A QUALITATIVE AND QUANTITATIVE ASSESSMENT OF THE SMALL-SCALE SNAPPER FISHERIES OF THE LAS PERLAS ARCHIPELAGO, PANAMA

by

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ABSTRACT

The snapper fisheries of the Las Perlas archipelago, Panama were investigated during May 2005. Biometric data was collected over the period Jan-May 2005 and catch records were available for the period 1999-2005. Qualitative interviews were undertaken throughout the archipelago to describe the nature of the fishery from a number of perspectives. It was found that the main snapper fishery was of a small-scale, (between ca. 70-20 tonnes yr^{-1}), and that peak season was Jan-May each year. The season for 2005 was late, beginning in mid-March for reasons unknown. The fishery was made up of two main species; *Lutjanus peru* and *Lutjanus guttatus*. The fishery was found to be moderately to heavily exploited, (Z= 0.72-1.59), and that a cyclic pattern was displayed bi-annually although findings were not conclusive in this respect due to the short time period of data available. Management measures were deemed to be necessary to ensure the continued future of the fishery. Recommended Minimum Landing Sizes were found to be between 36-40cm for *L. peru* and between 33-28cm for *L. guttatus*. Further management plans were thought to be necessary but require additional investigation before expanding on MLS.

Keywords: Snapper, Fisheries, Panama, Las Perlas archipelago, *Lutjanus peru*, *Lutjanus guttatus*, *Lutjanus argentiventris*.

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1.0 INTRODUCTION

This study was conducted in order to investigate the fishing practices, effects and potential management scenarios pertinent to the small-scale artisanal fisheries of the Las Perlas archipelago with particular reference to the *Lutjanus peru* (Red Snapper) and *Lutjanus guttatus* (Spotted Snapper) fisheries of Village A, Isla del Rey. The study was made possible through collaboration with the Smithsonian Tropical Research Institute (STRI), Panama City and fell under the umbrella project of the *Zona de Manejo Especial Archipiélago de Las Perlas*, which in turn has been organised and funded by the Darwin Initiative. The work is hoped to add to the growing body of scientific work concerning the ecology and conservation importance of this group of islands; with the hope of achieving effective long-term management plans for the region.

1.1 Study Area - Las Perlas Archipelago

The Las Perlas archipelago is located within the Gulf of Panama, on the Pacific-side of the Panama Isthmus, (between 8° 11'31"N 78° 46'22"W and 8° 40'16"N 78° 08'40"W). The archipelago is comprised of 53 basaltic rock islands, islets and shoals approximately 31km from the closest Panamanian coast (Berman, 2004). The largest island of the group is Isla del Rey, (on the southeastern side of which is located the village of Village A), followed by the islands of San José and Pedro González (Raab and Roche, 2005). 19

villages occur within the archipelago with a range of populations from 10 up to 700, but relatively the islands are to a large extent unpopulated and many islets etc. are completely uninhabited (Guzmán, pers. comm.). In recent years there has been a noticeable rise in tourism to the region with the majority concentrated around the northern island of Contadora and on the southern island of San José (Guzmán, pers. comm.).

Figure 1.1 A typical island scene in the Las Perlas archipelago[1].

1.2 Oceanographic Features of the Las Perlas Archipelago

The Gulf of Panama surrounding the archipelago is subject to variable environmental conditions mainly as a result of two large-scale oceanographic occurrences: (a) a wind-driven seasonal upwelling, and (b) the episodic (4-9 year interval) of sea warming as a result of the El Niño Southern Oscillation (ENSO) (Kwiecinski & Chial, 1987; D'Croz & Roberston, 1997). The upwelling season is governed by the Inter-Tropical Convergence Zone (ITCZ); a zone of low atmospheric pressure. The dry season (from January to April) is synonymous with the movement of the ITCZ to a position slightly south of Panama, during which period northeast tradewinds predominate (Forsbergh, 1969).

[1] http://centralamerica.com/panama/areas/graphics/sj2.jpg, 09/08/05.

Upwelling then occurs as the strong northerly winds displace nutrient-poor coastal water and draw nutrient-rich deep water to the surface resulting in large-scale phytoplankton blooms (D'Croz *et al*., 1991). These phytoplankton blooms support a rich fishery of anchovetas (*Cetengraulis mysticetus*) (Smayda, 1966; Forsbergh, 1969; D'Croz *et al*., 1991) and it is largely for this reason that the bulk of the Las Perlas snapper fishery occurs at this time. However, during the rainy season (May to December) a warm, low salinity and nutrient-poor watermass prevails in the Gulf of Panama (D'Croz *et al*., 1991). This is again related to the position of the ITCZ, which is located over or slightly to the north of Panama during this period and which causes the winds to be light and variable throughout the season (Forsbergh, 1969).

Water temperatures in the Gulf of Panama can range from cold (15-20°C) during seasonal upwelling, to warm (30-31°C) during ENSO events (D'Croz *et al*., 2001; Medina, 2004; Baxter, 2004). Guillard and Kilham (1977) state that as phytoplankton species differ in their tolerance to environmental changes, the patterns of seasonal succession may also be a consequence of these changes. This applies not only to the phytoplankton but also to those groups of organisms, like the snapper, that rely directly or indirectly on the phytoplankton abundance for their own growth throughout the year.

Figure 1.2 The location of Las Perlas archipelago in relation to mainland Panama[2].

Figure 1.3 The archipelago of Las Perlas with the main villages like Village A marked[3].

1.3 The Village A

While qualitative data were gather from around the whole archipelago, quantitative data on the snapper fisheries were limited to Village A, located on the southeastern edge of Isla del Rey (N 08°16'01.4" W 78°55'22.9"). The village has a population of

[2] http://www.survivornews.net/~images/albums/Panama/Location/Maps/Map%20Las%20Perlas%2001.jpg, 09/08/05.
[3] http://resources.survivorphoenix.com/graphics/albums/S7maps/mapa_lasperlas.thumb.jpg, 16/08/05.

approximately 700 people, of which about 160 are fishermen although this number can fluctuate quite substantially throughout the year depending on the successfulness of the fishery and the number of transient relatives passing through the village at certain times of the year that may also make up a section of the fishing community. The majority of the people of Village A make their living from the local fishery or from subsistence agriculture and husbandry (Guzman, pers. comm.). Both activities are almost exclusively performed by the men of the village. The women of the village are employed raising children, cooking and performing household tasks. A few travel inland to assist with small agricultural plots of land.

Figure 1.4 The beach at Village A where all fisheries landings were made, May 2005.

1.4 Small-scale Fisheries in Question within Las Perlas

The main focus of this study shall be to examine the snapper fisheries of Village A, however other fisheries shall be touched upon where relevant and where data are available. There has been very little work done on the biology and ecology and the

archipelago and even less is available with respect to fisheries of the region. Medina *et al.* (2004 unpubl.) produced a study on a now collapsed fishery within the archipelago. The archipelago historically had a very productive scallop fishery and previous to that had a world-renown pearl fishery; both of which subsequently collapsed. The work done by Medina *et al.* (2004 unpubl.) found that two decades after the collapse of the Las Perlas scallop fishery in the 1980s, there were no signs of recovery. Possible explanations for this include changes to the surrounding environmental conditions, lack of suitable available habitat for juvenile settlement and predation. Regardless of these issues however, remains the fact that fisheries within the archipelago have failed in the past and those that have failed, have also never recovered. Medina *et al.* (2004 unpubl.) state that once a resource collapses due to overexploitation, its potential for recovery is very limited. These issues have important implications for the current snapper fisheries of Las Perlas. It is interesting to note that the scallop fishery within Las Perlas had the largest increase in catch between 1985-1986, (from 4.1 tonnes of scallop meat exported to the US in 1985 to 2,050 tonnes in 1986) (Medina *et al*., 2004 unpubl.). This huge increase in catch is unlikely to be connected to an increase in recruitment, but more likely attributable to the presence of commercial shrimp fishing vessels now making up a significant part of the fishery. Previous to this the scallop fishery had been limited to local artisanal vessels and fishing techniques. With the arrival of commercial shrimp vessels, (working during the months of February and March when the shrimp fishery was banned), the recorded catch increased massively; most likely far beyond any natural recovery point the fishery was possible of maintaining without immediate intervention. This is an interesting point to cover as the number of larger commercial fishing vessels now making up part of the snapper fishery fleet of Las Perlas but working out of Panama City, as opposed to locally from the islands themselves, is on the increase (verb. comm. local fishermen).

1.5 Aims of the Study

- Collect qualitative data on the snapper fisheries throughout the Las Perlas archipelago through interviews with fishermen, local buyers and local officials.

- Characterise the biometrics of the main snapper fisheries in the Las Perlas archipelago, Panama.

- Quantify the scale of the snapper fishery based in Village A.

- Identify to what extent *Lutjanus peru* and *Lutjanus guttatus* are being landed before sexual maturity.

- Quantify Catch Per Unit Effort for snapper fishery at the Village.

- Identify the fishing potential of the Village A fishery and investigate whether the introduction of a Minimum Landing Size (MLS) or other restrictions, such as a No Take Zone, would increase the long-term productivity of the fishery.

2.0 LITERATURE REVIEW

2.1 General Fisheries Issues

The problems associated with fisheries both large and small across the globe have been well documented in recent years. Indeed there appears to be a surplus of information, models and recommendations on the most appropriate ways to manage a particular fishery and yet global fish stocks are still on the decline and the trend seems set to continue despite the best efforts of fisheries scientists to stem the tide. Overfishing has been determined as the leading cause of ecological extinction in coastal ecosystems and surpasses pollution and climate change as the worst anthropogenic disturbance to the world's oceans (Jackson *et al*., 2001). Fujita *et al*. (1998) state that many modern fisheries management strategies actually create incentives to overfish, thus leading to negative economic and environmental consequences. They define the aim of effective fisheries management to be: *"to ensure that fisheries yields are sustainable on a long-term basis while simultaneously protecting ecological health"* (Fujita *et al*., 1998). The evolution of such a statement comes after a long history of failed fisheries strategies. Conventional fisheries management in 'developed' countries followed the principle of attempting to achieve Maximum Sustainable Yield (MSY) from a fishery. It was believed that 'cropping' the natural population down to a level where the MSY could be achieved each year would be the most effective management strategy. However, such attempts largely failed and resulted in numerous declines and collapses in fisheries where they had been instigated (Larkin, 1977). It is likely that the failure of MSY as a fisheries management plan resulted from the fact that it did not adequately address the issue of natural variability (Fujita *et al*., 1998). More recent management plans have incorporated complex deterministic models, which produce a variety of recommended limits on fishing catch. However, all such strategies rely on accurate numbers at age or biomass at age; often the most difficult figures to obtain with any confidence. Hence, there has been a move towards management strategies that are built upon the 'precautionary approach'.

2.2 The 'Precautionary Approach' to Fisheries

The dynamics of exploited fish populations can be highly uncertain and the 'precautionary approach' to fisheries management addresses such uncertainties (Richards and Maguire, 1998). Cadrin (1999) for example, developed a risk-averse control rule, derived from surplus production model parameters and associated uncertainty, in order to manage fisheries for MSY while simultaneously rebuilding overfished stocks. Such models have a built-in 'precautionary approach' to the fishery that they are trying to manage. The success of such new predictive management tools has yet to be fully determined but what cannot be in question is the extent to which the effectiveness of such tools will be wholly dependent on the robustness of the data available for the fishery in question. That said, by the very nature of a 'precautionary approach' to fisheries; an absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures to ensure continued sustainability (Richards and Maguire, 1998). The lack of adequate scientific evidence has prevented or delayed the implementation of essential conservation measures in the past and the adoption of the 'precautionary approach' appears to be the only means of ensuring a continued supply of fish stocks in the face of mounting pressure and lack of comprehensive scientific information (Gulland, 1971).

Fujita *et al*. (1998) state a degree of insurance against stock collapse is gained for a certain amount of short-term economic cost with an expectation of increased economic benefits over the long term as a result of a more sustainable fishery. This is the case for all fisheries, regardless of size, and can be equally applicable to large-scale commercial fisheries or small artisanal fisheries. Obviously the impact of such an increase in economic cost is dependent on the particular fishery involved and would have to be investigated before any management practices were put in place.

2.3 Small-scale Artisanal Fisheries

Comprehensive regional treatment of artisanal or small-scale fisheries in the Neotropics and specifically in the Tropical Eastern Pacific (TEP), is notably absent from the literature to date (Pauly and Agüero, 1992). For this reason, in-depth studies into the ecology, biology and socioeconomic issues surrounding such fisheries must be carried out before further efforts can be made to develop management strategies or guidelines concerning them, if indeed there proves to be a requirement for them. The importance of research into these issues stems from a number of reasons; the common-property nature of small-scale fisheries resources, often increased population growth in regions with such fisheries, (and hence increased demand for small-scale fisheries produce), and the often 'top-down', politically-orientated approach by the governments concerned when attempting to introduce management practices within these fisheries (Agüero and Lockwood, 1986).

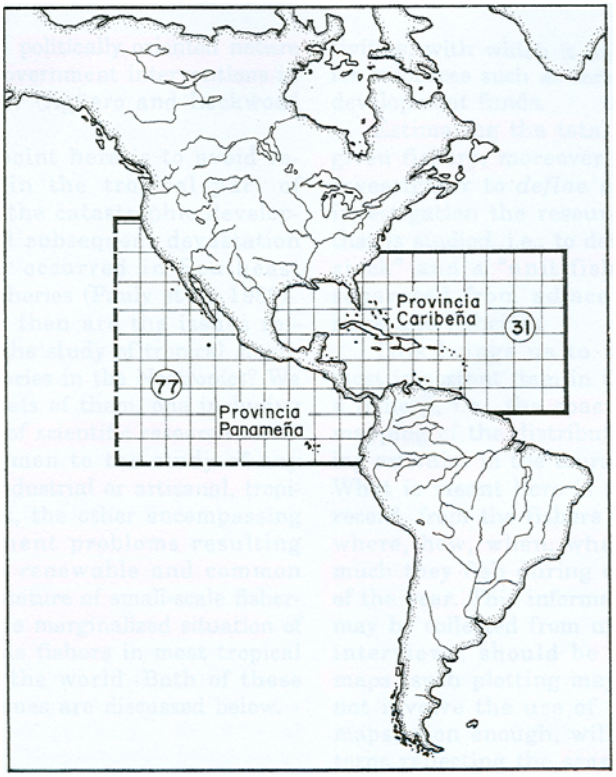

Figure 2.1 Two FAO fishing areas (Western Central Atlantic [31] and Eastern Central Pacific [77]) covering the corresponding biogeographic provinces. These areas represent the Neotropics (From Pauly and Agüero, 1992).

Pauly and Agüero (1992) set out the two main issues relevant to the study of small-scale fisheries in the Neotropics. The first one being the need for further scientific work on issues common to the study of any fishery, large or small, i.e. biometric data, CPUE data, stock recruitment etc., and the second incorporating all issues relating to the management problems stemming from the renewable and common-property nature of small-scale fisheries and the marginalised situation of such fishermen in most tropical areas of the world.

An important starting point in the understanding of a tropical small-scale fishery begins with an estimation of the total monthly and total annual catch (Gulland, 1980). Total annual catch estimates are important as they can be incorporated into a number of statistical or mathematical models (e.g. Schaefer, 1954; Fox, 1970) in order to further understand trends within the fishery. Annual catch figures are also important because they give an understanding of the total size and gross value of a fishery (Pauly and Agüero, 1992). Furthermore gaining reliable catch statistics is an essential requirement in any attempt to introduce effective and informed management of a fishery (Gulland, 1980).

A further aspect which is important to define relates to the spacio-temporal mapping of the distribution of fishing activities throughout the year (Pauly and Agüero, 1992). In relation to this it is important to have a record of exactly where, when, what and how much the fishermen of a particular fishery catch during each period of the year. This information can be gleaned through interviews from various sources associated with the fishery but primarily from the fishermen themselves. This information, once plotted, can be key to understanding the seasonal distribution of the exploited resource, identifying any fishing strategy that may be performed throughout a particular season in terms of following the fishery to certain grounds and even indicate any seasonal climatic changes that may periodically affect the fishery, e.g. upwelling cycles and larger-scale oceanographic oscillations, such as ENSO events. Experimental studies have been conducted using satellite data on daily temperature distribution patterns in the waters of small-scale fishing grounds as a means of allowing effective prediction of fish

distribution/abundance. This information has obvious implications in terms of increasing the efficiency of small-scale fishermen encountering their catch, thus increasing the net returns from their fishing activity (Barbieri, 1987). However, this is not likely to be a viable means of increasing the efficiency of most small-scale tropical fisheries due to the nature of the data required and the cost of obtaining such information.

A study by Ruttenberg (2001) into the effects of artisanal fisheries on marine communities within the Galapagos Islands found that such fisheries not only affect the abundance and biomass of targeted species but also have an impact on the community structure of the area being exploited. The changes to community structure indicate that such fisheries have the potential to have cascading effects on non-commercial species throughout the community. Ruttenberg (2001) does go on to state however, that the direct effects of this study fishery were largely limited to the primary targeted species; probably as a result of the high specificity of the fishing gear used. This statement could also easily apply to the snapper fisheries of Las Perlas as the fishing gear used within the archipelago comprises of hand-lines set to a fairly specific depth and bated with squid and sardines deliberately to target snapper. Furthermore, on the basis of a rapid assessment conducted throughout the data collection period, it would appear that this specificity is also present within the Las Perlas snapper fisheries as 'Revoltura' (by-catch) remained consistently less than 10% of the total catch throughout the whole sampling period.

That even small-scale artisanal fisheries can have a substantial impact on tropical reef-associated fisheries cannot be in doubt. The potential for overexploitation is ever present but circumstances pertaining to each individual fishery in question dictate whether or not the exploitation is sustainable or not. Bohnsack (1990) identified some of the major problems associated with such fisheries:

1. Potential recruitment overfishing because of insufficient spawning stock biomass;
2. Increased probability of recruitment failure due to environmental uncertainty and shorter generation times;

3. Loss of genetic diversity within species resulting in undesirable stock characteristics;
4. Growth overfishing for many species;
5. Declines in overall abundance and average fish size;
6. Loss of biotic (interspecific genetic) diversity;
7. Potential disruptive reef fish community instability and permanent alterations; and
8. Faster selection against desirable traits due to shorter generation times.

The term 'small-scale' fishery, used throughout this document, corresponds to 'artisanal' or 'traditional' used elsewhere in other sources (Pauly *et al.*, 1982). The choice of the term small-scale results from the nature of the fisheries associated with the Las Perlas archipelago and in particular the nature of the main snapper fisheries found there. These fisheries could be classified as 'artisanal' or 'subsistence' from their scale and the traditional practices used to catch the fish, i.e. using hand-line and small wooden boats. However, there is considerable commercial value associated with the catch and the majority of the *Lujanus peru* and *Lutjanus guttatus* caught as part of these fisheries are not consumed within the archipelago but are transported to the mainland for resale, often as far as the United States.

2.4 Small-scale Fisheries and Marine Reserves

Marine reserves, among a number of other management strategies, are a useful tool in addressing some of the critical fisheries problems commented on above. Marine reserves are rapidly gaining recognition as an important management tool in the regulation of fisheries partly as a result of their three-dimensional nature. They can preserve not only the targeted resource but other resources within the defined area; other fish species, other marine species and the ecological habitat as a whole. Such complex ecological systems need to be protected in an integrated manner. This has not always been achieved with previous fisheries attempts that may have focused on only a small subsection of a complex system. The means by which most marine reserves are implemented from a fisheries perspective is through 'No Take Zones', 'Limited Access' or 'Seasonal Access'.

Effectively it is the complete regulation of fishing practices within a designated zone. The importance of marine reserves for fisheries can be illustrated in a number of ways. Primarily a protected area allows the fish within to grow and reach a size allied with sexual maturity. It also allows reproduction to occur and recruitment within the fishery to gain an advantage and finally it is argued that they also act as an exporter of adult fish and younger larvae into areas where there is an active harvest, thus ultimately adding to the fishery as opposed to purely restricting the area that can be fished (Rakitin and Kramer, 1996; Chapman and Kramer, 1999; Russ *et al*., 2004). Marine reserves have shown to be effective in providing benefits to small-scale fisheries in the form of larger catches, greater catch rates and decreased fishing effort (Russ *et al*., 2004). A study conducted by Kamukuru *et al*. (2004) examined the effectiveness of Marine Protected Areas (MPAs) in improving localised fish stocks with particular reference to the benefits this might bring to local small-scale fisheries. Their work looked at comparing the density and size of the black spot snapper (*Lutjanus fulviflamma*) within the Mafia Island Marine Park (MIMP), Tanzania to adjacent intensively fished areas (IFAs). Their results showed that the target species was over four times more numerous, its biomass six to ten times higher and individual sizes on an average 37% larger in the MPA when compared the IFAs. The study supports the argument that MPAs can play a key role in the conservation of habitats and the management of local fisheries (Kamukuru *et al*., 2004). This work is further supported by that done by Alcala *et al*. (2005) in no-take marine reserves in the Philippines. They found that fish biomass increased within reserves and trap and gillnet catches outside the reserve also increased, indicating that marine reserves may help maintain or even enhance local fishery yields in the long-term.

Bohnsack (1990) comments on the importance of marine reserves as an effective management tool from the point of view of providing insurance against management and recruitment failures. He also highlights the fact that they can simplify enforcement and crucially, have equitable impact among fishermen. This final point is potentially the most important, as many fisheries management strategies have failed due to the unequal distribution of their costs throughout user groups and hence the subsequent lack of adherence to schemes by various participants.

2.4.1 Modelling the effectiveness of Marine Reserves with respect to Fisheries

Arreguín-Sánchez *et al*. (2004) has shown through modelling that it is necessary to offset economic and social requirements with ecological needs for a fisheries management plan to be effective. However, the above points illustrate that there does not necessarily have to be an inverse relationship between these two factors and that improvements in the ecological state of a fishery can also ultimately lead to improvements in the socio-economics associated with a fishery in the long-term, if not the short-term. Sumaila (1998) developed a bioeconomic model in order to assess protected marine reserves as a fisheries management tool. The work makes the important point that the establishment of a marine reserve is only beneficial when net transfer rates of fish out of the reserve are 'reasonably' high and reserve sizes are large. Sumaila (1998) states the importance of these two requirements are related to the fact that large reserves provide good protection for fish stocks in the face of a shock to the fishery, (such as a severe recruitment failure in non-protected areas), and also high transfer rates make the protected fish available for harvesting after the 'shock' has occurred. Possibly some of the most recent work in this field bas been done by Side and Jowitt (in press). Their working model indicates that a number of factors are critical when considering the benefits/costs of marine reserves [closed areas], including the present state of the fishery, growth/reproductive rates and dispersion rates, and the size and shape of the areas closed to fishing.

The number of works currently being published on the effectiveness of marine reserves in preserving and promoting not only small-scale local fisheries but also the potential to have a significant beneficial impact on larger oceanic commercial fisheries, is expanding rapidly. Hence the connection between this investigation into Las Perlas fisheries and the current plans being initiated into creating a marine reserve around the archipelago, is one that needs to be made firmly and earlier on in the development stages of any management plan.

2.5 Zona de Manejo Especial Archipiélago de Las Perlas

The work carried out for this MSc thesis was undertaken in collaboration with the Smithsonian Tropical Research Institute (STRI) and under the auspices of the Darwin Initiative Project. It is from the Darwin Initiative that the impetus for the *Zona de Manejo Especial Archipiélago de Las Perlas* has come. This project is currently underway in an attempt to protect the Las Perlas archipelago from a number of anthropogenic threats; overfishing, habitat degradation, pollution and ecological diversity loss among others. The project aims to create a Marine Protected Area (MPA) in order to conserve the ecological health and wealth of the region. The archipelago is an eminently suitable site for an MPA; of the 780 fish species found on the Pacific coast of Panama, 737 can be found in the Las Perlas archipelago (Robertson and Allen, 2002). Such high biodiversity at upper trophic levels is indicative of a worthy site for the establishment of an MPA.

Within the archipelago six villages rely heavily on fishing as a means of subsistence and income; San Miguel, Casaya, Ensenada, Esmeralda, Pedro González and Martín Perez (Guzman, pers. comm.). For this reason the impact of the designation of the archipelago as an MPA and the possible resultant legislation with regards to its associated fisheries, has to be examined with great care. If legislation or management plans are required in order to better manage the current small-scale fisheries being practised in Las Perlas, all efforts would need to be taken in order to ensure their continued economic viability and the welfare of the local people that rely on them. As it stands currently however, both the local communities of fishermen and some industrial and artisanal fishing boats based on the mainland, do exert a significant pressure on the fisheries around the archipelago (Raab and Roche, 2005). To date there has been no detailed study of the extent to which such small-scale fisheries, as exist around the archipelago, are affecting localised snapper stocks. The archipelago is renowned as a site of extremely high fish abundance due to the seasonal upwelling that occurs around the region in the dry season (Raab and Roche, 2005). It is at this point that fishing pressure is intensified throughout the fishing communities of the archipelago (Guzman, pers. comm.). It is known that considerable quantities of snapper and other groups of large pelagic fish are

caught at this time, but accurate estimates of stocks, catches or fishing effort have not yet been documented.

2.6 Relevant Fisheries Legislation within Panama

Current legislation within Panama is extremely limited with regards to pelagic fisheries such as that of the snapper fisheries of Las Perlas. The *Decreto Ejecutivo* (Decree) No. 49 from July 20th 1992 banned the fishing of any snapper using gillnets or 'trasmallos' (trammel nets) and also imposed a requirement for all vessels with a capacity of greater than 10 tonnes to have a license. Infractions on this decree could be subject to a US$1,000 fine. This being the only legislation with regards to any snapper fishery in Panama, it can be seen that there is no regulation on Allowable Catches or on Minimum Landing Sizes (MLS) applicable anywhere in Panama (Guzman, pers. comm.). Suman (2002) further, states that all coastal management legislation within Panama is contradictory and confusing; *"with new laws only adding to the confusion"*. Hence there is a great need to investigate the extent and current sustainability of the snapper fisheries of the Las Perlas archipelago before any legislation regarding fishing practices within the new MPA can reasonably go ahead.

2.7 Snapper Literature

Little work appears to have been done that specifically focuses on Pacific species of snapper commonly fished in the Las Perlas archipelago. Some work has been done on TEP fish species in general but there appears to be a distinct gap in the literature regarding TEP snapper species. Vera and Sanchez (1997) found that patterns in marine fish communities in the TEP showed distinct differences between winter and La Niña groups. Furthermore they showed that *Lutjanus peru* was particularly abundant in La Niña years. It is possible that *Lutjanus peru* populations may be negatively affected by El Niño and then enhanced by La Niña, due to improved recruitment throughout this time (Vera and Sanchez, 1997). Vera and Sanchez (1997) also found that during the summer period the most abundant stage of *Lutjanus guttatus* were mature adults, which migrate

from deep to shallow waters for spawning. Juveniles are thought to be dominant in winter, generally gathering around rocky reefs and stony bottoms (Vera and Sanchez, 1997). *Lutjanus guttatus* reproduce largely in the summer, when it is the main time of arrival to the coast for spawning, hence increasing numbers significantly along the coast and subsequently the catch. The abundances of these snapper species are known to display semi-periodic changes in relation to climatic fluctuations. The changes being related specifically to ENSO, availability of food resources and the conditions during the reproductive period.

