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# Reef fish community structure of El Pelado Islet marine area, Santa Elena, Ecuador: baseline for MPA establishment

Julien Dubois Floro



Maria H. Cornejo-Rodriguez, PhD, CENAIM Prof.Dr Magda Vincx, UGent

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# <u>Abstract</u>

Ecuador has extremely diverse marine ecosystems, with a range from temperate to tropical communities; also within the coastal area, the fish communities are one of the most diverse taxa. The Tropical Eastern Pacific (TEP) faces major threats to marine biodiversity (i.e. overexploitation fisheries, habitat degradation, global climate change, etc.) where scarce studies have been performed. The El Pelado islet (01° 55, 9' S - 80° 47,2' W), in the leeward side of the Puntilla of Santa Elena, constituted by several rocky reefs was studied to achieve a baseline fish biodiversity assessment. This study was conducted by underwater visual census (UVC), during the wet season (March, April and May 2012). In total six sites were investigated; in total 5751 fishes of 5 families (Pomacentridae (45,8%), Labridae (18,8%), Haemulidae (9,3%) and Serranidae (6,3%)) with a total of 52 species were recorded. The species found in the study area concurred with other studies from Ecuador and other Tropical Eastern Pacific (TEP) countries. Mesocarnivores, macrocarnivores and planktivorous were the dominant trophic guilds in terms of species richness and density, were as herbivorous obtained the highest biomass. Our results suggest an elevated fishing pressure in El Pelado marine area (commercial species obtained: low density and biomass). Since El Pelado is of great importance with a long term tradition resource use for the stakeholders (traditional fishermen, compressor fishermen and dive operators), a comanagement no-take marine protected area (MPA) project is viewed as important for possibly contribution to fisheries, biodiversity, habitat restoration and tourism development. Furthermore stakeholders consider the protection of the islet important for future generations and favoured on the MPA establishment.

**Keywords**: Underwater Visual census (UVC), Reef fish ecology, Marine Protected area (MPA), Co-management, Tropical Eastern Pacific (TEP).

## Resumen

Ecuador es reconocido como poseedor de ecosistemas marinos extremamente diversos, albergando especies de clima temperado hasta tropical, siendo el grupo de peces uno de los más diverso. A pesar de que en El Pacifico Oriental Tropical se enfrenta graves amenazas a la biodiversidad marina (sobreexplotación pesqueras, la degradación del hábitat, cambio climático global, etc.), son escasos los estudios que se han realizado al respecto. Se estudió la composición la comunidad de peces del islote El Pelado (01° 55, 9' S – 80° 47,2' W), formación rocosa rodeada de arrecifes rocosos y coralinos localizado en la zona norte de la Puntilla de Santa Elena.

Se realizó una evaluación de la diversidad biológica en los peces mediante censos visuales submarinos (UVC), durante la temporada de húmeda del hemisferio sur (Marzo, Abril y Mayo 2012). Seis bancos de arrecifes escogidos, donde se obtuvieron 5751 peces de 5 familias (Pomacentridae (45,8%), Labridae (18,8%), Haemulidae (9,3%) and Serranidae (6,3%)) correspondiendo a 52 especies. Este resultado concuerda con estudios realizados en Ecuador y otros países de lo Pacifico Oriental Tropical. Mesocarnivores, macrocarnivores y planktivorous fueron los grupos tróficos mas abundantes y con mas densidad y los herbívoros el grupo con mas biomasa. Nuestros resultados sugieren una elevada presión pesquera en la zona de estudio (Especies comerciales obtenidas: baja densidad y biomasa). Dado que El Pelado es de gran importancia por la larga tradición pesquera y turística, los usuarios locales consideran que la protección de el Islote El Pelado es importante. Extendiendo la importancia para un proyecto a largo plazo de área protegida marina (sin extracción) con co-manejo, posiblemente contribuyendo a la pesca, la biodiversidad, la restauración del hábitat y el desarrollo turístico para generaciones actuales y futuras de las comunidades de Ayangue y San Pedro (Provincia de Santa Elena, Ecuador).

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# **1.Introduction**

The Tropical Eastern Pacific (TEP) region is constituted by tropical and subtropical Pacific coast including the offshore biogeographic islands of central and South America (Robertson et al., 2004). The northern limit of the TEP region is situated at the Magdalena Bay on the Pacific coast of Baja California (25°N) and the southern limit is recognized to be south of Guayaquil (4°S) (Zapata and Robertson, 2007; Robertson and Cramer, 2009). The TEP region is divided into 3 biogeographic provinces: Cortez, Panamic, Ocean Island (these biogeographic divisions are mainly due to relative sharp temperature gradients between temperate and tropical conditions) (Fig.1). The first two provinces constitute the continental shores and the third province, Ocean Island, represent the offshore biogeographic islands (Robertson and Cramer, 2009). Ecuador mainland is located at the southern limit of the TEP region; this implies that the coastal area is located in the Panamic province, where the Galapagos Islands are located in the Ocean Island province. The TEP is the most isolated tropical marine biogeographic region in the world (Robertson et al., 2004), mainly due to several biophysical processes (see Robertson and Cramer, 2009).



**Figure.1** – Tropical Eastern Pacific (TEP) biogeographic provinces, Cortez, Panamic, Ocean Island (see www.stri.org/sftep). Adapted from (Robertson and Cramer, 2009).

This isolation and dissimilarities between and within provinces is considered to be important for speciation (Robertson and Cramer, 2009), resulting in a high level of shore-fish endemism (72%) (1222 named and 58 known undescribed shallow-water species) (Zapata and Robertson, 2007).

The geophysical and environmental history of the coral reefs development in the TEP region is one of the greatest extreme cases in the world, where extreme environmental conditions results in high perturbation rates (Cortés, 1997), consequentially developing in a most fragile ecosystem (i.e. if compared with the Caribbean corals), with subsequent low coral diversity and slow recovery rates (Cortés, 1993, 1997). Moreover, the TEP region main habitats for reef-associated fishes are rocky reefs and algae dominated shores (Myers et Accordingly al., 2011). to several studies (Castellanos-Galindo et al., 2005; Dominici-Arosemena et al., 2005; Arosemena and Wolff, 2006) these habitats are populated with a diverse fish community in the Panamic province (including Ecuador coastal area) and Galapagos Islands (Edgar et al., 2004). But although the tropical rocky reefs support this important biodiversity, the scientific and conservation effort towards this habitat seems still unappreciated when compared to the coral reefs (Vroom et al., 2006). The necessity of conserving and developing research for this fragile ecosystem is clearly urgent, where the establishment of no-take marine reserves can clearly aid to protect the rocky fish communities and the biodiversity reef associated with this ecosystem (NRC, 2001). The establishment of marine protected areas could provide protection to fish biodiversity, by reducing or banning harvesting, habitat destruction resulting from anthropogenic effects (Myers et al., 2011). MPAs could result in the increase of target fish species density, biomass and mean body size and furthermore increase the biodiversity of this areas (Halpern and Warner, 2002; Halpern, 2003; Lubchenco et al., 2003). If spillover effects could be the case, it is still under investigation.

From 2012 onwards, the objective agreed under the CBD (International Convention on Biological Diversity) of establishing a representative global network of effective marine protected areas (MPAs) (CBD 2010) is encouraging the world governments



to expand the global MPAs network (Edgar et al., 2009). Since 1993, Ecuador is a member part of the international Convention on Biological Diversity (CBD). Since then, Ecuador is increasing the number of MPAs to expand the world coverage of marine protected areas from 1 percent to 10 percent by 2020 (CBD 2010). Ecuador is one of the "Megadiverse" countries (if grouped, these "Megadiverse" countries represent 70% of the world fauna and flora species; Terán et al., 2006), divided in four geographical regions: the Andes mountains, the Amazon forest, the coast and the Galapagos Islands. Ecuador is recognized to scope extremely diverse marine ecosystems ranging from: beaches, bays, estuaries, cliffs, coastal lagoons and the most typical the rocky shores (Arriaga, 2000; Gabor, 2002). Although high rates of biodiversity are present, the major part of the research was concentrated in plankton ecology and fishery resources (Cruz et al., 2003; Terán et al., 2006). Ecuador is in a privileged geographical position due to the several marine currents that converge at the coast (Fig.2).



**Figure.2** – The main currents and water masses interactions with the Ecuador coastal area. Where ASTS (Subtropical Superficial water), AESS (Equatorial Subsuperficial Water) and ATS (Tropical Superficial water), adapted from Briceño, (2004).

In the north, the warm and low saline, coastal tropical current of El Niño and from the south, the Humboldt cold, subtropical, saline current, merging with the Equatorial subsurface current (known as well as Cromwell current) (Cruz *et al.*, 2003; Terán *et al.*, 2004) and the formation of the Equatorial front, that undergoes seasonality with

elevated thermal/salinity variations (Cucalon, 1986). Equatorial front Moreover, the endures an unpredictable cyclical event, El Niño; consider being the warm phase of the ENSO (El Niño Southern-Oscillation) (Cruz et al., 2003). The El Niño event is translated in a change of the trade winds (normal westbound trade winds blowing abnormally eastward) increasing the temperature of the ocean upper layer and reduced upwelling, inducing changes in the local climate, affecting the marine and terrestrial biota (see Espinoza, 1996; Arriaga, 2000; Terán et al., 2004; Zambrano, 2007). Consequently Ecuador is one of the most affected countries due to the geographic position in South America. The mixture of different water masses has prompted the coast of Ecuador as well the Galapagos Islands, to embrace a highly productive coastal zone (Arriaga, 2000; Cruz et al., 2003). Due to the effects of these physical oceanography conditions, the coast of Ecuador has been divided into 3 areas: where the small cape (Puntilla) of Santa Elena, divides the area III (cold water, southern part) with area II (warm water, central part) (see Cruz et al., 2003). The conglomeration of these water bodies makes it possible to have temperate and tropical marine communities (Rivera et al., 2008), co-occurring; similar patterns are present in the Galapagos Islands (Edgar et al., 2004).

For the coast of Ecuador there are 111 species of molluscs reported (being the second most important group), 13 species of echinoderms and 85 species of crustaceans (Cruz et al., 2003). For the group of hermatypic (reef-building) corals 15 species (examples of species: Pavona clavus) are recorded and for the ahermatypic (not reef-building) corals 31 species (examples of species: *Tubastrea coccinea*) are recorded (Glynn et al., 1983). For the Ecuador coastal area, the fish group is reported to have 270 species, being the most diverse (Cruz et al., 2003). The article 405, enacted in 2008, of the Ecuadorian constitution, established the National system of Protected Areas (SNAP); where the Ministry of the Environment (MAE), is in charge of enforcing and manage the Protected Areas to guarantee the regulation and biodiversity conservation efforts (MAE, 2012).

In 2008, several reserves were established (Alava *et al.*, 2012); among them, the *Reserva de Producción Faunística Marino Costera Puntilla de Santa Elena* 



(REMACOPSE) was establish by the MAE (Ecuadorian Ministry of the Environment) and two Ecuadorian foundations, the Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM) and the Fundación Natura Capítulo Guayaquil (FNCG). This area is characterized to have a narrow continental platform and also being the most salient part of the eastern Pacific (Torres et al., 2003; Terán et al., 2004). This marine reserve is located in the Puntilla of Santa Elena; where the marine ecosystems diversity are dominated by rocky reefs, sandy and rocky substrate (Rivera et al., 2008), with an elevated primary and secondary production (Torres et al., 2003) and composed by an array of Peruvian and Indo-Pacific Panamic. marine biodiversity (Rivera et al., 2008). The baseline study developed by Rivera et al., 2008, concludes that the area (previous the marine reserve establishment) received an elevated fishing pressure, since the results show a low density (fish m<sup>-2</sup>) of fish species (less than 2 commercial fishes per 500 m<sup>2</sup>) (Rivera *et al.*, 2008).

knowledge of the Ecuadorian The coastal ichthyofauna still remains poor, especially for the small and cryptic fauna (Béarez et al., 2007). The most important commercial species fished in Ecuador are 'corvina' (Cynoscion sp.), 'perela' (Paralabrax sp.), 'camotillo' (Diplectrum spp.), 'lenguado' (Paralichthyies spp.), and shrimp (Litopenaeus spp.) (Cruz et al., 2003). According to Rivera (2008), the REMACOPSE marine reserve was composed by 86 fish species corresponding to 33 families. Eleven fish species are considered the most important commercial species (Table 1), and fish species are considered as relevant 16 ornamental species (non-commercial species) (Table 2), found in the marine reserve. The baseline studies (Terán, 1997; Rivera et al., 2008) are the only Ecuadorian research so far, which assessed the possible fish taxa present in rocky and coral reef ecosystems of continental Ecuador.

