State of the *Anadara tuberculosa* (Bivalvia: Archidae) fishery in Las Perlas Archipelago, Panama.

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Submitted: **September 2007**

Submitted as part assessment for the degree of Master of Science in

Marine Resource Development and Protection

Centre for Marine Biodiversity and Biotechnology

School of Life Sciences

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ACKNOWLEDGEMENTS

I would like to thank Dr. Hamish Mair and Dr. Héctor Guzmán for their time, patience, helpful suggestions and support during my stay in Panama. I would also like to thank the Smithsonian Tropical Research Institute for the use of their facilities at Panama City.

Field work would not have been possible without the precious assistance of Carlos Guevara, Julio Agujetas and Alexis Lam. Special thanks to Inez Campbell who helped me with all of my field work and particularly with the translating part of the surveys.

Thank you to the "Dream Team" members, Andrea Gear, Emma Kennedy, Sam Neal and Katherine Nisbet for your support.

Thanks to the Las Perlas community, especially people from San Miguel, Casaya, Ensenada and Martin Perez.

And finally, this project would not have been possible without the financial support of the Heriot-Watt Alumni Fund.

ABSTRACT

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 cockle *Anadara tuberculosa* in Las Perlas Archipelago. The project involved the collection of both quantitative and qualitative data. The quantitative data including shell sizes, meat weight, ratio between males and females, abundance and patterns of distribution were collected in five different mangroves areas in Las Perla Archipelago. The qualitative data were collected through interviews with local fishermen in four villages (San Miguel, Casaya, Ensenada and Martin Perez) and through personal observation. The ratio of males to females was 1:3.5 . A significant relationship was found between shell length and shell width as well as between shell length and meat weight. Length-width and the length-weight relationship did not differ significantly between the sexes. Length frequency analysis revealed that cockles are removed from the stock at a length of 32cm up to 72cm. (4.7% have a size comprised between 32-41 cm, 40.4% between 42-51, 49.6% between 52-61cm and 5.3% between 62-72 cm). Two main density peaks were observed, with the highest numbers of individual being caught around 51-52 cm and around 57 cm. All the females of *Anadara tubercuosa* collected in Las Perlas Archipelago were found at a sexually mature stage. According to these results, *Anadara tuberculosa* with a shell length superior to 32 mm are sexually mature. Concerning its patterns of distribution, results showed that the cockles live inside the mangrove trees and that a greater number of cockle is found in areas inside the first mangroves trees along the estuary than in areas inside the mangroves trees closer to the land. Along the estuary, the highest number of *Anadara tuberculosa* was found at the canal mouths and the abundance of the cockle was decreasing when going upstream in the estuary. The main phenomenon observed during the survey was that the Quantitative Catch Per Unit Effort is lower today than a decade ago. Depending on the mangrove areas the Quantitative Catch Per Unit Effort decreased from 50% in Martin Perez up to 90% in Casaya. *Anadara tuberculosa* stock is relied upon heavily as a source of income for a large proportion of the population of the Las Perlas Archipelago. Therefore, apart 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.

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 cockle *Anadara tuberculosa* in Las Perlas Archipelago. The study was made possible through collaboration with the Smithsonian Tropical Research Institute in 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 archipelago, with the hope of achieving effective long-term management plans for the region.

1.1 Description of *Anadara tuberculosa*

1.1.1 Morphology and biology

Morphologically, this species is constituted of two valves of equal shape which are obliquely oval. Each valve has 34 to 37 radial ribs and a dark brown periostracum with bristles between the ribs (Ficture 1). The dorsal margin of the valves is angular. Maximum length for this species is 110 mm, but it seems to be mainly correlated with the harvesting effort. MacKenzie, in 2001, showed that where harvesting is lightest, as in Mexico, the cockles had a longer chance to grow and were as large as 75 mm. Where harvesting is heaviest, as in Guatemala, El Salvador, and Peru, the cockles were the smallest because they had the least time to grow, and all were less than 55 mm.

Figure 1 : Picture of *Anadara tuberculosa.*

The shell lengths at which *Anadara tuberculosa* are first sexually mature vary for different countries. In Costa Rica, *Anadara tuberculosa* is first sexually mature at lengths of 23 –26 mm and it takes about 3 to 8 months for the cockle to reach this length

(Ampie & Cruz 1989), while in the Colombian Pacific, according to Borda & Cruz, they are first sexually mature at lengths of 44 mm and the size of first maturity is reached in 12 months. The males' sex products are white or cream coloured while those of the females are orange (Cruz, 1987a; Fournier and de la Cruz, 1987). The sex ratio is 1:1, and there is no sex reversal. The cockle reproduces during the whole year, but the main spawning seasons are in May and September. After hatching, the larvae are planktonic and remain as larvae between 23 and 31 days in oceanic waters; during this period they have been able to identify 4 phases: trocófora, veliger, larva with umbo and lastly the larva oculada or pediveliger that remains in the water column between 13 and 15 days (Borda & Cruz, 2004). This last phase returns to the mangrove areas with the help of the currents and of the tide changes, where they settle as postlarvae (5.5 mm and duration between 4 and 5 months) to a substrate (Figure 2). The juveniles (between 18 and 30 mm) have duration of 6 months. They recruit to the fishing area between 6 to 10 months after spawning. The seasonal cycle of the juveniles varies considerably from year to year, but a period of maximum recruitment has been observed in the months of May, August and December (Borda & Cruz, 2004).

Little is known about the predation pressure on *A. tuberculosa,* however they are somewhat protected by the prop roots of the mangrove trees, unlike deeper burrowing species such as *A. similis,* which burrows roughly 30 cm deep in the mud but lives primarily in mud flats uncovered by mangrove trees (Stern-Pirlot, 2004). The predatory snail *Cymatium wiegmanni* is reported to prey upon *A. tuberculosa* when they are placed subtidally (Villalobos & Baez 1983). Scientists in Mexico and Ecuador have reported that small *A. tuberculosa* are eaten by Tetraodontidae (puffer-fish) species during high tides (MacKenzie 2001). Other animals found to prey on small *Anadara* in Southeast Asia are the gastropods *Natica maculos*a and *Thais carinifera,* the starfish *Asterias amurensis,* the catfish *Plotosus anguillaris* and some wading bird species such as the greenshank, *Tringa nebularia* (Broom 1985).

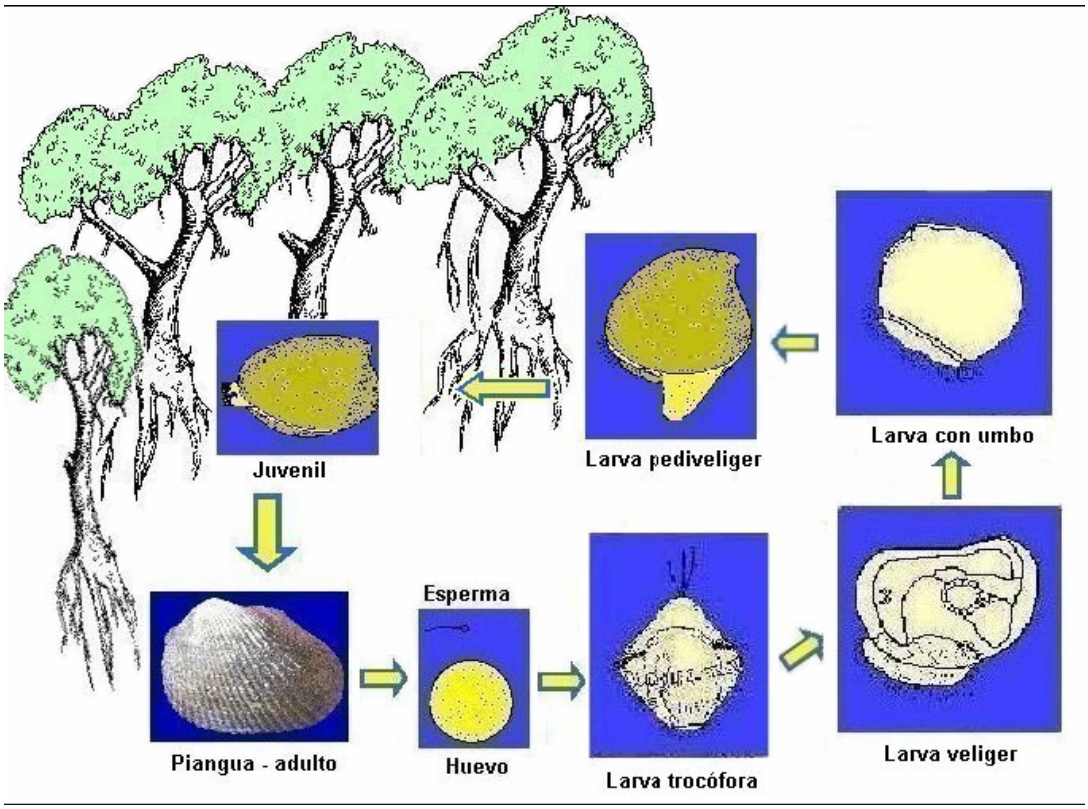


Figure 2 : Schematic of the life cycle of *Anadara tuberculosa*. Figure extracted from Borda & Cruz, 2004.

1.1.2 Distribution and habitat

The mangrove cockles *Anadara tuberculosa* are by far the most important molluscs along the Pacific Coast of Latin America, which encompasses a biogeographic zone that Briggs (1974) has defined as the Tropical East Pacific Region. The extent of their range is about 6,350 km, from Laguna Ballena, Baja California Sur in Mexico, to Bahia de Tumbes in Peru (Mora Sanchez, 1990; Cruz and Jimenez, 1994).

Anadara tuberculosa inhabit level mud sediments in mangrove swamps which occur along the main-lands and islands of lagoons. The cockle is found in several centimetres of mud below the base of the roots of the red mangrove, *Rhizophora mangle*. This red mangrove is the most commonly occurring species within the Las Perlas Archipelago (Betts, 2006). They are most commonly found across western Africa to the Pacific coast

of tropical America (Tomlinson, 1999). This mangrove species is shade intolerant, but has a wide tolerance range for salinity (Benfield, 2002). *Rhizophora mangle* can be found in diverse forms. It can form short scrubs, or woody trees that may grow up to around 30 m tall (Tomlinson, 1999) and can be found in off-shore stands, fringing, riverine or inshore basin forests. The most noticeable characteristic of Rhizophora are their aerial stilt roots. When the trees grow to around 30 m tall, their root system becomes extremely large and complex. The propagules are shaped like rods that have elongated hypocotyls that float (Benfield, 2002). *Rhizophora mangle* is a hardy species, and tend to be long lived, which allows them to grow to such heights (Betts, 2006).

In addition, sparse quantities of *Anadara tuberculosa* have been found in intertidal mud flats between the mangrove trees and the low tide line (Rosero, 1998). The deep at which the cockle is found varies between a few centimetres and more than 20 cm. It seems that *Anadara tuberculosa* is found deeper in the mud in colder countries and during winter (MacKenzie, 2001). The swamps become flooded with estuarine water during mid and high tides, and their mud substrates become covered by 1 m or more of water. The water drains off during ebbing tides, leaving the substrate bare for about 4 h during low tides (MacKenzie, 2001). *Anadara tuberculosa,* which is mostly growing in the mud zones of the red mangroves, *Rhizophora mangle,* can also be found in lower densities in the black mangroves, *Avicenia germinans*, where sediments are more compact and have more woody fiber (MacKenzie, 2001). However, *Anadara tuberculosa* is never found in sandy or shelly bottoms even in the presence of red mangroves (Baquiero, 1980).

1.1.3 *Anadara tuberculosa* in the study area

There have been some studies conducted on the cockle *Anadara tuberculosa* in the Pacific coast of Panama (MacKenzie, 2001, Carmen, 1999), but as far as the author is aware non in the Archipelago of Las Perlas. However, previous research on the mangrove cover and structure in Las Perlas Archipelago has revealed that the red mangrove *Rhizophora mangle*, inside which the cockle grows, is present in high abundance in the islands with two other species, *Laguncularia racemosa* and *Pelliciera rhizophoreae* (Betts, T. 2006; McGowan, T. 2006).

1.2 Study area : Las Perlas Archipelago

Las Perlas Archipelago is located within the “Bay of Panama” approximately 31 km from the closest Panamanian coast, on the Pacific side (Berman, 2004). This archipelago is composed of over 240 basaltic rock islands, islets and outcrops which are the remnants of an ancient coastal mountain range called Cordillera Costera (Rubio, 1949). The main islands are Isla Del Ray, Contadora, San Miguel, San José and Pedro Gonzalez. The archipelago islands are mainly covered by dense tropical rainforest and the archipelago comprises several marine environments including coral reefs and mangroves. Among these islands, only a few are populated, with 19 villages spread across the archipelago with a population range from 10 up to 700 (Campbell, 2005). Most of these villages do not support large scale of infrastructures. Only few islands such as Isla Contadora, in the north of the archipelago, have been largely transformed by the development of human facilities including paved road network, electricity generating plant and water supply infrastructure, as well as a marina and an airstrip. This island has been the main point for tourism development in the archipelago and is now home to numerous luxurious private residences and hotels.

The economy in the Las Perlas Archipelago was for a long time mainly concentred on small-scale agriculture and artisanal fisheries (Campbell, 2005). Certainly due to the relative isolation of the archipelago and the small size of most of its islands, which made them inappropriate for colonisation, the archipelago has been of poor interest to developers and the scientific community in the past (Goarin, 2006). However, the development of modern transport such as planes and fast boats means that isolation is becoming impossible and resources more accessible and attractive. Attracted by the opportunity to observe a fantastic terrestrial and marine life sanctuary, the tourism industry has become increasingly more important. In 1994, the Las Perlas Archipelago was designated as a special tourism development area for Panama, called Tourism Zone 8 (Law 8, June 14, 1994) and it is part of the Whale Sanctuary of Panama (including territorial waters: Pacific and Caribbean) (J. M. Guevara, 1995). Since then, there has been a noticeable rise in tourism to the archipelago with the majority concentrated around the Isla Contadora and on the southern island of San José. But tourism has not been the only industry attracted by the marine resources of the archipelago. The fishery industry has grown and people now come from the mainland of Panama and neighbouring countries to exploit its marine resources. The islands of the archipelago

were for a long time little affected by anthropogenic influences. However, the increasing tourism and fisheries development and a historical legacy of misuse have now impacted upon the archipelago in a number of ways.

1.3 The Darwin Project Initiative

This dissertation study is a contribution to the Darwin Initiative for the Las Perlas Archipelago which was initiated four years ago with the collaboration of Heriot-Watt University, Edinburgh and the Smithsonian Tropical Research Institute (STRI), Panama.

The Darwin Initiative for the Las Perlas Archipelago is part of the Darwin Project, a fund created by the British Department for the Environment, Food and Rural Affairs to promote sustainable development around the world and help developing countries meet their commitments to the United Nations Convention on Biological Diversity. In light of the recent interest of developers in the area - in particular the tourism industry - and of the negative impact of over-fishing, the Darwin Initiative's aims for the Las Perlas Archipelago is to build up research expertise in a team dedicated to obtaining habitat information and to producing management plans for the marine and coastal environment of the archipelago.

In just four years, the Darwin Initiative for the Las Perlas Archipelago has already contributed significant material to the understanding of the natural environment of the archipelago. This has included mapping with remote sensors and GIS, the description of marine and coastal communities and habitats, as well as socioeconomical studies on fisheries and involvement of the local population to the sustainable management of their islands. Campbell, in 2005, found that 92.5% of the local population believes that a Marine Protected Area would be beneficial to the management of the archipelago. Scientific evidence of the benefits and necessity of the introduction of management tools in Las Perlas Archipelago gathered by the Darwin Initiative and STRI has contributed to the government's awareness of local issues. In October 2005, a law to create a Special Management Zone was submitted to the National Assembly of Panama. This Special Management Zone and associated regulation are effective since the 31st of May 2007, covering a total area of 168,771 hectares, including two nautical miles around the satellite zones of Isla Galera and Roca Trollope (Figure 3).

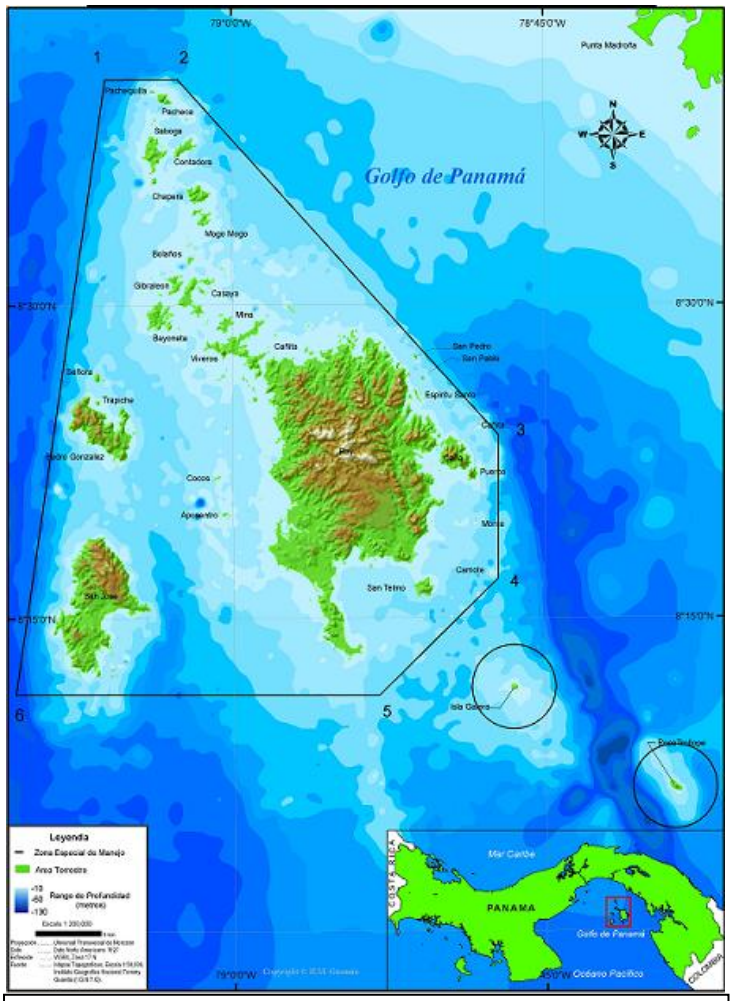


Figure 3 : Map of the Las Perlas Archipelago with the Special Management Zone.