2.7.1 A Comparative Study of a Similar Snapper Fishery off Mexico

A useful piece of work was conducted by Santamaría and Chávez (1999) looking at a fishery off the Pacific coast of Mexico, which examined biometrics for both *Lutjanus peru* and *Lutjanus guttatus*. This study provides a useful comparison in terms of applicable methodologies for fieldwork, data collection, data manipulation and analysis. Their study was conducted over a longer time period, with greater frequency and more access to the field to collect data, in terms of time and sampling equipment. However, it does provide a good comparison as the species involved are the same, the region of the TEP being used by the fisheries is also roughly the same and finally the techniques and equipment used to catch the fish are directly comparable. All these reasons enable useful comparisons to be drawn between the two studies. Similar analyses were performed in terms of Length-weight relationships and Length-frequency analysis. Santamaría and Chávez (1999) however, were able to progress further with fisheries analyses, in terms of creating a Von Bertelanffy growth curve etc., as they were able to determine with some degree of accuracy the age classes involved in their sample population. This was to prove impossible with the study of the fishery in Las Perlas.

2.7.2 Reproductive Strategies within TEP Snapper Species

Santamaría and Chávez (1999) state that *Lutjanus peru* behaves with a similar reproductive pattern to that of other species that live in tropical environments, i.e. that the

relatively reduced seasonal changeability determines the possibility to find individuals in reproduction at any time of the year. However, this seems to contradict the occurrence of the seasonal upwelling of the region, which would represent a singularly large seasonal change to the temperature and nutrient output of the region. It is possible that their results indicated that there was no clear seasonal cycle to reproduction, either because the region they were sampling in was not as seasonal in terms of large-scale oceanographic processes as the region of Las Perlas or perhaps some other issue in their sampling resulted in a lack of seasonality being expressed in their data. These problems are commonly associated with fisheries biometric analysis and can be seen within the data of this study also. However, anecdotal evidence over numerous years supports the theory that the *Lutjanus peru* and *Lutjanus guttatus* fisheries, at least around Las Perlas, are heavily seasonal. Furthermore, Santamaría and Chávez (1999) go on to state that some seasonality is expressed in the form of two peaks of great intensity throughout the year. Such peaks would probably not be present if there was not some seasonality to the reproductive cycle of these fish.

2.7.3 Age Trends for Lutjanus peru

The groups of present age classes of these two species within commercial captures are recorded to include fish from the first year class until the age of 21. Furthermore, it is considered that the fish mature up to the age of three years (Santamaría and Chávez, 1999), although maturity can occur some time before this. Their studies for *Lutjanus peru* indicate that a larger proportion of immature males are captured compared with that of females. They also record the total maximum length for *Lutjanus peru* to be 95cm. Populations with extensive longevity, like *Lutjanus peru*, are characterised by their size being limited by density and with that an intrinsic drop in its growth rate, resulting in them becoming highly vulnerable to exploitation (Santamaría and Chávez, 1999). Thus it is particularly necessary with such species of fish to closely monitor the intensity of exploitation and also to avoid the capture of young individuals particularly if they are before sexual maturity as this would quickly accelerate the exhaustion of the resource (Santamaría and Chávez, 1999). According to their models the optimum level of catch

corresponds to a minimum age of capture of 2-3 years and to a fishing mortality of F = 0.35. They suggest that these figures indicate the need to impose a minimum landing size equivalent to that of two years of age at least, as they found that nearly 50% of fish captured had ages less than one year are were all immature.

2.7.4 Length-weight Relationships for Lutjanidae

In a study into the Length-weight relationship parameters for 27 *Lutjanus* species it was found that there was a particularly narrow relationship for the parameters of K and L for the family in general but for those particularly close relatives it was even more pronounced, (a value for the family oscillated only between 2.53 and 3.273), (Pauly and Binohlan, 1996).

2.8 Description of Fish Surveyed

2.8.1 Lutjanus peru (Nichols & Murphy, 1922)

Pacific Red Snapper

Common Spanish Name: Pargo Rojo/ Pargo Seda

Lutjanus peru grow to a maximum length of ca. 95cm total length, with a maximum recorded weight of 5,810g. It has a minimum population doubling time of 1.4-4.4 years (K=0.26). They are a reef associated fish with a depth range of approximately 40m. Found often over hard bottoms in inshore reef areas up to a depth of at least 80m. They are carnivorous, feeding on large invertebrates and other fish. Most fisheries associated with it are subsistence fisheries and their distribution is located around the Eastern Pacific, from Mexico to Peru (Allen, 1985). The range of red snapper is generally thought to be distributed along the continental shelf out to the shelf edge and demonstrate an affinity for vertical structures (Patterson III *et al*., 2001).

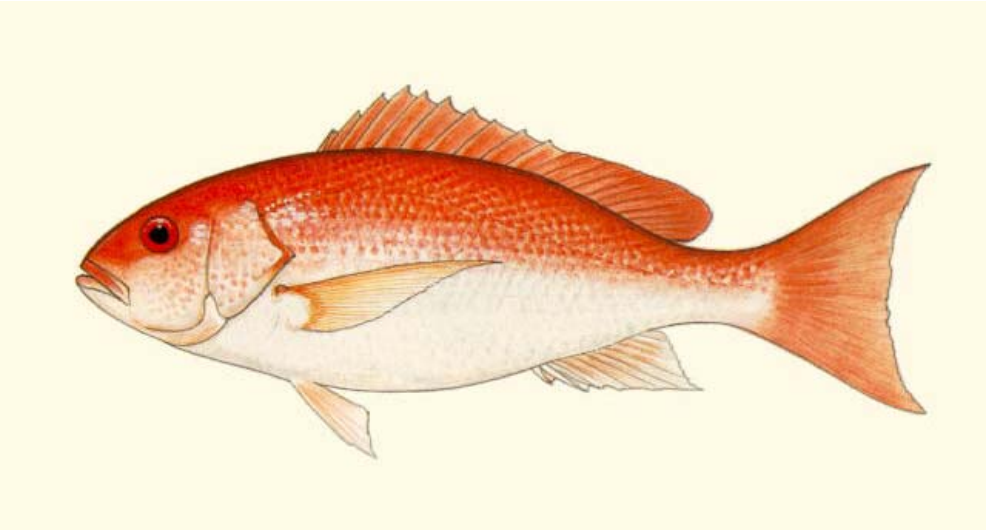

Figure 2.2 Image of *Lutjanus peru*[4].

The fish has 10 dorsal spines, 13-14 dorsal soft rays, 3 anal spines and 8 anal soft rays. The preorbital bone is very broad in adults. Large specimens develop a groove from the front of the eye to the nostrils and on the upper part of the preopercle behind the eye. The scale rows on the back rise obliquely above the lateral line. In colouration the species is mainly red to pink with a silver hue and the fins reddish (Allen, 1985).

2.8.2 Lutjanus guttatus (Steindachner,1869)

Spotted Rose Snapper

Common Spanish Name: Pargo Mancha

Lutjanus guttatus grow to a maximum length of ca. 90cm with a maximum recorded weight of 1, 310g (Allen, 1985). This species is also reef associated and has a depth range of around 30m (Fischer *et al*., 1995). The fisheries for this species vary between local artisanal fisheries, small-scale commercial fisheries and game fishing. They have a minimum population doubling time of 1.4-4.4 years and are found distributed throughout the Eastern Pacific from Mexico to Peru (Allen, 1985). The species is found over hard bottoms in inshore reef areas. Generally solitary or in small groups but may occasionally form big schools. Juveniles inhabit estuaries and river mouths. Carnivorous, feeding on

[4] http://www.fishbase.org/Summary/SpeciesSummary.cfm?id=170, 30/07/05.

invertebrates and fish (Allen, 1985). The species has a wide diet including; fish, crustaceans, echinoderms and molluscs. Individuals below 20cm tend to feed on shrimp, whereas after 50cm squid dominates the diet (Rodriguez, 2003). According to Grimes (1987) Lutjanidae in general are fast growing and spawn in batches over an extended period of time, depending on the availability of food for larvae. However, if food is abundant during a season, (like that found around the Las Perlas archipelago due to the seasonal upwelling), then reproduction will be seasonal. However, if food is scarce the spawning will be continuous and in small batches (Grimes, 1987; Rodriguez, 2003). In Mexico the spawning season of *Lutjanus guttatus* is thought to take place from July to November and February to April in Guerrero coast, Mexico (Arellano-Martínez *et al*., 2001). The latter period matches that of the peak snapper fishery off Las Perlas (Guzman, pers. comm.). In Guatemala Pérez-Cifuentes *et al.* (1999) reported sexual maturation sizes to be 31cm and 33cm for males and females, respectively.

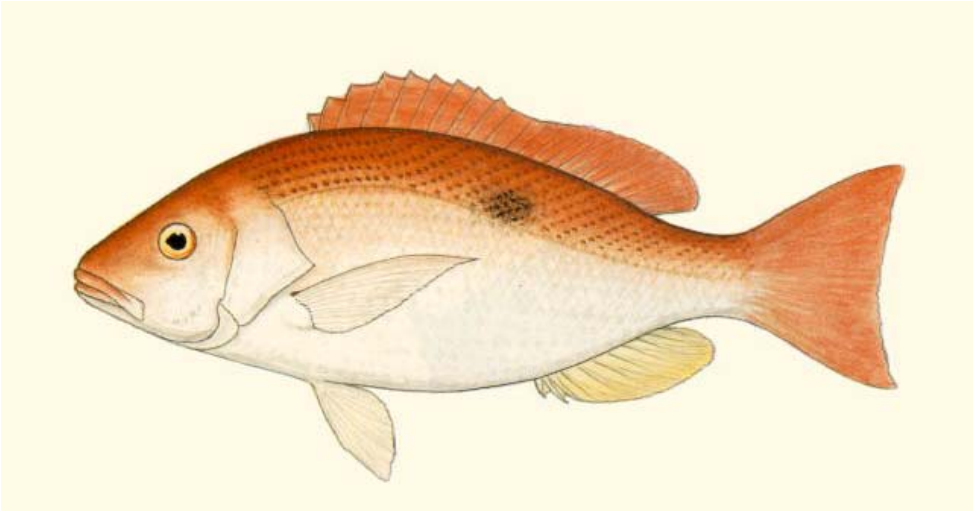

Figure 2.3 Image of *Lutjanus guttatus*[5].

The species has 10 dorsal spines, 12-13 dorsal soft rays, 3 anal spines and 8 anal soft rays. It is pale crimson on the side of the body, often with a silvery sheen of horizontal rows of bluish spots; belly golden yellow. The head with bluish spots and irregular broken lines, especially across the cheek. A large blackish blotch on the upper back

[5] http://www.fishbase.org/Photos/ThumbnailsSummary.cfm?ID=152, 30/07/05.

below the posterior dorsal spines is the most distinguishing identifying mark (Allen, 1985).

2.8.3 Lutjanus argentiventris (Peters, 1869)

Yellow Snapper

Common Spanish Name: Pargo Amarillo

Lutjanus argentiventris reaches a maximum total length of ca. 71cm and a maximum recorded weight of 1300g. The species is reef associated with a depth range of 3-60m. It is found in inshore reef areas over hard bottoms until at least 60m depth. The species is known to be somewhat tolerant of freshwater. The species forms aggregations during daylight and shelter as solitary fish in caves. The species is carnivorous, feeding on fish, shrimp, crabs and molluscs. The species is associated with both small-scale and larger-scale commercial fisheries along with some artisanal fisheries. It is subtropical with a distribution range in the Eastern Pacific, notably southern California to Peru. It is rarely found north of Baja California, Mexico. However, it is also found around the Cocos and Galapagos islands (Allen, 1985). Rojas *et al*. (2004) reports that advanced sexual maturity stages were observed throughout their whole study (March 1997 to December 2000) with no clear reproductive pattern. Furthermore, they found that the average size at sexual maturity was 515mm TL and that the Length-weight relationship was not significantly different between the sexes.

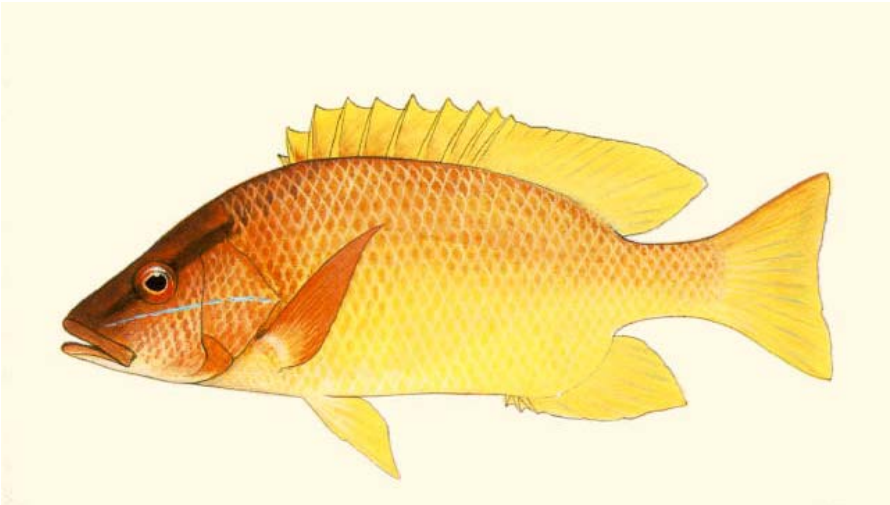

Figure 2.4 Image of *Lutjanus argentiventris*[6].

The species has a total of 10 dorsal spines, 14 dorsal soft rays, 3 anal spines and 8 anal soft rays. The forehead slopes steeply with the snout being somewhat pointed. The scale rows on the back are parallel with the lateral line. The species is characterised by being rosy red anteriorly, becoming bright orange to yellow over most of the body. The fins are mainly yellow or orange; the inside of the mouth is white and a bluish horizontal streak runs below the eye (Allen, 1985).

2.9 Overview of Analyses Techniques used for Small-scale Fisheries Data

2.9.1 Small-scale Fisheries Analyses Methods

A number of particular features apply when dealing with small-scale fisheries data. Primarily, there is often not the same access to regular, accurate and/or scientific catch and stock data. Small-scale fisheries are often found in remote parts of the world, with little access to adequate scientific equipment and with fishermen that are often unused to being subjected to such close scrutiny from government bodies etc. In these respects small-scale fisheries are very different from commercial, controlled fisheries and for this reason the methods and data available from them is often quite different. There are other technical difficulties associated with the fish themselves, for example there is an inherent difficultly in determining age in tropical fish and this has important implications for the type of analysis possible to perform on the data collected (see below).

2.9.2 Ageing Methods

In many applications of stock assessment it is necessary to find a substitute for age-dependent data. This is because collecting age-specific data is inherently difficult and even where possible; often highly expensive (Gallucci *et al*., 1996). Nonetheless, a number of methods are in use for assessing the age of fish within a population in relation

[6] http://www.fishbase.org/Photos/ThumbnailsSummary.cfm?ID=14088, 30/07/05.

to Total Length. This is an important relationship to understand as it allows insight into the proportion of a total catch that may be being caught sexually immature, purely through length measurements of the fish. It is obviously impossible to look at gonad stages for every fish landed within a particular fishery. Hence it is necessary to gain an understanding of maturity and age from a single length measurement. Different methods are used depending on the availability of samples, time restrictions and access to the fish being caught and landed by the fishery. Otolith ageing is now a common method for assessing age of fish. The otoliths act as a marker of age by laying down yearly growths which can be counted under the microscope, like tree rings. Another method that has been used to determine age involved looking at sections of vertebrae under the microscope again for ring formations. Rodriguez (2003) states that vertebrae show clearer ring definition and deposition of the material follows an expected pattern making it easier to correctly identify year class. The study of *Lutjanus guttatus* vertebrae and otoliths identified a strong linear relationship between the total length of the fish and the radius of the vertebrae; this being the main requirement for acceptance of an ageing structure (Brennan and Cailliet, 1989).

A further method for understanding age-at-maturity is through the 'mark-recapture' method. This method involves capturing a number of individuals from a stock, marking them, releasing them and then capturing them again the following year (Patterson III *et al*., 2001). Total Length measurements are taken each time they are landed and a comparison made between years. In this way a known age of fish can be linked to particular lengths and hence length at sexual maturity information can be calculated through this process. However, this technique requires a large amount of time and financial investment. Furthermore a significant number of fish have to be marked for the results to be rigorous and the experiment to be successful. There is also the chance that few to no fish will be recaptured, and as the years progress the chances of getting older fish diminishes rapidly. In a study conducted by Patterson III *et al*. (2001) they were unable to validate ages of snapper beyond 8 years due to the relatively few old snapper recaptured.

2.9.3 Population Assessment Methods

2.9.4 CPUE Methods

3.0 METHODS

3.1 Fieldwork

The fieldwork component of the project involved collection of qualitative data through interviews with local people throughout a number of villages around the archipelago. The qualitative data collection stage was conducted over ten days; villages were visited by research boat and interviews conducted over approximately 3-6 hours. Four villages in total were visited for qualitative information and two villages visited for quantitative data, i.e. the biometrics of the particular fisheries concerned with those two villages. The quantitative data collection involved recording biometric data directly from the fisheries. It was not possible to collect data on the population through any other means. While fishing data cannot be directly taken as a measure of the fish population as a whole, the means by which the snapper are caught is fairly specific to the type of fish, (i.e. by handline), and data collected from fisheries landings can be assumed to be fairly representative of the actual population. There will of course be a small proportion of the population that may be too small to be hooked by the handlines and this section of the population will not be represented adequately by purely fishing catch data. However, considering the limited methodologies, time and equipment available to this study it would not have been feasible to conduct an effective population study of *Lutjanus peru* and *Lutjanus guttatus* through any other means than by fisheries catch data.

3.2 Qualitative Research

The qualitative section of this research project was collected mainly through interviews conducted with local fishermen, buyers and officials throughout the main villages of Las Perlas. The interview format can be found outlined below.

Qualitative Questionnaire
Saboga, Casaya and San Miguel

1. **How many fishermen work in the village?**
2. **How much caught per day (weight) per boat?**
3. **How many hours per week spent fishing?**
4. **What is the snapper proportion of the catch (species, weight, number)?**
5. **What is the species composition of the catch?**
6. **Where are the main fishing sites?**
7. **What is the total biomass caught from the village (month/year)?**
8. **What are the sizes of boats?**
9. **What equipment is regularly used?**
10. **What is the number of lines/hooks per boat in use?**
11. **Is there seasonality to certain parts of the catch?**

Figure 3.1 Interview format for collecting qualitative information on the snapper fisheries of Las Perlas.

Interviews were conducted through a local Panamanian translator (Inez Campbell) who was fluent in both English and Spanish. The translator was also familiar with the local area, aware of regional issues and a competent marine scientist who had previous experience in interviewing people on fisheries issues within these communities. This experience proved invaluable throughout the interview sessions as those interviewed responded warmly and openly to all questions. Transcripts of interviews from all villages can be found in the Appendix. Interviews with Corregidors (official community representative), buyers and fishermen were conducted for Casaya, Pedro Gonzalez and San Miguel and with the Corregidor and main buyer at Village A. It should be noted that while the format of the questionnaires remained unchanged throughout the interviews, the responses to questions were varied and often pertinent information was gleaned through comments that did not fall within the specific questionnaire.

3.3 Quantitative Biometric Data Collection

Biometric data on the snapper fisheries of Las Perlas were collected over an eight month period from January to August 2005. Village A was the focus of this data

collection as the fishery based out of Village A is consistent, of a substantial size and relatively self-contained. All fish caught by fishermen from the village were returned to the village each night. The fishermen tended to fish in the same areas at the same times and hence it was relatively simple to accompany the fishermen to the main fishing grounds or to wait for them to return to the village with their catch at the end of every fishing day. Data were collected on two main snapper species; *Lutjanus peru* (Red Snapper) and *Lutjanus guttatus* (Spotted Snapper). Other species that could easily be sampled at the time of catch were also recorded, for example; *Lutjanus argentiventris* (Yellow Snapper), *Epinephelus morio* (Red Grouper) and *Epinephelus niveatus* (Snowy Grouper). Measurements were taken for Total Length, Standard Length (i.e. base of the caudal fin where it meets the caudal peduncle), Total Weight, Sex, Gonad Maturity Phase (i.e. Immature Virginal, Premature, Incipient Maturity, Advanced Maturity, Breeding), Gonad Weight and Gut Weight.

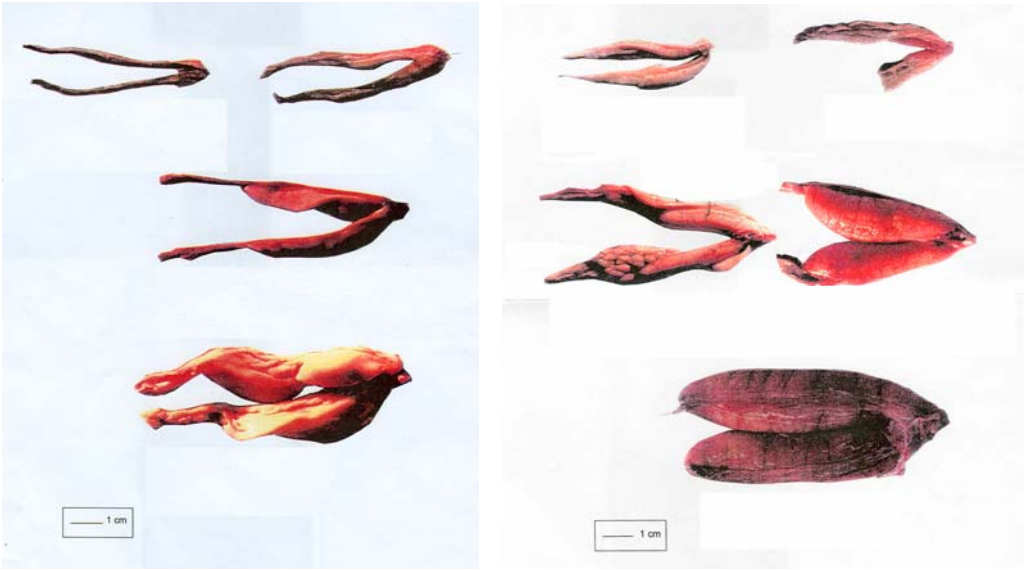

Figure 3.2 Showing gonad stages for both males and females (shown in greater detail in Appendix V).

Length measurements were taken using a flat wooden board and measuring tape, with measurements being recorded to the nearest 0.5cm. A more accurate measurement, while preferable, was not possible with the materials available in the field. However, an improvement in this technique would be recommended for further studies.

Figure 3.3 Taking Total Length and Total Weight Measurements from the fishermen, May 2005.

Weight measurements are notoriously difficult to take accurately in the field; however efforts were taken to ensure standardisation. All measurements for weight were recorded using the same equipment; a mechanical hanging scale that measured in pounds and ounces. Enough time was allowed at each weighing for the scale to balance and ensure the most accurate weight measurement could be taken. Identification of sex, gonad maturity stage and weight were all performed at a later stage as it would have been impossible to perform these measurements accurately in the field. Therefore all gonads and guts were bagged during the cleaning process and put aside to be measured separately. Sex and gonad phase were determined by macroscopic examination of the gonads and if necessary dissected using a standard dissection kit. Gonads were weighed using a digital balance accurate to +/- 1.0g.

Figure 3.4 Gonad stage identification and weighing of gonads etc.

Biometric data were collected by a number of marine scientists throughout the sampling period but efforts were taken to ensure standardisation between methods, identification and agreement on gonad phase etc. Data were collected by a member of the Smithsonian Tropical Research Institute for all months excluding May, where the data were collected by the author.

Sampling for biometrics involved two techniques. The first being to accompany fishermen from the Village A to their fishing sites all day and record length and weight measurements while out in the field and collect gonad samples for fish gutted and cleaned whilst at sea. The other technique for gathering biometric data was to wait for the fishermen to return to the village beach in the early evening and assist in the cleaning process whilst simultaneously gathering biometric data. Both techniques worked successfully and a large proportion of the catch of the village per day was able to be assessed by a combination of these two methods, however it was not possible to take biometrics for all fish caught in the village per day in this manner as it proved impossible to get to all fishing boats before some fish were cleaned and taken to the processing plant. Hence it would not be possible to accurately get an estimation of CPUE for the fishery by this means.

3.4 Biometric Data Interpretation and Analysis

Biometric data interpretation and analysis was performed using Microsoft Excel software and the SPSS statistical package. Fisheries analyses and modelling were performed using the methodologies as set out in Sparre and Venema (1998) and Gallucci *et al*. (1996) with respect to Length frequency analysis, Length weight analysis and Maturity Ogive analysis, among others. More information pertaining to the analysis done on the datasets can be found in the Results section of this study.

3.5 Quantitative Catch Per Unit Effort (CPUE) Data

A further reason for the choice of Village A as an appropriate site to assess fishing effort and snapper biometrics in the Las Perlas archipelago was the fact that all fish caught by fishermen of Village A were channelled onto the market through only one buyer. In this way it was possible to gain both informative biometrics on the Red and Spotted Snapper fisheries of the area and also to possibly gain complete information on CPUE for this particular fishery. Following discussions with the buyer in Village A it was possible to gain access to catch records spanning seven years; from 1999 until 2005. While the records were not wholly complete for all years it proved an immense resource of fisheries information for the area. The means of collecting this data involved transcription of hand-written books into a database. Data took the form of Date of Catch, Type of Catch (unfortunately snapper species were often not separated into individual species but rather recorded as simply generic 'snapper') and Weight of Catch (in pounds and ounces). Each record represented the days catch for an individual fisherman. As each fisherman used only one line (with multiple hooks) it was possible to use this data to gain a measure of CPUE. Furthermore each record was divided into three categories; 'Grande' (Large), 'Chico' (Small) and 'Revoltura' (By-catch). These categories were used by the buyer to assess the proportion of larger to smaller fish coming in and all to measure the proportion of targeted catch to by-catch. Hence where specified there was a measure of particular snapper species, but generally all snapper species were grouped together under one heading. All 'Revoltura' was not identified but would be made up of a wide range of

fish including jacks, sharks, needlefish etc. ‘Revoltura’ was predominantly made up of pelagic white fish.

4.0 QUALITATIVE RESULTS

4.1 Introduction

The results laid out below are data collected from qualitative interviews conducted throughout the archipelago over a period of 10 days in May 2005. As such this information can only be seen as a guide, it is not quantitative in any way. However, efforts were taken to ensure that the information collected was as accurate as possible and no fishery was sampled without several interviews being conducted with a range of user groups to ensure the most unbiased collection of data. (The methodology for the collection of information can be found in the Methods section of this report). The information below is a summary of all that taken from interviews and general comments from local people in the archipelago. (Full transcripts of all interviews conducted for all fisheries and all villages can be found in Appendix I).