**Table.1** – List of the most representative commercial species (from the86 species) of the REMACOPSE marine reserve (*in Rivera et al.*, 2008).

Local Name	Common Name	Scientific Name
Burro frijol	Burrito Grunt	Anisotremus interruptus
Vieja ribetiada	Mexican Hogfish	Bodianus diplotaenia
Cabrilla enjambre	Pacific graysby	Cephalopholis panamensis
Plumero	Graery threadfin seabass	Cratinus agassizii
Mero pintado	Goliath grouper	Epinephelus itajara
Cabrilla	Starry grouper	Epinephelus labriformis
Roncador	Grey grunt	Haemulon scudderi
Señorita cocinera	Yellow snapper	Lutjanus argentiventris
Cabrilla plomuda	Broomtail grouper	Mycteroperca xenarcha
Corvinilla listada	Gungo highhat	Pareques viola
Huayape	Longfin yellowtail	Seriola rivoleana

An extension of the REMACOPSE marine reserve has been considered, in the northern area. In this area, there is an islet called "El Pelado" (Fig.3) with several rocky and coral reefs located within the area, deprived of any detailed scientific information about the fish communities or any other taxa biodiversity.

The El Pelado islet is a highly touristic area, used mainly for snorkeling and diving, but with a significant spearfishing and traditional fishing pressure by local fishermen, increasing the necessity to understand the impact generated by this activity (Fernando Rivera, NAZCA institute, pers. communication). The El Pelado islet reefs and the adjacent areas are ecologically important since they gather an abundant marine species biodiversity associated with reef ecosystems (i.e. demersal fishes, corals, and others) (Mendívez et al., 2010). Moreover, the islet is an important resting area for marine coastal birds, mainly for Brown Pelicans (Pelecanus occidentalis) and Blue footed booby (Sula nebouxi) (Haase, 2011).

Two Tern species are also living on the islet, Bridle Tern (*Onychoprion anaethetus*) and Inca Tern (*Larosterna inca*), furthermore the last one was found to be mating in the islet, being the first

**Table.2** – List of the most representative **ornamental** species (non-commercial species) (from the 86 species) of the REMACOPSE marine reserve (*in* Rivera *et al.*, 2008).

Local Name	Common Name	Scientific Name
Petaca banderita	Panamic sergeant major	Abudefduf troschelii
Lija tildada	Scribbled leatherjacket filefish	Aluterus scriptus
Burro	Silvergrey grunt	Anisotremus caesius
Trompetero chino	Chinese trumpetfish	Aulostomus chinensis
Tamboril punteado	Spotted sharpnosed puffer	Canthigaster punctatissima
Mariposa triple	Threebanded butterflyfish	Chaetodon humeralis
Pez erizo balón	Longspined porcupinefish	Diodon holocanthus
Ronco chere-chere	Chere-chere grunt	Haemulon steindachneri
Pez ángel real	King angelfish	Holocanthus passer
Mariposa barbero	Blacknosed butterflyfish	Johnrandallia nigrirostris
Chivo amarillo	Mexican Goatfish	Mulloidichthys dentatus
Pez angel de cortés	Cortez angelfish	Pomacanthus zonipectus
Cachudo	Stone triggerfish	Pseudobalistes naufragium
Jaqueta dos colores	Beaubrummel	Stegastes flavilatus
Vieja arco iris	Cortez rainbow wrasse	Thalassoma lucasanum
Idolo moro	Moorish idol	Zanclus cornutus

registered case in Ecuador (Haase, 2011). The presence of different bird species denotes the necessity to protect and conserve the islet, as the Inca Tern (*Larosterna inca*) is categorised as Near Threatened IUCN lower risk conservation status (Birdlife International, 2012). On the other hand, the Ecuadorian coast is an important breeding area for the Humpback Whale (*Megaptera novaeangliae*) during the austral winter (June-September); El Pelado islet is used as a milling (socializing



behaviour) area (Alava et al., 2012). Next to the biological importance of the area, a well-managed approach could allow another touristic revenue for the Ayangue, San Pedro and Valdivia towns (Whale-watching business). The El Pelado marine area is proposed in this study, for a future marine reserve in Ecuador coastal area. Although, the establishment of MPAs is viewed as an important conservation tool for fisheries, biodiversity, habitat restoration and tourism development (Christie and White, 2007), the lack of management, compliance and illegal activities exhibits the majority of MPAs in the world as "paper parks" (Kelleher et al., 1995; McClanahan, 1999). The Ecuadorian MPAs unfortunately follow the same outcome (Alava et 2012); therefore more information and al., knowledge is needed to increase public awareness about the importance of implementing efficient MPAs.

The present study will update the scientific information of the El Pelado area. Actually, the research efforts are sparse in the area, which hampers the development of management plans essential for the conservation and sustainable use of the rocky reef and associated fish species. Additionally, to design the future MPA management plan, taking into account the socio-economic context, we included a social study of the El Pelado stakeholders (Fishermen and Dive center of Avangue, Fishermen of San Pedro and Valdivia villages). Furthermore the gradual degradation of the natural environment due to the climate change and growing human pressure increases the importance of initiating qualified quantitative studies on the biodiversity of coastal areas.

The main objectives of this study will be to identify and study rocky reef fish communities of El Pelado marine area and assess the stakeholder's opinion for a future marine reserve establishment. For this research four aspects will be investigate:

1) Identify the biodiversity in terms of species richness and species dominance per site.

2) Measuring population densities.

3) Determine the size estimates (mean sizes, mean weights, and individual and total biomass).

4) Social opinion study of the future marine reserve establishment, interviewing the main stakeholders of the El Pelado marine area.

The aim of this study is also to provide a baseline study for the creation of a co-management no-take MPA of the study area.

## **2. Material and Methods**

#### 2.1. Study area

The field study was done along the El Pelado islet  $(01^{\circ} 55, 9' S - 80^{\circ} 47, 2' W)$  marine area, found north of the Santa Elena province, located at 3.7 nautical miles (n.m.) in front of San Pedro village and 5 n.m. northwest from Ayangue village (Fig.3). The El Pelado is mainly a rock formed islet, rising 10 meters above the sea level (INOCAR, 2005), with 70 meters wide and 20 meters large (Haase, 2011). El Pelado islet is in the Leeward side of the Puntilla of Santa Elena, constituted by several rocky reefs. These rocky reefs are extended, usually formed by rock agglomerate and slab with large boulders, accompanied with cauliflower corals (Pocillopora spp., Pavona spp.), high diversity of Octocorals (mainly gorgonians species), including of Black presence coral (Antipathes the galapagensis) (Terán et al., 2004), listed in appendix II in CITES. Hence these rocky reefs produce a complex ecosystem, particularly the vast extensions of Octocorals species present in the El Pelado marine area. An elevated fishing pressure upon demersal fishes and the benthic fauna (i.e. oysters, Spondylus spp., Octopus, lobsters. holothurians spp., etc.) affects the marine area of El Pelado (see Mendívez et al., 2010). The islet was integrated in the Special Area of Management (SAM) of San Pedro-Valdivia-Manglaralto (PMRC, 1993) until 2008, once the Ministry of the (MAE) Environment assumed directly the management of these areas in Ecuador.





**Figure.3** – Map of Ecuador, the red square indicates the REMACOPSE marine reserve with the research location (1); the REMACOPSE marine reserve with the El Pelado islet location, found north of the Santa Elena province (2); In front of Valdivia and San Pedro town (CENAIM (*Centro Nacional de Acuicultura e Investigaciones Marinas*) research centre), is located the El Pelado islet, the research study site (3).

#### 2.2 Sampling design

A total of 6 Sites, corresponding each to a specific reef location (Fig.4; Table.3) were sampled using

underwater visual census (UVC- see section 2.4) to assess the reef fish community, in a course of 8 sampling days. Each sampling day was organized to cover 1 to 3 reefs sampled a day with one to



maximum 3 transects per reef (depending on visibility conditions), during the months of March, April and May 2012, corresponding to the wet season (Briceño, 2004; winter season in Ecuador). Fishermen local knowledge was used to assess the position of the reefs. Each reef location was chosen randomly, within the El Pelado marine area. Each reef location included the major representative substrate features (i.e. gorgonias and corals species, etc.).



**Figure.4** – Map of El Pelado Islet (Brown area), with the 0,5 nautical mile MPA proposal (Orange area; corresponding to  $0,7 \text{ km}^2$ ) and the approximated sampling sites locations.

The justifications aforementioned are the main assumptions used to choose the location of the sites, since no biodiversity assessment studies are present for this area. At each site all fish species where counted, using the distance sampling theory, providing estimates of species richness, population density and size estimates for each species. The sampling strategy defined in this research was based on randomly selecting the sample units (Kulbicki, 1990; Labrosse *et al.* 2002; Thomas *et al.*, 2010). At each reef we considered an area representing 10000  $m^2$ , incorporating the main features of the reefs, where three transects (see section 2.3) were deployed at each station for the data collection.

Table.3 - Site names and coordinates
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Reef Name	Latitude	Longitude
(1)El 40	01°56'12''S	80°47'09''W
(2)Rabo del Viejo	01°55'59,3"S	80°4'11"W
(3)La Pared	01°56'2,5"S	80°47'23,5"W
(4)El Pelado	01°56'4,6"S	80°47'20,94"W
(5)La Viejita	01°56'3,4"S	80°47'33,8"W
(6)San Ignacio	01°55'55"S	80°47'17,6"W

The transect deployment follows a systematic sampling (Thomas *et al.*, 2010), consisting in randomly selecting the direction and transect location within the reef station area (square area of 100x100 meters) (Kulbicki, 1990; Labrosse *et al.*, 2002). Transect random selection enable us to perform comparisons in space (i.e. between biotopes) and time (Kulbicki, 1990; Labrosse *et al.*, 2002). In order to minimize variability in fish densities (high activity periods - early morning and late afternoon) the sampling was limited between 0900 and 1700 hours (see Carpenter *et al.*, 1981), hence avoiding the reduce visibility due to the sun angle. The final total dataset comprised 18 transects.

#### 2.2.1 Different collected components

#### Species richness and density

Currently, the study aims at measuring all species, including small and cryptic species. The main reason is to collect information on species richness, even though some species are excluded from the quantitative analysis due to the likelihood of inconsistent detection (example: a diver can see a scorpion fish camouflaged against the substrate, but the probability to count all the specimen along the transect is very small) (Banks *et al.*, 2004). In these cases, an indication of the presence of these species provides qualitative information still valid although the estimates are questionable for analytical purposes. Additionally after collecting the number of species we can calculate the density (fish m<sup>-2</sup>) and biomass (g m<sup>-2</sup>) (see section 2.8).

#### Size distribution

For all the species recorded within transect boundaries, we estimated the size (cm), which is the total length of a fish, between the tip of the snout to the farthest end of the tail (TL- total length). It can be challenging to estimate the size of a specimen, therefore we used a non-invasive technique of verification; an underwater data sheet slate (with the dimensions previously calculated), the distance between our thumb and index finger extended, and the distance between the shoulder and the opposite hand when the arm is extended sideways to form a wing; these approaches are the best underwater references available (Banks *et al.*, 2004). This



eliminates having to carry additional equipment underwater, with a consistent and suitable framework for verification of sizes, which can be easily estimated in the wrong way due to the magnification caused by the diver mask.

#### Other Data

Environmental data collected during the sampling campaign was seawater temperature (Suunto Zoop ® dive computer), visibility (horizontal distance visibility using the data slate, more details section 2.3), wave surge (classification: no, weak or strong swell; Annex 1), tide, wind (Beaufort scale; Annex 1) and current strength (classification: no, weak or strong current; Annex 1), depth (Suunto Zoop ® dive computer) and cloud cover (classification: 0 to 8; zero meaning no cloud and 8 completely covered; Annex 1). Other information included in the data was the site name, date, diver name and dive time. During the sampling campaign we registered the observations of other important taxa (i.e. Birds, marine mammals, turtles, etc.) but it was not include in the quantitative study of this research.