1.4 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 stop this phenomenon. 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.

The main focus of this study shall be to examine the fishery of *Anadara tuberculosa* in the Las Perlas Archipelago. There has been very little work done on the biology and ecology of the Archipelago and even less is available with respect to fisheries of the region. Medina *et al*., in 2007, 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, but both of which subsequently collapsed. The work done by Medina *et al.,* in 2007, found that more than twenty years after the collapse of the Las Perlas scallop fishery in the 1980s, there was no sign 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.,* in 2007 state that once a resource collapses due to overexploitation, its potential for recovery is very limited. These issues have important implications for the current cockle fishery of Las Perlas. Indeed, anecdotal reports from cockle harvesters indicate that most areas of Las Perlas have seen a decline in the abundance and sizes of *Anadara tuberculosa* over the past 10-20 years, suggesting that the fishing pressure on this species is too high. A high fishing effort combined with a falling catch per unit effort would suggest that many people are reliant on harvesting this species for income because they continue to carry out this activity despite its increasing difficulty and decreasing returns. Because of this, discussion is currently taking place among policy makers and academics regarding the management of the *Anadara tuberculosa* fishery in Panama.

1.5 Aims

Anecdotal reports from cockle harvesters indicate that most areas of Las Perlas Archipelago have seen a decline in the abundance and sizes of *Anadara tuberculosa* over the past 10-20 years, suggesting that the fishing pressure on this species is too

high. A high fishing effort combined with a falling catch per unit effort would suggest that many people are reliant on harvesting this species for income because they continue to carry out this activity despite its increasing difficulty and decreasing returns. Because of this, discussion is currently taking place among policy makers and academics regarding the management of the *Anadara tuberculosa* fishery in Panama.

Thus, the main objective of this study is to quantify the population parameters of *Anadara tuberculosa* in Las Perlas and the effect that the fishery is having on the standing stock of this resource. To accomplish these overarching objectives, ratio between males and females of *Anadara tuberculosa*, length-width and length-weight relationships, harvesting rates and sizes, catch-per-unit effort and distribution patterns of *Anadara tuberculosa* are determined. Additionally, an attempt is made to understand how important this fishery is to the harvesters, their families and communities to potentially explain why the fishery is in its current state and suggest viable management options if necessary. The assessment of the socioeconomic importance of *Anadara tuberculosa* and the nature of the fishery at the study sites is undertaken by collection of information through interviews with local fishermen.

Five mangrove complexes and their corresponding four human settlements in Las Perlas Archipelago were chosen for this study. These villages, San Miguel, Casaya, Ensenada and Martin Perez were chosen because they each have a well-established community of cockle harvesters, potentially making the fisheries at each place roughly comparable. Because it was necessary to work closely with cockle harvesters in order to carry out the sampling design, sites were also chosen according to enthusiasm of community members to participate.

2.0 METHODOLOGY

2.1 Field work

Field research was conducted in the Las Perlas Archipelago between the 5 of May 2007 and 12 of May 2007. The project involved two types of research: quantitative data collection and qualitative data collection. The quantitative data collection involved recording biometric data from in-situ surveys. The qualitative data was collecting through interviews with local fishermen and personal observation.

2.1.1 Quantitative in-situ data collection

Different sites were surveyed within the archipelago. A small rigid inflatable research boat was used to access each sampling site. However, because sites were surveyed at low tide, it was sometimes necessary to walk in shallow water to access the sampling area.

The first part of the survey consisted of collection of information on the techniques used by local fishermen to harvest *Anadara tuberculosa*. The two first days of the survey were used to obtain general background information on the cockle fishery, by accompanying a group of fishermen into the mangroves and partaking in harvesting activities. During these two days, specific attention was given to the type of environment where the cockles were found. Pictures of this environment were taken as well as notes relative to the type of substrata and habitat where the cockles were growing.

During the next five days of field work, the research concentrated on surveying the principal fishery sites within the archipelago. Five sampling sites were selected after interviews with local fishermen in order to conduct the survey in areas where cockles were usually harvested by local communities (Figure 4 (Sites 1, 2, 3, 4 and 5)). Most of the time a group of local fishermen accompanied the scientists to help them with the collection of cockle samples. At each site, the presence of *Anadara tuberculosa* was recorded and each individual found was collected and kept alive in bucket of water (recycled every day) for future laboratory analysis (Figure 7.A). For each site, the

number of harvesters; the time spent on the site looking for cockles, and the number of cockles collected were recorded to estimate the Quantitative Catch Per Unit Effort.

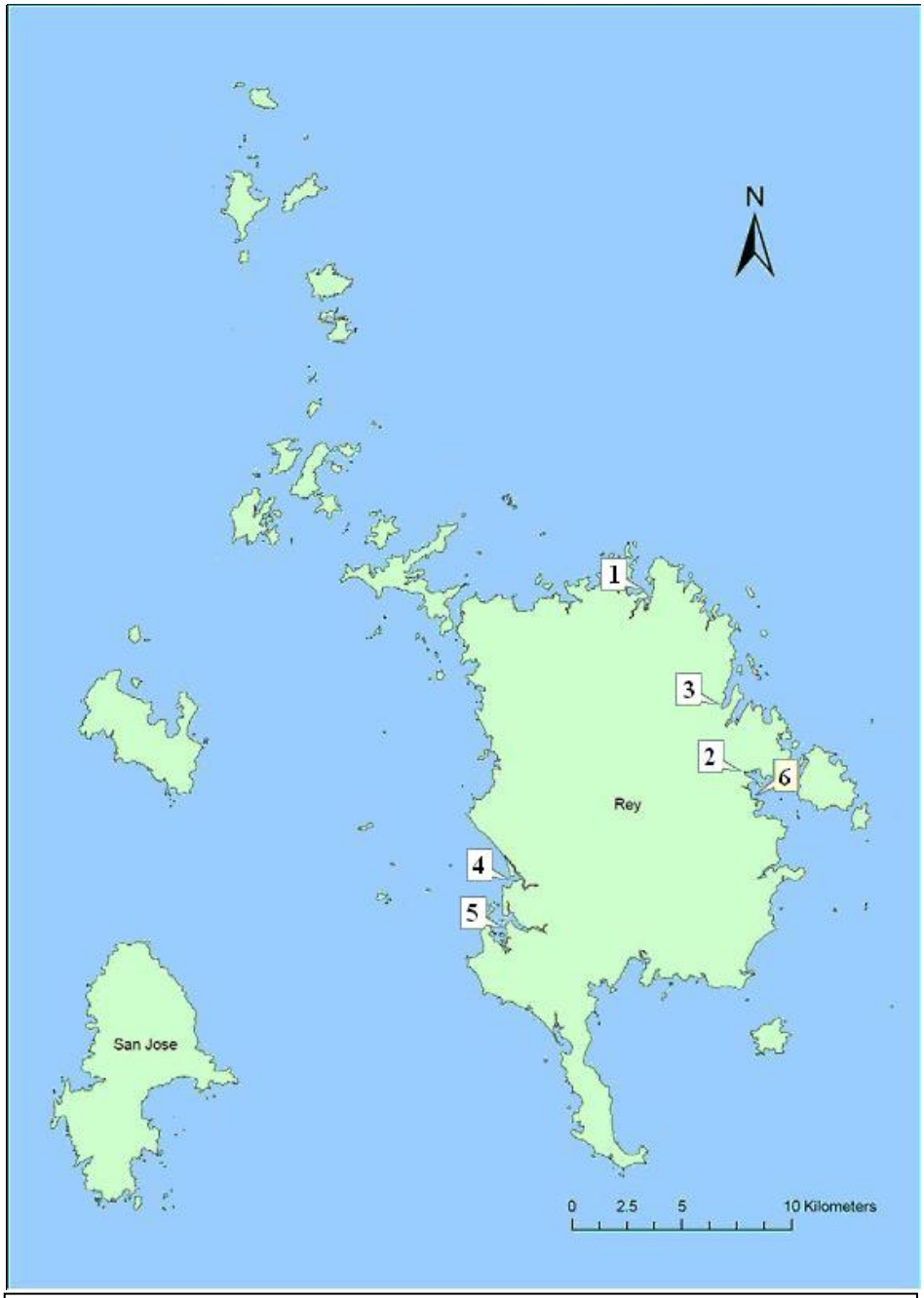


Figure 4 : location of the sampling Sites.

Another part of the survey conducted in the field was the research of specific patterns of distribution of the cockle along an estuaries. For this survey, 16 m^2 quadrats (4×4 m) were used. Because of the specific environment fashioned by mangroves, with a very high density of strong roots, it was not possible to use usual rigid quadrats. Quadrats

were designed using four fine 4 m cords. The research of specific patterns of distribution of the cockle was undertaken in an estuary close to Ensenada (Figure 4 (Site 6)). The distribution pattern of *Anadara tuberculosa* was studied at 3 different stations along this estuary. The first station was at the mouth of the estuary, the second and the third were upstream in the estuary (Figure 5). At each station, 3 different areas were sampled: one on the intertidal mudflats between the mangrove trees and the low tide line (*a*), one inside the first mangrove trees along the estuary (*b*) and the third one inside the mangrove trees closer to the land (*c*) (Figure). For each area at each station, 3 quadrats were used. For each quadrat, the number of *Anadara tuberculosa* was recorded and each individual found was measured and then released back to the place were it was found.

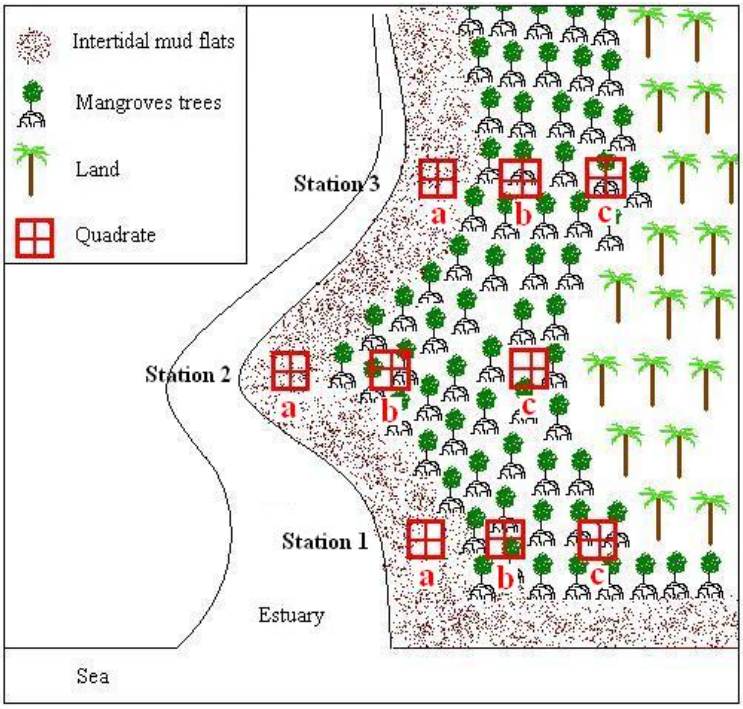


Figure 5 : Schematic diagram of the sampled areas along the estuary, showing the 3 survey stations and different areas sampled at each station (Area *a* is the area on the intertidal mud flats between the mangrove trees and the low tide line, Area *b* is inside the first mangroves trees along the estuary and Area *c* is inside the mangroves trees closer to the land).

2.1.2 Qualitative Research

The qualitative section of this research project was collected mainly through interviews conducted with local fishermen throughout the main villages of Las Perlas. General information regarding the daily routine of fishermen was obtained through accompanying a group of them into the mangroves and partaking in harvesting activities. On these days, first-hand observation and experience was combined with learning through unstructured interviews and listening to stories. In addition, structured interviews with fishermen were conducted over approximately 2 hours in different villages. Basic information, such as age, gender and main occupation, was collected as well as information about the cockle harvesting and economic information. The interview format can be found outlined below in Figure 6. 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 I. Interviews with Corregidors (the official community representative) and/or fishermen were conducted for San Miguel, Casaya, Ensenada and Martin Perez. 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.

Basic Information:

- Age
- Gender
- Occupation

Harvesting Information:

- Who harvests the concha negra in the village, men, women, children?
- Where do you find the concha negra?
- How are the concha negra distributed within the mangroves (patched or isolated)?
- How deep are the concha negra you harvest?
- When is the best time to harvest the concha negra during the day?
- Is the concha negra harvested all the year or is there any season?
- How many times per week do you harvest?
- How many hours per day?
- Since when have you harvested the concha negra, for how many years?
- How often do you return to the same place to harvest concha negra?
- What equipment do you use for harvesting (boat, gloves, bag, bucket, etc.….?)
- How many buckets per hour and per harvester today? And before?
- How do you conserve the concha?
- Since you began as a concha negra harvester, has the number of concha in the mangrove: decreased, increased or remained the same?
- Since you began as a concha negra harvester, has the size of concha in the mangrove: decreased, increased or remained the same?
- Do you have any idea to explain these phenomena?
- Is there any danger encountered when harvesting the concha in mangroves?
- Do you know any concha negra predator?
- What do you do with the shell of the concha?
- Which other species do you collect in the areas where you harvest pianguas?

Economic Information:

- Do you harvest concha negra for local consumption or to sell?
- If harvested for local consumption, how many and how often do you eat it?
- Is there any specific occasion?
- For what price do you sell a bucket of concha negra?
- To whom do you sell the concha negra you collect?
- If that person sells them to someone else, to whom does he sell them and where?
- What other income-earning activities to you have outside of harvesting concha negra?

Figure 6 : Interview format used to obtain qualitative information from local fishermen.

2.2 Laboratory analysis

Laboratory analysis was conducted in the STRI laboratory in Panama City between the 14th of May 2007 and 26th of May 2007. The laboratory part of the project consisted of biometric analysis of the collected samples of *Anadara tuberculosa*.

2.2.1 Biometric data analysis

Specimens of *Anadara tuberculosa* collected during the field work survey in the Las Perlas Archipelago were kept alive in a tank with a specialised mud and recycled sea water system (Figure 7.B).

Figure 7 : Picture of a typical bucket used to transport and conserve the cockles (A) and of the tank used to keep the cockles alive with the recycled sea water system.

Biometric data interpretation and analysis was performed using Microsoft Excel and Minitab statistical software.

Proportional relationships between shell length and shell width, as well as proportional relationships between shell length and fresh weight, were established. This was done by measuring the shell lengths and widths to the nearest 0.5 mm using a Vernier caliper (Figure 8) and the weight of the fresh meat to the nearest gram (Figure 9.D) for all the individuals collected.

Length was defined as the maximum shell length (usually from the outer edge of the hinge to the outermost growth margin) (Figure 8.A) and width was measured where the individual was “thickest” (Figure 8.B). The fresh meat was defined as the whole flesh present within the shell. To extract the whole fresh meat, cockles were dissected and the meat was separated from the shell. Particular attention was taken when opening shells in order to avoid tissue damage. The shell was placed on a flat surface with the dorsal area

(charnella) facing downwards. A scalpel was used to open the shell ventrally by cutting the abductor muscles (Figure 9.B and 9.C).

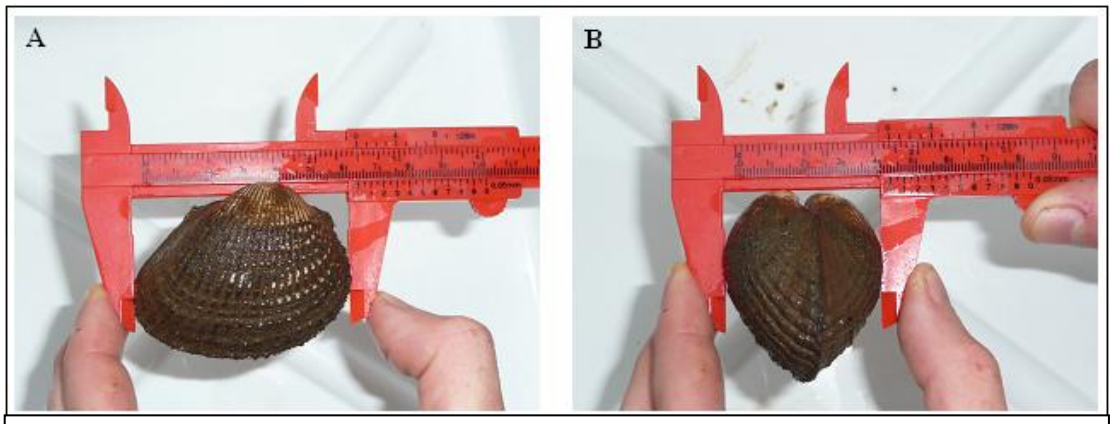


Figure 8 : Dimensions used for A. length and B. width measurements.

Figure 9 : Dissection phases to extract the meat of *Anadara tuberculosa*. The shell was placed on a flat surface with the dorsal area facing downwards (A). A scalpel was used to open the shell ventrally by cutting the abductor muscles (B) and (C). The fresh meat was then weighed to the nearest gram (D).

For each individual collected, the sex and gonad phase were also determined by macroscopic examination after dissection. In order to identify the cockle's gender, a dorsal-ventral incision was made into tissues towards the anterior section of the cockle. Gonad tissue occupies part of the visceral mass (Figure 10) and, depending on the maturity stage, it tends to eventually occupy the lateral walls. Classification of sex can be made according to the colour of the sexual components: females normally present a red-orange coloration, sometimes pale pink, and males a creamy colour.

