LATE TAÍNO OCCUPATION OF JAMAICA: A ZOOARCHAEOLOGICAL ANALYSIS OF FAUNAL MATERIALS FROM THE BLUEFIELDS BAY SITE

by

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ABSTRACT

Late Taíno Occupation of Jamaica: A Zooarchaeological Analysis of Faunal Materials from the Bluefields Bay Site

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My thesis seeks to answer the broad questions: can foragers alter marine resources in island settings and can zooarchaeological data provide insights into these changes. To begin understanding these broad issues, I focus on a faunal sample from a site located in Belmont, Jamaica, near the Bluefields Bay marine sanctuary. The site dates to the late Taíno occupation of Jamaica, known as Meillacan Ostionoid (cal A.D. 900 to 1500). My central hypothesis suggests that human predation led to a decrease in large-bodied, high-ranked fish populations through time, a concept known as resource depression. Resource depression follows the logical outcomes of the prey choice model from behavioral ecology. To reveal signals of resource depression and declining foraging efficiency, I calculated two relative abundance indices, measured changes in fish body size, and calculated three diversity indices measuring different aspects of fish community composition. The results of my analyses suggest that resource depression is occurring based on decreasing body size of fishes, and changes in community composition consistent with expectations drawn from the prey choice model. Returning to the broader questions, I calculated the same diversity indices and determined new relative abundance indices for a trans-Caribbean dataset that revealed similar trends as those seen in the Bluefields Bay faunal sample.

(209 Pages)

PUBLIC ABSTRACT

Late Taíno Occupation of Jamaica: A Zooarchaeological Analysis of Faunal Materials from the Bluefields Bay Site

Diana M. Azevedo

My thesis seeks to answer the broad questions: can early foragers alter marine resources in island settings and can archaeological data provide insights into these changes. These questions highlight two important issues. The first issue reflects the common belief that small-scale societies did not affect their environments. The second issue centers on growing concern over the collapse of fisheries across the globe.

To answer these questions, I use fish bones recovered from an archaeological site located in Belmont, Jamaica near the Bluefields Bay marine sanctuary. The Bluefields Bay site dates to the late Taíno occupation of Jamaica. The name Taíno refers to the peoples who greeted Columbus. I conduct my analyses through the identification of the faunal bones to lowest taxonomic level, and apply the theoretical tool known as resource depression to detect declines in the relative abundance of large-bodied fishes, reductions in fish body size, and changes to fish community composition. I found significant changes in body size and diversity of fishes through time, pointing to shifts in the marine ecosystem due to human exploitation that occurred nearly a thousand years ago.

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CONTENTS

Page

ABSTRACT iii

PUBLIC ABSTRACT v

ACKNOWLEDGEMENTS vi

LIST OF TABLES ix

LIST OF FIGURES xii

CHAPTER

1. AN INTRODUCTION TO THE BLUEFIELDS BAY THESIS RESEARCH AND ORGANIZATION 1

    Research Design 3
    Thesis Organization 7

2. JAMAICAN AND CARIBBEAN GEOGRAPHY AND ARCHAEOLOGY 10

    The Geography and Geology of the West Indies and Jamaica 11
    Caribbean Culture History and the Taíno 18
    Jamaican Prehistory and the Gap in Knowledge 26

3. CARIBBEAN AND JAMAICAN FISHERIES AND FISHES 31

    Human Impacts on Caribbean and Jamaican Fisheries: Past and Present 31
    Caribbean Fishes and their Vulnerability to Overexploitation 44

4. METHODS OF ZOOARCHAEOLOGICAL ANALYSIS: SITE DESCRIPTION AND THE COLLECTION OF PRIMARY DATA 60

    Bluefields Bay Site Description and Field Work 60
    Faunal Analysis 65

5. THEORETICAL METHODS OF ANALYSIS: GENERATING SECONDARY DATA 79

Theoretical Background and Analytical Methods: Foraging Theory 80
Theoretical Background and Analytical Methods: Diversity Measures 90

6. SPECIMEN COUNTS, SPECIES ABUNDANCES, AND RESULTS OF THE BLUEFIELDS BAY FAUNAL SAMPLE 98

Primary Data Results 98
Secondary Data Results 106

7. DISCUSSION OF BLUEFIELDS BAY ANALYSES RESULTS AND A COMPARISON TO REGIONAL PATTERS 111

Bluefields Bay Analyses Results 112
Trans-Caribbean Studies 125

8. REVIEW OF THESIS RESEARCH 144

RERFERENCES CITED 147

APPENDICES 162

APPENDIX A 163
APPENDIX B 186

LIST OF TABLES

Table Page

1 Culture History Details Used by Caribbean Archaeologists 19

2 Attributes of Fishes that Increase Chances of Overexploitation and Reduce Populations, adapted from Roberts and Hawkins (1999) 45

3 Jamaican Fish and the Characteristics, Behaviors, and Physical Features That Lead to Increased Vulnerability to Overfishing 47

4 Raw Data from the Bluefields Bay Site: Artifact Counts for Units 5 and 8 62

5 Radiocarbon Analysis Results for the Bluefields Bay Site 65

6 USU’s Caribbean Fishes Comparative Collection Specimens 66

7 Rank Order of Caribbean Fishes Based on Body Size 88

8 Rank Order of Caribbean Fishes Based on Habitat 89

9 Assemblage Level Summary: Ichthyofaunal Element Counts 99

10 Results of the Taxonomic Identification Analysis for the Bluefields Bay Faunal Sample by Unit and Level 102

11 Assemblage Level Summary of Fishes Identified to Family, Genus, or Species: NISP, MNI, and Percentages 106

12 RAI Calculated by Level: Rank Order Determined by Size 107

13 RAI Calculated by Level: Rank Order Determined by Habitat 107

14 Average Vertebrae Diameters by Unit and Level, and a Combined Average (Combined $\bar{\times}$) 108

15 Average Pharyngeal Plate Lengths by Unit and Level, and Combined Average (Combined $\bar{\times}$) 108

16 Diversity Indices Calculated Using Fish NISP Values from the Bluefields Bay Faunal Sample 109

17 Carnivore/Herbivore Index Results 135

18 Relative Abundances by Site, Caribbean Dataset 141

19 Element Abbreviations 163

20 Element Counts for Unit 5, Level 1 164

21 Element Counts for Unit 5, Level 2 165

22 Element Counts for Unit 5, Level 3 166

23 Element Counts for Unit 5, Level 4 167

24 Element Counts for Unit 5, Level 5 168

25 Element Counts for Unit 5, Level 6 169

26 Element Counts for Unit 5, Level 7 170

27 Element Counts for Unit 5, Level 8 171

28 Element Counts for Unit 5, Level 9 172

29 Element Counts for Unit 5, Level 10 173

30 Element Counts for Unit 5, Level 11 174

31 Element Counts for Unit 8, Level 1 175

32 Element Counts for Unit 8, Level 2 176

33 Element Counts for Unit 8, Level 3 177

34 Element Counts for Unit 8, Level 4 178

35 Element Counts for Unit 8, Level 5 179

36 Element Counts for Unit 8, Level 6 180

37 Element Counts for Unit 8, Level 7 181

38 Element Counts for Unit 8, Level 8 182

39 Element Counts for Unit 8, Level 9 183

40 Element Counts for Unit 8, Level 10 184

41 Element Counts for Unit 8, Level 11 185

42 Taxonomic Families and their preferred Habitat (Patch) 186

43 Archaeological Sites in the Trans-Caribbean Dataset 187

44 Key for Date and Region Abbreviations 189

45 Descriptive Statistics for Diversity Measure Values 190

46 Shannon Index (*H’*) and Evenness Index (*e*) for Trans-Caribbean Dataset 191

47 Margalef Richness Index (*d’*) for Trans-Caribbean Dataset 193

48 Dominant Genus and Species Through Time 195

LIST OF FIGURES

Figure Page

1 Map of Caribbean Islands, with Regions and Other Subdivisions in All Caps .. 12

2 Map of Jamaica Including Parishes, Major Rivers, Mountains and Environments Noted in text, and the Approximate Location of Archaeological Sites 16

3 Approximate Location of the Bluefields Bay Archaeological Site 61

4 North Wall Profile Map of Units 3 and 8 63

5 North Wall Profile Map of Units 4 and 5 64

6 Vertebra Measurement Location.. 77

7 Pharyngeal Plate Measurement Location... 78

8 RAI Values Plotted through Time Using Size Ranks: (a) Unit 5, (b) Unit 8 ... 113

9 RAI Values Plotted over Time Using Size Ranks: Both Units......................... 113

10 RAI Values Plotted through Time Using Habitat Ranks: (a) Unit 5 Shallow over Benthic Ranked Fishes, (b) Unit 5 Shallow over Mid-Range Ranked Fishes, (c) Unit 5 Mid-Range over Benthic Ranked Fishes, (d) Unit 8 Shallow over Benthic Ranked Fishes, (e) Unit 8 Shallow over Mid-Range Ranked Fishes, and (f) Unit 8 Mid-Range over Benthic Ranked Fishes 114

11 Combined Units, RAI Values Plotted through Time Using Habitat Ranks: (a) Shallow over Benthic Ranked Fishes, (b) Shallow over Mid-Range Ranked Fishes, and (c) Mid-Range over Benthic Ranked Fishes................................. 116

12 Combined Units, RAI Values Plotted through Time Using Habitat Ranks: (a) Shallow over Benthic Ranked Fishes, (b) Shallow over Mid-Range Ranked Fishes, and (c) Mid-Range over Benthic Ranked Fishes................................. 117

13 Averages by Level for Vertebrae Metrics (mm) Plotted through Time: Both Units 118

14 Averages by Level for Scaridae Pharyngeal Plates Metrics (mm) through Time: (a) Unit5, (b) Unit 8 119

15 Averages by Level for Scaridae Pharyngeal Plate Metrics (mm) through Time: Both Units 120

16 Bluefields Bay Heterogeneity (*H’*) through Time 121

17 Bluefields Bay Evenness (*e*) through Time: (a) Inshore, (b) Reef 122

18 Bluefields Bay Richness (*d’*) through Time: (a) Inshore Family Values, (b) Inshore Genus Values, (c) Reef Family Values, and (d) Reef Genus Values .. 123

19 Richness values (*d’*) through Time: (a) Inshore Values, Both Units, (b) Reef Values, Both Units 124

20 Map of the Caribbean Marking All the Sites in the Trans-Caribbean Study (Refer to Table 43 for Site Numbers) 126

21 Trans-Caribbean Evenness through Time: (a) Inshore Values, (b) Reef Values, (c) Pelagic Values 127

22 Line Graph of Trans-Caribbean Evenness in Chronological Order.......... 129

23 Trans-Caribbean Family Richness through Time: (a) Inshore Values, (b) Reef Values, (c) Pelagic Values 131

24 Trans-Caribbean Heterogeneity through Time (1 = Archaic Age, 2 = Ceramic Age, 3 = Formative Age, 4 = proto-Historic Age).......... 132

25 Carnivore/Herbivore Index Results for Both Units 135

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CHAPTER 1

AN INTRODUCTION TO THE BLUEFIELDS BAY THESIS RESEARCH AND ORGANIZATION

My thesis seeks to answer the questions: can foragers alter marine resources in tropical and island settings, and can zooarchaeological data provide insight into these changes? These questions highlight two important issues. The first is the popular belief that small-scale societies practiced forms of conservation and did not affect their environments. Archaeologists are fully aware of the impacts people had on ancient environments (Grayson 2001), but that understanding does not always reach outside the discipline. If hunter-gatherer groups adversely affected fisheries and marine ecosystems, then our current fisheries management efforts need reevaluation. A reevaluation of fisheries management introduces the second issue highlighted by my thesis questions. This second issue is a growing concern over the collapse or near collapse of fisheries around the world (Dulvy et al. 2003; Hawkins and Roberts 2004; Jackson et al. 2001; Miloclavich and Klein 2004; Mullon et al. 2005). Mullon and colleagues (2005) document such collapses in an analysis based on numbers from the Food and Agriculture Organization of the United Nations (FAO) that revealed 366 fisheries had collapsed. In addition, research by Dulvy and colleagues (2003) confirmed 133 local, regional, and global extinctions of marine populations.

How are fisheries management strategies currently determined? According to Jackson and colleagues (2001), most ecological researchers use local field studies, many of which lasted only a few years and were conducted after the 1950s. Such studies fail to account for important environmental disturbances, such as the El Niño Southern Oscillation (ENSO), and long-term cycles and shifts in marine regimes (Jackson et al. 2001). These environmental disturbances account for natural fluctuations in marine productivity and population changes. Given the limited chronological window provided by recent and modern wildlife management studies, the question arises as to why ecologists and fisheries managers ignore or even criticize historical and archaeological data (see Baisre 2010 for an example of such criticisms). Jackson and colleagues (2001) suggest the reason lies in the sacrifice of precision and analytical elegance prized by ecologists. However, archaeological, paleoecological, and historical data reveal lags ranging from decades to centuries between the onset of overfishing and changes in ecological communities. Archaeological and historical data can clarify underlying causes and rates of ecological change that modern studies miss, leading to improved restoration and management strategies.

To answer the broad questions asked in my initial paragraph and to add archaeological data available to ecologists and fisheries managers, I focused my research on a faunal sample from the Bluefields Bay archaeological site located in western Jamaica. The Bluefields Bay shell midden lies near the small town of Belmont and dates to the late Taíno occupation of Jamaica, known as Meillacan Ostionoid (cal A.D. 900 to 1500). I use zooarchaeological methods to provide insights into the effects the Bluefields

Bay Taíno had on their local marine base. Within the context of my thesis research, a zooarchaeological study offers clear links to the pre-Columbian Bluefields Bay environment. Overall, the identification and analysis of vertebrate and invertebrate species used as food by aboriginal peoples sheds light on animal community structure, population dynamics, habitat use, food procurement techniques, and food preferences (Scudder 2006).

In this thesis, I pursued a zooarchaeological analysis using the ichthyofaunal remains specifically. The Bluefields Bay faunal sample contains 17,761 specimens, 8,961 (50.45%) of which I identified to Osteichthyes (bony fishes) representing the emphasis of my research. Ichthyofauna identified to lower taxonomic levels equate to 331 individuals based on the minimum number of individuals (MNI) present (number of identified specimens or NISP = 913). The Osteichthyes identified allowed me to explore changes in fish through time, including changes in size, community structure, and apportionment.

Research Design

My research aims to fill gaps in our understanding of if and how the Bluefields Bay Taíno altered their local marine resources, adding to a growing body of research studying the ways foragers across the globe impact marine ecosystems. My central hypothesis is that the Bluefields Bay Taíno targeted large bodied, high-ranked fishes. This behavior caused declines in the relative abundances and body size of these prey types, altering the ichthyofaunal community composition. My hypothesis proposes human predation decreased certain fish populations through time, a concept known as resource depression.

Resource depression suggests that predator behavior affects prey availability by reducing prey capture rates in the predator's immediate vicinity (Charnov et al. 1976). A researcher applies the logical outcomes of the prey choice model from foraging theory to study the effects of predator behavior on prey availability (see Charnov and Orians 1973; MacArthur and Pianka 1966; Schoener 1971; Stephens and Krebs 1986). The prey choice model holds that a predator's most efficient strategy is to take the highest ranked prey when a predator encounters it. Predators shift to lower-ranked prey only when higher-ranked prey becomes less common. The reduction in high-ranked prey could result from a predator's behaviors, thus resource depression becomes a tool useful for quantifying the effects humans, as predators, have on their environment. Zooarchaeologists document the effects of resource depression by measuring changes in foraging efficiency (the net return per unit of time), requiring researchers to determine changes in prey choice (numbers of exploited resources), and prey size (Broughton 2002; Grayson and Cannon 1999; Nagaoka 2002). Within this theoretical context, I seek evidence of resource depression in the fish remains from the Bluefields Bay faunal sample.

Primary Data. To understand how the Taíno may have altered their local marine ecosystem, I employ zooarchaeological methods of analysis. Zooarchaeologists study the animal remains excavated from archaeological sites to pursue anthropological questions as well as zoological and ecological issues. Anthropological interests include nutrition, resource use, economics, residential patterns, ritual, social identity, and other aspects of human life involving animals (Reitz and Wing 2008). Zoological and ecological interests includes extinctions, changes in zoogeographical distribution, morphological characteristics, population structure, domestication, paleoenvironmental conditions, and ecological relationships of fauna that may or may not predate humans in a region. Zooarchaeologists derive concepts, methods, and explanations from the social and natural sciences, as well as the humanities. In addition, zooarchaeologists explore the impacts on the landscape from the animal’s perspectives, but also focus on environmental evolution and zoogeographical relationships (Reitz and Wing 2008).

Analyzing archaeofaunal assemblages involves identifying and quantifying animal remains from archaeological sites (Daly 1969; Gilmore 1949; Olsen 1971; Reitz and Wing 2008). For this project, I used both the USU comparative collection and several online sources to make taxonomic identifications. I identified the faunal remains to the lowest possible taxonomic level given my experience and available comparative specimens. I then quantified both the number of identified specimens (NISP), representing the potential maximum of individuals present, and the minimum number of individuals (MNI) within the sample. By determining what species were present and how their numbers change across the occupational sequence of the site, I hoped to reveal patterns in prey use and ecological diversity through time. I tested my hypothesis using faunal evidence of changing foraging efficiency, as documented by shifts in prey choice and prey size (Broughton 2002; Grayson and Cannon 1999; Nagaoka 2002).

Secondary Data. I generated secondary data from the primary ichthyofaunal data of taxonomic identification and quantities. I used the secondary data to document resource depression, via changing prey choice and prey size. I also determined changes in fish community composition by calculating three diversity indices. Prey choice represents one measure used to observe resource depression and zooarchaeologists calculate relative abundance indices to do so (Bayham 1979; Broughton 1994, 1997, 2002; Butler 2001; Butler and Campbell 2004; Byers et al. 2005; Cannon 2000; Lyman 2003; Nagaoka 2002; Stiner et al. 1999). Bayham (1979) became the first archaeologist to use relative abundances in determining prey choice. Applying the concepts of the prey choice model, he regarded large animals as highest rank because they offer higher energy returns (i.e. higher foraging efficiency) than small animals (Bayham 1979). For my purposes, I calculated two relative abundance indices. One index used body size (as a proxy measure for foraging efficiency) and the other used habitat (as a measure of search and handling costs) to determine rank orders.

Prey size represents another measure used to document resource depression (Butler 2001; Wing 2001; Wing and Wing 2001). To determine if fish body size changed over time, I measured all complete vertebrae centra contained in my sample. Unbroken vertebrae provide a gross measure of shifts in mean size. I also measured parrotfish (Scaridae) lower pharyngeal plates, to monitor trends in this taxon’s body size. Both vertebra and pharyngeal plate measurements correlate well with body weight and provided a proxy for fish size (Wing and Wing 2001).

To understand how the Bluefields Bay Taíno changed the composition of their local fish community, I calculated three diversity indices. Each index measures a different aspect of diversity. Odum and Barrett (2005) describe two components of diversity. The first is richness, expressed as the number of species present, and the other is evenness, representing the relative abundance of different species present. Richness therefore, refers to the variety of taxa contributing to a community, while evenness attempts to describe the relative species abundance. In addition, Hardesty (1980) includes another concept he calls "total species diversity," which combines richness and evenness. This concept is also termed "heterogeneity" by Bobrowsky and Ball (1989) and Peet (1974). Bobrowsky and Ball (1989) suggest using the Shannon information index (H') (Shannon and Weaver 1949) to compute heterogeneity and the Margalef diversity index (d') (Margalef 1968) for computing species richness. I derived evenness (e) using a part of the Shannon index equation, as the first part of the equation calculates the relative abundance of species in different habitats. In addition, I used statistical models, such as Spearman's rho (r_s) and Mann-Whitney tests (U), to determine if temporal changes in prey choice, prey size, and species composition were significant (Field 2013). I computed all statistical values using IBM SPSS version 22.

Thesis Organization

Evaluating how the Jamaican Taíno may have conditioned the local marine ecosystem reflected in the Bluefields Bay faunal sample requires several steps. In Chapter 2, I begin by discussing the question, "can foragers alter marine ecosystems," including a brief review of zooarchaeological evidence supporting a definitive "yes" to that question. I then introduce the geography and geology of the Caribbean islands, providing a context for my thesis research. In addition, I discuss the natural history of

Jamaica. Following the environmental background section, I review Caribbean culture history, including the various archaeological ages and the prehistory of Jamaica. I end this section by reviewing the gap in knowledge including the lack of widely published Jamaican faunal analyses, a pre-Columbian fisheries baseline, and the way my thesis fills these gaps.

In Chapter 3, I shift my focus to Caribbean fisheries and the vulnerability of fish species to overharvesting. I begin by reviewing the documented impacts humans have on Caribbean and Jamaican fisheries, both past and present. Within this section, I offer a debate centered on the merits of archaeological and historical data in contributing to the restoration and management of fisheries. I next provide details on prehistoric, historic, and current information about the impacts humans have on marine environments. I then present nine fishes targeted by Jamaican artisanal fishers, and one unique fish species observed in archaeological sites. I discuss how their life history and behavioral ecology affect their vulnerability to overexploitation.

In Chapter 4, I detail the methods of my analysis and the generation of primary data. I first discuss the site, presenting profile maps, radiocarbon dates, and raw data counts. Next, I detail the methods I use in identifying the sample, particularly the characteristics I use to identify a specimens taxonomic family, genus or species. I end the chapter with the methods I use to quantify the sample.

In Chapter 5, I present my methods for creating secondary data. I begin with an introduction to foraging theory and the prey choice model, followed by a review of its use in previous research. After the review of several case studies, I provide details on the methods I used. Following that, I introduce the concept of ecological diversity, and discuss how archaeologists use it to answer questions about past human/environment interrelationships. Following this review, I provide the equations I used for computing evenness, richness, and heterogeneity. I end with predictions I made using the prey choice model and diversity measures.

In Chapter 6, I present my primary data results. I next provide the secondary data results, including the relative abundances, body size measurements, and diversity indices. I then discuss the implications of my findings in Chapter 7, providing statistical analyses and visual representations. I then take the Bluefields Bay data and compare it to a trans-Caribbean analysis using the same three diversity indices and calculating new relative abundance indices. Following that, I discuss scenarios other than resource depression that can account for the trends and the kinds of studies needed to exclude them. I perform one such study and examine changing fishing technology at Bluefields Bay. I conclude with a summary of my thesis research and directions for future studies in Chapter 8.

CHAPTER 2

JAMAICAN AND CARIBBEAN GEOGRAPHY, GEOLOGY, AND ARCHAEOLOGY

Zooarchaeologists around the world are answering “yes” to the question: can foragers alter marine ecosystems? Archaeologists have successfully documented the effects of human predation on local resources in a variety of coastal environments. These environments include California (Broughton 1994, 1997, 2002; Erlandson and Rick 2010), the Pacific Northwest (Butler and Campbell 2004), Polynesia (Butler 2001; Morrison and Hunt 2007; Nagaoka 2001, 2002), South America (Reitz 2001; Rosello et al. 2001; Wake et al. 2013), and the Caribbean (Atkinson 2006; Blick 2007; Carder et al. 2007; Carlson and Keegan 2004; deFrance et al. 1996; Fitzpatrick et al. 2008; Keegan et al. 2003; Newsom and Wing 2004; Reitz 2004; Scudder 2006; Steadman and Jones 2006; Wing 1989, 2001; Wing and Reitz 1982; Wing and Wing 2001). Each researcher approaches the question using a variety of methods. These methods include the explicit use of optimization models (Broughton 1994, 1997, 2002; Butler 2001; Butler and Campbell 2004; Nagaoka 2001, 2002), the calculation of biomass and trophic analysis (Reitz 2004; Wing and Wing 2001), using percentages of MNI and NISP values (Newsom and Wing 2004; Reitz 2001; Wing 1989), calculating meat weights (McKillop 1984), and allometric regression (Orchard and Crockford 2010; Reitz et al. 1987; Reitz and Wing 2008).

From these studies, it is clear that multiple avenues exist for exploring this question, and I use but a few in my thesis, focusing on optimization models and determining signals of resource depression. It is also clear from the studies listed above that foraging theory has not been explicitly used in Caribbean zooarchaeology. My thesis therefore, fills a gap in the absence of applying this methodology in this region of the world.

Along with methodology, it is important to provide background information to facilitate the presentation of my thesis research. Therefore, I introduce in this chapter important aspects of Jamaica and the Caribbean. I provide environmental background to my research area, including regional designations and archipelagos. I also discuss the natural history of Jamaica specifically. Next, I examine the culture history of the Caribbean, providing details on the archaeological ages used by researchers. I then discuss the rise of the Taíno, their origins and regional differences. Following these topics, I review research pertaining to prehistoric Jamaica. I end the chapter by further discussing the gap in knowledge that my thesis research aims to fill.

The Geography and Geology of the West Indies and Jamaica

The West Indies encompasses an area roughly 2,754,000 km^2 (Fitzpatrick et al. 2008) and includes more than 7,000 islands (Woolwine-Moen and Moen 2011). To begin untangling Caribbean island diversity, researchers often divide the West Indies into a variety of regions or archipelagos (Figure 1). The four main regions include the Greater Antilles, Lesser Antilles, Bahamian Archipelago, and Southern Caribbean (see Keegan

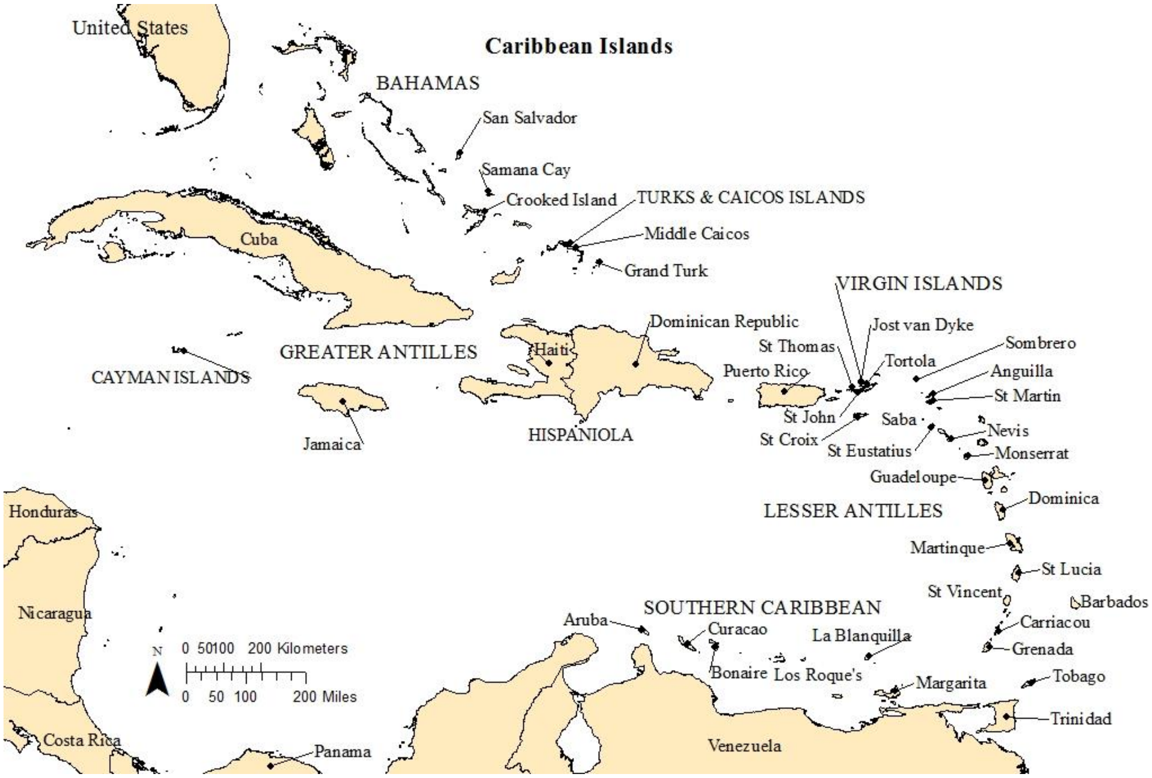


Figure 1. Map of Caribbean Islands, with Regions and Other Subdivisions in All Caps.

1994 for a full list; also Newsom and Wing 2004). Other groupings of the smaller islands include the Netherlands Antilles, Cayman Islands, Virgin Islands, the Trinidad/Tobago group, and the Turks and Caicos (Fitzpatrick et al. 2008; Newsom and Wing 2004).