#### 2.3 Sampling procedure

The UVC (underwater visual census) survey belt transects length of 50 meters is used in several studies (Kulbicki, 1990; Edgar *et al.*, 1997; Edgar and Barrett, 1997; Samoilys and Carlos, 2000; Labrosse *et al.*, 2002 and others). The sampling procedure in this research is based on the methodology used by Kulbicki, (1990), Kulbicki and Sarramégna, (1999), Labrosse *et al.*, (2002) and Bozec *et al.*, (2011). At each station two divers (one of the divers was the author) (Fig.5) worked to evaluate the fish species encountered.



**Figure.5** - Transect line of 50 meters long, with the 5x10 meters marked intervals; d1 and d2 corresponds to the variable distance counting, adapted from (Labrosse *et al.* 2002).

Before starting the count, the divers wait 5 minutes as "recovery time", to reduce the disturbance, resulting from the diving (Bohnsack and Bannerrot, 1986; MacNeil *et al.*, 2008; Kulbicki *et al.*, 2010). On the other hand, the transect line was unrolled by small fractions, usually around 3 meters, to reduce the disturbance and minimize the possibility of fish double counts, implied by the divers movement; both divers took into account to swim with the same speed (Lincoln Smith, 1988) and keep the buddy diver distance (minimal distance possible).

The mean speed during the sampling campaign was 1,43 m min<sup>-1</sup> $\pm$  S.E. 0,1471. The divers exchange sides between each transect to reduce error (MacNeil et al., 2008). The divers at each stop, using a sweeping mode (Fig.5) (from the transect imaginary line until the outer limit of the visibility), started to count larger and mobile species first (Bozec et al., 2011), since there are most likely to go into or out of the transect segment. Secondly, count the most active and abundant fish (Lincoln Smith, 1989). Therefore fish entering the transect boundaries after the counting begins where ignored. In this research we used the variable distance counting (Kulbicki, 1990, 1998; Kulbicki and Sarramégna, 1999; Labrosse et al., 2002; Bozec et al., 2011), that consists, taken into account for each fish, the distance from the transect at the time of observation. Then the observer diver assesses and registers the fish perpendicular distance from transect imaginary line (see section 2.5 and Fig.5). Using underwater slates, we registered the fish species, number of fish (in case of schooling fish), and the total length (TL- total length), where in case of schooling fish the median size was recorded taking into account to be representative of the school fish (Labrosse et al., 2002; Bozec et al., 2011). The maximum retained distance was 8 meters, after this distance the accuracy of visual census (i.e. species, size or perpendicular distance) maybe not valid (Bozec et al., 2011). Species with less than 5cm were not counted. Finally, the water visibility was recorded at the end of the survey, using the underwater slate as visual mark, in the transect line.



2.4 UVC (underwater visual census) methodology benefits and biases.

UVC methods are being used by field ecologists since the 1950's (Brock, 1954), and became the most accepted method for the estimation of reef fish abundance (Cheal and Thompson, 1997; Dickens et al., 2011). Moreover, the UVC technique is extensively used for surveying reef fish populations in temperate and tropical waters (Kulbicki and Sarramégna, 1999; Bozec et al., 2011). It is nondestructive, fast data gather and low cost technique (Watson et al., 1995; Watson and Quiin II, 1997; Thompson and Mapstone, 1997; Samoilys and Carlos, 2000), hence less selective when compared to other sampling techniques (Brock, 1954; Edgar et al., 2004). UVC methods are mainly used to provide rapid estimates of species richness, size estimates for each species (length frequency distribution), population density and biomass (Samoilys and Carlos, 2000). In UVC methods there are two different and most common used techniques, strip transects (Brock, 1954), and the stationary point counts (Bohnsack and Bannerrot, 1986). This study used the strip transects methods, since it is the most common technique in reef fish research.

The UVC methods have several biases induced by this technique affecting the density estimate (Brock, 1982; Edgar et al., 2004). Some of the most recognized errors for the UVC methods are: the environmental differences found in the different habitat surveyed (i.e. the substrate complexity) affecting the density estimate of the fish community (Brock, 1982; Lincoln Smith, 1989; Cheal and Thompson, 1997; Willis, 2001; Williams et al., 2006); the cryptic species detectability is reduced in this methods (cryptic species were not used in the quantitative analysis in this research) (Brock, 1982; Kulbicki, 1990; MacNeil et al., 2008) and due to the behavior that fishes have toward the diver ("shyness" or "attractiveness") that increases the bias in abundance estimate (see Kulbicki, 1998; Edgar et al., 2004; Watson et al., 1995, 2005). The taxonomic experience (identifying diver the different fish species) (Thompson and Mapstone, 1997), the swimming speeds of the observers (Lincoln Smith, 1988), the number of species and taxonomic behavior are a major influence in the detectability (Lincoln Smith, 1989). Additionally the surveys have to be at shallow water depths due

to diving restrictions (Harvey et al., 2001), besides the observing variability between divers used in the survey (Williams et al., 2006) and the transect width seems to be a great source of biases, altering the detectability among different species (Cheal and Thompson, 1997). Consequently depending on the width chosen, it will influence the density estimates (Cheal and Thompson, 1997; Mapstone and Ayling, 1998; Kulbicki and Sarramégna, 1999). Were as, UVC methods established by non-instantaneous counts, do not produce reliable density estimates (instantaneous counts are: surveyors do not count the fish that enters the transect after beginning the census) (Ward-Paige et al., 2010). Although several studies explain that the use of different UVC methods (strip transects, stationary point counts, stereo-video transects) together in the same research will reduce the bias and increase the quality of the study (Watson et al., 2005; Bozec et al., 2011), in this research we had not the budget or time to apply different techniques, and for this research, strip transects were estimated to be the most appropriated method in relation to time/budget possibilities and quality of data collected.

#### 2.5 Why using Distance sampling?

Distance sampling is a widely used technique for estimating the abundance of wildlife populations (Thomas et al., 2010), mainly developed for marine mammals. Distance sampling consists in, measuring the perpendicular distance (i.e. mammals, fish, etc.) from the transect strip (Thomas et al., 2010; Bozec et al., 2011). The theory formulated behind the distance sampling is based on the fact, that not all detectable fishes are necessarily spotted (Labrosse et al., 2002; Bozec et al., 2011); moreover the probability of detecting a fish species decreases with the observation distance and fish behavior (Kulbicki and Sarramégna, 1999; Labrosse et al., 2002; Thomas et al., 2010; Bozec et al., 2011). The distance sampling data of Bozec et al., (2011), probes that the distance of maximum detection correlates with the body size, meaning that the larger the fish, greater is the fleeing distance. Strip transects research not recording detection distances may have poorer patterns of detectability. Thus, distance sampling use in the research design is recommended, reducing inconsistent biases over (Bozec space and time et al., 2011).



Correspondingly, providing fish density and abundance estimates in relationship with the probability of detection (Thomas *et al.*, 2010; Bozec *et al.*, 2011). For the fact, distance sampling has not being commonly used in reef fish research (Kulbicki, 1990, 1998; Kulbicki and Sarramégna, 1999), however the distance sampling data can provide essential facts about the fish detectability (Bozec *et al.*, 2011). The distance sampling theory increases the strength of the research design, supporting the use of this tool, particularly to reduce under or overestimation due to the transect with.

2.6 Fish species Feeding and Zoogeography categories

Five feeding categories were used to classify the fish species according to the feeding habit. This classification was completed using the www.fishbase.org (Froese and Pauly, 2012) and www.stri.org/sftep (Robertson and Allen, 2008). The feeding categories were:

Herbivorous – feeding mainly algae or seagrass.

**Omnivorous** – feeding on both algae and animal prey.

**Macrocarnivores** – feeding on crustaceans (shrimp or crabs) and fish

**Mesocarnivores** – feeding on small crustaceans, polychaetes, molluscs and sessile invertebrates. **Planktivorous -** mainly feeding on plankton.

The zoogeography classification was possible using the Smithsonian tropical research institute, www.stri.org/sftep (Robertson and Allen, 2008). Four species categories resulted from this classification:

#### Tropical Eastern Pacific (TEP) endemic Indo-Pacific Origin Peruvian Province endemic Circumtropical origin

#### 2.7 Social Study Survey

A social study to the different villages stakeholders (Ayangue, San Pedro and Valdivia) that are known to use the El Pelado marine area was implemented in this research. The main stakeholders where identified to be the Fishermen of San Pedro and Ayangue village, but also the Diving operators present in Ayangue (no diving operators are present in San Pedro). The Valdivia village was ignored for this study due to the fact that there are no fishermen or diving operators present (being this statement confirmed by the villagers and us).

The main objective of this survey was to ask the opinion of the El Pelado major stakeholders, assessing the interest in the establishment of a Marine Protected Area (MPA). This bottom-up approach means. necessary decentralized governance from the National Government agencies Ministerio del Ambiente de Ecuador, (i.e. environmental agency - MAE), redistributing the management and enforcement capacity to the local stakeholders (Fishermen, Diving operators, NGOs (i.e. NAZCA institute) and CBOs (community based organizations), etc.), with the government support, generally known as co-management (see Sen and Nielsen, 1996; Borrini-Feyeraben et al., co-management implementation 2000). The encourages the design and management of MPAs success, contributing to the stakeholder's objectives (sustainable fisheries, increased tourism) (Gerhardinger et al., 2009; Cinner et al., 2012). Since it implies the active stakeholders involvement and establishing cooperation between the different identities (stakeholders with Government agencies), MPA governance with this bottom up approach should be designed where permanent or temporal management rights are granted to the stakeholders (Jones et al., 2011). This survey wanted to obtain the opinion of the major stakeholders, since the greater stakeholder involvement and increase support of the Government agencies are necessary to achieve a more equitable and effective management system (Da Silva, 2004), essential for a well design MPA.

The fishermen group in Ayangue is divided in two sub-groups, being the traditional fishermen and the "compressor" fishermen. The traditional fishermen use traditional fishing gear (i.e. line fishing, gill nets, seine nets, etc.), while the compressor fishermen use an air compressor on board, to dive, using spear guns or iron hooks to collect different species (i.e. fishes, octopus, lobsters, etc.). At San Pedro village, the fishermen group is composed only by traditional fishing gear.

During the months of April and May, we spent 8 days doing informal and semi-structured interviews



and one seminar, to assess the opinion of the stakeholders (see Annex 2). The first four days the interviews were led in San Pedro village, at the landing site (San Pedro beach). Hence, in Ayangue village, three days were used to do the interviews with the traditional fishermen and dive operators and one day to do the seminar with the compressor fishermen. The fishermen were randomly chosen along the landing sites of both villages, being also the case for the dive operators in Ayangue. The seminar was organized to interview the compressor fishermen, given the opportunity to assess this group's opinion by asking informal questions.

Fifteen and six questions surveys were used for the traditional fishermen and dive operators respectively. For the seminar, we use 13 questions surveys to assess the opinions of this group. The time spends to fill one questionnaire range from 10 to 20 minutes. Moreover the seminar workshop duration was about 1 hour.

Each questionnaire was formed to answer several aspects, touching from the historical use, importance, type of gear used, area zonation and the need for conservation of the El Pelado marine area.

#### 2.8 Data processing

UVC data was used to estimate species richness, fish population density, fish size and biomass for each transect at each station, using the distance sampling algorithms (Kulbicki *et al.*, 1990; Kulbicki and Sarramégna, 1999; Labrosse *et al.*, 2002). Consequently, fish cryptic species (see table.4 in section 3.1) associated to this data were only used in qualitative (abundance, species richness and diversity calculations).

The social study data were analyzed to acquire the stakeholder's opinion in relation to a future marine protected area establishment.

#### Species Richness and Diversity

Species richness (S) is the number of species observed at each site. To assess the fish species diversity represented in the community, we used the Shannon-Weiner Index (H') and the Pielou's evenness index (J'). The subsequent diversity indices formulas were used:

#### Shannon-Wiener Index (H')

$$H' = -\sum_{i=1}^{S} \left(\frac{ni}{N}\right) \left(\ln\frac{ni}{N}\right)$$

Where S represents the species richness; *ni* number of *i*th species; *N* total number of individuals.

Pielou's evenness index (J')

$$J' = \frac{H'}{H'_{max}}$$

Where H' represents the Shannon-Wiener index, being the actual estimate of the community;  $H'_{max}$ the maximum value of H'; obtained through  $H'_{max} = ln S$ .