4.2. General Fishing Practices throughout the Archipelago

The majority of the small-scale 'artisanal' fishing within the archipelago is either done with 'hook and line' during the snapper or grouper season or with skin-diving throughout the octopus and lobster season. There is some overlap between these two periods but generally the latter follows the former with the pelagic fish being caught from January to May and the lobster/octopus being heavily fished from May onwards. However octopus and lobster fishing does continue throughout the year. The majority of fishermen tend to focus on one fishery and remain with it as their main fishery, although once the season has finished they often move onto other fisheries for the interim period. The majority of fishing done throughout the archipelago is conducted from small fibreglass or wooden boats of ca. 7-8m in length with a ca. 40hp outboard engine. They do not tend to travel further than ca. 20-25km from their villages to get to fishing grounds; often the distance travelled is much less than this. There is usually 3-4 fishermen working on each boat with the catch being split equally between the fishermen. The boat is usually owned by the

skipper (also fishing) but there appears to be no monetary gain to be had from owning the vessel. The snapper fishermen tend to sell all snapper caught, (hence the reliability of the records kept by the buyer at Village A), and keep only the by-catch for their own consumption.

That said, there appears to be very little by-catch from the snapper fishery; less than 10% of fish caught were recorded as by-catch. Also it should be noted that very few snapper are returned for being undersized. The fishermen were recorded as saying that they would return anything less than 1lb but this was not corroborated by the biometric data collected or when watching the fishermen at work. All fish landed were kept; however there was a noticeable absence of smaller snapper (<1lb) being landed. It is possible that the size of the hooks or the bait being used (pieces of squid or sardines) prevents the catch from sampling smaller individuals. A further explanation is that the fishing grounds frequented during peak season may be snapper spawning grounds, (many adult females caught were close to releasing eggs). Therefore it is possible that juvenile fish are not associated with this area and are subsequently not sampled. During peak snapper season the fishery is often some distance offshore and the fish are in deep waters, often near the bottom of the water column. For this reason the fishermen tend to set their lines at around 100m depth and the lines tend to have around 10-15 hooks on each line.

There appears to be no attempts made at ensuring continuity of the fishery. In discussions with fishermen and buyers, El Niño is sometimes attributed to any downwards trends in catch but often no explanation is given. Some fishermen believe there is no trend downwards in catch and that the fishery has always been highly variable. Certainly no attempts seem to be made to protect certain key spawning/feeding areas. Indeed it is these areas that the fishery is targeted on. Furthermore there is no information available to the fishermen with which to use to make informed decisions should they so choose. There is no voluntary closed season for the snapper fisheries and any that can be caught throughout the year, even in the off season, are taken. However, when snapper are known to be in very short supply, i.e. during the middle of the off season, very few fishermen make decided efforts to catch snapper. Most move onto other fisheries, like the

lobster and octopus fishery, which are in greater relative abundance at that time of the year. In this way there may be a slight let up in fishing pressure but probably not enough to make a significant difference to future stock recruitment.

4.3 Village A Snapper Fishery

The snapper fishery of Village A is one of the most organised fisheries within the archipelago. All fish caught by fishermen of this fishery are brought back to the village and are channelled through a single buyer. Approximately 160 fishermen work in the village during the peak season, although this number drops in the off season. Of this number approximately 80 fish for snapper and 70 for octopus during the season. Some continue to specialise in octopus but many move into the snapper fishery for this period because it is so productive There are around 23 boats that work during the peak season for the snapper fishery and about half this number in the off season.

The season for *L. peru* tends to run between February and May each year with March and April being associated with the greatest catches. However this year the fishery started noticeably late, beginning in mid-March. It is not known the reason for this lateness in the start of the fishery but it is possible that it may be temperature related. Throughout the *L. peru* season they also catch *L. guttatus* and *L. argentiventris*. The former species being the most common after *L. peru* with *L. argentiventris* only occasionally being caught proportionally. The ratio between the two main species being caught varies throughout the season and between different years. In 2005 *L. guttatus* made up the bulk of the catch up until the *L. peru* season began to take over in mid-March at which point it rapidly overtook *L. guttatus* as the bulk of the fishery. The buyer of Village A fish commented that there had been more *L. guttatus* than *L. peru* caught this year up until March but that this ratio varies quite significantly between years.

Fishery Data	**Numbers**
Number of Fishermen	160
Number of Fishermen per Boat	3-4

Number of Lines per Boat	3-4
Number of Boats	23
Landing Data	
Quantity Snapper caught Peak Season/lbs per boat per day	200
Quantity By-catch caught Peak Season/lbs per boat per day	10
Quantity Snapper caught Off Season/lbs per boat per day	100
Quantity By-catch caught Off Season/lbs per boat per day	Minimal

Table 4.1 Shows particulars on the snapper fishery of Village A.

The main fishing grounds for the Village A snapper fishery are located in the region of Galera (08° 07'23.9" N, 78° 55'22.9" W). Galera is a well known and long used fishing ground for the fishermen of Village A. It is situated approximately 28km from the village. There are fishing grounds closer but Galera seems to be the most productive ground during the peak snapper season of February to May. Other areas that are used by the fishermen of Village A include regions southwest of Punta Cocos and southeast of the island of San José (see Appendix V).

Interviews with several members of the Village A fishing community all confirm that they believe that while there may be annual fluctuations in catch, the fishery has been displaying a general downwards trend over recent years.

4.4 Pedro Gonzalez Snapper Fishery

The fishery at Pedro Gonzalez is the second most significant of all the fisheries in the archipelago and this can be seen in the fact that it is the only one, outside of Village A, to

have a processing plant with an ice machine. There are approximately 80-100 fishermen working out of the village, which has a population of ca. 250.

Fishery Data	**Numbers**
Number of Fishermen	80-100
Number of Fishermen per Boat	3-4
Number of Lines per Boat	3-4
Number of Boats	30
Landing Data	
Quantity Snapper caught Peak Season/lbs per boat per day	200-300
Quantity By-catch caught Peak Season/lbs per boat per day	20
Quantity Snapper caught Off Season/lbs per boat per day	100
Quantity By-catch caught Off Season/lbs per boat per day	NA

Table 4.2 Shows particulars on the snapper fishery of Pedro Gonzalez.

Again with this fishery by-catch appeared to make up around 10% of the catch or less. *L. guttatus* formed the bulk of this fishery at the time of visit in May 2005. Fishermen knew of the abundant *L. peru* fishery being exploited by the fishermen of Village A at Galera but they did not make use of this. They believed it was uneconomic to travel such a distance even with such a productive fishery as was occurring at that time. Hence, the majority of the fish caught by fishermen from Pedro Gonzalez was from nearer fishing grounds such as around the island of San José and at Punta Cocos. Both these fishing grounds are shared with the fishery from Village A. At Pedro Gonzalez the same fishing techniques are used and the fishery runs over the same season. However, much smaller quantities of *L. peru* are recorded as being landed at Pedro Gonzalez than at Village A.

The fishermen at Pedro Gonzalez believe that the sudden end to the snapper fishery that occurs every year around their fishing region is due to the movement of sardines (the main snapper prey according to the fishermen) southwards to around the island of El Rey and beyond. Hence their explanation of why the snapper fishery continues in Village A while it may be concluded for the season at Pedro Gonzalez. The snapper fishery for Pedro Gonzalez started at the beginning of March and finished at the beginning of May. While this timing coincides with the start of the Village A fishery also, the beginning of the actual *L. peru* fishery only just occurred around mid-May. Furthermore, the time span for the fishery of Pedro Gonzalez has also been unusual in 2005 as the normal run of the fishery is until the end of May.

4.5 San Miguel Snapper Fishery

The fishermen of San Miguel fish during the day for snapper during peak season but fish only at night for snapper during the off season as they fish for sardines during the day throughout this period in order to catch adequate bait for the night fishing. They do this to improve the catch of snapper in the off season. The snapper season runs the same for San Miguel as it does for the other villages however they continue to fish for *L. Guttatus* throughout the year dur to their technique of gaining large quantities of bait through their day fishing. The benefits of this strategy can be seen in the higher off season catches for snapper for this village when compared to that of other villages.

Fishery Data	**Numbers**
Number of Fishermen	50-60
Number of Fishermen per Boat	3
Number of Lines per Boat	3
Number of Boats	18-35*

* Quite wide variation in the number of boats reported in interviews at San Miguel (see Appendix I).

Landing Data	
Quantity Snapper caught Peak Season/lbs per boat per day	>300
Quantity By-catch caught Peak Season/lbs per boat per day	30-90
Quantity Snapper caught Off Season/lbs per boat per day	90-200
Quantity By-catch caught Off Season/lbs per boat per day	10-30

Table 4.3 Shows particulars on the snapper fishery of San Miguel.

In peak season they do not need to fish at night for snapper as there are fewer requirements for bait and hence no need to spend daylight hours fishing for sardines. There are always a greater proportion of snapper caught than by-catch as with the other fisheries. Most catches are comprised of 90% snapper during peak season with the majority of the snapper caught being *L. guttatus*. The by-catch proportion remains the same in the off season, just less fish generally are landed. It is interesting to note that little of the San Miguel catch is made up of *L. peru* or *L. argentiventris*. Occasionally they do catch these species but in order to catch more *L. peru* they would have to travel to fishing grounds significantly further away and hence it does not often prove economical for the fishermen to do this.

While in the other villages it seems that the fishermen tend to place a heavier reliance on other fisheries in the snapper off season, this is less so in San Miguel as has been previously mentioned. The octopus fishery runs from May to October but the snapper fishery continues throughout. The catch in the off season, as has been shown, is roughly around half that caught during the peak season.

The three main snapper fisheries of the archipelago have been outlined above. While other fisheries do exist in some of the other villages, (see Appendix I for more details),

these three comprise the bulk of the fishing that occurs within Las Perlas. Due to the nature of the fishery at Village A and the availability of yearly as well as monthly data for this fishery, the remainder of the results section shall focus on data taken solely from this fishery. The data from Village A comprises of biometric data collected from January to May 2005 and catch data recorded locally by the buyer over the past seven years.

5.0 QUANTITATIVE RESULTS

5.1 Biometric Dataset

This section of the results shall examine the biometric data collected from the Village A fishery between January and May 2005. The type of data collected included total length, standard length, total weight, gonad maturation stage, sex etc. The sample size of this dataset is relative large.

Species	**Length-Weight Records**	**L-W and Gonad Records**
Lutjanus peru	984	806
Lutjanus guttatus	2573	772
Lutjanus argentiventris	168	56

Table 5.1 Shows extent of data available on species covered within the results section.

Table 5.1 clearly shows that the quantity of data available for both *L. peru* and *L. guttatus* is sufficient for any sex, length or weight analysis to be performed with a high degree of confidence. The extent of data available for *L. argentiventris* is much less and hence the types of analysis that can adequately be performed on it will be limited. The first type of analysis to be performed will be to examine the length-weight relationships of the two main species for which there are sufficient records. For this reason it is important to know the extent of the dataset that is being manipulated.

5.2 Length Weight Relationships

The weight of a fish increases in relation to the increase in volume and so the relationship between length (L) and weight (W) can be described using a power function of the form:

$$W = aL^b \qquad (1)$$

Transforming Length-Weight by Logs

If length and weight are transformed to logs then the relationship becomes:

$$\text{Log}_e \text{ W} = \log_e a + b \log_e \text{ L} \qquad (2)$$

In this form, *a* and *b* can be determined from a plot of $\log_e$ W(*y*) against $\log_e$ L(*x*) where $\log_e a$ is the intercept and *b* is the slope of the fitted linear relationship (Jennings *et al.*, 2001).

5.2.1 Logged Length-Weight Analysis for L. peru

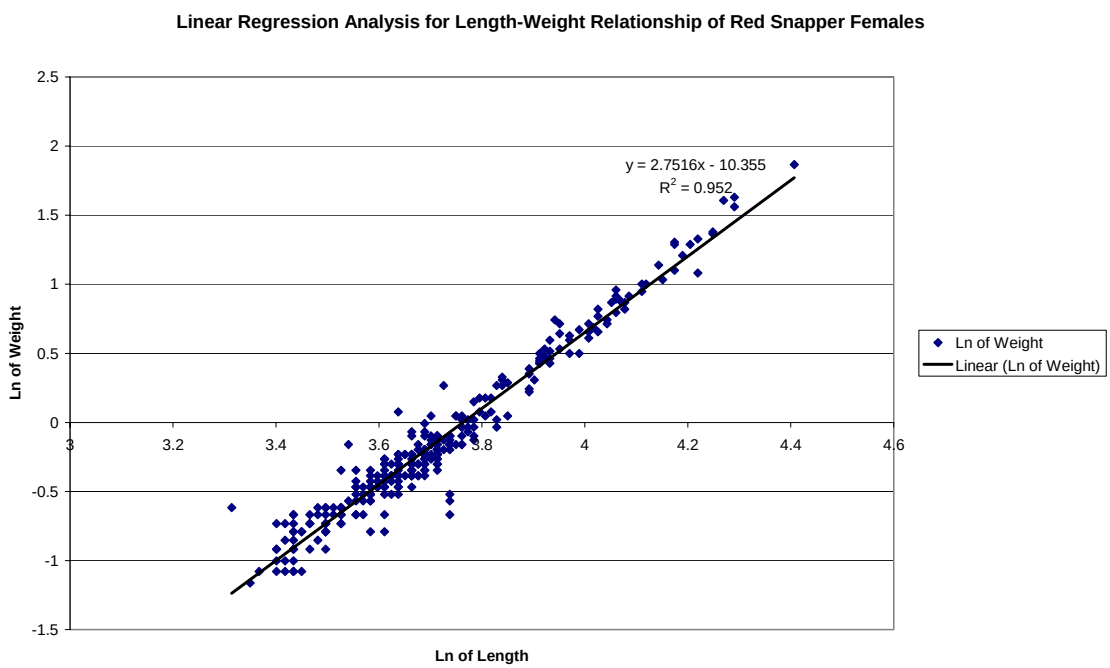

Figure 5.1 Linear regression analysis of logged length-weight relationship for female *L. peru* (y = 2.7516x – 10.355, R^2 = 0.952, *p* = <0.001, *n* = 317).

With the standard linear equation being $y = bx + a$ and using the formula above it is possible to quantify both *a* and *b* length-weight parameters.

$b = 2.7516$. $\log_e a = -10.355$ and hence $a = 3.18^{-05}$.

These length-weight parameters compare with $a = 0.0142$ and $b = 3.0000$ (Allen, 1985) for *L. peru* but it should be noted that the latter parameters are for both sexes together; comparative linear regression analyses for length-weight relationships for both sexes can be seen later in this section.

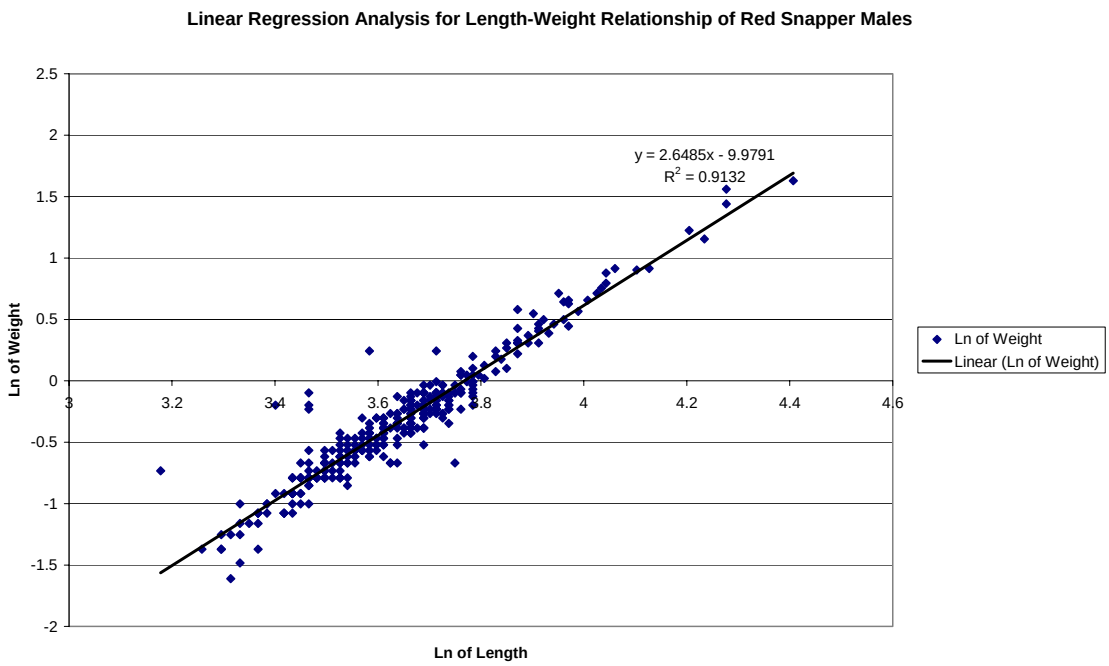

Figure 5.2 Linear regression analysis of logged length-weight relationship for male *L. peru* (y = 2.6485x – 9.9791, $R^2 = 0.9132$, $p = <0.001$, $n = 354$).

Figure 5.3 Linear regression analysis of logged length-weight relationship for both sexes of *L. peru* (y = 2.6464x – 9.9963, $R^2 = 0.931$, $p = <0.001$, $n = 671$).

	b	$\text{Log}_e\ a$	*a*
Allen (1985)	3.0000	N/A	0.0142
Female *L. peru*	2.7516	-10.355	3.1833^{-05}
Male *L. peru*	2.6485	-9.9791	4.6359^{-05}
Both Sexes	2.6464	-9.9963	4.5568^{-05}

Table 5.2 Compares length-weight parameters for *L. peru* for different sexes and from another source (Allen, 1985).

5.2.2 Logged Length-Weight Analysis for L. guttatus

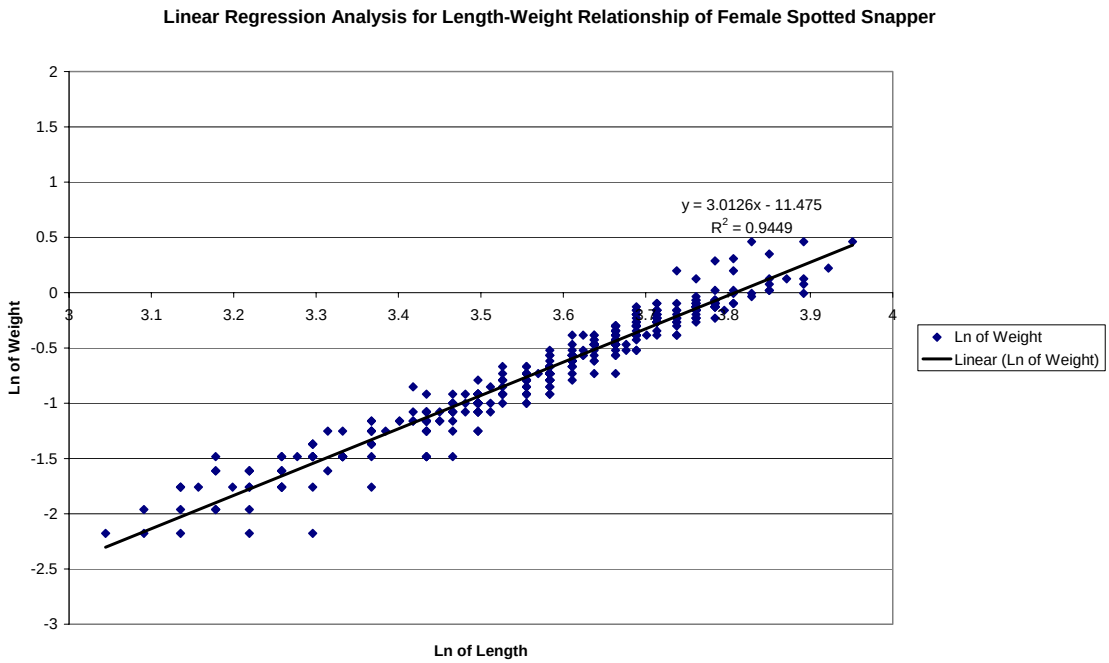

Figure 5.4 Linear regression analysis of logged length-weight relationship for female *L. guttatus* (y = 3.0126x – 11.475, $R^2 = 0.9449$, $p = <0.001$, $n = 434$).

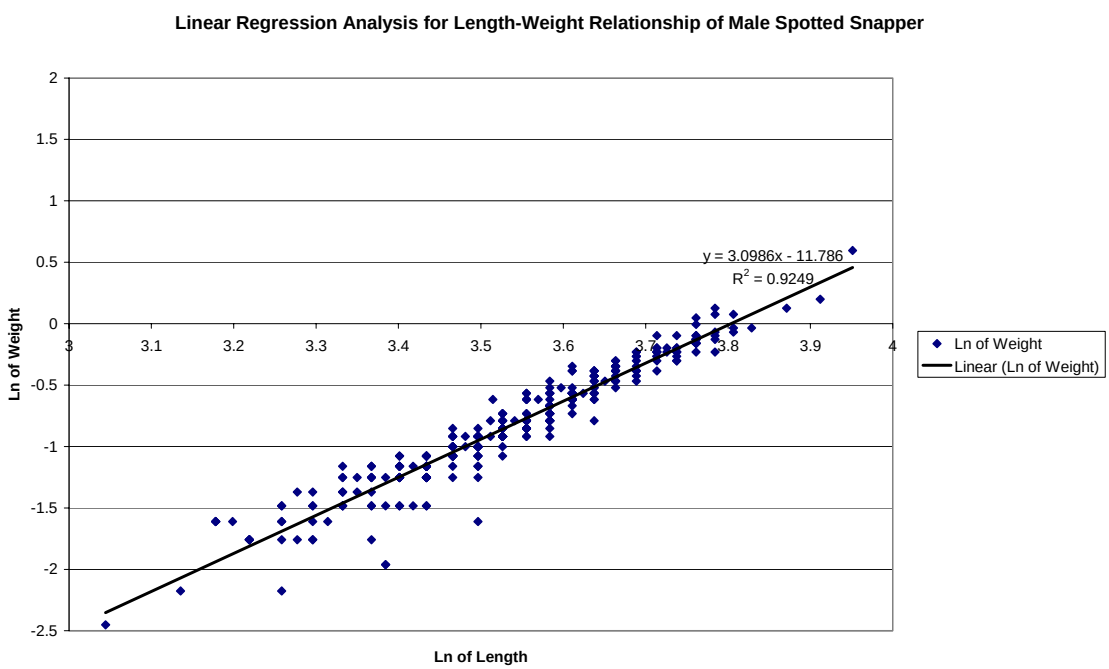

Figure 5.6 Linear regression analysis of logged length-weight relationship for male *L. guttatus* (y = 3.0986x – 11.786, $R^2 = 0.9249$, $p = <0.001$, $n = 338$).

Figure 5.7 Linear regression analysis of logged length-weight relationship for both sexes of *L. guttatus* (y = 2.8778x -10.984, $R^2 = 0.917$, $p = <0.001$, $n = 772$).

	b	$\text{Log}_e\ a$	*a*
Allen (1985)	3.0000	N/A	0.0143
Female *L. peru*	3.0126	-11.475	1.0387^{-05}
Male *L. peru*	3.0986	-11.786	7.6104^{-06}
Both Sexes	2.8778	-10.984	1.6971^{-05}

Table 5.3 Comparing Length-weight parameters for *L. guttatus* for different sexes and from another source (Allen, 1985).

5.2.3 Cubed Length-Weight Analysis for L. peru

In order to make a direct comparison between the Length-Weight parameters for this species given by Allen (1985) and those drawn from these results it is also necessary to perform linear regression analysis of the data for the two main fish species using the parameters as set down by Allen (1985). Allen (1985) determines the slope *b* for *L. peru* to be 3.0000. Therefore following the Length-Weight relationship equation, $W = aL^b$, it is

necessary to cube the length data. Cinco (1982) also demonstrates the common use of the 'cube law' with respect to calculating Length-weight relationships of other fish species.

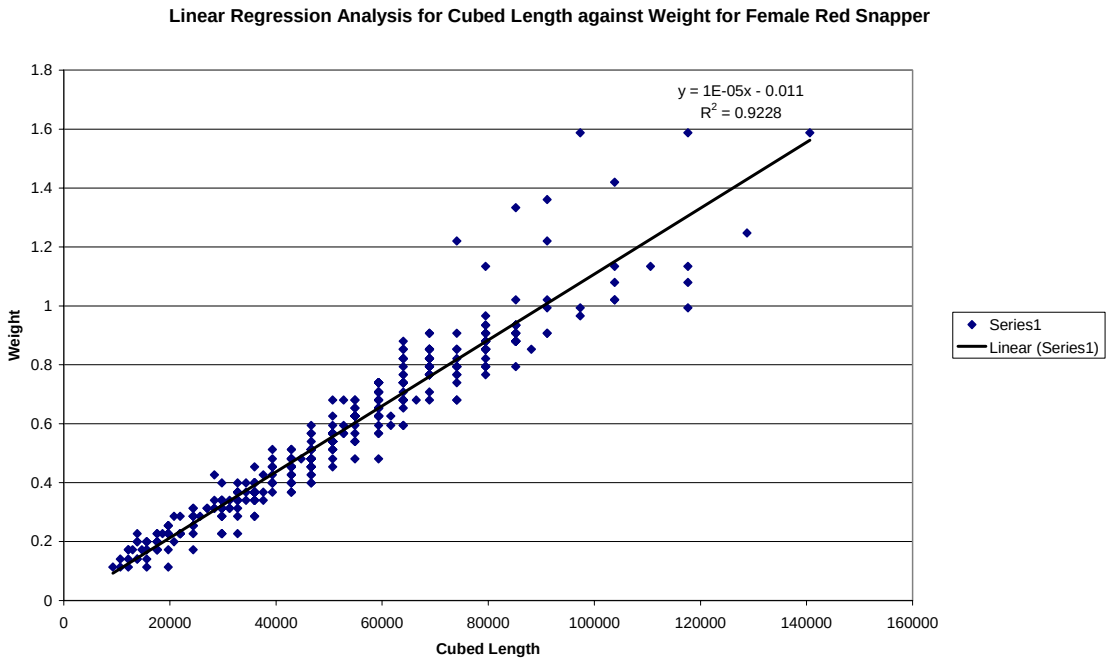

Figure 5.8 Linear regression analysis for cubed length against weight for female *L. peru* ($y = 1E^{-05}x - 0.011$, $R^2 = 0.9228$, $n = 317$).

As the R^2 value is 0.9228 for the above cubed analysis while the R^2 value is 0.952 for the logged analysis of the same data, this indicates that the latter method is a more accurate means of performing linear regression analysis on the data.

The values for *a* and *b* for this study are different to those recorded by Allen (1985) however it is not possible to determine clearly whether the difference is attributable to biological differences between the datasets or methodological differences within the analysis.

5.2.4 Statistical Analysis of Length-Weight Relationships for L. peru *and* L. guttatus

A statistical test was performed in order to identify if the L-W relationship differed significantly in relation to sex for these two species. An analysis of covariance (ANCOVA) was performed using SPSS software.

Tests of Between-Subjects Effects

Dependent Variable: logmass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	179.377(a)	3	59.792	3280.011	.000
Intercept	179.624	1	179.624	9853.587	.000
sexm1f2	.062	1	.062	3.375	**.067**
loglength	171.556	1	171.556	9410.972	.000
sexm1f2 * loglength	.063	1	.063	3.429	.065
Error	12.159	667	.018		
Total	230.479	671			
Corrected Total	191.536	670			

a **R Squared = .937 (Adjusted R Squared = .936)**

Table 5.4 ANCOVA test using SPSS on length-weight relationship for *L. peru*.