The Greater Antilles includes Cuba, Jamaica, Hispaniola (Haiti and the Dominican Republic), and Puerto Rico. Together these islands comprise roughly 194,000 km^2 of land (Wilson 2007:9). However, Keegan (1994) adds the U.S. Virgin Islands, Vieques, and the Cayman Islands to the Greater Antilles, bringing the total square kilometers to 208,312. The Virgin Islands, Cayman Islands and Vieques are separated from the Lesser Antilles by a deep trench, affecting colonization and explaining why

Keegan (1994) and Newsom and Wing (2004) add them to their analyses of the Greater Antilles.

The Greater Antilles exist in the climatic belt called the low latitudes, where trade winds dominate surface winds and blow mostly from the east (Gallucci 1985). Although they lie in tropical waters, the mountains and brisk trade winds temper the climate (Gallucci 1985). The larger four Greater Antilles islands contain fertile valleys that support large populations today and as in the past (Wilson 2007). The soil is fertile because of limestone and volcanic deposits. This combined with favorable climate allows crops to be grown throughout the year (Gallucci 1985). The islands receive between 200 to 1,500 mm of rainfall, depending on elevation (Newsom and Wing 2004).

The Lesser Antilles represent a chain of 15 major and many minor volcanic islands (Fitzpatrick et al. 2008) totaling nearly 12,000 km^2 (Wilson 2007:8). The islands of the Lesser Antilles are relatively close together, approximately 50 km between most of them (Newsom and Wing 2004), making exploration and settlement of the islands relatively easy (Rouse 1992). The islands form an arc from Sombrero in the north to Grenada in the south (Watters 1989). The average size of a Lesser Antilles island is about 400 km^2, though they range in size from about 13 km^2 for Saba to 1,700 km^2 for Guadeloupe. Many of the islands with mountains receive more rain than islands with lower elevations, but on average, they receive between 1,500 to 2,500 mm per year (Newsom and Wing 2004).

Researchers further subdivide the Lesser Antilles into the Leeward and Windward Islands. British administrators established the Windward-Leeward divisions, referencing the route taken by Columbus and subsequent voyages (Keegan 1994; Newsom and Wing 2004). The Leeward Islands extend north of Guadeloupe and the Windward Islands range south of Dominica.

The Bahamian Archipelago represents a chain of calcareous (containing calcium carbonate) islands (Keegan 1994) with less rainfall than the other island groups (Fitzpatrick et al. 2008). The Bahamas encompass 35 low limestone islands and more than 700 cays across the Atlantic Ocean and Caribbean Sea. According to Newsom and Wing (2004), the northern islands experience seasonal, cooler weather conditions, receive between 1,200 and 1,600 mm of rainfall, and occupy the humid-subhumid region. The central Bahamas receive less rainfall with an average of 800 to 1,100 mm a year, and the southern Bahamas receive the least rainfall. The central and southern Bahamas reside in the subhumid to semiarid provinces.

The Southern Caribbean includes the Netherlands Antilles, Margarita, Trinidad, Tobago, the Los Roque's island group, and a host of smaller islands that parallel the Venezuelan Coast (Keegan 1994; Newsom and Wing 2004). The islands from Curaçao to La Blanquilla are oceanic, separated from the South American mainland by a trench, while Aruba and Margarita are on the continental shelf. The Southern Caribbean islands range in size from Margarita, at 1,150 km^2, to the entire Los Roques island group at 40 km^2. Climatically, the Southern Caribbean islands receive low annual rainfall, 150 to 800 mm (Newsom and Wing 2004).

Although, Trinidad is included in the Southern Caribbean, archaeologists tend to exclude it from regional analyses, as it was part of the South American mainland until the end of the Pleistocene (Fitzpatrick et al. 2008; Keegan 1994; Newsom and Wing 2004). Trinidad is also the largest island in the region at 4,828 km^2. Another distinction of the Southern Caribbean region centers on the Netherlands Antilles: researchers often refer to it as the ABC islands, because it consists of Aruba, Bonaire, and Curaçao. These three islands contain nutrient-rich waters with abundant and diverse marine resources. They receive low annual rainfall making them arid and sparsely vegetated (Newsom and Wing 2004).

Geography and Natural History of Jamaica

Jamaica is part of the Greater Antilles and the third largest island in the Caribbean, stretching 235 km east to west and 80 km north to south (Figure 2). The total area of the island amounts to 11,264 km^2. Allsworth-Jones (2008) cites the climate of Jamaica as tropical maritime, with northeast trade winds and daily patterns of land/sea breezes modifying temperatures both diurnally and based on elevation. Three broad precipitation zones exist, with the northeast receiving the most rainfall per year (> 2,540 mm), the central mountainous region receiving moderate rainfall (> 1,270 – 2,540 mm per year), and the driest area being the southern coast (< 1,270 mm per year).

Geologically, Jamaica contains mostly limestone bedrock with scattered volcanic rocks (Keegan 1994). Most major landforms, such as mountains and valleys, formed after the island emerged from the sea between 5 and 10 million years ago (Lee 2006). Major landforms in Jamaica include mountain ranges, valleys, coastal plains, rivers, shorelines, cays, and banks. Four natural habitats exist on Jamaica (Allworth-Jones 2008). The first

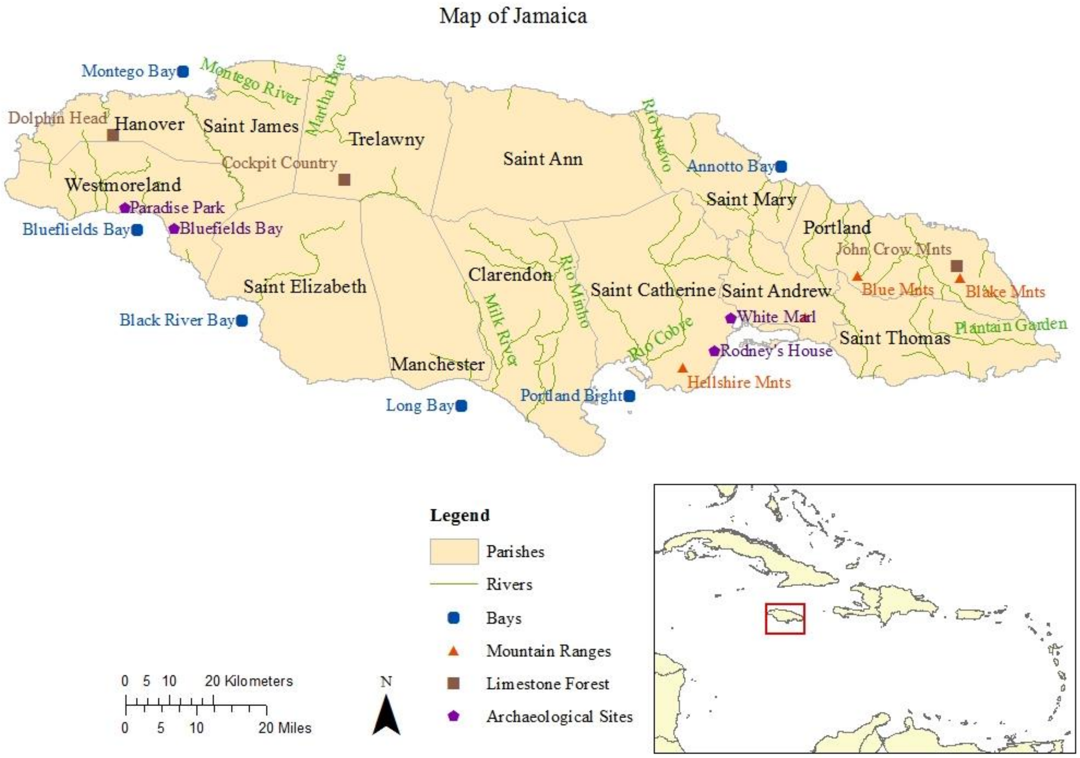


Figure 2. Map of Jamaica Including Parishes, Major Rivers, Mountains, and Environments Noted in Text, and the Approximate Location of Archaeological Sites.

is wetlands, including lagoons, shallow estuaries, mangroves, and swamps. The second is dry limestone forests or scrub. The third is wet limestone forests, most notably the Cockpit country, Dolphin Head, and the John Crow Mountains. The fourth and final habitat is montane forests confined to the Port Royal and Blue mountains.

The Blue Mountains are the highest of Jamaica’s five mountain ranges, at 2,256 m. According to Lee (2006), both the Blue Mountains and the John Crow Mountains contain patches of rain forest and high numbers of endemic species, while the Hellshire Mountains in the southeast include the endangered Jamaican *hutia* or “coney” (*Geocapromys brownii*) and the Jamaican iguana (*Cyclura collei*).

All major rivers in Jamaica are at least 32 km long (Lee 2006). Major north-flowing rivers include the Wagwater, Rio Grande, Martha Brae, Great River, and White River. Major south-flowing rivers include the Black River (the longest river on the island), Plantain Garden, Rio Cobre, Rio Minho, and Milk River.

Lee (2006) describes Jamaica as nearly surrounded by coastal lowlands. In the north, the coastal plain is narrow – usually less than 2 km wide – with lush vegetation and plentiful rainfall. The southern coast has a broad coastal plain with a variety of ecotypes, including semi-arid lands, dry limestone scrub forests, mangrove forests, herbaceous swamps, and marsh forests. The northern coasts consist of mainly white sand beaches derived from coral reefs close to shore. In the east, the beaches are more rugged and pebbly from stones and sand washed down by rivers. Much of the southern coast contains black sand beaches colored by metallic oxides carried from the interior and deposited on the shore.

Biodiversity on Jamaica includes numerous endemic flora and fauna. For flora, Jamaica has hundreds of species of flowering plants and ferns, 30 percent of which are endemic and occur nowhere else in the world (Lee 2006). As for mammalian fauna, the Jamaican *hutia* is a rabbit-sized rodent, similar to the South American guinea pig, and a staple in pre-Columbian Jamaican diets (Allsworth-Jones 2008; Newsom and Wing 2004; Wing and Wing 2001). Jamaica also has three kinds of native monkeys, now extinct, and a hairless, barkless dog similar to those observed in Mexico (Allsworth-Jones 2008). Marine mammals observed in Jamaica’s coastal waters include the pygmy sperm whale (*Kogia breviceps*), the melon-headed whale (*Peponocephala electra*), and the Antillean manatee (*Trichechus manatus*), along with the now extinct Caribbean monk seal (*Monachus tropicalis*) (Allsworth-Jones 2008; Newsom and Wing 2004).

Other Jamaican fauna include a variety of birds, reptiles, and mollusks. Jamaica has over 200 species of birds, including 25 endemic species. The most well-known bird species is the streamtail hummingbird, the islands national bird (Allsworth-Jones 2008; Lee 2006). Reptiles include several small lizards, the Jamaican iguana, the American crocodile, nine species of snakes, the endemic pond turtle, and four species of sea turtles (Allsworth-Jones 2008; Lee 2006). Archaeologists have observed the Jamaican iguana, as well as several species of turtles and snakes in middens across the Caribbean (Allsworth-Jones 2008; Newsom and Wing 2004). Jamaica has one of the most diverse mollusk fauna in the world. There are thousands of marine invertebrate species, including hard and soft corals, mollusks, and crustaceans (Lee 2006).

Caribbean Culture History and the Taíno

Caribbean archaeology has focused primarily on creating chronologies and artifact classifications (Allsworth-Jones 2008; Rouse 1992; Wilson 2007), along with determining the origins of the first inhabitants (Rouse 1992; Wilson 2007). More recent shifts to processual and explanatory research have begun to address questions of adaptation, cultural evolution, social and political organization, and even ideology and cosmology (Keegan 1994; Wilson 2007). However, to begin understanding Caribbean archaeology requires an introduction to the terms used by researchers. For instance, in North American archaeology the term ‘Archaic’ refers to sites dating between 10,000

Table 1. Culture History Details Used by Caribbean Archaeologists.

Age	Date Range	Series	Subseries
Lithic	4000-2000 B.C.	Casmiroid	Casimiran, Courian, and Redondan
Archaic	2000-200 B.C.	Ortoiroid	Corosan, Jolly Beach, Boutbois, and Ortoire
Ceramic	200 B.C. to A.D. 600	Saladoid	Ronquinan, Cedrosan, and Huencan
Formative	A.D. 600 to A.D. 1500	Ostionoid	Ostionan, Meillacan, and Palmetto

to 3,000 years ago, while in the Caribbean, an Archaic site dates from 4,000 to 2,200 years ago.

The system used by Caribbean archaeologists stems from over 50 years of research by Irving Rouse (Keegan 1994; Rouse 1992). Ceramic styles form the basis of Rouse's chronology, with the series and subseries names define a culture and a people (Table 1) (Rouse 1992; Wilson 2007). Rouse uses stratigraphic relations of diagnostic artifacts to determine the temporal positions of cultures, while calendar years derive from mean radiocarbon dates (Keegan 1994; Rouse 1992). In addition, there are five distinct ages within Caribbean prehistory: Lithic, Archaic, Ceramic, Formative, and Historic (Allsworth-Jones 2008; Keegan 1994; Rouse 1992; Wilson 2007). The following discussion excludes the Historic period and focuses primarily on the Archaic, Ceramic, and Formative ages, as the majority of archaeological sites date to these times. Date ranges for each age come from Keegan's (1994) introduction to West Indian archaeology.

Lithic Age, 4000-2000 B.C. Very few sites characterize the Lithic period due in part to the early Holocene rise in sea level (Keegan 1994; Wilson 2007). The earliest archaeological sites in the Greater Antilles date to 4000 B.C. and are located on Cuba, the Dominican Republic, and Haiti (Wilson 2007). Lithic-age sites contain unretouched macroblades made from flint cores. These flint blades were most likely used for woodworking based on wear patterns (Keegan 1994; Rouse 1989). Lithic age sites also lack grinding tools, such as mortars and pestles, and pottery (Keegan 1994; Rouse 1992; Wilson 2007). Lithic-age foragers subsisted primarily on land mammals, such as *hutia*, seals, manatee, and sea turtles, but shifted to shellfish gathering and fishing by around 2000 B.C. (Wilson 2007).

Rouse (1992) categorizes the Lithic-age peoples of the Greater Antilles as Casimiroid, with dates ranging from 4000-400 B.C. He further divides the Casimiroid series into three subseries: Casimiran, Courian, and Redondan. The Casimiran subseries received its name from excavations of Casimira and Berrera-Mordán, in the Dominican Republic (Keegan 1994; Rouse 1992). These excavations revealed a lack of grinding stones and pottery (Rouse 1992). Two sites in Cuba yielded habitation areas, food remains and a chronology that suggests early Lithic-aged peoples gradually developed into Archaic peoples (Keegan 1994; Rouse 1992). The Courian and Redondan subseries both succeeded Casimiran. The Courian subseries replaced Casimiran in Cuba and the Redondan subseries replaced Casimiran in Haiti and the Dominican Republic (Rouse 1992).

Archaic Age, 2000-200 B.C. Keegan (1994) notes two perspectives on the Archaic, with the first focusing on it as an age defined by the absence of pottery, an abundance of marine mollusks and the presence of ground stone and/or shell. The second perspective casts the Archaic as a developmental stage characterized by terrestrial-based hunting strategies shifting into marine-oriented strategies (Keegan 1994; Wing 1989).

Traditionally, Archaic peoples were considered pre-agriculturalists, however, recent paleobotanical studies point to a Caribbean horticultural complex dating to this era (Keegan 1994).

Rouse named these Archaic-aged peoples the Ortoiroid, after the Ortoire site on Trinidad (Rouse 1992; Wilson 2007). Related cultures extend to the Orinoco Delta of the South American mainland and as far north as Puerto Rico and the Virgin Islands (Rouse 1992). Rouse's dates for the Ortoiroid series range from 2000-400 B.C., slightly older then dates given by Keegan (1994). The Ortoiroid peoples began settling in places they were familiar with (Wilson 2007), but later oriented both their villages and resource gathering towards the sea. The Ortoiroid first appeared in Trinidad and migrated as far as Puerto Rico by 1000 B.C. (Rouse 1992).

Rouse (1992) subdivides the Ortoiroid series by using the absence of diagnostic traits rather than specific traits, as this series contains so few artifacts. The Corosan subseries is observed in Puerto Rico and the Virgin Islands, while similar cultures are divided into the Jolly Beach subseries on Antigua, the Boutbois on Martinique, and the Ortoire on Trinidad. The Corosan subseries combine the Coroso culture of Puerto Rico and the Krum Bay culture of the Virgin Islands. Boomert (2000) postulates that nearly all the preceramic sites on Trinidad and Tobago fit within the Ortoiroid series, suggesting foragers focused on resources observed along the coasts, in mangroves, and in shallow reefs.

Ceramic Age, 200 B.C. to A.D. 600. The earliest Ceramic Age sites in the Caribbean date to about 500 B.C. and are located on Puerto Rico, the U.S. Virgin Islands, and the Leeward Islands (Keegan 2000). Besides ceramics as an obvious diagnostic characteristic, these people lived in large, permanent villages, and grew crops (Wilson 2007). Between A.D. 1 and A.D. 500, there is at least one Ceramic-aged site established on every major island (Keegan 2000), with a remarkably similar material culture throughout (Wilson 2007).

Rouse (1992) names the Ceramic culture the Saladoid series, after the Saladero site in Venezuela dating to around 2500 B.C. Rouse (1992) believes the appearance of the Saladoid culture in the Caribbean represents a major migration from mainland South America up the Lesser Antillean chain, leading him to name the series after the Venezuelan site. However, recent research has added complexity to this picture by suggesting migrating groups were more diverse than originally proposed. In addition, the interaction between Archaic-age peoples already living on the islands and the migrating Saladoid groups may have influenced Saladoid culture more than previously thought (Wilson 2007).

Rouse (1992) subdivides the Saladoid culture into the Ronquinan, Cedrosan, and Huencan subseries. The Ronquinan culture emerged in the Orinoco Valley of mainland South American, and dates from 2140 to 620 B.C. The Ronquinan pottery is undecorated and consists of modeled-incised and white-on-red pots, along with clay griddles used for baking bread from cassava flour (Rouse 1989, 1992). The Cedrosan subseries pottery is high quality and more elaborately decorated than in the Americas (Keegan 2000). Cedrosan pottery occurs from 530 B.C. to 655 A.D (Rouse 1992). The peoples who made Cedrosan pottery inhabited islands of both the Greater and Lesser Antilles, making them the most widespread (Keegan 2000). The material culture from the Huencan subseries is very distinctive, containing decorated incised crosshatching and an absence of painted pottery (Rouse 1992). Along with the pottery, Huencan sites include small zoomorphic pendants made of exotic stone (Keegan 2000; Rouse 1992).

Formative Age, A.D. 600 to A.D. 1500. The end of the Saladoid culture marks the beginning of social and political elaboration across the Caribbean. While, some areas experienced dramatic changes over a short period, other islands experienced slow change (Wilson 2007). The Formative Age represents a cultural divergence of the Greater and Lesser Antilles. The Greater Antilles expanded into the Ostionoid culture, and the Lesser Antilles experienced slow changes until the invasion of mainland peoples called the Island Caribs (Keegan 2000). The Ostionoid culture dates from 600 to 1500 A.D. and archaeological identifiers include a pottery type known as “redware” (Keegan 2000; Rouse 1992; Wilson 2007). The name refers to the use of red, rather than white, paint as the primary background, whereas Saladoid pottery uses both.

Rouse (1992) further subdivides the Ostionoid series into three subseries, the Ostionan, Meillacan, and Palmetto. The Ostionan peoples appear to have migrated from eastern Hispaniola using two routes. The first route took them through the Cibao Valley of the Dominican Republic and the other followed the southern coast of Hispaniola. The route through the Cibao Valley took them to the eastern tip of Cuba while the southern coast took them across the Jamaica Channel to the southern part of Jamaica. The Meillacan subseries centers in the Cibao Valley of Haiti, expands into the Windward Passage between Cuba and Hispaniola and radiates west into central Cuba and south to

Jamaica. Meillacan ceramics have similar forms to Ostionan pottery, but with more incurving bowls and the red paint is abandoned in place of roughened surfaces (Wilson 2007). The Palmetto subseries occurs in the Bahamian Archipelago and is represented by thick, crude, and mostly shell-tempered pottery. The Palmetto subseries is too different to be placed in either the Ostionan or Meillacan cultures, and is currently unaffiliated (Rouse 1992).

Population movement and cultural change punctuates the Ostionoid series. Rouse (1992) believes the Ostionoid culture arose from Saladoid peoples from South America moving north to Puerto Rico around 200 B.C., with 600 A.D. marking a major change in material culture on the western side of the Mona Passage (between Puerto Rico and Hispaniola). Another opinion proposes that the chiefdoms of the Ostionoid period emerged from a lineage-based hierarchy of the Saladoid culture (Keegan 2000).

Rouse (1992) employs the culture-historic model to create his chronological system and there are several issues with it. According to Allsworth-Jones (2008), the primary issue is with the dates, as Rouse did not take into account the calibration of radiocarbon dates, which would considerably blur the lines between the different series. In addition, Keegan (2000) views the different pottery decorations as a veneer that reinforced social ties between islands and may tell researchers more about social alliances in isolated places than the existence of distinct cultures.

Nevertheless, Caribbean archaeologists do agree on several points. One such point is that Lithic and Archaic peoples were mobile forager groups who had less of an impact on the environment than did their more settled Ceramic and Formative era counterparts

(Fitzpatrick et al. 2008). Even then, findings indicate that indigenous populations of only 500-1000 people can have significant impacts on the environment (Blick 2007). In addition, Lithic-age sites are rare in the Caribbean and difficult to distinguish (Fitzpatrick et al. 2008; Keegan 1994; Rouse 1992). Moreover, archaeologists describe Archaic peoples as ‘fisher-foragers.’ ‘Fisher-foragers’ relied on reef and nearshore species of fish, turtles, and invertebrates, along with small game hunting of rodents and iguanas (Keegan 1994). For Ceramic-age people, the abundance of marine resources in their middens explains why colonists from the mainland of South America may have moved into the islands (Fitzpatrick et al. 2008).

The Caribbean Taíno

Researchers call the foragers at the heart of this study either the Taíno or the Arawak. Taíno is currently the preferred term as Arawak refers also to foragers living in Venezuela (Allsworth-Jones 2008). Rouse (1992) defines the Taíno as the ethnic group inhabiting the northern Caribbean, who greeted Columbus when his ships and he arrived in 1492. However, they did not call themselves Taíno, but by the names of the places in which they lived. For example, those foragers living in Puerto Rico called themselves *Borniquen*, their name for the island, and foragers living in the Bahamian Archipelago called themselves *Lucayo,* the word for small islands. Keegan and Carlson (2008) distinguish the inhabitants of the Bahamas as *Lucayan* Taínos. Rouse (1992) calls those foragers living in the northeastern part of Hispaniola as Ciguayan Taínos, those residing in Jamaica and Cuba as Western Taíno, and those dwelling in the Virgin Islands and

Leeward Island as Eastern Taíno. He also distinguishes a Classic Taíno group who inhabited the majority of Hispaniola and all of Puerto Rico.

The Taíno either arose from the Formative eras Ostionoid cultural complex (Rouse 1992) or developed from Archaic peoples of the northern Caribbean (Keegan and Atkinson 2006). They are associated archaeologically with the first evidence of simple chiefdoms in the Caribbean. In the case of the Taíno, the archaeological signals for social hierarchy and complexity are the building of ball courts and large plazas, the cultivation of domestic crops, the maintenance of domestic and managed animals, and the assumed control of resource production and distribution (Newsom and Wing 2004). The word Taíno means "good" or "noble" and several members spoke the word to Columbus to indicate they were not the southern Island-Carib peoples. Island-Caribs migrated from the mainland and were culturally distinct from the Taínos (Allsworth-Jones 2008; Rouse 1992).

Jamaican Prehistory and the Gap in Knowledge

The ancestors of the Taíno colonized Jamaica and the Bahamas during the Formative Age, after A.D. 600 (Atkinson 2006; Wilson 2007). Jamaican ceramics fall under two categories. The first is the "Redware" or "Little River" style, which corresponds to the Ostionan Ostionoid subseries. The second is the "White Marl" style that corresponds to the Meillacan Ostionoid subseries (Allworth-Jones 2008). Earlier sites on the island correspond to Redware pottery that is replaced almost entirely by the White Marl style after 900 A.D. (Wilson 2007). Keegan and Atkinson (2006) suggest these two styles represent two different migrations of peoples into Jamaica. They propose the White Marl or Meillacan culture eventually replaced or were absorbed by the Redware or Ostionan culture.

Preliminary observations in Jamaica, suggest the Redware culture preferred coastal or riverine sites and locations between 0 to 15 m above sea level, while the White Marl culture was more diverse in its settlement patterns (Atkinson 2006). According to Atkinson (2006), the Meillacans penetrated farther inland, but did not inhabit the mountain range. Moreover, research indicates that the White Marl culture was less dependent on marine resources and more dependent on agrarian resources than the earlier Redware culture (Atkinson 2006). In addition, Carlson and Keegan (2004) note that at Paradise Park, the Ostionan site faunal material consists of fish, sea turtle, freshwater turtle, iguana, and a few hutia, while the Meillacan site produced dense deposits of fish and hutia, plus small amounts of bird, turtle, crocodile, and iguana. Fishing intensified over time, as the variety of fish species is more than double at the Meillacan site and there are a higher number of small fishes in these later deposits.

Flora on Jamaica was largely transformed by the Taíno as they cultivated wild plants and introduced domesticated plants (Allsworth-Jones 2008). The Jamaican Taíno practiced horticulture, implying small-scale house gardens containing a range of plants. Manioc, or cassava (*Manihot esculenta*), being the most important crop, with sweet potato (*Ipomoea batatas*) a close second (Allsworth-Jones 2008).

Rouse (1992) places the Jamaican indigenous peoples under the term “Western Ostionoid” or “Western Taíno,” as they were not as socially advanced as their neighbors.

However, this assumption appears erroneous next to evidence presented by Allsworth-Jones (2008). He notes that Rouse’s requirements for being highly developed includes ball courts, wooden stools, elaborate stone zemis, and petroglyphs, all of which have been observed in Jamaica. Allsworth-Jones (2008) and Keegan (1994) prefer not to distinguish between Jamaican Taíno and Classic Taíno, and instead use the general term Taíno to describe the peoples of the Greater Antilles.

Gap in Knowledge

To date, researchers frequently regard Jamaican prehistory as one of the least studied subjects in the Caribbean, although this view is slowly changing as researchers publish their studies in international journals and discuss their findings at conferences (Atkinson 2006). Many researchers only publish their studies in Jamaica’s two publications, the *Archaeology Jamaica* newsletter, and the *Jamaica Journal*, not easily available outside the island.

The few available publications of archaeofaunal remains in Jamaica include, but are not limited to, Allsworth-Jones (2008), Newsom and Wing (2004), Keegan et al. (2003), Carlson and Keegan (2004), and Scudder (2006). Allsworth-Jones (2008) reports findings from the James Lee survey, the largest ever conducted in Jamaica. However, surface only collection limited the quantity of zooarchaeological remains. Newsom and Wing (2004) compiled data from across the Caribbean, but reported archaeofaunal remains from only one site on Jamaica, called White Marl. White Marl is 5.6 km inland from Kingston Harbor located on the southern side of the island and within the St.

Catherine parish. The White Marl site was excavated in 1964 when course screening was used. Course screens allow for the loss of small faunal remains, especially fish bones. Keegan et al. (2003) report their excavation of two sites in the Westmoreland parish, on private property known as Paradise Park, but they limit the discussion to the invertebrates. Carlson and Keegan (2004) discuss the faunal remains from Paradise Park, but they use summary figures to make comparisons with other sites in the West Indies. The summary data means detailed information is lacking on the archaeofauna from Paradise Park. Scudder (2006) provides the faunal data and analysis for the Rodney's House site located in the parish of St. Catherine. She presents the data as a list of species present, but does not provide counts useful for other types of analyses.

In summary, the five studies discussed above provide disparate data; making comparison and analysis by other researchers difficult (refer to Figure 2 for approximate locations). Survey-only data lack time depth, making a study of changes through time impossible. Both Carlson and Keegan's (2004), and Scudder's (2006), articles reveal how data presented in published books and journals often lacks details needed to perform other analyses. The Newsom and Wing (2004) book is the only published study suitable for other analyses, as it presents detailed data for sites across the Caribbean. Unfortunately, the authors report on only one site from Jamaica. The limited number of published faunal data from Jamaica reveals gaps in our understandings of Jamaican Taíno impacts to local marine ecosystems.