The sexual maturity of the cockle was determined for the females by macroscopic observation of the gonads. Four main development stages can be observed (Table 1).

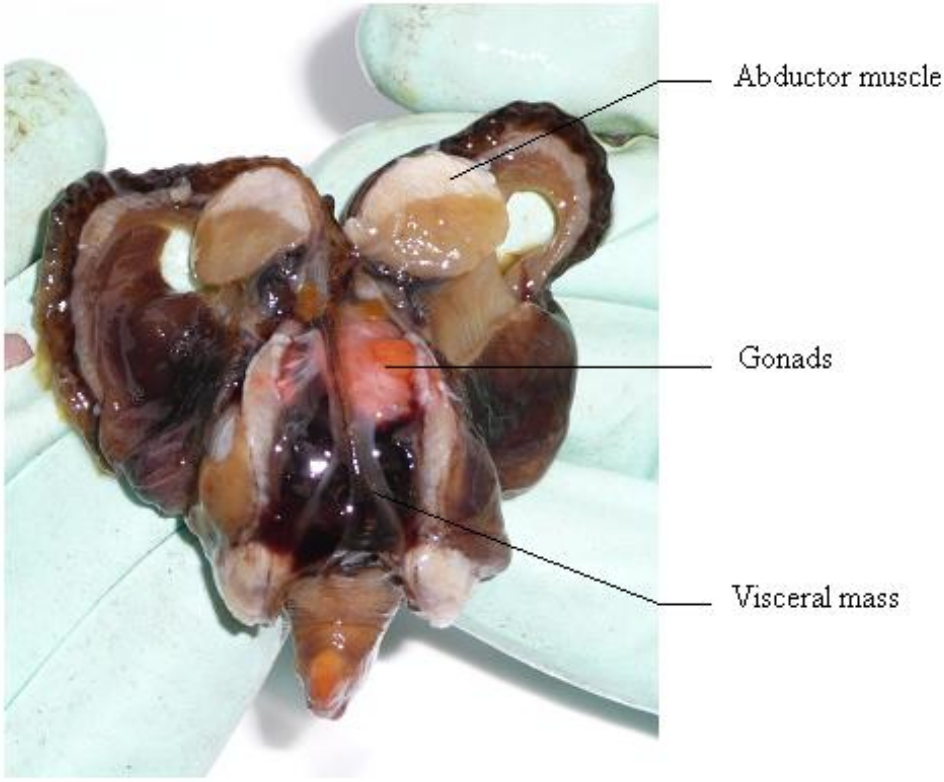


Figure 10 : Picture of a dissected cockle showing the position of the gonads tissues.

Grade	Stage	Macroscopic observation
I	**Indeterminate**	Visceral mass flacid. Gonads difficult to observe
II	**Developing/on the increase**	Low gonad contents around visceral mass walls. *Initial development* (ID).
		More presence of gonad contents around visceral walls *Intermediate development* (TD).
III	**Mature**	Large quantity of gonad contents covering the visceral mass walls, corresponding to an *advance development* (AD), or, there is an excess of gonad contents – *mature stage* (MS).
IV	**About to Spawn**	Creases are observed externally on the visceral mass and through a transversal incision low quantity of gonad contents is observed internally.

Table 1: Sexual maturity scale for *Anadara tuberculosa* (observed after a transversal incision)

In total, 552 individuals were used for these calculations. After determining that there was no significant difference in these ratios among sampling sites, measurements from all sites were combined for an overall picture of the biometric relationships for the species in Las Perlas Archipelago as a whole.

2.2.2 Determination of the Quantitative Catch Per Unit Effort

Data collected at each sampling site detailing the number of harvesters, the number of hours they spent harvesting within the mangrove and the number of “concha negra” they harvested were used to estimate the Quantitative Catch Per Unit Effort. From this data, the average number of *Anadara tuberculosa* collected per hour per harvester in each area is determined.

3.0 QUALITATIVE RESULTS

3.1 Introduction

The qualitative data have been collected from interviews conducted in four villages within the Las Perlas Archipelago: San Miguel, Casaya, Ensenada and Martin Perez. This information cannot be seen as quantitative. However, efforts were taken to ensure that the information collected was as accurate as possible, by interviewing different people in each village. The information below is a summary taken from interviews and general comments from local people in the archipelago. (Full transcripts of all interviews conducted for all villages can be found in Appendix I).

3.2 General Fishing Practices throughout the archipelago.

Within the archipelago the cockle *Anadara tuberculosa* is commonly named "Concha Negra" (black cockle) by the local fishermen. The concha negra is harvested in all the villages visited. Nearly all the fishermen harvest cockles to sell, but some harvest them only for their own food. In Casaya and Martin Perez, everybody - men, women and children (Figure 11.B) - participated in the harvesting, whereas this occupation is left only to the women in San Miguel and Ensenada.

The fishermen of all the villages harvest cockles during low tide when the mud surface of the mangroves fall bare and they can walk on them. The fishermen's expenses are small, because harvesting does not involve any heavy lifting. Some fishermen, such as those in San Miguel, can reach the harvesting areas by walking through the forest. Other fishermen have a short walk from their homes to their boats and then a 10 to 40 minute boat run to harvesting areas. Nearly all fishermen travel to and from the cockle harvesting areas in wooden canoes. The canoes are propelled using wooden paddles or by outboard motors. Usually, a group of 2 to 5 people, generally family members, go together in the canoes to the harvesting area. Within the mangroves, they go barefoot when harvesting cockles, and usually harvest barehanded. Nets, sacks or plastic buckets are used to hold the cockles during harvesting.

Cockles are found between the mangrove roots (Figure 11.D) in the cool shade under the mangrove canopies (Figure 11.E), and the fishermen are autonomous, but it is

unpleasant walking and probing in soft mud. The fishermen reach down and feel in the mud with their fingers for the cockles. Their hands penetrate the mud up to their wrists to find *Anadara tuberculosa* (10-20 cm deep). As they walk to a new place, stop, and reach around aerial prop roots for cockles, their legs may sink into mud half way to their knees, and much effort is often expended squeezing their bodies between the roots to gain access to places where they can get cockles (Figure 11.C). Some groups of prop roots are too densely packed for fishermen to penetrate (Figure 11.A).

Fishermen spend about 4 hours a day harvesting, and then return to their boats, slosh their cockles in water to wash off the mud (this may also be done back at the village shore) and go back to their villages. They often set some cockles aside for home use before taking the remainder to dealers in the villages or keeping them at home until a dealer comes for them. To preserve the concha for few days, they keep them alive in nets in the sea or simply leave them in plastic buckets were they can live for a few days out of the water.

The intensity of the cockle fishery depends on the demand. When a buyer orders cockles, the fishermen in all villages usually harvest cockles 2 to 7 days a week. The days missed are during neap tides or heavy rains when harvesting is difficult or impossible. When there is no specific demand for cockles, fishermen only harvest a few days per month for their own consumption. There is no particular season for cockle harvesting so fishermen can harvest all the year. However, they go to a different area each day, leaving harvested sites for about 3 to 5 months to allow the cockle to recover (fishermen in Ensenada left harvested sites for about 3 years according to the fishermen interviewed). They do not know whether anyone else may have harvested there while they were absent. If the cockles are scarce, they move to another location.

When harvesting cockles in the mangroves, fishermen are exposed to mosquitoes that can be abundant during the rainy season. But the main danger for the fishermen is the bees. Many people have been very seriously attacked by bees when harvesting and in some cases, it was necessary to carry the victims to San Miguel village for medical care. Cockle fishermen also get skin abrasions when they rub against mangroves roots.

Concerning the presence of any wild predator of the cockle, fishermen from Martin Perez revealed the presence of a kind of raccoon that had been seen feasting on cockles, but no more information has come to light concerning this mammal.

All the fishermen interviewed declared selling the cockles to a woman coming especially to the archipelago from the mainland. It was not determined whether or not

this buyer was the same for all the villages. Fishermen from San Miguel and Casaya spoke about a Colombian woman. However it was difficult to get more information concerning the buyer and impossible to contact this buyer (since it is the buyer who contacts the fishermen to order cockles and the fishermen cannot contact them). In Casaya there is rarely a buyer who comes to the harvesters' homes. Instead, fishermen bring their harvest to Martin Perez to sell their cockles so it is probably the same Colombian woman who buys the cockles from the Matin Perez fishermen. According to the fishermen of Casaya, the buyer used to come every 2 weeks to Martin Perez. However, fishermen from Martin Perez stated that the woman came every 4-5 months to buy about 150 buckets. Such a long delay between each coming would be to allow the cockles to recover. The cockles are sold at between US$7 and US$9 per bucket plus gas for the boat. According to the fishermen one bucket holds about 400 cockles. However personal observation reveals that one bucket holds about 250-300 cockles. The buyer seems to export the cockles to Panama, Guatemala and Mexico. Once bought, the cockles are usually used to make a ceviche, a salad in which the uncooked cockle meat is combined with onions, peppers and other vegetables, and lime juice.

All harvesters from all the villages visited reported that there are fewer cockles in the mangrove now than when they first began harvesting (Table), and fishermen from San Miguel reported that the individuals they find now are smaller than when they began. The rest stated that the size of the individuals is still the same as always.

	San Miguel	**Casaya**	**Ensenada**	**Martin Perez**
Before	9-11 buckets/pers/day	4 buckets/pers/day	6-7 buckets/pers/day	4 buckets/pers/day
Today	2 buckets/pers/day	60-80 cockles/pers/day	1-2 buckets/pers/day	2 buckets/pers/day

Table 2 : Comparison of the quantity of cockles harvested by fishermen when they first began harvesting ('before') and today for each villages.

The major problem reported by harvesters in 3 of the 4 villages is that there is an overexploitation of the resources. The Martin Perez fishermen are the only ones that did not think that the observed decrease was due to overfishing, but due to a contamination.

Although the term contamination seems to be used by the locals to explain the decrease of the cockle population, no arguments have been given to explain this hypothesis. In two villages, San Miguel and Casaya, fishermen said that they were aware of the collapse of the cockle fishery, whereas the fishermen in the two other villages, Ensenada and Martin Perez, thought that the decrease of the abundance of the cockle observed today was part of their natural life cycle. Also, they believe their fishing practices have a reduced impact on the population; by harvesting only larger concha in the surface layer of mud, they believe they are leaving smaller concha in the lower layer undisturbed. This study was unable to substantiate these claims.

Another explanation developed by the fishermen was linked to the recent presence of Kuna fishermen in the area. During the interview in Casaya and Martin Perez, it was apparent that a certain level of animosity was felt toward the Kuna fishermen. According to these fishermen, "Kuna's are coming to destroy the natural resources of the archipelago" such as cockles, lobsters, and sea cucumbers.

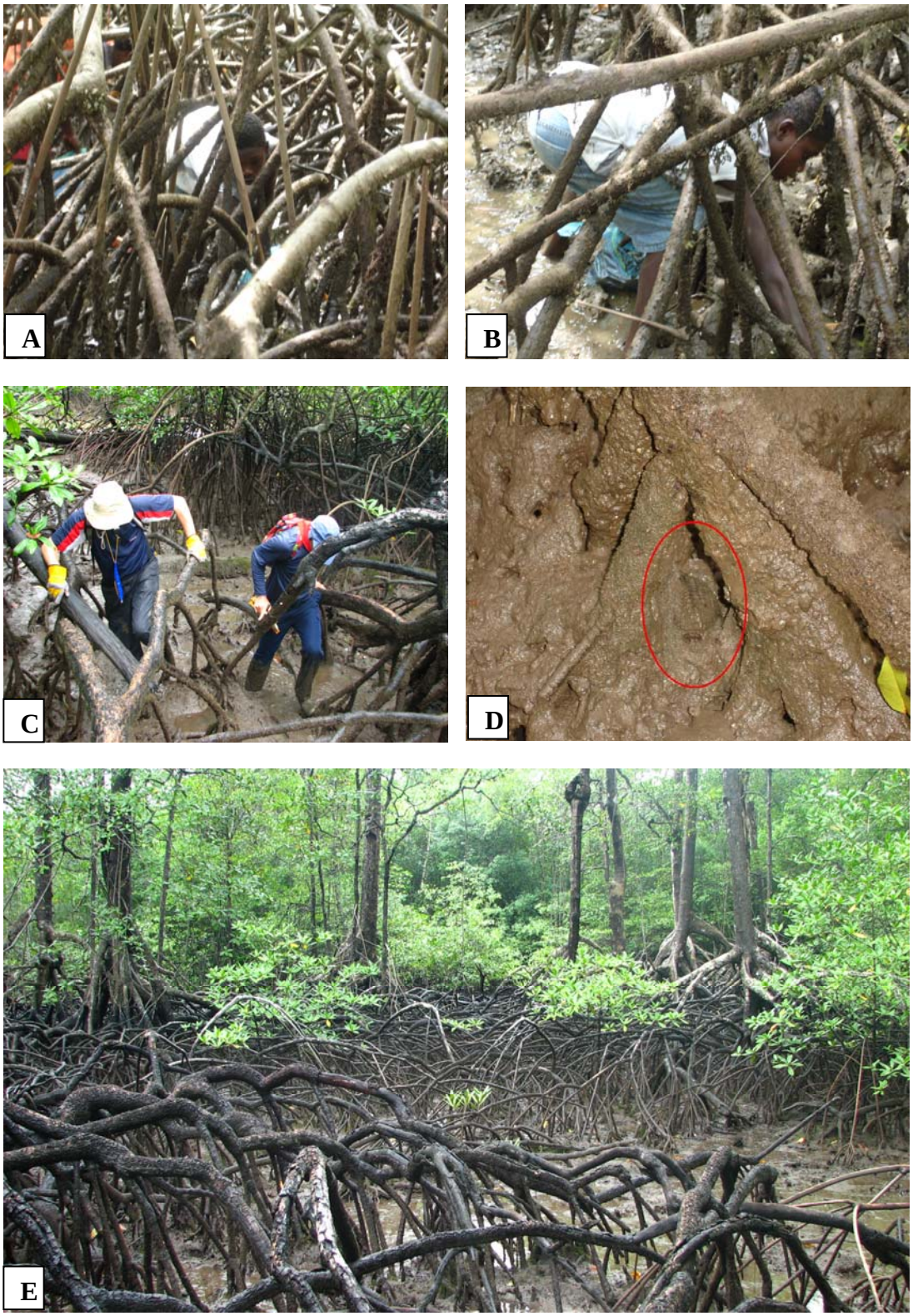


Figure 11: Pictures of the collection of *Anadara tuberculosa* (A-C); (D) an example of an individual (circled) within the mangrove prop root habitat (E).

4.0 QUANTITATIVE RESULTS

4.1 Biometric Data

The biometric section of the results examines the biometric data collected from the five sampling sites surveyed within the Las Perlas Archipelago between the 5th May and 12th May 2007. The type of data collected included shell length, shell width, fresh meat wet weight, sex and gonad maturation stage.

The quantity of data available for *Anadara tuberculosa* at each site varies significantly and is not always sufficient for any sex, length or weight analysis to be performed with a high degree of confidence (Table 3).

Sites	**1**	**2**	**3**	**4**	**5**	**Total**
Number of *Anadara tuberculosa* collected	333	14	17	184	4	552

Table 3 : Number of *Anadara tuberculosa* collected at each sampling site in Las Perlas Archipelago.

Table 3 clearly shows that the quantity of data available for *Anadara tuberculosa* at Site 1 and Site 4 is sufficient for any sex, length or weight analysis to be performed with a relatively high degree of confidence. Much less data is available for Site 2, Site 3 and Site 5 and hence the types of analysis that can adequately be performed on it will be limited.

Statistical analyses will be performed for Sites 1 and 2 as well as for the whole data collected in the archipelago.

The first type of analysis to be performed is the examination of the ratio between males and females of *Anadara tuberculosa* at Site 1, Site 4 and for the whole Archipelago for which there are sufficient records.

4.2 Ratio between Males and Females of *Anadara tuberculosa*.

The analysis has been performed for Site 1, Site 4 and for the whole Archipelago. Results for each site are presented in Figure 12.

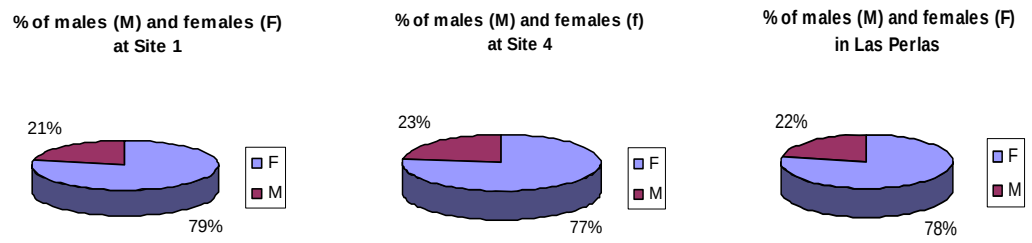


Figure 12 : Ratio between Males and Females of *Anadara tuberculosa* at Site 1, Site 4 and for the whole archipelago.