Table 5.4 shows the significance of both the slope and the interception to be Not Significant (0.067 and 0.065) while the significance of the relationship between length and weight to be highly Significant (0.000), as might be expected. This means that there is no significant difference in the Length-Weight relationship between the sexes of *L. peru*. Furthermore, the R^2 value is very high (0.937), indicating that the dataset has a clear linear relationship between length and weight once logged. This is to be expected as weight (or mass) is measured in three dimensions unlike length.

The same pattern can be seen in the analysis of *L. guttatus* in Table 5.5 below. The data shows both the slope and interception to be Not Significant (0.138 and 0.145), while again the clear strong statistical relationship between length and weight alone. Hence, again the Length-Weight relationship for *L. guttatus* does not seem to differ significantly between the sexes.

Tests of Between-Subjects Effects

Dependent Variable: lnmass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	183.244(a)	3	61.081	3874.003	.000
Intercept	193.838	1	193.838	12293.944	.000
sex	.035	1	.035	2.209	.138
lnlength	169.376	1	169.376	10742.494	**.000**
sex * lnlength	.034	1	.034	2.128	.145
Error	12.093	767	.016		
Total	624.911	771			
Corrected Total	195.337	770			

a R Squared = .938 (Adjusted R Squared = .938)

Table 5.5 ANCOVA test using SPSS on length-weight relationship for *L. guttatus*.

5.3 Length Frequency Analysis

5.3.1 Length Frequency Analysis for L. peru

Figure 5.9 indicates length frequency distribution for *L. peru* sampled from within the fishery of Village A for the period January to May 2005. All data were collected from measurements taken in the field and recorded by the same individuals throughout the period.

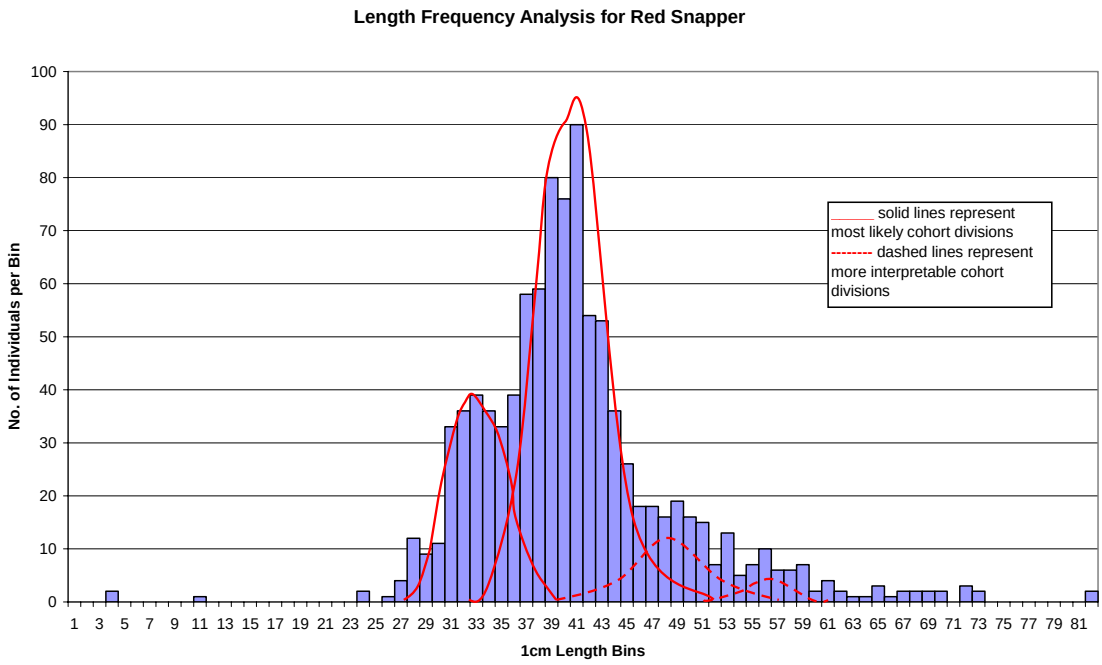

Figure 5.9 Length frequency distribution for *L. peru*, Village A fishery, Jan-May 2005 (n = 984).

Figure 5.9 above indicates that fish are being removed from the stock at ca. 25cm in length up to ca. 73cm. The highest numbers of individuals being caught within any one length class are around the 39-41cm length range. Applied over the histogram are rough estimations of possible age cohorts. The first two cohort classes support a fairly strong hypothesis, however the remaining two (dashed lines) are decidedly weaker as the age cohorts have begun to merge into one another and are less clearly defined. The cohort groupings can be further drawn out statistically by applying normative distributions to the data mode by mode, as seen below.

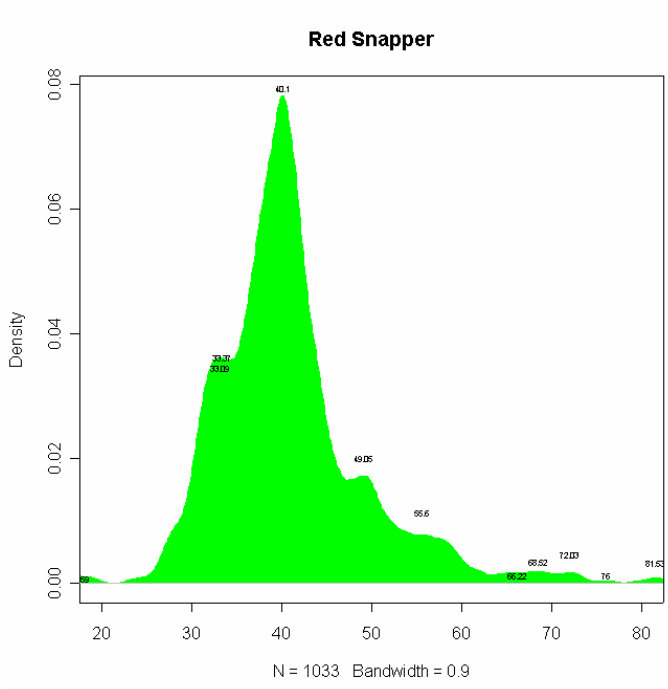

Figure 5.10 Density plot of length frequency data for *L. peru*, Village A fishery, Jan-May 2005 (*n* = 984).

Figure 5.10 represents a density plot of the length-frequency data for *L. peru* and picks out length peaks at 33cm, 40cm and 49cm. These three peaks correspond well to the first three age cohorts identified on the histogram, indicating that there are two or three age cohorts that can reasonably be extrapolated from the length-frequency analysis. However, the age cohorts are not displayed with enough strength for further modelling, (i.e. the von Bertalanffy growth curve), to be attempted with sufficient confidence. Higher resolution data, (i.e. length measurements taken to the nearest mm), enable density plots to be used with greater confidence and are also often easier to interpret (Side, pers. comm.). This is an improvement that could be made to the methodology of the study. Limited field equipment inhibited the taking of more precise measurements at the time of the study.

It is also equally possible that the ill-defined cohort classes could be a result of heavy fishing mortality obscuring any clear pattern with respect to age cohorts. This is often the case with data from fisheries that have undergone heavy fishing mortality (Side, pers. comm.). In this case it is possible to hypothesise that F>M, (where F = Fishing Mortality and M = Natural Mortality). Z = F + M, (where Z = Total Mortality). The Total Mortality

rate in this case is likely to be made up predominantly from F, as the results seem to indicate very high fishing pressure. Where K represents Growth Rate; a higher K value will generally support a higher F (and hence Z). Without better age analysis it is impossible to adequately produce a von Bertalanffy growth curve from the length frequency data shown above. Yet, knowing that L_{inf} for this species is likely to lie between 85cm and 95cm (other sources suggest an L_{inf} of 87cm (Allen, 1985)) and knowing also that the species lives for approximately 10 years or more; it would seem reasonable to suggest a K value of between 0.2 and 0.3 (Side, pers. comm.). This is confirmed by other sources, which place K = 0.26 for the species (Allen, 1985).

5.3.2 Calculating Z/K and Z using L. peru *Fishery Data*

There are a number of methodologies currently in use for calculating Total Mortality (Z) within a fishery. Some require known values for L_{inf} [Length Infinity, i.e. the asymptotic length or the mean length of very old fish (Sparre and Venema, 1998)], (e.g. Jones van Zalinge), and others can generate both a value for Linf and Z/K, (e.g. Powell-Weatherall).

(a) Powell-Weatherall Analysis for L. peru

This method produces a value for Z/K and for L_{inf} and is particularly suitable for situations where little or nothing is known about the fish stock in question (Sparre and Venema, 1998); an eminently suitable analysis for this fishery. On performing the analysis on a array of length 'bins', a range of values were produced for Z/K and L_{inf} (see below). (Full details of this analysis can be found in Appendix II).

Bin Size (cm)	**Z/K**	**Linf (cm)**
Bin 1	1.98	82.15
Bin 2	3.89	91.5
Bin 5	8.13	121.29

Table 5.6 Shows Z/K and Linf values produced from Powell-Weatherall analysis.

It is unlikely that the final L_{inf} display in the table is accurate as it is significantly greater than the recorded maximum length for the species; recorded maximum lengths are usually greater than the L_{inf} value for any given species. However the figures give an indication of the potential range of both Z/K and L_{inf} for this fishery. Further analysis is required to corroborate these figures.

(b) Jones and van Zalinge Analysis for L. peru

For this analysis it is necessary to input a L_{inf} value, such as was hypothesised previously. While the L_{inf} value has been to a degree supposed; this analysis is known to perform well, especially on large datasets such as that available in this study (Side, pers. comm.). A range of L_{inf} values were input and the results can been seen in the table below. (Full details of this analysis can be found in Appendix II).

Bin Size (cm)	**Input value of Linf**	**Z/K**
Bin 1	85	3.68
Bin 1	90	4.47
Bin 1	95	5.23
Bin 5	85	3.88
Bin 5	90	4.60
Bin 5	95	5.34

Table 5.7 Shows Z/K values produced from Jones and van Zalinge analysis.

The regression plots from these two analyses both have high R^2 values, with the lowest being on the Bin 5 analysis using Powell-Weatherall ($R^2 = 0.87$), which has already been noted to produce an unexpectedly high L_{inf} value and hence has already been discounted. Furthermore all regressions perform as expected, i.e. as Z/K increases so does the L_{inf}.

Therefore, according to these results;

- L_{inf} is likely to lie between 85cm and 95cm;

- Z/K is likely to lie between 3.6 and 5.3;

- and on the basis that K lies between 0.2 and 0.3 there must be a Total Mortality Rate (Z) of between 0.72 and 1.59.

To go beyond this level of analysis, based on the dataset available, would be placing too much weight on the initial findings and hypotheses. From the data it has been possible to gain a range of values for growth rate (K) for the species and an estimation of total mortality (Z) of the stock. Ideally it would be useful to gain estimates for the breakdown of Z in order to get a measure of F and M. However, this may again be extrapolating to far from the initial dataset. What can be hypothesised however is that the bulk of the fishery may be relying heavily on three age classes, if K does indeed lie between 0.2 and 0.3 (Side, pers. comm.). It would seem fair to postulate that fish begin to enter the fishery at around two years old (ca. 33cm length) with the bulk of the catch being made up of 3+ year old fishes and with older years contributing less and less. Although, as has been mentioned, the reliance on the age cohort classes coming out from the data should not be too great as the peaks may be only a residual pattern of cohort classes, altered quite dramatically by the substantial fishing pressure being put on them.

5.3.3 Length Frequency Analysis for L. guttatus

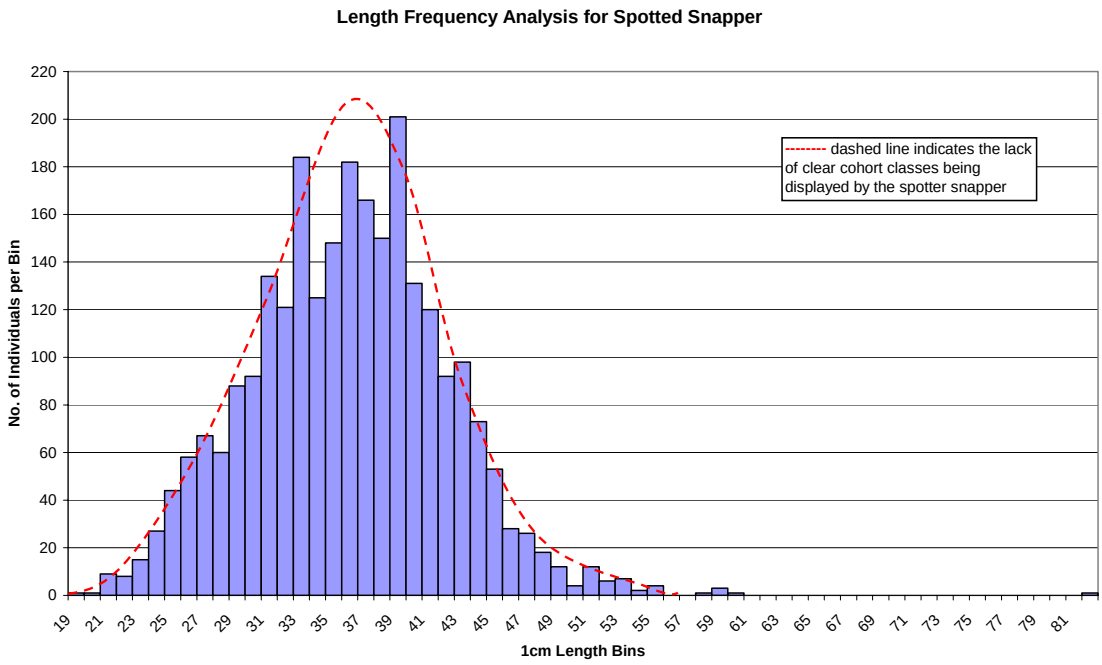

Figure 5.11 Length frequency distribution for *L. guttatus*, Village A fishery, Jan-May 2005 (*n* = 2573).

Figure 5.11 shows the length frequency distribution for *L. guttatus* sampled from within the fishery of Village A for the period January to May 2005. The data for *L. guttatus* differs dramatically from that of *L. peru*. Firstly the spread of lengths caught is much wider with *L. guttatus* and there are no age cohorts being displayed in any way, unlike the peaks seen in the dataset for *L. peru*. This could possibly be an indication that spawning of *L. guttatus* spans the entire year and that spawning of *L. peru* may be more seasonal. If spawning were seasonal for *L. peru* this would be a potential explanation for the slight display of cohort classes throughout the length frequency data. However, it is impossible to say conclusively whether or not this hypothesis is correct as the spread of length frequency could also be heavily influenced by fishing pressure. High fishing mortality could potentially influence the shape of the length frequency curve to a greater degree than expected and subsequently point to cohort classes that are not in fact present. However, due to the fact that no length frequency peaks are display in the *L. guttatus* data and hence no age classes are discernable in any form; it is not necessary to perform more complex analysis on the *L. gutattus* length frequency dataset.

Figure 5.11 does indicate that fish are being removed from the stock at lengths between ca. 21cm to 60cm. Furthermore, the spread of individuals being taken at certain sizes is much broader than that seen with *L. peru* and there is a less obvious peak in length at which the most individuals are being removed from the population.

5.4 Proportion of Fish Caught Sexually Mature

Data on this section is taken from biometrics collected over a five month period. All data, where sex and stage of maturity was recorded, was included.

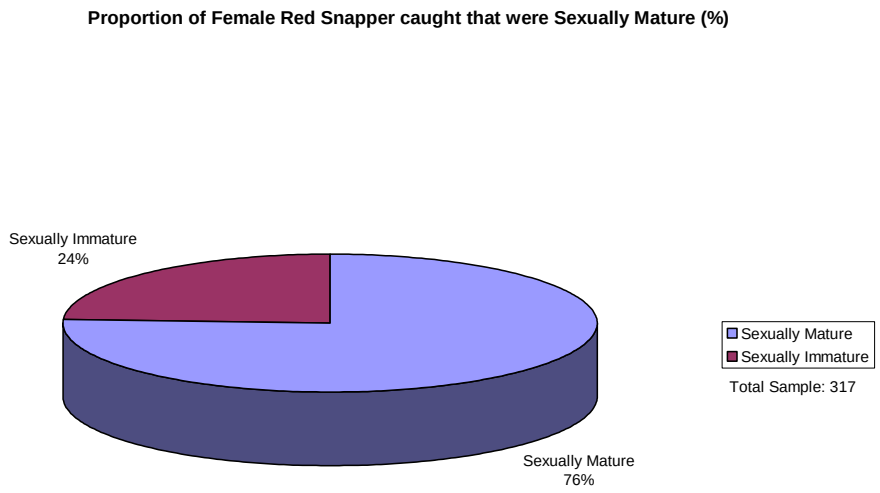

Figure 5.12 Proportion of female *L. peru* caught that were sexually mature compared to immature (*n* = 317).

Figure 5.12 above demonstrates that 24% of all female *L. peru* caught were sexually immature and 76% were mature. Therefore almost a quarter of the female *L. peru* portion of the catch were immature.

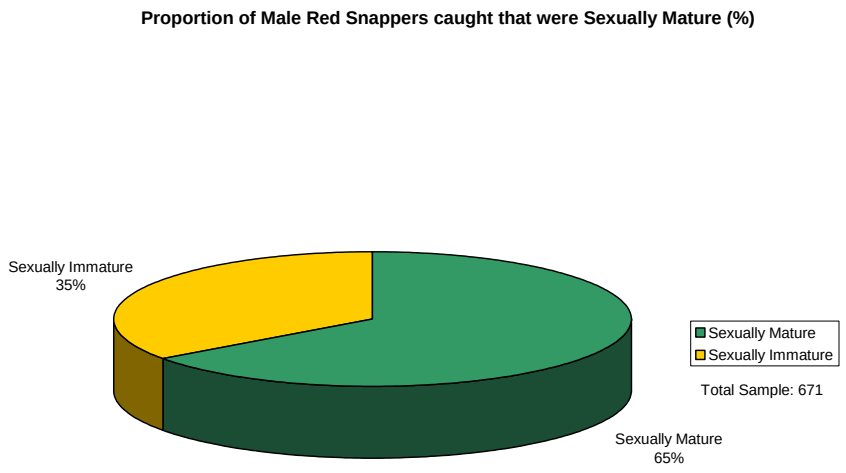

Figure 5.13 Proportion of male *L. peru* caught that were sexually mature compared to immature (n = 671).

Figure 5.13 shows that the proportion of males being caught throughout immaturity is slightly higher than in the females for this species (35%). It is possible that a number of samples were misidentified as immature for males due to gonads being removed accidentally by surveyors. However it seems unlikely that this can adequately explain the discrepancy as the frequency of such errors was small.

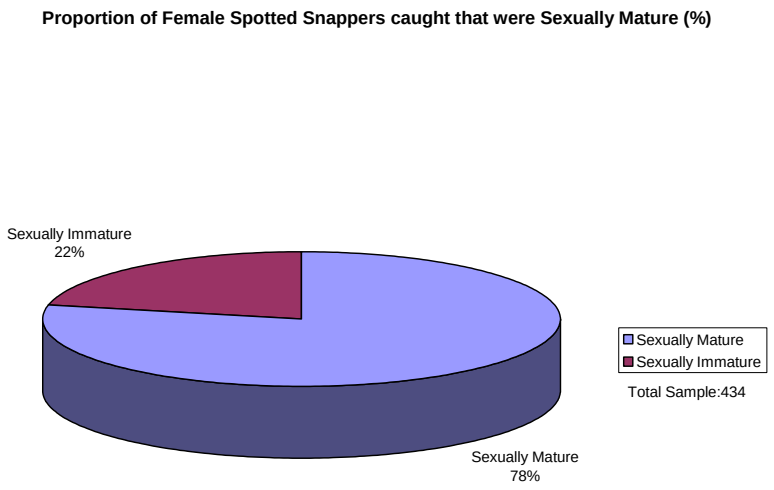

Figure 5.14 Proportion of female *L. guttatus* caught that were sexually mature compared to immature (*n* = 434).

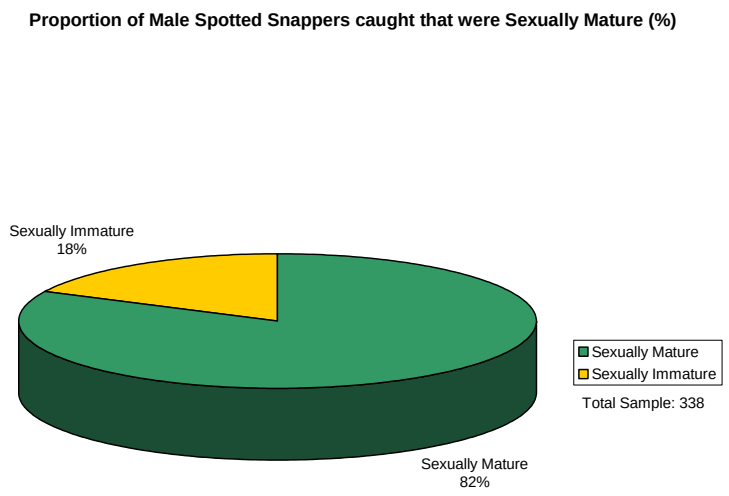

Figure 5.15 Proportion of male *L. guttatus* caught that were sexually mature compared to immature (*n* = 338).

The ratios of female *L. peru* and *L. guttatus* being caught sexually immature are very similar, (24% and 22% respectively), however the ratios of males being caught were shown to be quite different, (35% of *L. peru* caught immature and 18% of *L. guttatus*). There is no obvious explanation for this discrepancy and the point would possibly merit further investigation in any future study. Nevertheless, all of these figures are high in terms of the proportions of individuals being caught sexually immature. Overall, 31% of *L. peru* that make up the Village A fishery are being landed sexually immature and 20% of *L. guttatus*. This is a significant proportion of the catch being landed immature and subsequently a large percentage of the population that is not being able to reach its first breeding season. This has huge implications for the fishery in terms of future recruitment of stock.

5.5 Sexual Maturity in Relation to Length

This section examines the relationship between length of individuals and the point at which sexual maturity is reached. This relationship is important to understand in relation to fisheries as not all fish landed can be assessed for sexual maturity. It is much easier and faster to measure fish length and hence if the relationship between these two parameters can be defined with respect to a particular species then this has important implications when trying to assess the proportion of individuals being landed before sexual maturity. Obviously in the data above it was possible to define the proportion of catch being landed sexually immature as a large dataset was available on gonad stage, however such information is not always available and hence the importance of defining the relationship between sexual maturity and Total Length.

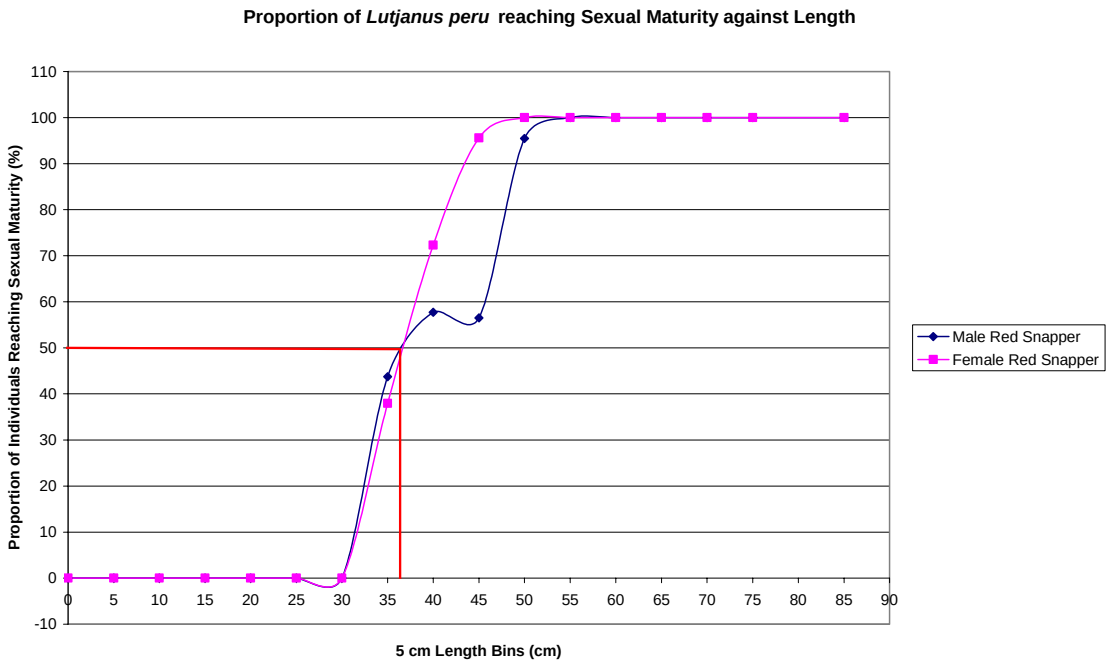

Figure 5.16 Maturity ogive calculated for *L. peru* using 5cm length 'bins' from biometric data collected from Village A, Jan-May 2005 ($n_m = 354$, $n_f = 317$).

Figure 5.16 displays length increments against proportion of individuals within each length 'bin' that have reached sexual maturity. Hence, the longer an individual, the older it is likely to be and subsequently the greater the proportion of individuals that have reached sexual maturity. Figure 5.16 displays the point of at which 50% sexual maturity is reached, i.e. where 50% of the individuals within a size class have achieved sexual maturity. For *L. peru* above, this point is shown to be the same for both sexes, at length ca. 36cm. The is an important finding as it can compared to the first length peak within the length frequency analysis shown previously, which occurred at 33cm. It is not known whether this length class reflects a first or second year cohort; however what can be stated with certainly is that a large number of individuals are being landed before the length at which 50% sexual maturity is reached (L_{50}), i.e. 36cm. 26% of the total catch is made up of individuals that are 36cm in length or less, i.e. below L_{50}. Furthermore, if 33cm length does correspond approximately to the second year class then a significant proportion of the population is being removed from by the fishery before it has had a chance to reproduce. According to Figure 5.16, at 33cm length only about 25% of

individuals will have reached sexual maturity. The second peak highlighted by the length frequency analysis occurred at 40cm. If this were to be a second age cohort then 60-70% of individuals would have reached sexual maturity by this length, according to the maturity ogive for *L. peru*. This is a much better proportion of individuals having reached the age of maturity but even this may not be sufficient to ensure sustainable recruitment for the fishery.