Continuing with the gap in knowledge, Keegan (2010) and Butler (2010) discuss the widespread use of trophic analysis in determining changes in pre-Columbian

Caribbean fisheries. They agree this may not be the best measure of past fishing intensity, as trophic analysis was established during the twentieth-century to study commercial fisheries (Pauly et al. 1988), and researchers do not always take into account its theoretical observations (Keegan 2010). Neither author addresses the use of optimization models and resource depression as tools that can measure past foraging efficiency, revealing an important gap in methodology within Caribbean archaeological studies. This gap provides another justification for my thesis research and the methods I use to analyze the Bluefields Bay faunal sample.

In conclusion, I have provided geographic information that allows readers to place my research in space. In addition, I have discussed the culture history and chronology of the region, useful for contextualizing Caribbean prehistory beyond the Bluefields Bay site. To further explore the ichthyofauna of the Caribbean, I provide reports documenting the impacts humans have had on marine environments in the Caribbean and Jamaica. These reports allow me to discuss the kinds of impacts the Jamaican Taíno may have had on their local marine ecosystem. In addition, I discuss the characteristics, life history, and behavioral ecology of ten fish families that imperil them to the impacts of overharvesting.

CHAPTER 3

CARIBBEAN AND JAMAICAN FISHERIES AND FISHES

In this chapter, I shift my focus to the history of Caribbean fisheries and the fish species important to artisanal fishers. I first discuss the documented impacts humans have had on Caribbean and Jamaican fisheries, using archaeological, historical, and current research. I also review a debate on the use of archaeological data in establishing a fisheries baseline and informing modern conservation efforts. Following that discussion, I provide details about the fish on which the Jamaican artisanal fishers focus. I model artisanal fishers as a proxy for pre-Columbian foragers. I highlight the species modern fishers see as important food resources and provide the life history and behavioral ecology of these fishes that make them vulnerable to overexploitation.

Human Impacts on Caribbean and Jamaican Fisheries: Past and Present

Resource overexploitation, especially with regard to fishing, has become a major concern as fisheries collapse or near the point of collapse (Dulvy et al. 2003; Hawkins and Roberts 2004; Jackson et al. 2001; Miloclavich and Klein 2004; Mullon et al. 2005). Miloclavich and Klein (2004) demonstrate that activities traceable to humans and that impact marine ecosystems include pollution leading to the degradation of water and land resources, diseases (such as coral bleaching), habitat loss, colonization by invasive species, and the reduction of marine productivity. A study by Mullon and colleagues

(2005) based on the United Nations' Food and Agriculture Organization (FAO) world fisheries catch database, revealed that 366 fisheries had collapsed. In addition, research by Dulvy and colleagues (2003) confirmed 133 local, regional, and global extinctions of marine populations. Moreover, Jackson and colleagues (2001) suggest ecological changes due to overfishing are similar across the globe in terms of reduced biomass and declines in large animal abundances. Although my research focuses on Jamaica and the Caribbean, the issue of overfishing is truly global.

To explore the impacts humans have had on marine environments in the Caribbean and Jamaica, I first discuss characteristics of overfishing and the importance of archaeological and historical data in contributing to the management of fisheries. I then review archaeological, historical, and current data pertaining to the impacts humans have had on Caribbean and Jamaican fisheries.

Characteristics of overfishing include the depletion of apex predators and larger individuals, truncated size and age distributions of targeted species (known as growth overfishing), and genetic changes in growth rates. Furthermore, declining fish biomass, altered community composition or functioning (signs of ecosystem overfishing), reduction of species diversity, and regional extirpations or global extinctions characterize overfishing (Blick 2007). Another sign of overfishing includes changes in landings from long-lived, high trophic level piscivores toward short-lived, low trophic level planktivorous and pelagic fishes (Pauly et al. 1988).

To explain further, *growth overfishing* equates to a substantial reduction in the proportion of large size classes as harvesting captures fish before they have time to grow.

Russ (1991) defines two other kinds of overfishing that increase in magnitude from growth overfishing: 1) *recruitment overfishing,* the adult stock has been reduced to a point where reproduction and recruitment are impaired and 2) *ecosystem overfishing,* fishing so intense that it changes the relative abundances of species or species composition (in regards to shifting biomass from originally abundant species to species less common). Zooarchaeological data provides evidence for all three types of overfishing. Growth and recruitment overfishing can be demonstrated using specimen measurements to determine size changes and if those size changes equate to a reduction in adult stock. Moreover, zooarchaeologists can demonstrate ecosystem overfishing using relative abundance indices and diversity measures.

As mentioned in the first chapter, most ecological researchers use local field studies, which lasted only a few years and were conducted after the 1950s. Such studies fail to account for important environmental disturbances (ENSO –El Niño Southern Oscillation), as well as long-term cycles and shifts in marine regimes and productivity. This is the value of historical and archaeological data, as these can provide longitudinal perspective on ecological change. However, Jackson et al. (2001) admit that precision and analytical elegance, prized by ecologists, must be sacrificed when using historical and archaeological data.

A debate over the merit of archaeological evidence for informing current fisheries issues recently took place in the *Journal of Island and Coastal Archaeology*. It began with Julio Baisre (2010), a marine biologist, challenging the contribution of archaeological data to marine environmental studies in the Caribbean, especially with regard to using these data in creating fisheries baselines. All respondents to his article (Butler 2010; deFrance 2010; Fitzpatrick 2010; Jones 2010; Keegan 2010; McClenachan et al. 2010) disagree with Baisre's statement that small prehistoric populations lacked adequate technology to affect Caribbean fisheries.

Advocates for the use of archaeological data discuss several issues with the idea that small-scale societies did not affect their environments. Keegan (2010) emphasizes overexploitation is a process, not an outcome, and McClenachan and colleagues (2010) demonstrate that modern ecosystems are the product of longer-term human activities, requiring the study of historic and prehistoric fisheries to understand current issues. Butler (2010) states that the generalization of prehistoric peoples as too simple to affect their environment becomes just as problematic as the view that human degradation of the environment is pervasive. She urges that an intermediate view is more useful, as the relationship between people and the environment remains highly variable. Jones (2010) argues that characterizing the human-environmental interaction, and determining the extent and nature of that interaction, is the true purpose of archaeological contributions.

de France (2010), one of the advocates for using archaeological data, explains that the technology of small-scale societies is far more complex than Baisre claims. Ancient technology may not have destroyed habitats like modern technology, but redundant use of shore habitats results in diminished returns. These diminished returns cause people to shift to new habitats, new technology, and/or to add new species to the diet in many instances around the globe. Fitzpatrick (2010) and Keegan (2010) agree that Baisre's assessment of human technology and population densities is an oversimplification of the issue, and that local cases need to be fully understood before researchers can place them in a Caribbean-wide context.

Moreover, Fitzpatrick (2010), another advocate of the archaeological data, admits to several challenges facing archaeologists in identifying past patterns. Weaknesses of archaeological data include sample size, disturbed cultural deposits, and poor recovery techniques. In addition, the use of different specialists for artifacts, faunal assemblages, and environmental factors creates difficulty when conducting regional studies. These difficulties arise from each researcher employing different methods to analyze the data, but such studies are not impossible. Archaeologists can and do contribute to modern issues of overfishing by providing data reaching far into the past. Such contributions include archaeological, historical, and current evidence of overfishing in the Caribbean and Jamaica. I highlight the kinds of impacts humans have had on marine environments in the following paragraphs.

Archaeological Evidence. In the Caribbean, archaeologists have observed evidence for declines in high-ranked resources including large fish, sea mammals, and turtles, along with evidence for the management of certain food species, and possible extirpation of breeding populations (Atkinson 2006; Blick 2007; Carlson and Keegan 2004; Carder et al. 2007; deFrance et al. 1996; Fitzpatrick et al. 2008; Keegan et al. 2003; Newsom and Wing 2004; Scudder 2006; Steadman and Jones 2006; Wilkinson 2001; Wing 1989, 2001; Wing and Scudder 1983; Wing and Wing 2001). Declines in abundances of larger, higher-ranked resources occurs throughout Caribbean archaeological sites (Carlson and Keegan 2004; Newsom and Wing 2004; Wing and

Wing 2001). In addition, Wilkinson (2001) and Wing (1989) suggest pre-Columbian peoples may have actively managed *hutia*, a large nocturnal herbivore, and the only surviving terrestrial mammal on Jamaica. Furthermore, Carlson and Keegan (2004) suggest that sea turtle breeding populations may have been extirpated by A.D. 1200, much earlier than historic data suggests.

Size does matter, at least in terms of the magnitude of changes in the human/environment interaction sphere. The smallest islands, such as the Bahamas, Turks and Caicos, and Grenadines, appear most susceptible to human impacts. The smallest islands have high levels of biodiversity, extensive coral reef systems, and marine resources that attracted unsustainably high numbers of foragers to their shores (Blick 2007; Fitzpatrick et al. 2008). Although, larger islands still experience major declines. Declines in terms of both size and abundance of high-ranked prey due to human foraging (Carlson and Keegan 2004; Colten and Worthington 2014; Steadman and Jones 2006; Wing and Wing 2001). Furthermore, Newsom and Wing (2004) suggest that archaeological patterns demonstrate clear differences between the resources used by people living on different island groups. Newsom and Wing (2004) provide the example of people living on small coral islands having access to quite different resources than people living inland on larger islands. Keegan (1994) and Wing (1989) also observe the pattern of Archaic peoples practicing different foraging strategies from the later Ceramic peoples by focusing on terrestrial rather than marine resources. Therefore, not only does physical location create patterns in the archaeological record, so too can differing cultures and timeframes.

Current archaeological research in the Caribbean suggests that Lithic- and Archaic-age peoples were mobile forager groups who had less of an impact on the environment than did their more settled Ceramic and Formative era counterparts (Fitzpatrick et al. 2008; Newsom and Wing 2004). Lithic-age peoples (4000 to 400 B.C.) subsided on shellfish and large game, such as seals and manatees. However, the rarity of sites dating to the early Lithic period makes analysis difficult (Keegan 1994). Archaic peoples (5000 to 200 B.C.) were ‘fisher-foragers,’ with their subsistence based on reef and nearshore species of fish, turtles, and invertebrates, along with small game hunting of *hutia* and iguanas (Fitzpatrick et al. 2008; Keegan 1994). In addition, Archaic-aged peoples emphasized marine mollusk collecting. Ceramic-age foragers (500 B.C. to A.D. 1400) focused on marine resources, particularly sea turtles, parrotfish, jacks, snappers, grunts, groupers, and the queen conch (Fitzpatrick et al. 2008; Newsom and Wing 2004). Finally, late Ceramic era sites reveal foragers tended to focus on a single species of fish and ignore terrestrial fauna (Carlson and Keegan 2004).

Several zooarchaeological studies have focused on Caribbean fish as subsistence resources. For example, Wing and Wing (2001) use body size, species composition, and mean trophic level analyses to assess the ecological structure of offshore resource patches. In this instance, their data were drawn from excavations in Puerto Rico (Greater Antilles), St. Thomas (Virgin Islands), Saba (Netherlands Antilles), and St. Martin and Nevis (Lesser Antilles). In each case, the faunal samples represented Saladoid (Ceramic Age) or post-Saladoid occupations. Their results revealed significant declines in the size distribution and estimated average weight of reef fishes on all five islands. Fishes experiencing declines in size include groupers (Serranidae) and snappers (Lutjanidae) on St. Thomas and surgeonfish (Acanthuridae), parrotfish (Scaridae), groupers and snappers on Nevis. Wing and Wing (2001) also observed significant declines in the mean trophic level of later deposits and a shift in dominant taxon from groupers, which are large reef dwelling fish, to mackerels and tuna (Scombridae), which are large pelagic fishes. Analyses at all five sites suggest early foragers overfished the reefs and moved to deeper waters to compensate.

Carlson and Keegan (2004) offer another study on prehistoric Caribbean fisheries using zooarchaeological data from Haiti and Jamaica (Greater Antilles), Grand Turk (Turks and Caicos island group), and San Salvador (Bahamas). Their sites date to similar periods as those described in Wing and Wing (2001). However, these authors use the terms Ostionan and Meillacan to distinguish early and late Ceramic sites. Their results suggest diet changed over time from green turtles, large carnivorous fishes, and large terrestrial animals to one of juvenile turtles, small-bodied terrestrial animals, and small-sized fishes. In addition, they found fewer species captured through time. *Sparisoma* (parrotfish) dominate the later Meillacan sites and provide up to 70 percent of the fish remains on islands where foragers used traps. They also find a shift from large reef-omnivore dominated patterns to small pelagic (herrings and tunas) fishes.

Colten and Worthington (2014) offer data from the site of Vega Del Palmar, Cuba (Greater Antilles) comparing pre-ceramic and ceramic faunal samples. The fish identified at the site appear similar in taxonomic composition, with a concentration on just a few species of snook (Centropomidae), grouper, snapper, and mullet (Mugilidae). However, they observed pronounced differences in the relative abundances of specific taxa. The relative abundance of snook changed from 33 percent of the fishes in the lower levels to 75 percent in the upper levels. Mullet show the largest change, from 14 percent in the upper levels to 40 percent in the lower levels. Both are smaller near shore species that document a shift away from larger, reef species.

Steadman and Jones (2006) compare archaeofaunal assemblages from two sites on Tobago (Southern Caribbean). Milford I represents a small pre-ceramic site, whereas Golden Grove is a large ceramic-period village. Both faunal assemblages contain over 90 percent fish bones. The authors observed five main chronological shifts in fishing. First, the NISP of tuna increases from 12 to 30 percent of the total fish assemblage. Second, Toadfish (Batrachoididae) NISP increases from 0.1 percent at Milford I to 8 percent at Golden Grove. Third, taxa inhabiting mangrove and brackish environments increase in NISP from 3.3 percent to 24.3 percent at Golden Grove. Fourth, the NISP of parrotfish declines from 45 percent at Milford I to 22 percent at Golden Grove. Fifth, carnivorous fishes inhabiting reefs (Carangidae, Haemulidae, Serranidae, and Lutjanidae) decline in NISP from 23 to 8 percent. These findings support prehistoric overfishing of reef fishes, with temporal shifts to inshore and pelagic fishes.

Shifting from the Caribbean more generally to Jamaica, Carlson and Keegan (2004) state that the Ostionan site at Paradise Park (cal. A.D. 870 ± 60) may represent an initial occupation and exploitation of the island. The Ostionan site consists of fish, sea turtle, freshwater turtle, iguana, and few *hutia*. The identified fishes come from large specimens of snapper, grouper, parrotfish, snook, and hogfish (Labridae). The Meillacanaged deposits contain dense fish and *hutia* remains, plus small amounts of birds, turtle, crocodile, and iguana. In addition to fish, a change in invertebrate harvesting is evident between the two sites. The Ostionan site contained mollusks preferring open waters, while the Meillacan site contained mollusks favoring muddier waters with low circulation. The authors suggest changes in harvested foods are linked to both cultural and environmental factors.

Continuing with Jamaica, Newsom and Wing (2004) analyze the White Marl site located farther inland than Paradise Park (Carlson and Keegan 2004). This site demonstrates a dominance in fishes preferring the inshore estuarine habitats, such as snook, porgy (Sparidae), mullet, and sleeper (Eleotridae). Reef fishes appear half as abundant at the site. The distance to coral reefs and the shore itself may have encouraged Jamaican foragers at White Marl to exploit resources closer to their homes. In contrast to other sites located closer to shore, which contain assemblages dominated by reef fishes.

Historic Data. Aspects of historic data add to our understanding of human impacts on marine ecosystems, just as archaeological data does. To begin, I look at Jackson's (1997) article in which he discusses the degradation of coral reefs in the Caribbean, focusing primarily on Jamaica. He chose Jamaica because he believes it is the worst case in the region today. Additionally, he chose Jamaica because the island offers the best historical record, reaching back nearly 350 years. Jamaica has the best historical data because British naturalists and fisheries managers left detailed written records (McClenachan et al. 2010). However, archaeological evidence offers details of coral reef fish composition back at least another 1,300 years, and although Jackson's (1997) study specifically used historical data, he makes an excellent case for including prehistoric data in fisheries management strategies.

Part of Jackson's (1997) insistence on using data gathered before the 1950s is because of a phenomenon known as shifting baseline syndrome. The concept suggests that as we are introduced to an area, what we see becomes the baseline. As such, divers who saw the reefs decades before have a different baseline, and so on (Pauly 1995). Using the green turtle (*Chelonia mydas*) as an example, Jackson suggests the decline in large vertebrates throughout the Caribbean occurred after 1600, fundamentally altering the functioning of coral reef ecosystems.

Jackson (1997) begins his argument by discussing how the Spaniards had depopulated Jamaica by the early 1600s. Spanish colonization was slow, with an estimated five thousand people in Jamaica when the English captured the island in 1655. As the Spanish had disrupted the agricultural base, the English turned to green turtles nesting on the nearby Grand Cayman Island to provide most of the meat for Jamaica until the 1730s. By the early 1800s, the green turtle fishery in the Cayman Islands was gone. In addition, McClenachan and colleagues (2010) note that during the 1800s, nearly every estate on Jamaica employed a fisher, many of which owned large nets deployed by dozens of slaves. Furthermore, the authors observed laws that existed in the 1800s regulating fishing. These laws suggest Jamaicans had already noticed declines in marine productivity.

According to McClenachan and colleagues (2010), pre-modern fishing techniques caused considerable changes to marine ecosystems. For instance, by the mid-1800s, fishing net technologies allowed for the capture of thousands of juvenile sharks and over 100 other species, while nearshore traps caught reef species indiscriminatingly. These pre-twentieth century fishing technologies removed ecologically significant quantities of fish. By 1881, only 15% of fish consumed in Jamaica could be caught locally (Jackson 1997). Despite these facts, an official report from 1901 was optimistic that more research could improve marine resource in the Caribbean. However, half a century later, the fisheries of Jamaica had not improved (Jackson 1997).

Current Data. Continuing with Jamaica, the decline noted in the 1880s continued through the 1990s, until Jamaican fisheries had suffered catastrophic changes in reef community composition (Hughes 1994). These changes in taxonomic composition are as follows: large, predatory species, such as sharks, jacks (Carangidae), snappers (Lutjanidae), triggerfish (Balistidae), and groupers (Serranidae) had disappeared, while turtles and manatees were extremely rare. Remaining fish, including herbivores such as parrotfish (Scaridae) and surgeonfish (Acanthuridae), were small. Overfishing on the northern coast of Jamaica had so sharply reduced adult stocks that fish populations relied heavily on larval recruitment from elsewhere in the Caribbean (Hughes 1994).

A more recent study performed by Hawkins sand Roberts (2004) calculated different fishing pressures of artisanal fishing on Bonaire, Saba, Puerto Rico, St. Lucia, Dominica, and Jamaica. The islands rank is listed in the previous sentence, with Bonaire having the smallest and Jamaica the largest fishing pressure. Artisan fishers provide a model for the kinds of impacts pre-Columbian foragers had on marine ecosystems.

Artisan fishers are small-scale, traditional fishers that make short trips close to shore. Moreover, their catches are mainly for local markets (Johnson 2005).

In Jamaica, Hawkins and Roberts (2004) studied 58 full time and 24 part time fishers, the highest of any other island in the study. These fishers used traps, hook and line, extensive spear, and net fishing techniques. The artisanal fishers targeted virtually everything larger than 10 cm, with the majority of each catch being small-bodied fishes. Large species of predators, such as snappers and groupers, were desirable but extremely uncommon.

The fishing intensity measure used by Hawkins and Roberts (2004) was the numbers of fishes divided by the size of the reef (km). They used direct observations in the different study areas to number fishes. The four commercially important families – groupers, snappers, parrotfish, and surgeonfish – showed order-of-magnitude abrupt declines across the different islands. Grunts (Haemulidae) were the only exception, with no clear pattern related to fishing pressure. They also observed that species diversity declined with increased fishing pressure. For example, a broad range of grouper and snapper species was present in the lightly fished islands of Bonaire and Saba, whereas the heavily fished island of Jamaica supported only the two smallest grouper species in any abundance.

Although these studies suggest the situation is dire, Jamaica has taken some steps to improve their fisheries. Between 2009 and 2010, the Jamaican government designated ten preserves across the country. The preserves create a ban on fishing to rebuild stocks. In addition, the Jamaican government called on local organizations to patrol the sanctuaries (Gordon 2011). One such sanctuary is Bluefields Bay, patrolled by the local Bluefields Bay Fishermen’s Friendly Society. A non-fishing zone allows fish to mature, reproduce, and “spill over” into permitted fishing zones, thus improving catches in terms of both size and time spent fishing (Jacks 2011). Sciberras and colleagues (2015) demonstrated the effectiveness of marine protected areas and found that no-take reserves had significantly higher biomass and diversity of targeted fish species within their boundaries relative to partially protected areas. Along with these measures, the baseline created from the Bluefields Bay faunal sample provides information helpful to the Fishermen’s Friendly Society as it combats the shifting baseline syndrome discussed previously. Moreover, the baseline offers data on the types and numbers of fishes previously inhabiting the bay.

Caribbean Fishes and their Vulnerability to Overexploitation

The vulnerability of fishes to overexploitation is an important topic for zooarchaeologists studying the interactions of ancient peoples and marine environments. Through an understanding of the characteristics that make fish populations more or less vulnerable, interpretations of zooarchaeological materials can be more robust. A way of looking at these characteristics comes from Roberts and Hawkins (1999). They observed six population attributes that increased the likelihood of overfishing leading to extirpation or extinction (Table 2).

Table 2. Attributes of Fishes that Increase Chances of Overexploitation and Reduce Populations, adapted from Roberts and Hawkins (1999).

Attribute	Description
Population Turnover	Long life span, slow growth rates, low natural mortality rates, and low production to biomass ratio
Reproduction	Old age or large size at sexual maturity, protandrous sex reversal, aggregated spawning at predictable locations, and density-dependent reproduction
Capacity for Recovery	Short dispersal, poor colonizing ability, strong density-dependent effects at settlement, and a response where mortality increases as numbers decrease
Range and Distribution	Small geographic ranges, high degrees of population patchiness, high habitat specificity, and habituating nearshore
Rarity	Small population size
High Trophic Position	Fishes occupying the top of the food web, specifically piscivores

The first attribute is *population turnover*, which equates to long life spans, slow growth rates, low natural mortality rates, and a low production to biomass ratio. The second attribute is *reproduction*, with features such as old age or large size at sexual maturity, protandrous (male-first) sex reversal, aggregated spawning at predictable locations, and density-dependent reproduction leading to imperilment. Third, is the *capacity for recovery*, including short dispersal (meaning low adult mobility and irregular or low larval recruitment), poor colonizing ability, strong density-dependent effects at settlement, and a response in which mortality increases as numbers decrease. The fourth attribute encompasses the *range and distribution* of fishes. Marine fishes with small geographic ranges are at higher risk to overfishing, relative to fishes with large ranges. Other factors of range and distribution leading to imperilment include high degrees of population patchiness, high habitat specificity, and habituating nearshore. The fifth attribute of vulnerability is *rarity* including a small population size. Finally, the sixth attribute is *high trophic position* or those fishes occupying the top of the food web, specifically piscivores (fish who feed on other fishes).

With consideration of these six attributes, I now focus on the behavioral ecology, characteristics, and life history of ten major food fishes observed in Jamaican marine environments. Jamaican artisan fishers divide their catches into two categories, “quality” and “common” (Sary et al. 2003). “Quality” fishes include six families, those being: groupers (Serranidae), snappers (Lutjanidae), goatfish (Mullidae), jacks (Carangidae), large grunts (Haemulidae), and pelagic predators such as mackerels (Scombridae). “Common” fishes include four families of reef species, including parrotfish (Scaridae), surgeonfish (Acanthuridae), angelfish (Pomacanthidae), and small grunts. I also discuss the porcupinefish (Diodontidae), because although the fish contains a fatal toxin, researchers find them in archaeological sites across the Caribbean. Table 3 demonstrates the basic characteristics, physical features, and life history of the fishes included in this discussion.

Serranidae. The Serranidae family, commonly known as groupers, seabasses, and hinds, includes 475 species in 67 genera, making them the largest fish family (Gibran 2007; Nelson 2006; Randall 1998). Serranids range in size from a few centimeters to 3 m long and 400 kg in weight. They are caught with hook-and-line, gill nets, trammel nets, bottom set longlines, spears, traps, and in trawls (Heemstra et al. 2003; Helfman et al. 2009). Most serranids are demersal (benthic or bottom-oriented) fishes living in tropical and subtropical areas (Heemstra et al. 2003). Serranidae prefer to live near rocky shores

Table 3. Jamaican Fish and the Characteristics, Behaviors, and Physical Features That Lead to Increased Vulnerability to Overfishing.

Taxa	Name	Size (cm)	Habitat	Vulnerable Trait
Serranidae	Grouper	60-121	Benthic, reef	High trophic position, habitat specificity, aggregated spawning, slow growth rate
Lutjanidae	Snapper	20-72	Mid-range, reef	High trophic position, aggregated spawning
Mullidae	Goatfish	12-38	Benthic	High trophic position
Carangidae	Jack	30-91	Offshore	High trophic position
Haemulidae	Grunts	28-45	Mid-range	High trophic position, habitat specificity
Scombridae	Tuna	30-213	Pelagic	High trophic position
Scaridae	Parrotfish	30-91	Shallow, reef	Complex reproduction strategies
Acanthuridae	Surgeonfish	15-38	Shallow, reef	Aggregated spawning
Pomacanthidae	Angelfish	20-45	Shallow, reef	Aggregated spawning

or coral shelves and in shallow water to 200 m deep (Gibran 2007).

Serranidae represent a large biomass, and maintain the role of top predators (Randall 1998), which is within the *high trophic position* attribute observed by Roberts and Hawkins (1999). Most serranid species live in solitary territories and feed on fish and crustaceans (Gibran 2007; Randall 1998), leading to high habitat specificity and falling under the *range and distribution* attribute. Groupers and seabasses use inertial sucking to draw prey into their large mouths and hold prey securely using thousands of small, rasp-like teeth that cover the jaws, tongue, and palate (Humann and DeLoach 2002; Wootton 1998).

The vast majority of serranids are sequential hermaphrodites, with most being protogynous, beginning life as female but later maturing to male (Heemstra et al. 2003; Humann and DeLoach 2002). Many groupers form large spawning aggregations at predictable times (Heemstra et al. 2003), which falls under the *reproduction* attribute of imperilment. Other characteristics that make groupers vulnerable to overfishing include their relatively slow growth rate (Heemstra et al. 2003). A slow growth rate makes them vulnerable under the *population turnover* attribute. The subfamily Epinephelinae are the most commercially important species, with the other two subfamilies (Serraninae and Anthiinae) consisting of mostly small species (Helfman et al. 2009). Groupers are among the most highly priced foodfishes, and are avidly sought by commercial, artisanal, and sport fishers (Heemstra et al. 2003) both today and in the past.

Lutjanidae. Similar to Serranidae are the Lutjanidae, commonly known as snappers. The family Lutjanidae contains 21 genera and 125 species mainly living in tropical and subtropical seas (Eschmeyer 2014). Lutjanids range from shallow coastal waters to considerable depths off continental slopes. Many other species reside in coral reefs and a few live in brackish estuaries (Johnson and Gill 1998). Snappers are mostly demersal and all are predators, usually active at night feeding on crustaceans and small fish (Humann and DeLoach 2002). Their feeding behaviors make them vulnerable to overfishing under the *high trophic position* attribute. Snappers have prominent canine teeth near the front of their jaw distinguishing them from similar appearing grunts (Humann and DeLoach 2002; Johnson and Gill 1998).

Mutton snapper (*Lutjanus analis*), dog snapper (*L. jocu*), and cubera snapper (*L. cyanopterus*) form large, transient spawning aggregations at traditional spawning grounds during consecutive late spring and early summer (DeLoach and Humann 2007). Their spawning behavior makes them vulnerable under the *reproduction* attribute. In addition, snappers include several of the Caribbean's most economically important reef fishes (Johnson and Gill 1998; Paris et al. 2005).

Mullidae. Goatfishes differ drastically from other marine and reef Perciformes by having developed hyoid barbels, and other specializations associated with the barbels (Gosline 1984). They commonly consume crustaceans using their chin barbels to flush prey (DeLoach and Humann 2007) giving them a *high trophic position* under Roberts and Hawkins (1999) attributes for vulnerability. The approximately 6 genera and 60 species of Mullidae occur in tropical to temperate shallow marine waters, and are observed around reefs and on sandy/muddy bottoms (Johnson and Gill 1998). Mullids are medium-size, nearshore predators (Helfman et al. 2009). According to Johnson and Gill (1998), goatfish are highly prized food fishes the world around, making them vulnerable to overexploitation.