4.3 Length Width Relationships

4.3.1 Graphical analysis of length-width relationship for *Anadara tuberculosa*

An analysis was performed for Site 1, Site 4 and for the whole archipelago. For each site, an analysis has been performed for the males, females and for the whole population (males and females). The biometric relationships between shell length (L) and shell width (W) for *Anadara tuberculosa* are shown below in 9 graphics where the y axis is the shell width and the x axis is the shell length (Figures 13, 14 and 15):

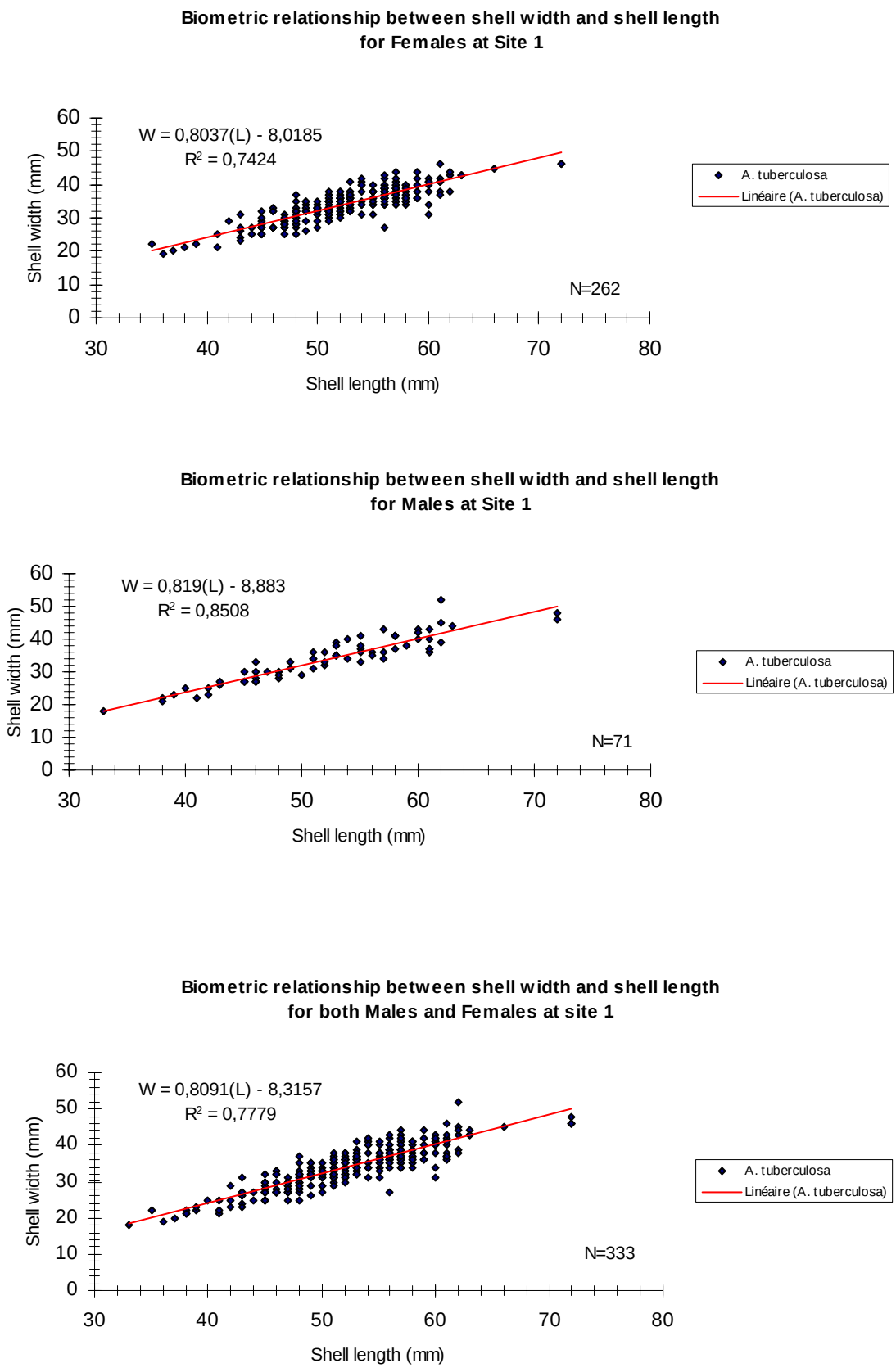


Figure 13 : Length Width Relationships for *Anadara tuberculosa* at Site 1.

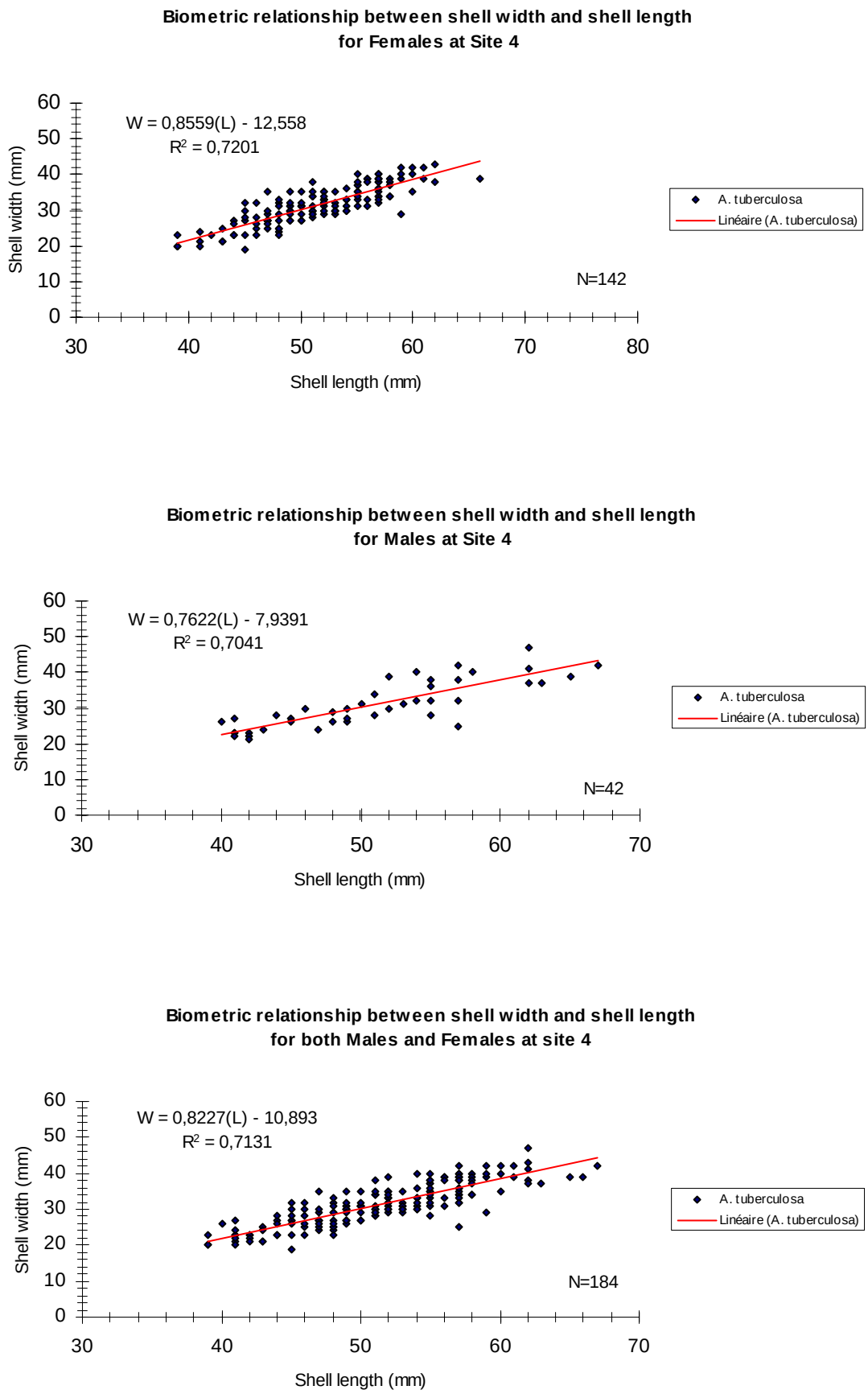


Figure 14 : Length Width Relationships for *Anadara tuberculosa* at Site 4.

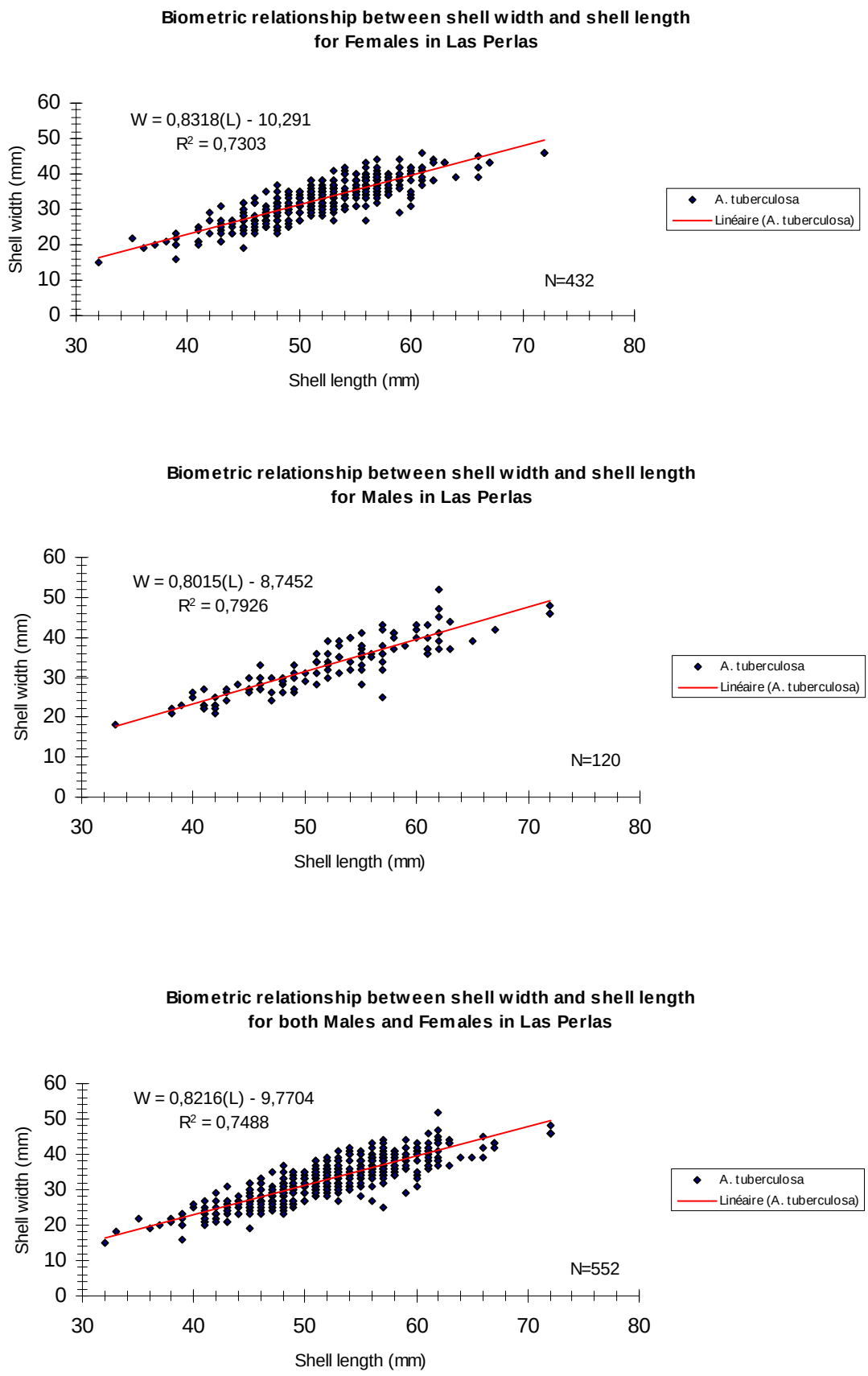


Figure 15 : Length Width Relationships for *Anadara tuberculosa* in Las Perlas.

The relationship between the width and length in *Anadara tuberculosa* is positive and linear. With the standard linear equation being W = *a*(L) + *b* and using the formula above in each graphic it is possible to quantify both *a* and *b* length-width parameters (Table 4).

Site 1	Females	Males	Both Males and Females
a	0.8037	0.819	0.8091
b	-8.0185	-8.883	-8.3157

Site 4	Females	Males	Both Males and Females
a	0.8559	0.7622	0.8227
b	-12.558	-7.9391	-10.893

Las Perlas	Females	Males	Both Males and Females
a	0.8318	0.8015	0.8216
b	-10.291	-8.7452	-9.7704

Table 4 : *a* and *b* value obtained from the linear regression of the Length Width Relationships for males, females and both males and females at Site 1, Site 4 and for the whole archipelago.

4.3.2 Statistical analysis of width-length relationships for *Anadara tuberculosa*

Using the Minitab software, the data have been analysed through an analysis of covariance (ANCOVA). This analysis has been performed to see if the width - length relationship differed significantly in relation to sex for the *Anadara tuberculosa*.

```
Analysis of Variance for Width (mm), using Adjusted SS for Tests

Source        DF    Seq SS    Adj SS  Adj MS      F      P
Sex            1      1,41      0,43    0,43   0,05  0,824
Length (mm)   35  14621,98  14621,98  417,77  48,19  0,000
Error        515   4464,97   4464,97    8,67
Total        551  19088,37

S = 2,94446   R-Sq = 76,61%   R-Sq(adj) = 74,97%

Term         Coef  SE Coef      T      P
Constant  31,2091   0,4950  63,05  0,000
Sex        0,0720   0,3242   0,22  0,824
```

Table 5 : Statistical Analysis of Width - Length Relationships for *Anadara tuberculosa*

Table 5 shows the significance of both the slope and the interception to be not significant (0.824) while the significance of the relationship between length and width is highly significant (0.000) as might be expected. This means that there is no significant difference in width - length relationship between the males and the females of *Anadara tuberculosa*.

4.4 Length Weight Relationships

4.4.1 Graphical analysis of length-weight relationship for *Anadara tuberculosa*

The analysis has been performed for Site 1, Site 4 and for the whole archipelago. For each site, analysis has been performed for the males, females and for the whole population (males and females). The biometric relationships between shell length (L) and fresh meat wet weight (M) for *Anadara tuberculosa* are shown below in 9 graphics where the y axis is the fresh meat weight and the x axis is the shell length (Figures 16, 17 and 18):

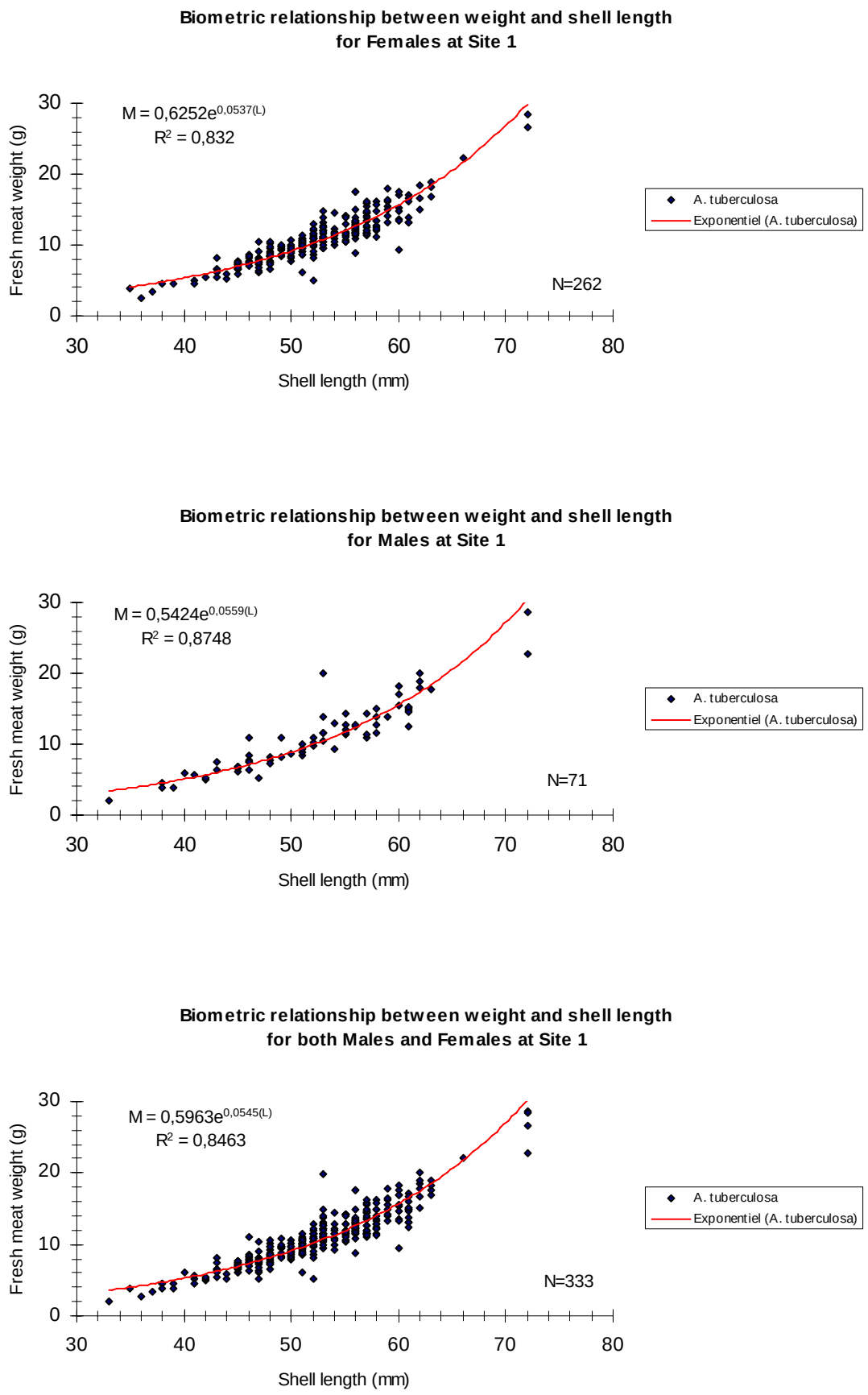
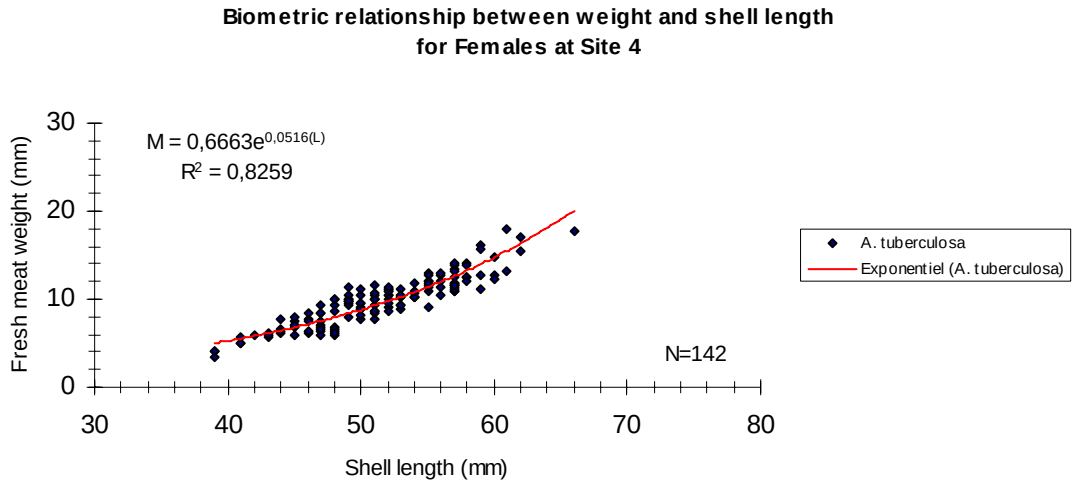
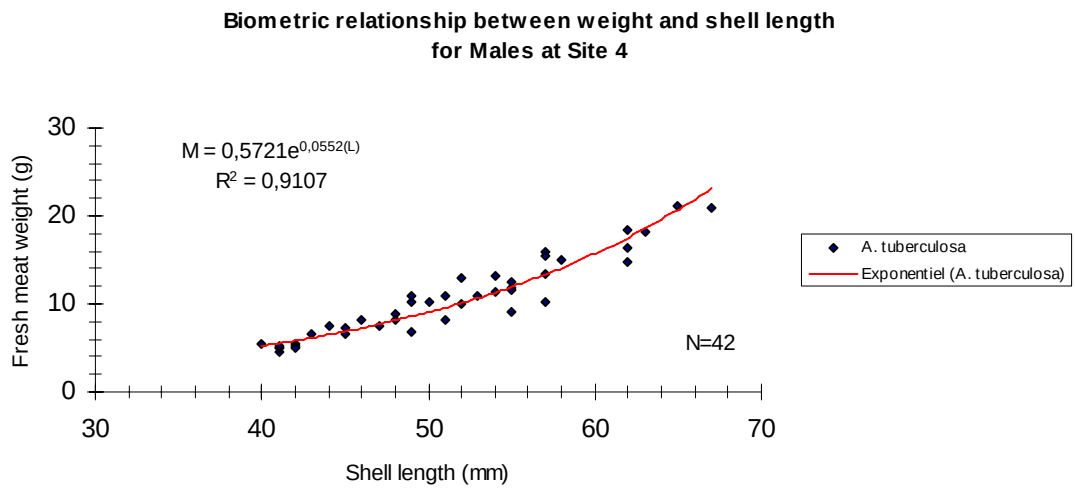


