Marine Ecology and Shellfish Exploitation in the Río Parita, Panama

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This undergraduate thesis is dedicated to my family for their continuous support, particularly my parents, Mark and Anne Lyall, and my grandparents, Elda McBride, Barbara Lyall, and Duncan Lyall. Your constant guidance and support is always appreciated.
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Abstract

Archaeological records show evidence of shellfish exploitation by hominids for up to 300,000 years. Similarly, a long history of shellfish use has been documented in Panama. Specifically, in the Río Parita Valley on the Pacific Coast of Panama, an archaeological survey conducted by Dr. Mikael Haller recovered twelve shell species, with *Anadara grandis* being the most widely distributed throughout the entire Lower Survey Zone. The earliest archaeological evidence of shell use in this area dates back to the Monagrillo Period, 2900 B.C. Evidence for shellfish exploitation prior to this date comes from other Panamanian sites such as Cueva de los Vampiros dating back to the Paleoindian period. The survey on which this study is based focused on artifacts dating to before the Spanish Conquest of 1522 A.D. This thesis focuses on investigating whether shellfish were collected for subsistence, economic reasons or a combination of both. It also examines the social organization of the people who used these sites. Using statistical analyses, the variables of (1) shell size; (2) distance carried from the mangrove where the species originates; (3) agricultural potential; (4) site order; (5) population density; and (6) evidence of craft production were examined. Preliminary results suggest that shell procurement strategies were complex and influenced by more than one socioeconomic factor.
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PREFACE

I want to thank the Anthropology Program and the Aquatic Resources Program at St Francis Xavier University for funding and support. This includes professors and fellow students in both programs who provided ideas, questions and advice that aided in the development of this thesis. Specifically, I would like to thank Dr. Mikael Haller, my advisor, and Dr. Clare Fawcett, my second reader.

I would also like to mention the funding provided for Dr. Haller, as the data used in this thesis came from his study. Awarded to Mikael J. Haller was a Doctoral Dissertation Improvement Grant from the National Science Foundation (#0139005), a Graduate Student Field Research Grant from the Center for Latin American Studies (University of Pittsburgh), and an International Studies Research Grant from the University Center for International Studies (University of Pittsburgh).
1.0 INTRODUCTION

Throughout history, humans and their ancestors have developed methods of collecting and using shellfish that are adaptive to their environments and their particular needs, dating as far back as 300,000 years ago (Lumley 1972:37). Often, the use of shellfish has had a lasting impact on how societies operate, from their subsistence patterns to their economic, political and social structures. Around the world, the study of shellfish has provided insights into sociopolitical aspects of various societies. On the North West Coast, for instance, anthropologists and archaeologists believe that shellfish are a critical resource in the development of the complex hunter-gatherer societies throughout the region. Archaeologists also believe that the control of shellfish, a crucial subsistence resource found in clusters, gave rise to the socio-political structure that makes this region so unique (Erlandson 1998; Matson and Coupland 1994).

The collection and manufacturing of shellfish can also reveal information about gender roles in a society. An example of this is found amongst the Meriam of the Great Barrier Reef and the Mardu of Australia's Great Sandy Desert, where men would rather try to hunt and risk failure than gather shellfish, an abundant, reliable resource, because gathering shellfish does not result in social recognition or prestige (Edgar 2002). This prestige, which is important to males, comes from the use of skill and the mastery required for hunting that is not present in gathering shellfish.

On the Pacific Coast of Panama, archaeological evidence of shell procurement dates back to the Paleoindian period at the Cueva de los Vampiros site (Pearson and Cooke 2002, Ranere and Hansell 1978). In the area of the Río Parita Valley, the Monagrillo phase, circa.
2900 B.C., shows evidence of shellfish use for human subsistence (Haller 2004; Ranere and Hansell 1978). Although individual sites have been examined throughout the Parita Bay, wide-spread surveys have not yet been conducted, mapping the distribution of human shellfish collection throughout the broader region. The goal for the study outlined in this paper is to conduct such an analysis for the Río Parita Survey Zone.

For this paper, I will be working with shellfish data recovered from the Río Parita Survey in Panama (Haller 2004). My goal is to investigate the role maritime exploitation played in pre-colonial societies in the region. Using statistical analyses, I examined the variables of shell sizes, distance carried from the mangrove where the species originates, site order, agricultural potential, and evidence of craft production. Although 12 species of molluscs were found in the survey zone, not all of them will be analyzed in this study, due to time constraints and the nature of their distribution. This study will deal mostly with *Anadara grandis*, the most widely distributed species, found throughout the entire lower part of the survey zone.

The main research questions addressed in this paper are (1) Were shellfish collected for subsistence, for economic reasons or for a combination of both (with ‘economic’ referring to collecting shell for working it and using it for craft production)? (2) What can the answer to this first question tell us about the social organization of the people who used these sites? These linked questions can be answered in various ways. The following is a list of questions and topics that arise from the consideration of these two primary questions:

1. How far were people moving the shells? Claassen (1998) says that people will not normally move shells more than about 11 km without the aid of pack animals. The people of the Río Parita area would not have used pack animals, but they may have been able to use water transportation along rivers. Are the shellfish collected in the Río Parita moved within this range, as dictated by Claassen? Do the river systems change this by allowing for easier travel? As it seems that *Anadara grandis* was distributed throughout the Lower Survey Zone, what was the range of distance the shell was carried?
2. Did the size of shells make any difference to how far they were moved from the collection point? Following the optimal foraging theory, why would the people take large, heavy shells with them? Why not just take the meat unless the shells were being used for something else? The optimal foraging theory dictates that, for the sake of time and efficiency, people will not discriminate; they will not select for size (Jochim 1976). Of course this theory applies when the shellfish are being collected for subsistence. Shell is used as a starvation food according to some, as mentioned by Claassen (1998), so perhaps it was collected more where agriculture was not as practical. To gauge this, we could ask, is there evidence of higher concentrations of shell in areas with poor soil productivity? This can be addressed through the use of Pearson’s regression analyses between distance and shell sizes, as well as GIS mapping, to gauge the distance the shells were moved, and the productivity of the soils in which the shell was found.

3. But were the shells being used for something else? Were the shells in this area being used more for economic purposes than for subsistence? How do we know one way or the other? If people were using the shellfish solely for subsistence purposes, and it was more cost effective to take the shell back instead of shelling it at the collection site, then we would expect to see smaller shells further from their source and larger shells closer to their source where they would not need to be moved quite so far. Or, perhaps, shell found at certain types of sites, classified as first-, second- or third-order sites, had been collected for craft purposes. If this were the case, then larger shells or larger quantities of shell would be found at these sites. In other words, if the shell is being collected for craft production, as opposed to subsistence, then the optimal foraging theory would not be applicable, and we would see fewer, larger shell at certain types of sites as evidence of selection. Regression analyses between these variables can give some insight into this. This question can also be addressed by examining studies from other sites in the area, particularly the first-order, large-centre sites.
4. Does our evidence suggest that shell was used more for craft production? We see the shell being taken, and we see no patterns to indicate *Anadara grandis* was more prominent in areas that would need supplementary foods to agriculture, so for what was this shellfish being used? How did craft production figure in? Was it a specialized activity, and if so, what determined a site’s involvement in craft production? Was it the site size? Or perhaps where soil productivity was lower, shell could have started mostly to account for the lack of agricultural potential and developed into a craft or cottage industry? These are questions that can be addressed through statistical regression analyses, as well as through exploring the findings of other studies throughout the region.

To commence the analysis, the following section will outline the research done in the past in this region of Panama. To understand the use of shellfish, as with any other subsistence or natural resource, it is important to understand the environment in which they lived, and the biology of the organisms themselves. This can have implications for the procurement strategies employed, as well as the importance of the resource to the people. This information will be addressed following review of literature, to provide the basis for shellfish analyses of the Río Parita Survey.
2.0 THE STUDY OF SHELLFISH

2.1 STUDYING SHELLS

In some capacity, shells have been studied by archaeologists for over 200 years in various parts of the world. Evidence suggests that the interest in collecting shells started relatively late in human development, possibly due to the global changes in sea levels thousands of years ago (Claassen 1998:1). In general, it appears as though humans started collecting shell at the time when the shorelines defined themselves roughly as they are today (Claassen 1998, Cooke 1999).

The earliest evidence of shellfish procurement in the world is at Terra Amata, a 300,000 year old site in France (Lumley 1972). Of course, this is a fascinating site, but it is not typical nor does it represent a time when shellfish were being collected elsewhere, including within the same region. Therefore it is not overly useful in the discussions of when humans began to collect shellfish, as it does not help in the understanding of any patterns of shellfish collection. In other words, shell was found at this site from 300,000 years ago, but nowhere else in France, or in the world, until 130,000 to 30,000 years ago. These later shells were found at several caves and open air sites in Africa, and demonstrate a more ubiquitous time for the initiation of shellfish collection (Claassen 1998).

Shellfish were collected as early as 10,000 years ago in the Americas, despite the later human occupation of the New World, and the subsequent later initiation of shellfish procurement (Claassen 1998:2). On the Pacific coast of North America through South America, the earliest sites are found in Peru dating back to 8300 and 8575 B.C., and
California, from 8300 B.C. where a shell midden site from Santa Rosa Island, California, from 9300 years ago shows that the occupants relied on shellfish for about 85 percent of their meat (Claassen 1998). This site seems to be typical of what was happening with maritime hunter-gatherers in this time period along the entire Pacific Coast (Erlandson et. al. 1999:255). On the Atlantic Coast of the Americas, however, no shell sites have been recovered from before about 5,000 B.C. This is probably a result of erosion from rising sea levels and storms that did not occur on the Pacific Coast during that same time period (Claassen 1998:2).

In these different regions, archaeologists and anthropologists studying shellfish collections and uses can learn a great deal about the social, and political structures, as well as gender roles within the societies. In many places around the world, shellfish collection is an activity performed by women, opening the possibility for discussion of gender roles. It is suggested by Brown (1988 cited in Jochim 1988:132) that it is in the best reproductive interest of a society to have women doing the activities with lower risk, such as gathering. This is why shellfish collecting is often considered a female activity, although this is not always the case. In general, in stable and rich environments, gender roles are well-defined and rigid, whereas more unpredictable environments may allow for more flexibility between gender roles to better the chances of survival (Jochim 1988:131). Often, these gendered activities will be interdependent. Amongst the Miskito, for example, women’s shellfish collecting is based on the returns of the men’s turtle hunting activities (Jochim 1988:131). Rigid gender roles in some areas might allow for stricter, more complex social structures to emerge and can reflect access to social status and power.

An example of these gender roles and prestige is found among the Meriam of the Great Barrier Reef and the Mardu of Australia's Great Sandy Desert, who are hunters and gatherers, even to this day (Edgar 2002). The women tend to hunt small burrowing animals, often through the use of fire to flush them out of their hiding spots. Men, on the other hand, pursue large game. In fact, it was noted that men will often risk failure in collecting food in their pursuits for larger animals, an activity that requires skill and strength. This
demonstration of skill is a way for men to distinguish themselves, and in so doing, to gain social standing and prestige within the group. This status is better gained through spearing the occasional fish or turtle than it is through constantly supplying shellfish, which are easy to acquire, to the subsistence base (Edgar 2002). It is the women who collect smaller animals, which are a more reliable source of subsistence, as their standing within the group does not seem to be related to hunting (Edgar 2002). This can relate to the situation in Panama, where men were also viewed as hunters and warriors (Helms 1979; Linares 1977). Perhaps this sort of social recognition was important there, as well, indicating that shellfish were not collected by the men. The Sitio Sierra site discussed below, for example, was inland. To obtain aquatic resources, the people either had to trade or make a dangerous journey trip by canoe down the river and into the delta (Cooke and Ranere 1999:118). In modern times, which may be our best indication of gender roles of the past, many of the commercial cockle fishermen in Panama are men, although women and children do collect shellfish for their own families. In general, throughout Central America, shellfish collecting is seen as an activity for poor men to provide for their families (MacKenzie 2001).

As seen partly in the above example, shellfish not only have a subsistence-based role, but also symbolic significance within a society. Shells can be processed, shared, discarded, curated, gifted, and modified, just to name a few functions. The uses can be based on ideas regarding associations of activities, cleanliness, health, feeding, and social organization including gender, and lineage ( Claassen 1998:220). As such, Claassen (1998) suggests three possible reasons why there might be a large amount of shellfish collected at any given site. 1) The presence of highly productive estuarine shellfish beds; 2) the relatively low risk and technology associated with collection; and 3) low human population density which would prevent overexploitation. In modern times the over-exploitation of commercial shellfish species along the Pacific Coast of Central America is a real concern (MacKenzie 2001).

