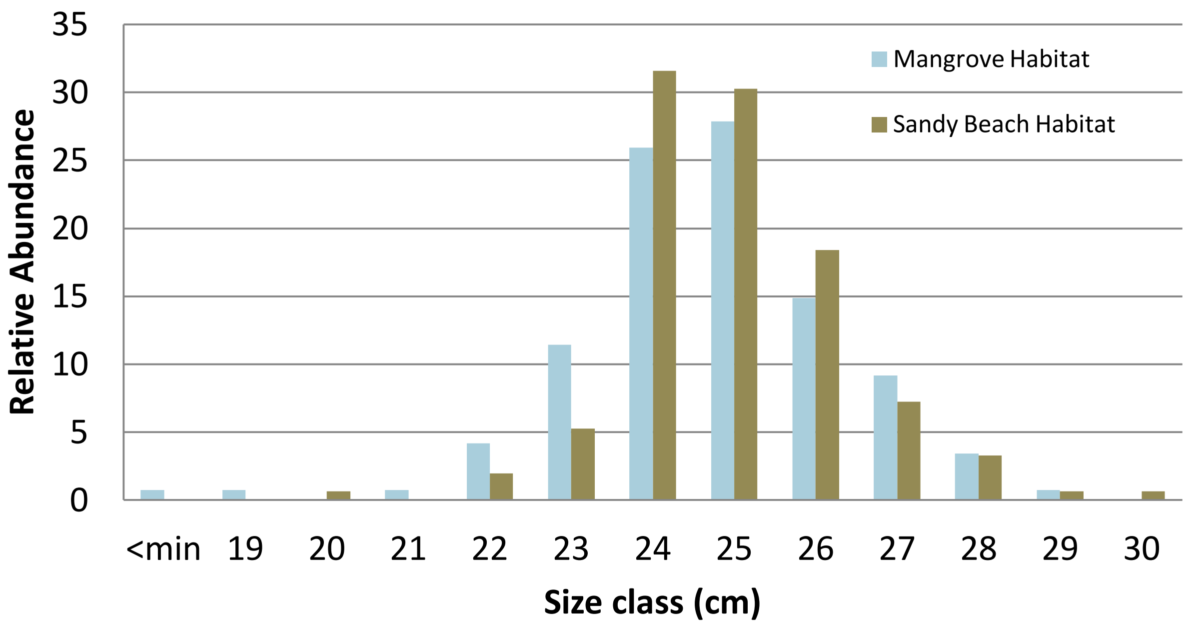


Figure 8. Fish length frequency histogram comparing the length of Lisa (M. curema) in mangrove and sandy beach habitat.

4.2. Artisanal Fishing Methods and Opinions:

All information reported on the methods used by artisanal fishermen in the port of Pedregal is a result of passive and participant observation and unstructured interviewing. The typical equipment of artisanal fishermen in the Port of Pedregal is referred to as a trasmallo.

The two captains accompanied for data collection used a trasmallo lisero -2,3,4 which refers to the size of the holes. The trasmallo is measured in brazos (arms). The conversion unit is roughly 1 brazo to 1.5 meters. The two trasmallos used during data collection for this study measured 180 X 3 brazos or 1215 m^2 and 180 X 3.5 brazos or 1417.5 m^2. Each boat is about 6 meters long and 1 meter wide and made of fiberglass like material. There is a bench in the back, half way up and in the bow of the boat. Half way down the length of the boat, on top of the gunnel, are two holes about 10 centimeters deep. Each boat has a team of fishermen consisting of the captain and two muchachos. The captain is usually an older man who drives the boat and sits on the back bench to operate the motor. The captain makes decisions about where to fish, when to have lunch and also gives the signal to jump for each fishing effort. The two boys sit on the other benches.

Before leaving the port the boats are prepared by mounting a 15 horsepower electric motor with an external container to supply gasoline. A Styrofoam container with ice may be brought to keep drinks cold and to maintain freshness of fish caught early in the day. This is stored in front of the gasoline container at the back of the boat. At times this was not used and at times only the revoltura was kept here while the Lisa were left out. If a very large fish was caught early in the day it might be cleaned and stored in this cooler early on. Lunch for the fishermen and my backpack were kept in, on or next to the cooler in bags to protect them from water. Two knives were brought for cleaning the fish. A wooden paddle is brought to aid in steering when the motor is turned off and also to move the catch more efficiently when it has built up. Life preservers (chalecos) were brought to help insulate the cooler and for my peace of mind. A wooden ruler with a headboard was brought when I accompanied for measuring purposes. The trasmallo is brought and stored in the front half of the boat. One or two devices for scaring the fish are brought. They are made of a large rock the size of two fists tied into mesh and hung from a rope about two meters or more long.