Carangidae. The family Carangidae includes jacks, scads, and pompanos, containing 140 species in 32 different genera (Johnson and Gill 1998). They inhabit tropical to temperate seas and are important food fishes (Johnson and Gill 1998). A recognizable feature of carangids is their isolated first two anal spines, located in front of the fin (Johnson and Gill 1998). Carangid body-shape tends to be slightly to very compressed (Helfman et al. 2009). Most jacks have silvery sides, large eyes, and darkish backs and are thin-shaped with deeply forked tails that facilitate speed (Humann and DeLoach 2002).

According to Humann and Deloach (2002), jacks are strong-swimming predators of the open sea with only a few species seen near reefs on a regular basis. Their diet makes them vulnerable to overharvesting under *the high trophic position* attribute. However, other characteristics such as spawning at sea, make them less vulnerable to overfishing. Scads on the other hand, are smaller, generally cigar-shaped fishes that swim in small to large schools. Scads tendency to school makes these species vulnerable to overfishing under the *range and distribution* attribute.

Haemulidae. With 17 genera and 175 species, the family Haemulidae contains large circumtropical fishes (Johnson and Gill 1998). Most grunts are benthic predators, giving them a *high trophic position*, increasing their risks of imperilment. The common name comes from the sound they produce by grinding their pharyngeal teeth deep in their throats and amplified by the air bladder (Humann and DeLoach 2002; Johnson and Gill 1998).

Grunts are closely related to snappers, but are generally smaller and lack the snappers’ sharp canine teeth (Humann and DeLoach 2002). Most grunts are colorful, nocturnal feeders scavenging the sand flats and grass beds near reefs for crustaceans (Humann and DeLoach 2002). They undertake distinctive migrations from daytime resting to nighttime feeding areas (Helfman et al. 2009), making them vulnerable under the *range and distribution* attribute. Grunt populations are high on reefs in continental or insular shelf areas with large grass beds and sand flats, islands lacking these habitats see a decrease in grunt populations (Humann and DeLoach 2002). Therefore, depending on the reef environment, grunts can be additionally vulnerable under the *range and distribution* attribute.

Scombridae. Tunas and mackerels (family Scombridae) include some of the most important species in commercial and recreational marine fisheries (Helfman et al. 2009; Johnson and Gill 1998). Their extreme economic value has led to several tuna species being overfished throughout their range (Helfman et al. 2009). The family contains 15 genera and 49 species observed worldwide in tropical and temperate waters (Johnson and Gill 1998). Scombrids range in size from 50 cm to 3 m and most are schooling fishes (Helfman et al. 2009). Many species roam the open ocean, while a few reside near coastal waters (Johnson and Gill 1998). Those fishes residing near shore are the *Scomber, Scomberomorus,* and *Acanthocybium* genera (Helfman et al. 2009).

Physically, scombrids are made for the pelagic zone. Johnson and Gill (1998) agree that scombrids are literally “swimming machines,” with every aspect of their external morphology designed for efficiency. Even a scombrids’ muscles are suited to continuous activity. Mackerels are long, silvery predators that only occasionally pass over reefs (Humann and DeLoach 2002) making them vulnerable to overharvesting under the *high trophic position* attribute. Distinguishing characteristics include two dorsal fins and a series of fins, called finlets, between the second dorsal fin, the anal fin, and the tail (Humann and DeLoach 2002).

Scaridae. A major common fish are the scarids (parrotfish) with 79 species among 10 genera (Choat and Bellwood 1998). Fourteen species of scarids reside in the

Western Atlantic and Caribbean (DeLoach and Humann 2007). In general, scarids are commonly observed on or near coral reefs, and within shallow waters to depths of 30 m (Bellwood 1994; Bellwood and Choat 1989; Humann and DeLoach 2002). They range in size from small (8 to 10 cm) to very large individuals (1 m) (Westneat 1999). They typically feed on algae and materials scraped from rocks and dead coral, sea grasses, and small bits of live coral with invertebrate prey (Bellwood 1994; Bellwood and Choat 1989; Westneat 1999).

Parrotfish teeth are fused in most species to form a pair of beak-like plates, with some species having clearly visible teeth (*Sparisoma*) and others with no visible teeth (*Scarus*) (Westneat 1999). In addition, a few genera (*Nicholsina*) have free, incisor-like teeth present externally in the upper and lower jaws (Bellwood 1994; Bellwood and Choat 1989). Pharyngeal dentition grinds the dead coral and algae into a fine slurry that is then digested (Bellwood 1994; Bellwood and Choat 1989). Parrotfish appear to have rapid growth rates, reaching maturity in 2 to 3 years and with a life expectancy of 7 to 10 years (Choat and Bellwood 1998), the opposite of the *population turnover* and *reproduction* attributes of vulnerability, yet more information about spawning changes this initial impression.

Choat and Bellwood (1998) provide details on the complex reproductive strategies of parrotfishes. They define a juvenile phase, initial phase and terminal phase of each individual fish. Juveniles of both sexes have a distinct color pattern. As juveniles mature, they take on the coloring of initial phase individuals. Initial phase coloring is often drab grays, reds, and browns. Most parrotfish in the initial phase are female, but some primary males exist with similar coloring to the females. Eventually, initial phase individuals change color, taking on terminal phase coloration. For females, the shift to terminal phase means becoming male. Females that change to male are known as secondary males, primary males just change color. Westneat (1999) suggests two spawning behaviors observed for scarids, one being an aggregation of initial-phase and terminal-phase fish, with individual groups of fish dashing upward from the aggregation and releasing eggs and sperm at the peak of the upward dash. The other pattern consists of pair-spawning between a terminal male and the initial phase females in his territory. The complex reproductive strategies discussed above lead to imperilment under the *reproduction* attribute, as many factors can disrupt the pattern.

Sparisoma viride. One species of Scaridae, *Sparisoma viride,* commonly known as the stoplight parrotfish, is the most frequently identified parrotfish at archaeological sites in the West Indies (Newsom and Wing 2004) and among the most common members of the Caribbean reef community (DeLoach and Humann 2007). *S. viride* is a large generalist herbivore that is common on Caribbean coral reefs from Bermuda to Brazil (Bruggemann et al. 1994). *S. viride* is a protogynous (female to male) hermaphrodite and demonstrates full sexual dichromatism (males are one color, females are another) (Bruggemann et al. 1994). On shallow reefs, stoplight parrotfish tend to gather in groups of initial and terminal phase individuals. On the deeper reef (3.2 to 25 m depth) terminal phase males maintain and defend permanent territories containing 3 to 7 initial phase females (Bruggemann et al. 1994). A small territory can lead to imperilment under the *range and distribution* attribute but other characteristics such as quick growth rates appears to keep their numbers high. Stoplight parrotfish are diurnal, spending 70 to 90 percent of their time foraging (Bruggemann et al. 1994).

Keegan and Carlson (2008) discuss how the stoplight parrotfish can be caught with hook and line. However, hook and line fishing does not account for their high numbers archaeologically, relative to carnivorous fishes caught the same way. Experiments with Haitian-style basketry traps indicate that stoplight parrotfish are the most common species captured and that other herbivorous fishes (such as surgeonfish) were also caught with the traps. This experimental data offers a reason for the high numbers of parrotfish in archaeological deposits. Another line of evidence suggesting pre-Columbian foragers may have preferred parrotfish comes from the Taíno word for them. A striped parrotfish, most likely the stoplight parrotfish, was called a "*buyón*" meaning "esteemed" (Keegan and Carlson 2008:54-55).

Acanthuridae. Surgeonfish contain 70 species in six genera that occur in all tropical seas. Surgeonfish range in size from about 20 cm to 100 cm, and range from drab to brightly colored. Acanthurids have deeply compressed, disc-like bodies and small mouths with incisor-like teeth suited for nibbling and scraping small animals and plants from rocks and corals (Johnson and Gill 1998).

The common name derives from a modified body scale into a scalpel-like spine on either side of the caudal peduncle (base of the anal fin to the base of the caudal fin). The surgeonfish uses the spine to inflict deep slashes on a victim (DeLoach and Humann 2007; Johnson and Gill 1998). The spines are attached by a ligament to the spinal column and cannot be voluntarily erected (DeLoach and Humann 2007). Surgeonfish feed continually throughout the day on a wide variety of plants (DeLoach and Humann 2007).

The three most common surgeonfishes in the Caribbean are the blue tang (*Acanthurus coeruleus*), ocean surgeonfish (*A. bahianus*), and doctorfish (*A. chururgus*). Blue Tang often feed in large aggregations, which include other surgeonfishes and some midnight parrotfish (*Scarus coelestinus*). They reproduce in pairs within resident spawning aggregations (DeLoach and Humann 2007). Blue Tang's predictable spawning behavior makes them vulnerable to overfishing under the *reproduction* attribute.

Pomacanthidae. Angelfish (family Pomacanthidae) contain 9 genera and 74 species of circumtropical, brightly colored reef fishes (Johnson and Gill 1998). A well-developed preopercular spine characterizes angelfish and differentiates them from similar butterflyfishes (DeLoach and Humann 2007; Helfman et al. 2009; Johnson and Gill 1998). Pomacanthids are round laterally compressed and have a continuous dorsal fin (DeLoach and Humann 2007). The genera *Holacanthus* and *Pomacanthus* feed regularly on sponges, while others rely on algae, and intertidal invertebrates (DeLoach and Humann 2007).

DeLoach and Humann (2007) discuss the reproductive behavior of angelfish and note that is largely unknown and what little is known is often contradictory. Two facts are certain: they all spawn at sunset during limited periods, and spawning occurs between one male and one female. The pomacanthids spawning behavior may lead to imperilment under the *reproduction* attribute of Roberts and Hawkins (1999) study. *Holacanthus* and two species of *Centropyge* are protogynous hermaphrodites that typically live in harems with the largest female transitioning to male when the dominant male dies. The dominant male pomancathid, mates exclusively with one to four females living in his territory. He patrols the boundaries of his territory regularly and visits each female. Other species are considered monogamous and many do not change sex (DeLoach and Humann 2007). However, Helfman and colleagues (2009) note the dramatic ontogenetic color changes seen in several species that begin with similar but striking patterns as juveniles and later change to species specific patterns at maturation. Angelfishes are among the few marine species where hybrids have been discovered (Helfman et al. 2009).

Diodontidae. Although not on the list of quality or common fishes, I explore the life history and behavioral ecology of the Diodontidae, or porcupinefish. Porcupinefish represent a unique case within the Bluefields Bay collection and wider Caribbean as they contain a deadly nerve toxin called tetrodotoxin. Keegan and Carlson (2008) propose porcupinefish may have been used in ritual practices to produce a trance-like state. On the other hand, the Taíno knew how to eat bitter manioc, which is poisonous unless properly processed. Therefore, Keegan and Carlson (2008) suggest the Taíno could have also learned how to process porcupinefish.

Matsuura and Tyler (1998) discuss how porcupinefish are similar to pufferfish, but their spines are much larger and stronger. Porcupinefish have fused maxillae and dentaries into one upper and lower jawbone. Diodontidae tend to be slow swimmers and are mostly observed in shallow tropical and temperate coastal waters. Porcupinefish, like pufferfish, can inflate their bodies to protect themselves from all but the largest of predators, such as tunas, dolphins, and marlins.

To explore the topic of vulnerability further, there are several differences between pelagic species and reef species of marine fishes. One difference is that large pelagic species often grow quickly, mature early, and forage over large ocean areas. These species rarely live longer than four to five years, meaning the population and biomass turn over rapidly. Large coral reef fishes are sedentary by comparison and depend on reef resource rather than dispersed food. They are relatively slow growing, slow maturing, and may live for decades. Many reef species also change habitat preference as they mature. These life history traits of reef fishes are characteristic of imperiled fish species in many habitats. In summation, reef fishes are locally vulnerable to overexploitation in contrast with pelagic fishes (Helfman 2007).

The characteristics, behaviors, and life history of fishes discussed in the above paragraphs, affect the fish's vulnerability to overexploitation by humans. Human predation has caused declines in the abundance and distribution of marine resources throughout time, both directly and indirectly. Helfman (2007) describes the modern indirect causes of fish population declines as habitat modification and loss, degraded water quality and introduction of alien species. Modern direct causes of declines include overfishing, trade in live fishes, and aquaculture or farmed fisheries.

Fishing and overfishing affect more than just population size. Overfishing also affects a fish's behavior, evolution of life history traits, food webs, and ecosystem interactions (Helfman 2007). Helfman suggests we view humans as predators, and place them in the world of fishes. Archaeologists have already adopted such an idea and are well aware of the impacts humans have had on prehistoric ecosystems (Grayson 2001).

The only way to study declines in prehistoric fish populations requires archaeological data and investigation, including the use of initial occupation periods (lower levels) of archaeological sites as “baseline” data. This baseline data is then used to extrapolate the kinds of impacts human have had on marine resources and provide insights into the management of these resources.

The data I generate using the Bluefields Bay faunal sample provides baseline data for the area and from it, I can suggest strategies for the management of the local fishery. These strategies can in turn, aid the Fisherman’s Friendly Society. Based on the data presented in the above paragraphs, pre-Columbian catches included large carnivorous species of groupers (Serranidae) and snappers (Lutjanidae) (Carlson and Keegan 2004; Steadman and Jones 2006; Wing and Wing 2001). A return of such species in terms of both abundance and size would indicate improvements to the Bay’s stock. In addition, an increased diversity of grouper and snapper species, especially the larger species, would also indicate improvements (Hawkins and Roberts 2004).

In summary, I have demonstrated that understanding the kinds of impacts humans have had on marine ecosystems requires both historic and archaeological data. From these types of data, we find that small-scale societies prior to European contact changed the relative abundance, sizes, and composition of Caribbean fisheries. In addition, these changes continued after Europeans began settling the islands. Furthermore, I presented data specific to Jamaican fishes, discussing how their life history and behavioral ecology can either insulate or expose them to overexploitation and possible extinction. My research at Bluefields Bay represents zooarchaeological analysis that can lead to understanding prehistoric changes, inform modern concerns of overfishing, and optimistically provide information to aid in reversing these trends. In the next chapter, I discuss the analytical and theoretical methods I use to fill gaps in our understanding of how the Bluefields Bay Taíno altered their local marine ecosystem.

CHAPTER 4

METHODS OF ZOOARCHAEOLOGICAL ANALYSIS: SITE DESCRITPION AND THE COLLECTION OF PRIMARY DATA

The methods I use in analyzing the Bluefields Bay faunal sample pertain to my hypothesis that Taíno foragers depressed high-ranked fishes in the local marine ecosystem. Testing my hypothesis requires the generation of primary data, such as the identification and quantification of the Bluefields Bay faunal sample. In the following paragraphs, I discuss the raw data collected from the Bluefields Bay site, along with details concerning the identification and quantification of the faunal sample.

Bluefields Bay Site Description and Field Work

The Bluefields Bay site is located near the town of Belmont, in the Westmoreland Parish, located on the western end of the island (Figure 3). Excavations took place during two separate field sessions in the winter of 2011 and 2012 with six units exposed. Heidi Savey lead excavations of Units 1 through 4 in January of 2011. Dr. David Byers lead excavations of Units 5 and 8 in January of 2012. All units were excavated using trowels, except for the most compacted parts of the site where the shell-packed sediment had to be loosened by gentle use of shovels and picks. Researchers maintained vertical control using 10 cm arbitrary levels. Depths were taken using an established subdatum 1 for Unit 8 and subdatum 2 for Unit 5. Elevations were converted to a 0 cm datum (or surface) in

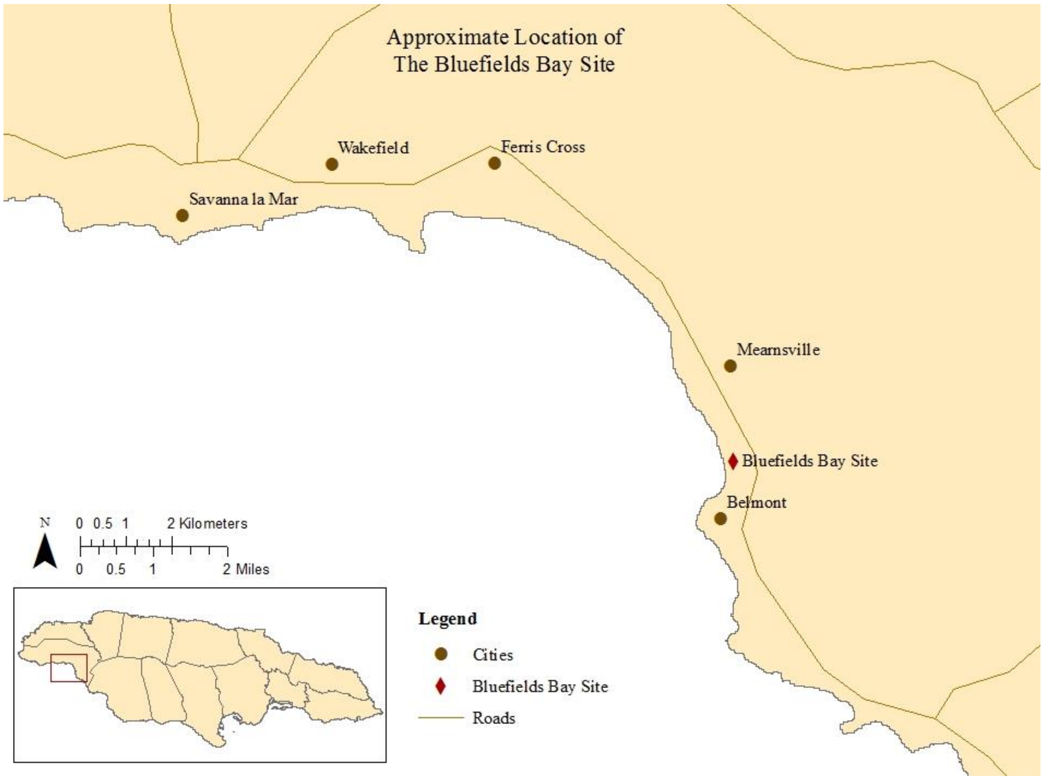


Figure 3. Approximate location of the Bluefields Bay Archaeological Site.

the lab. All excavated sediments were screened through 1/8 inch hardware cloth.

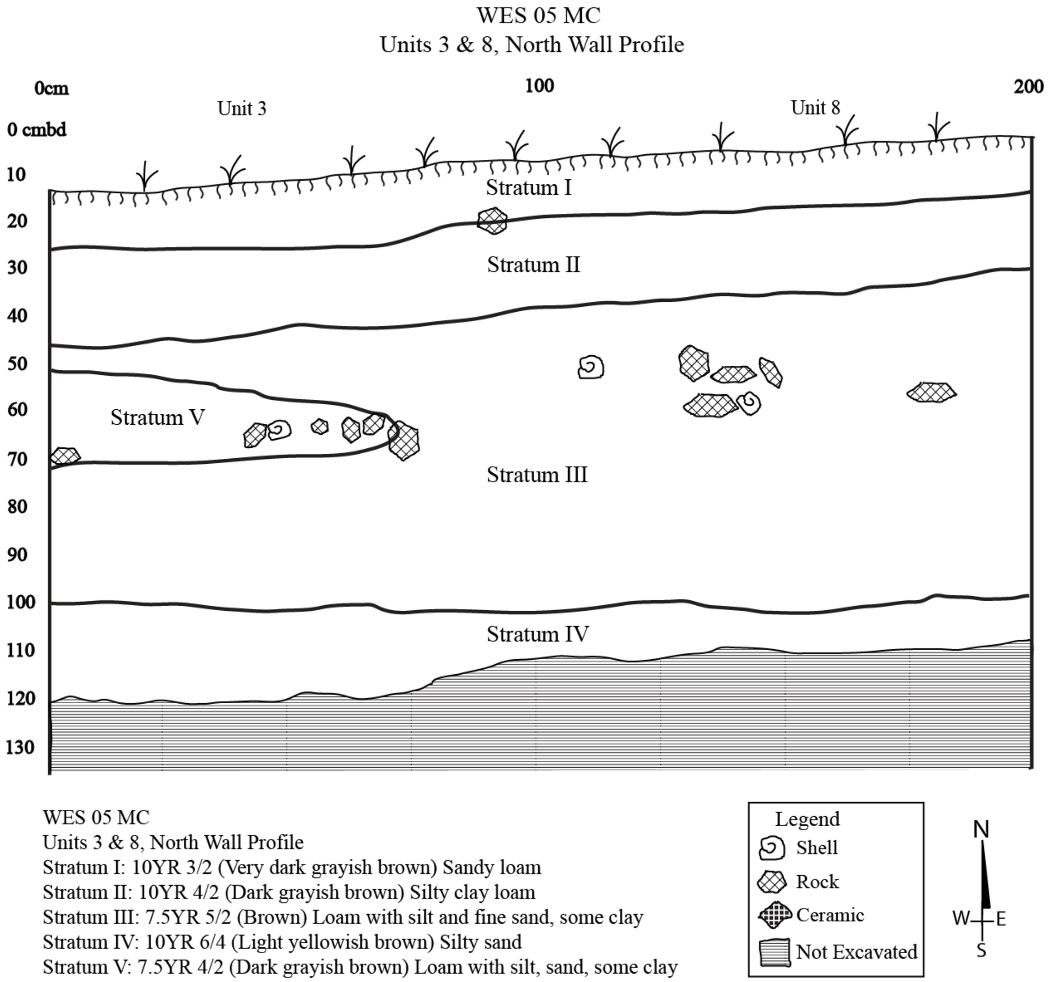
The faunal sample I analyzed came from Units 5 and 8. Provenience issues with faunal remains from the 2011 excavation lead Dr. Byers and myself to eliminate units 1 through 4 from the analysis. Specifically, during cleaning and curation several unit/level bags were combined into single lots. Moreover, which unit/level bags were accidentally combined is unknown. Unit 5 excavations took place between January 2-11 and this unit was excavated to a depth of 110 cm below datum. Unit 8 excavations were conducted during the same period and to the same depth of 110 cm below datum. Table 4 shows the total count of bones and ceramics observed in Units 5 and 8 by level.

Table 4. Raw Data from the Bluefields Bay Site: Artifact Counts for Units 5 and 8.

Unit 5	Bone	Shell	Unit 8	Bone	Shell	TOTAL BONE	TOTAL SHELL
Level 0	0	0	Level 0	3	15	3	15
Level 1	14	92	Level 1	147	461	161	553
Level 2	768	955	Level 2	475	749	1243	1704
Level 3	821	634	Level 3	909	595	1730	1229
Level 4	1319	542	Level 4	1191	574	2510	1116
Level 5	2119	707	Level 5	2354	2062	4473	2769
Level 6	1462	890	Level 6	1095	568	2557	1458
Level 7	1270	1286	Level 7	1912	844	3182	2130
Level 8	247	392	Level 8	718	479	965	871
Level 9	243	275	Level 9	197	165	440	440
Level 10	172	141	Level 10	248	116	420	257
Level 11	7	6	Level 11	70	26	77	32
TOTAL	8442	5920		9319	6654	17761	12574

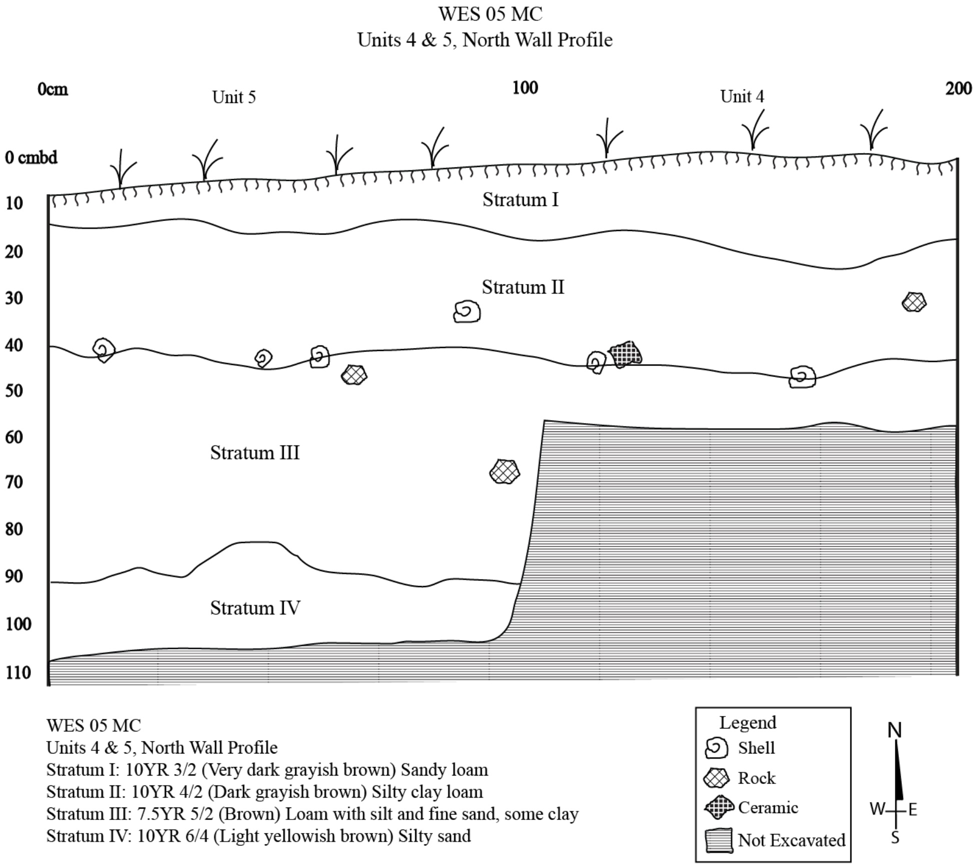
Units 3 and 8 contain five strata (Figure 4), all strata contained cultural material, including shells, ceramics, lithics, and bone, except Stratum IV. Stratum V is an inset in Unit 3 that does not extend into Unit 8 and does not influence the faunal sample I analyzed. I provide details pertaining to Munsell Soil Color and soil descriptions in Figure 4. Units 4 and 5 contain four strata (Figure 5). All strata contained cultural material, except Stratum IV. Again, details concerning Munsell Soil Color and soil descriptions are presented in Figure 5.

Three radiocarbon (^{14}C) dates were obtained from individual fish vertebra. Those vertebrae derive from Unit 3, Levels 1, 5, and 9. The radiocarbon results suggest the Taíno occupied the site for nearly 500 years. I present the details in Table 5. Level 1 radiocarbon dates correspond to Stratum I, while Level 5 and 9 correspond to Stratum III.



WES 05 MC
Units 3 & 8, North Wall Profile
Stratum I: 10YR 3/2 (Very dark grayish brown) Sandy loam
Stratum II: 10YR 4/2 (Dark grayish brown) Silty clay loam
Stratum III: 7.5YR 5/2 (Brown) Loam with silt and fine sand, some clay
Stratum IV: 10YR 6/4 (Light yellowish brown) Silty sand
Stratum V: 7.5YR 4/2 (Dark grayish brown) Loam with silt, sand, some clay

Figure 4. North Wall Profile Map of Units 3 and 8.



WES 05 MC
Units 4 & 5, North Wall Profile
Stratum I: 10YR 3/2 (Very dark grayish brown) Sandy loam
Stratum II: 10YR 4/2 (Dark grayish brown) Silty clay loam
Stratum III: 7.5YR 5/2 (Brown) Loam with silt and fine sand, some clay
Stratum IV: 10YR 6/4 (Light yellowish brown) Silty sand

Figure 5. North Wall Profile Map of Units 4 and 5.

Table 5. Radiocarbon Analysis Results for the Bluefields Bay Site.

Level	^{14}C Age	Cal Age BP	Cal Age AD
1	870 ± 46	450-610	AD 1340-1500
5	1200 ± 47	680-890	AD 1050-1270
9	1172 ± 32	670-850	AD 1100-1280

Faunal Analysis

Analyzing archaeofaunal assemblages involves first identifying, and then quantifying the remains (Daly 1969; Gilmore 1949, Olsen 1971). The identification process begins with sorting the assemblage into classes (i.e. fish, mammal, bird, etc.). I received aid from Martin Welker and Sarah Potter, two undergraduate students, in this initial sorting phase. Classes of animals besides fish and mammal identified include birds (Aves), sea mammals (Carnivora), and crabs (Crustacea). In addition, reptiles (Reptilia) such as iguanas and snakes, and sea turtles (Cheloniidae) were also identified. Birds and reptiles were identified using references in *Fish, Amphibian, and Reptile Remains from Archaeological Sites* (Olsen 1968). I also used several specimens of reptiles and birds found in USU’s zooarchaeological comparative collection for identification.

After the initial taxonomic class-level sorting, I organized the fish material into recognizable elements. I based my determination of elements on clear landmarks using Cannon (1987). Certain elements had several landmarks to use when pieces were fragmented, although others had very subtle landmarks. This step required attention to detail and a thorough knowledge of ichthyofaunal osteology.