A common debate revolves around why shellfish gathering was initiated in any given region. Some archaeologists, such as Erlandson (1988) and Claassen (1998), discuss
shellfish as a vital source of nutrients. The protein and carbohydrate content of shellfish both peak during the spring months, just prior to reproduction. Plants may have been the main source of calories with shellfish being the protein staple (Erlandson 1988:53). Shellfish are a poor source of calories, though Pacific Coast shellfish tend to be a better source than Atlantic Coast shellfish (Claassen 1998:183).

The primary role of protein is in the maintenance of proper development, reproduction and metabolic regulation. It is also the major source of building material for the body. Consuming shellfish is a relatively easy way of acquiring that protein. For example, Lishka and Sheets (1980:740 cited in Erlandson 1988:103) found that each aboriginal fisherman in Baja California collected enough clams during a low tide to satisfy the daily protein requirements of between 100 and 450 adults, or 40g protein/day. As such, it can be a rewarding activity for people nutritionally (Claassen 1998). Under certain circumstances, or during particular time periods, shellfish exploitation may be an optimal strategy in relation to terrestrial alternatives (Erlandson 1988:103). In various locations around the world, shellfish comprise a good 70-90 percent of the meat diet (Erlandson 1988:105).

In the 1970s, many archaeologists assumed that shellfish were mostly marginal resources—a starvation food—gathered only when people were lacking one of the above mentioned key nutrients in their diets. It was argued that, although people may not have been consciously aware of ‘proper’ nutrition, something lacking in the diet would manifest through decreased adaptive fitness (Erlandson 1988:103). More recent studies have emphasized the potential importance of shellfish in prehistoric diets, stressing that certain cultural or environmental circumstances would cause shellfish to emerge as a viable alternative to terrestrial resources. Jochim (1976) mentioned that the role of any food resource in a given economy is assessed best in a cultural ecological context that weighs various attributes of a resource against available alternative resources, and the dietary requirements, demographics, and technology of a human population. These attributes include size, nutrient composition, abundance, aggregation, seasonality, and reliability, to
name a few (Erlandson 1988:102-103). In this context, shellfish may have served as a
dietary staple, or a basic or necessary food item (Erlandson 1988:103).

2.2 SHELLFISH PROCUREMENT STRATEGIES

The methods of procurement vary with the type of shell being collected and the
characteristics of the region. Similarities often occur, nevertheless, regardless of where
shellfish are collected around the world. In studying the past methods of procurement, it is
often pertinent to turn to an examination of modern methods of indigenous gathering, as
they often have roots in prehistoric techniques. Some information exists from
ethnoarchaeological and ethnological projects from different areas of the world. Interest in
and documentation of harvesting methods was limited until the introduction of commercial
exploitation, when efficiency was presumably more of a focus than it would have been in
the past (Claassen 1998).

Two classifications of shellfish procurement apply globally: methods where the
individual either gets wet, or stays dry (Claassen 1998:41). One of the basic techniques is
simply extracting by hand, or toe. This method can be enhanced by technology, through the
use of a stick as a lever. This is done by using the stick to dig around the shellfish, or to put
in the gap between the valves, to pull it from the bottom of the body of water (Claassen
1998:41-42). In British Columbia, some shellfish-prying sticks have been found preserved
that are about 2,000 years old, though it is very rare to find shellfish sticks, baskets, or nets
made from organic materials at archaeological sites (Moss 1993:634). This is considered to
be a wet technique, as the gatherer will get damp during the collection. It has been found
that this technique is used regardless of the purpose behind collection, whether for the meat,
the shell itself, or the pearl (Claassen 1998:41-42). Often, in a harvesting expedition, only
one species will be the focus of collecting, although the target species can vary from day-to-
day (Claassen 1998).

In various parts of the world, diving for bivalves was practiced as well, which is
clearly a wet technique. In Japan, for example, diving to retrieve pearls and shell was one of
the roles of women. In the south-western Pacific, however, it was the job of men, who
would dive up to 110m depth, holding their breath for as long as 2 minutes. In Ghana, men
and women would both dive for freshwater mussels (Claassen 1998:41). In the United States
of America, diving without the aid of a breathing apparatus was done as well, up until the
1920s. At this time, the technology of SCUBA gear was introduced, increasing the amount
of time in which divers could be underwater, increasing efficiency (Claassen 1998:42). Even
with the invention of SCUBA gear, people still dive for shells using only masks and
goggles, in the Antigonish Harbour, Nova Scotia, for instance.

Dry techniques, which are often done from a watercraft of sorts, generally allow for
greater productivity than harvesting in the water by hand. In the United States and Canada,
the freshwater technique of brailing is an example. In this method, a branch is dragged
across the shoals, or multiple branches to increase efficiency. The targeted bivalves close on
anything that touches their mantle, so this way, all one needs to do is to pull the bivalves
from the branches (Claassen 1998:42). Obviously, this requires less effort than diving and
retrieving the bivalves individually by hand, and often allows for multiple shells to be
collected in a shorter period of time. This method has also been observed in China, where it
was done by women, and it was also a common technique by male French Canadian loggers
(Claassen 1994:15-16).

Similarly, Waselkov (1987) discusses the method used by the Maori, who used rakes
and scoops with long handles. Similar tong-like instruments have been seen in the Americas,
too. These were quite simply two long rakes that were hinged together. These could be used
to scoop molluscs from deep water. The user lowers the open tongs to the bottom, and closes
them together, lifting the sediment, debris, and consequently, the shells to the surface
(Claassen 1998:42). These strategies are elaborations of wet techniques, which evolved into
dry methods with different types and powers of boat, as well as with increasing technology, such as the incorporation of nets and dredges (Claassen 1998).

Not all species of bivalve are equally catchable with each technique; for example, the method used may depend on the amount of the shell that is above the sediment, or the overall visibility of the shellfish (Claassen 1998:42). For example, if the mantle is hidden, then the brail methods will not work. It has also been suggested by Erlandson (1988:53) that shellfish procurement may not be an efficient or even productive pursuit universally, but in relation to terrestrial alternatives, it may be an optimal subsistence strategy, depending on the circumstances, seasonal conditions and time period.

An extensive study of shellfish use took place on the Transkei coast of South Africa, where ecologists, archaeologists, and anthropologists have worked together to understand human adaptations through the use of shellfish (Claassen 1998:43). They are studying both past and present methods and patterns of exploitation of the intertidal molluscs along the 260 km shoreline. They mentioned with this study that people will not travel more than 11.26 km (or 7 mi) to gather shellfish (Claassen 1998:43). This could have interesting implications for the shellfish use in Panama, where only few archaeological sites are found at a distance greater than 11.26 km from the shoreline. In the Transkei study, most of the bivalves were taken in the shell, although chitons were shelled at the site (Claassen 1998:43).

In the Río Parita area, archaeologists are not certain if specific species of shellfish were shelled at the point of collection, though this may be the purpose of the fishing stations discussed below. In general, it is easier for the people to take certain types of shellfish with the shell. This means that if archaeological surveys do not uncover large amounts of shells, but some are found, the archaeologist can assume that the shell serves an alternate purpose, as not all shellfish are collected universally for mere subsistence (Claassen 1998). Also, because the people of this area were “exterminated, hybridized or radically hispanicized” shortly after initial contact (Romoli 1987 cited in Cooke and Ranere 1999:105), Cooke and Ranere say that continuity between fishing methods of pre- and post-colonial times cannot
be assumed (1999:105). Even so, they are studying an intertidal fish trap that they say may have been used in much the same way in the past as it is in the present (Cooke and Ranere 1999:105).

The following chapter contains a review of some of these studies pertaining to shellfish exploitation in the Parita Bay region of Panama. As mentioned above, the specific methods of procurement are not known, nor the specific gender roles. The literature does address some of the uses of shells at various sites, and the authors offer some speculation on specific indications of social structure.
3.0 REVIEW OF LITERATURE

3.1 ARCHAEOLOGY IN THE PARITA BAY

Shellfish use in Panama has been widely investigated by archaeologists within the past few decades. In the Parita Bay region alone, a number of excavations have recovered aquatic resources and some evidence of shell from subsistence or manufacturing. These excavations include, but are not necessarily limited to, studies by Carvajal (1998), Cooke (1999), Cooke and Tapia (1994), Cooke and Ranere (1989, 1992, 1999), Cooke and Sanchez (1997), Mayo (2004), McGimsey (1952), Pearson and Cooke (2002) and Ranere and Hansell (1978). Between these studies, some common themes and trends are presented, giving reason to believe we might see similar results in the shellfish remains from the Rio Parita Survey.

In past years, much of the research done along the coast of Panama focused on marine fish species, as opposed to shellfish species (Cooke, 1999). This is due in part to the high abundance of fish in the area, and therefore the great amount of fish remains found at archaeological sites. Also, according to Cooke and Ranere (1999:103), much of the past fisheries research has focused on the acquisition of commercially significant, non-estuarine species of fish, such as tunnies, groupers and big jacks. In recent years, this has been changing, with increasing focus on the study of shell midden sites and shells used as crafts (Carvajal 1998, Cooke and Ranere 1992, Mayo 2004, Ranere and Hansell 1978, Willey and McGimsey 1948). Many of these projects have taken place on the Pacific Coast, and specifically, in the Parita Bay.
Some of the main sites in the Parita Bay area that are relevant to this study are Monagrillo, Zapotal, Cerro Mangote, and Cerro Juan Díaz (Figure 1). Multiple authors have written on these sites, and the nature of shell use. They will be discussed in this chapter, as they present an insight into how shells can be used as indicators of social organization and structure. These sites also contained similar types of shells as the Río Parita data, with evidence of similar usages, and therefore may help in the understanding of why shellfish would be collected in this area.

Figure 1 Archæological sites mentioned in the text.
Monagrillo (4090 ± 70 B.C., Cooke 1995; Cooke and Ranere 1992), also commonly referred to as He-5, is a shell midden site found 1.5 km from the Pacific Coast, along the Parita Bay. It was established on a somewhat narrow neck of land that juts out into the salt flats of today’s environment. The site is “two low, parallel ridges separated by a central trough” (Ranere and Hansell 1978:46). Initially excavated in 1948 by Stirling, Monagrillo was thought to have measured approximately 435 m$^2$, or at least, that was the area of examination at that time and extensively excavations by Willey and McGimsey in 1952. By this final study, they discovered that the site actually measured 210 by 85 m (Ranere and Hansell 1978:46). In the 1978 excavations, only two cuts were made: one was 1-by-2 m into the south ridge, and the other was a 2-by-2 m cut into the north ridge (Ranere and Hansell 1978:46). These two ridges contained “culture-bearing deposits”, consisting of sand and shell in layers averaging approximately 2 m in thickness, when measured along the main axis (Ranere and Hansell 1978:46). This site is significant in that these cultural deposits contained the earliest pottery found in Lower Central America (Cooke 1995). I include this to demonstrate that this site has been studied in great depth, and therefore much is known about the nature of shellfish used.

One of the key findings at Monagrillo was that at the time of occupation, which was seemingly relatively short, the site was actually on the Parita Bay coastline (Ranere and Hansell 1978). It is apparent that occupation was therefore temporary, due to spring tide inundation, as seen by the water wearing on the potsherds in the lowest layers of the midden. The most intense occupation was seemingly in the period when the present coastline was established. This formation occurred through the transformation of the area into a lagoon when an offshore sandbar silted over. At this time, the amount of cultural artifacts of all kinds increased, including shell remains. The occupation seems to have ended when the lagoon silted in, and the area was converted into the salt flats we see today. According to Ranere and Hansell (1978:46), the site was continuously used, though sporadically as opposed to permanently. It is still presently used, due in part to the abundance of fish,
shellfish and other marine subsistence resources in the surrounding waters. Unfortunately, modern day occupation has destroyed much of the site (Haller 2004).

At Monagrillo, shell was in abundance; all species of shell found were from mudflats, or sandy shallow waters (Ranere and Hansell 1978:49). Curiously, the majority of the shell found was in concentrated lenses, rather than being evenly distributed throughout the site. We are reminded that “quantity alone is not sufficient to indicate shellfish as a dietary staple” (Ranere and Hansell 1978:49). Ranere and Hansell believed that analyses from this site would show that fish and crab were of equal or greater importance than shellfish, as thousands of small fish vertebrae were found at this site. Also of interest is the fact that archaeologists are unsure whether or not plants were yet domesticated. The wood charcoal found was not completely identified, except so far as to say that maize was not present (Ranere and Hansell 1978:49).