Figure 16 : Length Weight Relationships for *Anadara tuberculosa* at Site 1.





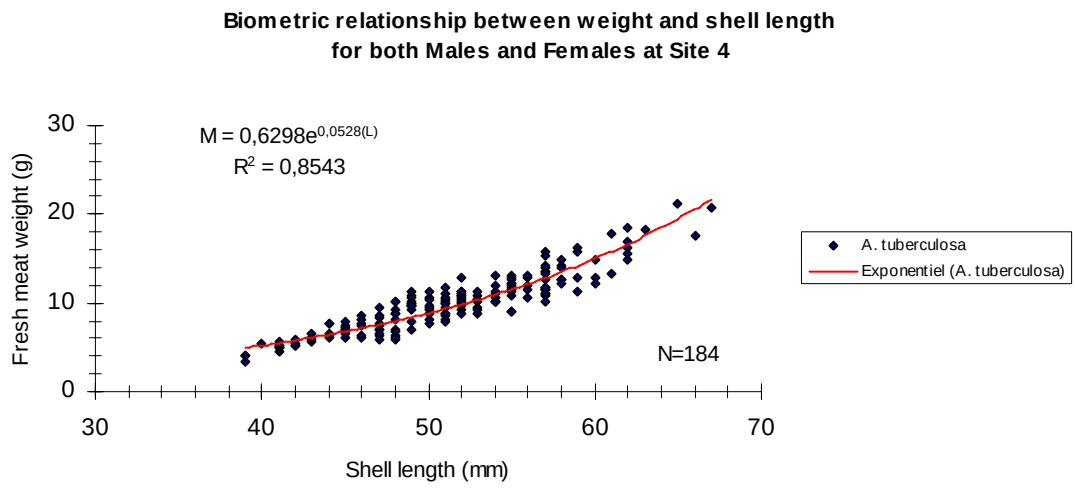


Figure 17 : Length Weight Relationships for *Anadara tuberculosa* at Site 4.

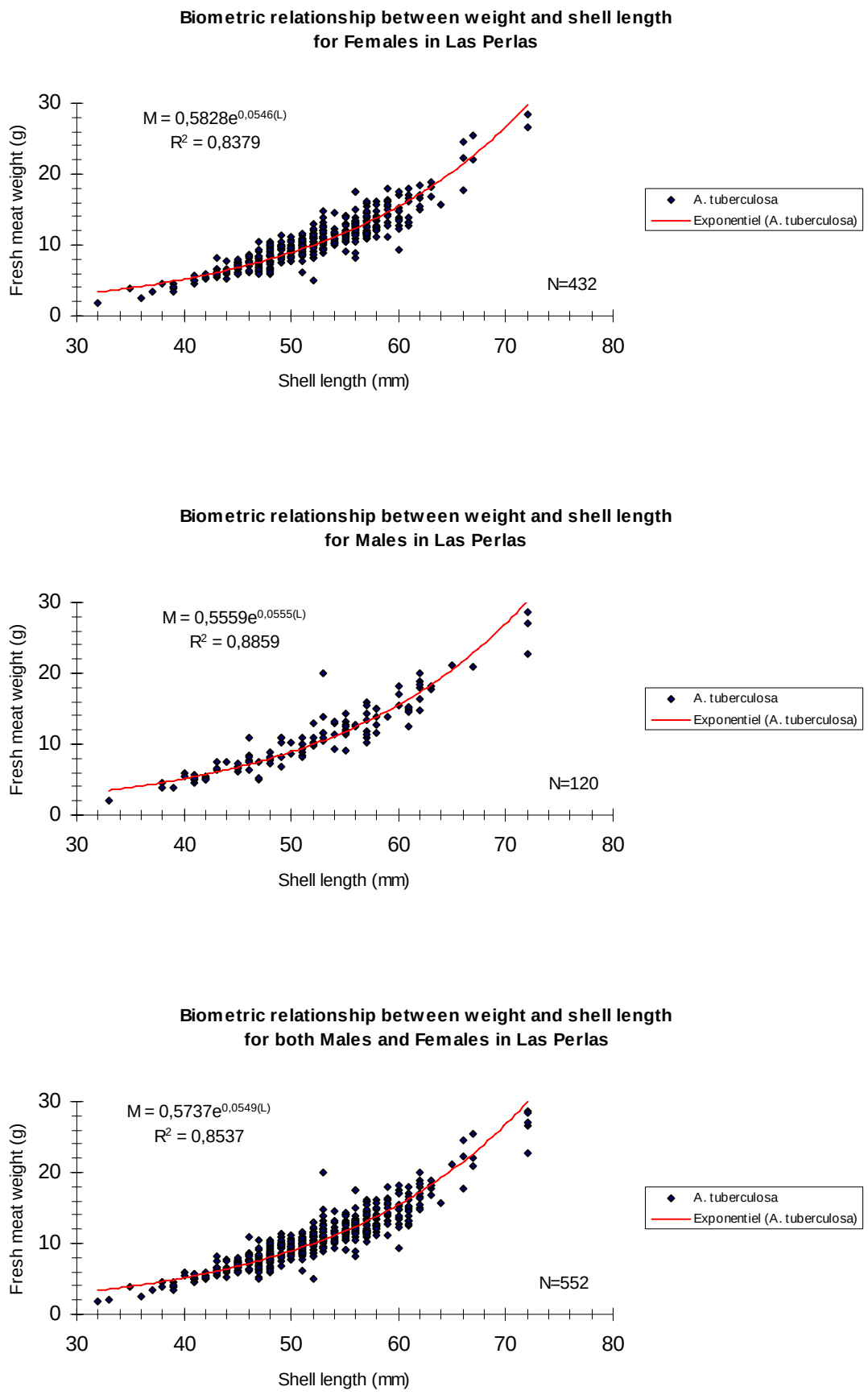


Figure 18 : Length Weight Relationships for *Anadara tuberculosa* in Las Perlas.

The weight of *Anadara tuberculosa* increases exponentially when length increases. With the standard exponential equation being $M = a\ e^{b(L)}$ and using the formula above in each graphic it is possible to quantify both *a* and *b* length-weight parameters (Table 6).

Site 1	Females	Males	Both Males and Females
a	0.6252	0.5424	0.5963
b	0.0537	0.0559	0.0545

Site 4	Females	Males	Both Males and Females
a	0.6663	0.5721	0.6298
b	0.0516	0.0552	0.0528

Las Perlas	Females	Males	Both Males and Females
a	0.5828	0.5559	0.5737
b	0.0546	0.0555	0.0549

Table 6 : *a* and *b* value obtained from the exponential equation Length Weight for males, females and both males and females at Site 1, Site 4 and for the whole archipelago.

4.4.2 Statistical analysis of weight-length relationships for *Anadara tuberculosa*

Using the Minitab software the data have been analysed through an analysis of covariance (ANCOVA). This analysis has been performed to see if the weight - length relationship differed significantly in relation to sex for the *Anadara tuberculosa*.

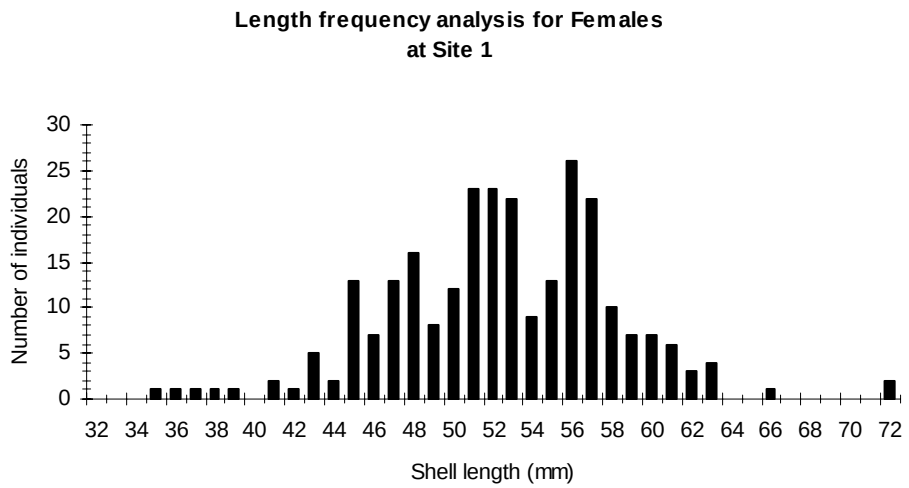
```
Analysis of Variance for Weight (g), using Adjusted SS for Tests

Source        DF   Seq SS   Adj SS  Adj MS      F      P
Sex            1    13,68     2,71    2,71   1,35  0,245
Length (mm)   35  6992,49  6992,49  199,79  99,67  0,000
Error        515  1032,26  1032,26    2,00
Total        551  8038,43

S = 1,41577   R-Sq = 87,16%   R-Sq(adj) = 86,26%

Term         Coef  SE Coef      T      P
Constant  10,3393   0,2380  43,44  0,000
Sex        0,1813   0,1559   1,16  0,245
```

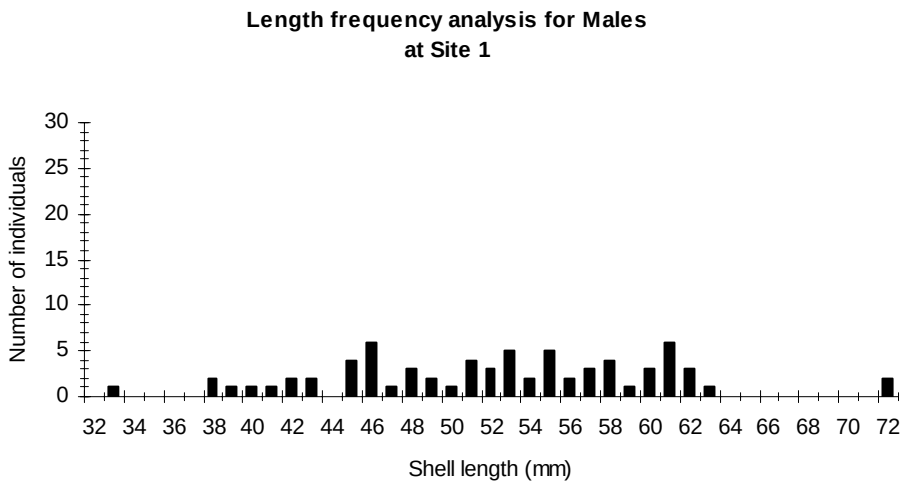
Table 7 : Statistical Analysis of Weight - Length Relationships for *Anadara tuberculosa.*

Table 7 shows the significance of both the slope and the interception to be not significant (0.245) while the significance of the relationship between length and weight is highly significant (0.000) as might be expected. This means that there is no significant difference in weight - length relationship between the males and the females of *Anadara tuberculosa.*

4.5 Length Frequency Analysis

The analysis has been performed for Site 1, Site 4 and for the whole archipelago. For each site, analysis has been performed for the males, females and for the whole population (males and females):





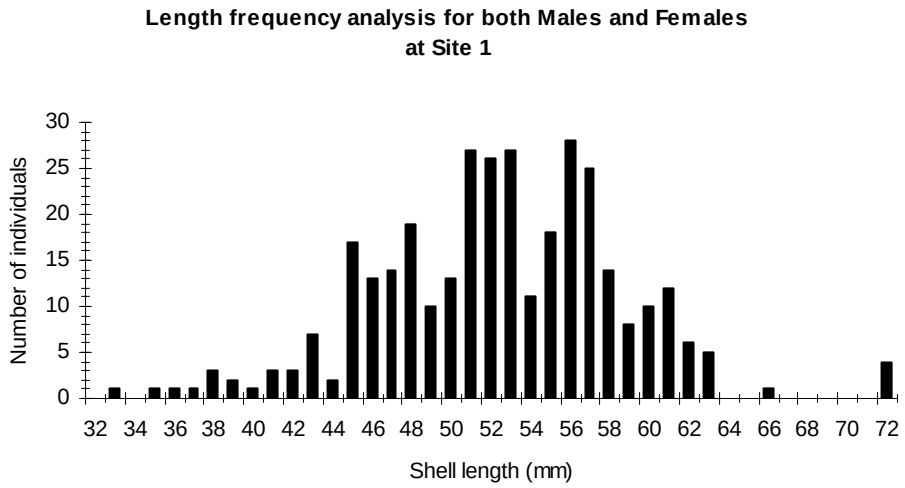


Figure 19 : Length Frequency Analysis for *Anadara tuberculosa* at Site 1.

Figure 19 suggests that at the Site 1, *Anadara tuberculosa* are being removed from the wild stock at a shell length of 33 mm up to 72 mm. The highest number of cockles being removed within any one length class is at 57 cm in length. The graphic also shows possible age cohorts. The cohort groups can be further statistically analyzed by a density plot, as seen in Figure20.