Next, I identified as many specimens as possible to lower taxonomic levels of family, genus, or species. However, there is a hierarchy of elements useful for verifying taxon since some characteristics are shared across Osteichthyes and others are more diagnostic (Colley 1990). Although fish skeletal morphology is highly variable, the jawbones (dentary, maxilla, premaxilla, articular and quadrate), preoperculum, operculum, cleithrum, hyomandibular, and certain neurocranial bones (vomer, parasphenoid, supraoccipital, frontal, otolith, ethmoid, and basioccipital) can help in achieving taxonomic identification (Colley 1990:212-213). Colley (1990) notes that most fin rays, pterygiophores, and ribs are undiagnostic.

I created the comparative collection used in the study, with the assistance of Dr. Dave Byers and other students during the winter (2012-2013) field session in Belmont, Jamaica. Fish for the collection were purchased from local fishers and macerated on site. I present a list of fishes in the comparative collection in Table 6. I also used several online comparative collections, in particular the Florida Museum of Natural History's Pictorial Skeletal Atlas of Fishes (http://www.flmnh.ufl.edu/fishatlas/content/default.html).

Table 6. USU's Caribbean Fishes Comparative Collection Specimens.

Specimen #	Family	Species	Common Name
001	Lutjanidae	*Lutjanus jocu*	Dog Snapper
002	Sparidae	*Calamus calamus*	Saucereye Porgy
003	Acanthuridae	*Acanthurus coeruleus*	Blue Tang
004	Carangidae	*Caranx crysos*	Jack Blue Runner
005	Carangidae	*Caranx crysos*	Jack Blue Runner
006	Holocentridae	*Holocentrus adscensionis*	Squirrel Fish
007	Scaridae	*Sparisoma viride*	Stoplight Parrotfish
008	Serranidae	*Epinephelus guttatus*	Red Hind
009	Ostraciidae	*Lactophrys polgonia*	Honeycomb Cowfish
010	Ostraciidae	*Lactophrys polgonia*	Honeycomb Cowfish

Table 6. Continued

Specimen #	Family	Species	Common Name
011	Haemulidae	*Haemulon plumieri*	White Grunt
012	Haemulidae	*Haemulon plumieri*	White Grunt
013	Pomacanthidae	*Pomacanthus arcuatus*	Gray Angelfish
014	Balistidae	*Balistes vetula*	Queen Triggerfish
015	Balistidae	*Balistes vetula*	Queen Triggerfish
016	Pomacanthidae	*Holacanthus tricolor*	Rock Beauty
017	Acanthuridae	*Acanthurus bahianus*	Ocean Surgeonfish
018	Pomacanthidae	*Pomacanthus arcuatus*	Gray Angelfish
019	Scaridae	*Sparisoma chrysopterum*	Redtail Parrotfish
020	Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper
021	Scaridae	*Scarus taeniopterus*	Princess Parrotfish
022	Scaridae	*Sparisoma rubripinne*	Redfin Parrotfish
023	Haemulidae	*Haemulon flavolineatum*	French Grunt
024	Lutjanidae	*Lutjanus synagris*	Lane Snapper
025	Balistidae	*Balistes vetula*	Queen Triggerfish
026	Gerreidae	*Gerres cinereus*	Yellowfin Majarra
027	Mugilidae	*Mugil curema*	White Mullet
028	Mugilidae	*Mugil curema*	White Mullet
029	Holocentridae	*Holocentrus adscensionis*	Squirrel Fish
030	Diodontidae	*Diodon hystrix*	Porcupinefish

Identifying Characteristics of the General Fish Categories

Osteichthyes. I identified a general fish category termed Osteichthyes (bony fishes) that includes those elements unidentified to a lower taxonomic level. The majority of such elements include fin rays, spines, and vertebrae. Fin rays and spines include dorsal, epipleural, interhaemal, anal, and caudal variations. Fin rays often appear similar in size and shape from one taxon to the next. For vertebrae, individual fish contain one atlas vertebra, several thoracic, precaudal, and caudal vertebrae, one penultimate vertebra, and one ultimate vertebra. Atlas vertebrae have distinctive fossa that attach to the basioccipital and exoccipital at the base of the neurocranium. Thoracic vertebrae have only the neural spine, while the precaudal vertebrae have a neural spine and two haemal spines. Caudal vertebrae have a joined haemal spine extending farther into the fish than thoracic vertebrae. The penultimate vertebrae have both a cranial and caudal articular surface with a shortened haemal spine and an elongated neural spine cranial to caudal. Ultimate vertebrae have only a cranial articular surface and a split caudal surface to accommodate the fish's tail.

Chondrichthyes. Chondrichthyes (cartilaginous fishes) is the other general category of fishes I identified, and is comprised of fishes with skeletons made of cartilage rather than bone. This means vertebrae and teeth are the few elements that survive in archaeological deposits. The taxon includes sharks, skates, and rays. Cartilaginous taxa have vertebrae markedly different from bony fishes. Chondrichthyes vertebrae lack both the neural and haemal spines as well as a neural canal, giving the vertebrae a smooth, rounded appearance.

Identifying Characteristics of Ichthyofauna

Maxillae. I identified maxillae by the size and shape of the mesial end, focusing on the external and internal processes, as lateral ends were usually broken. For jacks (Carangidae), the internal process points mesially and is slightly detached with a second flare of bone above it. The palatine process is thick and contains a noticeable lump behind the internal process. Along the superior edge of a jack's maxillae, behind the proximal end, is a sharp, spike of bone which is absent in other families. For groupers

(Serranidae) maxillae, the premaxillary sulcus is deeply grooved, while the internal process is thick and rounded, with a pointed process curving towards the premaxillary sulcus. The palatine process is also thick and rounded but pinches out towards the internal process. The external process is flat and pointed. Snapper (Lutjanidae) maxillae have an internal process that flares at the top and a bulbous area at the bottom with a small groove between the two, and a narrow premaxillary sulcus. The external process is flat and wavy. The palatine process is narrower than groupers but shaped similarly. Grunt (Haemulidae) maxillae have a narrow premaxillary sulcus with a shorter, thicker internal process and a longer, thinner external process. The palatine process is rounded and thicker than either process. Parrotfish (Scaridae) maxillae have a different shape from the previously mentioned families. Parrotfish have internal processes that are longer and more curved than the external process. The external process swoops cranially and the premaxillary sulcus is notched rather than grooved. Several parrotfish maxillae were complete meaning I could identify a caudal process that pointed posteriorly and note an absence of a maxillary process.

Dentaries. Similar to the maxilla, the dentaries from the Bluefields Bay collection have broken and/or missing lateral ends, I therefore focused on mesial ends for identification. In addition, as dentaries and premaxillae hold the teeth, features of tooth attachment aid in identification. Osteichthyes usually develop only one set of teeth (monophyodont), rather than developing several that are then replaced as they wear (polyphyodont) as seen in cartilaginous fishes. One large tooth protruding from the mesial labial edge, not in line with the other teeth sockets identifies wrasse (Labridae) dentary. For jacks, the dentaries have a single row of comb-like teeth along the superior edge, resulting in a roughened band rather than sockets. Carangids have a single mental foramen located on the mesial buccal side and several foramina located on the ventral buccal side. Groupers have multiple rows of small sockets that dip down on the mesial lingual side and appear similar in size along the superior edge, except for two large teeth on the mesial buccal end. When teeth are present, they are thin, needle-like and point inwards until they crest along the superior edge, at which point they turn upwards. For snappers, teeth sockets are round, with concentric rings around each hole. The sockets begin large mesially and diminish in size laterally. The inferior medial edge of snapper dentaries curve posteriorly then swoops out laterally. Mental foramina have set patterns used to determine the species lane snapper (*Lutjanus synagris*) and dog snapper (*L. jocu*). The dentary of lane snappers have a deep pit on the external wall, while dog snapper have a groove in the same location. Grunts have a lattice-like external wall, similar to other elements in the body that provides easy identification of specimens to this taxon. They also have thin, pointed teeth with a small concentration on the mesial superior end. Parrotfish dentaries have a zipper-like surface on the mesial end that locks the left and right dentary together. In addition, parrotfish have a horn-like structure on the anterior edge pointing caudally. Genus *Sparisoma* have teeth on the superior edge, while *Scarus* have a beak-like single surface tooth. Finally, porgies (Sparidae) have large rounded teeth that decrease in size laterally and have three to four sharp teeth on the mesial end.

Premaxillae. Premaxillae, similar to the other jawbones mentioned, have broken lateral ends and I therefore focus on mesial features including the shape of the ascending and articular processes. Jack premaxillae have separate ascending and articular processes higher up on the mesial end than groupers and snappers. Jacks also have a flared postmaxillary process when present. Grouper premaxillae have a thick articular process that is separate from the ascending process. Similar to the dentary, serranid teeth sockets are similar in size along the inferior edge. In addition, grouper premaxillae have two large teeth on the mesial buccal end. For snapper, teeth sockets are round with concentric rings and arranged in one row growing smaller laterally. However, the largest tooth hole is the third from the mesial end. I used features of the articular process to determine species. Lane snappers have a bulge at the distal end, while mahogany snapper (*Lutjanus. mahogoni*) have a large angle between the articular process and ascending process and dog snapper have a narrow angle. Grunts show a tightly fused articular and ascending process making the area one surface rather than two separate processes. Haemulids also have a slight lip of bone on the mesial/labial side before becoming the fused ascending process. Grunt teeth sockets align in a single row, but a concentration exists on the mesial end. Finally, grunts have one mental foramen close to the mesial edge. Parrotfish have a smooth mesial surface as compared to the dentary mesial surface. A horn-like feature exists on the anterior edge facing caudally which can be used to determine species. Redfin parrotfish (*Sparisoma rubripinne*) have three spines, one on lingual/medial end, and two buccal/laterally. Stoplight parrotfish (*S. viride*) have one spine on buccal/lateral end. Redtail parrotfish (*S. chrysopterum*) have one spine on the lingual/mesial surface that looks similar to a tiny tooth. Too often, the spikes used to identify species were broken or missing making species identification limited to one level in Unit 8. Triggerfish

(Balistidae) premaxillae have a grooved articular process on the mesial edge. Multiple teeth reside inside the bone, making identification possible from all the loose teeth. Porgy premaxillae have rounded, bubble-like teeth growing in multiple rows and declining in size laterally. In addition, the ascending and articular processes are fused together.

Angulars. Angulars, as part of the neurocranium, can help identify certain taxa in the following ways. Jack angulars have no inferior foramen; instead, they have a groove between the quadrate facet and retroarticular. The medial side has two fossae under the quadrate facet. The grouper angular has a thick coronoid process, with the process slightly more detached then in other families. The inferior crest is also thick and raised, coming off the postarticular process, while the inferior process comes to a point. The inferior foramen of serranids is small. Furthermore, the retroarticular is often separated from the main body of the articular and missing in much of the Bluefields Bay sample. For snapper, the angulars have a deep groove that extends form the postarticular process and ends in an inferior foramen. The medial side has one fossa under the quadrate facet and the inferior process ends with a thickening of the bone, rather than a point like in groupers. I used angulars to determine species, such that the dog snapper has an inferior foramen that is shallower than the mahogany snapper and lane snapper. The lane snapper angular has the deepest groove and the mahogany snapper has a lip covering the inferior foramen. Grunt angulars have an open facing quadrate facet. The postarticular process is small and rounded compared to the other families. Similar to other elements in grunts, the anterior crest has a connective bone creating a lattice-like structure. Parrotfish have angulars with a bar-like quadrate facet, rather than hook-like in most other families. They also have an additional process perpendicular to the anterior process beginning behind the retroarticular surface. The retroarticular surface flares into a crest. Porgy angulars have a quadrate facet split into two, one facing medially and the other laterally with the lateral facet larger than the medial facet. Angelfish (Pomacanthidae) have angulars with a highly rounded postarticular process. The retroarticular is slightly pointed medially, and the prearticular fossa is absent.

Hyomandibulars. Hyomandibulars are part of the hyoid arch that connects the dentary to the hyoid. Jack hyomandibulars have sphenotic facets and opercular processes that align. In addition, carangids have rounded opercular processes in line with preopercular grooves. For snapper, the hyomandibular has a peak of bone between the opercular process and the pterotic facet and a thick anterior crest. Grunt hyomandibulars have a rounded sphenotic facet and opercular process, while the pterotic facet is flattened. They also have a tube-like hyomandibular foramen. Parrotfish hyomandibulars have a pterotic facet that is rounded like a saddle, while the sphenotic facet is bar-shaped similar to the quadrate facet in the angular.

Quadrates. Most quadrates have a thicker, larger lateral condyle with a smaller, pointier mesial condyle. Grouper quadrates have two deep fossae on the lateral surface, while other families have a smooth lateral surface. The preopercular groove is deep and the ectopterygoid margin is thicker on the mesial side, but still attached to both. Grunt ectopterygoid margins are attached to only the lateral condyle rather than both the lateral and mesial condyles. The ectopterygoid margin is also shaped differently by thickening at the superior edge. Parrotfish quadrates are the opposite with the ectopterygoid margin attaching to only the mesial condyle. Triggerfish quadrates have a preopercular process that separates from the ectopterygoid margin. Similar to parrotfish, the ectopterygoid margin attaches to the mesial condyle.

Vomers. Vomers form the anterior part of the roof of the mouth. Grouper vomers have sockets for teeth that look very similar to their dentaries and premaxillae. The sockets form a V-shape, following the cranial edge of the vomer. Snappers, however, have a roughened T-shaped design with the top of the T along the cranial edges and the length of the T drawn caudally to the parasphenoid process. Grunt vomers have a smoother cranial end with no roughened areas for teeth but rather a lip along the edges. Moreover, they lack a dorsal crest making the dorsal side flat. Jack vomers have a roughened cranial area similar to the groupers, but with much smaller sockets.

Pharyngeal Plates. The pharyngeal arch is located in the throat of bony fishes, and similar to snakes, allows the fish to hold on to and swallow prey. In addition, the pharyngeal jaw has evolved many specializations depending on the type of resources used by the species (Map of Life 2015). Parrotfish have unique pharyngeal plates made for crushing coral; the upper pharyngeal plates are rectangular with rounded edges, while the lower pharyngeal plate is flat with a long ventral process. Wrasses have T-shaped pharyngeal plates with rounded teeth covering the grinding surface.

Others. Other elements useful in the identification process included taxa specific spines and some parasphenoids. Porcupinefish (Diodontidae) are covered in spines similar to puffer fishes. I easily identified the spines to this taxon, because they are three pronged. I identified no other elements to porcupinefish. The other spine identifiable to family is the primary dorsal spine of the triggerfish, which has a roughened anterior edge. Grunt parasphenoids have a flat posterior surface between the basioccipital and alar processes. Parrotfish parasphenoids have two concave grooves on the posterior surface.

Quantification of Faunal Materials

Quantification allows for the interpretation of archaeofaunal assemblages (Lyman 2008). Two basic units I tallied were the number of identified specimens (NISP) (Grayson 1979, Klein and Cruz-Uribe 1984) and the minimum number of individuals (MNI) (Howard 1930; Stock 1929; White 1953). NISP measures the total number of specimens identified, while MNI estimates the minimum number of individuals. Both NISP and MNI data represent assemblage level data.

NISP, according to Lyman (2008), is the most fundamental unit for tallying faunal remains. It represents the number of all specimens identified to skeletal element, including bones, teeth, and fragments. NISP requires the researcher to identify every specimen possible and then tally how many specimens for each taxon. Lyman (2008) suggests NISP is an observed measure because it is a direct tally and cumulative. In addition, he discusses various issues with NISP, the major one being the interdependence of skeletal remains inflating NISP values. By assuming all specimens came from different individuals, NISP is essentially an estimate of the maximum number of individuals present.

Stock (1929) and Howard (1930) first used MNI to alleviate some of the difficulties with NISP. They defined MNI as the most commonly occurring skeletal element of each taxon in an assemblage. Thus, if an assemblage consists of six left maxillae and eight right maxillae, then the assemblage contains at least eight individuals. This is because an individual animal has only one left and one right maxilla. Lyman (2008) suggests MNI solves the interdependence problem of NISP values, but introduces another issue of aggregation. The aggregation problem stems from an analyst tallying the most frequent skeletal element for varying proveniences, and then finding the MNI changes depending on the number of boundaries used.

Ringrose (1993) argues specimens from the same individual cannot be present in two locations. Therefore, it is nonsensical to calculate MNI at a level of aggregation where the same individual could not be observed together. Although the Bluefields Bay units were excavated using arbitrary 10 cm levels, I determined MNI by level. I used levels for two reasons, the first being because I used levels to calculate NISP and sought to keep the data consistent. The second reason was that as arbitrary levels were used to collect the specimens several levels spanned two strata, and rather than guessing which level belonged to which strata, I used levels to calculate MNI. However, as arbitrary levels may not be the best method for calculating MNI, I used NISP values in my analyses.

Specimen Level Data. Specimen level data I generated includes the identification of each element to lowest taxonomic level using the features listed in the previous paragraphs. However, another data point I collected at the specimen level was size metrics for all identified fish vertebrae and parrotfish (Scaridae) lower pharyngeal plates. I took all measurements using Mitutoyo Absolute Digimatic calipers with automatic input. Vertebrae provided a gross measure of size change through time (Steadman and Jones 2006; Wing and Wing 2001). Although, identification of vertebrae to lower taxonomic levels would have facilitated this study, I felt uncomfortable identifying family or genus due to the small comparative collection available to me. I measured only complete atlas, thoracic, precaudal, and caudal vertebrae, equaling 5,082 measurements. I took at least two measurements per vertebra to find the maximum diameter (Figure 6), recorded only the maximum, and avoided all spines. In addition, I took measurements of the lower pharyngeal grinding plates of all Scaridae to provide a family level record of size change (Carder et al. 2007). Broken plates were excluded from the analysis and only the plate was measured (Figure 7), equaling 37 measurements.

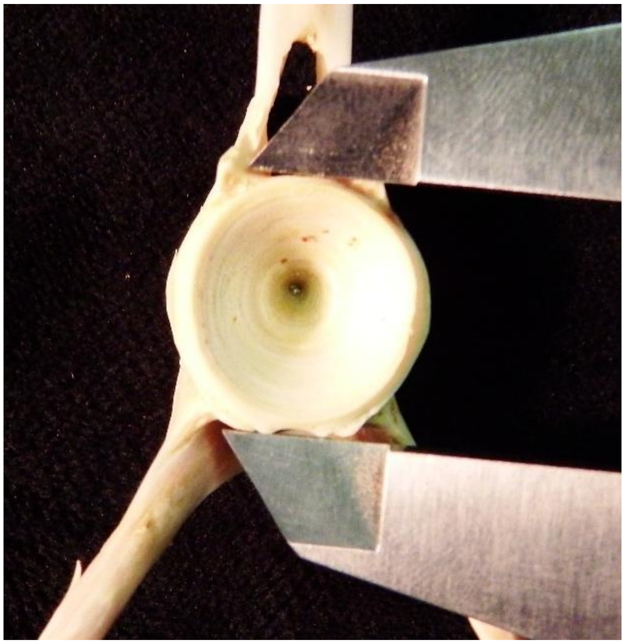


Figure 6. Vertebra Measurement Location.

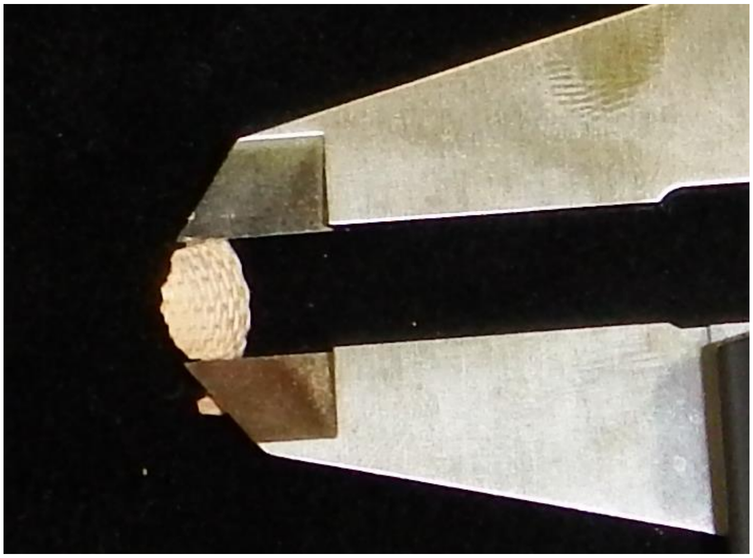


Figure 7. Pharyngeal Plate Measurement Location.

To summarize, the Bluefields Bay site was occupied for nearly 500 years (cal A.D. 1050-1500) coinciding with the late Formative era known as Meillacan Ostionoid. The ichthyofaunal materials I analyzed came from excavated Units 5 and 8, with the exclusion of Units 1-4 due to several provenience issues. I used the comparative collection (Table 6) and the detailed list of element attributes presented in this chapter to identify specimens to lowest possible taxon and to generate primary data. A shortcoming of the analysis is the inability to identify vertebrae to taxonomic family, which would have allowed increased detail in the study of changing fish size. For this reason, I conducted several studies that provide different lines of evidence for overfishing and resource depression. In the next chapter, I discuss the methods I use in these other studies, including a theoretical background of foraging theory, the prey choice model, ecological diversity, and diversity measures.

CHAPTER 5

THEORETICAL METHODS OF ANALYSIS: GENERATING SECONDARY DATA

Archaeologists have documented the effects of human predation on local resources in a variety of coastal environments. These environments include California (Broughton 1994, 1997, 2002; Erlandson and Rick 2010), the Pacific Northwest (Butler and Campbell 2004), Polynesia (Butler 2001; Morrison and Hunt 2007; Nagaoka 2001, 2002), South America (Reitz 2001; Rosello et al. 2001; Wake et al. 2013) and the Caribbean (Atkinson 2006; Blick 2007; Carlson and Keegan 2004; Carder et al. 2007; deFrance et al. 1996; Fitzpatrick et al. 2008; Keegan et al. 2003; Newsom and Wing 2004; Scudder 2006; Steadman and Jones 2006; Wing 2001; Wing and Wing 2001). Each researcher uses a variety of methods to determine the kinds of changes foragers make to their local marine base. Although there are multiple avenues for exploring the same types of questions, I focus on optimization models and determining signals of resource depression. Foraging theory has not been explicitly used in Caribbean zooarchaeology, so my thesis fills a research gap in this region of the world.

My methods for creating secondary data include explicit use of concepts observed within optimal foraging theory and diversity theory. I begin this section with an introduction of foraging theory and the prey choice model, offering details on its use in previous research. Following the review of several case studies, I provide details on the methods I use to determine changes in prey choice and prey size. I then introduce the concept of ecological diversity, and discuss how archaeologists use it to answer questions about past human/environment interrelationships. Following the review of case studies, I provide the equations I use for computing species diversity.

Theoretical Background and Analytical Methods: Foraging Theory

I conduct my analysis within the context of a theoretical tool known as resource depression, which uses concepts of the prey choice model. To understand the prey choice model's predictions requires a discussion of evolutionary ecology (EE) and its subfield, human behavioral ecology (HBE). EE emerged in the 1960s from the work of Charnov and Orians (1973), MacArthur and Pianka (1966), MacArthur and Levins (1967), Orians (1969) and others. EE created a way for archaeologists to study human-environment interrelations in a methodologically rigorous and theoretically sound manner (Cannon and Broughton 2010). EE defined, is the application of evolutionary theory to the study of adaptations in behavior, morphology, and life history (Cannon and Broughton 2010; Smith and Winterhalder 1992). Archaeologists began using HBE in the mid-1970s and focused on explaining behavioral variations within and among human populations (Gurven 2006). Central to HBE, is the concept of natural selection and the ways that it has designed behavior.

Natural selection changes the frequency of genotypes in a population by acting on phenotypic variation, genotypes having to do with genes and phenotypes representing the physical characteristics of an organism. For humans, phenotypes can include various cultural behaviors, which can change to meet new goals and respond to new conditions

(Kelly 1995). Heritable traits occur through genetic transmission from parent to offspring, and through individual or social learning (Gurven 2006). According to Kelly (1995), behavioral ecologists agree that humans select behaviors from a range of variants. These variants must maximize fitness. Fitness results from an organism's propensity to survive and reproduce in a particular environment and population. By focusing on fitness, researchers look at adaptations and potential number of descendants, not at actual reproduction (Smith and Winterhalder 1992).

HBE makes two assumptions: methodological individualism and optimization. Methodological individualism describes how the properties of groups are a result of its individual member's actions. It directs the focus of evolutionary ecology on individuals rather than the group. Both biological and cultural goals drive an individual's success. Optimization focuses on four main variables. The first is an individual's behavior. The second includes all the behavioral options available to an individual. The third variable is the currency that allows costs and benefits of an option to be evaluated. The fourth is a set of constraints that determine the options and their benefits (Kelly 1995).

Optimal foraging theory, first used in biology, employs mathematical models to predict foraging patterns. Foraging models contain three components: decision assumptions, currency assumptions, and constraint assumptions. Decision assumptions relate to prey choice and resource exploitation. Net energy returns measure currency assumptions. Finally, constraint assumptions include the exclusivity of searching and processing, sequential, random searching, and the assumption of complete information (Stephens and Krebs 1986). Smith (1983) notes four conditions of optimization. The first condition recognizes food energy may be in short supply, thus fitness becomes energy-limited. Second, the supply of specific nutrients is short, signifying fitness is nutrient-limited. Third, time for foraging is scarce, indicating fitness is limited by non-foraging activities. Lastly, foraging exposes the forager to greater risks meaning fitness costs expose the forager to predation, accident, climactic stress, etc.

The Prey Choice Model. One of the simpler optimal foraging models is the prey choice or diet-breadth model (Charnov and Orians 1973; MacArthur and Pianka 1966; Schoener 1971; Stephens and Krebs 1986). The prey choice model determines whether a forager will take or ignore a prey item upon encounter (Kelly 1995). The forager makes the prey choice within a homogenous patch using similar search strategies in each. Stephens and Krebs (1986) mention that diet, meaning the content of the stomach, and food preference, relating to when a forager simultaneously encounters prey items, is not strictly predicted by the prey choice model. However, the model does predict that on average foragers will take high-ranked prey when encountered, while low-ranked prey will only be taken when high-ranked prey are scarce. In other words, as encounter rates with higher-ranked prey decrease, foragers will add prey items to the diet in sequential rank order, broadening the diet.

Rank order refers to the profitability of prey types. Researchers rank prey from highest to lowest based on the “ratio of energy per attack to the handling time per attack” (Stephen and Krebs 1986:23). Researchers express this ratio as the average, long-term net return rate. However, it is impossible to view return rates in the past, as we do not have exact measures of caloric yields or pursuit and handling costs. Consequently, archaeologists must estimate this important parameter, and often do so using body size as a proxy measure for net return rates and for designating rank orders (Bayham 1979; Broughton 1994, 1997, 2002; Broughton et al. 2011; Butler 2001; Butler and Campbell 2004; Byers 2005; Cannon and Broughton 2010; Nagaoka 2002). Other sources of data for calculating return rates include ethnographic observations and experimental archaeological tests based on the relationship between body size and rank order (Grayson and Cannon 1999; Simms 1985; Zeanah and Simms 1999).

An important assumption of the prey choice model centers on prey being randomly distributed and not clumped, so the probability of encountering any prey types remains equal across space (Stephens and Krebs 1986). However, in the real world, prey distribution appears patchy rather than random. Therefore, an archaeologist can apply the expectations generated from the prey choice model to each patch separately to maintain fine-grained search assumptions (Broughton 2002; Butler 2001; Nagaoka 2001). Archaeologists define many different patches, including freshwater and marine fishes patches (Butler 2001), or terrestrial mammal, estuarine fish and waterfowl patches (Broughton 2002). Patches must include homogenous spatial entities meeting the assumptions of random encounter rates (Nagaoka 2001).

As the prey model asks if a forager will take or ignore a prey item, and predicts that resources are added to the diet in sequential order based on rank, then changes in relative abundances of high- to low-ranked prey can signify a change in the population density of high-ranked prey (Bayham 1979). Archaeologists term this decline in the abundance of high-ranked prey due to predator behavior, resource depression (Charnov et al. 1976). Most studies document resource depression by measuring changes in foraging efficiency as seen through the metrics of prey choice and prey size (Broughton 2002; Grayson and Cannon 1999; Nagaoka 2002).