#### **Population Density**

Several reef ecosystems studies (Polunin and Roberts 1993; Dufour *et al.* 1995; Russ and Alcala 1996 and others) used the relative abundance to assess the fish population estimates. The density estimation, for each transect, used in this study is based on distance sampling specially developed algorithms (Kulbicki *et al.*, 1990; Kulbicki and Sarramégna, 1999; Labrosse *et al.*, 2002).

The distance sampling counting (as aforementioned in the previous section), consists in dividing each transect side into one meter-wide corridor (0 to 1 meters; 1 to 2 meters; 2 to 3 meters, etc.). Consequently the fish distance at the time of observation was related with one of these imaginary corridors (Fig.5), where the median value of the associated corridor will correspond to the fish distance from the transect (i.e. if the fish is found at 1 meter from the transect, we assumed to be in the 1 to 2 meters corridor, therefore the calculation will be 1m + 0,5m median value; in case of schooling fishes we used an average between the closest to the transect with the more distant one (Fig.5)( Labrosse *et al.*, 2002).

The detectability function g(x) (see formula below) enables the densities calculations, thus allowing to extrapolate the probability of sighting a fish species (based on the variable distance counting theory) for

a given species, family or population. As so, the calculation of the different parameters necessary to obtained density and biomasses estimates are based in this algorithm (see section 2.8.1). Therefore the estimated density D is expressed as:

$$D = \frac{\sum_{i=1}^{p} ni}{La}$$
 where  $a = \int_{0}^{d_{max}} g(x) dx$ 

where D (fish m<sup>-2</sup>) for each transect; ni is the number of fish; the length of the transect L (50 m) and  $d_{max}$  the perpendicular distance from transect to the limit of detectability.

#### Fish size estimates

The size estimates of different fish population can be important for the future management of a MPA, since it provides an integrated metric quantity to the fish community (Menza *et al.*, 2006). The individual size estimates of fish species allow us to calculate mean weights, using length-weight ratios available in Kulbicki *et al.*, 2005 and www.fishbase.org (Froese and Pauly, 2012) and also biomass (fresh weight per surface area unit (g m<sup>-2</sup>) (Labrosse *et al.*, 2002).

The different parameters (species richness, population density and mean fish size estimates and biomasses) can demonstrate the state of the different fish population, specifically the ones that are fishermen targets, since the fishing activities influence these parameters (Russ and Alcala, 1996; Russ and Alcala, 1998<sup>a,b</sup>; Labrosse *et al.*, 2002).

2.8.1 Parameters Calculations (mean weights distance, density estimates, biomass estimates and variances)

The following parameters were developed using the distance sampling theory (Kulbicki *et al.*, 1990; Kulbicki and Sarramégna, 1999). These parameters calculations allow us, using the data from one or more transects, to assess the values for species, family or the overall population. Labrosse *et al.*, 2002 protocol, established all the mean weights distances parameters used to calculate density and biomass estimates with correspondent variances.

To obtain the **Mean weights distance** the following formula is used:

$$d_{m_j} = \frac{\sum_{i=1}^{p} n_{ij} \left( d_{ij} + 0.5 \right)}{\sum n_{ij}}$$

Where  $d_{m_j}$  (m) represents the Mean weighted distance; p is number of total (occurrences) of species j (can include several individuals in one observation);  $n_{ij}$  is number of fish in observation (occurrence); i = 1 (although can take higher value in events of fish schools);  $d_{ij}$  is transect perpendicular distance of fish i. With fish schools we used the alternate formula for  $d_{ij}$ :

$$d_{ij} = \frac{(d_1 + d_2)}{2}$$

The **Density estimates** for a given transect were calculated by the following formula:

$$D_j = \frac{\sum_{i=1}^p n_{ij}}{(2dm_i)L}$$

Where *D* is density (fish m<sup>2</sup>) fish species *j* for transect;  $n_{ij}$  is total number of species; *L* is length of transect (50 m);  $d_{m_j}$  is average transect perpendicular distance of fish *j*.

The **Biomass estimate** follows the same algorithm used for density estimates, however using length-weight ratios and the subsequent formula is:

$$B_i = \frac{\sum_{i=1}^p n_{ij} \cdot W_{ij}}{(2dm_i)L}$$

Where *B* is biomass (g m<sup>-2</sup>) fish species *i* for transect;  $n_{ij}$  is total number of species;  $W_{ij}$  is total or individual species estimated weight *i* using length-weight ratios ( $W = a \cdot L^b$ ); *L* is length of transect (50 m);  $d_{m_j}$  is average transect perpendicular distance of fish *j*.

The subsequent formulas enable us to calculate the density and biomass estimation accuracy and so, assessing the dispersion (variance), through

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standard deviation value calculation for a target population (Labrosse *et al.* 2002).

#### Variance calculation

The variance of the sampling unit (transect) can be given for any biotope and time frame. The variance for density and biomass estimation measurements can be calculated by the following formulas:

#### Variance density estimate

$$S_D^2 = \frac{\sum_{i=1}^{n} (D_i - \overline{D})^2}{n}$$

Where  $S_D^2$  is the density variance;  $D_i$  is density in transect i;  $\overline{D}$  is mean density of transects; n is number of transects.

#### Variance biomass estimate

$$S_B^2 = \frac{\sum_i^n (B_i - \overline{B})^2}{n}$$

Where  $S_D^2$  is the density variance;  $B_i$  is density in transect *i*;  $\overline{B}$  is mean density of transects; *n* is number of transects.

Consequently the standard deviation formulas for density and biomass can be obtained as follows:

#### **Density standard deviation**

$$S_D = \sqrt{S_D^2}$$

**Biomass standard deviation** 

$$S_B = \sqrt{S_B^2}$$

2.9 Statistical analysis

#### **Biological Data**

Species richness and diversity index were obtained per each site using the average number of 3 replicates per site. The density (fish m<sup>-2</sup>) and biomass ( $g m^{-2}$ ) resulting from the parameters calculation aforesaid were averaged, using 3 replicate per site, to obtain the total values per site. The species accumulation curve for the study area was obtained using a mean 50 randomizations (without replacement) through EstimateS software (Colwell, 2001). The total species richness of the study area was estimated using second-order Jackknife estimator (Colwell, 2001), since it provides a least biased estimates for small number of samples (Colwell and Coddington, 1994), acquired from EstimateS software (Colwell, 2001). Species recorded by only a single individual in the sample unit are "uniques", were as the number of observed species represented by two individuals in the sample unit are "duplicates" (Colwell and Coddington, 1994; Chao et al., 2005).

The variations in fish communities between sites calculated using multivariate statistics, were resulting from abundance similarity matrix of each fish species in all transects. The raw data matrix was root-transformed (overall) preceding analyses (Clarke and Warwick, 2001) downweighting the most abundant fish species and schooling fish. A SIMPER analyses was generated to examine the species that were responsible for the dissimilarity within and between sites in PRIMER6 software (PRIMER E Ltd, Plymouth; Clarke and Warwick, 2001). Species that were consistently important to dissimilarity in the comparisons of samples between sites were identified by the large values (i.e. >1) of the ratio  $\delta i/SD(\delta i)$  (Clarke and Warwick, 2001).

The Bray-Curtis similarity was the resemblance used, obtaining the patterns of similarity between sites by a MDS ordination plot in PRIMER. A oneway ANOSIM, using 999 permutations, was tested in PRIMER, to assess if the communities between sites were different.

#### Social Study Data

The data was analyzed to obtain the stakeholders outlook about the MPA implementation in the study area. The answers of the questionnaires were transformed in percentage to scope for a better interpretation of the data. This study also brought incite in the relationship between the two communities (Ayangue and San Pedro) and

between the stakeholders (Fishermen, compressor Fishermen and Diving operators).

# 3. Results

#### 3.1. Reef fish community

A total of 5751 fishes were censused from 6 different sites in the El Pelado marine area: 52 species from 5 different families were observed (Table.4). The families with highest species richness were Omnivorous **(S)** (17)species) and Macrocarnivores (16 species), both contributing for 63% of the total richness. Moreover the families occurring from the highest to the lowest values of density (fish  $m^{-2}$ ) and subsequent biomass (g  $m^{-2}$ ) are Planktivorous (29,4% fish m<sup>-2</sup>; 2,5 % g m<sup>-2</sup>), Mesocarnivores (28,8% fish m<sup>-2</sup>; 17,9 % g m<sup>-2</sup>), followed by Omnivorous (28,3% fish m<sup>-2</sup>; 26,1 % g m<sup>-2</sup>), Macrocarnivores (8,2% fish m<sup>-2</sup>; 4,6 % g m<sup>-2</sup>) and Herbivorous  $(5,2\% \text{ fish } \text{m}^{-2}; 48,9\% \text{ g } \text{m}^{-2})$ (Table.5).

The species richness per site varied from 16 to 24 (mean  $\pm$  standard error = 20 $\pm$ 2,64), where as the mean density and biomass per site was 0,951 $\pm$ 0,14 fish m<sup>-2</sup> and 121,8 $\pm$ 119,2 g m<sup>-2</sup> respectively.

The greatest mean density of fish were recorded at the El Pelado site  $(1,321\pm0,375 \text{ fish m}^{-2})$  and La Viejita site  $(1,301\pm0,488 \text{ fish m}^{-2})$ , on the other hand the lowest mean density was recorded at El 40 site  $(0,561\pm0,305 \text{ fish m}^{-2})$  (Fig.6). Additionally Rabo de Viejo  $(0,709\pm0,257 \text{ fish m}^{-2})$ , La Pared  $(0,864\pm0,156 \text{ fish m}^{-2})$  and San Ignacio  $(0,952\pm0,104 \text{ fish m}^{-2})$  obtain similar values.



**Figure.6** – Mean density of fish recorded at each site with standard error, values of density (fish  $m^{-2}$ ).

The greatest mean biomass per site was registered at the El Pelado site  $(297,99\pm287,43 \text{ g m}^{-2})$  and Rabo de Viejo site  $(179,27\pm196,7 \text{ g m}^{-2})$  (Fig.7). Both sites are characterized with elevated standard errors, values indicating a disturbance in standard error variance in one of the replicated transect.



**Figure.7** – Mean biomass of fish recorded at each site with standard error for all 3 replicated transect per site, values of biomass (g  $m^{-2}$ ).

Transect 2 of both sites was the cause of variance; consequently if we remove the disturbance (transect 2) the standard errors decrease. Nevertheless, even with the disturbance removal, El Pelado site  $(94,8\pm9,94 \text{ g m}^{-2})$  and Rabo de Viejo site  $(81,8\pm47,5 \text{ g m}^{-2})$  maintain the greatest mean biomass (Fig.8).



**Figure.8** – Mean biomass of fish recorded at each site with standard error, with the disturbance (transect 2) removed from the El Pelado and Rabo de Viejo sites, values of biomass (g  $m^{-2}$ ).



**Table.4** – Complete list of the 52 species separated by families. Species were classified within the different trophic groups (Herbivorous (**H**), Omnivorous (**O**), Macrocarnivores (**Mac.C**), Mesocarnivores (**Mes.C**) and Planktivorous (**P**). Each Species maximum size (cm) was acquire in www.fishbase.org (Froese and Pauly, 2012). Density (fish m<sup>-2</sup>), Biomass (g m<sup>-2</sup>) and Abundance (total n<sup>o</sup> of fish) are indicated for each species encountered in El Pelado marine Area.