While traveling away from port, the trasmallo and boat are prepared. The trasmallo is stored in a mesh bag and before the first catch, it is let loose of the bag and each end is restacked for ease of reeling out. It is kept folded accordion style oriented with the heavy end toward the bow and the side with small floats toward the center bench of the boat. Two poles harvested from the mangroves are fit to the holes on the gunnel so that they stand almost vertically about 2/3 of a meter high.

The next step in the process is to identify good places to throw the net. This appears to be based on intuition as well as the skill of identifying the sound and sight of fish biting at the surface of the water. The bite of the Lisa was usually the preferred signal although at times, the presence of Aguja seemed to spur a fishing effort, or no signal was identified. When looking for these signals, the captain turns the motor down so that it is extremely quiet and one of the muchachos holds the top corner of the trasmallo at the end with floats. Usually the rope on this end is passed around the pole on the side of the boat from which it will reel out and the muchacho holds the end in his hand.

When a good fishing spot has been identified, the captain gives the command to jump to the muchacho holding the top corner of the trasmallo. This command is usually “¡Dale!”. At that point he enters the water and holds the trasmallo while the captain quickly throttles the motor and speeds away. As the captain encircles the area in which the fish are believed to be, the trasmallo reels out of the boat, braced against the pole. The captain may stand at this time and bang the bottom of the boat with the paddle to scare the fish. The other muchacho sits in the front of the boat at this time and helps the trasmallo to set evenly in the water by periodically throwing the heavy end. At times, the trasmallo may be thrown out of the boat and reeled out without the first muchacho going with it. At times this may be because the water is too deep. This technique is more risky because the trasmallo can be pulled back and caught in the motor. This did occur once and the situation was rectified by untangling the trasmallo from the propeller. It was necessary to cut the net in order to do so. The resulting hole was fixed by tying the edges together manually and the trasmallo was still useable for a few days until the following Sunday. On Sunday, trasmallos are mended by other members of the fishing community using replacement netting.

When the trasmallo has been entirely reeled out, the captain and muchachos may do something to scare the fish out of the area and toward the net. Usually they do this by hitting the water with the rock, hitting the bottom of the boat with their feet or the paddle or hitting the water with their hands (for the muchacho who jumped into the water with the net). The time spent doing this before reeling the trasmallo back in varied between the two captains. One captain thoroughly traveled the entire area inside the net several times before reeling it in while the captain that I spent the most time with usually did not spend that much time doing this. If it is noticed that something particularly large is caught in the net, the muchachos often go straight to it and remove it by hand immediately and put it in the boat.

While reeling the trasmallo in, the first muchacho stays in the bow of the boat to pull in the heavy end. Either the muchacho that jumped into the water or the captain pulls in the top end. Whoever is not pulling in the top end occupies the back bench and helps to move the boat around following the trasmallo. The motor is turned off at this time. As the trasmallo is pulled back into the boat it is piled in the same accordion style so that it is ready for next time and the fish are removed. Fish are removed most efficiently by grasping the head and pushing the thumb into the gill on one side then pulling the fish through the hole. Fish determined to be too small for sale are thrown back. Usually fish that are kept are piled in the back half of the boat, behind the center bench and in front of the cooler and gasoline container. In order to help me with data collection, the fishermen called out the names of each fish as it came in and piled them behind the net and in front of the center bench in order to keep them separate from the fish caught earlier so that I could measure them and then put them in the bigger pile. This was very helpful and data collection would not have been possible without this help and sacrifice. It is a sacrifice because having live fish in front of the center bench endangers the feet of the person standing there because of the sharp spines in the fins of some species. For the same reason, handling the fish twice to move them from one spot to another is also dangerous.

At the end of the day, the trasmallo is folded in half and bound up by the mesh bag. All the fish are cleaned and the guts are thrown over the side except for some of the eggs which may be kept, the reason for this is unclear. The poles are taken down and the fish are rinsed before being loaded into crates and taken to La Marisqueria where they may be descaled and prepared for cooking for waiting customers or frozen for later. Trasmallos are stored inside La Marisqueria building overnight.