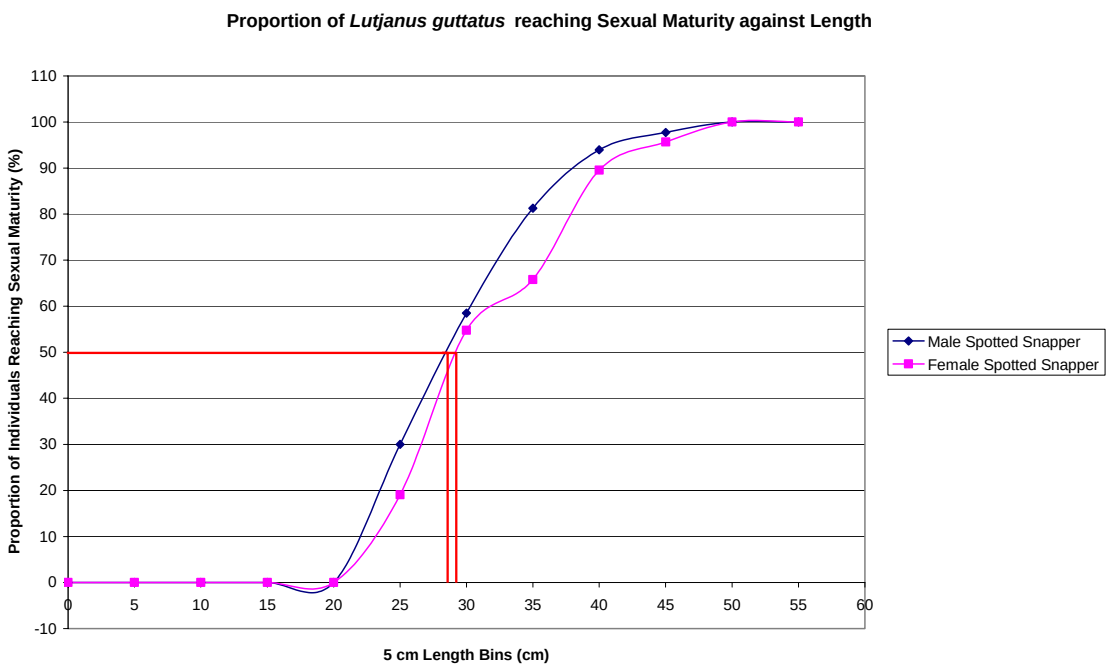

Figure 5.17 Maturity ogive calculated for *L. guttatus* using 5cm length 'bins' from biometric data collected from Village A, Jan-May 2005 ($n_m = 338$, $n_f = 434$).

Figure 5.17 shows percentage of individuals reaching sexual maturity against length for the species *L. guttatus*. The point at which 50% of individuals have reached sexual maturity (L_{50}) is shown to be ca. 28cm length. There is a slight difference in length between the sexes, but as it is less than 1cm it is not significant. Sexual maturity appears to be achieved at a significantly smaller size for *L. guttatus* than for *L. peru* (28cm compared with 36cm). As it was not possible to identify age cohorts from the length frequency analysis of *L. guttatus* little interpretation can be done with respect to age at sexual maturity. But comparisons can be made to the lengths at which a greater

proportion of individuals were being caught. The bulk of the fishery for *L. guttatus* appears to be made up of individuals greater than 28cm in length; however a proportion of the catch is made up of individuals that are as small as 22cm in length. 11% of the catch is made up of individuals that are 28cm in length or less, i.e. below L_{50}.

5.6 CPUE Analysis

An important point to note when interpreting CPUE results from small-scale fisheries data is that fishermen may tend to increase their effort in times when catch per effort is high and reduce this effort when catch per effort is low (Pauly *et al*., 1982). However, this issue is not necessarily a problem with respect to the data analysed in this section as CPUE data were gathered from buyer records and hence it may be fairly safely presumed that almost all caught at all times throughout the year went through the buyers books and hence any fluctuations in effort would be equally likely to be translated through to the CPUE analysis.

On brief examination of the large dataset available on the Village A snapper fishery from the buyer's records it was clear that catch fluctuated dramatically from year to year.

5.6.1 Catch on a Yearly Basis resulting from the Snapper Fishery of Village A

Below, Figure 5.18 shows yearly trends in total catch landed at Village A for snapper over a period of the last seven years.

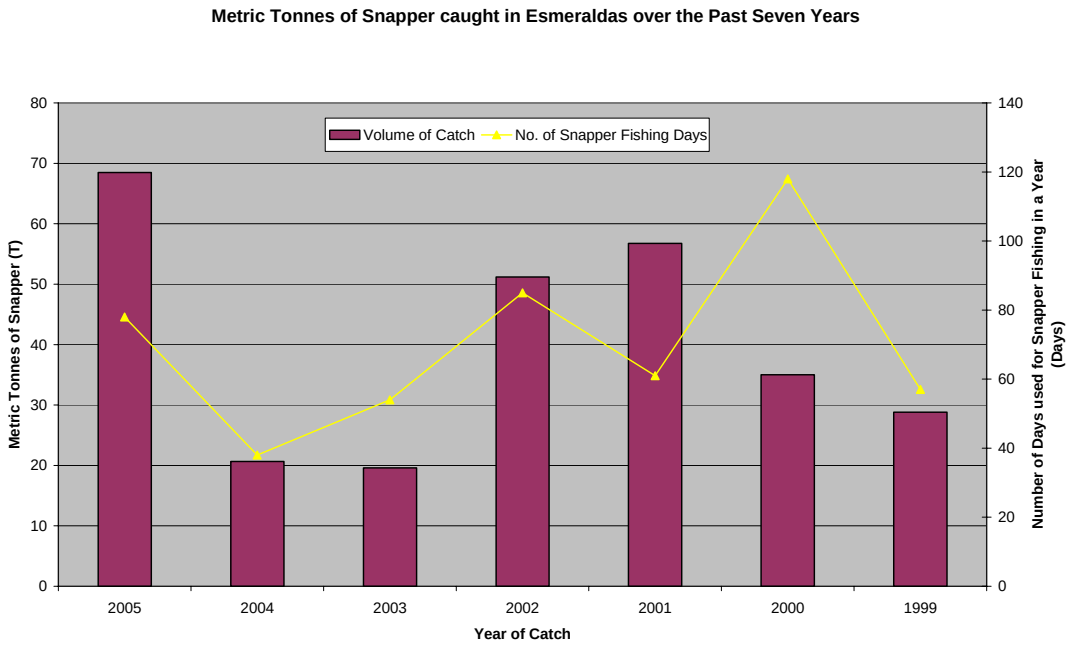

Figure 5.18 Shows metric tonnes of snapper caught by the Village A fishery over the last 7 years.

There is no clear pattern discernable from the yearly total catches; however it is noticeable that the 2005 catch is substantially larger than the previous two years. Further analysis will be necessary to extract any more information regarding the importance of these figures.

5.6.2 CPUE Analysis of Village A Data

It is possible to gain information on CPUE for this fishery as the records over the past seven years have included not only weights of fish landings but also the number of days over which these landings were taken and finally the number of fishermen per boat on each fishing trip, (and subsequently the number of lines per boat). With this type of data available there is enough information to perform reasonable CPUE analysis. Unfortunately there was not enough resolution in the data to distinguish between CPUE for different snapper species; however a measure of CPUE for combined species was possible. Furthermore, it is likely that the yearly catch is predominantly comprised of *L. peru* and *L. guttatus* with very few other snapper species occurring.

For the assessment of snapper total catch CPUE shall be expressed in kg/number of lines x fishing days, following the methodology for assessing CPUE set out by Mendoza and Larez (2004). Within the buyer's records each catch is noted under the boat's 'skipper'. Therefore each record represents the catch of 3-4 fishermen, (for the analysis it shall be presumed that there are 3 fishermen per boat). Hence each record shall account for a total of 3 lines in the calculation of CPUE.

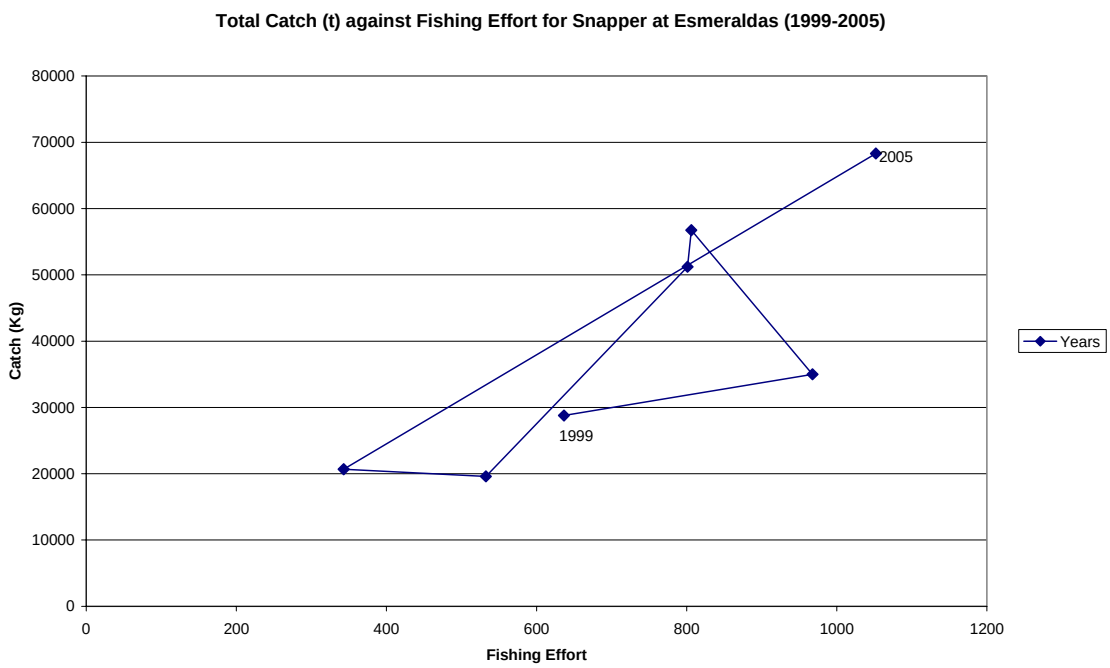

Figure 5.19 Relation between total catch (t) and fishing effort for the Village A snapper fishery during the period 1999-2005.

Figure 5.19 represents fishing effort in number of lines x days fishing. It shows that catch peaked in the 2005 season but that fishing effort was also at its peak at this time.

5.6.3 Estimating Maximum Sustainable Yield (MSY) using the Schaefer Model

The Maximum Sustainable Yield (MSY) can be estimated from the following data:

F(i) = effort in year i = 1, 2,…..,n

Y/f = yield (catch in weight) per unit of effort in year i.

Y/f may be derived from the yield, Y(i), of year i for the entire fishery and the corresponding effort, f(i), by:-

$$Y/f = Y(i)/f(i),\ I = 1,2,\ldots,n \qquad (3)$$

The simplest means of expressing yield per unit of effort, Y/f, as a function of the effort, f, is the linear model suggested by Schaefer (1954):

$$Y(i)/f(i) = a + b \times f(i) \ \text{ if } f(i) \leq -a/b \qquad (4)$$

This model requires that the slope, b, must be negative if the CPUE, Y/f, decreases for increasing effort, f. The intercept, a, is the Y/f value obtained just after the first boat fishes on the stock for the first time. The intercept value therefore must be positive. Thus, –a/b is positive and Y/f is zero for f = -a/b. Since a negative value of CPUE (Y/f) is not possible, the model only applies to f values lower than –a/b (Sparre and Venema, 1998).

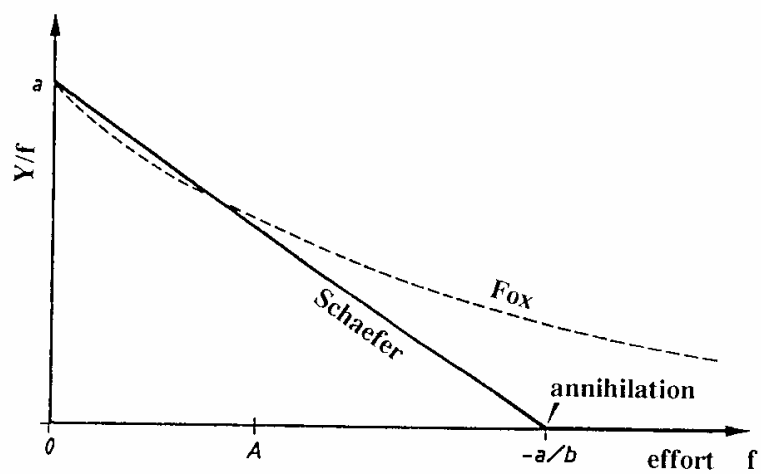

Figure 5.20 Illustrating the different assumptions behind the Schaefer and Fox models (taken from Sparre and Venema, 1998).

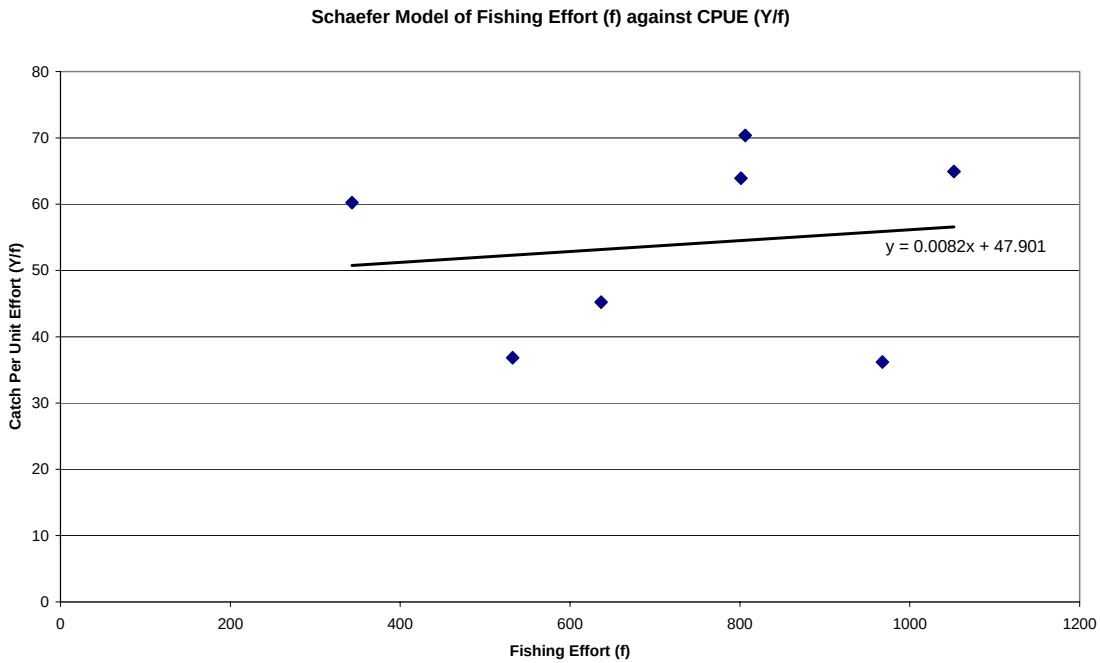

Figure 5.21 Schaefer model fit of observed CPUE against effort data for the snapper fishery of Village A during the period 1999-2005.

Figure 5.21 above demonstrates the Schaefer model as applied to the Village A CPUE data calculated using the methodology set out previously. The plot produced by the data in no way corresponds to an expected Schaefer plot, i.e. decreasing CPUE with increasing effort. Within a Schaefer model the slope, b, must have a negative value, as stated previously, and this is not shown to occur. Therefore the data does not correspond to a typical fishing pressure pattern as required by the Schaefer model. Obviously, it is intuitive that with a continued increase of fishing pressure over the years; CPUE must decrease. That this pattern is not displayed could be a result of the fact that the dataset spans only seven years. This short time span may not be sufficient for a true pattern to be discernable. Alternatively, it is possible that fishing pressure has coincided with peak years of snapper abundance. This is not improbable as fishermen have commented that they increase fishing effort when they know large quantities of snapper are around in order to maximise their return for the investment of fuel required to go fishing in the first place. A final possible hypothesis is that some external causality is influencing the pattern of CPUE; an issue that will be examined further in the next section. Ultimately however,

the flat line regression produced by the Schaefer plot indicates that it may not be possible to interpret the MSY from the current dataset.

5.6.4 Further CPUE Analysis – Identifying Trends

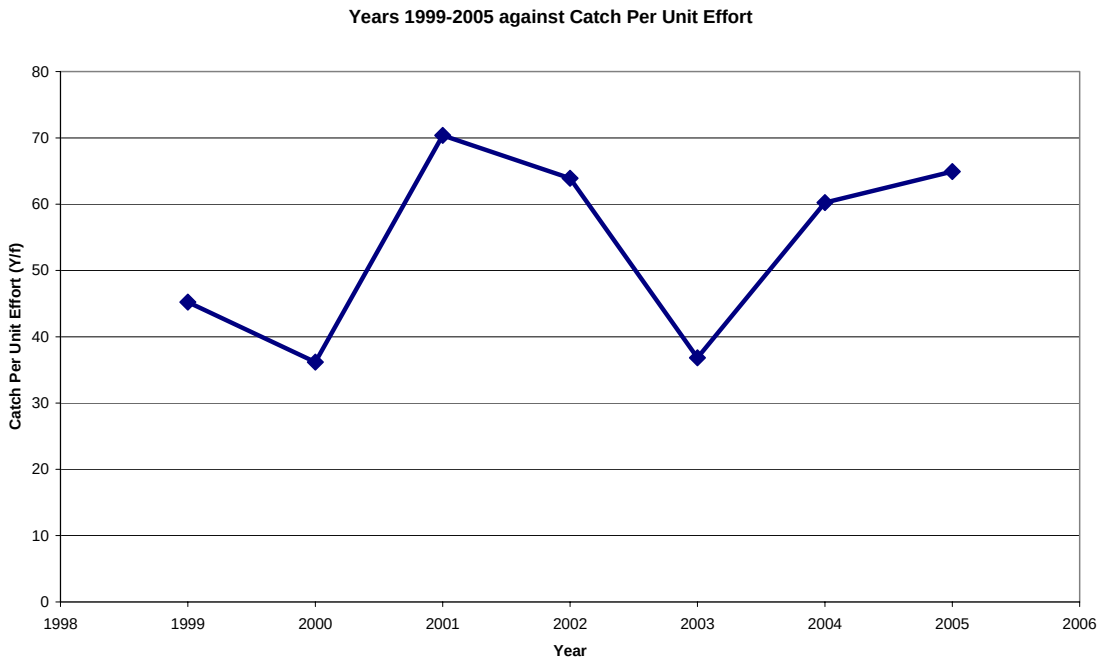

Figure 5.22 CPUE in relation to years for the Village A snapper fishery data, 1999-2005.

Figure 5.22 demonstrates further the unusual CPUE pattern displayed by the Village A fishery. As has been mentioned, the expected pattern with CPUE data is for a continued increase in fishing pressure to be matched with a continued decrease in CPUE. Therefore the expected plot would show a gradual decline in the CPUE from the top left of the figure to the bottom right. This pattern is not found in Figure 5.22 above. These unexpected findings may be a result of the fact that the fishery does not show the usual pattern of other fisheries; i.e. to increase fishing pressure continually over time. In fact Figure 5.22 shows fishing effort fluctuating dramatically over the short time period of the records. Increased fishing effort seems to be correlated with increased catch in some cases, e.g. 2005 and 2001. Although this relationship does not also coincide, for example there was increased fishing effort for 2000 that was not matched with an increased

proportion of catch (see Figure 5.19). The final figure (Figure 5.23) compares a plot of CPUE against actual catch data in order to further investigate the potential trend being displayed.

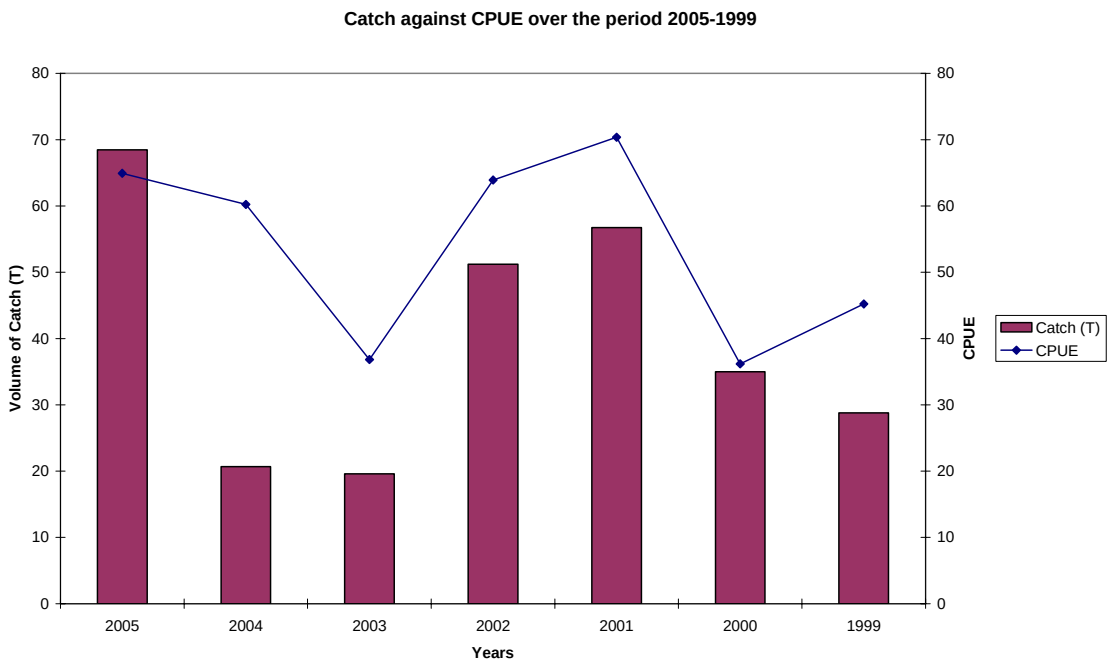

Figure 5.23 CPUE plotted against actual catch figures in tonnes over the period 1999-2005.

What Figure 5.23 indicates, (that figures previously have not clearly identified), is that there could well be a cyclic trend to the fishery. It is possible that if there is a cyclic pattern to the fishery it could potentially be linked to ENSO events. The presence of a cyclic pattern in the dataset would clearly explain the inconclusive findings of the Schaefer model. Hilborn and Waters (1992) found with a similar cyclic trend displayed by Pacific cod data that;

"The stock exhibits a strong cyclic trend, which the Schaefer model is totally unable to capture. The best Schaefer fit to these data is a flat line. The delay difference model, with a lag of three years to recruitment and a Ricker stock-recruitment curve ca capture the cyclic dynamics quite well".

Unfortunately it is not possible to proceed further with such time-delay analyses using the dataset currently available. Because of the ineffectiveness of using the Schaefer model in this scenario it is also not possible to quantify the Maximum Sustainable Yield (MSY) for the fishery. In order to quantify MSY it is necessary for the Schaefer model to produce a parabola from which to ascertain the point of MSY. The flat line created by the model is indicative of a dataset unsuitable for the Schaefer model approach.

With the dataset available from this study there is little more analysis that can be performed at this juncture. Had there been a longer period of data available it may have proved possible to quantify the MSY of the fishery and other biomass dynamics. This is worth bearing in mind for future studies concerning this fishery, as with a larger and longer-term dataset more reliable results may be forthcoming. However, the potential cyclic pattern within the dataset should also be recognised and the implications that this may have for future approaches to analysis should be noted.

6.0 DISCUSSION

6.1 General Characteristics of the Las Perlas Snapper Fisheries

Both *L. peru* and *L. guttatus* stock are relied upon heavily as a means of income for a large proportion of the population of the Las Perlas archipelago. Most fish caught are exported to the US and other countries abroad. Without this fishery there would be little employment left to the people of the archipelago other than subsistence agriculture. Therefore, aside from the ecological importance of conserving these fish stocks; there are crucial socio-economic reasons for ensuring the sustainability of the stock and the fishery associated with it. This study has aimed to highlight the extent of the relationship between the people of Las Perlas and this fishery. Furthermore, to quantify the extent of the fishery and reveal any significant trends or patterns that might be discernable from the fisheries records available.

Currently there is no control over the size at which snapper are caught, the length of season that fishermen can catch the stock in, the number of individuals that can be removed at any one time etc. The only limit placed on the fishery is that fish cannot be landed by gillnet. Therefore, there is the likelihood that the fishery is being exploited beyond the point at which it can sustain itself over the long-term. Fishermen have commented on the large-scale variability that appears to occur within the fishery and the general downwards trend that has been seen over recent years. No information could be gleaned as yet on if there is an environmental pattern to this variability but local sources confirm that there appears to be a close connection with ENSO events as well as the seasonal oscillation in temperature caused by upwelling around the region every year. Further work to investigate the strength and validity of this relationship would certainly appear merited.

6.2 Length Weight Relationships for Two Species of Snapper

An investigation into the Length-weight relationships for both *L. peru* and *L. guttatus* showed interesting results. As length and weight data were both available in large quantities for both species it was decided to perform an investigation into the L-W parameters, *a* and *b*, for the species and make a comparison of these findings with that of others from other studies into the respective species. Allen (1985) defined *a* and *b* for *L. peru* to be 0.0142 and 3.00, respectively. The linear regression analysis of the Village A data found *a* and *b* to be 4.5568^{-05} and 2.6464, respectively. These results are useful as they are similar to that of Allen (1985); indicating that the methods used for their production were appropriate. They also provide a useful comparative study by giving an alternative set of values to use for analysis of Length-weight relationships for this species when data on one or the other is not available. A similar pattern was found on analysis of the *L. guttatus* data (see Results section for details).

On performing a statistical analysis to compare the L-W relationships between sexes it was found that the L-W relationship did not differ significantly between the sexes. This was found to be the case for both species of snapper.

6.3 Estimation of L. peru *Growth Parameters*

Length frequency analysis and the use of a number of fisheries models, such as the Powell-Weatherall Analysis, identified a number of parameters relating to the growth of *L. peru*. It was found that L_{inf} for the species was likely to lie between 85 and 95cm, (supported by the findings of Allen (1985), i.e. L_{inf} = 87cm). Furthermore, that Z/K was likely to occur between 3.6 and 5.3. Finally, that K was likely to lie between 0.2 and 0.3 (supported by the findings of Allen (1985), i.e. K = 0.26) and hence that there must be a total mortality rate (Z) of between 0.72 and 1.59. Sparre and Venema (1998) define the gradations of exploitation in relation to Z as being the following:-

Light Exploitation: Z = 0.6

Medium Exploitation: Z = 0.9

Heavy Exploitation: Z = 1.2

With such a wide range in possible Z values for the Village A snapper fishery, it is not possible to say how close the stocks may be to collapse, if indeed such a thing were imminent at all. However, because the values do lie within the range of 'medium' to 'heavy' exploitation it is intuitive that some regulation of the fishery will be necessary, within the fairly immediate future.

6.4 Population Dynamic Findings from Biometric Analysis

In order to investigate any trends in population dynamics that may be occurring within the snapper stocks around Las Perlas, a close examination of the biometric data available was performed, including data that were collected throughout the time of the study and the period before, i.e. January to May 2005. Heavy fishing pressure seemed to be discernable in the length frequency plots for *L. peru*. The data indicated that *L. peru* were being removed from the fishery at ca. 25cm up to ca. 73cm, with the highest numbers of individuals being caught around the 40cm length mark. On the basis of maturity ogive analysis performed on the same dataset; it would seem likely that 50% sexual maturity in the population is reached at ca. 36cm for *L. peru* and ca. 28cn for *L. guttatus*. This means that 26% of the total catch of *L. peru* is made up of individuals that are 36cm or less and hence below L_{50}. The interpretation of sexual maturity proportions from length data is confirmed by the results of the actual gonad data available from the same dataset. The proportion of total catch for *L. peru* that were sexually immature were 24% for females and 35% for males. These results are taken from actual gonad samples and so are known to be accurate rather than just estimations calculated from other biometric parameters.