Family	Species	Common Name	Local Name	Density (fish m <sup>-2</sup> )	Biomass (g m <sup>-2</sup> )	Abundance
Acanthuridae	Prionurus laticlavius (H) (max: 60cm)	Razor surgeonfish	Cochinito	0,223	265,09	73
Balistidae	Pseudobalistes naufragium ( <b>O</b> ) (max: 100cm)	Stone triggerfish	Cachudo	0,024	15,03	×
	Balistes polylepis ( <b>O</b> ) (max: 76cm)	Finescale triggerfish	Pez puerco	0,006	3,01	7
Blenniidae	* <i>Ophioblennius steindachneri</i> ( <b>O</b> ) (max: 18cm)	Large-banded blenny	Borracho	0,085	n/a	28
Cirrhitidae	*Cirrhitus rivulatus (Mac.C) (max: 60cm)	Giant Hawkfish	Halcón	0,003	n/a	1
Chaetodontidae	Johnrandallia nigrirostris ( <b>O</b> ) (max: 20cm)	Blacknosed butterflyfish	Mariposa barbero	1,186	85,78	389
	Chaetodon humeralis ( <b>O</b> ) (max: 24,5cm)	Threebanded butterflyfish	Mariposa triple	0,515	31,07	169
Diodontidae	Diodon hystrix (Mes.C) (max: 91cm)	Spotted porcupinefish	Pez erizo	0,012	3,17	4
	Chilomycterus reticulatus (Mes.C) (max: 55cm)	Spotfin burrfish	Pez erizo	0,009	6,97	ŝ
	Diodon holocanthus (Mes.C) (max: 50cm)	Longspined porcupinefish	Pez erizo balón	0,052	14,70	17
Fistulariidae	*Fistularia commersonii (Mac.C) (max: 160cm)	Bluespotted cornetfish	Pez-corneta	0,006	n/a	7
Holocentridae	* <i>Myripristis leiognathus</i> ( <b>P</b> ) (max: 18cm)	Panamic soldierfish	Soldado	0,003	n/a	1
Lutjanidae	Lutjanus argentiventris (Mac.C) (max: 71cm)	Yellow snapper	Señorita cocinera	0,006	0,92	7
Pomacentridae	Abudefduf troschelii ( <b>O</b> ) (max: 20cm)	Panamic sergeant major	Petaca banderita	1,735	192,81	569



	Chromis atrilobata (P) (max: 13cm)	Scissortail damselfish	Castañuela	5,151	55,92	1689
	Microspathodon bairdii ( <b>O</b> ) (max: 25cm)	Bumphead damselfish	Jaqueta	0,217	64,79	71
	Microspathodon dorsalis ( <b>O</b> ) (max: 31cm)	Giant damselfish	Jaqueta	0,232	81,61	76
	Stegastes acapulcoensis ( <b>O</b> ) (max: 17cm)	Acapulco major	Castañeta	0,570	46,44	187
	Stegastes flavilatus (O) (max: 10cm)	Beaubrummel	Jaqueta dos colores	0,122	6,37	40
	* <i>Chromis crusma</i> ( <b>P</b> ) (max: 14cm)	Valparaiso chromis	Castañeta	0,009	n/a	3
Labridae	Thalassoma lucasanum ( <b>Mes.C</b> ) (max: 15cm)	Cortez rainbow wrasse	Vieja arco iris	0,695	7,83	228
	Halichoeres chierchiae (Mes.C) (max: 17,5cm)	Wounded wrasse	Vieja Herida	0,335	22,31	110
	Bodianus diplotaenia (Mes.C) (max: 76cm)	Mexican hogfish	Vieja ribetiada	0,540	112,98	177
	Halichoeres nicholsi (Mes.C) (max: 38cm)	Spinster wrasse	Doncella	0,143	23,59	47
	Halichoeres dispilus (Mes.C) (max: 25cm)	Chameleon wrasse	Señorita camaleón	1,583	33,90	519
Haemulidae	Anisotremus taeniatus (Mes.C) (max: 31cm)	Panama porkfish	Burro	0,311	25,19	102
	Haemulopsis leuciscus (Mes.C) (max: 41cm)	White grunt	Boquimorado	0,003	0,09	1
	Anisotremus caesius (Mes.C) (max: 30cm)	Silvergrey grunt	Roncador	0,009	0,39	$\mathfrak{c}$
	Haemulon flaviguttatum (Mes.C) (max: 42cm)	Yellowspotted grunt	Roncador	1,314	154,79	431
Pomacanthidae	Holacanthus passer ( <b>O</b> ) (max: 35,6cm)	King angelfish	Ángel real	0,052	19,61	17
	Pomacanthus zonipectus (0)	Cortez angelfish	Ángel	0,088	37,92	29



Tetraodontidae	(max: 46cm) Arothron meleagris ( <b>O</b> )	Guinea Fowl puffer	Tamboril	0,003	0,09	
	(max: 50cm) *Canthigaster punctatissima ( <b>0</b> ) (max: 9cm)	Spotted sharpnosed puffer	Tamboril punteado	0,021	n/a	
Kyphosidae	Kyphosus elegans ( <b>O</b> ) (max: 53cm)	Cortez sea chub	Chopa	0,095	6,99	
Scaridae	Scarus perrico (H) (max: 76cm)	Bumphead parrotfish	Loro	0,671	836,6	~
	Nicholsina denticulata ( <b>H</b> ) (max: 32cm)	Loosetooth parrotfish	Loro	0,021	8,01	
	Scarus compressus ( <b>O</b> ) (max: 68cm)	Azure parrotfish	Loro	0,006	0,76	
Monacanthidae	Aluterus scriptus ( <b>O</b> ) (max: 110cm)	Scribbled leatherjacket filefish	Lija tildada	0,006	1,05	
Carangidae	Seriola rivoliana (Mac.C) (max: 160cm)	Longfin yellowtail	Huayaipe	0,012	0,43	
Serranidae	Epinephelus labriformis (Mac.C) (max: 60cm)	Starry grouper	Cabrilla	0,128	39,97	
	Paranthias colonus (Mac.C) (max: 35,6cm)	Creolefish	Gringo	0,799	27,05	
	Serranus psittacinus (Mac.C) (max: 17,8cm)	Barred serrano	Serrano	0,122	3,24	
	Cratinus agassizii (Mac.C) (max: 60cm)	Grey threadfin seabass	Plumero	0,018	6,33	
	Cephalopholis panamensis ( <b>Mac.</b> C) (max: 31cm)	Pacific graysby	Cabrilla enjambre	0,024	7,00	
	*Rypticus bicolor (Mac.C) (max: 28cm)	Mottled soapfish	Jabonero	0,006	n/a	
Sciaenidae	Pareques Viola (Mes.C) (max: 30cm)	Gungo highhat	Corvinilla listada	0,043	1,56	
	Odontoscion eurymesops (Mac.C) (max: 25cm)	Galapagos croaker	Corvina bronce	0,290	19,46	



ε		1	4	1	5751
n/a	n/a	n/a	n/a	n/a	2270,9
0,009	0,003	0,003	0,012	0,003	17,5
Trompetero chino	Morena pecas blancas	Morena de piedra	Raya-redonda	Lagarto de arrecife	TOTAL
Chinese trumpetfish	White spotted moray	Hourglass moray	Round stingray	Sauro Lizardfish	
*Aulostomus chinensis (Mac.C) (max: 80cm)	*Muraena argus (Mac.C) (max: 120cm)	* <i>Muraena clepsydra</i> ( <b>Mac.C</b> ) (max: 120cm)	*Urobatis halleri (Mac.C) (max: 58cm)	*Synodus lacertinus (Mac.C) (max: 20cm)	s not calculated
Aulostomidae	Muraenidae		Urotrygonidae	Synodontidae	* – Cryptic specie n/a –Biomass was



The lowest mean biomass recorded was in the El 40 site  $(44,92\pm34,1 \text{ g m}^{-2})$ , were as La Pared  $(64,61\pm17,5 \text{ g m}^{-2})$ , La Viejita  $(75,23\pm12 \text{ g m}^{-2})$  and San Ignacio  $(68,7\pm9,8 \text{ g m}^{-2})$  sites registered similar values.

Ten species contributing for the highest total abundance and biomass were Johnrandallia nigrirostris (6,8%; 3,8%), Abudefduf troschelii (9,9%; 8,5%), Stegastes acapulcoensis (3,3%; 2%), Scarus perrico (3,8%; 36,8%), Paranthias colonus (4,6%; 1,2%), Thalassoma lucasanum (3,9%;0,34%), Bodianus *diplotaenia* (3,1%) 4,9%), Halichoeres dispilus (9%, 1,5%), Haemulon flaviguttatum (7,5%; 6,8%) and Chromis atrilobata (29,4%; 2,5%) (Fig.9).

**Table.5** – El Pelado marine are trophic structure. For each trophic level, we indicate Species Richness (S) values and Density, Biomass values in percentage

Trophic structure	Species Richness (S)	% Density (fish m <sup>-2</sup> )	% Biomass (g m <sup>-2</sup> )
Herbivorous	3	5,2	48,9
Omnivorous	17	28,3	26,1
Macrocarnivores	16	8,2	4,6
Mesocarnivores	13	28,8	17,9
Planktivorous	3	29,4	2,5

The ten species represent 81,22% of the total abundance and 68,4% of the total biomass registered in the study area. The highest value of abundance is attributed to *Chromis atrilobata* 



Figure.9 – The columns represent abundance (%) and the line the biomass (%) of the ten most contributing species for the total abundance and biomass recorded in the study area. Were (1) Johnrandallia nigrirostris, (2) Abudefduf troschelii, (3) Stegastes acapulcoensis, (4) Scarus perrico, (5) Paranthias colonus, (6) Thalassoma lucasanum, (7) Bodianus diplotaenia, (8) Halichoeres dispilus, (9) Haemulon flaviguttatum, (10) Chromis atrilobata.

(29,4%), though with a low biomass. This species is part of the Pomacentridae family and usually is found to be in large fish schools (>100 fishes) but with small fish sizes (<8cm; Table.4 – max. 13cm) resulting in high values of abundance but with low values of biomass. *Scarus perrico* species represents 36,8% of the total biomass, resulting to be the highest value.

On the other hand, this species has one of the lowest abundance values. This contrast is due to the occasional sighting of this species along transects, usually found in large fish schools (>100), while characterised by large fish sizes (<40cm; Table.4 – max.78cm). These ten species can be considered dominant in the study area.

At the family level the Pomacentridae were the most dominant, accounting for 45,8% of the total abundance, followed by the Labridae (18,8%), Haemulidae (9,3%) and Serranidae (6,3%). These 4 most high ranked families correspond to 80,2% of the total abundance in the study area. Regarding the family distribution per site the Pomacentridae (7 species) obtain the highest values in El Pelado (2,33 fish  $m^{-2}$ ), La Viejita (2,33 fish  $m^{-2}$ ) and La Pared  $(1,51 \text{ fish m}^2)$ , respectively, were as El 40 (0,42 fish  $m^{-2}$ ) account for the lowest values (Fig.10). Labridae (5 species) family account for a more uniform distribution along the sites, occurring the highest abundances in El 40 (0,76 fish  $m^{-2}$ ), and La Viejita  $(0,69 \text{ fish m}^{-2})$  sites, although the variance between sites are not large (Fig.10). The Labridae pattern of distribution along sites expresses a clear common presence along the study area. The family Haemulidae (4 species) are described to have a more patchiness presence along sites (Fig.10), occurring the highest value of abundance in the San Ignacio (1,08 fish  $m^{-2}$ ), La Viejita (0,26 fish  $m^{-2}$ ) and La Pared  $(0,20 \text{ fish m}^{-2})$  site. Haemulidae lowest values occurred in El Pelado site (0,003 fish  $m^{-2}$ ) and Rabo de Viejo (0,02 fish  $m^{-2}$ ). Additionally, one of the most speciose families, Serranidae (6 species) presented the lowest values of abundance along sites. The highest values occurred La Pared (0,40 fish m<sup>-2</sup>), Rabo de Viejo  $(0.29 \text{ fish m}^{-2})$  and La Viejita  $(0.23 \text{ fish m}^{-2})$ , were as the lowest values are found to be in El 40 (0,04 fish  $m^{-2}$ ) and El Pelado (0,015 fish  $m^{-2}$ ) (Fig.10).

Fourteen species encountered were considered commercial from the total species richness (Table.6). Families accounted for the highest



**Figure.10** – Abundance (total n° of fish) values with the subsequent standard error for the 4 most abundant families, Serranidae, Labridae (above) and Haemulidae, Pomacentridae (below), along the sites of the El Pelado marine area.

contribution of commercial species abundance were Haemulidae (46,4%; 3 species), Serranidae (27,8%; 5 species), Labridae (15,4%; 1 species) and Sciaenidae (9,5%; 2 species). Moreover the first 3 families comprise 94% of the commercial fish total biomass. These 5 species represented the biggest contributors for the commercial species abundance when compared with biomass values (Table.6; Larger contributors Highlighted). Epinephelus labriformis, Paranthias colonus are the Serranidae highest contributors; Anisotremus taeniatus and Haemulon flaviguttatum are the Haemulidae highest contributors, lastly Bodianus diplotaenia represents the only contributor for the Labridae family. The commercial fish sizes accounted in the study area ranged from 6 to 40cm.