In total, six fishermen were questioned using semi-structured interviewing techniques and a survey, 9 questions in length. All participants were first informed that participation was not necessary and anonymity would be maintained. The survey results were as follows:

1. How long have you been fishing here?

   The average number of years of fishing was 14.2 years and ranged from 3 to 20 years. A total of three participants answered 20 years and indicated that this was an estimate because they had been in the business their whole life.

2. Have you noticed a change in the fish population here in the last few years?

    Three of six participants felt that the fish population had changed and had increased.

    One participant felt that the fish population had not changed.

    Two of six participants felt that the fish population had changed and had diminished. One of the participants also indicated that the reason that the fish population had diminished was the increasing competition with other fishermen.

3. Have you noticed a change in the population of certain types of fish recently?

    One participant felt that all types had increased.

    Two of six participants felt that all types had diminished.

    One participant felt that the population of Lisa had increased while revoltura had decreased.

    One participant felt that the population of both Lisa and Corvina Plateada had increased.

    One participant's answer was not understood.

4. Have you noticed a change in the length or size of the fish caught?

    Two of six participants felt that the size of the fish had increased, two felt that it had not changed and two felt that it had diminished.

5. Do you have an objective type of fish and what is it?

    Three of six participants answered that Lisa was the target species.

    One answered that Lisa and revoltura were targeted.

    One answered that Pargo was the target type of fish.

One answered that the fish (unencountered in this study) called Cazón and sharks were the target.

6. What type of fish was the target 10 years ago?

    Five of six participants responded that their target type had not changed.

    One participant did not include Lisa as a target type of fish 10 years ago, while it was included as a target type now.

7. Where do you prefer to fish?

    All six participants responded by labeling the areas of Boca Chica, Isla Boca Brava (an island on the coast by Boca Chica) and the surrounding area.

8. Why are these areas preferred?

    All six participants responded that there is a greater abundance of fish in these areas.

    This was the prompt to group catch data by the locations of the two ports (Pedregal and Boca Chica) and compare measures of biodiversity and CPUE in the two areas.

    Four of the six participants also said that the size of the fish was greater in these areas.

    No length data was collected for the fish harvested in the Boca Chica area so it was not possible to test this claim.

9. Have officials from ANAM, ARAP or MarViva ever questioned you about your activities.

    Three of six participants answered that they had never been questioned by any of these organizations.

    One participant responded that this had occurred with ARAP ten times in total.

Two of six participants responded that this had occurred once (one indicating that the organization was ARAP).

Two of six participants also indicated that officials for these organizations were interested in activities closer to PNMGCH and Isla Paridas.

5. Discussion:

5.1 Fish Diversity:

The H' value and J' value reported for this study area falls within the range of H' values reported by Fuetry et al. (2010) for a study of the icthyofauna of Zancudo Mangrove in Golfo Dulce, Costa Rica during the rainy season. Although this study area included a variety of habitats dominated by mangroves, the number of species reported falls short of the species richness reported for the Zancudo Mangrove by Fuetry et al. (2010) and the rocky shore habitat of the Playa Blanca Marine Reserve in Costa Rica reported by Myers et al. (2011). This is most likely a result of the sampling procedure used. A total of four types of nets were used to sample in the Zancudo Mangrove and visual surveys were used to sample in the Playa Blanca Marine Reserve while the source of samples in this study was in fact the catch from only one type of net (Feutry et al 2010, Myers et al. 2011). The family richness was also lower. However, many of the more abundant families identified in this study were also encountered in other studies. Ronnback et al (1999) also found species belonging to the families Belonidae, Engraulidae, Gerreidae, Mugilidae and Tetraodontidae as well in a study of the Pagbilao Mangroves in the Phillipines. There were also common families between this study of the Rio Chiriquí delta, which included relatively less rocky shore habitat, and a study done in the rocky shore habitat of nearby Bahía Honda, Panama by Dominici-Arosemena and Wolff (2006). Overall ten of the twenty families identified in this study were also found in Bahía Honda. Scianidae, a family with

4 species present in this study, had only one member encountered in Bahía Honda. Additionally, the family Mugilidae was encountered in Bahía Honda but none of the species in this family identified in Bahía Honda were the same as the single Mugilidae species identified as the dominant species in this study area. Of the four dominant families identified in Bahía Honda only the Haemulidae family was encountered in this study.