The site of Zapotal is located about 6 km from the mouth of the Río Santa María, on a rise that extends into the floodplains (Ranere and Hansell 1978:49). In 1954, Willey and McGimsey measured the site, concluding that it extended 200 m along the ridge, and 20 m on either side. In this excavation, six 3 m² test pits were excavated. Not much is known about Zapotal, though it is clear that it, too, was once on the shores of the Parita Bay, like Monagrillo (Ranere and Hansell, 1978:50). This was determined through the evidence of beach deposits underneath the lower most layer that contained cultural remains (Ranere and Hansell 1978:50). It is believed that this site was occupied at a time when an active lagoon was in the vicinity, where marine resources such as shellfish would have been abundant. Shell at this site was crushed and scattered throughout the midden. Though Ranere and Hansell do not suggest further ideas as to what shell in this form may imply about the site, Willey and McGimsey proposed that Zapotal was actually a station for fishing and shellfish collection. Based on the pottery, this site was dated slightly later in time than Monagrillo (Willey and McGimsey 1958, cited in Ranere and Hansell 1978:50).

Cerro Mangote is one of the extensively studied sites in the Parita Bay area. It is a shell midden site about 4 km upstream of Zapotal, along the Río Santa María (Ranere and Hansell
1778:49), about 1-3 km from the shoreline at the time of occupation (Cooke and Ranere 1989:297). Cooke and Ranere (1999:302) speculate that this site was not actually located on the main channel of the Río Santa María, based on the lack of freshwater fish remains at the site. The fishermen would never need to travel more than 7 km to find large supplies of fish (Cooke and Ranere 1999).

McGimsey excavated this site in 1956 in such detail that his data is still mostly used today. In this initial study, McGimsey found, again, that the site was near the base of the hill, Cerro Mangote, which was right at the coastline. Now, however, the site is located about 10 km upstream from the mouth of the river. McGimsey (1958) describes the site as being in an hourglass-like shape, about 55 m long and 25 m wide at its maximum. Cooke and Ranere (1992) dated the initial time period of settlement at 6670 ± 215 B.C, being abandoned in about 5000 B.C. Hansell and Ranere (1978:50-51) also quote McGimsey as reporting in 1956 that, regardless of the fact that fish and molluscs were not highly represented in his sample, he believed fish did play a large role in the diet of the people of Cerro Mangote. He did not feel that his excavations were representative of the actual aquatic resource matter of the site, according to Ranere and Hansell (1978:51). The study of the later pair seemed to support the idea that fish were underrepresented, even though they were unable to do further excavations at that time. McGimsey states, however, that “The occupants [of Cerro Mangote] appear to have relied primarily on shellfish, supplemented by hunting, for their protein” (1958:160). This idea is supported by Cooke and Ranere (1992:125), though another option is presented along with it. They suggest that perhaps this site was only occupied seasonally or occasionally, by a transhumant group, who would have lived away from the coast the rest of the year. This would conceivably mean that the occupants would not be taking shell away with them, at least not in large amounts. Based on the fact that over ninety burials were found at the site, Cooke and Ranere (1992:126) believe that the residents kept coming back to the site for a long time.

Even though Ranere and Hansell were unable to do further excavations at Cerro Mangote, the excavations that were done at Monagrillo in continuance of McGimsey’s
study, showed that McGimsey underestimated the amount of fish and shell at Monagrillo. Therefore, it is not a large stretch to assume that estimates by McGimsey at other sites were lacking in marine faunal remains. Ranere and Hansell (1978) and Cooke (1992) estimated that at both Monagrillo and Cerro Mangote, the amount of protein coming from the sea was greater than the amount of protein obtained from terrestrial sources (Ranere and Hansell 1978).

No evidence of actual plant remains were found at Cerro Mangote, although plant processing tools were found, such as edge-ground cobbles, pebble milling stones and boulder milling-stone bases (Ranere and Hansell 1978:51). Consequently, the archaeologists assumed that plants played a role, though they were unable to say for certain precisely what that role was or even whether or not domestication was achieved. This is something that Piperno et. al. (1985) noted as well, in that agriculture was a sudden acquisition in Panama.

Aguadulce Shelter is not a shell midden site, but a rock shelter with evidence of shellfish remains (Cooke and Ranere 1992:297; Ranere and Hansell 1978:51). Although the current coastline is about 18 km away from the site, it was quite a few kilometres closer when the shelter was probably occupied. Ranere and McCarty conducted the first excavations of this site in 1973, and three pits were excavated at that time. One was 1-by-1 m and two were 1-by-2 m. Two years later, two additional 1-by-2 m pits were dug. Cultural deposits went down about 85 cm, containing both pre-ceramic and ceramic components (Ranere and Hansell 1978). Based on the evidence recovered and some shell dating, as opposed to firm radio-carbon dating, archaeologists estimated that Aguadulce was occupied between the fifth and the first millennium B.C. (Piperno et al. 1985). This was determined based on the similarities between the Preceramic component of Aguadulce and the Cerro Mangote site, and the similarities of the ceramic component of Aguadulce to the Monagrillo site (Ranere and Hansell 1978). Later analyses of shell through radio carbon dating, as reported by Piperno et. al. in 1985, suggest the site was occupied between 3890 ± 95 B.C to 590 ± 70 B.C. The final decision, as of 1985, about the time of occupation was that the site dated from the late 3rd millennium B.C. (Piperno 1985).
The Aguadulce site had many features similar to Monagrillo, including shellfish species. According to Ranere and Hansell (1978:51), the only shellfish species found here were mudflat and sandy- or shallow-water species. Also, similar edge-ground cobbles, bolder milling-stone bases and pottery styles were recovered. Though similarities were abundant, the Aquadulce site had thousands of chipped stone tools and flakes that were not found at Monagrillo, suggesting different activities were done by the people (Ranere and Hansell 1978:51).

Significantly fewer shell remains were found at Aquadulce than Monagrillo (Ranere and Hansell 1978). Curiously, when one might expect a lack of marine subsistence to be as a result of cultivation, the evidence does not lead to this conclusion. Other than numerous palm-nut fragments found in 1978, little charcoal exists among the remains found at the site (Ranere and Hansell 1978:51). Most of the protein for this rock shelter was obtained through deer, and to a lesser degree turtle, with enough also coming from fish, crab and shellfish, that aquatic resources could be mentioned as a significant component, as well (Ranere and Hansell 1978:51-52). On top of these subsistence resources, agriculture seems to have been introduced around 2500-1000 B.C. throughout the entire Santa María basin. This range of initiation is based on recovered phytolylths of teosinte (Cooke and Ranere 1992).

La Cueva de los Ladrones is a rockshelter site that is located about 25 km away from the Río Parita (Ranere and Hansell 1978:53). According to Piperno et. al. (1985), it was occupied by the early third millennium B.C. Agriculture seems to have started rather suddenly here too, probably with initial occupation in 4910 B.C. This is significantly earlier than the projected range for the beginning of cultivation as cited above. This may be because La Cueva de los Ladrones is deemed to have been a better environment for agriculture than Aguadulce because 1) it was a more attractive dwelling, with room for over 30 people (1 person per 10 km²), as well as increased shelter from swift dry season winds; 2) the annual precipitation was only 300-500 mm more per year than Aguadulce, but the rainy season was more reliable with fewer variations; and 3) Aguadulce was located in the swampy plains,
surrounded by forests. As such, it would have been harder to fell and burn vegetation to create crop lands (Piperno et. al. 1985, Ranere and Hansell 1978).

Sitio Sierra is also in the Santa María basin. This site was a nucleated farming village that was occupied from about 200 B.C. to the Spanish Conquest. It was located approximately 12 km inland at the time of occupation (Cooke and Ranere 1999:108). Cooke and Ranere (1999:107) consider Sitio Sierra to be an estuarine site, as they remind us that a site can be significantly far from the coastline and still be considered as part of the estuary. It was in a good location for compromise between proximity to both nektonic and littoral resources, and the fertile colluvium for maize agriculture (Cooke and Ranere 1999).

At the Vampiros site (Pearson and Cooke 2002), shell dates back to the ninth millennium B.C. and at Corrona, 5980 ± 100 B.C. The shell found was not *Anadara grandis*, but other *Anadara* species (Cooke and Ranere 1992:124) Humans at Carabali, 55 km inland, collected molluscs in 4500 B.C. as well. Consequently, archaeologists know that shells were being moved great distances. It is estimated that around 7000-5000 B.C., sea resources became crucial in diet. This estimation was based on fish more than on shell, as Cooke and Ranere (1992:124) pointed out that any shell they found could have been for “trinkets” instead of subsistence. This meant that they could be keeping the shell for the sake of the shell itself and not as garbage from subsistence activities. This information could be critical in analysing the shell found in the Río Parita area, as well.

Cooke (1999) notes that a shift occurred in fishing techniques in the Parita Bay sometime between 5000 B.C. and 2200-1800 B.C. The first date corresponds with the abandonment of Cerro Mangote, though the specific date is questionable, and the later date corresponds to the occupation of Sitio Sierra, where again the dates are in contention (Cooke and Ranere 1999; Ranere and Hansell 1978). At Cerro Mangote, the focus of the occupants was more on fishing in areas that were closer to their site, such as mangroves, and drying salt marsh pools (Cooke 1999:38). Cooke also argued that this allowed for simpler methods of capture to be used. With Sitio Sierra though, the development of new fishing technologies such as fine-meshed gill nets, would have allowed the inhabitants to broaden their search.
area, to the small shoaling fish species, which could be tracked through the shallow estuaries, based on local knowledge of their movements, and possibly the use of watercrafts (Cooke 1999:38). Today, watercrafts are still used, and even shared; one boat will be hired to take several families to their sites, and the owner of the boat is paid with a portion of the shellfish collected (MacKenzie 2001).

In many sites, the shellfish remains showed signs of being worked, as seen in grave goods. El Indio is a site containing burials, including the Tonosi phase burials of children and adolescents. In these burials, the adolescents were buried with objects made of shell, whereas the children were buried with other elaborate grave goods (Briggs 1989). Briggs (1989) suggests that children, unable to have formed their own identities within the society, had more standardized grave goods, whereas adults had more varied objects. At the site of El Cafetal, however, shell was exclusively associated with adult burials, along with bone and metal objects, whereas lithics were only buried with children and adolescents (Briggs 1989). He suggests that, in both cases, the evidence points towards an egalitarian society of some degree. Cooke (1992) noted that these trends continued out of the Tonosi phase, becoming indicators of social stratification several centuries later. This indicates that the presence of worked shell evolved into a signifier of high status.

Cerro Juan Díaz in the Río Parita area is a significant site for shellfish remains, as well. Diana Carvajal (1998) examined a shell midden site at Cerro Juan Díaz, proposing that inhabitants of the site were only exploiting maritime resources near the coast, as the remains of molluscs near the site were from the estuary. Similarly, Julia Mayo (2004) discussed the evidence of a shell workshop at Cerro Juan Díaz in the Río Parita. Indications of a workshop are tools, debitage from working the shell, and the final products themselves. By examining the remains, Mayo was able to determine that working the shell involved techniques such as grinding, incising, cutting, perforation, and percussion, whether it was direct or indirect (Mayo 2004). Similar workshops were also found at Río La Villa Valley, by Isaza (2004). Shell tools of a similar fashion were found by Hansell (1988) at La Mula-Sarigua, a shell midden site and a village showing evidence of nucleation. Even though this site has
protected status as a national park, the size of this midden has been steadily decreasing over the last few decades, due to human extraction (Haller, personal communication). Cooke and Ranere cite the apogee of La Mula-Sarigua as coinciding with a time of change, when rockshelters were being abandoned as the most common dwellings, epitomizing the “ascendancy of colluvial riverine zones as the axes of cultural development in the region” (1992:127). Contrary to those at Cerro Juan Díaz, the shell tools from La Mula-Sarigua do not appear to have been used for jewellery production, but for scraping or percussion (Hansell 1988).

Shells were also found as a common grave good at Cerro Juan Díaz, and were especially concentrated in graves from about A.D. 150 and 700 (Mayo 2004). Haller (2004:154) reports that “shell artifacts in similar form and quantity were encountered at He-4 in mortuary contexts”, as well as in the Río Tonosi Valley. Various species are used for this craft production, including *Anadara grandis*, *Spondylus* spp., *Pinctada mazatlanica*, *Strombus galeatus*, *Conus patricius*, and *Melongena patula*. For *Anadara grandis*, the shell is worked by detach- ing the ventral, creating slender pieces that were made into pendants (Haller 2004:155). At Cerro Juan Díaz, “eye-tooth” beads were also manufactured from *Anadara grandis* using indirect percussion techniques (Mayo 2004).