Commercial fishes of sizes ranging 14 to 15 cm dominated, followed by 12 cm fish sizes.

**Table.6** – Fourteen commercial species with the abundance (total n° of fish) and biomass (%) values for the study area. Highlighted species represent the larger contributors. (\*) -Cryptic species, no biomass calculations.

Commercial	Abundance	% Biomass
Species		$(g m^{-2})$
L. argentiventris	2	0,04
S. rivoliana	4	0,02
E. labriformis	42	1,76
P. colonus	262	1,19
C. agassizii	6	0,28
C. panamensis	8	0,31
R. bicolor	2	*
O. eurymesops	95	0,86
M. argus	1	*
U. halleri	4	*
B. diplotaenia	177	4,98
A. taeniatus	102	1,11
H. leuciscus	1	0,00
H. flaviguttatum	431	6,82
P. Viola	14	0,07
TOTAL	1151	17,43

Furthermore, large fish sizes range among 20 to 25 cm (Fig.11). The small size fish class (12, 14 and 15 cm) are mainly represented by *Haemulon flaviguttatum, Anisotremus taeniatus, Paranthias colonus* and *Odontoscion eurymesops* (Fig.11). These 4 species are also the dominant class for biomass, contributing to 53% of the commercial fish total biomass. Larger fish size class (20 to 25 cm) were dominated by *Bodianus diplotaenia*, followed by *Haemulon flaviguttatum*, contributing to 33% of the commercial fish total biomass (Fig.11). The other species have a more miscellaneous fish size distribution along the different sizes.



**Figure.11** – Commercial fish sizes compared with abundance (total n° of fish). (1) Accounts for the larger contributors of abundance with sizes ranging from 14 to 15 cm, *Haemulon flaviguttatum, Anisotremus taeniatus* and *Paranthias colonus.* (2) Fish sizes with 12 cm, *Odontoscion eurymesops* and *Haemulon flaviguttatum* are the major contributors. (3) Sizes ranging from 20 to 25 cm, *Bodianus diplotaenia* and *Haemulon flaviguttatum* were the highest contributors.

The non-commercial species made up the most important part of the species richness (38 species), density (79,98%) and biomass (82,43%) of the study area. Notice that the no commercial value species are in great majority if compared with the commercial species.

The El Pelado marine area zoogeography was characterized by species mainly from the Tropical Eastern Pacific (TEP) origin, demonstrating an elevated endemism among this community structure (Table.7). Circumtropical (common to Atlantic, Pacific and Indian Oceans) origin was the second most important classification, were as the small



contribution was from the Peruvian Province (Table.7).

**Table.7** – Zoogeographic composition of El Pelado marine area reef fish community structure

Tropical Eastern Pacific (TEP)	Indo- Pacific	Peruvian Province	Circumtropical
80,8%	5,8%	3,8%	9,62%

The study area species accumulation curve did not appear to reach an asymptote (Fig.12).

Eight species were recorded as duplicates (Species recorded in only 2 locations) (15,4%) and 9 species considered uniques (Species recorded in only one location) (17,3%). Rabo de the Viejo was the only site to not registered uniques species. The uniques curve do not seems to reach an asymptote; probably the uniques species were not well sampled. On the other hand the duplicates curve reaches an asymptote indicating that this species were well sampled (Fig.12).



**Figure.12** – Species accumulation curve with the increase of the number of samples (transects) for the El Pelado marine area. Duplicates (species recorded only in 2 locations) and uniques (species recorded only in one location). Jackknife second (Jack2) and standard error, estimates the total species richness El Pelado marine area.

The second order Jackknife estimator indicates a probable estimation about the total richness for the study area. In this case the total richness estimation seems to be at 62 species, detecting a possible underestimation for this research.



### 3.2. Reef fish diversity

The mean species richness (S), Shannon-Wiener diversity (H') and Pielou's evenness (J') index were used for comparison of fish species between sites (Table.8). La Pared and San Ignacio site registered the highest value for species richness (23 and 22 species respectively), while El 40 site accounted for the lowest value (16 species). The Shannon's index highest value, which is sensitive to rare species, was attributed to El 40 and La Viejita site. Whereas Rabo de Viejo registered the lowest Shannon's index value site, moreover the remaining sites (San Ignacio, La Pared, El Pelado) obtain similar values (Table.8).

Table.8 – Mean species richness (S), Shannon-Wiener diversity (H') and Pielou's evenness (J') index values for each site.

Reef Name	Species Richness (S)	Shannon- Wiener Index (H')	Pielou's Evenness (J')
(1)El 40	16	2,4	0,6
(2)Rabo del Viejo	18	1,6	0,4
(3)La Pared	23	1,9	0,5
(4)El Pelado	20	1,8	0,5
(5)La Viejita	20	2,4	0,6
(6)San Ignacio	22	2,0	0,5

The Pielou's evenness (J') index values obtain for the different sites were similar, although the lowest values was accounted to Rabo de Viejo site. All sites registered low values of evenness indicating that the individuals among species were not evenly distributed, since the dominant species aforementioned (section 3.1.) accounted for the largest abundance contribution in the study area.

#### 3.3. Similarity between Sites

The main result of the multidimensional scaling (MDS) did not reveal an apparent separation of fish community between sites. The analyses stress values was 0,16, indicating a fair condition for interpretation (Fig.13). The nMDS plot suggests a large-scale similarity between sites, demonstrated by strong replicates aggregation, confirmed by the ANOSIM analyses not significant values (Global R value of 0,169 and P>0,01). The nMDS plot outliers (RabViej1 and El401; sampled the same day), correspond to the first transects of these sites



Figure.13 – nMDS plot of the similarity in community structure among all replicates in the El Pelado marine area sites.

indicating a similarity variation greatly separating from the other transects. The SIMPER analysis indicates the contribution of species influential in the average dissimilarity between pairwise sites. Nine groups with more than 50% average dissimilarity resulted from the SIMPER analysis (Table.9).

From the highest to lowest dissimilarity group:

- **Rabo de Viejo** with **El 40** average dissimilarity = 61,63%.
- El Pelado with El 40 average dissimilarity = 61,30%.
- EL 40 with La Pared average dissimilarity = 57,81%.
- El 40 with San Ignacio average dissimilarity =57,54%.
- La Viejita with **El 40** average dissimilarity = 56,84%.
- La Viejita with **Rabo de Viejo** average dissimilarity = 56,12%.
- El Pelado with **Rabo de Viejo** average dissimilarity = 55,71%.
- **Rabo de Viejo** with San Ignacio average dissimilarity = 55,27%.
- El Pelado with San Ignacio average dissimilarity = 53,61%.

The highlighted sites (El 40 and Rabo de Viejo) result to be the most dissimilar sites when compared with the remaining sites.



Table.9 - Results of SIMPER analysis showing species contributing the most for the nine Pairwise groups with more than 50% average dissimilarity. Species are ranked in order of the larger contribution to the lowest. The five largest contributors were chosen.

Sites Groups	El Pelado	E140	La Viejita	Rabo de Viejo
El 40	Chromis atrilobata – 19,02% Thalassoma lucasanum – 6,56%		Chromis atrilobata - 17,55% Halichoeres dispilus - 9,16%	Halichoeres dispilus - 9,33% Chromis atrilobata - 8,63%
	Halichoeres dispilus – 5,40% Stoorstes acamilcoensis – 4 72%		Haemulon flaviguttatum - 6,68% Thalascoma lucasanum - 5 88%	Paranthias colonus - 7,93% Abudefduf troschelii - 6 79%
	Microspathodon bairdii – 4,53		Paranthias colonus - 5,86%	Scarus perrico - 6,35%
San Ionacio	Haemulon flaviguttatum – 11,60%	Chromis atrilobata – 12,39%		Haemulon flaviguttatum - 11,95%
	Halichoeres dispilus – 6,61%	Halichoeres dispilus – 9,60%		Paranthias colonus - 6,28%
	Microspathodon dorsalis – 4,93%	Thalassoma lucasanum – 6,49		Chromis atrilobata - 6,27%
	Anisotremus taeniatus – 4,29%	Anisotremus taeniatus – $5,34\%$		Scarus perrico - 5,92%
	<i>Chromis atrilobata</i> – 11,91%		Chromis atrilobata - 14,17%	
Baho da	Abudefduf troschelii – 7,24%		Abudefduf troschelii - 8,97%	
	Scarus perrico – 6,79%		Halichoeres dispilus - 7,72%	
Viejo	Thalassoma lucasanum – 6,01%		Haemulon flaviguttatum - 6,25%	
	Paranthias colonus – 5,94%		Paranthias colonus - 6,07%	
		<i>Chromis atrilobata</i> – 14,66%		
		Paranthias colonus $-9,57\%$		
La Pared		Halichoeres dispilus – 8,47%		
		Haemulon flaviguttatum – 6,21%		
		Abudefduf troschelii – 6,06%		

All species identified as the most influential for dissimilarity are dominant species as abovementioned (section 3.1).

3.4. Other data

The table 10 resumes the most important environmental data collected during the sampling campaign, for each site.

**Table.10** – Mean depth, visibility and temperature for all the sampling sites of the El Pelado marine area.

Reef Name	Mean Depth (m)	Mean Visibility (m)	Mean Bottom Temp. (C°)
(1)El 40	14	7	25
(2)Rabo del Viejo	14	7	24
(3)La Pared	17	6	23
(4)El Pelado	12	15	26
(5)La Viejita	15	11	24
(6)San Ignacio	19	11	24

#### 3.5. Social Study

Fifth seven traditional fishermen were interviewed in San Pedro town. Seven traditional fishermen (T.f.) and 5 dive operators (D.o.) were interviewed in Ayangue town; moreover in the seminar workshop 11 compressor fishermen (C.f.) were interviewed. In both towns, all stakeholders interviewed, answered being native of their towns (San Pedro T.f. - 96,5% said yes; Ayangue T.f., D.o. and C.f.- 100% said yes). The majority San Pedro T.f. (86%) did not take part of a cooperative, although the town had three active fishing cooperatives, Asociación de Pescadores, Asociación 29 de Marzo and Asociación 1 de Noviembre, being the first one the most important. In Ayangue town, the T.f. (71%) are also independent from the only traditional fishermen cooperative (Asociación de los Pescadores). On the other hand, Ayangue D.o. (80%) are in majority part of one cooperative (Asociación Islote El Pelado, Asociación lancheros turisticos, Organización arena y sol) and the C.f. (100%) are part of the only recent compressor fishermen cooperative, Nueva union de Ayangue.

Some questions of traditional use of the area were asked, intended to perceive how important is fishing for both towns. The T.f. and C.f. were asked if their grandparents and parents were fishers (San Pedro T.f. said - 87,7%; 82,5%; Ayangue T.f. -100%, 85,7%; Ayangue C.f. - 100%, 100%). The answers reveal an important traditional used of the area in the past generations, but also when fishers were asked if they hoped the new generation to be fishermen the majority said yes (San Pedro T.f. said - 73,3%; Ayangue T.f. - 85, 7%; Ayangue C.f. -81,81%). While fishers that said no, expressed the difficulties of this work (i.e. less fish, hard working and low pay) and desired a better life for the descendants (i.e. more studying, for better employments). Conclusively when fishers were asked how important was the fishing for the community the great majority replied as very important (San Pedro T.f. said - 93%; Ayangue T.f. -100%; Ayangue C.f. -100%), thus saying that fishing is there subsistence.

The study area is part of a fishing ground used by both towns, so fishermen were asked how many fishers in average used the El Pelado marine area. San Pedro T.f. answer was rather unclear (<30



fishers (19,3%), 50 fishers (24,6%), >100 fishers (19,3%), <200 fishers (17,5%), >200 fishers (19,3%)), although 50 fishers was the number more agreed on. Ayangue T.f. (60%) answered more than 200 fishers used the area and the C.f. explains that 40 fishers (total number of C.f. fishermen) fished the El Pelado marine area with a compressor. This number can give us a perspective of users extent to the Islet, since no data is available.

The T.f. and C.f. were asked if the number of fishermen incremented the last years and the majority confirm that yes (San Pedro T.f. said – 98,2%; Ayangue T.f. – 85,7%; Ayangue C.f. – 100%). Accordingly to T.f. and C.f. the increment of fisherman in both towns was perceived differently, San Pedro T.f. described a 20 to 50% increase, Ayangue T.f. said a 10 to 50% increase, were as the C.f. affirmed a 2% increase. Consequently, both stakeholders affirm an increase, especially by the youths.