Major advantages of foraging models are their ability to allow for scientific rigor and hypothesis testing within zooarchaeological research. Researchers use the models to generate testable hypotheses or use the model as the null hypothesis, in which the mathematically predicted behavior is compared to actual human behavior. The models themselves are not being tested. This approach enables the disentanglement of selective influences acting on behaviors. Advantages of the prey choice model specifically include its simplicity in execution. The logical conclusions of the prey model are easily followed, allowing zooarchaeologists to navigate between the predictions of the model and the archaeofaunal remains they research. Although there are constraints when applying optimization models to the archaeological record, archaeologists have used them in creative ways and applied them to a diverse set of questions.

Literature Review

In other regions of the world, zooarchaeologists have applied similar methods and focused on changes to ichthyofauna through time. Broughton (1994), Butler (2001), Butler and Campbell (2004), and Nagaoka (2004) all use relative abundance indices to study the changes foragers have on marine ecosystems. They provide examples I can use to calculate relative abundances for the Bluefields Bay faunal sample. Although, each researcher uses different criteria to rank taxa, they all define high and low ranked resources. Broughton (1994), for example, studied the faunal remains from sites across the Sacramento Valley of California. He calculated several relative abundances for different animal classes, such as a mammal/fish index and a fish index.

The mammal/fish index provided results that were negative, linear, and highly significant. However, substantial differences in body size exist among the mammals included in the index. For this reason, Broughton calculates indices within the mammal and fish class. The fish index looked at the proportion of anadromous fishes (those that travel from the ocean to fresh water rivers to spawn, such as salmon and sturgeons) to freshwater fishes. The results of Broughton’s fish index demonstrate low levels of anadromous fishes for all but one site. However, anadromous fishes are the high-ranked resource in this index, meaning a signal for resource depression appears absent. Therefore, Broughton interprets the results in a different way. He accounts for the low proportion of anadromous fishes as seasonal variations in their availability and this allows him to interpret the occupation of the sites in his study area.

Butler (2001) also uses relative abundance indices and establishes changing fish use in Polynesia. Similar to Broughton (1994), Butler defines rank based on size, creating a large-bodied, high-ranked group and a small-bodied, low-ranked group. However, she calculates two different indices, one for fishes residing in freshwater, and another for marine fishes. In this way, she is able to define two separate patches. She calculated the large to small indices and observed decreasing abundance of large-bodies fishes and an increasing abundance of small-bodied fishes in both patches. Her results are consistent with the expectations derived from the prey choice model. A broadening of the diet occurred in Butler’s study area, which includes increased harvesting of low-ranked resources when encounter rates with high-ranked resources began declining.

In a similar study, Nagaoka (2002) uses foraging models to document resource depression in New Zealand. She divides vertebrates into coastal, inland, or offshore habitats, much like Butler (2001) and Broughton (2004) did to create discrete patches. She then calculates several relative abundance indices within each habitat. Her results suggest early exploitation centered on high-ranked prey, but as encounter-rates with these prey types declined, lower-ranked prey were added to the diet.

Finally, Butler and Campbell (2004) use zooarchaeological data to test intensification models proposed for the Pacific Northwest that suggest social complexity is accounted for by the abundance and intense exploitation of certain resources, namely salmonids. They define intensification as the narrowing of the subsistence focus to a few resources that yield storable surpluses. They calculate several relative abundance indices for fishes, mammals, and birds. However, their ranking is not specifically based on body size. Rather, for fish, they define *Salmonidae* as high-ranked based on the intensification models they aim to test. Contrary to expectations from the region’s intensification models, the salmonid index actually increases slightly over time, although the results are not significant. In addition, they note the range of relative abundance values suggesting that salmon were the focus in some locations and only a minor resource in others. The authors conclude that their results do not support general intensification models for the region nor do they support a decline in salmon use due to resource depression using relative abundances.

Although, Butler and Campbell’s (2004) study does not support regional intensification models, these authors used zooarchaeological data to show that resource depression may not occur in all cases. Their study is useful for me because they broke down their relative abundance values by period, then site, to tease apart the details in their results and create a more complete picture. I do the same when I compare the Bluefields Bay faunal sample to a trans-Caribbean dataset. The Bluefields Bay sample is my site-specific detail, while the trans-Caribbean data provides period specific data.

Methods for Quantifying Resource Depression: Relative Abundance Indices and Body Size

Based on the foraging theory background information and literature review presented in the above paragraphs, I now discuss the predictions made for the Bluefields Bay faunal sample. I then provide the analytical methods I use to monitor resource depression via the calculation of relative abundance indices (RAI) and changes in body size through time.

Relative Abundance Indices. Predictions made for RAI follow a similar pattern to the studies discussed in the previous section, in that I expect to see declines in the relative abundance of high-ranked fish through time to document ecosystem overfishing. RAI are a well-established and peer-reviewed method of measuring changes in the frequencies of taxa through time from zooarchaeological data (Bayham 1979; Broughton 1994, 1997, 2002; Butler 2001; Butler and Campbell 2004; Byers et al. 2005; Cannon 2000; Lyman 2003; Nagaoka 2002; Stiner and Munro 2002; Stiner et al. 1999). Shifts in the relative abundance of high-ranked prey can reflect changes in human foraging efficiency and can document signals of resource depression. A relative abundance measure commonly used by zooarchaeologists is the proportion of high-ranked taxa to high-ranked plus low-ranked taxa (Bayham 1979; Broughton 1994, 2002; Cannon 2000; Nagaoka 2002). A larger index value means the assemblage contains a greater proportion of the high-ranked taxa in the sample, and therefore a higher foraging efficiency.

I use two different categories to determine rank. The first is average body size of taxonomic families (Bayham 1979). I took the average maximum and minimum size for fishes belonging to each family, as provided by Humann and DeLoach (2002). Families given high rank had adult body sizes greater than 20 cm on the smallest end, and sizes exceeding 45 cm on the highest end. I choose 45 cm as the cutoff because this amount appeared to be the maximum length of several smaller fishes. Smaller fishes were categorized as low-ranked prey. Table 7 provides a list of taxonomic family and their size ranges, as well as the separation of high- and low-ranked taxa.

Table 7. Rank Order of Caribbean Fishes Based on Body Size.

High-Ranked	Size	Low-Ranked	Size
Carangidae	30-91 cm	Balistidae	20-40 cm
Lutjanidae	20-72 cm	Holocentridae	7-38 cm
Scaridae	30-91 cm	Haemulidae	28-45 cm
Serranidae	60-121 cm	Labridae	5-45 cm
Diodontidae	30-60 cm	Mugilidae	20-40 cm
		Pomacanthidae	20-45 cm
		Sparidae	20-38 cm

The second category I use to define rank is a fish's preferred habitat (Broughton 1994). I define high rank as those fishes living within the shallow zone. Inshore/ estuarine fishes live within easy reach of early foragers, and although often small (Wheeler and Jones 1989), are located near other non-fish resources such as shellfish and marine mammals (Newsom and Wing 2004). I also define a middle rank and include fishes inhabiting the mid-range zone, frequenting between shallow and benthic zones. I assign lowest rank to fishes living within the benthic/pelagic zone. Offshore fishes require the highest levels of technological investment including boats and/or nets, as they are not easily caught using hook and line fishing (Wheeler and Jones 1989). I determined the taxonomic family inhabiting the three zones using Humann and DeLoach (2002) (Table 8). In addition, I use NISP values to calculate the two indices.

Table 8. Rank Order of Caribbean Fishes Based on Habitat.

High Rank Shallow /Inshore	Mid Rank Mid-Range	Low Rank Benthic/Pelagic
Holocentridae	Balistidae	Carangidae
Mugilidae	Haemulidae	Diodontidae
Pomacanthidae	Labridae	Serranidae
L. synagris	Lutjanidae	Sparidae
Scaridae	L. Jocu	
Sparisoma		
S. chrysopterum		
S. viride		
S. rubripinne		

Body Size. Another way to express resource depression is through changes in fish size (Butler 2001). The predictions produced by the theoretical and literature review in the previous section, suggest foragers target high-ranked large-bodied fishes resulting in size declines through time. For this part of the analysis, I took the specimen level data I generated through the measurement of vertebrae and pharyngeal plates, and ran statistical and linear analyses on the average sizes by level. By arranging the averages by level, I was able to see trends through time, and whether or not fish size is decreasing, increasing, or remaining the same. Changes in body size document growth overfishing.

Theoretical Background and Analytical Methods: Diversity Measures

Ecological theory specifies that the adaptations of many organisms reflect the distribution and abundance of the prey on which they depend. Generalists, feeding on a variety of organisms in roughly equal numbers, differ from specialists that prey on fewer numbers of taxa but which consume large quantities of those taxa (Grayson 1981). Other important concepts in ecology include competition and predation. MacArthur (1972) defines predation as one species gaining nourishment from another, while two species are competing when an increase in either one harms the other. Predation and competition have profound effects on species distribution and abundances.

In order to measure the effects of predation and competition, and to better understand ecological systems, ecologists and archaeologists employ diversity indices to quantify and describe community composition. The underlying assumption for the use of diversity indices is that the abundance of a species, to some extent, reflects its success at competing for limited resources. All environments have finite resources and set the upper limit to the number of individuals, as well as species, it can support (Magurran 2004).

Bobrowsky and Ball (1989) note diversity is a complex topic that can be analyzed using multiple equations and approaches. The term diversity, therefore, equates to different components of an ecosystem. Odum and Barrett (2005) describe two components as richness, expressed as the number of species present, and evenness, representing the relative abundance of species. Richness therefore, refers to the variety of taxa contributing to a community while evenness attempts to describe the similarity in species abundance. A rich environment is one with many species and an even population contains similar abundances of all species (Nagaoka 2001). The opposite of evenness is dominance, where one or a few species dominate the community (Magurran 2004:18). Odum and Barrett (2005) stress the importance of considering both evenness and richness, because one ecosystem may have an equal number of species present (richness) but very different proportions of these species (evenness). Hardesty (1980) adds another concept he calls "total species diversity," which combines richness and evenness. This concept is also termed "heterogeneity" by Bobrowsky and Ball (1989) and Peet (1974).

In addition, biodiversity measurement is fundamentally a comparative discipline; a single index value does not inform the research. Rather, researchers gain information by asking, for example, whether reef "*x*" has more fish species than reef "*y*" (Magurran 2004). One form of comparative investigation centers on the analyses of shifts in species richness along spatial and/or temporal lines. Such investigations reflect the interests of archaeologists, who use diversity measures to compare faunal material from different times, different geographical locations, or both (Cruz-Uribe 1988; Grayson 1979; Lyman 2008). Moreover, several archaeologists blend diversity measures with expectations derived from the prey choice model. They use diversity measures to express declines in foraging efficiency (Nagaoka 2001). The blending of the prey choice model with measures of diversity is what I accomplish within my analysis of the Bluefields Bay faunal sample.

Literature Review

Wing (1975) first introduced measures of evenness to zooarchaeological studies, while Grayson (1981) brought it to a wider audience by discussing the effects of sample size on its results. Grayson and Delpech (1998) also used evenness, calculated as the Shannon index divided by the number of taxa present, to demonstrate that the dominance of high-ranked resources (red deer and reindeer) correlates with less even assemblages in southwestern France.

More thoroughly discussed here is Nagaoka's study (2001). She uses diversity measures to determine changes in foraging efficiency and diet breadth resulting from declining populations of high-ranked resources in New Zealand. She examines changes in evenness, used to measure declines in foraging efficiency. Drawing from the prey choice model, she expects high ranked prey to be taken every time they are encountered, thus the initial distribution of prey taken should be very uneven. If foraging efficiency decreases, then it should be reflected in an increase in the evenness index.

However, a problem with evenness centers on its inability to take into account the position of prey in a ranking system. To counter this problem, Nagaoka determines changes in richness. She uses richness to examine changes in diet breadth because it counts the number of prey types in a sample. Again, drawing from the prey choice model, she expects that as large-bodied, high-ranked prey populations decline, the mean foraging return rate may decline to the point where lower ranked taxa are added to the diet. If diet breadth expands, then richness should increase.

Nagaoka (2001) first explores the predictions she made using the prey choice models logic for the entire assemblage. Her results demonstrate a significant increase in evenness over time, indicating an increase in lower ranked taxa to the diet and signaling a decline in foraging efficiency. Richness values also increase over time, but these results are significantly correlated with sample size, meaning either sample size or actual increases in richness could be driving the relationship. She then defines three patches in which to test the prey choice models predictions. Her three patches are offshore, coastal, and inland. Evenness increases significantly time within the inland patch, consistent with the assemblage level analysis. Conversely, richness increases within the inland patch. The coastal patch reveals different patterns of resource exploitation, as evenness remains moderately stable, so too does richness. For the coastal patch, it appears that no shifts occur from larger to smaller taxa. Evenness in the offshore patch declines significantly through time suggesting a heavier reliance on fish species as higher ranked inland resources declined.

In Butler and Campbell’s (2004) study, they calculate diversity using the Shannon information index equation to represent evenness. Similar to Nagaoka (2001), they suggest a high evenness value indicates some taxa were used in relatively equal proportions, while a low value indicates some taxa were used in relatively higher proportions than others were. Again, the evenness index does not specify which taxon increase. Instead, the authors use it to estimate the degree of specialization versus generalization of Pacific Northwest foragers. Similar to their findings using relative abundance indices, their evenness results have no distinct linear trend and appear to discount the regional intensification models of the Pacific Northwest.

Both Nagaoka (2001) and Butler and Campbell (2004) make use of diversity measures, albeit to explore different phenomenon within their study area. Nagaoka uses both an evenness and richness index to determine changes in diet breadth in New Zealand, while Butler and Campbell use only an evenness index to test intensification models of the Northwest Coast. Applying measures of diversity to the Bluefields Bay faunal sample, I take an additional step by calculating heterogeneity along with richness and evenness.

Methods for Quantifying Resource Depression: Diversity Indices

I calculated three diversity indices to measure species diversity, each representing a different aspect of the community. Bobrowsky and Ball (1989) suggest the Shannon information index (*H'*) (Shannon and Weaver 1949) for compute heterogeneity and the Margalef diversity index (Margalef 1968) for computing species richness. Magurran (2004) also suggests using the Margalef diversity index for computing richness and cites ease of calculation as an advantage of the index. Within my review, several authors use the Shannon information index as a measure of evenness (Nagaoka 2001). Others use the

Shannon index to measure heterogeneity (Bobrowsky and Ball 1989). For this reason, I calculated evenness using a portion of the Shannon index equation (Magurran 2004).

The Shannon index is derived from information theory and represents a formula useful in assessing the complexity of multiple kinds of systems (Odum and Barrett 2005). The index is based on the rationale that the diversity, or information, in an environment can be measured similarly to the information contained in a code or message (Magurran 2004; Shannon and Weaver 1949). The Shannon information index (*H'*) is calculated as follows for an infinite system:

$$H' = -\sum p_i \log(p_i),$$

where p_i equals the relative abundance of the individuals belonging to the *i*th species (Cruz-Uribe 1988; Odum and Barrett 2005). The higher the *H'* value, the greater the species diversity present in that particular ecosystem (Odum and Barrett 2005). I calculated the Shannon index for the total number of families and genera present rather than species, since the data contained so few identified species.

I derived evenness (e) from the relative abundance calculated for the Shannon index (p_i in the equation above), which required the number of fishes in each habitat divided by the total number of fishes present. Based on the previous literature review, I expect evenness to increase over time in the Bluefields Bay faunal sample. An increase in evenness suggests foraging efficiency is declining and offers a signal for resource depression. Evenness should increase as lower-ranked resources are added to the diet.

Richness reflects the oldest and most fundamental concept in species diversity studies (Peet 1974). Margalef (1968) suggests a natural logarithmic relationship between numbers of species and individuals in a community. The Margalef richness index (*d'*) is calculated as follows:

$$d' = (S - 1)/logN,$$

where S is the number of species and *N* refers to the number of individuals (Margalef 1968). I use NISP as proxy measures for "individuals" (Cruz-Uribe 1988). Based on the expectations derived from the prey choice model, I predict richness is low in the lower levels of the Bluefields Bay site and should increase in the upper levels as encounter rates with high-ranked resources decline and lower-ranked resources are added to the diet.

Hypothesis and Predictions

My central hypothesis is that the Bluefields Bay Taíno targeted large bodied, high-ranked fishes, and caused declines in the relative abundances and body size of these prey types, altering the ichthyofaunal community composition. Based on the information presented, I have made predictions for each analysis. For RAI values, I expect to see declines in the relative abundance of high-ranked fish through time. The theoretical and literature review of the prey choice model and resource depression in the previous section, suggests foragers target high-ranked large-bodied fishes resulting in size declines through time. I therefore also predict the size of fishes to decline over time and allowing me to document the effects of growth overfishing.

Using diversity measures to document changes in fish community composition and foraging efficiency, I can make predictions based on a combination of the prey choice model and which aspect of community composition the index is measuring. For evenness and richness, I expect an increase over time as foraging efficiency declines and more fish species are added to the diet. In addition, I predict heterogeneity will decrease over time as marine fish diversity declines due changes in high-ranked prey populations.

In conclusion, I have outlined the different methods I use to create secondary data and to determine changes in the marine ecosystem of Bluefields Bay. The methods I chose fill a research gap in the region, offering a different way to view subsistence patterns. Although, the reason Caribbean archaeologist calculate biomass and trophic analysis is to communicate with ecologists. Ecologists use these terms and ideas when viewing current marine ecosystems. Including these studies in my thesis would have matched their intentions and contributed to my conclusions in unforeseeable ways. By using the prey choice model exclusively, I limited my scope, but not the implications of my results. In the next chapter, I discuss both the primary and secondary data results.

CHAPTER 6

SPECIMEN COUNTS, SPECIES ABUNDANCES, AND RESULTS OF THE BLUEFIELDS BAY FAUNAL ANALYSIS

In this chapter, I present the results of the primary and secondary data analyses, using the methods already mentioned. I begin by providing the primary data results of the identified and quantified zooarchaeological remains from the Bluefields Bay site. I then present the secondary data results, including the calculation of two relative abundance indices (RAI), changes in body size, and the calculation of three diversity indices.

Primary Data Results

Overall, the Bluefields Bay faunal sample contains 17,761 specimens. I identified 8,961 specimens to the general taxon of Osteichthyes (bony fishes). Osteichthyes equal 50.45 percent of the sample. I also identified 2,591 specimens to Rodentia (rodents). The taxon Rodentia includes both Jamaican rice rats (*Oryzomys antillarum*) and *hutia* (*Geocapromys brownii*) and equals 14.59 percent of the sample. Unidentified specimens represent 35.93 percent of the sample and total 6,301 specimens. Other identified taxa include Reptilia (reptiles) (NISP = 23), Crustacea (crustaceans) (NISP = 11), Aves (birds) (NISP = 15), and Carnivora (sea mammals) (NISP = 43), comprising 2.15 percent of the sample.

The most abundant fish elements include vertebrae (NISP = 4,833) and fin rays (NISP = 1,925), undoubtedly related to the high frequency of these elements in the fish skeleton. Other abundant skeletal elements include premaxillae (NISP = 205), maxillae (NISP = 198), dentaries (NISP = 174), angulars (NISP = 142), quadrates (NISP = 122), and pharyngeal bones (NISP = 106). Element counts for each Unit and Level are presented in Appendix A and a summary of Osteichthyes element counts is presented in Table 9.

Table 9. Assemblage Level Summary: Ichthyofauna Element Counts.

Element	Identified Taxa	Unidentified	TOTAL
Angular	92	50	142
Atlas		128	128
Basioccipital		61	61
Certahyal		78	78
Cleithrum		18	18
Dentary	129	45	174
Dorsal Spine	9		9
Epihyal		19	19
Exocciptial		8	8
Fin rays		1925	1925
Frontal		1	1
Hyomandibular	8	40	48
Maxilla	160	38	198
Opercle	1	26	27
Palatine	3	58	61
Parashenoid	14	51	65
Pharyngeal Bone	73	33	106
Postemporal		14	14
Premaxilla	182	23	205
Preopercle		33	33
Quadrate	36	86	122
Scapula		16	16

Table 9. Continued

Element	Identified Taxa	Unidentified	TOTAL
Spine	126		126
Supracleithrum		12	12
Supraoccipital		14	14
Teeth	24	8	32
Ultimate vertebrae		32	32
Unidentifiable		401	401
Vertebrae		4833	4833
Vomer	32	5	37
TOTAL	889	8056	8945

The following elements are included in the taxon Osteichthyes: fin rays (NISP = 1,925), vertebrae (NISP = 4,833), atlas vertebrae (NISP = 128), and all other bony fish elements I was unable to identify to a more specific taxonomic level. The other general fish taxon I identified is Chondrichthyes (cartilaginous fishes), including sharks, skates, and rays, which were identified by vertebrae and in one case, a tooth (observed in Unit 8, Level 3) (NISP 38). I excluded Chondrichthyes from the following analysis because too few were identified for meaningful comparison.

Elements identified to genus and species include premaxillae (NISP = 182), maxillae (NISP = 160), and dentaries (NISP = 129), angulars (NISP = 92), pharyngeal bones (NISP = 73), quadrates (NISP = 36), and vomers (NISP = 32). I observed no scales (NISP = 0) or otoliths (NISP = 0). Elements classified but not identified to genus or species include the occipital region (supraoccipital, exoccipital, and basioccipital), the frontal, preopercle, hyoid arch (epihyal, ceratohyal), pectoral girdle (posttemporal, supracleithrum, scapula, and cleithrum), and ultimate vertebra.

From the element classification, I identified 757 specimens to taxonomic family. These families include triggerfish (Balistidae), jacks (Carangidae), porcupinefish (Diodontidae), grunts (Haemulidae), squirrelfish (Holocentridae), wrasse (Labridae), snappers (Lutjanidae), mullets (Mugilidae), angelfish (Pomacanthidae), parrotfish (Scaridae), groupers (Serranidae), and porgy (Sparidae). Moreover, based on species-specific osteological characteristics, I was able to identify 132 specimens to the following species: redtail parrotfish (*Sparisoma chrysopterum*), stoplight parrotfish (*S. viride*), redfin parrotfish (*S. rubripinne*), lane snapper (*Lutjanus synagris*), and dog snapper (*L. jocu*). Along with the three species of parrotfish, I identify one genus, *Sparisoma*, based on dentary and premaxilla characteristics.

I present the identification results by unit and level in Table 10. Overall, Unit 8 contains more specimens (NISP = 9946), while Unit 5 contains less (NISP = 8010). Unit 8 also has more families identified than Unit 5, with the addition of squirrelfish, mullets, and angelfish to the other families identified in both units. However, porcupinefish are more common in Unit 5 (NISP = 115) than Unit 8 (NISP = 10).

Table 11 provides an assemblage level summary of NISP and MNI values for fish taxa and includes percentages. Grunts represents the most common family (NISP = 217, MNI = 56, 16.92%), followed by parrotfish (NISP = 86, MNI = 47, 14.2%), snappers (NISP = 118, MNI = 44, 12.92%), and groupers (NISP = 128, MNI = 38 11.48%). Other noteworthy high percentages of fish taxa include the species lane snapper (*Lutjanus synagris*) (NISP = 56, MNI = 32, 9.67%), and the parrotfish genus *Sparisoma* (NISP = 51, MNI = 29, 8.76%). The major difference between percentages calculated for

Table 10. Results of the Taxonomic Identification Analysis for the Bluefields Bay Faunal Sample by Unit and Level.

Unit 5		Level 1		Level 2		Level 3		Level 4		Level 5	
Scientific Name	Common Name	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Unidentified				206		203		645		627	
Aves	bird					1				1	
Carnivora	sea mammal			2		5		2		1	
Rodentia	rodent	1		1	1	3		1		3	
Geocapromys cf. *brownii*	hutia	3	1	171	9	175	7	224	7	199	8
Reptilia	reptile			1		1				3	
Chondrichthyes	cartilaginous fishes	1		1						3	
Osteichthyes	bony fishes	7		300		343		405		876	
Balistidae	triggerfish					1	1	3	1	5	1
Carangidae	jack							1	1	5	1
Diodontidae	porcupinefish			3	1	5	1	12	1	80	4
Haemulidae	grunt			1	1	7	3	12	4	29	6
Labridae	wrasse			1	1						
Lutjanidae	snapper			3	1	3	1	6	3	14	4
Lutjanus synagris	lane snapper					1	1	1	1	9	2
L. jocu	dog snapper					2	1			5	3
Scaridae	parrotfish			1	1			2	2	11	6
Sparisoma sp.	parrotfish			2	1	1	1	4	1	10	5
Serranidae	grouper			10	2	3	1	10	2	20	4
Sparidae	porgy									2	1

Table 10. (Continued)

Unit 5		Level 6		Level 7		Level 8		Level 9		Level 10		Level 11	
Scientific Name	Common Name	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Unidentified		425		525		88		93		60			
Aves	bird	1		1		1				1			
Carnivora	sea mammal	3		1		1				2			
Crustacea	crab			2									
Rodentia	rodent	5		5		3		1					
Geocapromys cf. *brownii*	hutia	154	8	157	10	46	4	42	3	26	1	3	1
Reptilia	reptile	2		4									
Chondrichthyes	cartilaginous fishes	2		2								1	
Osteichthyes	bony fishes	633		624		95		105		45		2	
Balistidae	triggerfish	1	1	2	1								
Carangidae	jack	3	1					1	1				
Diodontidae	porcupinefish	9	1	3	1	2	1	1	1				
Haemulidae	grunt	15	4	23	5	2	1	1	1	1	1		
Labridae	wrasse			1	1								
Lutjanidae	snapper	8	4	11	3	1	1	2	1	2	1		
Lutjanus synagris	lane snapper	3	2	4	2								
L. jocu	dog snapper	1	1	2	2								
Scaridae	parrotfish	7	2	4	3	4	3	1	1				
Sparisoma sp.	parrotfish	2	1	4	2								
Serranidae	grouper	9	3	10	2	2	1	2	2	2	1		
Sparidae	porgy	2	1	2	1								

Table 10. (Continued)

Unit 8		Level 1		Level 2		Level 3		Level 4	
Scientific Name	Common Name	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Unidentified		30		132		226		373	
Aves	bird			1				1	
Carnivora	sea mammal			2		2			
Crustacea	crab					4			
Rodentia	rodent							1	
Geocapromys cf. *brownii*	hutia	32	1	99	6	94	3	108	10
Reptilia	reptile			1				3	
Cheloniidae	sea turtle							2	
Iguanidae	iguana								
Chondrichthyes	cartilaginous fish			1		1		6	
Osteichthyes	bony fishes	75		219		472		642	
Balistidae	triggerfish	3	1	1	1	4	2	3	1
Carangidae	jack					1	1		
Haemulidae	grunt			3	1	3	1	7	2
Holocentridae	squirrelfish					2	1		
Labridae	wrasse							1	1
Lutjanidae	snapper					6	3	15	6
L. synagris	lane snapper					4	2	5	2
L. jocu	dog snapper					4	2	1	1
Pomacanthidae	angelfish					1	1	1	1
Scaridae	parrotfish	1	1	3	1	2	1	6	2
Sparisoma sp.	parrotfish	1	1	3	2			5	3
Serranidae	grouper	1	1	3	1	8	4	10	2
Sparidae	porgy					1	1	5	1

Table 10. (Continued)

Unit 8		Level 5		Level 6		Level 7		Level 8	
Scientific Name	Common Name	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Unidentified		960		684		673		237	
Aves	bird					6			
Carnivora	sea mammal	11		9		3		1	
Crustacea	crab	1		1		1			
Rodentia	rodent	4				2		2	
Geocapromys cf. *brownii*	hutia	299	10	141	4	228	8	126	5
Reptilia	reptile			1					
Cheloniidae	sea turtle			1		1			
Iguanidae	iguana	1		2					
Chondrichthyes	cartilaginous fishes			6		4		2	
Osteichthyes	bony fishes	1029		751		859		322	
Balistidae	triggerfish	3	2	6	1	3	1	4	2
Carangidae	jack	1	1	1	1	4	1	1	1
Diodontidae	porcupinefish	4	1			3	1		
Haemulidae	grunt	33	7	37	8	24	4	5	1
Holocentridae	squirrelfish								
Labridae	wrasse	2	1	2	1	2	1		
Lutjanidae	snapper	15	4	14	6	11	3	4	1
Lutjanus synagris	lane snapper	9	4	6	5	5	5	5	3
L. jocu	dog snapper	7	5	6	2	2	1	1	1
Mugilidae	mullet	1	1						
Scaridae	parrotfish	14	9	13	8	15	6	2	1
Sparisoma sp.	parrotfish	7	4	4	2	5	3	1	1
S. chrysopterum	redtail parrotfish	1	1						
S. viride	stoplight parrotfish	1	1						
S. rubripinne	redfin parrotfish	1	1						
Serranidae	grouper	15	3	13	3	12	5	4	1
Sparidae	porgy	6	2	3	1	4	2	1	1

NISP values and MNI values lies within the taxa Diodontidae. The NISP of Diodontidae is much higher than the MNI value for this taxon due to the many spines, in the range of 16-20 per individual (DeLoach and Humann 2007), inflating NISP values.