More specifically with shell production, *Anadara grandis* is also found in many sites in the form of shell pendants. Mayo (2004) has uncovered these at Cerro Juan Díaz, and Cooke et al. (2000) at El Cano. This is mentioned by Cooke and Sanchez (1997) as well, with reference to the idea that control over local resources, manufacturing, and exchange may have factored into the emergence of chiefly societies in Central Panama. Also, a cache of *A. grandis* pendants was found at La Canaza in the Río Tonosi Valley by Ichon (1980). A sort of standardization and increase of the geographic range of artifacts also increased in the Cubita phase, between 500 A.D. and 700 A.D (Cooke and Sanchez 1997). It should also be noted that, in the Cubita phase, for example, other species of shell were being worked into pendants. The most notable of these was *Spondylus*, one fragment of which was also found in the Río Parita Survey by Haller (2004:123).
Future studies are being proposed at He-4 (Locascio 2007; Menzies 2006). The authors draw attention to the fact that considerable wealth is demonstrated in burials, including those at He-4, through worked shell beads. The production and standardization of shell jewellery in Central Panama also increased significantly during the Cubitá phase, 500 A.D.-700 A.D. (Locascio 2007; Menzies 2006). As such, Menzies (2006) and Locascio (2007) suggest that the two concentrations of shell on the margins of He-4 imply that shell working was a form of organized production at the site. This being said, they note that the shell itself is not spatially associated with evidence of elite occupation, which is curious if shell items are considered luxury goods, as is often the case (Claassen 1998; Locascio 2007; Menzies 2006). Menzies (2006) and Locascio (2007) are proposing further excavations to discover whether or not He-4 will actually contradict the common idea of craft production directly contributing to the development and maintenance of status.

3.2 SUMMARY

The Río Parita project differs slightly from the projects mentioned above because it is a regional Survey. The extensive excavations above were conducted on one specific site. This way, we are presented with detailed information about the people living within the boundaries of the site. The Río Parita project, however, covered 104 km² in total and located 378 archaeological sites (Haller 2004:29). The shell information with which I am working is not from a specific settlement, but from many. Although household archaeology and site specific excavations are important, it is equally important to conduct regional examinations, to gain a better holistic and comparative understanding of what the people in the area were doing. It is also possible this way to clarify the relations between these groups of people. We can possibly expect to find different kinds of information about some of the smaller sites
from studying regionally, whereas the excavations above are more useful for understanding the larger centres.

Worldwide, a lot of data about the use of shellfish by human populations is still missing in the archaeological records (Claassen 1998). As of yet, cross-cultural comparison has been minimal, because not enough information currently exists about the roles of shellfish in various places around the world. Even within the well-examined variable of subsistence base, we are still lacking comparable, cross-cultural studies. Based on the studies above, all sites in the Parita Bay Region were using shellfish at certain times. The trend of the uses over time is that shellfish were collected for subsistence, shifting to craft production (Carvajal 1998; Cooke 1999; Cooke and Tapia 1994; Cooke and Ranere 1989, 1992, 1999; Cooke and Sanchez 1997; Locascio 2007; Mayo 2004; Menzies 2006; McGimsey 1952; Pearson and Cooke 2002; and Ranere and Hansell 1978).

At Monagrillo, from as early as 4090 B.C., before the advent of agriculture, and at Cerro Mangote around 6670 B.C., large amounts of shell were found along with many fish bones (Ranere and Hansell 1978). This shell was unworked and clearly used as food. In this time and in this area, most of the protein came from the sea (Ranere and Hansell 1978). This is logical in the above mentioned cases, as there was no evidence of agriculture. Evidence of plant charcoal was found, but not species that were cultivated. Linares et. al. (1975:187) says that the most common limiting factors for human populations are available protein supplies, such as shellfish or some cultivated plants. Many groups of gatherers and early cultivators could survive, and become fairly sedentary where aquatic resources of fish and shellfish were common, such as in the Parita Bay. Also Aquadulce and other rock shelters, while having shell, have more protein from terrestrial game (Ranere and Hansell 1978). These sites were not as old as the coastal sites, suggesting that the reliance on shellfish as a protein staple generally decreased over time.

The people of Monagrillo and Cerro Mangote would have been on the coast, and it would not have been difficult for them to acquire the shell, or carry it the short distance to their site (Cooke and Ranere 1999; Ranere and Hansell 1978). This site is still sporadically
used for this reason. The most intense occupation was seemingly when the present coastline was established through the transformation of the area into a lagoon when an offshore sandbar silted over (Ranere and Hansell 1978). At Zapotal, the same situation occurred, as it was once on the banks of the bay. It was slightly older than Monagrillo, with lots of crushed shell in a time of hunter/gatherers, so this, too, could have been a fishing station, or an early sedentary site (Cooke and Ranere 1999; Ranere and Hansell 1978).

Trends in the uses of shell start to shift at rock shelters and sites such as Cerro Juan Díaz, where shells are worked into craft beads in burials (Carvajal 1998; Mayo 2004). In the El India burials, shell is seen as a grave good that was earned with age, where children had standard goods, but adolescents had shell. This meant that shell had to be ‘earned’. This was always done within the context of an egalitarian society (Briggs 1989).

In short, archaeological records clearly demonstrate that a long history of shellfish use exists in Panama, particularly in the Río Parita Valley. Excavations throughout the region present evidence of human shellfish procurement dating back to the Paleoindian period, and extending straight through to modern times (Pearson and Cooke 2002; Ranere and Cooke 1978).
4.0 ENVIRONMENT AND SHELLFISH

Shellfish have been collected in marine and freshwater environments by peoples around the world for millennia. The reasons for collecting shellfish vary by species, location, availability of alternative resources, and specific cultural traits of the people who are collecting. As such, it is pertinent to discuss the environment in question, as well as the organisms being collected. This will be followed by a brief description of both the mollusc *Anadara grandis* that is analysed in this paper, and the specific ecosystem inhabited, which is the mangrove swamp.

4.1 THE PANAMANIAN ENVIRONMENT

Panama is located in Central America, as the land bridge between North and South America. It is characterized by mangrove-fringed shorelines, followed by low-lying swamp lands, marshes, and salt flats. Past that, the terrain turns to plains, foothills, and mountains. The foothills run the length of the country, creating a distinct physical barrier between the Atlantic and the Pacific coasts of Panama. Several major river systems run down through the foothills and plains, opening to the ocean with broad, alluvial plains (Haller 2004).

The Gulf of Panama is characterized by localized coastal upwelling, along with nutrient enrichment and lower surface temperatures in the windy, dry season months, of December to April (Cooke 1992). As a result of this, combined with the mudflats of the alluviums, this area is well known for biodiversity. Historical and archaeological records
suggest that this facilitation of large populations of crustaceans, molluscs and fish were established about 7000 years ago (Cooke 1992, Ranere and Hansell 1978).

The Río Parita estuary is on the Pacific Coast of Panama, in the Eastern Tropical Pacific area, as described by Cooke (1992). The Río Parita basin has a total drainage of about 575 km² and flows approximately 70 km from the piedmont zone to the coastal plain region. Figure 2 from Haller (2004) illustrates the position of the Río Parita in the Parita Bay. This map also illustrates other major rivers in the Parita Bay mentioned throughout this paper; mainly the Río Santa María. These rivers have broad alluvial plains that cross the Ilanos and drain into the bay. The Río Santa María and the Río La Villa watersheds are significantly larger than the Río Parita, 3,315 km² and 1,251 km² respectively, though prehistoric occupation was quite concentrated in the Río Parita (Haller 2004:20).

Figure 2. Map of the Parita Bay Survey Zone

This image, used with the permission of Dr. Haller (2004:19), shows the survey zone. The Lower Survey Zone and the Upper Survey Zone are both outlined and labelled. It was the Lower Survey Zone where Anadara grandis was found.
The shoreline of the Parita Bay and the adjacent plains are the driest regions in Panama. The annual rainfall varies from less than 1,000 mm along the coast, to 1,600 mm on the Ilanos, and to well over 3,000 mm when closer to the continental divide (Ranere and Hansell 1978). Cooke and Ranere (1999) say that precipitation is around 4000-3000 mm at elevations above 300 m on the cordilleras and foothills, and 1,800-1,000 mm on plains adjacent to the bay. About 90-95 percent of the precipitation occurs in the rainy season, from May to November. During the dry season, the normally-navigable Río Santa María becomes riddled with sand bars and dunes, inhibiting watercraft travel (Cooke and Tapia 1994:288).

Within the Río Parita watershed, however, the mean annual precipitation is 1,683 mm, and only 45 mm in the dry season (Haller 2004:20). Naturally, along with the change in precipitation comes a drastic change in the amount of vegetation (Haller 2004:20). Also, the annual mean temperature is around 27 degrees Celsius, changing little throughout the year.

This region was reconstructed by Tosi (Haller 2004) as dry tropical or permontane forest when elevations are below 100 m, and moist tropical and moist premontane forest for 100 m-600 m elevation above sea level. Today, however, this type of vegetation is only found in small isolated pockets in and around rocky outcrops in the Ilanos and in a somewhat modified form as gallery forests along some of the major rivers. Today, the vegetation is primarily savanna that is maintained by fire, and is used for cattle grazing. Therefore, nowadays, the common types of plants are species of trees and shrubs that are fire-resistant, such as chumico, maranon, and nance.

The environment directly influences the types of organisms that can survive and thrive in a particular area. It was mentioned above that the Parita Bay encompasses the perfect conditions for a large variety of aquatic species to thrive. In the following section, I will discuss the shellfish species on which this paper is focussed.
4.2 SHELLFISH BIOLOGY

Shellfish are part of the phylum Mollusca, which, along with snails and bivalves, also includes slugs and squids. This encompasses a large variety of creatures, but all Mollusca are identified by their hard shell, soft body, and slippery skin. Of course, other than these basic characteristics, molluscs can vary greatly. It was estimated in 1958 that 80,000 species of molluscs existed worldwide (Morton 1958). Three quarters of all the world’s molluscs are gastropods (Class Gastropoda), and out of the aquatic species, they are the most commonly seen. In the Parita Bay, the molluscs in the class Gastropoda include Cerithidea valida, Natica (Natica) unifasciata, Malea ringens, Olivella (Lamprodona) volutella and Strombus galeatus (Haller 2004, identified by Diane Carvajal). Gastropods are considered to be univalved, meaning that the shell forms a spiral, with its lowest, widest coil serving as the spacious body whorl (Morton 1958:32).

Bivalves are also in abundance globally (Morton 1958:15). Molluscs of the class Bivalvia are those with, among other things, two halves, or valves (Morton 1958:54). The valves can be either symmetrical or asymmetrical (Claassen 1998:18). These halves are drawn together by two adductor muscles, on the anterior and the posterior (Morton 1958:54, Claassen 1998:18). When bivalves are visibly open, these muscles are relaxed (Morton 1958:55), as the ligament that joins the shell is springy and elastic (Claassen 1998:18). Most bivalves have a wedge-shaped foot, used for locomotion and burrowing, no head, two siphons, and gills (Claassen 1998:18). The outer portion of the shell is referred to as the margin, with the dorsal margin being at the top of the shell where the umbo is found. The umbo is the part of the shell where the “teeth” and the ligament are located (Claassen 1998:19). The siphons and the foot are located closer to the ventral margin, with the foot located on the anterior margin and the siphons on the posterior (Figure 3).
Figure 3. Basic diagram of a bivalve

Bivalves tend to be more sedentary than gastropods, as many of them borrow, and some even bore into the rocks. Others have become permanently anchored to hard surfaces, such as some oysters, meaning that the foot used by most molluscs is either reduced or lost (Morton 1958:54). Certain bivalves, which are commonly referred to as ‘cockles’, such as *Anadara* sp. (MacKenzie 2001), are further characterized as being plump, with thick, heavy and prominently-sculpted valves (Morton 1958:57). These valves fit tightly together, which often makes them challenging to break open (MacKenzie 2001, Morton 1958:58). The posterior third is usually exposed, and the siphons are short.

In the study by Haller (2004), five gastropod species and seven bivalve species were recorded and identified (for names and frequencies, please refer to Appendix A). These species were collected by early inhabitants from a variety of locations, ranging from the floodplains, mangroves, and mud flats, right out to the open ocean. For this paper, the species on which I will focus is the large bivalve, *Anadara grandis*. This species’ range is from Mexico to the northern most tip of Peru, and is found in the mangrove swamps in the Río Parita (MacKenzie 2001). Consequently, it is pertinent to briefly discuss mangroves, as
the efficiency of gathering does also depend on the specific environment in which the shell is located. Also, mangroves are important ecosystems around the world, and are at a high risk from damage by humans.

4.3 MANGROVES AND ESTUARIES

An estuary is an area of the coastal zone in which saline ocean water, freshwater, land and atmosphere all interact (Cooke and Ranere 1999:105). Estuaries can be classified in different ways. 1) the lower estuary, which is connected with the open ocean, free from barriers; 2) the middle estuary, which is an area of strong freshwater and saltwater mixing; and 3) the upper or fluvial estuary, which is mostly freshwater, but subject to tidal intrusions (Cooke and Ranere 1999:106-107). The C-shaped coast line of the Parita bay is considered a recent intrusion of the Pacific Ocean, and consequently, the area is sheltered. This makes for a protected bay area, with weak wave action, but no restrictions for tides. As a result, this is a low energy environment, heavily colonized by mangroves (Cooke and Ranere 1999:107).