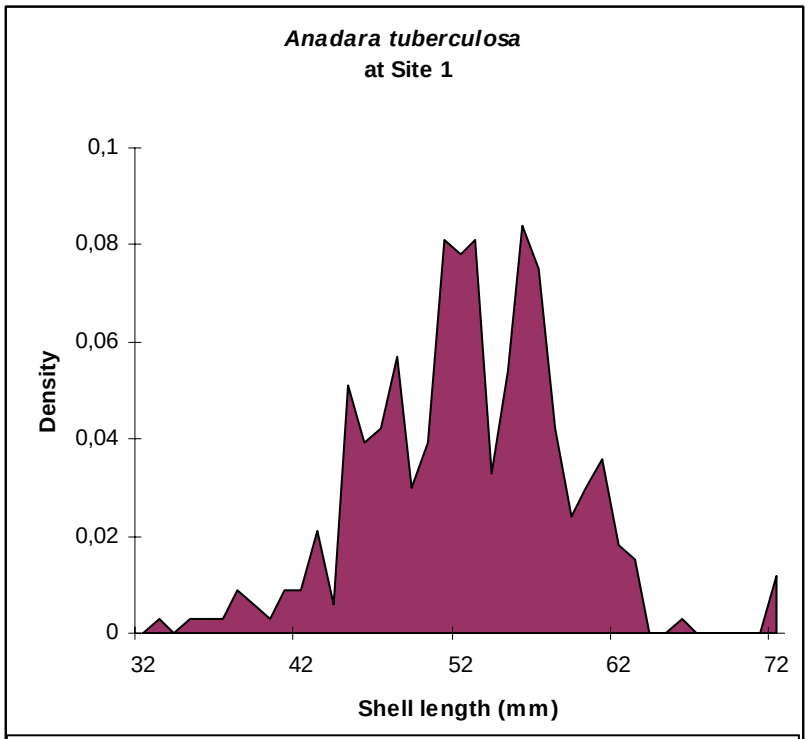
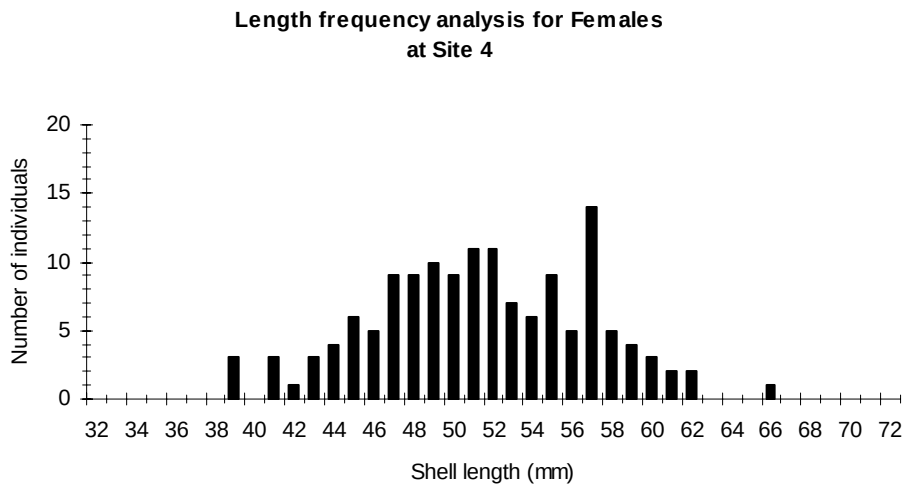
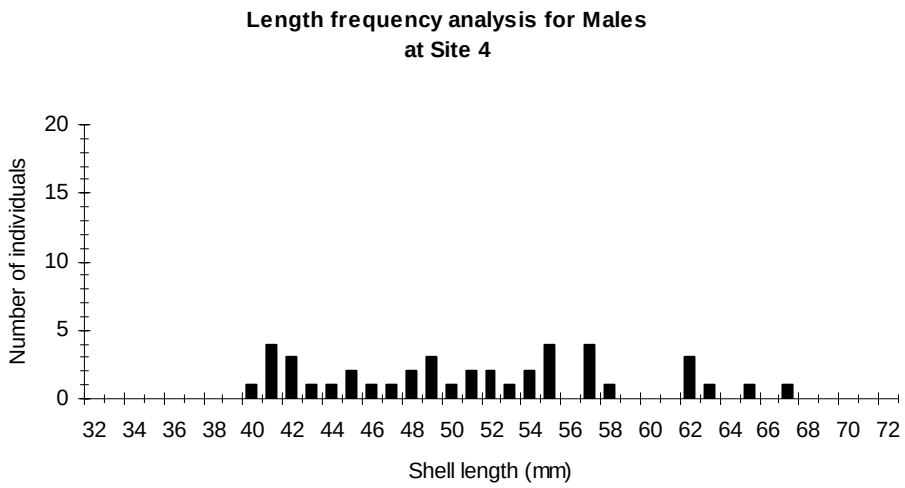


Figure 20 : Density plot of length frequency data for *Anadara tuberculosa* at Site 1.





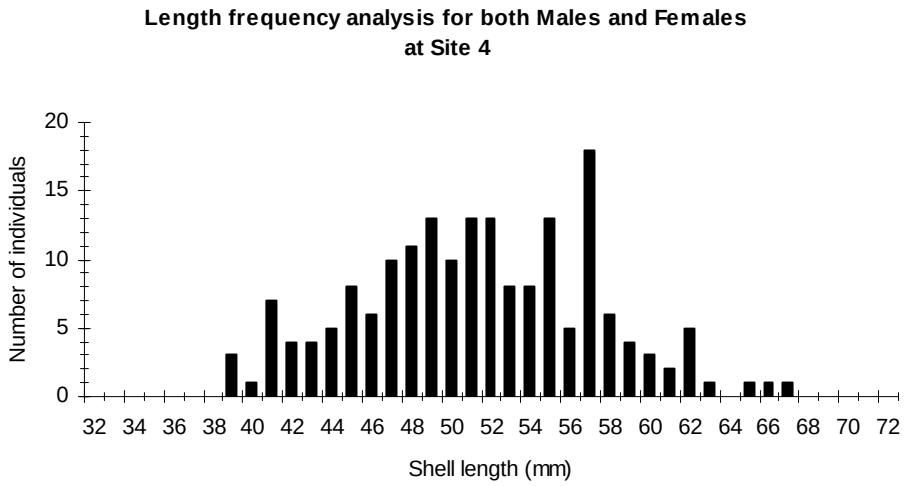


Figure 21 : Length Frequency Analysis for *Anadara tuberculosa* at Site 4.

Figure 21 shows that at Site 4, cockles are being removed from the stock at 39 cm in length up to 67 cm. The highest number of cockle being removed within any one length class is at 57 cm in length. The graphic also shows possible age cohorts. The cohort groups can be further statistically analyzed by a density plot, as seen in Figure 22.

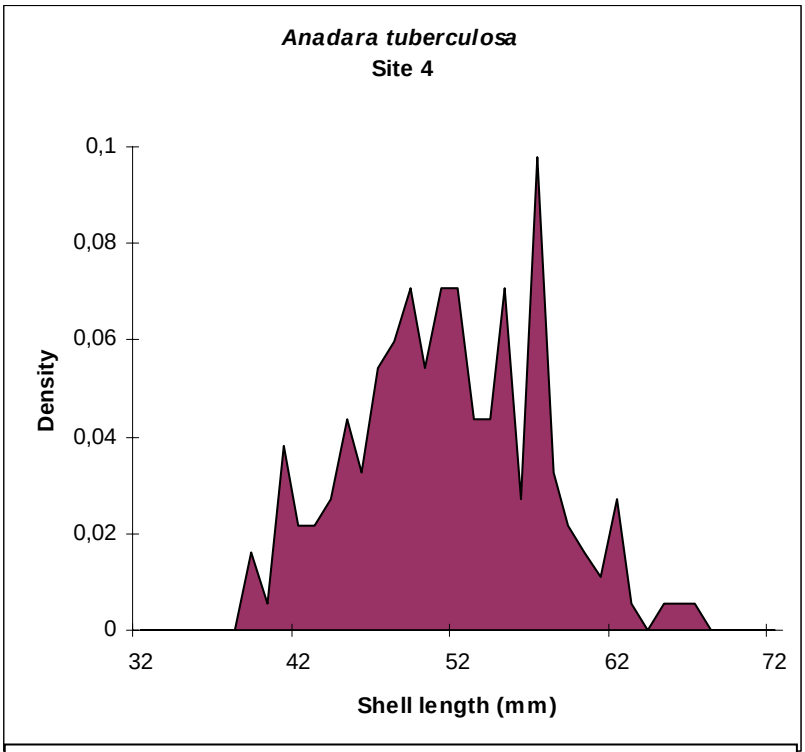


Figure 22: Density plot of length frequency data for *Anadara tuberculosa* at Site 2.

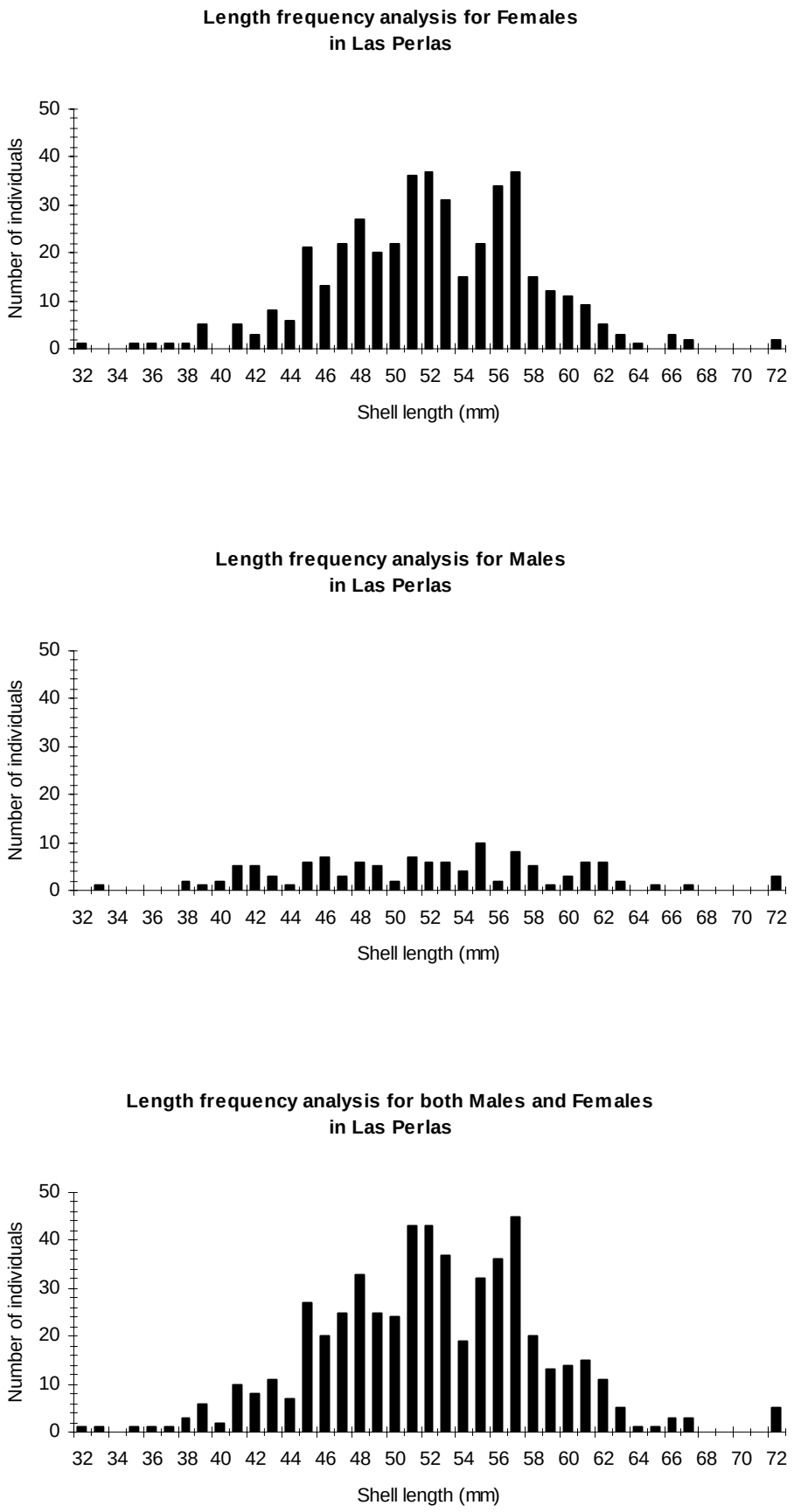


Figure 23 : Length Frequency Analysis for *Anadara tuberculosa* in Las Perlas.

Figure 23 shows that for Las Perlas, cockles are being removed from the stock at 32 cm in length up to 72 cm. The highest number of cockle being removed within any one length class is at 57 cm in length. Another peak can be observed at 51-52 cm but with a slightly lower value of number of individuals than at 57 cm. The graphic also shows possible age cohorts. The cohort groups can be further statistically analyzed by a density plot, as seen in Figure 24.

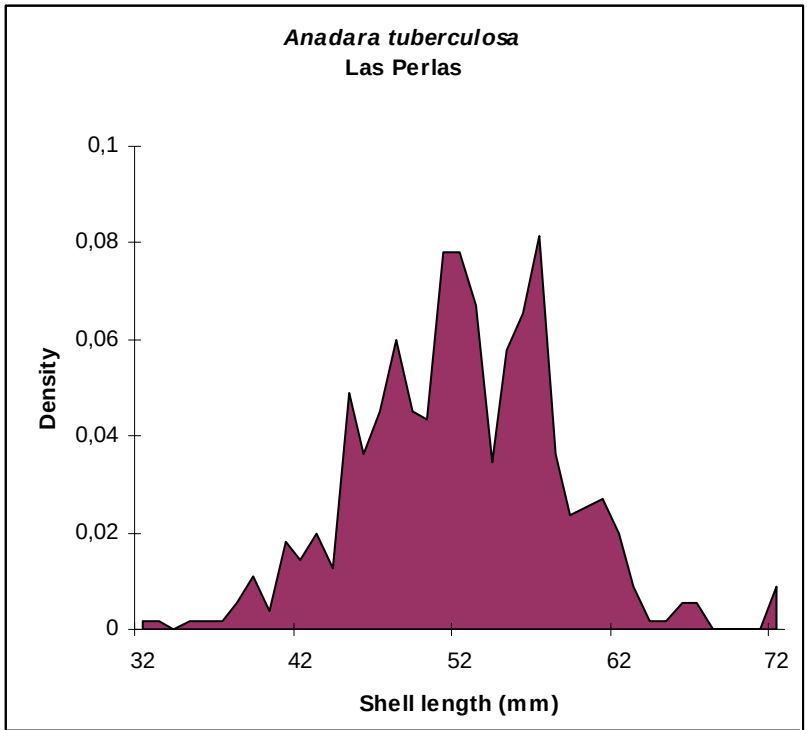


Figure 24 : Density plot of length frequency data for *Anadara tuberculosa* for Las Perlas.

4.6 Proportion of *Anadara tuberculosa* Harvested Sexually Mature

The data of this section have been collected during a period of five days at each of the five sampling sites. The sex and gonad maturity phase have been observed by macroscopic analysis.

The shell length of females of *Anadara tuberculosa* collected during this survey was found to be between 32 mm and 72 mm.

All the females of *Anadara tubercuosa* collected in Las Perlas Archipelago were found at a sexually mature stage with a large quantity of gonad contents covering the visceral mass walls. However, distinction between advanced development and full maturity was not possible by macroscopic observation. No *Anadara tuberculosa* have been found to be at a developing stage.

4.7 Quantitative Catch Per Unit Effort Analysis

This analysis has been performed for all sites surveyed: Site 1, Site 2, Site 3, Site 4 and Site 5. For each site, the number of harvesters, the time spent on site looking for the cockle and the number of cockles collected was recorded. Data are presented in the table below with the resulting calculated value of the Quantitative Catch Per Unit Effort. Quantitative Catch Per Unit Effort is estimated in number of cockles collected per harvester and per hour (Table 8).

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Number of harvester	3	2	2	3	1
Time (min)	60	20	20	40	20
Number of *A. tuberculosa* collected	333	14	17	184	4
QCPUE	111	21	25.5	92	12

Table 8 : Quantitative Catch Per Unit Effort at the five site analysed.

An important point to note when interpreting Quantitative Catch Per Unit Effort 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 Quantitative Catch Per Unit Effort data were gathered from scientists' records working with local harvesters. A brief examination of the dataset available for the *Anadara tuberculosa* fishery shows clearly that catch fluctuated considerably from site to site.

4.8 Distribution patterns along the estuary in Ensenada

Another analysis conducted during this survey was the research of specific patterns of distribution of the cockle along the estuary in Ensenada (Figure 4 (Site 6)). The distribution pattern of *Anadara tuberculosa* was studied at 3 different stations along this estuary. At each station, 3 different areas were sampled: one on the intertidal mud flats between the mangrove trees and the low tide line (*a*), one among the first mangrove trees along the estuary (*b*) and the third one inside the mangrove trees closer to the land (*c*) (Figure 25). The average numbers of *A. tuberculosa* per m^2 in each area for each station along the estuary are presented in the graph below.

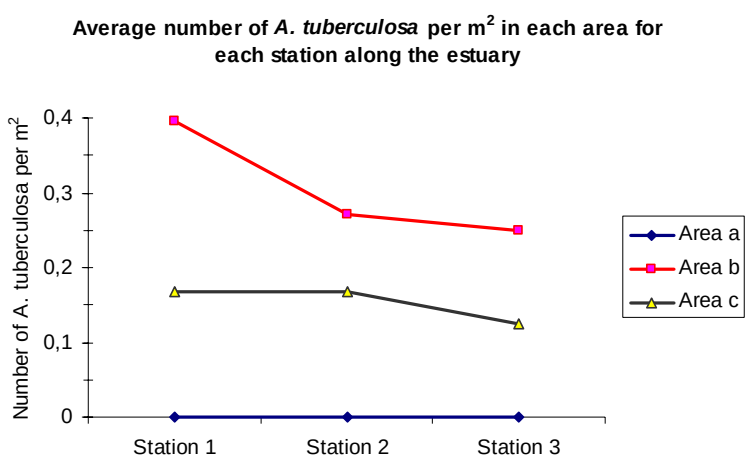


Figure 25 : Average number of *A. tuberculosa* per m2 in each area for each station along the estuary. (Area *a* is the area on the intertidal mud flats between the mangrove trees and the low tide line, Area *b* is inside the first mangroves trees along the estuary and Area *c* is inside the mangroves trees closer to the land).

5.0 DISCUSSION

5.1 Population Characteristics

5.1.1 Ratio between males and females of *Anadara tuberculosa*

Anadara tuberculosa has separate sexes. No evidence of sexual reversal has been observed for this species (Cruz, 1984, 1987). The ratio of males to females for *Anadara tuberculosa* were found to be constant for all the sites surveyed, with 1 male to 3.5 females. This corresponds to 22 % the population being male and 78 % females in the Las Perlas Archipelago. These results differ from previous work on *Anadara tuberculosa* such as those of Cruz (1984, 1987), Vega (1994) and Mac Kenzie (2001), who all found a ratio close to 1:1. One hypothesis that could explain such a ratio is that the males are more difficult to harvest than the females. This could be due to differing patterns of distribution between male and female *Anadara tuberculosa* in the Las Perlas Archipelago. Another hypothesis could be that the physico-chemical properties of the mangroves in Las Perlas favour the development of females or interfere with the development of the males. It is necessary to extend the researches in this domain to explain this observed phenomenon.