The fishing gear mainly used in the El Pelado marine area are gillnets, hand line and spearfishing answered the T.f. (San Pedro T.f. said – 96,5%; Ayangue T.f. – 100%). We asked if the T.f. were interested in prohibit fishing gear and the majority said yes (San Pedro T.f. said – 89,5%; Ayangue T.f. – 85,7%), mainly against the spearfishing, gillnets, la Planta (fishing boats that use light to attract fish) and industrial fishing (specially the shrimp fishing vessels that fish near the island and coast).

All stakeholders agree to implement a marine protected area (MPA) (San Pedro T.f. said -93%; Ayangue T.f. – 100%; Ayangue C.f. – 100%; Ayangue D.o. - 100%)) in El Pelado marine area. But the compressor fishermen only agree if the Ecuadorian government assist them to change fishing gear (become traditional fishermen) or completely change occupation, financing them (i.e. tourism), since Ayangue is still a developing tourism area. The T.f. of San Pedro (T.f. said -66,7%) did agree in the establishment of a cooperative between both towns to manage the MPA, but the T.f. and C.f. (T.f. said - 100% and C.f. -100%) of Ayangue were against it, expressing the need to protect their own community. The T.f. and C.f. were also asked if they approved for an MPA area of half nautical mile covering the main reefs sampled in this study, again both town concur



in the answered, agreeing (San Pedro T.f. said -84,2%; Ayangue T.f. - 100%; Ayangue C.f. -100%;). All stakeholders were asked, since eventually fishing will be forbidden in the half nautical mile area around the islet, a tax (2 to 3 dollars) should be applied to the D.o. for to help conserving the El Pelado marine area and the answered was yes in great majority (San Pedro T.f. - 82,5% said yes; Avangue T.f., D.o. and C.f.-100% said yes). The D.o. were asked how many clients did they manage per year, 300 to 1600 clients. Although this number can be larger, since we could not interview all dive operators of Avangue town or even the dive centres from Guayaquil. If well applied the tax could bring incomes for both communities, helping supporting the implementation measures for conservation (i.e. Guard patrolling the area, mooring buoys that reduce benthic damage, awareness workshop's, etc.)

Conclusively all stakeholders were asked if it is important and what could be the benefit of the MPA implementation, the majority answered (San Pedro T.f. – 91,2% said yes; Ayangue T.f., D.o. and C.f.– 100% said yes), justifying saying, it is important the protection of the islet for future generations, could increase the fish production, increase tourism in the area and is good for the communities.

## 4. Discussion

The investigations in the El Pelado marine area performed in this study (from March-May 2012) indicate low reef fish diversity compared with other Ecuadorian studies (national park of Manchalilla (PNM) - 143 spp., Terán, 1997; REMACOPSE marine reserve - 86 spp., Rivera et al., 2008 and Galapagos marine reserve (GMR) – 175 spp., Edgar et al., 2004). The majority of El Pelado marine area species were observed in the aforementioned studies suggesting species wide distribution along the Panamic province (Mora and Robertson, 2005) in the Tropical Eastern Pacific (TEP), although GMR substantially higher number of species is probably due to different biogeographic patterns shaping the local fauna (Edgar et al., 2004). Moreover, other Tropical eastern Pacific (TEP) studies similarly present much higher species richness (71 spp., Zapata and Morales, 1997; 70 spp., DominiciArosemena *et al.*, 2005; **180 spp**., Dominici-Arosemena and Wolff, 2005; **126 spp**., Dominici-Arosemena and Wolff, 2006; **72 spp**., Myers *et al.*, 2010). Nonetheless these comparisons can be biased, since the survey effort and geographic area surveyed was smaller in this study. Besides, the Tropical eastern Pacific (TEP) species richness "centre of origin" are hypothesised to be Panama/Costa Rica and Gulf of California (Mora and Robertson, 2005), resulting in large species richness.

Floeter et al., 2004 affirms that spatially trophic groups (mesocarnivores, distributed macrocarnivores and planktivorous) feed on high nutritious (high protein content) food sources (usually dominating), concurring with our data in terms of fish species richness and density, were as low biomass can suggest low quantities of prey in El Pelado. More research in terms of prey availability might explain this suggestion. On the other hand, omnivores (feed on intermediate quality food, see Floeter et al., 2004) are found in high density and biomass values in the El Pelado marine area. Hence this dominance is possibly related to anthropogenic impacts (i.e. fishing, diving), typically low quality food (i.e. algae, detritus and sessile invertebrates) abundant areas (Rangel et al., 2007). Our study registered low herbivorous species richness and abundance not typical for tropical areas (Floeter et al., 2004). Nevertheless in TEP low herbivorous abundance is typical (Dominici-Arosemena et al., 2005) due to the unstable ocean currents and temperatures values (i.e. ENSO), that do not necessarily benefit plant material food be easily digested (Dominici-Arosemena, 2006), characteristically common in warmer waters fishes (Floeter et al., 2004). However Herbivores gave the highest contribution in biomass, suggesting elevated herbivore food (i.e. benthic algae, hermatypic coral, plankton, etc.), low fishing pressure enabling the growth of this species and probably the scarcity of apex predators (i.e. sharks).

El Pelado and La Viejita sites registered a more elevated mean density of fish, possibly due to two factors. Firstly, maximum visibility was registered in both sites, very important for underwater visual census (UVC), where fish detectability is reduced in lower visibility (Edgar *et al.*, 2004; Bozec *et al.*, 2011), although visibility

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differences between sites can be reduced if longer sampling campaigns are taken into account. Since we sample in a short time frame, opportunities to postpone a sampling day due to visibility were scarce. Consequently we recommend longer sampling campaigns at different seasons (dry and wet seasons) taken into account the visibility parameter as a main factor for susceptible error. Secondly the substrate in both sites appeared to be more complex, larger reef boulders and ledges (i.e. underwater ridges) aggregates in El Pelado and reef overhangs with smaller ledges in La Viejita (Dubois Floro, pers. observation). El 40 and Rabo de Viejo sites low density values can possibly be explain probably due to low visibility, besides the abovementioned factors, nutrients input from the coastal population (Ayangue, San Pedro and Valdivia towns) with currents influences can alter the visibility, due to algae growth. Terán (1997) described this possibility for the PNM marine reserve. Both sites substrate morphology seems less complex (dropping wall - El 40; low slope rock platform with small boulders -Rabo de Viejo) Floro, observation). possibly (Dubois pers. influencing the density results. However reef substrate complexity can determine fish distribution (Dominici-Arosemena et al., 2005; Dominici-Arosemena, 2006; Mendonça-Neto et al., 2008), to statistically confirm this assumption in El Pelado marine area more research is needed (i.e. hermatypic and ahermatypic corals identification, multibeam sonar to assess reefs 3D views, substrate readings assessments, etc.)

The biomass values were elevated in El Pelado being related with density values, but are elevated in Rabo de Viejo, a site with lower density values. In abovementioned sites, one of the replicates (transect 2; different sampling days) was characterised with two large schools of different species (Scarus perrico and Prionurus laticlavius). Considerably increasing the biomass values (El Pelado and Rabo de Viejo biomass for transect 2 -2,3; 2,5 times higher when compared with the site mean biomass). Being located close to the islet but at opposite sites indicates the herbivore roving behaviour of these species, characteristic for Acanthuridae and Scaridae families (Floeter et al., 2004; Dominici-Arosemena and Wolff, 2005), suggesting a constant movement around the El

Pelado area searching for food. Moreover, these species were large size fishes (Scarus perrico <40cm; Prionurus laticlavius <40cm), sustaining the biomass discrepancy when compared to the remaining sites. The presence of these herbivores in great abundance around these sites indicates a possible feeding ground. Additionally, El Pelado islet is an important seabird resting area, implying important amounts of guano (faeces with high nitrogen concentration), chick carcasses, feathers, fish scraps, production and via runoff could increase herbivores food production (Sánchez-Piñero and Gary, 1995). Finally El Pelado site registered both schools in the same replicate, but in lower density explaining the smaller standard error, were as Rabo de Viejo only recorded the Scarus perrico fish school although in larger density obtaining a larger error. Biomass values remain the highest, even when the disturbance of transect 2 is removed from El Pelado and Rabo de Viejo sites, though expected in El Pelado site (due to the elevated mean density values). On the other hand, Rabo de Viejo high values of biomass (even with lower mean density values) are possibly explained due to high abundance values of Paranthias colonus, usually found in large schools (Dubois Floro, pers. observation). Paranthias colonus species were mainly found in high densities in transect 1, however comparing with other Serranidae species, this species as a roving behaviour, suggesting constant travel searching for food.

The dominant species of El Pelado marine area are typically dominant in the TEP (Terán, 1997; Dominici-Arosemena et al., 2005; Dominici-Arosemena and Wolff, 2006; Myers et al., 2011). Dominici-Arosemena, 2006, affirms that the most dominant species in TEP are Thalassoma lucasanum, Chromis atrilobata and Halichoeres dispilus, confirmed by high abundance values found in the study area. These species are predictably found in shallow rocky reef exposed zones, hence this exposed zones are characterized to have an elevated benthic and fish diversity (Dominici-Arosemena, 2006), corroborating with the important fish diversity in the study area. The species dominance supports that fish size estimates are extremely important for biomass values, were as comparing a small size fish (Chromis atrilobata) present with high densities with a typical large size



fish (*Scarus perrico*) we obtain a drastic difference. Both species are non-territorial (Dominici-Arosemena and Wolff, 2005), were as *C. atrilobata* are largely found in the majority of the sites, while the highest density values were at the deepest sites, characteristics already remarked by Dominici-Arosemena, (2006). Conclusively we suggest no interaction between abovementioned species were found, since density and biomass in this case, firmly dependant of abundance and fish size.

In the TEP the dominant families are Haemulidae Labridae. Serranidae, and Pomacentridae (Dominici-Arosemena, 2006; Myers et al., 2011), validating our findings for El Pelado area and also supported by similar results in local studies (Terán, 1997; Rivera et al., 2008). A general dominance of Pomacentridae family in El Pelado, La Viejita and La Pared sites can possibly support the idea of a more complex substratum, since this family are characteristic of territorial species that need microhabitats formed by complex substrate to live (Floeter et al., 2004). We suggest that fisheries do not affect Pomacentridae family (see Russ and Alcala, 1998<sup>a,b</sup>), since no commercial species are present in the family and fishing gear (i.e. gillnets, seine nets, spearfishing, etc.) used in El Pelado target other larger species. Hence this can possibly explain the Pomacentridae high abundance in the study area. Labridae family are relatively well establish among all sites, although with smaller values of abundance in Rabo de Viejo and La Pared sites. suggesting a possible Serranidae predation effect (highest values in the referred sites), to small size and more abundant species of Labridae family (Halichoeres dispilus <10cm and Halichoeres *chierchiae* < 15cm). Moreover the Labridae family can be intermediately affected by fishing (Russ and Alcala, 1998<sup>b</sup>) however in this study area only one species (Bodianus diplotaenia) is of commercial interest suggesting low fishing pressure on this family, thus presenting a such uniform abundance distribution. Haemulidae family seems to be influence by depth, suggests the highest abundance values found in San Ignacio, La Pared and La Viejita, also confirmed by similar results in Dominici-Arosemena et al., 2005. However Dominici-Arosemena, 2006, affirms that typically the Haemulidae family constitutes the shallow rocky reefs area (< 15m deep) in TEP, thus more research

is need in El Pelado area to support the Haemulidae distribution. Serranidae general low abundance in the study area can suggest a high fishing pressure in the region, since this family have an elevated commercial interest (Russ and Alcala, 1998<sup>a,b</sup>). Serranidae are generally characterized as demersal sedentary family (low mobility) in close association with reef substrate (Floeter et al., 2004) and are important prev fish regulators (i.e. Pomacentridae and Labridae) (Dominici-Arosemena and Wolff, 2006). Therefore suggesting the actual Serranidae distribution along the sites, higher values of predators (Serranidae) with lower values of prey (Pomacentridae and Labridae). However as abovementioned, these suggestions need supplementary research to achieve clearer results.

Commercial fish species (Labridae, Haemulidae and Serranidae families) present a low density and biomass (Alcala *et al.*, 2005; Lester *et al* 2009) and correspondingly small body sizes, factors that possibly can be attributed to elevated fishing pressure in the study area (Lester *et al* 2009; McClanahan, 2010).