Strictly speaking, the term ‘mangrove’ actually refers to the types of woody vegetation, trees and shrubs, found in this intertidal zone (Hogarth 1999:1). The term is colloquially understood in the English language as the actual zone itself, as in, a swamp comprised of mangrove trees and shrubs. Mangroves are generally considered to be found only in tropical areas. The mangrove in Panama and in tropical regions in general is found in the intertidal zone, or the estuary (Hogarth 1999:1-2). As such, freshwater and saline waters mix, varying in concentration depending on proximity to the mouth of a river, and the distance from the shoreline. This means that the mangroves of the area are frequently inundated with tidal waters. The soils are therefore almost completely waterlogged (Hogarth 1999:4). Having said this, depending on the proximity in the mangrove swamp, some soils also have a tendency to become quite dry during low tides. Around the Río Santa María in
the Parita Bay, for example, the *Rhizophora* mangroves, which are the specific dominant mangrove species there, can run inland along the run-off/tidal channels as far as 8 km. This brings them close to the site of Cerro Mangote, which will be discussed below (Cooke and Ranere 1999:107-108).

Mangroves are good sources of many resources. In addition to fish and shellfish, these swamps can provide humans with timber, and firewood, small animals and birds for hunting (Haller 2004:21). Even though they are ideal locations for gathering resources, it is actually difficult, if not impossible, to live in mangrove swamps, because of the partial submersion of the soils during moderate to high tides. Though habitation is not possible, mangroves, including those in the Río Parita estuary in Panama, are often near navigable rivers (Cooke and Ranere 1992). This means that travel to and from the mangroves for the acquisition of these resources could be made easier with the aid of water crafts. In much of Central and South America today, this is exactly what happens, as communities will often hire a boat to take them to various shell beds, paying the driver for his services with a portion of the bivalves they collect (MacKenzie 2001). Of course, in modern times, the mangroves are often threatened through activities such as over-harvesting, and shrimp farming. It is estimated that about 50 percent of the world’s mangroves are lost to shrimp farms (MacKenzie 2001). In the Río Parita area, it was noted by Haller (personal communication) that shrimp farms threaten to encroach on known archaeological sites, potentially destroying yet-undiscovered deposits in the process.

When mangroves are significantly damaged, it is hard for them to recover, due to another of their characteristics—the complex root systems of the mangrove trees (MacKenzie 2001). These cause the mangroves to serve as buffers between the ocean and the land, protecting the shoreline against such things as large waves, or storm surges. Similarly, mangrove roots capture sediments washing from the land, protecting reefs from sedimentation and contributing to the rich soils of the mangrove swamps (Hogarth 1999). These roots also serve to create excellent habitats for many organisms, such as fish, crustaceans, and of course, molluscs. The combination of the tangle of roots and the rich,
saturated soils mentioned above creates an ideal location for many aquatic organisms, including filter-feeding molluscs, such as *Anadara grandis*, to live (Hogarth 1999, MacKenzie 2001).

Any species that live within the mangrove swamps must be adaptable, though, as with the nature of the mangrove, marine organisms face the risk of dehydration and overheating. This risk is amplified in warmer climates, such as Panama. This is because of the risk that organisms will become dehydrated during low tide, due to evaporation, or concentrated salinity. During high tide, the water is warmer and the oxygen levels are lower (Hogarth 1999). Due to the fact that it is such a harsh environment, with unique features, the species that live there are often specialists, only occurring within the mangroves (Hogarth 1999).

The most common molluscs in the mangroves are snails and bivalves, with snails generally being the most conspicuous of these. Few of these species are unique to the mangroves, though (Hogarth 1999). For example, those that are found in the mud are often also in the mudflats, and those on the tree roots are often on other hard surfaces, such as rocks on the shoreline. This is true for bivalves also. The most visible are found attached to the tree and shrub roots, but many are also in the mud, such as the genus *Anadara*. They can borrow as deep as 15-45 cm into the mud, depending on the tide at the time, and the specific species (MacKenzie 2001). As such, it is important to have an understanding of the individual mollusc species, particularly *Anadara grandis*—the focus of this study.
5.0 METHODS

5.1 FIELD METHODS

The data collected for this study is from the doctoral thesis of Mikael Haller (2004). The goal of his research was to evaluate the current models in place to interpret the development of social complexity in Panama through studying the Río Parita Valley on the Pacific Coast. I have included some of his methods here, as they are pertinent to the data I was given for my analysis.

Pilot studies for this project were conducted in 2000 by Haller, in an attempt to gain better knowledge of factors such as surface visibility, potential artifact density, and to assess the possibility of actually conducting a regional systematic survey in the Río Parita Valley. Through this, it was determined that, in the dry season when they were first assessing, surface visibility was actually quite great, and artifact density was also fairly high. It was noted that, “Even well into the 2002 wet season, the surface cover was sparse and surface artifacts easily visible; surface collecting was thus a rapid and effective means of recovering samples” (Haller 2004:25). Through systematic full-coverage surveying, the entire zone of 104 km² was covered.

Surveyors were spaced so that they could see and hear each other, to avoid the chances of the survey line being broken, or of surveyors continuing when the group had stopped. This also allowed the surveyors to congregate faster when a collection unit had been identified, as it was found that, logically, the greater the distance between the surveyors, the greater the amount of time for them to assemble at a collection unit, or to
reform the survey line (Haller 2004:26-28). The distance of 25 m between team members was chosen as in the Río Santa María project (Weiland 1984:35), as this was the smallest collection unit found in those surveys. The surveyors were divided into two teams, each consisting of a leader and 3 workers. The area to be covered per day was determined in part by following natural and cultural landmarks, such as rivers and roads. These teams each managed to cover approximately 1 km\(^2\) per day, regardless of hindrances (Haller 2004:26). Several impediments to the surveying and the collection process by the teams were encountered. For instance, some locations were identified as “undesirable”, such as swamps, thick brush, forested peaks, and farms, as well as hazardous flora and fauna. Some areas were also hard to access, due to factors such as barbed wire, marking boundaries of farm fields (Haller 2004:26-28). In such situations, instead of bypassing the area, the team would either break line to go through a gate, reforming once through the obstacle, or would find other ways over the obstruction before reconvening. Permission to cross private property was most often granted freely, contributing to the general ease in accessing the entire survey zone (Haller 2004:26-27).

Naturally, efforts to standardize the collection process had to be made. The inherent risk that the information will be biased in a ground survey is always a concern for archaeologists. For example, the majority of people are more likely to see items that look like an artifact, as in brightly coloured pottery, for example, or objects that are larger. As a result, some things may be overlooked, such as a chipped stone flake. Biases in archaeological studies will always be present, and the fact that the shell in this survey was obtained through surface collections means that there will be a bias attached (Peacock 2000). Therefore, an effort to standardize methods of collection must be made; what will be collected, by whom, and in what circumstances? In this situation, when an artifact was located, the team member would simply call to the other workers to indicate what they had found, but a full stop for further exploration was avoided (Haller 2004:28). Rather, the searching would progress at the same pace until two artifacts were found within a hectare of one another. When more artifacts were discovered within 100 m of the first one found, a
surface collection was undertaken. In the rare occasions that, within the 100 m, three artifacts were not recovered, the first two were discarded, and the count would return to zero (Haller 2004:28).

The ideal collection unit size was 1 ha (100 m x 100 m). Once the three artifacts were found within the allotted 100 m, the team would gather for a more in-depth search, to approximate the boundaries and artifact density of the area in question. If it was determined that the area was less than 1 ha, which was the standard collection unit, then only one artifact sample was taken to represent the entire concentration. If the area was determined to be greater than 1 ha, then it would be divided into units of approximately 1 ha (Haller 2004:27). “The total number of lots for the Río Parita Survey was 1265, which included 14 comparative collections and 14 positive shovel probes, thus, leaving a total of 1237 surface collections where 1017 (82.2 percent) were general and 220 (17.8 percent) were systematic. Additionally, there were 378 sites recorded producing an average of 3.3 collection units per site” (Haller 2004:29).

Surface collection took place in one of two forms: general or systematic. A general collection was done when artifact densities were equal to or less than one artifact per squared metre. Systematic surface collections were completed when artifact densities were greater than one artifact per square metre. The sample size for a general collection was 20 artifacts, including the original three found. In a systematic surface collection, the standard was the size as opposed to the number of artifacts, taking place in circles with diameters of 3 m (Haller 2004:26-28). The centre of the circle was selected before any knowledge was gained about the artifact density of the surrounding area, in an attempt to reduce the bias of sampling in the most artifact-rich areas. Also, through surface sampling, the issue discussed previously of bias in collecting the larger, aesthetically appealing artifacts was addressed, as surveyors gathered all that was present in the circle (Haller 2004:26-28).

The distance of 100 m was also used to assign clusters of collection units into sites. For example, if more than one site was found within 100 m, they could be classified together as being a part of one site (Haller 2004:27-28). Generally, though, artifacts were clearly
parts of well-defined clusters, separated from other clusters by vacant spaces. As a result, in the Río Parita project, sites were considered to be actual prehistoric communities, and also formed the basis for ranking and sizing, which are variables used in this paper. Most of the settlement analyses done by Haller (2004:27-28) are based on the individual collection units.

The boundaries of the collection units were recorded on maps that had been created through the digitalization of topographic maps, superimposed over corresponding aerial photos and then printed on photographic paper at a 1:10,000 scale (1 cm = 100 m: Haller 2004:28). These maps were later digitized, and were the maps used in this study, in calculating the distances Anadara grandis were moved, the type of soil on which the sites were located, and for recording the shell densities by site.

In rare instances, approximately 50 times in the entire survey, vegetation cover became dense to the point that surface visibility was impracticable. When this was the case, shovel probes (20 cm$^3$) were used, placed about every 50 m until surface visibility was restored (Haller 2004:28). If a site is within the alluvial areas, then a shovel probe may not be able to recover them, as a result of the building sediment. In the Río Parita Survey, however, evidence suggests that prehistoric peoples did not inhabit this zone (Haller 2004). Naturally, until stratigraphic excavations have occurred, this will not be known for certain, and missed deeply buried sites are a concern in the Río Parita project (Haller 2004). This could have implications particularly for shell. If the Anadara grandis is being found in the estuary, sites near the alluvium would be of particular interest. These sites might be placed on ideal soils for agriculture, and they would be closest to a good source of shellfish as well. This could tell us a lot about the actual relationship between the cultivated plants and the shellfish consumption, if these sites did actually exist.
5.2 STATISTICAL METHODS

All calculations were made through the analysis of data collected by Dr. Mikael Haller and his team during the 2002 field season. It was gathered as specified in the previous chapter. During his collections, shell remains of varying species were noted at 249 of the 348 collection units, with only two of which were in the upper survey zone. Thirty three lots showed evidence of craft production using *Anadara grandis*. The rest of the lots with *Anadara grandis* did not show signs of craft production. Due to the lack of time and relevance in the field, the shells were not dated, so there is no temporal variable in this analysis.

All of the data from lots with shells were organized using spreadsheets in Microsoft Excel. Figure 4 is a visual depiction of some of the specimens found in the survey. Table 1 demonstrates where each of the species is normally found. From there, basic information was calculated using SPSS. This included frequencies of species, demonstrated in Appendix A. The frequencies of species showed that *Ostrea cochapila* was by far the most numerous species, although on examination of the specimens, it is clear that most of these are fragments and are represented by a few concentrations of this particular shell. Following *Ostrea cochapila* is *Anadara grandis*, with 329 specimens (Appendix A). Due mostly to the limitations posed by time and by measurements taken in the field, only *Anadara grandis* was chosen to be examined for this study. Also, this species is known to be used for more than merely subsistence, but also for craft production (Carvajal 1998, Cooke 1999, Cooke and Sanchez 1997, Mayo 2004). Another factor that made it of interest for study is that it was the most widely distributed, as it was found at 171 sites across the entire Lower Survey Zone (Haller 2004:155, Table 1).
A depiction of some of the shell species found in the survey. Top row: *Anadara grandis*. Middle row left to right: *Pitar (Lamelliconcha) paytensis*; *Ostrea cochapila*; *Strombus galeatus*; *Chione*). Bottom row left to right: *Anadara (Anadara) similis*; *Spondylus princeps*; *Natica (Natica) unifasciata*; *Cerithidea valida*. Identification by Diana Carvajal, University of Calgary. Photo taken by Haller.