5.1.2 Length Width Relationships

A study of the length-width relationship was performed, using the large amount of data collected from different sites in the Las Perlas Archipelago. Firstly, a regression analysis was performed on the width and length data for each site. The similarity of the linear regressions for each site and the parameters *a* and *b*, demonstrated a significant relationship between length and width. The *a* parameter varied between 0.8091 and 0.8227 for both males and females, with a value of 0.8216 for the whole archipelago. The *b* parameter varied from -8.3157 to -10.893 for both males and females, with a value of -9.7704 for the whole archipelago's analysis. A further analysis of the length and width parameters was performed to find differences in this relationship between sexes. The graphs for both sexes are similar to the graphs for each sex separately at each site and for the whole archipelago (Figures 13, 14 and 15). The *a* parameter varied from

0.7622 to 0.8559 and the *b* parameter varied from -12.558 to -7.9391. A further statistical analysis was performed to ensure the relationships findings on the previous analysis. This analysis confirmed that there was a significant relationship between length and width, and that this relationship did not differ significantly between the sexes.

5.1.3 Length Weight Relationships

An investigation into the relationship between length and weight for *Anadara tuberculosa* in the Las Perlas Archipelago gave interesting results (Figures 16, 17 and 18). As length and weight data were both available in large quantities it was decided to perform an investigation into the length-weight parameters, *a* and *b*, for *Anadara tuberculosa* and make a comparison of these findings with that of others from earlier studies into the respective species. Benavides (2001) and Stern-Pirlot (2004) described the relationship between length and weight as an exponential relationship. This was confirmed by the results obtained during this survey. Benavides (2001) defined *a* and *b* for *Anadara tuberculosa* to be 0.28 and 0.06, respectively. The exponential analysis for the whole Archipelago data found *a* and *b* to be 0.5737 and 0.0549, respectively. This result is useful as it is close to that of Benavides (2001); indicating that the methodology used was appropriate. It also provides 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. The statistical analyses performed showed that the length-weight relationship did not differ significantly between the sexes.

5.1.4 Length Frequency Analysis

The length frequency analysis performed for *Anadara tuberculosa* for the whole archipelago demonstrated interesting trends in population dynamics that occurs within the Anadara stock of the Las Perlas fishery. The cockle is removed from the stock at a length of 32 cm up to 72 cm. For the whole archipelago, 4.7 % of the cockles collected have a size comprised between 32 and 41 cm, 40.4 % between 42 and 51, 49.6 % between 52 and 61cm and 5.3 % between 62 and 72 cm. Among these different peaks, two main peaks were apparent, showing that the highest numbers of individuals caught

were around 51-52 cm and around 57 cm (Figure 23). These same peaks can be observed in the Density Plot (Figure 24). The length frequency analysis developed for each site produced similar peaks to that of the whole archipelago. These two main peaks could appear due to possible age cohorts occurring within the fishery. The analysis was performed separately for males and females. The length frequency analysis developed for the females show the same two main peaks. However no particular pattern has been observed for the length of the males.

A longer term monitoring project in different areas of the archipelago and in areas where no harvesting take place could be useful to determinate if these patterns are similar all over the year and whether or not they are a part of the natural life cycle, or if they are or due to interference with the fishery.

5.1.5 Proportion of *Anadara tuberculosa* Harvested Sexually Mature

The maturity stage of *Anadara tubercuosa* was investigated using the females collected. All the females of *Anadara tubercuosa* collected in Las Perlas Archipelago were found at a sexually mature stage, with a large percentage of gonads covering the visceral mass walls. Several studies have been done to determine the average size at which *Anadara tuberculosa* can be sexually mature in other countries. For Squires *et al*. in 1975, the maturity size reported was 32 mm, for Franco (1995) the maturity size was 30 mm, for Herran (1983) it was 39 mm, for Puentes (1997) it was 36 mm, for Borda and Portilla (1998) it was 25 mm in Colombia, and for Ampie and Cruz in 1989 it was between 23.2 and 26.2 mm in Costa Rica. For others species of the gender Anadara, the maturity size observed was around 30 mm (Cruz, 1987; Natajaran and Jhon, 1983; Narasimhan, 1988; Broom, 1983; Ting *et al*., 1972; Yoloye, 1974; Yankson, 1982). The shell length of females of *Anadara tuberculosa* collected during this survey is comprised between 32 mm and 72 mm. According to these results, all the *Anadara tuberculosa* with a shell length superior to 32 mm were sexually mature. This result coincides with most of the results found in the previous research.

5.1.6 Distribution patterns along the estuary in Ensenada

A specific distribution pattern of *Anadara tuberculosa* can be observed along this estuary. *Anadara tuberculosa* were never found on the intertidal mud flats between the

mangrove trees and the low tide line, confirming that this cockle lives around the mangrove tree roots. A greater number of *Anadara tuberculosa* was found in areas inside the first mangroves trees along the estuary than in areas inside the mangroves trees closer to the land. This phenomenon can be mainly explained by the differing quality of the sediment in these two areas. Sediments around the first mangroves trees along the estuary are soft and the cockles can easily penetrate inside the soft mud up to 15-20 cm deep, which is the depth at which they were found living. Closer to the mainland, sediments between the mangrove tree roots become harder, with a much higher quantity of gravels and small rocks. This environment is more hostile to the growth and settlement of the cockle.

Along the estuary, the highest numbers of *Anadara tuberculosa* were found at the canal mouths and the abundance of the cockle decreased when going upstream in the estuary. This result is similar to the one found by Benavides and Carrión in their study on the abundance and morphometry of *Anadara tuberculosa* and *A. similis* in the Manglar de Purruja, in Costa Rica. This distribution pattern can be explained by the difference of salinity along the estuary, since salinity decreases when going upstream in an estuary. However, these patterns of distribution have been observed in only one estuary, and the number of samples was too low to be statistically analysed. To increase the quality and the significance of these observations, it would be necessary to conduct similar surveys in different estuaries in Las Perlas using more samples and collecting physico-chemical data at each area in order to define more precisely the relationships between abundance of *Anadara tuberculosa* and important physico-chemical factors such as salinity level, temperature, pH, etc.

5.2 The Fishery

5.2.1 *Anadara tuberculosa* fishery

The general fishing practices throughout the archipelago have been developed in the Qualitative section of the Results Chapter.

5.2.2 Quantitative Catch Per Unit Effort Analysis

The available data were not full enough to perform a detailed Quantitative Catch Per Unit Effort analysis. The data collected on the field were only representative of the landings at a specific date in a particular area. The ones collected from interviews have not been scientifically proved. For this reason therefore the data have been treated as qualitative data. The main pattern observed during this survey is that the Quantitative Catch Per Unit Effort is lower today than it used to be about 10 years ago. Depending on the mangrove areas the Quantitative Catch Per Unit Effort decreased from 50% in Martin Perez up to 90% in Casaya. However, a longer term of data collection is necessary to show any regular annual fluctuations (see Recommendation part in Management part).

5.3 Management

5.3.1 Actual management

Anadara tuberculosa stock is relied upon heavily as a source of income for a large proportion of the population of the Las Perlas Archipelago. Without this fishery there would be less employment left to the people of the archipelago other than fish fishery and subsistence agriculture. Therefore, apart 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 no management plan has been developed by government officials to regulate the fishery of *Anadara tuberculosa* in Las Perlas Archipelago and there are no dependable statistics about landings for this species in Panama. Management of this population at the national level is hindered by the lack of such information. There is no control over the size at which *Anadara tuberculosa* are harvested, the length of season that fishermen can catch the stock in, the number of individuals that can be removed at any one time etc, resulting in an overexploitation of the stocks in Las Perlas. The benefits of a minimum landing size for any fishery have been proved in many places

where has become a strategy of its management. The governments of other Central and Latin American countries have a regulation regarding the minimum harvestable size of *Anadara tuberculosa* to prevent the harvest of immature cockles and maintain adequate spawning stocks. The minimum harvested length appeared to range from 47 to 60 mm, depending on the country (MacKenzie, 2001). According to these data, 18% to 90% of the cockles harvested in Las Perlas Archipelago would be under these legal minimum sizes. Another fact that can explain the decrease of the stock of *Anadara tuberculosa* in Las Perlas Archipelago is that cockles are harvested all over the year. Several researches have been done concerning the spawning season of *Anadara tuberculosa* and it appears that the greatest spawning activity is during May-September, with 70% of the cockle spent in may and 50% spent in September (Cruz, 1984a). Harvesting cockles during these main spawning seasons can have deleterious effect on the stocks.

However, many cares must be taken by the government when establishing management plan to regulate the Cockle fishery in order to avoid its collapse. The situation of the *Anadara tuberculosa* fishery is not different that of many "top-down" resources. The Organization for Economic Cooperation and Development (in Lane & Stephenson 2000) states, "while top-down, command and control style management reduces the transaction costs of having to strike bargains with user groups, it sets up a barrier between managers and resource users." Furthermore, this type of regulation creates incentives to break the rules and misreport catches and, without the support of fishermen, the chances of fisheries regulations succeeding are poor (Nielsen & Vedsmand 1999).

5.3.2 Recommendations

In her survey on the population dynamics and fisheries exploitation of *Anadara tuberculosa* on the Pacific coast of Costa Rica, Stern-Pirlot (2004) used a self-reporting catch and effort sheet (Table 9) that was distributed and fill in by the cockle fishermen in order to get data on the Quantitative Catch Per Unit Effort. The establishment of a self-reporting catch and effort sheet that could be used throughout Panama would be an easy way to get the presently lacking good estimation of overall fisheries effort and catches in the country for those resources without centralized landing sites. This simple method has proven to produce very reliable and accurate data and requires little additional effort on the part of harvesters and scientists. This kind of data on a larger

scale and over a longer time period would be immensely valuable in stock assessment and monitoring. In addition, implementing such a data-gathering campaign would be a first step to involving communities in the management of their resource.

Date	Site	Number of harvester	Number of cockle harvested	Time spend
*	*	*	*	*

Table 9 : example of a self-reporting catch and effort sheet

Many accounts of successful small-scale resource management demonstrate that it is often "community-based" strategies, which are effective at combating the traditional resource-management problems associated with command and control situations (Aiken et al. 1999; Hernandez & Kemton 2003; Lane & Stephenson 2000; Wiber et al. 2004).
One management alternative for *Anadara tuberculosa* in Panama would be to follow the example of the *Anadara antiquata* scenario in Fiji reported by Tawake et al. in 2001. Much like harvesters in Panama for *Anadara tuberculosa* today, in the early 1990s, cockle harvesters in Fiji reported that one or two generations back, they were able to spend only a few hours to gather many bags full of large *Anadara antiquata* from the mudflats in front of the mangrove as opposed to the half-bag of small ones they were gathering after an full day of work more recently. In response to this, a community-based management plan was established and carried out by the villagers in cooperation with scientists in which a 24-hectare no-harvest zone was established for three years as an attempt to regenerate the supply of cockles. After three years of community commitment, enforcement and monitoring, the population of *Anadara antiquata* grew by roughly 1000% in the off-limits area and substantially (300-500%) in the surrounding still fished areas as well due to increased recruitment success and larval transport. Other studies on bivalves confirm that establishing a protected broodstock is very effective in regenerating and maintaining healthy harvestable populations (Kennedy 1989). Such a scheme could be attempted in some mangrove areas in Panama and more precisely in Las Perlas Archipelago with commitment on the part of communities, scientists and policy makers. The biggest challenge would again be enforcement. However, Martin Perez would be a good place for a first attempt of such a

strategy because there is already a well organized and committed group of cockle harvesters, the mangrove area is relatively small and isolated, and there is a need for an effective plan. Control of the area could be granted to the association of harvester who could collectively decide on a closed area of appropriate size, be trained on monitoring of cockle size-frequencies and densities by scientists while collecting baseline data, and develop an effective enforcement regime. Since harvesting can only take place during limited hours anyway, effective enforcement in such a setting is not unattainable.

5.4 Suggestions for further study

The ultimate goal is work with community members towards a sustainable cockle fishery. To continue working towards that goal with this community and its cockle population, there are several areas that require more research before any sort of action be taken. Biologically, if some sort of cockle rearing area is undertaken, maturation times and life expectancy need to be better examined. Socially, the community dynamics need to be better understood. It seems that there would be some struggle for power within the community if management decisions were left to them. It is necessary to evaluate the way such decisions can be taken to benefit everyone. It also must be known what community member would have an interest in learning about the cockle and its environment. The awareness of action needs to be realized and incorporated into management action. An environmental education program would also be ideal. One trend in successful community based programs is the implementation of some sort of workshop or program that educates the community as to the reasons why their environment is critical to the success of the species. Making them aware of the importance of their role in conservation would help in the project's success. Also, if the community is expected to self-regulate there must be a basic understanding about what they are regulating. This educational support would illustrate how the community is critical to the long term success of the cockle species.

6.0 CONCLUSION

The ratio between males and females of *Anadara tuberculosa* in Las Perlas Archipelago was found to be of 1 male for 3.5 females. Statistical analysis shows that there is a significant relationship between shell length and shell width of *Anadara tuberculosa*, and that the length-width relationship does not differ significantly between the sexes. Another statistical analysis comparing the length-weight relationships between sexes shows that the length-weight relationship did not differ significantly between the sexes.

The length frequency analysis reveals that cockles are removed from the stock at a length of 32cm up to 72cm. In the archipelago, 4.7% of the cockles collected have a size comprised between 32 and 41 cm, 40.4% between 42 and 51, 49.6% between 52 and 61cm and 5.3% between 62 and 72 cm. Two main density peaks are observed, with the highest numbers of individual being caught around 51-52 cm and around 57 cm.

All the females of *Anadara tubercuosa* collected in Las Perlas Archipelago are found at a sexually mature stage. According to these results, all the *Anadara tuberculosa* with a shell length superior to 32 mm are sexually mature.

A specific distribution pattern of *Anadara tuberculosa* is observed along an estuary: *Anadara tuberculosa* are never found on the intertidal mud flats between the mangrove trees and the low tide line, confirming that this cockle live inside the mangrove trees. A greater number of *Anadara tuberculosa* is found in areas inside the first mangroves trees along the estuary than in areas inside the mangroves trees closer to the land. Along the estuary, the highest number of *Anadara tuberculosa* is found at the canal mouths and the abundance of the cockle is decreasing when going upstream in the estuary.

The main phenomenon observed during the survey is that the Quantitative Catch Per Unit Effort is lower today than it used to be about 10 years ago. Depending on the mangrove areas the Quantitative Catch Per Unit Effort decreased from 50% in Martin Perez up to 90% in Casaya. *Anadara tuberculosa* stock is relied upon heavily as a source of income for a large proportion of the population of the Las Perlas Archipelago. Without this fishery there would be less employment left to the people of the archipelago other than fish fishery and subsistence agriculture. Therefore, apart 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.

A more detailed background data are needed to explain all the trends on the fishing activities being carried out within Las Perlas fishery. Long term collection of records of the *Anadara tuberculosa* fishery in the Las Perlas Archipelago would be helpful to determine if the observed patterns are similar throughout the year.

7.0 REFERENCES

Aiken K. A., Kong G. A., Smikle S., Mahon R., and Appeldorn R. (1999). The queen conch fishery on Pedro Bank, Jamaica: discovery, development, management. Ocean and Coastal Management 42:1069-1081.

Ampie C. and Cruz R. A. (1989). Tamaño y madurez sexual de Anadara tuberculosa (Bivalvia: Arcidae) en Costa Rica. Brenesia. 31: 21-24.

Baquiero E. (1980). Population structure of the mangrove cockle Anadara tuberculosa (Sowerby, 1833) from eight mangrove swamps in Magdalena and Almejas Bays, Baja California Sur, Mexico. Proc. Natl. Shellfish. Assoc. 70:201–206.

Benavides S. A. M. and Carrión B. R. (2001). Abundance and morphometry of tuberculosa Anadara and A. similis (Mollusca: Bivalvia) in the Manglar de Purruja, Dulce Gulf, Costa Rica. Rev Biol Trop. 49 Suppl 2:315-20.

Benfield S. (2005). Mapping coral reefs and associated sublittoral habitats: A comparison of optical remote sensors and image classifiers and a study of the community structure of reef-associated fish. Thesis (PhD). Heriot-Watt University, Edinburgh, United Kingdom. 260pp.

Betts T. (2006). An assessment of Mangrove Cover and forest structure in Las Perlas, Panama. Thesis (MSc). Heriot-Watt University, Edinburgh, United Kingdom. 58pp.

Berman J. (2004). Sponge diversity in coral frameworks and coral communities within the Las Perlas Archipelago, Panama. Thesis (MSc). Heriot-Watt University, Edinburgh, United Kingdom. 83pp.

Borda R. and Portilla M. (1998). Talla de captura, madurez sexual, comercialización y recomendaciones para el manejo de Anadara tuberculosa (piangua hembra) en la Ensenada de Tumaco (Nariño), Pacífico Colombiano. Colombia, Memorias XI

Seminario Nacional de Política, Ciencias y Tecnologías del Mar, en conmemoración del Año Internacional de los Océanos.

Borda C. A. and Cruz R. (2004). Reproduccion y reclutamiento del molusco Anadara tuberculosa (Sowerby, 1833) en el pacifico colombiano. Rev. Invest. Mar. 25(3):185-195.

Briggs J. C. (1974). Marine zoogeography. McGraw-Hill Book Co., N.Y. 475 p.

Broom M.J. (1983). Gonad development and spawning in Anadara granosa (L.) (Bivalvia: Arcidae). Aquaculture 30: 211-219.

Broom M. J. (1985). The Biology and Culture of Marine Bivalve Molluscs of the Genus Anadara. ICLARM Studies and Reviews 12:1-37.