Table 11. Assemblage Level Summary of Fishes Identified to Family, Genus, or Species: NISP, MNI, and Percentages.

Taxa	Common	NISP	% NISP	MNI	% MNI
Balistidae	Triggerfish	39	4.27	16	4.83
Carangidae	Jacks	19	2.08	10	3.02
Diodontidae	Porcupinefish	125	13.69	14	4.23
Haemulidae	Grunts	217	23.77	56	16.92
Holocentridae	Squirrelfish	2	0.22	1	0.30
Labridae	Wrasse	9	0.99	6	1.81
Lutjanidae	Snapper	118	12.92	44	13.29
Lutjanus synagris	Lane snapper	56	6.13	32	9.67
L. jocu	Dog snapper	32	3.50	20	6.04
Mugilidae	Mullet	1	0.11	1	0.30
Pomacanthidae	Angelfish	2	0.22	2	0.60
Scaridae	Parrotfish	86	9.42	47	14.20
Sparisoma spp.	Parrotfish	51	5.59	29	8.76
S. chrysopterum	Redfin	1	0.11	1	0.30
S. viride	Stoplight	1	0.11	1	0.30
S. rubripinne	Redtail	1	0.11	1	0.30
Serranidae	Grouper	128	14.02	38	11.48
Sparidae	Porgy	25	2.74	12	3.63
TOTAL		913	100	331	100

Secondary Data Results

Relative Abundance Indices. I calculated RAI using two separate criteria to determine rank order. The equation I use to calculate RAI is high-ranked over low- plus high-ranked fishes. A larger RAI value means the assemblage contains a greater proportion of the high-ranked taxa in the sample, and therefore, a higher foraging efficiency. Refer back to Tables 4 and 5 for details on taxonomic rank. In Table 12, I present the RAI values using body size to rank fishes, with the largest fishes given the highest rank. Note that levels 1 and 11 have no value; this is because I excluded levels with less than 10 specimens. Additionally, I separated data by unit.

Table 12. RAI Calculated by Level: Rank Order Determined by Size.

Level	2	3	4	5	6	7	8	9	10
Unit 5	.90	.65	.69	.81	.69	.58	.82	.88	.80
Unit 8	.69	.63	.76	.63	.54	.58	.64	.50	.90

For the other set of RAI values, I used preferred habitat for ranking fishes, assigning highest rank to fishes inhabiting the shallow/reef zone, middle rank to fishes in the mid-range zone, and lowest rank to fishes in the pelagic/offshore zone. Table 13 provides the values for Units 5 and 8. Again, I did not calculate values for levels with less than 10 specimens, which is Level 1, 10, and 11.

Table 13. RAI Calculated by Level: Rank Order Determined by Habitat.

Level	2	3	4	5	6	7	8	9
Unit 5	.38	.65	.55	.44	.62	.77	.64	.57
Unit 8	.77	.72	.75	.78	.84	.86	.79	.77

Body Size. To capture any temporal trends in fish body size across the Bluefields Bay occupational sequence, I recorded size metrics for vertebrae and parrotfish pharyngeal plates. Although specimen level data such as measurements are considered primary level data, I use each level's average to determine trends over time, generating secondary data. I present the average vertebrae diameters by unit and level in Table 14. Scaridae pharyngeal plate averages are displayed in Table 15.

Table 14. Average Vertebrae Diameters by Unit and Level, and a Combined Average (Combined $\bar{\times}$).

Level	Unit 8	Unit 5	Combined $\bar{\times}$
1	4.08	4.82	4.45
2	4.78	4.46	4.62
3	4.43	4.67	4.55
4	4.18	4.63	4.40
5	4.03	3.96	3.99
6	3.90	3.94	3.92
7	4.30	6.25	5.27
8	4.50	5.20	4.85
9	6.06	4.94	5.50
10	6.37	5.09	5.73
11	4.92	6.40	5.66

Table 15. Average Pharyngeal Plate Lengths by Unit and Level, and a Combined Average (Combined $\bar{\times}$).

Level	Unit 8	Unit 5	Combined $\bar{\times}$
4		5.42	5.42
5	7.54	8.65	8.09
6	7.74	6.83	7.28
7	6.65	7.58	7.12
8	6.68	8.56	7.62

Diversity Indices. The following details the three diversity indices I calculated for the Bluefields Bay faunal sample. As a reminder, I calculated evenness, or the relative abundance of species present, from the Shannon index equation. I express evenness values using the symbol *e.* Richness is symbolized by *d’* and was calculated using the Margalef index. *H’* symbolizes the results from the Shannon information index and represents heterogeneity in fish community composition. I present the calculations of the three indices in Table 16.

Table 16. Diversity Indices Calculated Using Fish NISP Values from the Bluefields Bay Faunal Sample.

				d'			
		e		Inshore		Reef	
Level	H'	Inshore	Reef	Family	Genus	Family	Genus
11						2.096	
10	0.245	0.067	0.933			1.745	0.873
9	0.314	0.095	0.905	3.322	3.322	3.128	0.782
8	0.202	0.051	0.949	3.322	3.322	3.88	0.638
7	0.252	0.069	0.931	1	1	2.821	0.47
6	0.212	0.055	0.945	1.048	1.048	2.736	0.456
5	0.194	0.048	0.952	1.701	0.85	2.429	0.405
4	0.212	0.055	0.945	1.285	1.285	2.47	0.496
3	0.131	0.029	0.971	3.322	3.322	3.833	0.548
2			1			3.918	
1			1			2.570	

In this chapter, I have presented both the primary and secondary data results for the Bluefields Bay faunal sample. Primary data encompassed element counts and identification of specimens to lowest taxonomic level. Secondary data derived from the methods I presented in the previous chapter, which aimed to uncover if changes occurred in the Bluefields Bay marine ecosystem. Of note is the difference between units, both in terms of specimen counts and species identified. For this reason, I first discuss each unit separately and then combine the data to see if that strengthens any trends during my analysis. That discussion takes place in the next chapter, where I determine if the predictions I made will reject or fail to reject my hypothesis. Additionally, I discuss the implications of these findings. Once I have discussed the results from the Bluefields Bay faunal sample, I return to my broad questions (can foragers alter marine ecosystems in island and tropical settings and can zooarchaeological data provide insight?) by comparing Bluefields Bay with sites across the Caribbean.

CHAPTER 7

DISCUSSION OF BLUEFIELDS BAY RESULTS AND A COMPARISON TO REGIONAL PATTERNS

Using the prey choice model, I hypothesized that the Bluefields Bay Taíno altered their local marine ecosystem by targeting large-bodied, high-ranked fishes. I tested this hypothesis by calculating two relative abundance indices (RAI), measuring fish elements as a proxy for body size, and calculating three diversity indices. Abundance indices measure changes in the relative contribution of each taxon to the diet, and a decline in fish body size indicates both resource depression and growth overfishing. Therefore, if my hypothesis is correct I expect to see declines in high ranked taxa and a decline in fish body size. I used diversity measures to indicate ecosystem overfishing and to signal declining foraging efficiency. I calculated a diversity index for both the reef and inshore patch, and measure evenness (p_i in the Shannon Index), richness (Margalef Index), and heterogeneity (Shannon Information Index). I predicted each index would increase over time as the diet broadened to include lower-ranked species.

Following the discussion of the Bluefields Bay site, I expand my analysis to the greater Caribbean. The trans-Caribbean study allows me to compare the Bluefields Bay data with other islands and cultural periods. It also adds pertinent information to the broader questions asked in my introduction: can foragers alter marine resources in tropical and island settings? Moreover, can zooarchaeological data provide insight into these changes? Based on my thesis research and the information presented herein, I have answered yes to both questions.

Bluefields Bay Analyses Results

Relative Abundance Indices

For the RAI analysis, I used two different criteria to rank fishes. I took the average maximum and minimum sizes for species belonging to each family, with high rank assigned to adults exceeding 45 cm. Smaller fishes were categorized as low-ranked prey. Table 7 provides a list of taxonomic family and their size ranges, as well as the separation of high- and low-ranked taxa.

The second criteria I used to define rank centers on a fish's preferred habitat. I defined high rank as those fishes living within the shallow inshore zone, as these fishes would be closest to Taíno foragers collecting other resources on the shores. I also defined a middle rank and included fishes inhabiting the mid-range zone, frequenting between shallow and benthic zones. I assigned low rank to fishes living within the benthic zone, as these fishes often require higher investments in time and energy, reducing the net return rate. Table 8 provides a list of fish rankings based on preferred habitat.

RAI values calculated when size was used to rank fishes, demonstrates a slight decrease through time for both units, as shown by the best-fit line (Figures 8a and 8b). A Spearman's *rho* test of the relationship between levels and RAI values based on size ranks did not find a significant correlation (Unit 5: $r_s = -.067$, $p = .432$; Unit 8 $r_s = .134$, $p = .366$). Combining the units into one scatterplot, the best-fit line shows a decrease in

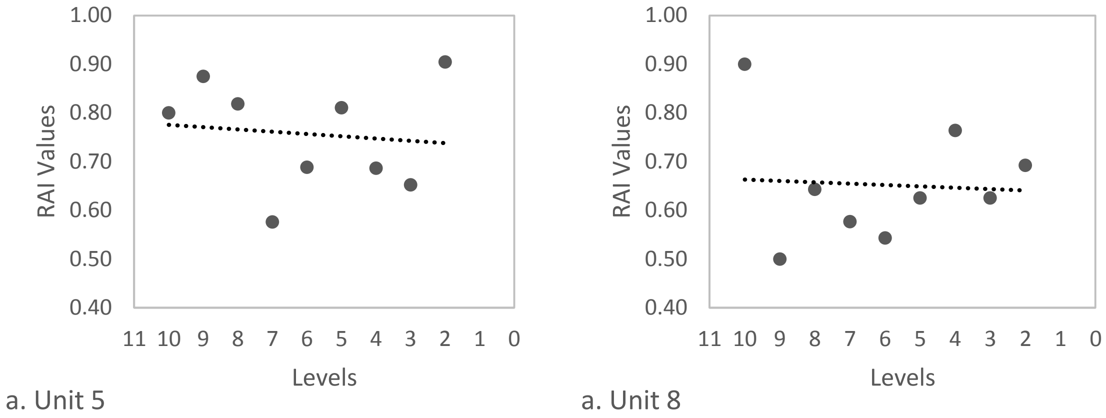


Figure 8. RAI Values plotted through Time Using Size Ranks: (a) Unit 5, (b) Unit 8.

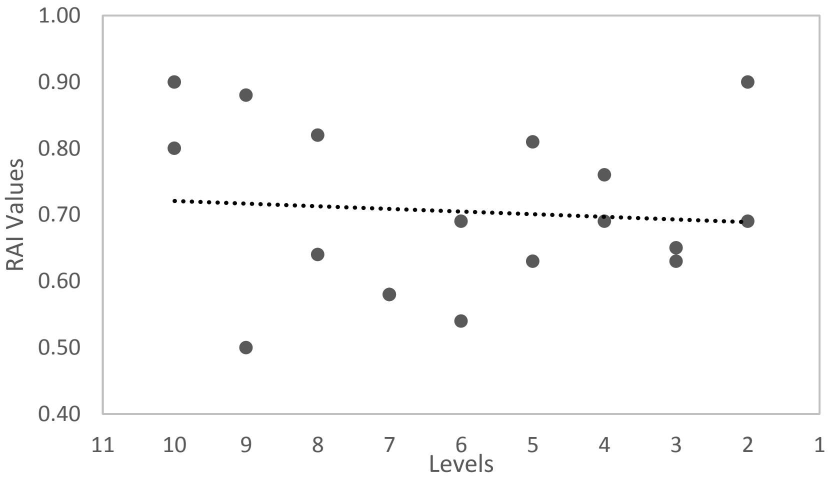
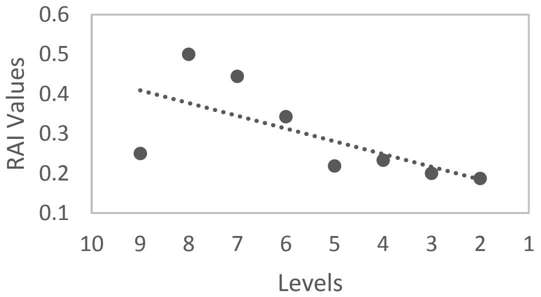


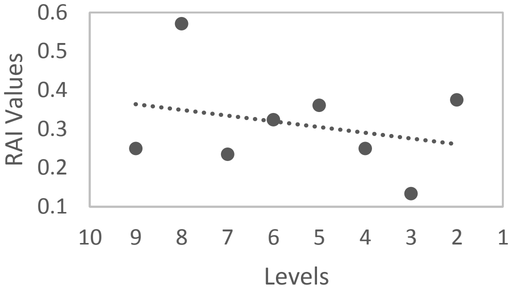
Figure 9. RAI Values plotted over Time Using Size Ranks: Both Units.

high-ranked fishes through time (Figure 9). However, the change through time is still not significant (*U* = 33.5, *z* = -.580, *r* = -.137, *p* = .562). The results for RAI values using size to rank fishes show a slight decline in high-ranked, large-bodied prey, but the change is not significant.

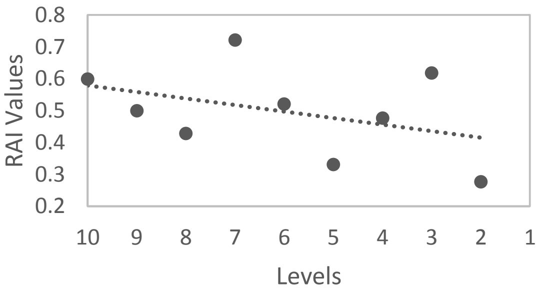
RAI values calculated when habitat was used to rank fishes provides mixed



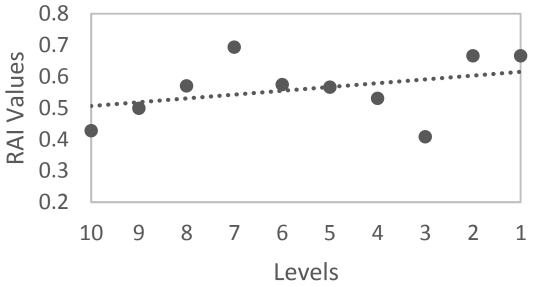
a. Unit 5 Shallow/Benthic



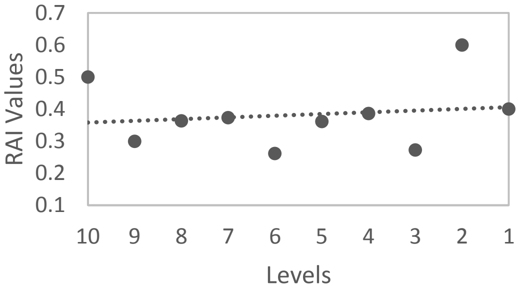
b. Unit 5 Shallow/Mid-Range



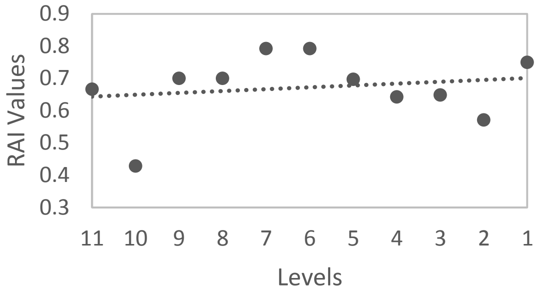
c. Unit 5 Mid-Range/Benthic



d. Unit 8 Shallow/Benthic



e. Unit 8 Shallow/Mid-Range



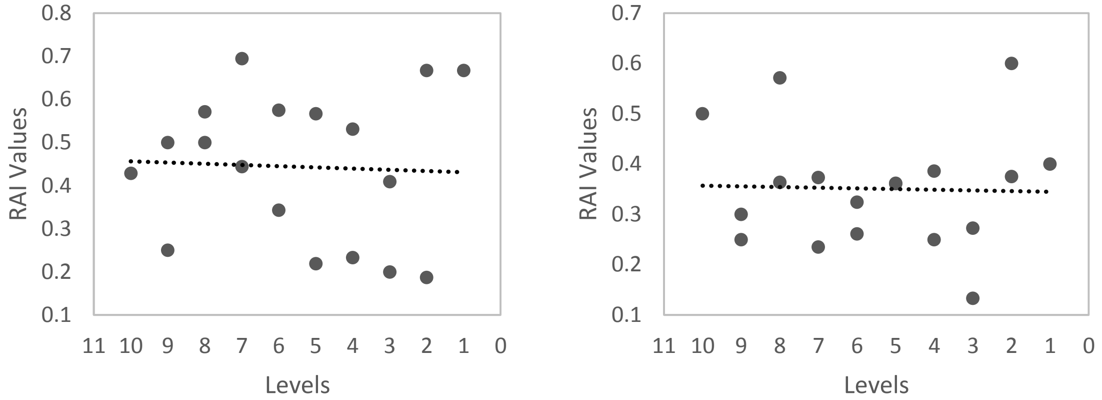
f. Unit 8 Mid-Range/Benthic

Figure 10. RAI Values plotted through Time Using Habitat Ranks: (a) Unit 5 Shallow over Benthic Ranked Fishes, (b) Unit 5 Shallow over Mid-Range Ranked Fishes, (c) Unit 5 Mid-Range over Benthic Ranked Fishes, (d) Unit 8 Shallow over Benthic Ranked Fishes, (e) Unit 8 Shallow over Mid-Range Ranked Fishes, and (f) Unit 8 Mid-Range over Benthic Ranked Fishes.

results (Figures 10a-10f). Unit 5 RAI values show a consistent decrease in the higher ranked resources through time (Figures 10a-10c). In addition, the relationship between levels and Unit 5's Shallow/Benthic RAI values correlates significantly (r_s =

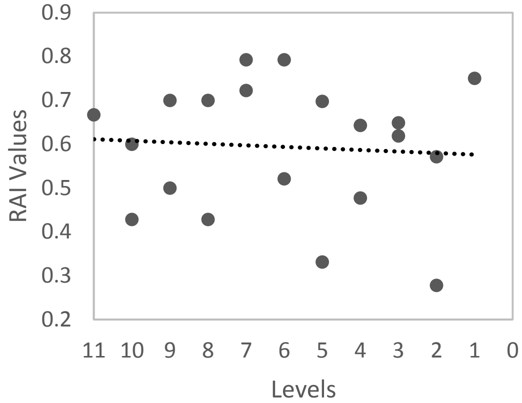
-.833, p = .005). The other RAI values of Unit 5 do not correlate significantly (Shallow/Mid-Range r_s = -.06, p = .444; Mid-Range/Benthic r_s = -.333, p = .19). Unit 8 RAI values suggest a slight increase through time for all three combinations, the opposite of what I expected. Although, the relationship between levels and Unit 8's RAI values does not correlate significantly (Shallow/Benthic r_s = .316, p = .187; Shallow/Mid-Range r_s =. 188, p = .302; Mid-Range/Benthic r_s = .005, p = .495).

I combined the units into one analysis (Figures 11a-11c) and for each combination there appears to be a decrease in RAI values through time. The largest decrease is seen between the highest ranked fishes (Shallow zone) and the lowest ranked fishes (Benthic zone) (Figure 11a). I expected this, as the difference between highest and lowest ranking fishes should provide the largest change, if my rankings are correct. However, none of the decreases seen in the best-fit line are significant (Shallow/Benthic U = 30, z = -.928, r = -.219, p = .353; Shallow/Mid-Range U = 36.5, z = -.353, r = -.083, p = .724; Mid-Range/Benthic U = 36, z = -1.026, r = -.242 p = .305). These results hint that resource depression and possible declines in foraging efficiency may have occurred at pre-Columbian Bluefields Bay. Possible explanations for these trends include the criteria I used. Ranking taxa differently may shift the trend in either direction. Alternatively, the changes between high and low ranked taxa are better viewed between strata, than levels. As stated previously, several levels spanned different strata leading me to use levels over strata as the unit of time. The results do not provide a definitive signal. To corroborate these results, I included more than one analysis in my thesis research.



a. Shallow/Benthic

b. Shallow/Mid-Range

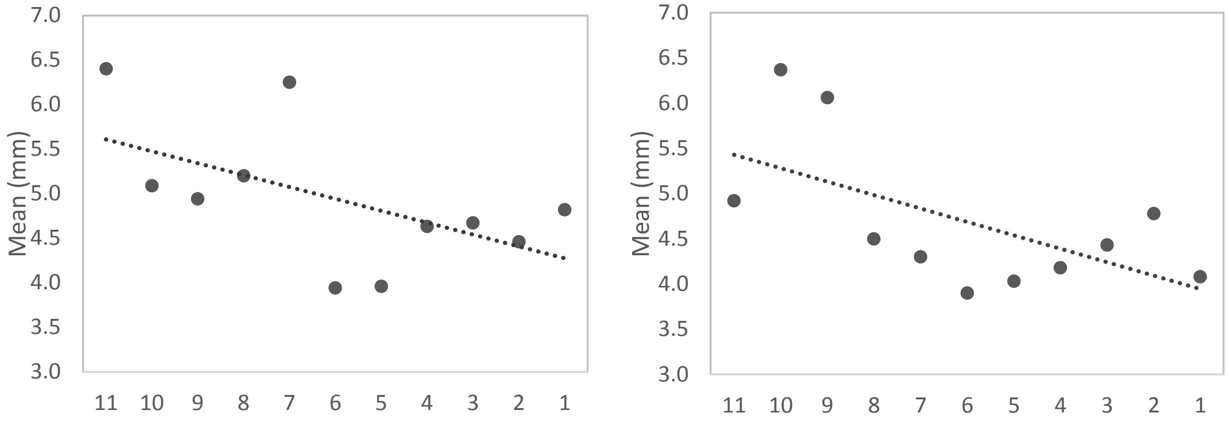


c. Mid-Range/Benthic

Figure 11. Combined Units, RAI Values plotted through Time Using Habitat Ranks: (a) Shallow over Benthic Ranked Fishes, (b) Shallow over Mid-Range Ranked Fishes, and (c) Mid-Range over Benthic Ranked Fishes.

<u>Body Size</u>

Using the predictions stated previously, I expect to see a decline in body size as growth overfishing occurs, signaling resource depression. Based on vertebrae metrics, the best-fit line suggests a steep decline in vertebrae size over time for both Units 5 and 8 (Figures 12a and 12b). The relationship between levels and average vertebrae metrics is significantly correlated (Unit 5: $r_s = -.627$, $p = .019$; Unit 8: $r_s = -.573$, $p = .033$). These unit results suggest gross size of ichthyofauna from Bluefields Bay decreased through



a. Unit 5

b. Unit 8

Figure 12. Averages by Level for Vertebrae Metrics (mm) plotted through Time: (a) Unit 5, (b) Unit 8.

time, matching the predictions I made using the prey choice models logic, and signaling both resource depression and growth overfishing.

I then combined the units. The single scatterplot (Figure 13) demonstrates a best-fit line that decreases steeply from lower to upper levels. Computing a Spearman's *rho* using both units average vertebrae measurements, I observed a significant correlation between levels –Level 1 being the youngest and Level 11 being the oldest– and vertebrae diameters ($r_s = -.691$, $p = .017$). A negative correlation is consistent with my expectations. The decreases in average vertebrae diameter is statistically significant based on a Mann-Whitney test ($U = 30$, $z = -1.978$, $r = -.422$, $p = .048$). The observed trend in vertebrae measurements strongly suggest growth overfishing occurred at the Bluefields Bay site and provides a clear signal of resource depression.

However, Level 5 and 6 averages are much lower than the other levels and I propose two possible explanations. The first explanation attributes the pattern to the quantity of vertebrae recovered from those levels. Combining the units, Level 5 had

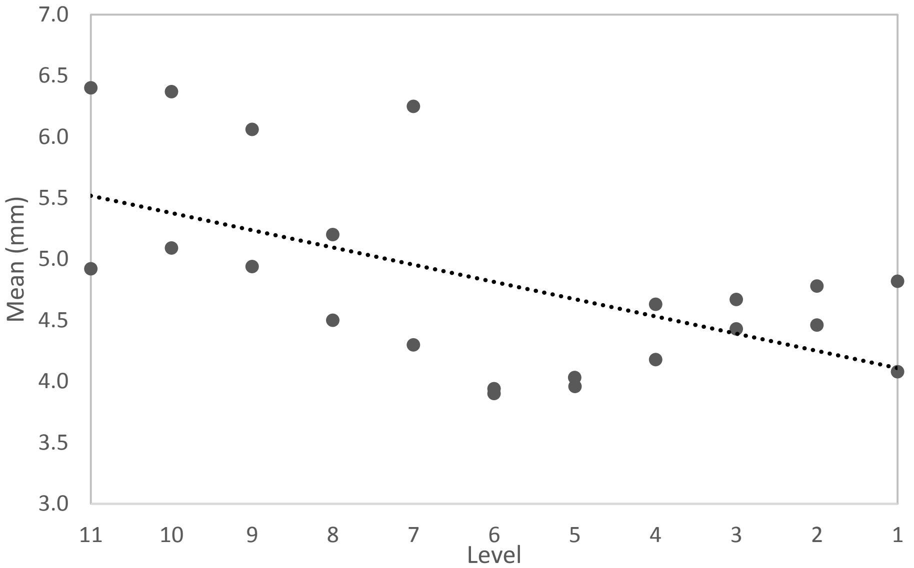


Figure 13. Averages by Level for Vertebrae Metrics (mm) plotted through Time: Both Units.

1,303 measurements, while Level 6 had 1,081, compare that to Level 9, which has 116 measurements or Level 2, which has 356 measurements.

The other explanation derives from Broughton’s (2002) distant patch model. The model suggests foragers travel farther to reach larger and higher ranked resources when sizes begin decreasing. Therefore, an initial decline and then later incline can still signal resource depression. Black-tailed deer (*Odocoileus hemionus*) are the second highest-ranked terrestrial mammal. This taxa decreases over the lower four strata and then increases across the upper six. He takes into account the behavioral ecology of the black-tailed deer and determines this species has a much larger range than the other high-ranked resources. Therefore, Broughton proposes the Emeryville Shellmound foragers traveled further to acquire the black-tailed deer. The distant patch model accounts for the increasing relative abundance of these species in accordance with other signals of declining foraging efficiency. To use the distant patch model in the Bluefields Bay analysis would require species data. Species data would provide the necessary and detailed ranges of fishes. As this data is not available, I was unable to perform such a study.

Next, I discuss the lower pharyngeal plates of all parrotfish to provide a family level record of size change. I plotted the average measurements for Units 5 and 8 in Figures 14a and 14b. Unit 5 demonstrates a decrease through time; however, Unit 8 shows an increase. Neither unit has a significantly correlated relationship between levels and average values (Unit 5 $r_s = -.40$, $p = .252$; Unit 8 $r_s = .80$, $p = .10$). I again combined the means of both units (Figure 15) and a best-fit line demonstrates a decrease in size from the earlier to later occupation of the Bluefields Bay site. However, this difference is not significant ($U = 7.0$, $z = -.516$, $r = -.172$, $p = .606$). These results hint that parrotfish size is decreasing through time. However, I suspect the small sample size has influenced the results. More pharyngeal plate measurements are needed to confirm the trend.

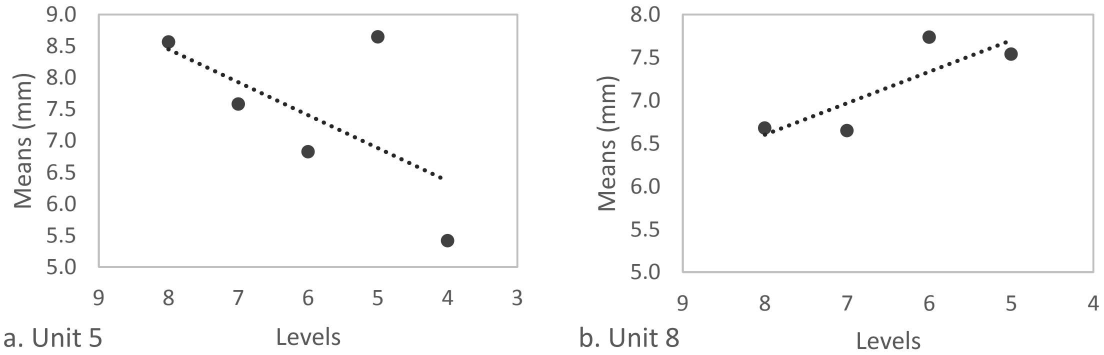


Figure 14. Averages by Level for Scaridae Pharyngeal Plates Metrics (mm) through Time: (a) Unit5, (b) Unit 8.