Table 1. Shell species found in the Lower Survey Zone, from Haller (2004:123)

<table>
<thead>
<tr>
<th>Mollusc Type</th>
<th>Native Habitat</th>
<th>Number of Lots</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anadara grandis</em></td>
<td>Estuary-mangrove</td>
<td>171</td>
<td>Entire Lower Survey Zone</td>
</tr>
<tr>
<td><em>Pitar (Lamelliconcha) paytensis</em></td>
<td>Mud Flats</td>
<td>32</td>
<td>Entire Lower Survey Zone</td>
</tr>
<tr>
<td><em>Ostrea cochapila</em></td>
<td>Ocean</td>
<td>64</td>
<td>Entire Lower Survey Zone</td>
</tr>
<tr>
<td><em>Strombus galeatus</em></td>
<td>Ocean/Mud Flats</td>
<td>13</td>
<td>Entire Lower Survey Zone</td>
</tr>
<tr>
<td><em>Prothotaca (Leukoma) asperrima</em></td>
<td>Mud Flats</td>
<td>22</td>
<td>Entire Lower Survey Zone</td>
</tr>
<tr>
<td><em>Anadara (Anadara) similis</em></td>
<td>Mud Flats</td>
<td>38</td>
<td>Entire Lower Survey Zone</td>
</tr>
<tr>
<td><em>Spondylus princeps</em></td>
<td>Ocean</td>
<td>1</td>
<td>Shell Pendant</td>
</tr>
<tr>
<td><em>Cerithidea valida</em></td>
<td>Ocean/Mud Flats</td>
<td>5</td>
<td>&lt; 4 km from coast</td>
</tr>
<tr>
<td><em>Polymesoda sp.</em></td>
<td>Floodplain</td>
<td>12</td>
<td>Entire Lower Survey Zone</td>
</tr>
<tr>
<td><em>Olivella (Lamprodona) volutella</em></td>
<td>Mud Flats</td>
<td>1</td>
<td>Salt Flats</td>
</tr>
<tr>
<td><em>Malea ringens</em></td>
<td>Ocean</td>
<td>3</td>
<td>Salt Flats</td>
</tr>
<tr>
<td><em>Chione (Ilichione) subrugosa</em></td>
<td>Mud Flats</td>
<td>2</td>
<td>Salt Flats</td>
</tr>
</tbody>
</table>

In the field, due to time constraints as well as relevance to the study being done at that point, measurements were not recorded for all species, but only for *Anadara grandis*. Haller and his team determined size in the field by measuring the valve length (V-length) as outlined by Claassen (1998:109). As *Anadara grandis* is a bivalve, measurements were conducted by measuring the distance between the anterior wall of the shell and the posterial
wall (Figure 5). The valve height (V-height) was also measured as defined by Claassen, measuring from the dorsal to the ventral (Figure 6).

Figure 5. Valve height measurement

Figure 6. Valve length measurement
The results for the frequencies of the sizes of shell showed that most of the shells were classified as medium, as seen in the stem-and-leaf diagrams in Appendix B. Generally, one would expect to find more shells measuring in the middle range than the extreme sizes. Of the measured shells, 22.5 percent of the total shells were small, 43.1 percent medium and 34.4 percent large. This is to be expected in a relatively normally distributed batch. This could also be expressed by the continuous, measurement value assigned to the size, as opposed to simply the small, medium or large ranking measurement. As such, the V-lengths ranged from 3.80 cm to 13.60 cm with a mean of 8.84 (sd = 2.38). V-height ranged from 3.20 cm to 10.60 cm, with a mean of 7.21 cm (sd = 1.88), as seen in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Statistics on the Sizes of Shells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>% of total</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Sd</td>
</tr>
<tr>
<td>Md</td>
</tr>
</tbody>
</table>

Only 5.2 percent of the shells were still intact, about 3.1 percent were broken, and the vast majority, about 91.3 percent, were fragments (Table 3). This might provide some insight about the uses of the shell, as fragmented shell is often noted to be used for such things as floor drainage (Haller, personal communication). Intact shells could be used for this as well; at He-4, Haller (2004) found a modern path of shells, good for drainage and traction in the mud (Figure 7).
Table 3. Frequencies and percentages of broken, intact, or fragmented shells.

<table>
<thead>
<tr>
<th>State</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact</td>
<td>98</td>
<td>5.2</td>
</tr>
<tr>
<td>Broken</td>
<td>59</td>
<td>3.1</td>
</tr>
<tr>
<td>Fragment</td>
<td>1720</td>
<td>91.3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>99.6</td>
</tr>
</tbody>
</table>

Figure 7. A modern shell path at He-4

This demonstrates how shell could be used for drainage and traction. Photo taken by Dr. Mikael Haller.

Measurements for V-length were used to classify shell sizes. To determine the validity of using the V-length instead of the V-height, a regression analysis was run between the two. To justify using one measurement as a representative of size instead of the other, it would first have to be determined whether or not a correlation existed between them. The regression showed that the correlation between V-length and V-height was strong with a high significance ($r = .952$, $p = .000$). Both the statistical analysis and the graphical representation (Figure 8) show that almost a perfect linear correlation exists between the V-length and V-height, where as the length increases, so does the height. Because of this, we can be confident in using either measurement to represent the size. V-length was chosen.
because the batch had a normal distribution (Appendix B) and also because more of the specimens were measured for the V-length than the V-height.

![Graph showing regression analysis of V-length and V-height](image)

**Figure 8. Regression analysis of V-length and V-height**

This figure shows the strong positive correlation between the two measurements, justifying why either measurement could be used to represent the size.

The first question in analysing the recovered shell was whether or not the variable of distance influenced the variable of size. Would the size of the shell decrease the further the lots was from the source? To calculate distance, the boundaries of the lots were plotted on a survey map in AutoCAD, along with the boundaries of the mangrove, where *Anadara grandis* is found, adjusted to take into account boundary changes over the last 2,000 years. Once all of these were plotted, distance was measured from the centre of the lot to the closest part of the mangrove. Once distance was determined, a regression analysis was run between V-length and distance, yielding a very weak correlation with very high significance ($r = -0.184, p = .000$). Only 3.4 percent of the variation in distance can be explained by V-
length. Through this and the corresponding scatter plot (Figure 9), we can be fairly certain that all sizes of shell were found throughout the Lower Survey Zone, regardless of distance from the origin. This random pattern suggests that the size of the shell did not play a role in the selection process. It should be noted, however, that this analysis also showed that no *Anadara grandis* was recovered in the upper survey zone, suggesting that perhaps the size of the shell did play some sort of a role, as the upper survey zone is further than the 11.26 km distance suggested by Claassen (1998:43) as the limit for traveling to gather shellfish. These results showed that no sites beyond 10.4 km had *Anadara grandis*, which is consistent with Claassen’s work (1998).

**Figure 9. V-length and Distance.**

This shows a very weak correlation with very high significance ($r = .184, p = .000$)
This answer raised new questions about why size did not seem to have influenced the selection of shells. For this, the optimal foraging theory seemed to come into play (Smith and Winterhalder 1985; Jochim 1988). It is possible that it was more efficient to collect all sizes of shell, and transport shell back to inland sites as opposed to spending extra energy to seek out specific shells.

As a next step, shell density was examined. The shell density index was determined by dividing the amount of shell by the total amount of artifacts found in the lot yielding the proportion of artifacts that were made of shell.

As it was established that size was uniform throughout the Lower Survey Zone, we next examined soil arability, or productivity, which was split into ranks of high arability as a value of 1, moderate arability as a value of 2, low arability as a value of 3 and non-arable as a value of 4 (Haller 2004:164-178). For these purposes, soil arability refers to its agricultural potential. Therefore, if a lot was designated as having high soil productivity, it had greater agricultural potential. The hypothesis being tested was that the less arable the soil, the more individuals would have relied on other forms of available subsistence or conversely; the more arable, the soil, the more successful and prominent cultivation would be, and the less reliance on other foods. To test this, a rank order test, the Spearman’s Correlation, was run on SPSS.

First, this was run on the number of shells found (NISP) against the soil productivity. This data yielded a weak correlation with very low significance ($r = .014, p = .855$), meaning that no definitive relationship exists between soil arability and the amount of shells. Following this, the shell density index was. This, too, showed a weak correlation, though this time negative, between soil productivity and the amount of shell, with low significance ($r = -.108, p = .600$). This means that, from this data, it is unclear as to just how important soil productivity was in predicting the amount of shell at a site. This implies that we cannot be sure if shellfish were being consumed as a ‘starvation food’, substituting for the lack of agricultural ability. It would seem that high occurrences of shellfish were most common at
moderately arable sites, though this may simply reflect the fact that the majority of sites were located in this type of soil. Sites with high productivity were least likely to have shell remains in high proportions. This being said, it still cannot be said for certain whether or not these are anything more than simply trends, based on the low significance. As such, it is pertinent to examine the possibility that shell was wanted, or at least used, for something other than simply a source of food.

The next comparison was between shell density and population density. It was thought that if any significant differences were seen between various productivity levels, this could be a result of the levels of populations living in those areas. For example, it is known that He-4 is located in soil of low productivity, and as such, we might expect to see more shell by default. Testing the population density against the shell density could tell whether or not a greater population simply meant an increased amount of shell. To test this, the population index created by Haller was used: the DAI – Density Area Index (Haller 2004:35-41). A comparison of shell density index and DAI also yielded indecisive results. The result was a weak negative correlation with moderately high significance ($r = -.170$, $p = .011$). This means that we can be moderately sure that not a great deal of the variation in shell density was a result of population density, and that this slight relationship was actually negative: the greater the population density, the lower the shell density. This is represented in Figure 10, as well, where we see that the lower the population density, the more likely for there to be shell, and/or a higher shell density index. This meant that the third-order sites, or the hamlets, were more likely to have larger amounts of shell. So if this shell was not an indication of subsistence, then for what else might it have been used? This is the motivation behind the next set of analyses, examining craft production.
Figure 10. Population density and shell density index

This graph shows a very slight trend that the lower the population index, the greater the shell density.

Thirty-three collection units had evidence of *Anadara grandis* shell-based craft production. Therefore, the next step was to examine the use of shells for production as opposed to merely subsistence. This was done first by running a regression through SPSS for shell production in relation to the shell density index. The thought behind this test was that this could show whether or not increased shell density was present at lots with shell production, as this might suggest that shell was brought back from the mangrove as a raw material for the primary purpose of production.

The variable of craft production was introduced, first through comparison with the shell density index. Again, a weak correlation between shell density and craft production occurred, with a high significance ($r = .019, p = .002$). We can be fairly certain that not much of the variation in shell density was a result of craft production. In Figure 11, the trend
is that for sites displaying evidence of craft production, the greater the shell density index, the greater the evidence of craft production. This being said, it is also obvious that some of the sites with the greater shell densities had no evidence of craft production.

The presence of craft production did not necessarily indicate a higher concentration of shells.

The next test was conducted to gauge the relationship between site order and the shell density index. Similarly to population density, the site order was a method of indicating the amount of people at a site, and possibly sociopolitical activities associated with the sites. The results were similar for shell density and site order, through a rank analysis, as it is remarkably similar to the population and shell analysis, though using Spearman’s rank instead of Pearson’s regression. The result was a weak correlation, albeit not as weak as the previous, Pearson’s regression analysis, with relatively high significance ($r = .171$, $p =$
This means that some variation was seen; the higher the complexity of the site, the greater the amount of shell found. Consequently, it is possible that shell in lower ranked sites, or those considered to be more complex, were using the shell for economic, trade-based purposes rather than subsistence. In other words, were specific types of sites involved in different types of activities? This could possibly be an explanation as to why larger shells were also brought to farther sites.

To test this hypothesis, a Spearman’s Rank correlation was run in SPSS between craft production and site order. It should be noted too that in general, more shell was found at third-order sites than at the first-order or second, most likely due to the fact that a higher proportion of the sites were third-order. The analysis of craft production and site order did not yield significant relationships either, as the results showed a weak positive correlation with moderately low significance ($r = .051, p = .504$). This being said, second-order sites in this sample did not show signs of craft production. The vast majority of craft production took place at third order sites, with some taking place at first-order sites, as third-order sites are generally more numerous than second-order sites. The lack of significance may be partly attributable to the small sample size, but it also shows that most of the shell production did take place at one order of site, and might indicate that shell craft production was a cottage industry to supplement the “economic” wealth of farmers.

As a final note, for the results, a regression analysis was run using all the independent variables against a dependant variable to eliminate the independent variables that were insignificant. These results are presented in Appendix C.