El Pelado marine area zoogeography results coincided in the same time with Rivera *et al.*, 2008 results, were the majority of the species were from the Panamic province. Where as the Indo-Pacific origin of some species can be possibly related to teleplanic larvae (capable of long distance dispersal), moreover ENSO events can actively transport larvae to TEP (Glynn and Ault, 2000; Miloslavich *et al.*, 2011).

For future research in the El Pelado area we advise a larger sampling effort with more replicates and/or sites, to possibly reach an asymptote in the species accumulation curve. More sampling effort could increase the number, distribution or abundance of species already discovered, while diminishing the uniques (species recorded in one location) number (Gladstone, 2007). However Zapata and Robertson (2007), explains that TEP reef fish fauna is considerably larger than the identified until know, thus we need larger sample effort in the area to consider reaching the asymptote. Yet an estimate for the total richness (if increased sampling effort) of the El Pelado area is given by the second order Jackknife estimator (see Palmer, 1991), demonstrating that probably the most cryptic species were not registered.



Consequently due to limited time and budget, limited the sampling performed; however obtain essential information for a baseline assessment of the area.

Fish species richness and diversity was higher in sites suggested as more complex in terms of substrate, consistent pattern present in other studies (Dominici-Arosemena, 2006; Mendonça-Neto et al., 2008). However El 40 site diversity large. implying possible value was а underestimation bias at this site (possibly due to visibility or high fishing pressure, since this site is one of the sites far apart of the islet and the traditional fishing gear might be used were as in other sites (i.e. El Pelado, Rabo de Viejo, La Pared or La Viejita) it is more difficult due to larger reefs, possibly damaging the gear). consequently increasing the diversity value due to uncommon and low abundance species, were Shannon-Wiener index is most sensible. Reinforced by dissimilarity results, indicating El 40 and Rabo de Viejo sites very dissimilar, when compared with the remain sites. Mainly due to no/or low presence of specific species (see section 3.3), in both sites, causing this difference. Additionally we suggest that the dominant species possibly interfered in the differences of species diversity and evenness between sites, Zapata and Morales, (1997) obtain similar influence in their results. Conclusively we recommend future studies in the study area to take into account the substrate biodiversity (i.e. including benthic organisms), while comparing fish diversity, obtaining a broader view between communities relationship.

The similarity pattern observed for the El Pelado area revealed no significant variation between study sites suggesting a homogenous area in terms of fish species, providing only a preliminary assessment of the area in terms of general fish biodiversity rather than between the study sites. Future studies in the area are recommend to include sites outside the El Pelado marine area to achieve better overall comparisons.

This fish biodiversity assessment should be considered as baseline information, using the study sites as control sites for future research (i.e. BACIP research for MPA assessment Sale *et al.*, 2005).

The El Pelado User's information gathered gives a broader image for the design development and MPA implementation, besides an elevated support towards the El Pelado conservation. We considered the establishment of a no-take MPA for the El Pelado marine area, with a perimeter of half nautical mile (corresponding to  $0.7 \text{ km}^2$ ), supported in great majority by the stakeholders (see section 3.5). Stakeholders support towards а comanagement MPA (see Borrini-Feyerabend et al., 2000) is viewed as important for a future effective management (Jameson et al., 2002), hence this important conservation tool (MPA) (Sale et al., 2005) is essential for fisheries, biodiversity, habitat restoration and tourism development (Christie and White, 2007).

On the other hand, the compressor fishermen were keen to MPA establishment, but with certain conditions, hence this stakeholder should be largely seen as a conditional group for MPA establishment success. Therefore being the most dependent group, if the no-take MPA is created, stronger consideration should be employed toward this matter. Consequently a strong Ecuadorian government support can eventually increase the MPA restrictions compliance, helping this group change activities, since predominant rejection (traditional fishermen opinions: i.e. too much pressure on the reefs, they fish all day long, depletion of El Pelado resource, etc.) is experienced by the remain stakeholders towards compressor fishermen. Importantly however is the general knowledge of the stakeholders considering the El Pelado conservation with MPA implementation an essential future for both communities (i.e. benefic for future generations, fisheries, tourism, etc.), more importantly as fishermen number are constantly increasing (see section 3.5) (Alava et al., 2012).

El Pelado marine area is of great importance with a long term tradition resource use for the stakeholders, since fisheries and diving are major subsidiary activities for the communities (San Pedro - fishing; Ayangue- fishing and diving). Both communities support towards conservation activities should bring a positive future for a long term project, however more awareness and community work towards the MPA implementation is recommended. Starting by applying increased effort towards a cooperative organization for the future MPA management between both communities, since especially the fishermen perceived it as unfeasible (occurring similar problems in GMR -Galapagos marine reserve; Heylings and Bravo, 2007). Secondly more information should provide to the stakeholders in what way MPAs are established (time frame needed to obtain results, benefits, management regulations, etc.) integrating the Ecuadorian government agencies (i.e. MAE) and NGO's (i.e. NAZCA institute) for necessary support. The government and NGO's involvement is important specially to have a legislative (i.e. officially recognized MPA included in the National Service of Ecuadorian protected areas (SNAP) with stakeholders as legal property holders, for conservation commitments) and scientific (i.e. awareness workshop's, MPA monitoring, etc.). The use of co-management in South America countries has being implemented quiet recently (Friedlander et al., 2003; Howard et al., 2003; Moreno-Sánchez et al., 2010); nevertheless co-managed MPAs around the world are given viable lessons for to include in future research (see review Olsen and Christie, 2000). Furthermore Heylings and Bravo (2007), research in the GMR should be part of the MPA design and implementation. As so, measuring the governance evaluation process and participation level of each stakeholder, implying flexibility towards change in management and adapting to possible problems.

Russ and Alcala (1996), studied display a perfect example of a well-documented small MPA with a co-management governance regime providing success for conservation and social goals. Halpern (2003) affirms that small no take MPAs provide conservation benefits (i.e. increase of fish size, biomass). Still more research is recommended to El Pelado marine area to obtain detailed bathymetry, hydrodynamics, substrate habitat and integrate this information with larval dispersal studies (Sale et al., 2005), while other studies demonstrated that small reserves can have spillover effects (Halpern, 2003, Russ et al., 2004). Taken into account the possible spillover effect a broader view is recommended, suggesting for a future MPAs network (Sale et al., 2005) in Ecuador (i.e. REMACOPSE marine reserve to the south, PNM to the north).



#### 4.1 Conclusions and recommendations

This baseline study achieved for the El Pelado marine area is an essential initial fish biodiversity assessment, for a region threatened by fisheries, climate change, ENSO events, habitat degradation, etc. (Cruz et al., 2003). El Pelado marine area is suggested to be exposed to an elevated fishing pressure, increasing the need for a no take MPA implementation, consequently protecting fish stocks overexploitation essential against for future generations (Sale et al., 2005). This paper demonstrated the keen stakeholders support for the no take MPA implementation, "opening the door", for the Ecuadorian government and NGO's to demarche a long term co-management project. Moreover this MPA implementation could encourage the implementation of other small reserves (i.e. Islet Los Ahorcados), while creating a need for MPA networking with other official (SNAP recognized) MPAs along the coast (i.e. REMACOPSE marine reserve, PNM marine reserve).

However we recommend more advanced ecological (i.e. studies local physical and chemical oceanographic processes, assessment of benthic fauna, spillover effects, fishermen local ecological knowledge (LEK) to assess the possible spawning grounds, as well temporal and spatial variations of fish species, etc.) essential for a successful MPA design. This approach needs to be combined with more public and stakeholders awareness in both communities to achieve a long term co-management project.

Conclusively is suggested that a no take MPA in El Pelado marine area with stakeholder's empowerment can be achieved, bringing an optimistic future for the region and in particular for Ayangue and San Pedro communities (Santa Elena Province).

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# Annex 1

**Table.10** – Environment data recorded at all sites. Each site is divided by the 3 replicates. Were as: wave surge (classification: no, weak or strong swell), tide, wind (Beaufort scale), current strength (classification: no, weak or strong current), cloud cover (classification: 0 to 8; zero meaning no cloud and 8 completely covered).

Reef Names	W	ave su	rge		Tide			Wi	nd	Curr	ent str	ength	Clo	oud co	over
(1)El 40	no	no	no	low	low	low	0	1	0	S	no	W	5	5	6
(2)Rabo del Viejo	no	no	no	low	low	low	0	1	0	W	no	no	3	5	2
(3)La Pared	W	no	no	high	high	high	2	0	0	no	no	no	7	8	2
(4)El Pelado	no	no	no	high	low	high	0	1	0	no	no	no	7	5	3
(5)La Viejita	no	no	no	high	low	high	0	0	0	no	no	no	7	8	8
(6)San Ignacio	no	no	no	high	low	high	0	0	0	W	no	W	7	2	8



# Annex 2

#### Traditional Fishermen interviews

- 1. Usted es originario de que pueblo?
- 2. Usted hace parte de alguna cooperativa pesquera, o pesca solo?
- 3. Sus Padres eran Pescadores?
- 4. Sus Abuelos eran Pescadores?
- 5. Usted desea que sus hijos sean Pescadores?
- 6. Cuanto importante es la pesca para Valdivia y San Pedro o Ayangue?
- 7. Cuanto Pescadores (valor mediano) pescan en la zona marítima de lo islote El Pelado?
- 8. Lo numero de Pescadores incrementó o disminuido estos últimos años?
- 9. Que arte de pesca es usado en el Pelado?
- 10. Usted lo interesaría prohibir algunos de las artes usadas?
- 11. Usted lo interesaría una creación de una Reserva Marina en la área marítima de El Pelado?

12. Lo interesaría la creación de una cooperativa entre San Pedro, Valdivia y Ayangue para la gestión de la Reserva marina?

13. Usted lo interesaría la creación de una zona (media milla marina) dentro de la Reserva marina donde no se podría pescar para la recuperación de la naturaleza?

14. Lo interesaría tener zonas dentro de la Reserva donde (no se pesca), mas solo se podría bucear, reduciendo lo impacto de la naturaleza, mas los buceadores tenderían que pagar un imposto (2 a 3 dólares) para ayudar a proteger la Reserva Marina?

15. Se la Reserva marina es un día creada con vosotros siendo los principales gestores de la reserva, seria benéfico para ustedes y futura generaciones?

#### **Diving Operators**

1. Usted es originario?

2. Cuantos clientes tiene (media anual) que quieren bucear en el Pelado?

3. Usted lo interesaría una creación de una Reserva Marina en la área marítima de El Pelado?

4. Lo interesaría tener zonas dentro de la Reserva donde (no pesca) solo se podría bucear, reduciendo lo impacto de la naturaleza, mas los buceadores tenderían que pagar un imposto (2 a 3 dólares) para ayudar a proteger la Reserva Marina?

5. Se la Reserva Marina es un día creada con vosotros (Pescadores y Buceadores) siendo los principales gestores de la reserva, seria benéfico para ustedes y futura generaciones?

#### Compressor Fishermen Seminar

- 1. Usted es originario de que pueblo?
- 2. Usted hace parte de alguna cooperativa pesquera, o pesca solo?
- 3. Sus Padres eran Pescadores?
- 4. Sus Abuelos eran Pescadores?
- 5. Usted desea que sus hijos sean Pescadores?
- 6. Cuanto importante es la pesca para Valdivia y San Pedro o Ayangue?
- 7. Cuanto Pescadores (valor mediano) pescan en la zona marítima de lo islote El Pelado?
- 8. Lo numero de Pescadores incrementó o disminuido estos últimos años?
- 9. Usted lo interesaría una creación de una Reserva Marina en la área marítima de El Pelado?

10. Lo interesaría la creación de una cooperativa entre San Pedro, Valdivia y Ayangue para la gestión de la Reserva marina?

11. Usted lo interesaría la creación de una zona (media milla marina) dentro de la Reserva marina donde no se podría pescar para la recuperación de la naturaleza?

12. Lo interesaría tener zonas dentro de la Reserva donde (no se pesca), mas solo se podría bucear, reduciendo lo impacto de la naturaleza, mas los buceadores tenderían que pagar un imposto (2 a 3 dólares) para ayudar a proteger la Reserva Marina?

13. Se la Reserva marina es un día creada con vosotros siendo los principales gestores de la reserva, seria benéfico para ustedes y futura generaciones?