When the maturity ogive data for *L. peru* is compared to the length frequency analysis performed for the same species, there are also a number of interesting findings. From the maturity ogive analysis, it would seem that at 33cm length around 25% of individuals will have achieved sexual maturity. The length 33cm is picked out because this is the

length identified by the first peak in the length frequency analysis and hence likely to be the first age cohort displayed by the data. It is not known whether this first peak represents a true age class and if it does whether it represents year class 1 or 2.

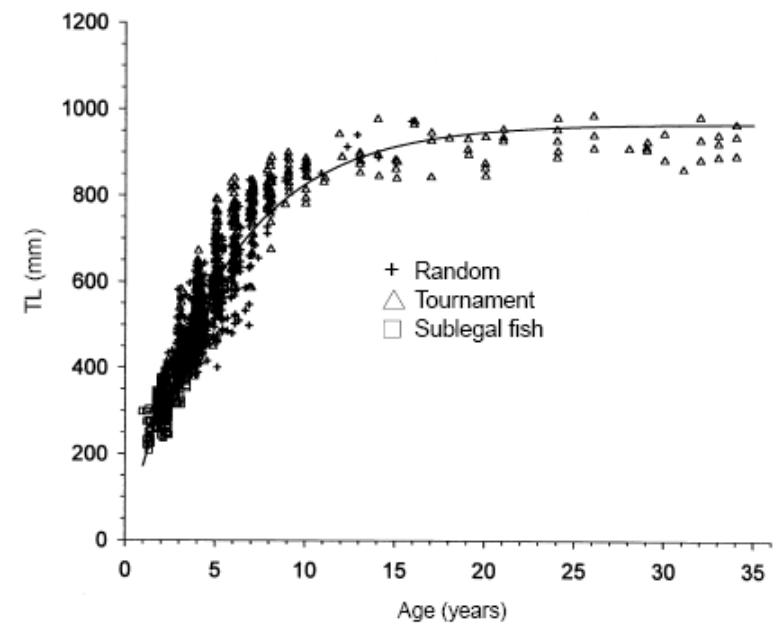

Figure 6

Scatterplot of red snapper TL-at-age data for all fish assigned ages. Plotted line is the von Bertalanffy growth function fitted to the data.

Figure 6.1 Plot of TL-at-age data for red snapper (taken from Patterson III *et al*. (2001)).

Data from other sources would indicate that year class 1 corresponds to 20-25cm, year class 2 to ca. 30cm and year class 3 to 40-45cm (Patterson III *et al*., 2001). On the basis of this it would indicate that fish of 33cm in length would most likely be around 2 years old. Therefore of the first age cohort being significantly removed from the population, only about 25% would have reached sexual maturity. By the second cohort peak, at ca. 40cm, 60-70% of individuals would have reached sexual maturity. This is a much better proportion of the population reaching sexual maturity and far healthier for the stock. Unfortunately, as has been mentioned, it was not possible to identify any cohort classes for *L. guttatus* but it was still possible to determine the length at which 50% sexual

maturity was reached for the species and this has important implications when trying to determine a MLS for the fishery.

6.5 Minimum Landing Sizes (MLS)

The potential benefits of a Minimum Landing Size (MLS) for the Village A snapper fishery are indicated. A study conducted by Manooch III *et al*. (1998) into a similar snapper fishery off the southeastern United States found that while landings of snapper declined, (due to a lack of fishing control in the form of quotas etc.), the MLS regulations introduced resulted in an increase in the mean size of snapper landed. They concluded that the spawning potential ratio could be improved with a decrease in fishing mortality or an increase in age at entry to the fishery. MLS was shown to be an effective strategy in improving the L_{inf} of the stock. On the basis of known benefits to fisheries stock of the introduction of a MLS, the data illustrated above give enough information in order to determine a suitable MLS. Obviously it is important to allow young fish entering a fishery to have a chance to spawn at least once before being removed from the breeding stock of the population. Therefore in many fisheries the length of first capture (the MLS) is above the length of 50% maturity for this reason. For this to be the case in the Village A snapper fishery a MLS for *L. peru* would have to be introduced that was greater than 36cm. An ideal limit would perhaps even be 40cm as this would allow 60-70% of the stock to reach sexual maturity before capture and hence give a built in uncertainty or safety factor to the fishery. Such uncertainty factors have been mentioned previously, and allow the fishery to survive unpredictable disasters that occasionally influence all fisheries for example a bad recruitment year or negative environmental impacts such as ENSO that do influence the fisheries of this region. Hence, a MLS for *L. peru* would be indicated between 36-40cm Total Length.

For *L. guttatus*, as the 50% sexual maturity is reached at 28cm with 60-70% sexually mature at length ca. 33cm. Therefore it would seem sensible to suggest MLS of the form below:-

Species	MLS with Inbuilt Safety Factor (cm/TL)	Minimum MLS (cm/TL)
L. peru	40	36
L. guttatus	33	28

Table 6.1 Suggested Minimum Landing Sizes for *L. peru* and *L. guttatus* for the Las Perlas snapper fisheries.

The introduction of a MLS would have a long-term beneficial effect on the fishery; however it alone may not prove sufficient in preventing overexploitation having a significant impact on fish stocks. Creating a MLS purely on the basis of the 50% sexual maturity length is not enough to ensure the sustainability of a fishery. For many fish species, the older (larger) an individual is, the more eggs it produces relative to the younger (smaller) ones. Therefore it is important to preserve a stock of the older fish within a population as well as the immature ones. Also if a fishery continues long-term and removes the older/larger individuals again and again, progressively the proportion of larger individuals within the population will get less and less over time. This will ultimately lead to an overall reduction in the L_{inf} of the species and concurrently reduce the reproductive fecundity of the population by removing these larger older and more reproductive adults. Hence other management measures should be put in place alongside MLS to ensure long-term viability of a fishery.

6.6 Protection of Snapper Stock around Las Perlas

Other than imposing a MLS on the fishery, the ideal option would seem to be already set up in the form of the plans for an MPA around the archipelago. Obviously the snapper species that this study is concerned with are often found a significant distance offshore. Hence, the distribution of these fish stocks should be examined in greater detail to ensure that the boundaries of the newly proposed MPA include some proportion of the spawning grounds of these fish within them. The benefits of a spatial approach to fisheries protection have already been covered but it is an important point to highlight once again. The current proposed boundary is only ca. 3km offshore for the majority of the area and

the main snapper fishing grounds are a considerable distance outside of this (see Appendix IV). However, the fishing grounds off Punta Cocos and southwest of the island of San José could well be incorporated within the MPA boundary. In this case, providing there were significant movement of stock between these areas and the main fishing grounds, it is possible that the new MPA could have beneficial effects on the snapper stocks of the region. Further studies would be required to understand the extent of exchange that may occur between the snapper stocks in the different fishing regions. It may be that the stocks exploited nearer to shore do not exchange with the offshore stocks, in which case there will be little 'spill-over' effect from the MPA into the main fishing grounds. However, if there is sufficient movement then this could well be another management strategy for conserving the snapper stocks of Las Perlas alongside the introduction of a MLS.

6.7 Findings from Analysis of Yearly Village A Catch Data

The yearly catch of the Village A fishery was found to fluctuate quite significantly within the time period of the data available. Over seven years the catch went from a low of 20 tonnes to the highest recorded catch of 68 tonnes. There were no obvious expected patterns in the data, i.e. no marked decline or stasis. Furthermore, volume of catch did not particularly correlate with effort. The CPUE was lowest in 2000 and 2003 and highest in 2002 and 2005. However, the fluctuations do indicate the possibility of a cyclical pattern to the fishery. This inter-annual variability could potentially be explained by deliberate differences in effort by the fishermen depending on the fishing conditions of the year concerned. This variance in effort is in turn most likely attributable to some changing environmental variable, such as ENSO events. The variation in catch over the years is mirrored by a variation in CPUE (see Figure 5.23). This correlation is a clear indication of the presence of a classic cyclic pattern. Because of this cyclic pattern it was not possible to proceed further with Length Cohort Analysis (LCA) as the time-lag analysis approach now appropriate would require more parameters than currently available from this dataset. Furthermore, if indeed, a cyclic pattern is conclusively found within the fishery and it is related to ENSO events for example; a much longer time series of data

will be required to fully understand this relationship. Decadal data instead of yearly data would be necessary, alongside long-term ENSO event data, i.e. Sea Surface Temperature (SST) and chlorophyll data. Certainly the question of cyclic patterns in relation to environmental variability in particular, merits investigation by further studies.

6.8 Other Threats to the Fishery

A crucial area of further research on this fishery would be to look at the extent to which other fishing vessels may be removing stock from the fishery. These other vessels are larger in size and scale and are outside of the Village A village fishery in that the catches are not recorded nor go through the local buyer. This has only recently started to occur. Previously, this fishery, as with the other small-scale fisheries of the archipelago, was dominated almost exclusively by local fishermen from Las Perlas. However, in recent years, as the shrimp fishery around the archipelago has begun to collapse, larger mainland-associated fishing vessels have started to transfer their licences and fish for snapper, grouper and shark in the deeper waters surrounding the archipelago. The extent to which these fisheries actually overlap is not known. Anecdotal evidence from the islands indicates that some fishing grounds are beginning to be shared and that the larger vessels, while in smaller numbers, appear to have a greater landing capacity than the smaller traditional vessels. This issue is currently under discussion by the National Fishery Commission of Panama, however these activities at the present time, while they do occur; are illegal. Hence, obviously it is very difficult to get any figures on what proportion of the fishery may or may not be affected by these vessels. It is a vital step in the understanding of the dynamics of this fishery, to identify how significant this exploitation may be. If the stock removed by shrimp vessels is of different maturity/length distribution or if it is a significant proportion of the stock hence unidentified; the implication could be enormous in terms of fisheries modelling.

7.0 CONCLUSIONS

There was found to be no significant difference in the length-weight relationships between the sexes of *L. peru* or between the sexes of *L. guttatus*. There was found to be a total mortality rate (Z) of between 0.72 and 1.59, indicating medium to heavy exploitation of the fishery. It is questionable whether this can be adequately explained by the small-scale fisheries of the archipelago and could be influenced by external fishing pressure from the mainland. The people of Las Perlas were found to rely heavily on the snapper fishery with it providing the main source of income for the populations of a number of villages in the archipelago.

On the basis of the catch data collected over the seven year period, it would seem that the snapper fishery of Village A is highly variable with a cyclic trend being displayed, although this requires further investigation to accurately determine its nature. The relatively high proportion of immature individuals that are present within the catch and the unknown fishing pressure possibly being exerted but as yet un-quantified; indicate that it would be sensible to introduce measures to ensure the continued sustainability of this fishery while further studies can be carried out. The emphasis here would be on the 'precautionary principle' because apart from the quantification of MLS recommendations, there is little further that can be concluded with regards to any large-scale trend in the fishery at the present time. More conclusive statements are likely to result from a longer-term dataset. The data indicates that significant fishing pressure is being placed on the current stock and measures should be taken to ensure that the stock is not exploited beyond the point of potential recovery. Suggested measures include the introduction of Minimum Landing Sizes and, upon further investigation, the use of the proposed MPA by way of 'spill-over' effects and increased numbers of larger adult snapper in the surrounding region.

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APPENDICES

APPENDIX I - Qualitative Data

I.I Qualitative Data from Esmeraldas

Qualitative Interviews - Background

This section will deal with data collected qualitatively from informal interviews with local residents from a number of villages throughout Las Perlas. The data was collected through approaching local fishermen and buyers with a translator and asking general questions on the particulars of the snapper fishery based solely in their village. Questions were targeted towards Red Snapper in particular but information gleaned on other snapper species or the genus in general was included in the question format. The same standard questions were always asked but often a different answer was given to questions and so sometimes different questions appear listed. Also supplementary questions were often asked in different villages as the direction of interview changed depending on the fisherman being interviewed.

Details of Interviews at Esmeraldas

Interview Date: 19/05/05.
Interviewees: Eneida (Buyer), Emeterio Vasquez (Corregidor)
Location: N 08°16'01.4" W 78°55'22.9"
(GPS position taken using GPSmap 76S. The map datum was WGS 84 and used a True North Reference).
Population: ca. 600 people

Interview Session with Corregidor of Esmeraldas (Emeterio Vasquez)

Q. How many fishermen work in the village?
A. 160 fishermen, 70% fish almost exclusively for snapper.
Q. How much fish is caught per day per boat?
A. In season: 200lbs/boat plus 10lbs of 'revoltura'. Off season: catch octopus and lobster.
Q. How many hours per week spent fishing?
A. If weather is fine they go out everyday and all of the fishermen go out.
Q. What is the species composition of the catch?
A. Mostly Pargo mancha, Pargo amarillo and Pargo seda.
Q. Where are the main fishing sites?
A. South Balera, East and South Punta Cocos, Southeast San José.
Q. What are the boat sizes?
A. 25 feet and made of fiberglass.
Q. What equipment is regularly used?
A. Line with 3 to 5 hooks and weights, 80-100 feet deep.
Q. What are the numbers of lines/hooks per boat in use?
A. 3-4 fishermen per boat with 10-15 hooks per line.
Q. Is there seasonality to certain parts of the catch?
A. Usually the season runs between February to May.

General Discussion with Corregidor (Emeterio Vasquez)

There are approximately 160 fishermen in Esmeraldas, 70% of which fish for snapper. When it is the off season they fish for octopus mainly. Very few fishermen aim to catch snapper in the off season. The season runs between Feb-May. This year it was unusual as it began late, mid-March for the Red Snapper. They catch, Spotted, Yellow and Red Snapper. They catch ca. 200lbs/boat of Red Snapper in peak season. The proportion of different species within the catch depends on the time of the season. Sometimes 70% Red Snapper, 30% Spotted Snapper and no Yellow Snapper. The main fishing sites are south of Galera, Southwest of Punta Cocos and Southeast San José. (At Galera the fishermen were fishing at 300ft with 10-15 hooks with squid bait). They catch a very small amount of 'Revoltura', only an extra 10lbs after 200lbs of snapper. They catch grouper mainly in the wet season, May-Dec. They use a different method to catch grouper, (wrap line around a tank with 5 hooks. With net trap another fish which is like tuna and is found in shallow water to use as bait or use a big sardine). To fish grouper they fish near the bottom as that is where they are mostly found. Very little 'Revoltura' is returned to the water. There is a lot of competition with larger vessels from Panama. They sell Red Snapper for 0.60USD per lb. This is the same price for grouper. They sell 'Revoltura', (when sold), for 0.10USD per lb. All year round they have the same prices that they sell to the buyer for. Red Snapper is the main fishery for the village. Dolphin Fish is a small sub-fishery. It is sold for 0.80USD per lb. Dolphin Fish are caught during the winter season. It is caught using a floating line with bait, (usually squid). The fishery fluctuates year to year but he believes there has been a general and noticeable downwards trend.

Interview Session with Buyer of Esmeraldas (Eneida)

Q. How many fishermen work in the village?
A. 72 fishing for fish (snapper and grouper) and 62 fishing for octopus. There are 23 boats during the Season and half of this number during the Off Season.
Q. How much fish is caught per day per boat?
A. Red Snapper during the Season: 4,000lbs for all boats per day, Octopus 200-250lbs for all boats per day. Off Season: 1,500-2,000lbs for all boats per day. 'Revoltura': 800lbs per day on top of the snapper catch, in the off season little snapper so no 'Revoltura'.
Q. What is the species composition of the catch?
A. There has been more Yellow Snapper and Spotted Snapper than Red Snapper this year.
Q. Where are the main fishing sites?
A. Anywhere south of Galera.
Q. What equipment is regularly used?
A. Lines with 5-6 hooks to catch Red snapper and they are baited with sardines or squid. Lines with 1 hook to catch other types of fish, again baited with sardines or squid.
Q. At what cost do you buy from the fishermen?

A. 0.60-0.70USD per lb for snapper, 0.15USD per lb for 'Revoltura', 1.00USD per lb for Octopus.

Q. Is there seasonality to certain parts of the catch?

A. The Season runs from March-April, Off Season is Feb and Jan. Lobster Season is May-June but they buy until Dec. Octopus Season is Jun-early Aug.

General Discussion with Buyer (Eneida)

She comments that the fisheries in general have been decreasing in the last two years due to El Nĩno. 72 fishermen in the village fish for snapper and grouper with approximately 62 of these fishing for octopus in the Off Season. Jan-Feb is usually the very start of the season and so has less, while Mar-Apr is Peak Season. They bring in 4,000lbs per day for all boats of Red Snapper during the Peak Season. In the off Season they bring in 1, 500-2,000lbs for all boats per day of Red Snapper. There are 23 boats in the village all of which fish for snapper, but in the Off Season half the number of boats go out. June-begin Aug is the good season for octopus. In Peak Season they catch 800lbs of 'Revoltura' on top of 4,000lbs of snapper for all boats per day. In the Off Season for snapper they dedicate time for octopus and any 'Revoltura' they catch is used almost exclusively for their own consumption. When fishing for octopus instead of snapper they are using diving techniques instead of lines and so have very little 'Revoltura' caught as a bi-product. There has been more Spotted Snapper and Yellow Snapper than Red Snapper this season; this varies a lot between years. This week (19-05-05) is the first week this year that they have caught mostly Red Snapper. This is very unusual as they mostly catch Red by this time of year. They use sardines and squid for bait and this is the same for catching all species. For Yellow Snapper and Spotted Snapper they just use one hook as the fish tends to swim away and so need to be taken out immediately. With Red Snapper they stay still and so keep the line down and allow others to be caught on the same line. In the last two years the fishery has gone down. Last year was bad and this year has been even worse.

I.II Qualitative Data from Pedro Gonzalez

Details of Interviews at Pedro Gonzalez

Interview Date: 12/05/05
Interviewees: Antonio Gudino (Corregidor), Roman Perez (Buyer), Marcel Jiménez (Fisherman).
Location: N 08º 25'47.5" W 79º 06'0.80"
(GPS position taken using GPSmap 76S. The map datum was WGS 84 and used a True North Reference).
Population:

Interview Session with Fisherman (Marcel Jimenez)

Q. How many fishermen work in the village?
A. 80-100 fishermen.
Q. How many hours spent fishing per day?
A. 6am-6pm, approximately 12 hours.
Q. What is the snapper proportion of the catch?
A. 90 out of 100 lbs caught.
Q. Where are the main fishing sites?
A. San Jose, Pta Coco, South of the island.
Q. What is the total biomass of snapper caught in the village in peak season?
A. 15,000 lbs per month.
Q. What are the lengths of the boats?
A. 20-25 ft.
Q. What equipment is regularly used?
A. Line with bait, squid and sardines.
Q. When is the main season for the snapper fishery in Pedro Gonzalez?
A. March- April
Q. How many boats in the village?
A. 30 boats, 2-3 fishermen per boat.

General Discussion at Pedro Gonzalez (with Antonio Gudino)

Fishermen are not contracted to a particular buyer on the island. Snapper is sold for ca. USD 0.60/lb. In the main snapper season for the island they can land ca. 1,000lb/day for the whole village. This equates to around 200lb/day/boat. Buyer (Roman Perez) described buying 3,000lbs in three days in a very good season. Snapper is the target group for fishermen at Pedro Gonzalez due to its commercial value. Snapper is sold on I Panama City for ca. USD 1.40-1.60/lb. The non-target species are known collectively as 'Revoltura'. These species are not as profitable as targeted species and are sold to the buyer for ca. USD 0.20/lb and then sold on in Panama City for ca. USD 0.50-0.60/lb. 'Caracol' (*Haemulon maculicada*) is a species that makes up 'Revoltura' as is 'Chopa' (*Sectator ocyurus*). According to the fishermen of Pedro Gonzalez, 'Pargo Amarillo' (*Lutjanus argentiventris*) also come under the grouping of 'Revoltura'.

Octopus is the most profitable fishery per lb as it is bought for ca. USD 1.0 and sold in Panama City for ca. USD 2.25. The season for octopus is May-December in Pedro Gonzalez. Octopus is caught using mask, sometimes snorkel and fins and a 'chouso', which is a type of spiked implement.

Anecdotal conversations with fishermen in Pedro Gonzalez indicates that they believe that the sudden end of the snapper fishery around their area is caused by the sardines (the main prey) moving south to El Rey and beyond. Hence the snapper fishery may be over in Pedro Gonzalez but continue in Esmeraldas village, to the south. The snapper fishery in Pedro Gonzalez for 2005 started in the beginning of March and finished at the beginning of May. This is reportedly not the normal run of the fishery, which usually runs to the end of May in Pedro Gonzalez, and extends beyond this in the south.

Interview Session with Buyer (Roman Perez)

Q. How many fishermen in the village?
A. 80-100 fishermen.
Q. How much snapper caught per day per boat in season?
A. ca. 200-300lbs per day per boat.
Q. How much snapper caught total during season for the whole village?
A. 1,000lbs of snapper per day for all boats. In the best season he recorded 3,000lbs over three days for the whole village.

General Discussion with Buyer (Roman Perez)

The fishery is divided up into two rough groupings: 'Pargo' (Target species) and 'Revoltura' (Non-target but saleable species). The lists below are some examples of local names of fish that fall into one or other of the categories.

'Pargo': 'Seda', 'Merete', 'Mancha', 'Roncador', 'Cherna'.
'Revoltura': 'Caracol' (*Haemulon* mac*ulicada*), 'Chopa salema', "Pargo amrillo', 'Jurel', 'Sierra', 'Huanca', 'Lisa'.

Octopus is caught using 'chuzo' (a spike that kills indiscriminately). Lobster are caught using 'figa' (a boathook-like implement, which has lower mortality) or 'lasso' (a hoop of flexible material that has the lowest mortality and allows the greatest option for inspecting the lobster for immaturity or eggs before killing).

I.III Qualitative Data from San Miguel

Details of Interviews at San Miguel

Interview Date: 13/05/05 & 14/05/05.
Interviewees: Juan (Fisherman)
Location: N 08º 27'25.5" W 78º 56'19.1"

(GPS position taken using GPSmap 76S. The map datum was WGS 84 and used a True North Reference).
Population: ca. 600 people

Interview Session with Juan (Fisherman)

Q. How many fishermen work in the village?
A. 18 boats with 3 fishermen per boat.
Q. How much snapper is caught per day per boat?
A. In peak season ca. 300lbs per boat per day of P. mancha. In off season ca. 90-200lbs per boat per day.
Q. How many hours per day spent fishing?
A. 6am-4.30-5pm and 6pm-3am at night (if night-fishing).
Q. What is the snapper proportion of the catch?
A. More snapper than 'Revoltura' during the season.
Q. Where are the main fishing sites?
A. Membrillo, Caracoles, Elefante (during the off season) and Bayoneta, Corillo, South-west of the island (during the season).
Q. What are the sizes of the boats?
A. 25ft.
Q. What equipment is regularly used?
A. Spider (when there are no sardines), a hook and line when there are sardines. The line is baited with live bait and weighted. They fish at around 15m depth.
Q. When is the snapper season for them?
A. Starts in Jan and ends in March but they continue to fish P. mancha throughout the year.

General Discussion with Fisherman (Juan)

The fishermen fish for sardines during the day in the off season when there are not many P. mancha and so they have more need to bait the hooks. They continue to fish for Pargo throughout the year. In peak season they do not need to fish at night as there is less need for sardines to bait the hooks as there are far more snapper around to catch during the day. There is always many more snapper than 'Revoltura'. When they catch fish in the snapper season the proportion of the catch is comprised of ca. 90% snapper and almost all of that is P. mancha. There is the same proportion of snapper in the catch during the off season but they catch less fish overall, (i.e. ca. 90-200lbs per boat per day compares with 300lbs in season).They pretty much only sell the snapper, not the 'Revoltura' and they sell on the day of catch, or if night fishing on the following morning. Very little of the catch is comprised of P. Amarillo or P. rocco. Occasionally they do catch these two species, but if they wanted to catch these species they would have to go fishing much further away from the island and so it is not economical.

The octopus fishery is around May-Oct, however the snapper fishery continues throughout. They fish everyday during the season and almost as frequently in the off season. There are 5 buyers in the village but only one buys snapper. They sell P. mancha for ca. USD 0.80/lb and sell P. Amarillo for ca. USD 0.45/lb.

Interview Session with Corregidor of San Miguel (Segundino Henriquez)

Q. How many fishermen work in the village?
A. ca. 60 boats and about 5 people per boat. It varies according to the fishermen and the boat.
Q. How much caught per day per boat?
A. Nov-Apr (peak season) max ca. 600lbs per boat per day, May-Oct (off season) max ca. 300lbs per boat per day. An average day is probably much less than this, possibly ca. 100lbs.
Q. How many hours a day spent fishing?
A. In the season during the day they fish 5am-2pm to get sardines. Night fishing is only in the off season.
Q. What is the snapper proportion of the catch?
A. 70% snapper to 30% 'Revoltura'. This year there has been more snapper than 'Revoltura'. They don't keep the 'Revoltura' if it is small or a non-saleable species. They only catch Pargo mancha.
Q. Where are the main fishing sites?
A. Nov-Apr (high season) – Bayoneta, Grillo.
May-Oct (off season) – outside Caracol, Contadora.
P. Amarillo in the same sites and season.
Q. What are the sizes of the boats?
A. ca. 25ft.
Q. What equipment is regularly used?
A. 'Spider' and live bait (sardines).
Q. What us the set up of hooks and lines?
A. 2 hooks per line with live bait. Fish at 10m for P. mancha and P. Amarillo. Use 'spider' with a good season, but is becoming less effective. Live bait is now the best method. The method of baiting the hooks with live sardines came with fishermen from Panama City over 10 years ago. Technique shown to be more effectively.

General Discussion with Corregidor (Segundino Henriquez)

Snapper is sold for ca. USD 0.60 or to Oscar Lasso (a buyer that specializes in snapper and only this fishery) ca. USD 0.85. 'Revoltura' is sold for ca. USD 0.25. Types of 'Revoltura' include Cojinua, Jurel, white fish, Corvina rayada, Corvina Amarillo, Sierra

(the names for these fish are common names used in the local area). There are five buyers in San Miguel. Four buy according to the season, only Oscar buys exclusively snapper.

In the summer until April they catch up to 600lbs of snapper per boat per day. When they fish for sardines during the day they keep them alive by placing them in a box in the centre of the 'Panga' (boat) filled with seawater. They used to use only the 'spider' when fishing was better but when the new technique was introduced to the islands they moved on to mostly using the live bait technique all the time. Using only the 'spider' in peak season results in a much lower catch, ca. 200lbs per boat per day compared to ca. 600lbs.

The catch in the off season, May-Oct, is about half the peak season catch (ca. 300lbs per boat per day). They always try to go north rather than south for P. mancha. Different times were given for travel time to the fishery, between 40mins and 1.5 hours. They only go night fishing in the off season, i.e. currently. They fish 5am-2pm for sardines in the off season. Last year the buyers would buy 'Revoltura' but this year would not take as much and so some is thrown back and the rest used for consumption within the village. They catch roughly 70% snapper to 30% 'Revoltura'. This year there was a greater proportion of snapper to 'Revoltura' within the catch. Both size and species dictates what gets rejected from a by-catch perspective. According to the fishermen, fish less 1lb get thrown back although this contradicts our measurements of fish landed at this particular village in the course of a day; where a significant proportion of the caught snapper were less than 1lb.