For the dependant variable shell density, it seemed that the independent variables soil productivity and site order were excludable, but population density and craft production had an impact (Appendix C). For the dependant variable of craft production, the independent variables, soil productivity and site order, again, were excluded, and population and shell density were seen as significant (Appendix C).
5.3 SUMMARY

Using statistical analyses, the variables of (1) shell size; (2) distance carried from the mangrove where the species originates; (3) agricultural potential; (4) site order; (5) population density and (6) evidence of craft production were examined. Results of these analyses suggest that shell procurement strategies were complex and influenced by more than one socioeconomic factor.

Shell size did not influence the distance that it was recovered from the mangrove, indicating that the people were not selecting based on the size of the shell. The amount of shell that was found at individual sites could not be predicted by the distance from the mangrove to the site. In other words, simply because a site was closer to the source of acquisition did not mean that more shell was recovered. No particular site order was found to have more or less shell than any other site order, indicating that it was not a restricted or specialized resource. Similarly, population was not a crucial factor in determining how much shell would be found at a site. This might suggest that perhaps the people were not using the shell purely for subsistence; in that situation, one might expect to see more shell where more people would need to consume it.

There was a very weak correlation between craft production and shell density, indicating that larger amounts of shell did not necessarily mean that there would be craft production. Also, third and first-order sites both showed evidence of craft production, though in this sample, second-order site did not. This suggests that craft production might have been a specialized activity, but to what degree is not yet known.

Some trends did emerge, even if the significance was too low to determine if this trend had any meaning. For example, a trend was evident that for sites containing evidence of craft production, a greater shell density index, the greater the evidence of craft production. This being said, it is also obvious that some of the sites with the greater shell
density indexes had no evidence of craft production. In this case, it would seem that a larger sample size might decrease this trend.

A slight tendency emerged that sites with highly productive soil were more likely to have smaller amounts of shell, and sites with moderately productive soil were the most likely to have larger amounts of shell remains. This may simply be because more sites were found in moderately-arable soil, and fewer sites were found in the rare highly-arable soils.
6.0 DISCUSSION

Small, medium and large *Anadara grandis* shells in equal proportions were found throughout the valley. The hypothesis behind this was to examine if the further distance the site was from the source of the shell resulted in a smaller shell size. If the point of collecting the shell by the pre-historic people was for subsistence purposes, it would be expected that 1) small amounts of shell would be found at the sites, as the meat could be transported without the added weight of the shell, or 2) larger shells would be closer to the source and smaller shells would be further, as it would be less efficient to transport the larger shell over great distances. Also, these people did not have domestic pack animals, so shells would have to be transported manually. This being said, the basin and the mangroves are interlaced with river systems, which would have been navigable by small boats during the rainy season. This is how the shell harvesters transport the shell now (MacKenzie 2001), so it is not inconceivable that this happened in the past, as well. Cooke and Ranere (1992) discuss such a situation.

Developed in ecology as a way of examining the subsistence collection of organisms, the Optimal Foraging theory dictates that natural selection over time favours efficiency in food collection; foods are selected to maximize net efficiency in acquiring them (Smith and Winterhalder 1985:645; Jochim 1988:130). Of course, this theory must be altered slightly when being taken from ecology to anthropology, as societal factors must be taken into consideration as well. Some factors that may influence the choice of which foods to consume include storability, risk in acquisition, and social factors, such as gender roles (Jochim 1988:130). This theory may have some merit in this case, if one continues to view
shell as having been collected for subsistence. Perhaps it was more efficient and practical simply to take all of the shellfish in a shell bed, as opposed to seeking out those of a particular size. For example, if one was looking for those we classified as “small,” which might be easier to carry further distances and would allow for more to be collected, one might have to walk a fair distance and search several beds simply to find the desired size. Optimal foraging theories might say that it was easier and more cost efficient to take those shells that were found specifically in a designated area. In this survey, 171 of the total lots showed evidence that *Anadara grandis* was collected by the inhabitants. It is also possible that the cultural factors presented by Jochim (1988) would therefore apply. For example, it is unclear as of yet if different groups of people would have had control over certain shell beds, or if shell collection was organized on the basis of, “first come, first served.”

Similarly to optimal foraging theory, the possibility of shellfish collected as pooled resources remains in question. As of yet, evidence does not exist that would answer the question of whether or not people gathered shellfish simply for their own purposes or for trading or community use. In proposed studies by Haller (2006), one of the concepts that will be investigated involves feasting on deer, for example. For this to be possible there would need to be a sort of pooling or collection of resources, followed by some form of redistribution. It is entirely possible that there existed natural or social restrictions on the use of the mangrove, or that limited control was held over the area, and those harvesting required a certain right to do so. The data presented in this thesis do suggest that this is a possibility. This may help to explain the ubiquitous distribution of the *Anadara grandis* shells, as well as the abundance of other shell throughout the Lower Survey Zone. Some of the other species, for instance, that were in abundance were collected from the open ocean, such as *Ostrea cochapila*. As mentioned in Chapter 2, it would require an increased level of skill to acquire maritime species from the open ocean (Cooke 1992; Cooke and Tapia 1994). Although this species has not yet been studied in great depth from the Río Parita Survey, it was found in large quantities, in fragments. This may coincide with research mentioned in Chapter 3, wherein Zapotal was considered a fishing station, due to large quantities of
crushed shell (Ranere and Hansell 1978). This was not something seen with *Anadara grandis*, though. Perhaps, then, the distribution by distance, agricultural potential, and site order suggest that *Anadara grandis* were being controlled. The data on shellfish could be combined with information on other forms of subsistence, such as evidence of cultivation and animal bones in future studies to gain an understanding of the nature of subsistence in the Río Parita area.

It can also be noted that Haller (2004:114) discusses the idea proposed by Helms (1994:57) that one of the focuses of warfare was to acquire additional lands for cultivation and to gain fishing grounds, suggesting, of course, that these resources would be of restricted access. Haller’s study suggests that, in the Río Parita Survey, this was not the case. As seen in the analysis of *Anadara grandis* distribution, as well as size and distance from the original source, it is clear that the pattern of distribution is random, and the shellfish *Anadara grandis* alone is ubiquitous throughout the lower valley. This seems to suggest that an element of equal access existed, at least to the mangrove resources. Of course, as mentioned above, this may not be equal access at all, but it might imply a redistribution system was used. Haller (2004) also suggests that when a resource is abundant, as is indeed the case of marine resources in the Río Parita, they would be quite challenging to control.

Although control over aquatic fauna is an uncommon situation, it not impossible, nor is it unseen. In areas such as the Pacific North-West Coast, in British Columbia, for example, aquatic resources are in abundance, cultivation was not practiced to a large extent, and yet complex societies were able to develop. Shellfish, archaeologists believe, were a controlled resource, based on archaeological and ethnographical data (Matson and Coupland 1994; Moss 1993). For some bands, shellfish was seen as a food of poverty, or laziness. This is partly linked to outbreaks of PSP from eating contaminated shells amongst the Tlingit, as well as to the ethnographical processes themselves (Moss 1993). It has been argued that shellfish collection around the world is commonly the “women’s job” (Claassen 1998:175). Brown (1970, cited in Jochim 1988) suggests that this is because it is in the best
reproductive interest of a hunter/gatherer population to have women performing the tasks that are less dangerous.

Archaeological and ethnographical evidence exists of shellfish playing a significant role in subsistence, and in turn, social organization, amongst the Haida, for example (Moss 1993). Archaeological studies in the area have yielded results that suggest that shellfish was a resource that was controlled by certain households (Matson and Coupland 1994). This could have been possible through the "clumping" nature of shellfish beds, making them more controllable by a particular group. It seems that these households had the rights to cultivate certain beaches (Moss 1993). This argument is that shellfish were the scarce resource, or at least shellfish beds, that served as the catalyst for complexity. It was a limited resource simply by its nature, through clustering. Along the Panama Bay, however, *Anadara grandis* does not cluster, but is found throughout the mangroves, which extend the length of the shore. This also supports what Menzies (2006) and Locascio (2007) proposed from the evidence of He-4, that shell manufacturing was not actually an activity associated with elites, or control and power, though shellfish were most certainly consumed at the site. So perhaps it was not shellfish in Panama that was the controllable resource, but something else that was equally precious and rare, but was not present amongst the people of the North West coast: cultivation, or cultivable lands.

In the Río Parita Valley, cultivation or horticulture has been practiced for nearly 5,000 years, based on the archaeological records (Piperno et. al. 1998). Evidence of higher amounts of shell was not found in conjunction with less potential for agriculture, as we had predicted if shell was used as subsistence and starvation food. A slight trend showed that more shell remains, compared to the amount of other materials, was found at sites with moderate productivity. The Parita Bay region offered a broad spectrum of resources, other than simply aquatic resources.

Piperno et. al. (1985:872; Piperno and Pearsall 1998) discuss the reasons for why agriculture would be suddenly adopted in a region such as Panama. These reasons include 1) population pressure and nucleation, 2) sedentism, 3) the colonization of montane or pluvial
areas, and 4) widespread environmental degradation. Piperno et al. (1985) say that it may have been better to cultivate on slopes; vegetation is easier to remove there than it is in forested alluvium. Part of the reason for this revolves around technology. It takes a great deal of effort to clear thick mangrove trees, or any heavily forested area. Technology could be more basic for effectively clearing sloped terrain than it would need to be for forested alluvia. Then, the people may have moved permanent settlements and cultivation to the alluvium sites when soils became thin and depredated in the slopes, and/or technology evolved to allow for easier cultivation of more treed areas (Ranere 1992:34). Cooke and Ranere (1984:12) note that stone axes found in the central and western Panama were used for wood working activities, such as hollowing out canoes, and clearing forests. Perhaps this type of technology contributed to the movement of cultivation to the more heavily forested areas (Cooke et al. 2003:114-115; Griggs 2000; Ranere 1980:122; Sheets et al. 1980:405).

Haller (2004) suggests that this might have occurred during the Tonosi period (ca. A.D. 250-550) when population gravitates to the alluvium of the Río Parita Valley. Coincidentally, it is during that period where we see a drastic reduction in La Mula-Sarigua’s population—a first-order site located adjacent to the mangrove/estuary region. It seems as though the people are not as tied to the resources, and are moving a greater distance from them. This could help to explain why shell was not recovered in the upper survey zone, where perhaps the slopes were higher and less vegetated, and therefore agriculture was more widely practiced there in this time period. In the lower zones, where agriculture may have been practiced, but conceivably to a lesser degree, shell for subsistence may have been more important as a source of protein than in the higher zones. It is also possible that the upper zone was a buffer zone between two chiefdoms, which would also account for the smaller settlements and the lack of shellfish there (Haller 2004).

Cooke and Ranere (1992:126) mention that, in Panama, population increase seems to have preceded cultivation. It is also known that, in the Río Parita area, carrying capacity was never reached, so that was most likely not an influence on the initiation of agriculture (Haller 2004:115). Cooke and Ranere (1992:125-126) mention that population increase and
sedentism was associated more with the maximization of aquatic resources around 4000 B.C. than with the introduction of agriculture, as seems similar to the situation mentioned above in the Pacific North-West. When shellfish and fish are in abundance, cultivation is not necessarily crucial in the facilitation of population increase (Linares et. al. 1975:144). Of course, the difference is that, by approximately 2500 B.C., cultivation was becoming more widespread in Panama, including the Parita Bay areas. Cooke and Ranere (1992:126) discuss what they refer to as “a causal relationship between maize’s use as a staple crop and accelerated population growth [that] is inferred by the coincidence” of maize appearing in both archaeological and paleovegetational records after 2500 B.C. with an equally noticeable change in settlement sizes and distribution. In other words, archaeologists believe that cultivation allowed for the increase of population, and the wider distribution of sedentary sites, but this may be incidental.

Unfortunately, the relationships between agriculture and shell usage were undetermined, as the statistical significance was quite low. Similarly, the trend for shell size and soil arability showed that, if any pattern were seen, the higher order sites contained larger shells than lower order sites. Based on the weak correlation and the very low significance, though, this is not a relationship that can be expanded on much in this report. Therefore, it is safe to explore the idea that shell was used for something other than mere subsistence, in the place of agriculture.