Campbell I. (2005). The Role of local communities in the designation of a Marine Protected Area in Las Perlas Archipelago, Panama. Thesis (MSc). Heriot-Watt University, Edinburgh, United Kingdom. 98pp

Carmen I. L. D. (1999). Actividad Pesquera de la Concha Negra, Anadara tuberculosa (Bivalvia:Arcidae), en Puerto Pedregal, David, Chiriqui, Panama, con Recomendaciones para su Manejo y Ordenamiento Sostenible. M. Sc. en Ciencias con especialización en Ecología y Conservación Profesora Especial en la Universidad Autónoma de Chiriquí.

Cruz R. A. and Palacios J. A. (1983). Biometría del molusco Anadara tuberculosa (Pelecypoda: Arcidae) de Punta Morales, Puntarenas, Costa Rica. Rev. Biol. Trop. 31: 45-50.

Cruz R.A. (1984). Algunos aspectos reproductivos y variación mensual del índice de condición de Anadara similis (Pelecypoda: Arcidae) de Jicaral, Puntarenas, Costa Rica. Brenesia. 22: 95-105

Cruz R. A. (1984a). Algunos aspectos de la reproducción en Anadara tuberculosa (Pelecypoda: Arcidae) de Punta Morales, Puntarenas, Costa Rica. Rev. Biol. Trop. 32: 45-50.

Cruz R. A. (1986). Tamaño y madurez sexual en Anadara grandis (Pelecypoda: Arcidae), Brenesia. 27: 9-12.

Cruz R.A. (1987). Tamaño y madurez sexual de Anadara grandis (Pelecypoda: Arcidae). Brenesia 27:9-12.

Cruz R. A. (1987a). The reproductive cycle of the mangrove cockle Anadara grandis (Bivalvia: Arcidae) in Costa Rica. Brenesia 27:1–8.

Cruz R. A. (1989). Tamaño y madurez sexual de Anadara tuberculosa (Bivalvia: Arcidae) en Costa Rica. Brenesia. 31: 21-24.

Cruz R. A. and Jimenez J. A. (1994). Moluscos asociados a los areas de manglar de la Costa Pacifica de America Central: guia. Heredia, C. R. Efuna, p. 18–20.

Fournier M. L. and de la Cruz E. (1987). Reproduction of the cockle Anadara grandis in Costa Rica. Naga 10(1):6.

Fujita R.M., Foran T. and Zevos I. (1998). Innovative approaches for fostering conservation in marine fisheries. Ecological Applications. 8(1) Supplement, S139-S150.

Franco L. (1995): Uso y conservación de moluscos del género Anadara (Mollusca: Bivalvia). Evidencia poblacional de un gradiente de explotación humana en el Chocó, Costa Pacífica colombiana. Colombia, Universidad Nacional de Bogotá, Tesis de Maestría, 139 pp.

Goarin M. (2006). Monitoring and Management of beaches in the Archipelago Las Perlas, Panama. Thesis (MSc). Heriot-Watt University, Edinburgh, United Kingdom. 114pp.

Hernandez A. and Kemton W. (2003). Changes in fisheries management in Mexico: Effects of increasing scientific input and public participation. Ocean and Coastal Management 46:507-526.

Herrán Y. (1983). Estudios histológicos del ciclo gonádico de la “piangua” Anadara (Anadara) tuberculosa y Anadara (Anadara) similis en la costa Pacífica colombiana. Thesis, Universidad del Valle., 76 pp.

Jackson J. B. C., Hughes T. P., Pandolfi, J. et al. Historical overfishing and the collapse of coastal ecosystems. Science 293, 629-638 (2001).

Kennedy V. S. (1989). The Chesapeake Bay oyster fishery: traditional management practices. Pages 455-477 in Caddy J. F. editor. Marine Invertebrate Fisheries: Their Assessment and Management. John Wiley & Sons, Rome, Italy.

Koch V. (1995). Zur Populations biologie und ökologischen Rolle der Mangrovenschnecke Thais kiosquiformis im Golf von Nicoya, Costa Rica. Page 61. Diplomarbeit. Zentrum für Marine Tropenökologie und Fachbereich II, Biologie. Universität Bremen, Bremen, Germany.

Lane D. E. and Stephenson R. L. (2000). Institutional arrangements for fisheries: alternate structures and impediments to change. Marine Policy 24:385-393.

MacKenzie, C. L., Jr. (1999). A history of the pearl oyster fishery in the Archipielago de las Perlas, Panama. Marine Fisheries Review 61(2):57-64.

MacKenzie C. L. Jr. (2001). The Fisheries for Mangrove Cockles, Anadara spp., from Mexico to Peru, With Descriptions of Their Habitats and Biology, the Fishermen’s Lives, and the Effects of Shrimp Farming. Marine Fisheries Review 63(1).

Medina B., Guzman H. and Mair J.M. (2007). Failed recovery of a collapsed scallop (Argopecten ventricosus) fishery in Las Perlas Archipelago, Panama. Journal of Shellfish Research, Vol. 26, No. 1, 9-15.

McGowan T. (2006). An assessment of mangrove forest structure in the Las Perlas Islands, Panama. Thesis (MSc). Heriot-Watt University, Edinburgh, United Kingdom. 147pp

Mora Sanchez E. M. (1990). Catologo de bivalvos marinos del Ecuador. Bol. Cientifico Tecnico, Inst. Nacional de Pesca, Guayaquil, Ecuador 10(1):1–136.

Natajaran R. and G. Jhon (1983). Reproduction in the edible ribbed clam Anadara rhombea from the backwaters of Porto Novo. J. Mar. Science 12(2):90-95.

Narasimham K.A. (1988). Biology of the blood clam Anadara granosa (Linnaeus) in Kakinada Bay. J. Mar. Biol. Assoc. India. 30(1-2):137- 50.

Puentes G. V. (1997). Aspectos biológico pesqueros de la piangua Anadara spp. en el Parque Nacional Natural Sanquianga. Ministerio del Medio Ambiente, Unidad Administradora Especial del Sistema de Parques Nacionales Naturales, Informe final, 43 pp.

Rosero J. and Burgos M. (1998). La pesquiera de concha prieta en las zonas especiales de manejo. Neptuno. Bulletin Informativo Semestral PMRC-INP 1(1):2.

Rubio A. (1949). Notas sobre geologia de Panama. Departamento de Cultura y Publicaciones del Ministerio de Educacion, Imprenta Nacional 1666-1948.

Squires H., Estevez M., Barona O. and Mora O. (1975): Mangrove Cockles, Anadara spp. of the Pacific Coast of Colombia. The Veliger 18(1):57-68.

Stern-Pirlot A. (2004). Populatuion dynamics and fisheries exploitation of Anadara tuberculosa (Bivalvia Arcidae) at three sites on the Pacific coast of Costa Rica. M.Sc. Thesis, University of Bremen, Bremen, Germany.

Tawake A., Parks J., Radikedke P., Aalbersberg B., Vuki V. and Salafsky N. (2001). Harvesting Clams and Data. Conservation Biology in Practice 2:32-35.

Ting Y.Y, Kasahara S. and Nakamura N. (1972). An ecological study of the so-called Mogai (Anadara subcrenata (Lischke)) cultured in Kasaoka Bay. J. Fac. Fish. Amin. Husb. 11: 91-110.

Tomlinson P. B. (1999). The botany of mangroves. Cambridge University Press, Cambridge.

Vega A. J. (1994). Estructura de población, rendimiento y épocas reproductivas de Anadara spp. (Bivalvia: Arcidae) en la Reserva Forestal Térraba-Sierpe, Puntarenas, Costa Rica. Con recomendaciones para su manejo. Tesis de Maestría. Universidad de Costa Rica. 119 pág.

Villalobos C. R. (1983). Tasa de crecimiento y mortalidad en Anadara tuberculosa (Bivalvia: Arcidae) bajo dos sistemas de cultivo en el Pacifico de Costa Rica. Rev. Lat. Acui. Lima-Peru:1-54.

Wiber M., Berkes F., Charles A., and Kearney J. (2004). Participatory research supporting community-based fishery management. Marine Policy 28: 459–468.

Yankson K. (1982). Gonad maturation and sexuality in the West African bloody cockle, Anadara senilis (L). J. Molluscan Stud. 48: 294 - 300.

Yoloye V. (1974). The sexual phases of the west African Bloody cockle, Anadara senilis (L). Proc. Malac. Soc. London, (41):25-27.

APPENDIX I: Interview transcript

Interview in San Miguel 05/05/07

Harvesting Information:

• Who harvest the concha negra in the village, men, women, children?

Women usually fish it.

• Where do you find the concha negra?

Where the mangroves are very dense, in the superficial soft mud layer ("lama"), in the holes between the roots.

• How are the concha negra distributed within the mangroves (patched or isolated)?

Dispersed in different areas.

• How deep are the concha negra you harvest?

10-15 cm.

• When is the best time to harvest the concha negra during the day?

Any time when the water is shallow (Half tide, between high and low)

• Is the concha negra harvested all the year or is there any season?

Fished all over the year.

• How many times per week do you harvest?

Depends on the demand. Sometimes, each day when demand is high, sometimes no fishery during several weeks.

• How many hours per day?

As much as possible when demand is high: around 3-4 h

• Since when have you harvested the concha negra, for how many years?

More than 10 years.

• How often do you return to the same place to harvest concha negra?

/

• What equipment do you use for harvesting (boat, gloves, bag, bucket, etc.….?)

Just bags to carry the concha.

• How many bucket per hour and per harvester today? And before?

Today, 2 buckets per person per day. Before (10 years ago): 9-11 buckets per person per day

• How do you conserve the concha?

Concha are eaten the day of harvesting. When sold, concha are conserved in bucket for few days with water.

• Since you began as a concha negra harvester, has the number of concha in the mangrove: decreased, increased or remained the same?

Decrease

• Since you began as a concha negra harvester, has the size of concha in the mangrove: decreased, increased or remained the same?

Decrease

• Do you have any idea to explain these phenomena?

Overfishing

• Is there any danger encountered when harvesting the concha in mangroves?

No

• Do you know any concha negra predator?

No

• What do you do with the shell of the concha?

Nothing

• Which other species do you collect in the areas where you harvest pianguas?

/

Economic Information:

• Do you harvest concha negra for local consumption or to sell?

To sell and to eat

• If harvested for local consumption, how many and how often do you eat it?

Sometimes not often

• Is there any specific occasion?

No.

• For what price do you sell a bucket of concha negra?

$7.00 per bucket (About 400 concha)

• To whom do you sell the concha negra you collect?

It was to a Colombian woman

• If that person sells them to someone else, to whom does he sell them and where?

She sells to Panama and other countries

• What other income-earning activities to you have outside of harvesting concha negra?

/

Other information collected:

Before concha were found superficially between the mangroves roots, now concha are much deeper in the mud.

Interview in Casayada in Casaya Island 09/07/07

Harvesting Information:

• Who harvest the concha negra in the village, men, women, children?

Every body

• Where do you find the concha negra?

In the mangroves, in the holes between the roots, in the superficial mud layer ("lama").

• How are the concha negra distributed within the mangroves (patched or isolated)?

Isolated.

• How deep are the concha negra you harvest?

10-20 cm.

• When is the best time to harvest the concha negra during the day?

Low tide.

• Is the concha negra harvested all the year or is there any season?

All over the year.

• How many times per week do you harvest?

Depends on the demand. Sometimes, each day when demand is high, sometimes no fishery during several weeks.

• How many hours per day?

Depend on the tide.

• Since when have you harvested the concha negra, for how many years?

/

• How often do you return to the same place to harvest concha negra?

/

• What equipment do you use for harvesting (boat, gloves, bag, bucket, etc.….?)

Bags

• How many bucket per hour and per harvester today? And before?

Today, 15-20 concha per person per hour. Before, 1 bucket per person per hour.

• How do you conserve the concha?

In nets in water.

• Since you began as a concha negra harvester, has the number of concha in the mangrove: decreased, increased or remained the same?

Decrease

• Since you began as a concha negra harvester, has the size of concha in the mangrove: decreased, increased or remained the same?

/

• Do you have any idea to explain these phenomena?

Overexploitation + Kunas that come to overfish the resources of the Archipelago.

• Is there any danger encountered when harvesting the concha in mangroves?

No.

• Do you know any concha negra predator?

No.

• What do you do with the shell of the concha?

Nothing.

• Which other species do you collect in the areas where you harvest pianguas?

Pied de buro (Anadara grandis)

Economic Information:

• Do you harvest concha negra for local consumption or to sell?

Both.

• If harvested for local consumption, how many and how often do you eat it?

Sometimes.

• Is there any specific occasion?

In May there is a party when they eat concha negra.

• For what price do you sell a bucket of concha negra?

$7.00 per bucket.

• To whom do you sell the concha negra you collect?

(They go to Martin Perez to sell it) Colombian lady (each 2 weeks).

• If that person sells them to someone else, to whom does he sell them and where?

Nicaragua + Panama +other countries.

• What other income-earning activities to you have outside of harvesting concha negra?

Fishing

Other information collected:

Hate Kunas that come from other place to destroy the resources of the archipelago.

Interview in Ensenada 10/05/07

Harvesting Information:

• Who harvest the concha negra in the village, men, women, children?

Women.

• Where do you find the concha negra?

In the mangroves, in the holes between the roots, in the superficial mud layer ("lama").

• How are the concha negra distributed within the mangroves (patched or isolated)?

Isolated.

• How deep are the concha negra you harvest?

10-20 cm.

• When is the best time to harvest the concha negra during the day?

Low tide.

• Is the concha negra harvested all the year or is there any season?

All year.

• How many times per week do you harvest?

7 days a week 3 years ago. Rarely, there was no real activity this year.

• How many hours per day?

4/5 h per day.

• Since when have you harvested the concha negra, for how many years?

/

• How often do you return to the same place to harvest concha negra?

They are waiting 3 years when to return to a place where they harvested the concha.

• What equipment do you use for harvesting (boat, gloves, bag, bucket, etc.….?)

Bags.

• How many bucket per hour and per harvester today? And before?

Today, 1-2 buckets per person in 5 hours. 15 years ago 6-7 buckets per person in 4 hours.

• How do you conserve the concha?

No conservation. If for sell, they harvest the days before he come. If for local consumption, they cook it the night after fishing.

• Since you began as a concha negra harvester, has the number of concha in the mangrove: decreased, increased or remained the same?

Decrease**.**

• Since you began as a concha negra harvester, has the size of concha in the mangrove: decreased, increased or remained the same?

/

• Do you have any idea to explain these phenomena?

Overexploitation.

• Is there any danger encountered when harvesting the concha in mangroves?

Yes, bees. Very dangerous

• Do you know any concha negra predator?

No.

• What do you do with the shell of the concha?

Nothing.

• Which other species do you collect in the areas where you harvest pianguas?

/

Economic Information:

• Do you harvest concha negra for local consumption or to sell?

Mostly for sell.

• If harvested for local consumption, how many and how often do you eat it?

Rarely.

• Is there any specific occasion?

No.

• For what price do you sell a bucket of concha negra?

$9.00 per bucket

• To whom do you sell the concha negra you collect?

A women who come to the village (no more information).

• If that person sells them to someone else, to whom does he sell them and where?

Don't know.

• What other income-earning activities to you have outside of harvesting concha negra?

/

Other information collected:

They say that the number of concha is decreasing but they think that it is part of their natural life cycle and that you just have to let them rest. They don't think that the collapse is going one because they respect the small size. They don't take the smallest concha.

Interview in Martin Perez 12/05/07

Harvesting Information:

• Who harvest the concha negra in the village, men, women, children?

Every body, every age.

• Where do you find the concha negra?

In the mangroves, in the holes between the roots, in the superficial mud layer ("lama").

• How are the concha negra distributed within the mangroves (patched or isolated)?

/

• How deep are the concha negra you harvest?

10-20 cm.

• When is the best time to harvest the concha negra during the day?

Low tide.

• Is the concha negra harvested all the year or is there any season?

All the year. Ebb tide is the best (every 15 days)

• How many times per week do you harvest?

1-2 days a week when there is a demand. If not few times a month.

• How many hours per day?

4h a day.

• Since when have you harvested the concha negra, for how many years?

/

• How often do you return to the same place to harvest concha negra?

They wait 3-5 months.

• What equipment do you use for harvesting (boat, gloves, bag, bucket, etc.….?)

Bags.

• How many bucket per hour and per harvester today? And before?

Today, 2 buckets per person per day. Before, 4 buckets per person per day.

• How do you conserve the concha?

In nets in the mangrove or in sea water.

• Since you began as a concha negra harvester, has the number of concha in the mangrove: decreased, increased or remained the same?

Low decrease.

• Since you began as a concha negra harvester, has the size of concha in the mangrove: decreased, increased or remained the same?

/

• Do you have any idea to explain these phenomena?

Contamination.

• Is there any danger encountered when harvesting the concha in mangroves?

Bees are a real danger. Many people have been very seriously attacked. They need to go to San Miguel village for care.

• Do you know any concha negra predator?

A kind of raccoon has been seen feeding on cocha negra.

• What do you do with the shell of the concha?

Nothing.

• Which other species do you collect in the areas where you harvest pianguas?

Pied de buro (Anadara grandis)

Economic Information:

• Do you harvest concha negra for local consumption or to sell?

Both.

• If harvested for local consumption, how many and how often do you eat it?

1 time a month.

• Is there any specific occasion?

No.

• For what price do you sell a bucket of concha negra?

$7.50 + gas for the boat.

• To whom do you sell the concha negra you collect?

A women (she buy 150 buckets each 4-5 months)

• If that person sells them to someone else, to whom does he sell them and where?

She sells it to Guatemala and Mexico.

• What other income-earning activities to you have outside of harvesting concha negra?

/

Other information collected:

They say that the buyer let 4-5 month between each request, time for the concha to recover.

They say that the number of concha is decreasing but they think it is due to a contamination…

They think that they are fishing only the big concha that are living in the superficial layer of the mud and that smaller concha are living deeper in the mud so they are not destructed by fishing.

Also problem with Kunas.