P. mancha is almost exclusively present in the catch with only a few occasional catches of P. Amarillo and even less of P. rocco. 'Cheurna' is classified under their system as a 'Pargo' species. They sell 'Revoltura' by bulk, not by individual species. 'Revoltura' sold for ca. USD 0.25/lb. Catch snapper using a line with two hooks attached and live bait. The cost of snapper doubles as well as 'Revoltura' once it reaches Panama City. Only a minority of snapper fishermen move into the octopus and lobster fishery once the snapper season finishes, most just continue to fish snapper at a lower rate.

They catch ca. 200-300lbs per boat per day of octopus on a good days fishing in peak season. Octopus sells for ca. USD 1.25/lb or ca. USD 0.75 when really abundant. They use ca. 10 gallons of petrol per day of fishing and petrol costs ca. USD 3.25/gallon. Catch is split equally between all the fishermen on the boat. The boat is owned by the skipper but there appears to be no monetary gain for owning the vessel. They sell all the snapper and use 'Revoltura' for their own consumption only. Fishery fluctuates yearly but apparently there has no noticeable decline that the fishermen have noticed.

Interview Session with a Buyer (Rodolfo Ibarbez)

Q. How many fishermen work in the village?
A. 35 boats with 3 people per boat (= ca. 105)
Q. How much snapper is caught per day per boat?

A. In the season ca. 4,000lbs for all boats, in the off season ca. 1,000lbs for all boats. In the peaks season they fish during the day for both snapper and the sardines with which to catch them (as there are more snapper around in the season also).

Q. How many hours spent fishing per day?

A. Every day during the season and between 6am-3pm and 6pm-2am (in off season only).

Q. What is the snapper proportion of the catch?

A. In the season 80% more snapper than 'Revoltura'. In the off season less snapper and more 'Revoltura' so that the distribution within the catch switches the other way around.

Q. Where are the main fishing sites?

A. In season: Grillo, Bayoneta, Pedro Gonzalez. Off season: Bayoneta, Viveros, San Telmo, Ensenada. In the off season they use only 3 gallons of petrol/day whereas in peak season they use 8 gallons/day as its more gain for the investment.

Q. What equipment is regularly used?

A. Hook and line and live bait. They fish at around 16m depth.

Q. What is the number of hooks per line?

A. 2 hooks per line.

General Discussion with Buyer (Roldolfo Ibarbez)

He buys snapper for ca. USD 0.60/lb and 'Revoltura' for ca. USD 0.25/lb. Octopus fishery season is May-Nov and can be up to ca. 3,000lbs octopus per day for all boats fishing. There is around 30 boats fishing for octopus and lobster in the village. Octopus is bought for ca. USD 1.25/lb. Lobster fishery is between May-Nov and can bring in up to ca. 200lbs/day. This is bought for ca. USD 8.00. He doesn't think that the lobster fishery is going down in size or frequency of catch. Snapper and octopus fishery vary greatly from year to year but he doesn't believe that either has noticeably declined in recent years. Not much 'Revoltura' returned to the sea, most kept for local consumption but those that are returned are done so live.

The village has 35 boats with 3 people per boat. The season catch for snapper is 4,000lbs for boats per day. In the off season this drops t 1,000lbs. In the season they fish during the day as can catch sardines and snapper at the same time. In the off season not so many sardines so need to fish at night for these for the next day. 80% of catch is snapper in the season, in the off season they catch more 'Revoltura' than snapper. Buyer says he lowers price of snapper sold to the US market as they require length and species identification before import, lowering the price allows someone else to do this part of the process.

I.IV Qualitative Data from Casaya

Details of Interviews at Casaya

Interview Date: 12/05/05
Interviewees: Eduard Sosa (Corregidor), Andres Robles (Octopus fisherman).
Location: N 08º 31'14.0" W 79º 01'31.0"

(GPS position taken using GPSmap 76S. The map datum was WGS 84 and used a True North Reference).
Population: ca. 100 people

Interview Session with Corregidor of Casaya (Eduard Sosa)

Q. How many fishermen work in the village?
A. 15 fishermen.
Q. How many hours spent fishing per hour?
A. 6am-11am and 11pm-4am, so spent a considerable amount of time at night fishing.
Q. How much snapper is caught in season for the village?
A. ca. 60-70lbs per month for the village (Nov).
Q. What is the species composition of snapper caught?
A. A mixture of Pargo mancha and Pargo amarillo.
Q. Where are the main fishing sites for Casaya?
A. In front of Bolanos, Membrillo, Boyenena (for Nov fishery).
Q. What are the sizes of boats used?
A. 25ft.
Q. What equipment is regularly used?
A. Long-lines with 'Spider' attachments on ca. 60m of line.

Q. What is the number of lines per boat?
A. 3 fishermen per boat, and so 3 lines.
Q. Is there a seasonality to the snapper fishery?
A. There is a summer fishery that runs March and April (greater numbers of fish and found in more locations) and a winter fishery in November. In Mar-Apr use 'spider' technique and in Nov use baited hooks.

General Discussion at Casaya (with Eduard Sosa and Andres Robles)

In the summer the fish snapper with spider attachment and in winter with the same attachment but with live bait. There are 15 fishermen operating in the village and they fish snapper for 1 month in the winter (Nov) and two months in the summer (Mar-Apr). The main commercial fishery is octopus so all snapper caught is for local consumption. They catch Pargo mancha and Pargo Amarillo but never Pargo seda. Ca. 60-70lbs of snapper is caught in peak season month (Nov). More P. mancha is caught than P. Amarillo (around 40lbs for the P. mancha). Total catch of all fish species for an average month for the whole village would be ca. 100lbs. The largest fish fishery occurs in the months of March and April (>100lbs).

The 'spider' attachment comprises threes hooks of 3-4cm long. One hook is attached 20cm above a small lead weight (6-7cm long). The other two hooks are attached laterally and posteriorly to the lead weight. This lure is mostly used on its own in the summer season and with live bait in the winter season and during night fishing. Bait is commonly live sardines. There is reportedly better fishing at night than during the day. Snapper smaller than ca. 0.5lb are thrown back so some return on catch of small immature fish but

not much. However, small snapper are currently not caught with significant frequency compared to larger fish of the same species.

Saboga island catches all three main species of snapper, (P. mancha, P. Amarillo and P. seda) but do not sell on, use only for local consumption.

Discussion on Octopus Fishery (with Andres Robles)

Octopus sold to buyer for ca. USD 1.25/lb but this could go down to as low as ca. USD 0.80/lb. Oysters are sold for ca. USD 0.75/lb and this doubles when it reaches Panama City. 100lb/day can be caught of octopus for the whole village but some days can be as low as 10lbs. Fishing for octopus occurs <150m from the shore while fishing for snapper occurs ca. 2km from shore. Oysters are caught and if no buyer is found they are chucked back in close to shore to be recovered another day. Have noticed change in octopus numbers by season. Octopus fishery is more preferred as it has a higher value per lb and are easier to find. There was previously a large oyster fishery but this has declined significantly in recent years. It used to be the largest fishery for the village but has been replaced by the octopus fishery as numbers declined. The same pattern is now being seen in the octopus fishery. Buyers of all fisheries are mostly resident on the respective islands.

APPENDIX II

II.I Details of Z/K and Linf Analyses for Lutjanus peru

(a) Powell-Weatherall Analysis

x						y
Length interval		**L**	**Number caught**	**C*midL**	**mean length of fish longer than L'**	
L1	**L2**	**mid**	**C(L1,L2)**		**L (mean)**	**L(mean)-L'**
4	5	4.5	0	0	40.48265	36.482653
5	6	5.5	0	0	40.48265	35.482653
6	7	6.5	0	0	40.48265	34.482653
7	8	7.5	0	0	40.48265	33.482653
8	9	8.5	0	0	40.48265	32.482653
9	10	9.5	0	0	40.48265	31.482653
10	11	10.5	1	10.5	40.48265	30.482653
11	12	11.5	0	0	40.51328	29.513279

From regression plot

y = -0.3358x + 27.587

intercept =	**27.59**	a
slope =	**-0.336**	b

12	13	12.5	0	0	40.51328	28.513279	**Linf =**	**82.15**	-(a/b)
13	14	13.5	0	0	40.51328	27.513279	**Z/K =**	**1.978**	- (1+b)/b
14	15	14.5	0	0	40.51328	26.513279			
15	16	15.5	0	0	40.51328	25.513279			
16	17	16.5	0	0	40.51328	24.513279			
17	18	17.5	0	0	40.51328	23.513279			
18	19	18.5	0	0	40.51328	22.513279			
19	20	19.5	0	0	40.51328	21.513279			
20	21	20.5	0	0	40.51328	20.513279			
21	22	21.5	0	0	40.51328	19.513279			
22	23	22.5	0	0	40.51328	18.513279			
23	24	23.5	2	47	40.51328	17.513279			
24	25	24.5	0	0	40.54811	16.548106			
25	26	25.5	1	25.5	40.54811	15.548106			
26	27	26.5	4	106	40.56352	14.563525			
27	28	27.5	12	330	40.6214	13.621399			
28	29	28.5	9	256.5	40.78542	12.785417			
29	30	29.5	11	324.5	40.90168	11.901682			
30	31	30.5	33	1006.5	41.03511	11.035106			
31	32	31.5	36	1134	41.41841	10.418412			
32	33	32.5	39	1267.5	41.82836	9.8283582			
33	34	33.5	36	1206	42.26563	9.265625			
34	35	34.5	33	1138.5	42.66206	8.6620603			
35	36	35.5	39	1384.5	43.01507	8.0150721			
36	37	36.5	58	2117	43.41989	7.4198895			
37	38	37.5	59	2212.5	44.02252	7.0225225			
38	39	38.5	80	3080	44.65651	6.6565074			
39	40	39.5	76	3002	45.59108	6.5910816			
40	41	40.5	90	3645	46.61752	6.6175166			
41	42	41.5	54	2241	48.14266	7.1426593			
42	43	42.5	53	2252.5	49.31107	7.3110749			
43	44	43.5	36	1566	50.73228	7.7322835			
44	45	44.5	26	1157	51.92661	7.9266055			
45	46	45.5	18	819	52.93229	7.9322917			
46	47	46.5	18	837	53.70115	7.7011494			
47	48	47.5	16	760	54.53205	7.5320513			
48	49	48.5	19	921.5	55.33571	7.3357143			
49	50	49.5	16	792	56.40909	7.4090909			
50	51	50.5	15	757.5	57.4619	7.4619048			
51	52	51.5	7	360.5	58.62222	7.6222222			
52	53	52.5	13	682.5	59.22289	7.2228916			
53	54	53.5	5	267.5	60.47143	7.4714286			
54	55	54.5	7	381.5	61.00769	7.0076923			
55	56	55.5	10	555	61.7931	6.7931034			
56	57	56.5	6	339	63.10417	7.1041667			
57	58	57.5	6	345	64.04762	7.047619			
58	59	58.5	7	409.5	65.13889	7.1388889			
59	60	59.5	2	119	66.74138	7.7413793	used		

60	61	60.5	4	242	67.27778	7.2777778	used
61	62	61.5	2	123	68.45652	7.4565217	used
62	63	62.5	1	62.5	69.11905	7.1190476	used
63	64	63.5	1	63.5	69.45	6.45	used
64	65	64.5	3	193.5	69.76316	5.7631579	used
65	66	65.5	1	65.5	70.75	5.75	used
66	67	66.5	2	133	71.1	5.1	used
67	68	67.5	2	135	71.80769	4.8076923	used
68	69	68.5	2	137	72.59091	4.5909091	used
69	70	69.5	2	139	73.5	4.5	used
70	71	70.5	0	0	74.64286	4.6428571	used
71	72	71.5	3	214.5	74.64286	3.6428571	used
72	73	72.5	2	145	77	5	
73	74	73.5	0	0	81.5	8.5	
74	75	74.5	0	0	81.5	7.5	
75	76	75.5	0	0	81.5	6.5	
76	77	76.5	0	0	81.5	5.5	
77	78	77.5	0	0	81.5	4.5	
78	79	78.5	0	0	81.5	3.5	
79	80	79.5	0	0	81.5	2.5	
80	81	80.5	0	0	81.5	1.5	
81	82	81.5	2	163	81.5	0.5	

Figure II.I Demonstrates workings of Powell-Weatherall analysis for Bin Size 1.

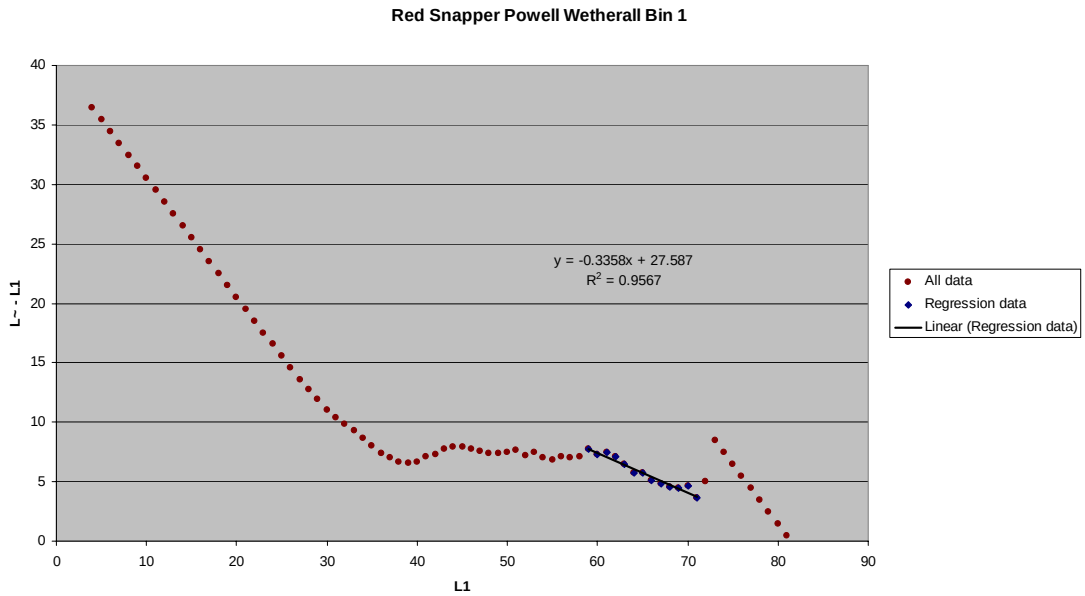

Figure II.II Regression plot for Powell-Weatherall analysis for Bin Size 1.

x Length interval L1	L2	L mid	Number caught C(L1,L2)	C*midL	y mean length of fish longer than L' L (mean)	L(mean)-L'
2	4	3	2	6	39.80378	37.80378
4	6	5	0	0	39.891	35.891
6	8	7	0	0	39.891	33.891
8	10	9	0	0	39.891	31.891
10	12	11	1	11	39.891	29.891
12	14	13	0	0	39.92527	27.92527
14	16	15	0	0	39.92527	25.92527
16	18	17	0	0	39.92527	23.92527
18	20	19	0	0	39.92527	21.92527
20	22	21	0	0	39.92527	19.92527
22	24	23	2	46	39.92527	17.92527
24	26	25	1	25	39.96552	15.96552
26	28	27	16	432	39.98333	13.98333
28	30	29	20	580	40.23544	12.23544
30	32	31	69	2139	40.51493	10.51493
32	34	33	75	2475	41.40816	9.408163
34	36	35	72	2520	42.36364	8.363636
36	38	37	117	4329	43.26531	7.265306
38	40	39	156	6084	44.82166	6.821656
40	42	41	144	5904	47.70476	7.704762

From regression plot		
y = -0.2044x + 18.7		
intercept =	**18.7**	a
slope =	**-0.204**	b
Linf =	**91.487**	-(a/b)
Z/K =	**3.8924**	-(1+b)/b

42	44	43	18	774	53.35088	11.35088	used
44	46	45	10	450	54.56863	10.56863	used
46	48	47	3	141	55.23776	9.237762	used
48	50	49	35	1715	55.41429	7.414286	used
50	52	51	22	1122	57.55238	7.552381	used
52	54	53	18	954	59.28916	7.289157	used
54	56	55	17	935	61.03077	7.030769	used
56	58	57	12	684	63.16667	7.166667	used
58	60	59	9	531	65.22222	7.222222	used
60	62	61	6	366	67.2963	7.296296	used
62	64	63	2	126	69.09524	7.095238	used
64	66	65	4	260	69.73684	5.736842	used
66	68	67	4	268	71	5	used
68	70	69	4	276	72.45455	4.454545	used
70	72	71	3	213	74.42857	4.428571	
72	74	73	2	146	77	5	
74	76	75	0	0	81	7	
76	78	77	0	0	81	5	
78	80	79	0	0	81	3	
80	82	81	2	162	81	1	
82	84	83	0	0	83	1	

Figure II.III Demonstrates workings of Powell-Weatherall analysis for Bin Size 2.

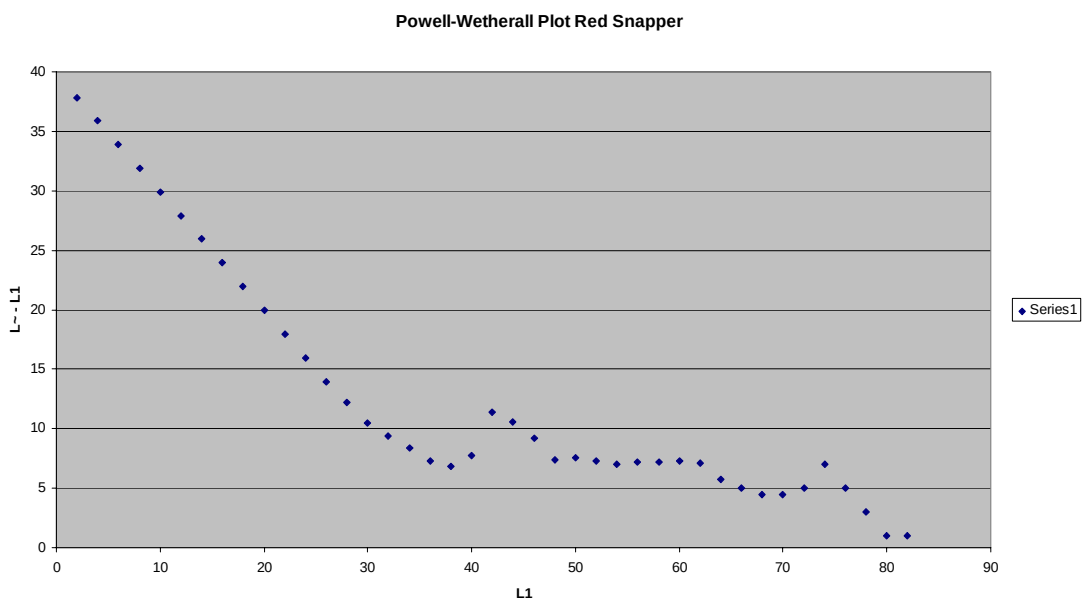

Figure II.IV Regression plot for Powell-Weatherall analysis for Bin Size 2.

x						y
Length interval		**L**	**Number caught**	**C*midL**	**mean length of fish longer than L'**	
L1	**L2**	**mid**	**C(L1,L2)**		**L (mean)**	**L(mean)-L'**

0	5	2.5	11	27.5	40.06526	40.06526	From regression plot		
5	10	7.5	1	7.5	40.48477	35.48477	**y = -0.1095x + 13.281**		
10	15	12.5	2	25	40.51829	30.51829			
15	20	17.5	0	0	40.57536	25.57536	**intercept =**	**13.281**	a
20	25	22.5	2	45	40.57536	20.57536	**slope =**	**-0.1095**	b
25	30	27.5	37	1017.5	40.61224	15.61224			
30	35	32.5	178	5785	41.12672	11.12672	**Linf =**	**121.29**	-(a/b)
35	40	37.5	313	11737.5	43.13399	8.133987	**Z/K =**	**8.1324**	-(1+b)/b
40	45	42.5	259	11007.5	47.0354	7.035398			
45	50	47.5	88	4180	53.12176	8.121762	used		
50	55	52.5	47	2467.5	57.83333	7.833333	used		
55	60	57.5	31	1782.5	62.15517	7.155172	used		
60	65	62.5	11	687.5	67.5	7.5	used		
65	70	67.5	9	607.5	70.9375	5.9375	used		
70	75	72.5	5	362.5	75.35714	5.357143	used		
75	80	77.5	0	0	82.5	7.5			
80	85	82.5	2	165	82.5	2.5			

Figure II.V Demonstrates workings of Powell-Weatherall analysis for Bin Size 5.

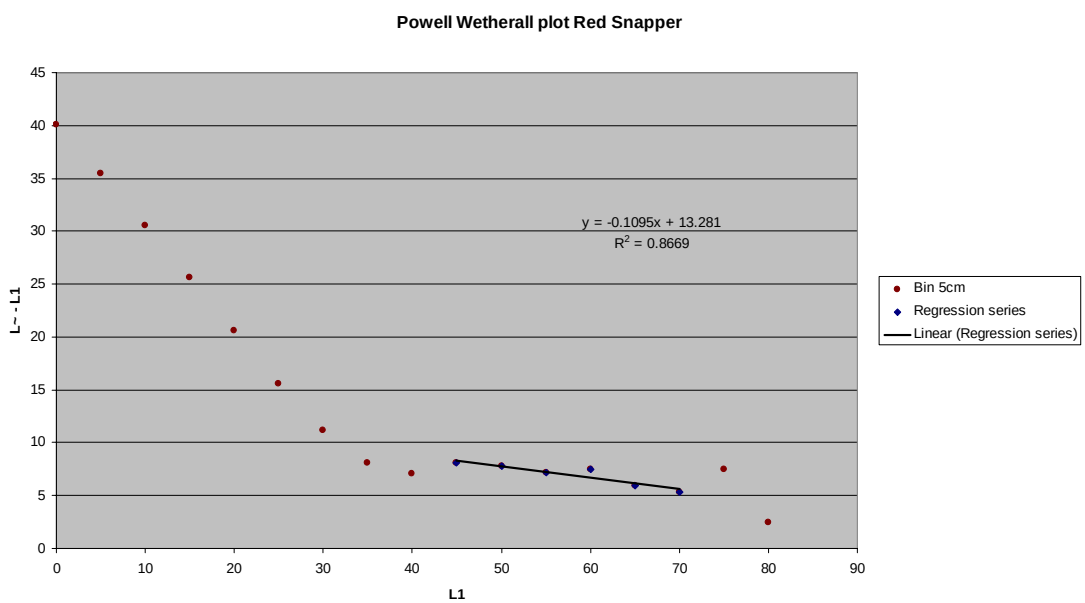

Figure II.VI Regression plot for Powell-Weatherall analysis for Bin Size 5.

(b) Jones and van Zalinge Analysis

Length interval L1	L2	L mid	No. caught C(L1,L2)	bkwds cum. catch (sum C)	ln(Linf-L1)	ln(sum C)	Z/K	Z
4	5	4.5	0	980	4.51086	6.887553		
5	6	5.5	0	980	4.49981	6.887553		
6	7	6.5	0	980	4.488636	6.887553		
7	8	7.5	0	980	4.477337	6.887553		
8	9	8.5	0	980	4.465908	6.887553		
9	10	9.5	0	980	4.454347	6.887553		
10	11	10.5	1	980	4.442651	6.887553		
11	12	11.5	0	979	4.430817	6.886532		
12	13	12.5	0	979	4.418841	6.886532		
13	14	13.5	0	979	4.406719	6.886532		
14	15	14.5	0	979	4.394449	6.886532		
15	16	15.5	0	979	4.382027	6.886532		
16	17	16.5	0	979	4.369448	6.886532		
17	18	17.5	0	979	4.356709	6.886532		
18	19	18.5	0	979	4.343805	6.886532		
19	20	19.5	0	979	4.330733	6.886532		
20	21	20.5	0	979	4.317488	6.886532		
21	22	21.5	0	979	4.304065	6.886532		
22	23	22.5	0	979	4.290459	6.886532		
23	24	23.5	2	979	4.276666	6.886532		
24	25	24.5	0	977	4.26268	6.884487		
25	26	25.5	1	977	4.248495	6.884487		
26	27	26.5	4	976	4.234107	6.883463		
27	28	27.5	12	972	4.219508	6.879356		
28	29	28.5	9	960	4.204693	6.866933		
29	30	29.5	11	951	4.189655	6.857514		
30	31	30.5	33	940	4.174387	6.84588		
31	32	31.5	36	907	4.158883	6.810142		
32	33	32.5	39	871	4.143135	6.769642		
33	34	33.5	36	832	4.127134	6.723832		
34	35	34.5	33	796	4.110874	6.679599		
35	36	35.5	39	763	4.094345	6.637258		
36	37	36.5	58	724	4.077537	6.584791		
37	38	37.5	59	666	4.060443	6.50129		
38	39	38.5	80	607	4.043051	6.408529	5.33	1.39
39	40	39.5	76	527	4.025352	6.267201	6.67	1.74
40	41	40.5	90	451	4.007333	6.111467	7.41	1.93
41	42	41.5	54	361	3.988984	5.888878	8.53	2.22
42	43	42.5	53	307	3.970292	5.726848	8.87	2.31
43	44	43.5	36	254	3.951244	5.537334	9.11	2.37

Summary with Bin 2

Linf	Z/K
85	3.68
90	4.47
95	5.23

y = 5.1257x - 14.71
R2 = 0.9775

Z/K = slope = 9.10508 for longest length cohort
others calculated back to 37-38 cm cohort

44	45	44.5	26	218	3.931826	5.384495	9.09	2.36
45	46	45.5	18	192	3.912023	5.257495	8.89	2.31
46	47	46.5	18	174	3.89182	5.159055	8.55	2.22
47	48	47.5	16	156	3.871201	5.049856	8.2	2.13
48	49	48.5	19	140	3.850148	4.941642	7.87	2.05
49	50	49.5	16	121	3.828641	4.795791	7.64	1.99
50	51	50.5	15	105	3.806662	4.65396	7.45	1.94
51	52	51.5	7	90	3.78419	4.49981	7.32	1.9
52	53	52.5	13	83	3.7612	4.418841	7.13	1.85
53	54	53.5	5	70	3.73767	4.248495	7.01	1.82
54	55	54.5	7	65	3.713572	4.174387	6.84	1.78
55	56	55.5	10	58	3.688879	4.060443	6.67	1.74
56	57	56.5	6	48	3.663562	3.871201	6.57	1.71
57	58	57.5	6	42	3.637586	3.73767	6.48	1.68
58	59	58.5	7	36	3.610918	3.583519	6.4	1.66
59	60	59.5	2	29	3.583519	3.367296	6.36	1.65
60	61	60.5	4	27	3.555348	3.295837	6.28	1.63
61	62	61.5	2	23	3.526361	3.135494	6.2	1.61
62	63	62.5	1	21	3.496508	3.044522	6.11	1.59
63	64	63.5	1	20	3.465736	2.995732	5.99	1.56
64	65	64.5	3	19	3.433987	2.944439	5.84	1.52
65	66	65.5	1	16	3.401197	2.772589	5.72	1.49
66	67	66.5	2	15	3.367296	2.70805	5.58	1.45
67	68	67.5	2	13	3.332205	2.564949	5.46	1.42
68	69	68.5	2	11	3.295837	2.397895	5.36	1.39
69	70	69.5	2	9	3.258097	2.197225	5.27	1.37
70	71	70.5	0	7	3.218876	1.94591	5.22	1.36
71	72	71.5	3	7	3.178054	1.94591	5.13	1.33
72	73	72.5	2	4	3.135494	1.386294	5.12	1.33
73	74	73.5	0	2	3.091042	0.693147	5.21	1.35
74	75	74.5	0	2	3.044522	0.693147	5.23	1.36
75	76	75.5	0	2	2.995732	0.693147		
76	77	76.5	0	2	2.944439	0.693147		
77	78	77.5	0	2	2.890372	0.693147		
78	79	78.5	0	2	2.833213	0.693147		
79	80	79.5	0	2	2.772589	0.693147		
80	81	80.5	0	2	2.70805	0.693147		
81	82	81.5	2	2	2.639057	0.693147		

Figure II.VII Demonstrates workings of Jones and van Zalinge analysis for Bin Size 1.