If more shellfish were being used for subsistence in the lower zone, then perhaps the people would also be more likely to develop craft production techniques with these shells. Different species of shell were found throughout the survey zone, made into objects such as beads, as seen from the *Spondylus* frog pendant, as well as pendant blanks of *Anadara grandis*. Mayo (2004) noted that similar types of shell beads were found in burials from Cerro Juan Díaz, for example. Also, at Cerro Mangote, McGimsey (1958) thought that the *Anadara* spp. shells left in tact, and unmodified, may have been used as receptacles. A similar process may have occurred in the Río Parita area.
The presence of craft production did not seem to relate to shell density. In other words, greater amounts of shell did not necessarily mean there was more evidence of craft production. Only 33 of the 171 lots with *Anadara grandis* showed any evidence of craft production. Haller (2004) suggests that perhaps the working of shell was a “cottage industry”, or something that was done when other activities were not possible, such as agriculture in the dry seasons. We also know from these results with relatively high certainty that craft production was not an activity limited to one particular site order. This might support the idea of a cottage industry, as it was not an activity specialized by a specific site order, but the degree of specialization is not yet known. The large workshop at Cerro Juan Diaz (Mayo 2004) suggests that shell craft production might have been specialized, but more evidence from a range of site types is required before a conclusive statement can be made.
7.0 CONCLUSION

The evidence from the shellfish data collected in the Río Parita Survey suggests that shellfish were an important component of the lives of the prehistoric inhabitants of the area. None of the *Anadara grandis* shells were carried beyond 10.70 km from the Parita Bay, which is still a great distance. Water crafts may have been used, though it is still a difficult journey, and rivers are not as navigable during the dry season. Also, the optimal foraging theory, which outlines the fact that organisms, or human beings as the case may be, will adopt subsistence strategies that maximize their net gain with minimum energy expenditure (Jochim 1988) is important, because the shells were not being selected by size, according to the evidence from this study. All of these factors combined may tell us that subsistence was the primary goal of shellfish collection.

Even though subsistence appears to be a primary reason for collecting, craft production using shell was also important within the region. Shell working is an activity that is common to many ceramic sites in the Parita Bay region, as mentioned by Carvajal (1998), Cooke (1999), Cooke and Tapia (1994), Cooke and Ranere (1989, 1992, 1999), Cooke and Sanchez (1997), Haller (2004), Locascio (2007), Mayo (2004), McGimsey (1952), Menzies (2006), and Ranere and Hansell (1978). The evidence of craft production in the Río Parita Survey is not exclusive to any particular type of site, such as those with a certain kind of soil productivity or rank. Perhaps, then, this craft production was done as a cottage industry, and not as a specialized activity. Shells might also have been a pooled resource, as most sites have shell in some capacity, even if it was a species other than *Anadara grandis*. This study seems to be consistent with similar studies in the area, in that shell was, initially, gathered as
a protein staple in the diet, and evolved to craft and economic usages. To confirm this in the future, though, the remainder of the shellfish species should be analyzed, along with the addition of the variable of time to gauge the changes in the use of this resource.

It does not appear that shellfish were the catalyst in the development of complex chiefly societies in the Río Parita, as they were in the Pacific Northwest Coast (Erlandson 1988; Matson and Coupland 1994). Shellfish were clearly important, but whether or not any group or individual could control the abundant mangrove resources in the Parita Bay is questionable. If resource control was influential, perhaps, it the control was more centered on productive cultivable land, as this was more of a clustered, limited resource, although Haller (2004) doubts this was the case.

Shellfish are still gathered today in much the same ways that they were in the past, due to their nutritional value and the possibilities for the shells to be made into trinkets. There is still much work that can be done in discovering the development of shellfish use over time, and the specific role that they held in prehistoric society in Panama and beyond. Further studies are currently being proposed in the area, by Haller (2006), Menzies (2006) and Locascio (2007). With every survey, and with every excavation, more data is being uncovered that can add to our growing understanding of the importance of aquatic resources in the survival and societal development of people in aquatic settings around the world.

Studying shellfish can tell researchers much about the societies being examined. The rules and patterns for collecting shells can demonstrate the types of socioeconomic structures present in the society; archaeologists can also learn about gender roles and equality between men and women, and between other groups in society. In Australia, for example, the men of the Meriam of the Great Barrier Reef and the Mardu of Australia's Great Sandy Desert gain prestige through attempting to hunt; even if they fail, they have a better chance of being recognized than they would be if they had simply gathered shellfish (Edgar 2002). Collecting, in general, including collecting shellfish, is commonly considered to be an activity done by women in hunter/gatherer societies (Claassen 1999). Also,
archaeological evidence and analysis of shell remains often help determine the subsistence patterns of the people, as well as some of the economic activities, such as craft production.

Not only are shellfish a protein staple in the diet, but it requires little energy and skill to collect shellfish by hand, or through simple technologies, such as sticks, rakes, and tongs. The artifacts used in these technologies often do not preserve well, but researchers can look at modern techniques among indigenous peoples as analogy to what might have been done in the past. This study is just one of many that highlight the importance placed on shellfish procurement by human populations and their hominid ancestors.
8.0 RECOMMENDATIONS

This was a small-scale study that barely even began to delve into the shell data from the Río Parita Survey. Initially, the goal was to analyze all shell in the survey, but due to time constraints, this has not yet happened. As a result, for any real conclusions to be derived as to the significance of shellfish in the lives of the people in this time, the remaining species of shell found in the surveys need to be examined. For example, evidence appears to suggest that *Anadara grandis* was not used for drainage purposes in housing, as evidence of this would be seen through large amounts of fragmented shells in relation to the number of other artifacts found in a collection lot. At He-4, evidence suggests that *Anadara grandis* could have been used as a sort of pathway, almost like stepping stones. On initial investigation of other species of shell in the Río Parita Survey though, it is possible that other types of shell, namely *Ostrea cochapila*, may have been used *en masse*, as large amounts of it were found concentrated at sites. Similarly, a *Spondylus princeps* shell was found worked into the shape of a frog pendant, suggesting that other species of shellfish were used for economic purposes as well. The shaping of shell into beads was seen in other studies mentioned throughout this thesis. The frog pendant was something found in other regions, meaning that there might have been economic exchange or contact between groups. Further investigation may yield other uses for shell of different species, and may also give greater insight into the sheer amount of shell found throughout the survey zone.

This study not only focused merely on one species of mollusc, but also on one species of marine-based protein. It must be recalled also that fish would make up a large portion of the diet, as suggested in other studies (Cooke and Tapia 1994, for example).
A further limitation in this study involves the lack of temporal variables. Shell found was not dated, and therefore a temporal analysis were absent from this study. Instead, the shell mentioned spans a period of about 1,700 years (from about 200 B.C.-A.D. 1522). Temporal variables could be introduced in several ways. For instance, the shell could be dated through radio carbon analysis (Cooke and Ranere 1992, Ranere and Hansell 1978). Of course, this process can be expensive, and damages the artifact in question, which may not be ideal in this situation. Alternatively, these shells could be dated through association with the other artifacts found at the site. This variable would allow this information to be analysed in a cultural evolutionary scale. As mentioned above, authors such as Cooke and Ranere (1992), Locascio (2007), Menzies (2006), Piperno et. al. (1985), and Ranere and Hansell (1978) have found that marine resource uses changed throughout Panama over time, and adding this new dimension to the study may show different results. For example, adding time may show a change in the use of Anadara grandis by site order, depending on the cultural stage, as Cooke and Ranere (1992) found that shell became a burial good that indicated status and age, and Menzies (2006) and Locascio (2007) propose that, in the Cubitá phase, shellfish manufacturing may not have been associated with elites, but may have been a common activity, and more specifically, an important form of subsistence.

Currently, studies are underway throughout the Río Parita Valley and neighbouring regions focusing on the use of shell at individual, large sites, such as those of Mayo (2004) at Cerro Juan Díaz and Sitio Sierra, and Menzies (2006) and Locascio (2007) at He-4. These studies prove useful in identifying what the larger centres were doing, and compliment broader studies of the smaller sites. Cooke and Sanchez (1997) also discuss the possibility that, in this same phase, goods were being manufactured as a form of control and for exchange. Although recent evidence may now question this idea (Menzies 2006; Locascio 2007), it shows how broader regional studies can be highly beneficial. In the future, further studies, in greater depth than the surface collection, might show that shell was more common at these large centres, but less common for craft production at smaller sites.
### APPENDIX A – Shell Frequencies by Species

<table>
<thead>
<tr>
<th>Frequency (NISP) (% of total)</th>
<th>Species (found in the Río Parita Survey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>329 (17.5%)</td>
<td><em>Anadara (Grandiarca) grandis</em></td>
</tr>
<tr>
<td>202 (10.7%)</td>
<td><em>Pitar (Lamelliconcha) paytensis</em></td>
</tr>
<tr>
<td>900 (47.8%)</td>
<td><em>Ostrea cochapila</em></td>
</tr>
<tr>
<td>14 (.7%)</td>
<td><em>Strombus gracilus</em></td>
</tr>
<tr>
<td>72 (3.8%)</td>
<td><em>Prothotaca (Leukoma) asperrima</em></td>
</tr>
<tr>
<td>118 (6.3%)</td>
<td><em>Spondylus princeps</em></td>
</tr>
<tr>
<td>1 (.1%)</td>
<td><em>Natica (Natica) unifasciata</em></td>
</tr>
<tr>
<td>63 (3.3%)</td>
<td><em>Cerithidea valida</em></td>
</tr>
<tr>
<td>10 (.5%)</td>
<td><em>Polymesoda sp</em></td>
</tr>
<tr>
<td>143 (7.6%)</td>
<td><em>Olivella (Lamprodona),volutella</em></td>
</tr>
<tr>
<td>2 (.1%)</td>
<td><em>Malea ringens</em></td>
</tr>
<tr>
<td>2 (.1%)</td>
<td><em>Chione (Ilichione subrugosa</em></td>
</tr>
<tr>
<td>6 (.3%)</td>
<td><em>longoron</em></td>
</tr>
<tr>
<td>1 (.1%)</td>
<td><em>Anadara (Anadara) similis</em></td>
</tr>
<tr>
<td>21 (1.1%)</td>
<td><em>Unknown</em></td>
</tr>
</tbody>
</table>
APPENDIX B – Stem and Leaf

The large batch is fairly normally distributed. The medium batch seems to be as well, though it is possibly bi-modal. The small batch, however, does not have a normal distribution. There are two outliers at the lower end as well as gaps in the plot.

**Stem and Leaf Plot – Small V-length**

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<td>5 .</td>
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<tr>
<td>3.00</td>
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<td>5 . 66</td>
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<td>5 . 9</td>
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<td>6 . 01</td>
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</tr>
<tr>
<td>1.00</td>
<td>6 . 6</td>
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<tr>
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<td>6 . 89</td>
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Stem width: 1.00

**Stem and Leaf Plot – Medium V-length**

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<tr>
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<td>3.00</td>
<td>8 . 689</td>
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<td>9 . 1111122234</td>
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<td>3.00</td>
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<td>10 . 00</td>
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</table>

Stem width: 1.00

**Stem and Leaf Plot – Large V-length**

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<tbody>
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<tr>
<td>1.00</td>
<td>10 . 9</td>
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<tr>
<td>8.00</td>
<td>11 . 11223344</td>
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<td>2.00</td>
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<td>2.00</td>
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Stem width: 1.00
### Regression – Shell density and Population Index, Craft Production, Soil Productivity, and Site Order

**Variables Entered/Removed(b)**

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<th>Variables Entered</th>
<th>Variables Removed</th>
<th>Method</th>
</tr>
</thead>
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<td>Site Order</td>
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<tr>
<td>3</td>
<td>.</td>
<td>Soil Productivity</td>
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</table>

a All requested variables entered.  
b Dependent Variable: ShelIndex

data Excluded Variables(c)

<table>
<thead>
<tr>
<th>Model</th>
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<th>Significance</th>
<th>Partial Correlation</th>
<th>Collinearity Statistics</th>
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<td>.119</td>
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<td>Order</td>
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<td>Soil Productivity</td>
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<td>.156</td>
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a Predictors in the Model: (Constant), PopInd, CraftInd1, SoilProd  
b Predictors in the Model: (Constant), PopInd, CraftInd1  
c Dependent Variable: ShellIndex
**Regression – Craft Production and shell density, soil productivity, and site order**

Variables Entered/Removed (b)

<table>
<thead>
<tr>
<th>Model</th>
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<th>Variables Removed</th>
<th>Method</th>
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<tbody>
<tr>
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<td>Shell Index</td>
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a All requested variables entered.

b Dependent Variable: CraftInd1

Excluded Variables (d)

<table>
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<tr>
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<td>4</td>
<td>Shell Index</td>
<td>.019(c)</td>
<td>.247</td>
<td>.805</td>
<td>.019</td>
</tr>
<tr>
<td></td>
<td>Site Order</td>
<td>.089(c)</td>
<td>1.166</td>
<td>.245</td>
<td>.089</td>
</tr>
<tr>
<td></td>
<td>Soil Productivity</td>
<td>-.095(c)</td>
<td>-1.251</td>
<td>.212</td>
<td>-.095</td>
</tr>
</tbody>
</table>

a Predictors in the Model: (Constant), Soil Productivity, Site Order

b Predictors in the Model: (Constant), Soil Productivity

c Predictor: (constant)

d Dependent Variable: Craft Production
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