In contrast, a study done in the mangroves of Palmar, Ecuador, compared the degraded mangrove habitat of Rio Palmar to the nearby tidal river of Rio Javita and reported the same species richness and a decreased family richness compared to this study. Unlike, this study, a bag seine net was used to sample Rio Palmar and Rio Javita in both the rainy and the dry seasons. Species and family richness may be more similar between the study of Palmar, Ecuador and this mangrove area for several reasons. Rio Palmar mangrove region has experienced extreme habitat loss for the purpose of shrimp farming in the last three decades. This degradation of the mangrove habitat could have negatively affected the fish community, resulting in a decrease in biodiversity (Shervette et al. 2007). The Rio Chiriquí delta also suffers from habitat loss due to coastal development and artisanal logging as well as contamination from coastal runoff and solid waste. Therefore, this mangrove habitat could be experiencing similar changes in fish community as a result. This is also suggested by the fact that only one species was considered dominant while the study done by Myers et al found a group of species in each category; dominant, common, uncommon and rare. A comparatively larger proportion of the species encountered in this study were categorized as rare as well. Alternatively, the sampling methods of both studies could have excluded species from the results. Of the three most diverse families found in the mangrove habitat of Palmar, the second and third, Gerreidae and Engraulidae, were also found in this study area. The most abundant species in this study, *M. curema*, was the fourth most abundant species in the Rio Palmar mangroves. There were seven families common to both Rio Palmar mangroves and this study area.

Despite the fact that several species were most likely missed by using only one type of gear to sample the fish community of the Rio Chiriquí Delta, the cumulative species curve indicates that further sampling would not have yielded a large number of new species. This is evidenced by the asymptotic nature of the graph. This is only relevant for this time of the year, with this type of gear and in the most frequently sampled habitat type (mangrove). Additionally, it is prudent to consider that the fishermen whose catch was being studied for the majority of the study period had a target species in mind (*M. curema*). They were actively searching for this species of fish in order to purposefully maximize the catch of the most economically important species. Therefore, the only way that the reported values of diversity can be considered unbiased, for the purpose of comparing them with other similar studies, is to assume that the fisherman's efforts to target *M. curema* had no effect on the catch and this is unlikely. This bias does not affect intra-investigation comparisons i.e. Pedregal versus Boca Chica regions and the four habitat types.

5.2 Length Frequency and Community Structure

Shervette et al. (2007) were also able to collect length data for the fish caught in Palmar Ecuador and reported that three species had greater lengths in non-mangrove sites compared to mangrove sites. This could be an indication of an ontogenetic shift in habitat use by these species. The mangrove habitat is utilized by juvenile individuals of these species (Shervette et al. 2007). The fourth species tested in this manner was *M. curema*, which did not show any difference in length between the two habitats. This is consistent with the data presented from the Rio Chiriquí delta region which shows no difference between the lengths of *M.curema* in mangrove versus sandy beach habitat. Therefore, this species does not illustrate a distinction in habitats used by different age classes. This species may still show a shift in habitat utilization throughout development. Fishermen commented that long-line fishing further out in the Golfo de Chiriquí yields much larger individuals of these species. It is possible that a difference in length in the sampling region would have been found in other species if enough data was available to compare length in mangrove and non-mangrove habitat.

Lengths are also reported for three other species, HAE1, GER2 and CAR1 from this study area. All three of which showed a normal size class distribution. The Vieja shows a large number of individuals smaller than the mean length but still saleable, as well as an individual of superior length which may suggest a healthy age structure and unexploited population. The Jurel however has a noteworthy proportion of individuals below saleable length and did not have any individuals in the size classes between the most frequent two classes and the largest class. This could be a result of the low number of samples (n=18) however Anderson and Nuemann (1996) identify a large proportions of a fish population that is less than the targeted size as an indication of exploitation. Therefore, this could also indicate an exploited population with an overabundance of juveniles and a dearth of individuals of economic value. The Brillantina showed an extremely elevated proportion of individuals below the saleable size classes but a normal distribution of size classes of saleable length as well. This may indicate exploitation due to the disproportional abundance of juveniles in this species as well, or it could be an artifact of the particular life cycle of this species with older individuals utilizing different habitats.