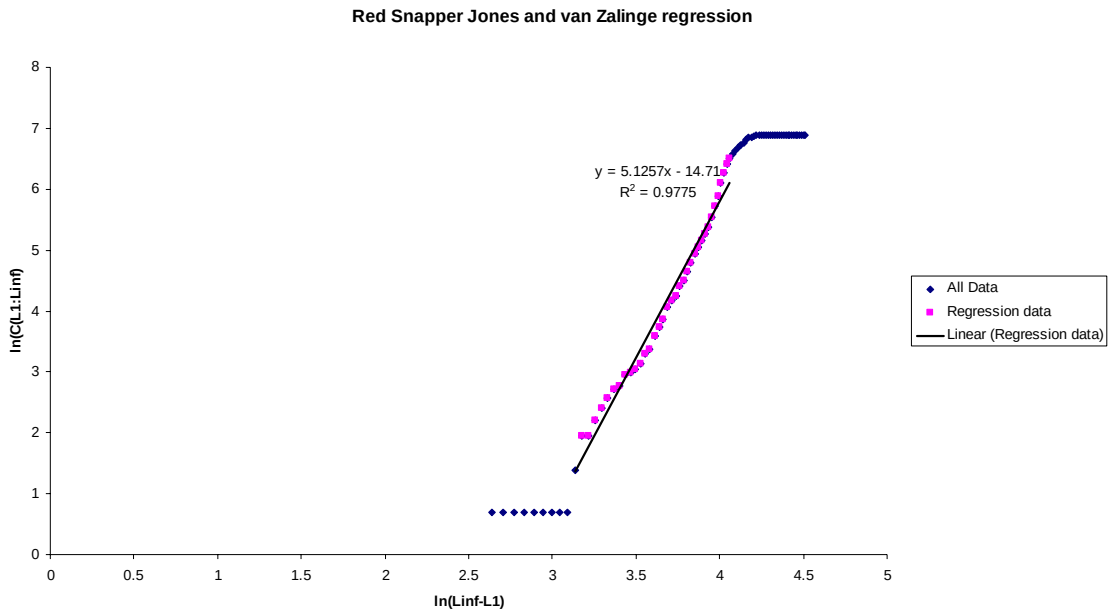

Figure II.VIII Regression plot for Jones and van Zalinge analysis for Bin Size 1.

Length interval L1	L2	L mid	No. caught C(L1,L2)	bkwds cum. catch (sum C)	ln(Linf-L1)	ln(sum C)	Z/K	Z
0	5	2.5	11	996	4.553877	6.903747		
5	10	7.5	1	985	4.49981	6.892642		
10	15	12.5	2	984	4.442651	6.891626		
15	20	17.5	0	982	4.382027	6.889591		
20	25	22.5	2	982	4.317488	6.889591		
25	30	27.5	37	980	4.248495	6.887553		
30	35	32.5	178	943	4.174387	6.849066		
35	40	37.5	313	765	4.094345	6.639876		
40	45	42.5	259	452	4.007333	6.113682	6.05	1.57
45	50	47.5	88	193	3.912023	5.26269	7.58	1.97
50	55	52.5	47	105	3.806662	4.65396	7.1	1.85
55	60	57.5	31	58	3.688879	4.060443	6.51	1.69
60	65	62.5	11	27	3.555348	3.295837	6.22	1.62
65	70	67.5	9	16	3.401197	2.772589	5.68	1.48
70	75	72.5	5	7	3.218876	1.94591	5.34	1.39
75	80	77.5	0	2	2.995732	0.693147		
80	85	82.5	2	2	2.70805	0.693147		

y = 3.881x - 8.8943
R2 = 0.9718

Z/K = slope = 5.338722 for longest length cohort
others calculated back to 40-45 cm cohort

Table of values
Linf Z/K

85	3.88
90	4.6
95	5.34

Figure II.IX Demonstrates workings of Jones and van Zalinge analysis for Bin Size 5.

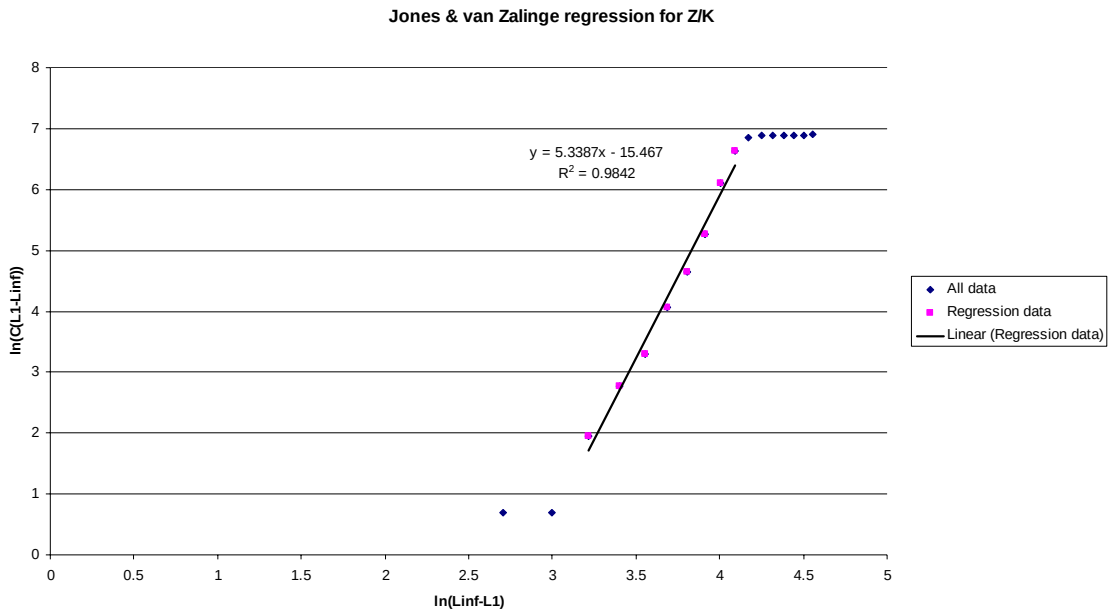

Figure II.X Regression plot for Jones and van Zalinge analysis for Bin Size 5.

APPENDIX III – Illustrating Fisheries Selection Pressures

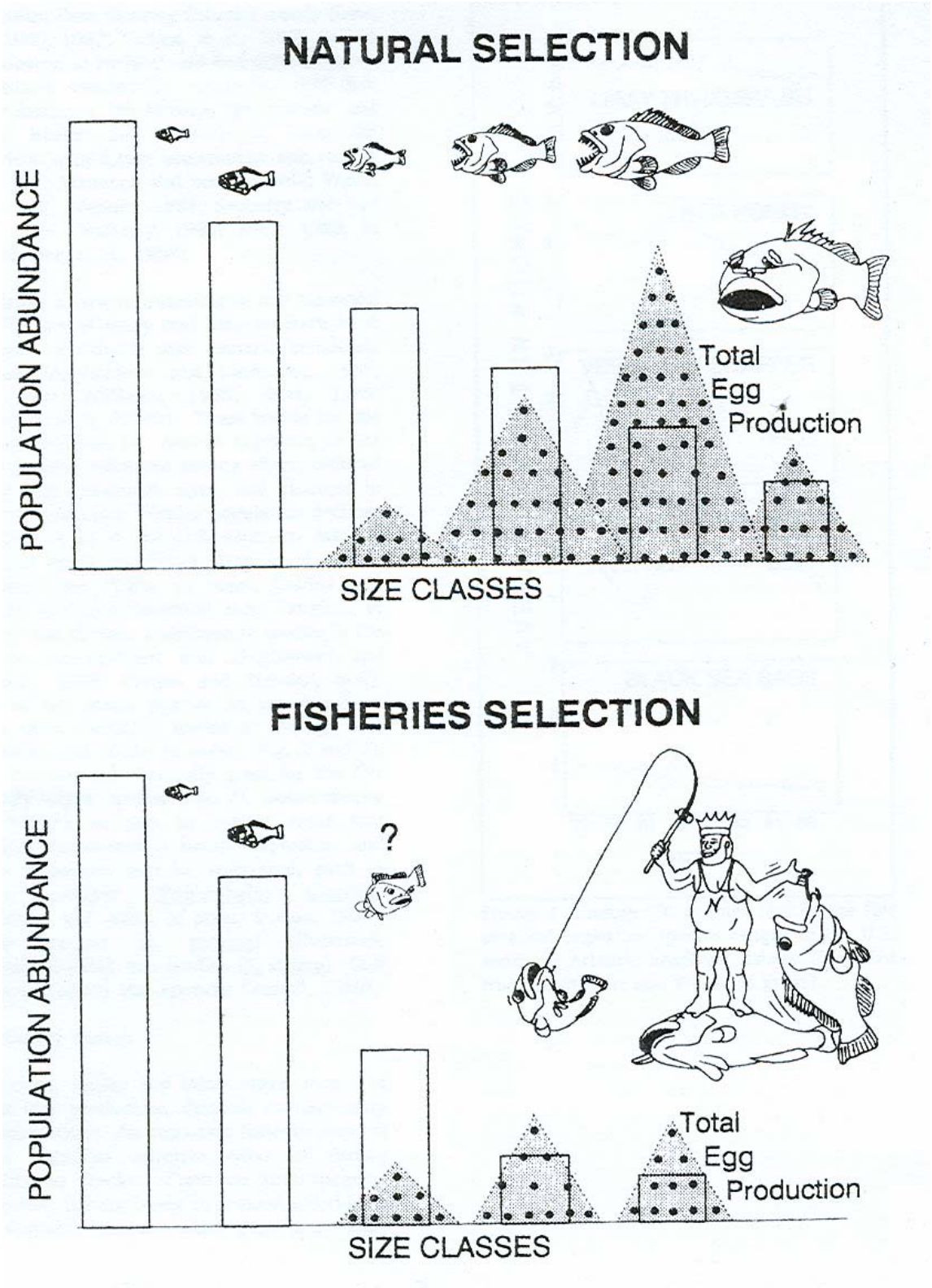

Figure III.I The effects of fisheries selection pressure compared with that of natural selection on population size structure and total egg production (taken from Bohnsack, 1990).

APPENDIX IV – Map of the Archipelago of Las Perlas in Relation to Snapper Fishing Grounds

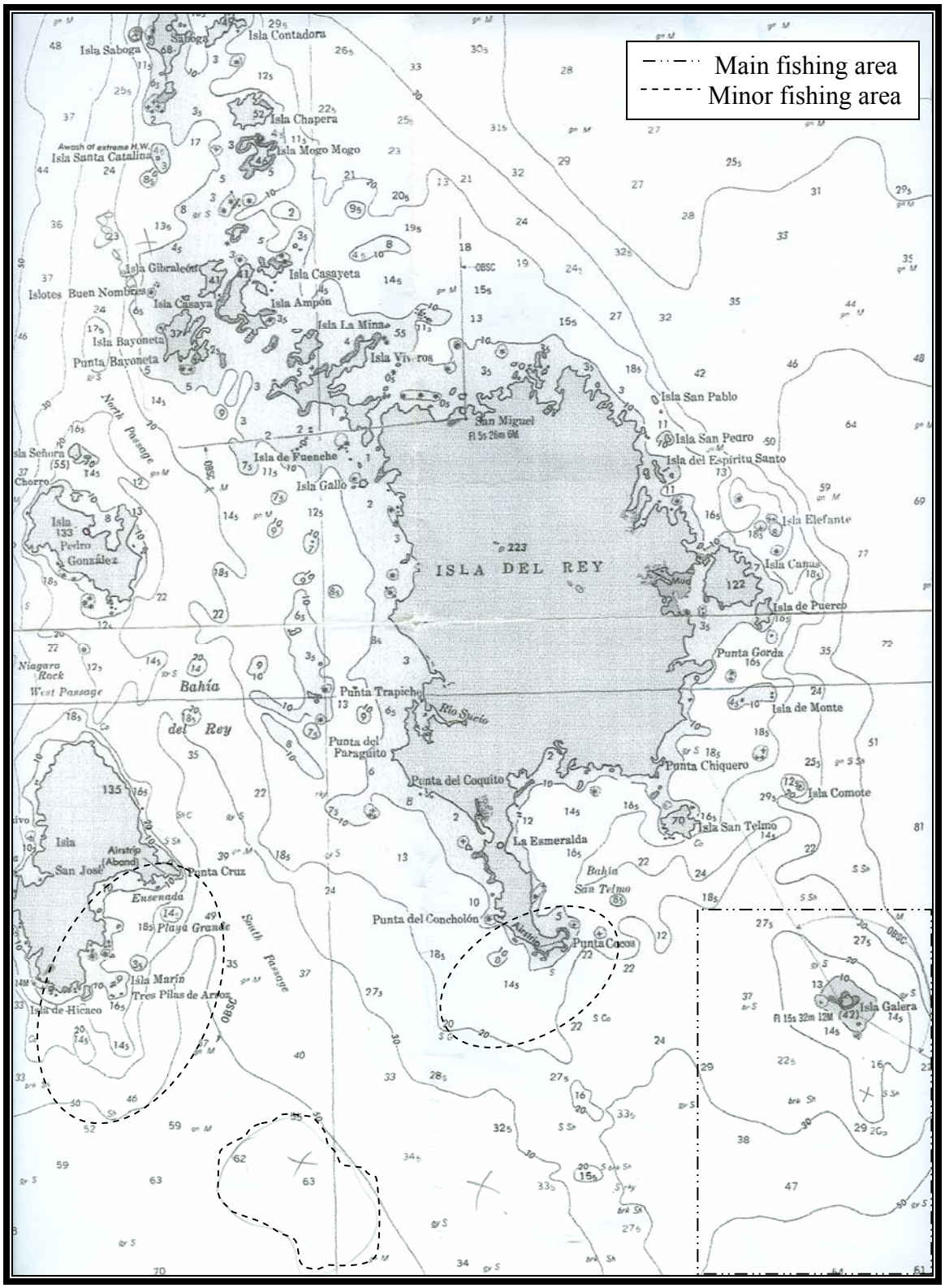

Figure IV.I Map of the Las Perlas archipelago showing the rough areas used by fishermen of Esmeraldas for the snapper fishery (From anecdotal sources within Esmeraldas).

APPENDIX V – Gonad Stages of Maturity for Male and Female Snapper

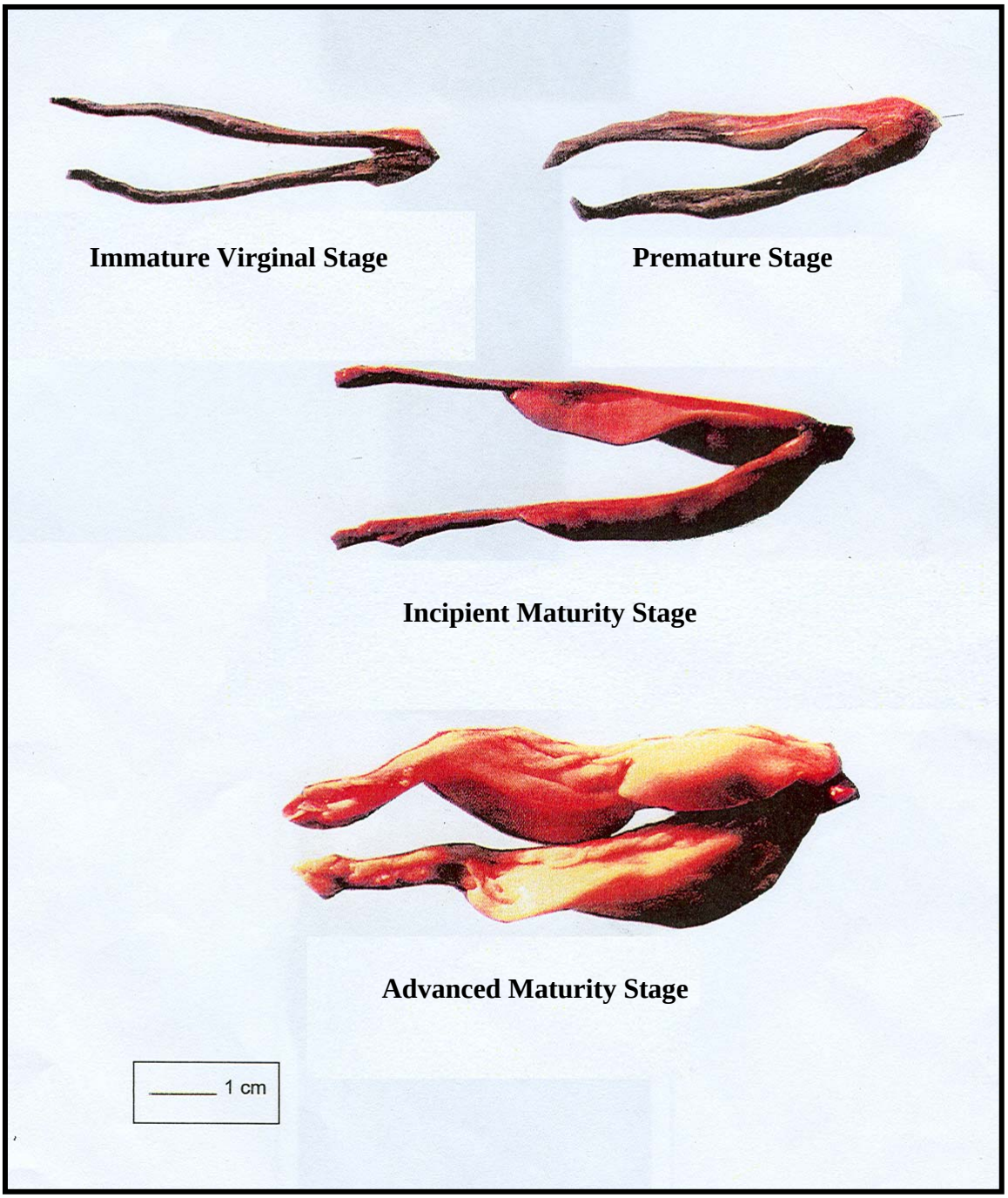

Figure V.I Male snapper gonads at varying stages of maturity from immature to fully mature.

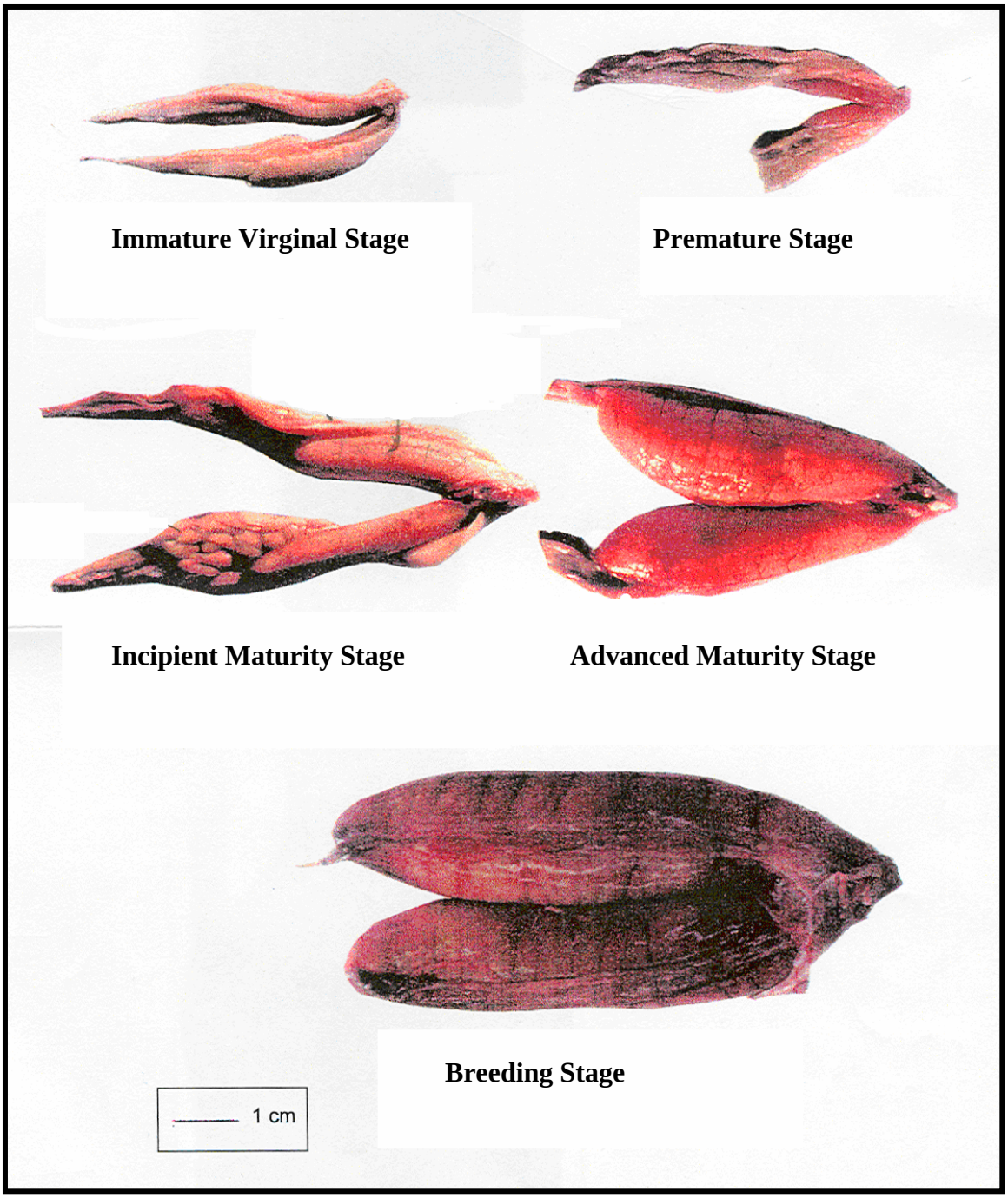

Figure V.II Female snapper gonads at varying stages of maturity from immature to fully mature.

APPENDIX VI – Map of the Archipelago Shown in Relation to Panama

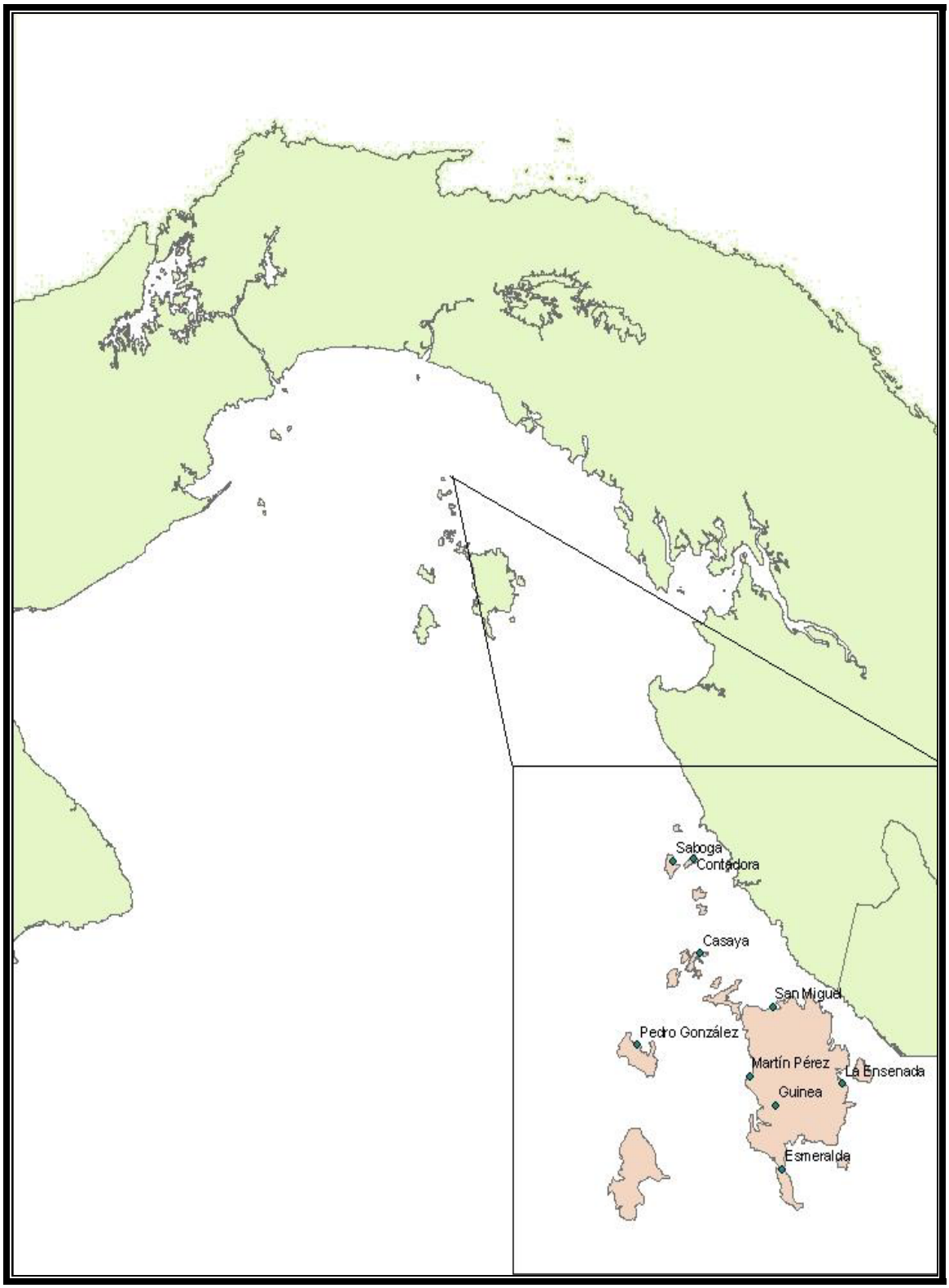

Figure VI.I Shows insert of Las Perlas archipelago within the Gulf of Panama, created using ArcGIS.