5.3 Comparison of Two fishing Grounds

In structured and unstructured interviewing, the fishermen differentiated between two main fishing areas in front of the two nearby ports of Pedregal and Boca Chica. Catches from both areas were compared in order to investigate the relationship between the popular opinions that there is a greater abundance of fish in the Boca Chica region. The elevated CPUE for the Boca Chica region indicated that much more fish is obtained per catch in this area compared to the Pedregal region. The fishermen are therefore correct in thinking that a larger catch may be obtained by traveling to this location. However, the values of H’, S’ and J’ decreased in Boca Chica indicating a decrease in diversity of both abundant and rarely encountered species and a poor distribution across species types overall. This is illustrated by the clear dominance of the Mugilidae family and the *M. curema* species in this area and the elevated species and family richness of the Pedregal region. Although both areas were dominated by *M. curema*, it made up a larger proportion of the catch in the Boca Chica area, indicating greater dominance in the fish community in that area. The S’ value for Boca Chica is more noticeably depressed by this change in family composition than the H’ value because of its sensitivity to changes in more abundant species populations. Additionally, the distribution of individuals across the species encountered is more equal in Pedregal as indicated by the J’ value. By fishing in Boca Chica, the artisanal fishermen of Pedregal increase the chance of catching more fish in total and more fish of the target species. However, this region harbors less biodiversity which could indicate greater biotic stress or could be related to a variety of environmental variables such as habitat heterogeneity (Dominici-Arosemena and Wolff 2006).

5.4. Comparison across Habitat Types:

Comparisons across habitat types yield the conclusion that the sandy beach habitat supports the fish community with the greatest diversity as measured by the H’ value and the greatest evenness of species as measured by the J’ value. The rocky shore habitat, is second in biodiversity according to the H’ and J’ measures however the elevated S’ value sets it apart. This extremely high index is most likely a result of the dramatic decrease in abundance of the dominant species from the mangrove and mixed mangrove/rocky shore habitat types. The greatest H’ values were reported for the rocky shore and sandy beach habitats indicating that the relative abundances of less common species increased in these areas. This is illustrated by the fact that the most abundant families in sandy beach and rocky shore habitat were the second or third most abundant families from the other areas and the lowest relative abundance of the dominant species for the total area were found in these habitat types.

Family richness was positively associated with the n value for the catches in each habitat type. This could indicate that continued sampling of the less investigated habitat types (all but mangrove) would yield more species and higher H’, S’ or J’ values. However, based on the data available here, it can be concluded that each habitat type provides niches for a unique community of icthyofauna.

5. 5. Artisanal Fishermen of Pedregal

The small-scale fishery of Pedregal supports a culturally rich activity that defines the people involved. There is a lot of pride involved in the occupation in this region and the skills employed are a valuable asset that is passed down from captains to muchachos. Not only does the fishery provide the food and capital that helps these fishermen to maintain their way of life but it is also a different kind of sustenance. The fisherman with whom the most time was spent indicated that he did not fulfill his job in the cooperative for the payment but because he wanted to do it. For these reasons, maintaining this fishery through sustainable management is crucial for the sake of biodiversity and the people that are tied to it.

Disagreement about the trends of the fish populations in this fishery were noted in the interview responses and it is thought that this may be due to the fact that different fishermen had different target species. This multi-species, multi-use approach to fisheries management is admirable however, if the fishermen are commenting on the population trends of their specific target species, then they may be hinting at an overall trend of decreasing diversity, toward the single dominant species that was identified in this study. While increasing the population of the most commonly targeted species, *M. curema*, may initially seem economically advantageous, for the long-term health of the ecosystem, it may be helpful to diversify the targeted species.

6. Conclusion:

The Rio Chiriqui delta and surrounding inter-island areas provide habitat for a highly diverse fish community that supports the artisanal fisheries based in Pedregal. This study area contains a variety of habitats that function together to make this possible. These habitats may be threatened by the current activities and based on this data the fish community may be beginning to reflect biotic stress on the habitat. The interactions between these habitat types are yet unknown and require further study in order to understand how degradation of one habitat will affect another. This information is baseline ecological data that can help to inform future decision makers in issues of land use and artisanal fisheries management.

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