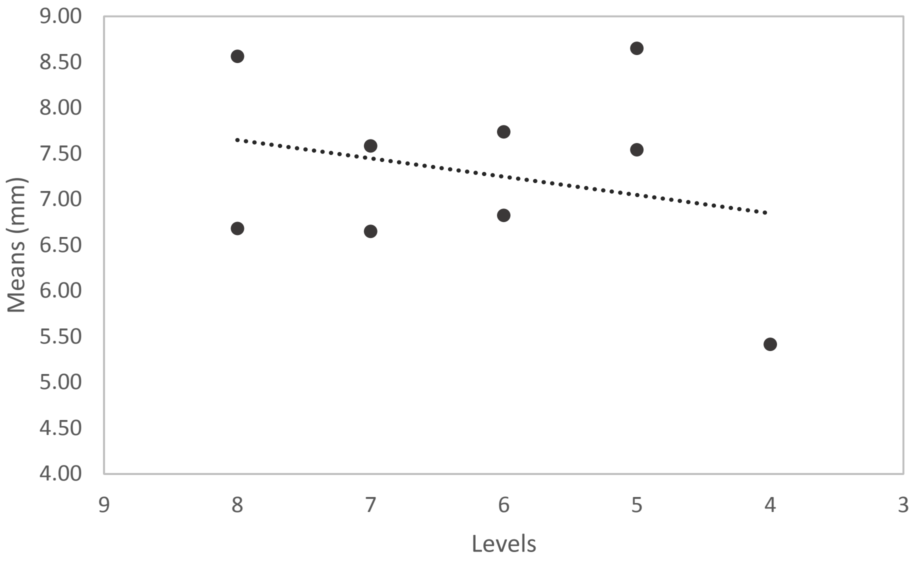


Figure 15. Averages by Level for Scaridae Pharyngeal Plate Metrics (mm) through Time: Both Units.

Diversity Indices

Diversity indices measure different aspects of an ecological community, and I use them to document changes in fish community composition and to signal declining foraging efficiency. Aspects of community composition diversity indices measure include evenness, richness, and heterogeneity. I predict that all three will increase through time as the diet broadens and lower-ranked species are added to the diet.

Evenness. Evenness values at the Bluefields Bay site show a slight decrease in inshore evenness and a slight increase in reef evenness from the lower to upper levels (Figures 16a and 16b). Spearman's correlation coefficient for both patches demonstrates a significant relationship between levels and evenness values (inshore r_s = -.695, p = .028; reef r_s = .695, p = .028). Reef evenness follows my predictions made from the prey choice models logical outcomes.

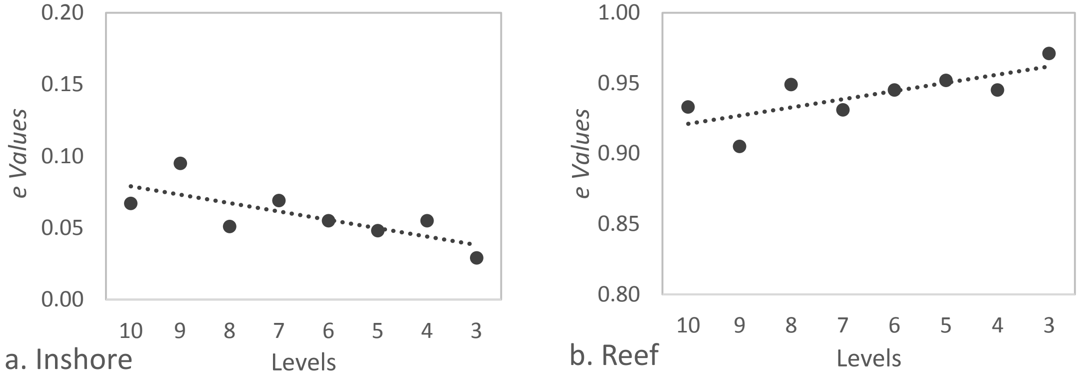
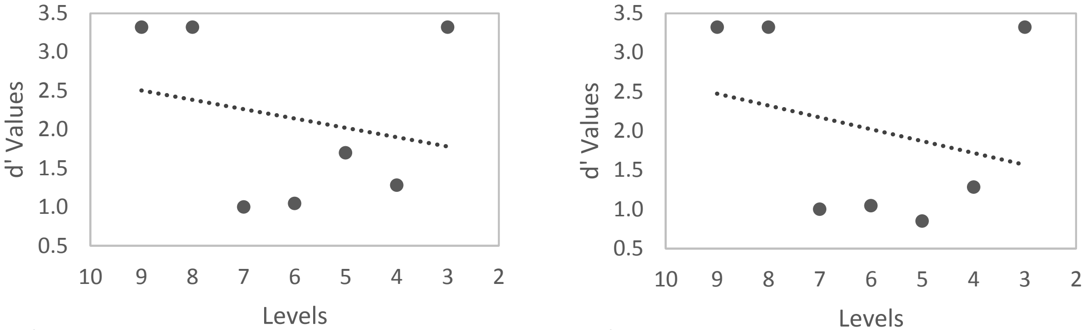


Figure 16. Bluefields Bay Evenness (*e*) through Time: (a) Inshore, (b) Reef.

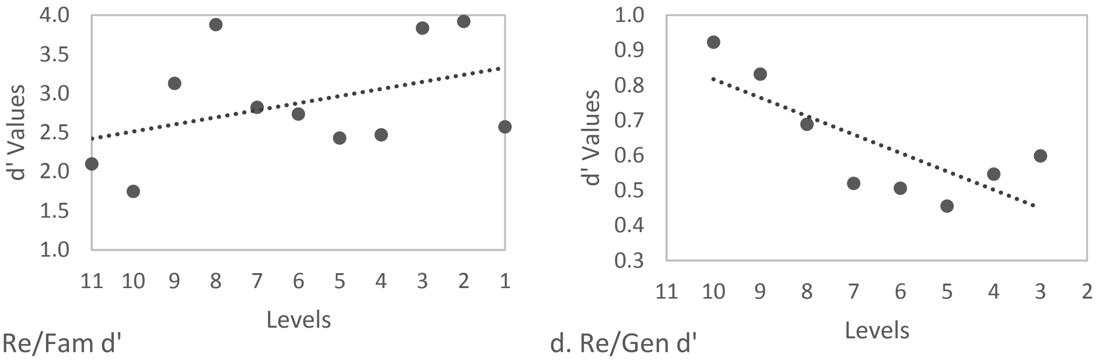
Why, then, is inshore evenness displaying the opposite trend? I propose the Taíno targeted fishes in the inshore patch first and then moved to the reef patch as the inshore patch experienced declines in the availability of high-ranked fishes. This would account for the difference in evenness values, because the relative abundance of species shifted from the inshore patch to the reef patch. However, the differences between upper (Levels 1-5) and lower (Levels 6-11) levels is not significant (inshore $U = 1.5$, $z = -1.8$, $r = -.636$, $p = .071$; reef $U = 1.5$, $z = -1.8$, $r = -.636$, $p = .071$). Interestingly, reef evenness has much higher values than inshore evenness. I interpret this to mean the Bluefields Bay faunal sample contains more reef species than inshore species.

Richness. The Margalef equation allowed for the calculation of both a family and genus value within the inshore and reef patches. In the Bluefields Bay faunal sample, scatterplot best-fit lines (Figures 17a-17d) show all the values decrease through time except in Reef Family richness (Figure 17c). Richness values (*d’*) for each taxa and zone do not correlate significantly with levels based on a Spearman’s *rho* test (Inshore/Family values $r_s = -.111$, $p = .406$; Inshore/Genus values $r_s = -.185$, $p = .345$; Reef/Family values



a. In/Fam d'

b. In/Gen d'



c. Re/Fam d'

d. Re/Gen d'

Figure 17. Bluefields Bay Richness (*d'*) through Time: (a) Inshore Family Values, (b) Inshore Genus Values, (c) Reef Family Values, and (d) Reef Genus Values.

$r_s = .382$, $p = .123$), although Reef Genus richness has an almost significant relationship between levels and values ($r_s = -.619$, $p = .051$). These results oppose my predictions for richness at the Bluefields Bay site, as I expected to see increases through time.

Looking at the data a different way by combining the units into one inshore and one reef scatterplot (Figures 18a-18b), I observed richness contains a similar pattern as evenness. This pattern is inshore *d'* values decreases and reef *d'* increases through time. Here again, the same premise I used for evenness is demonstrated in richness. When foraging efficiency declines, then lower-ranked species are added to the diet, thus increasing richness through time. Reef richness adheres to this. However, when the Taíno shifted from inshore to reef patches, and began targeting fewer inshore fishes, inshore richness

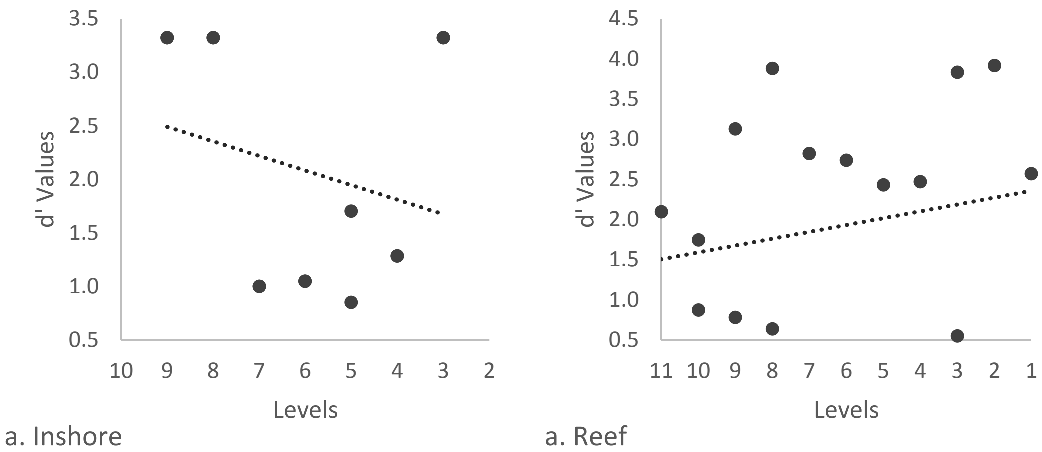


Figure 18. Richness values (*d'*) through Time: (a) Inshore Values, Both Units, (b) Reef Values, Both Units.

declined while reef richness increased. However, the differences between upper (younger) and lower (older) levels is not significant based on Mann-Whitney tests (inshore U = 24, z < .001, r < -.002, p = 1.0; reef U = 42, z = .165, r = .038, p = .869).

Heterogeneity. Heterogeneity, as a combination of evenness and richness, demonstrates a decline through time at the Bluefields Bay site (Figure 19), as displayed by the best-fit line. The relationship between levels and *H'* values is statistically significant based on a Spearman's correlation coefficient (r_s = .695, p = .028). However, a Mann-Whitney test suggests the changes are not significant (U = 1.5, z = -1.8, p = .072), although the effect size between levels and heterogeneity values is large (r = -.636). A decline in both evenness and richness is inconsistent with my predictions.

A possible explanation comes from Carlson and Keegan (2004). They looked at archaeofaunal assemblages from several islands, but more importantly, they used data from Paradise Park. Paradise Park is near the Bluefields Bay site. They demonstrated that late Ceramic-aged peoples tended to focus on only a few reef species. This may

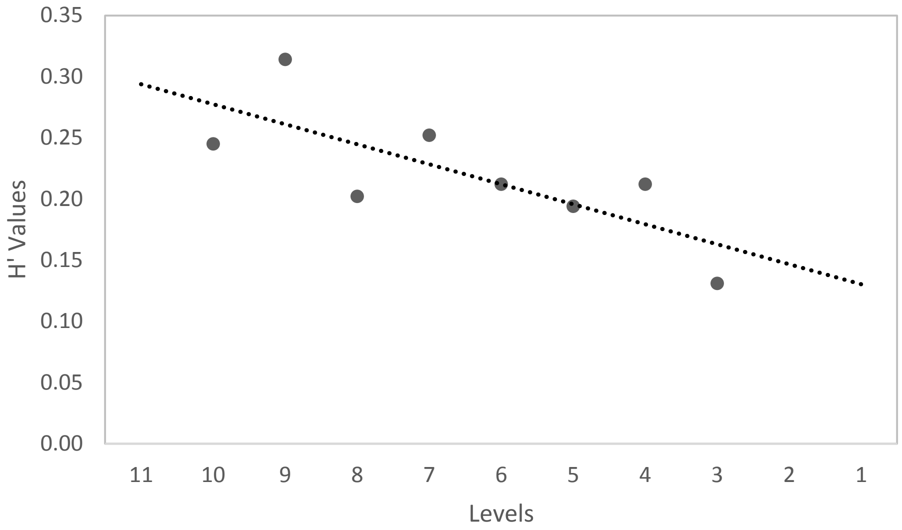


Figure 19. Bluefields Bay Heterogeneity (*H’*) through Time.

account for the overall decline in diversity even though the reef patch seems to be showing signs of declining foraging efficiency through increased evenness and richness.

In summary, my analyses have provided signals of resource depression in the Bluefields Bay faunal sample using relative abundance indices, changes in fish body size, and shifts in fish community composition. Although I did not always expect the outcomes in my analysis, I was able to show compelling evidence for a declining foraging efficiency and possible human caused resource depression at Bluefields Bay. Now that I have demonstrated the kinds of changes the Bluefields Bay Taíno made to their local marine ecosystem, I wish to broaden my research to include islands and cultural periods throughout the Caribbean.

Trans-Caribbean Studies

Are the patterns I have observed in the Bluefields Bay assemblage representative of broader regional trends? To compare the Bluefields Bay faunal sample with sites across the Caribbean, I performed two additional studies. For these studies, I gathered two supplementary datasets. I used one dataset (the trans-Caribbean dataset) for calculating the same diversity indices as those calculated for the Bluefields Bay sample. I used the other dataset to calculate additional RAI values (RAI dataset). Both studies reveal the Bluefields Bay Taíno altered their local marine ecosystem in similar ways to those foragers living at other times and on other islands.

The Trans-Caribbean Dataset and Diversity Indices

The first study uses the trans-Caribbean dataset, which contains 53 data points from 46 sites on 24 different islands (Figure 20). I added the Bluefields Bay faunal sample as two data points, one data point averaged from the upper levels (1-5), and one averaged from the lower levels (6-11). Sources for the data derive from Carder et al. (2007), Colten et al. (2009), Colten and Worthington (2014), LeFebvre (2007), Newsom and Wing (2004), Quitmyer (2003), and Steadman and Jones (2006). The predictions made for the three diversity indices are the same as those made for the Bluefields Bay data, in that I expect evenness, richness, and heterogeneity to increase through time.

The differences between the trans-Caribbean dataset and the Bluefields Bay dataset include an increased temporal and spatial scale. The trans-Caribbean data spans

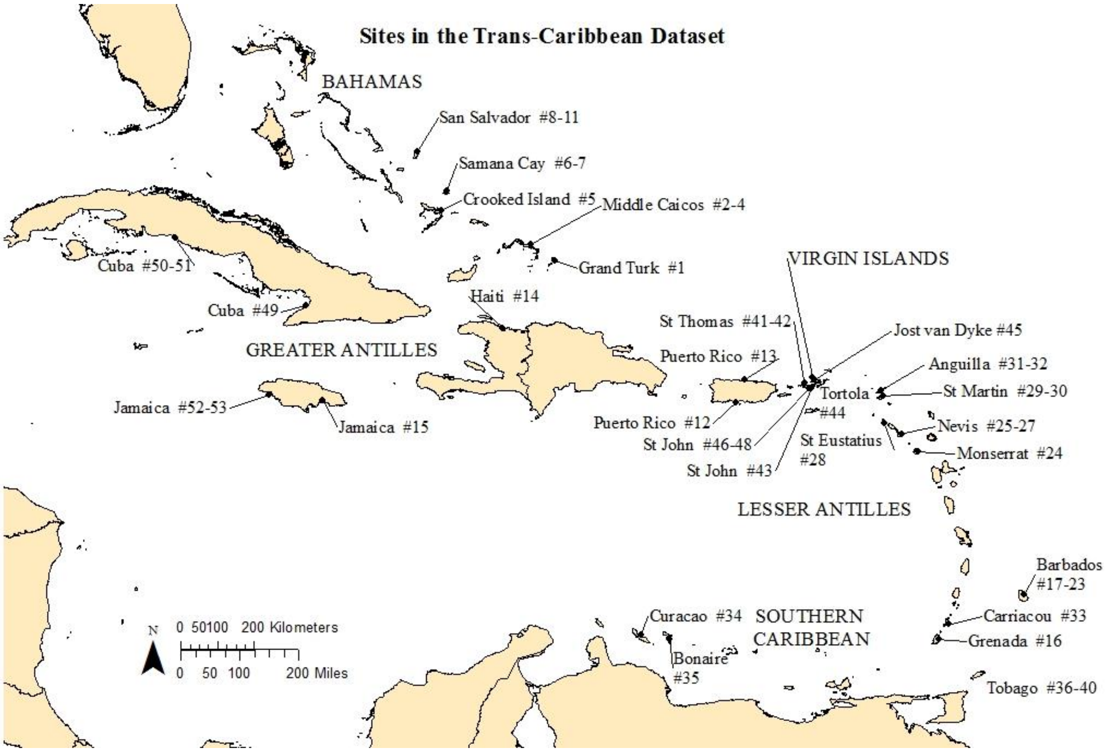
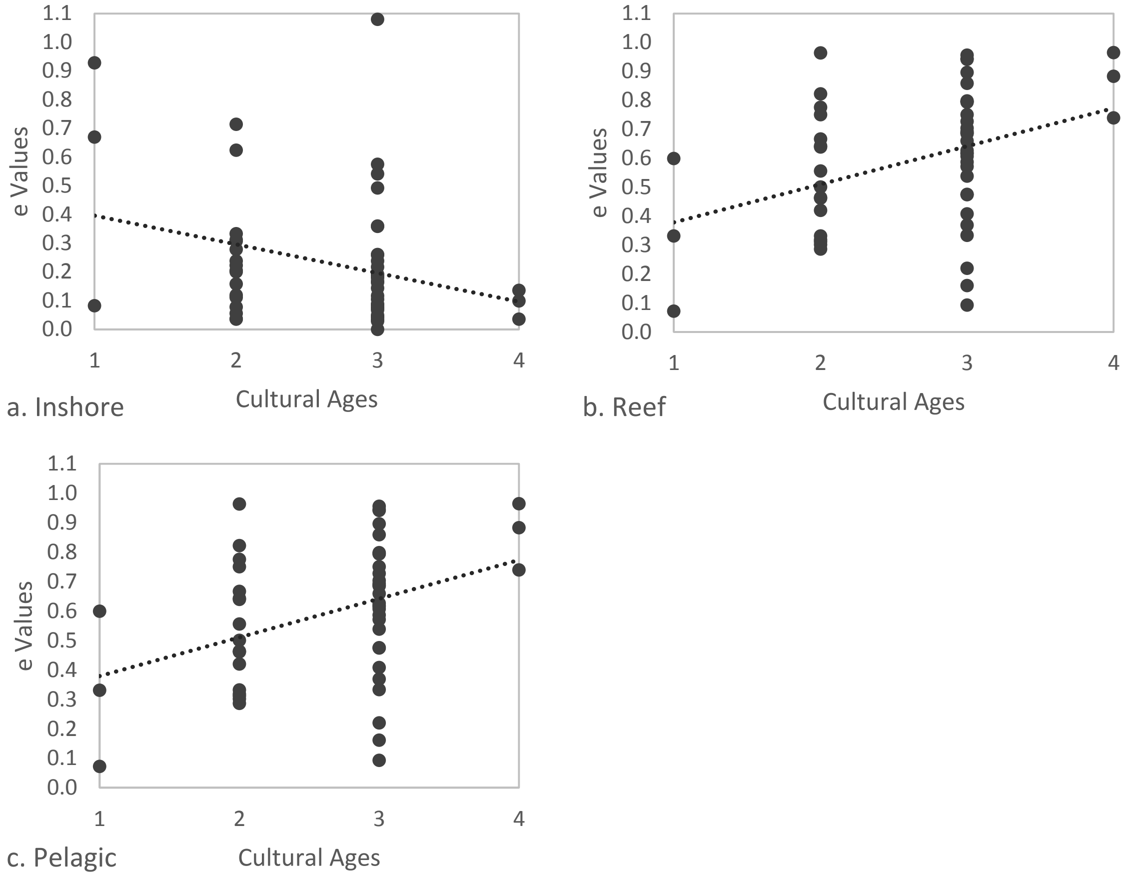


Figure 20. Map of the Caribbean Marking All the Sites in the Pan-Caribbean Study (refer to Table 44 for Site Numbers).

the Lithic to the proto-Historic eras, while the Bluefields Bay site dates to the Formative era. I use the term proto-Historic as several sites date to the early 1400s prior to contact through to the 1650s. Furthermore, the spatial scale of the trans-Caribbean dataset is larger. It includes islands from the major regions of the Greater Antilles, Lesser Antilles, Southern Caribbean, and Bahamian Archipelago. For further discussion and results of the trans-Caribbean study, including a list of all the sites and descriptive statistics of index values, see Appendix B. Also included in Appendix B, are the results of a dominant genus and species study using the trans-Caribbean dataset.

Evenness. The evenness index allowed for the separation of inshore, reef and pelagic values. A scatterplot of *e* values (Figures 21a-21c) shows that reef and pelagic



a. Inshore

b. Reef

c. Pelagic

Figure 21. Trans-Caribbean Evenness through Time: (a) Inshore Values, (b) Reef Values, (c) Pelagic Values.

evenness increase, while inshore evenness decreases from the Archaic to the proto-Historic. Reef and pelagic evenness increasing over time is consistent with my predictions. Both patches provide a signal for declining foraging efficiency and resource depression across the Caribbean. Reef evenness correlates significantly with levels based on a Spearman’s *rho* test ($r_s = .322$, $p = .009$). However, inshore and pelagic evenness do not (inshore $r_s = -.215$, $p = .061$; pelagic $r_s = .110$, $p = .215$). Moreover, evenness values are not significant between the Ceramic and Formative ages (inshore $U = 236.5$, $z =$

-.536, *r* = -.078, *p* = .592; reef *U* = 222.5, *z* = -.843, *r* = -.123, *p* = .399; pelagic *U* = 227.5, *z* = -.734, *r* = -.107, *p* = .463).

Again, inshore evenness is declining rather than increasing. This trend is similar to the Bluefields Bay results, but is it for the same reason? Looking at the trans-Caribbean data differently (Figure 22), reveals a pattern that suggests Caribbean foragers may have first targeted reef fishes, and then shifted to inshore or pelagic fishes. This pattern opposes my earlier suggestion that inshore fishes were targeted first. The pattern has two parts; first, reef evenness values were normally higher than inshore or pelagic values, suggesting there are more reef fishes in the faunal samples. Second, when reef evenness values decline, inshore or pelagic values increased. An example (see Appendix B, Table 47) comes from the Lesser Antilles. The Formative-aged Heywood site has a low reef value (*e* = .220), while pelagic evenness is high (*e* = .732). Then, at the Golden Rock site, reef evenness is low (*e* = .369), but rather than pelagic evenness being higher, inshore evenness is higher (*e* = .574). Similarly in the Bahamas, site MC-6 reveals a low reef evenness (*e* = .408) and a high inshore evenness (*e* = .541), while site SM-7 also demonstrates a low reef evenness (*e* = .093), but a high pelagic evenness (*e* = .164).

This pattern also suggests how the Caribbean foragers responded to and interacted with the different marine ecosystems of each island. An example comes from the Vega del Palmar site on Cuba. Both the Archaic data point and the Ceramic data point have high inshore evenness values and low reef values, with no pelagic values. This suggests the marine ecosystem may have supported larger numbers of inshore fishes

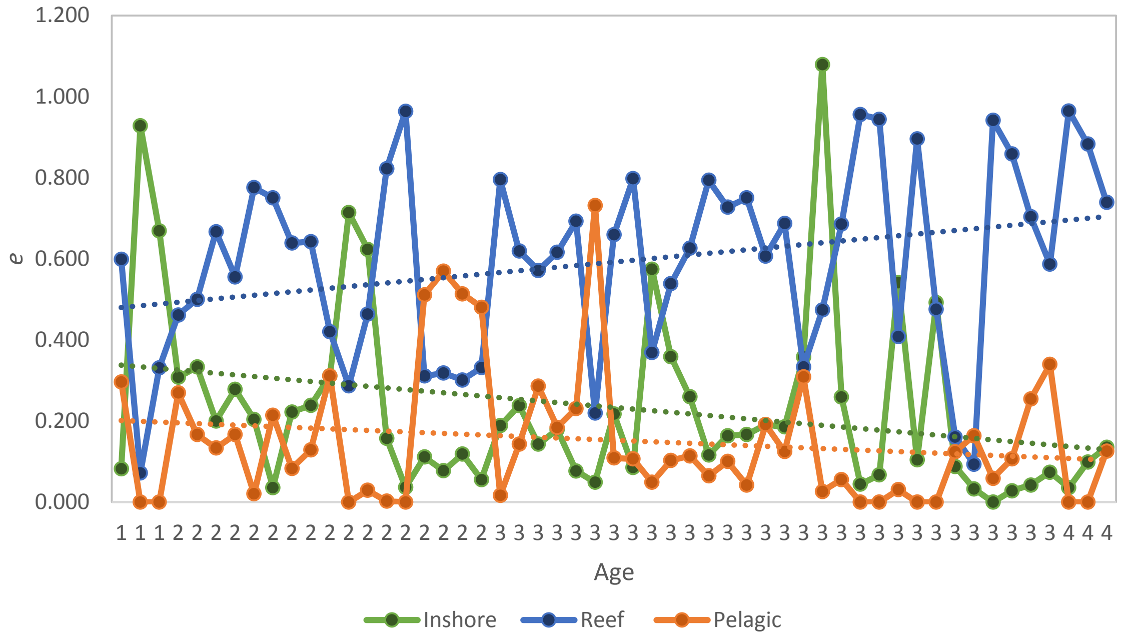


Figure 22. Line Graph of Trans-Caribbean Evenness Values in Chronological Order.

with little to no access to pelagic fishes. Additionally, on Tobago, the Archaic-aged site (TOB3) has a high inshore value (*e* = .082) relative to lower reef (*e* = .599) and pelagic values (*e* = .296). However, at the Ceramic-aged site (TOB13), all three data points have high pelagic values (*e* = .511, .569, .514, .481) relative to reef (*e* = .311, .318, .301, .332) and inshore values (*e* = .111, .077, .118, .055). This suggests the Archaic-aged foragers targeted inshore fishes, and the Ceramic-aged foragers shifted to pelagic fishes. Furthermore, this shifting evenness on Tobago may have to do with changing climate, cultural preferences, or a decline in foraging efficiency within the inshore patch, and a shift to higher returns in the pelagic patch. Either way, the archaeofaunal samples on Tobago highlight the differences each island has in regards to marine ecosystems and conforms to trends seen at Bluefields Bay.

The examples I have provided here also highlight the difficulties in comparing regional trends, as each island has such variation. This variation lead to changing human responses and leaves the reasons for these changes unclear. In an effort to corroborate the trends seen in evenness, I calculated richness and heterogeneity.

Richness. Richness measures the number of different species present and I use the Margalef equation to calculate values. Although I was able to calculate a richness value for both taxonomic family and genus, I discuss only the family richness values as genus values had too few data points for statistical analysis. The scatterplots show that inshore and reef richness increases, while pelagic richness remains steady through time (Figures 23a-23c). Spearman's correlation coefficients demonstrate all three patches have non-significant relationships between time and *d'* values (inshore $r_s = .063$, $p = .328$; reef $r_s = .199$, $p = .077$; pelagic $r_s = -.014$, $p = .461$). Similarly, the differences between the Ceramic and Formative era's richness values are not significant for each patch (inshore $U = 243.5$, $z = -.255$, $r = -.037$, $p = .799$; reef $U = 211$, $z = -.282$, $r = -.142$, $p = .33$; pelagic $U = 242.5$, $z = -.282$, $r = -.041$, $p = .778$).

Increasing richness in the inshore and reef zones is consistent with my predictions, and while pelagic richness may not adhere to my predictions, it does not oppose them. Possible explanations for the trends in richness include a declining foraging efficiency within the inshore and reef patch, and a subsequent increase in diet breadth. The inclusion of more data, appears to reveal a declining foraging efficiency within the inshore patch that was absent in the Bluefields Bay results. A steady pelagic richness may suggest Caribbean foragers targeted only a few species from this patch, and did not

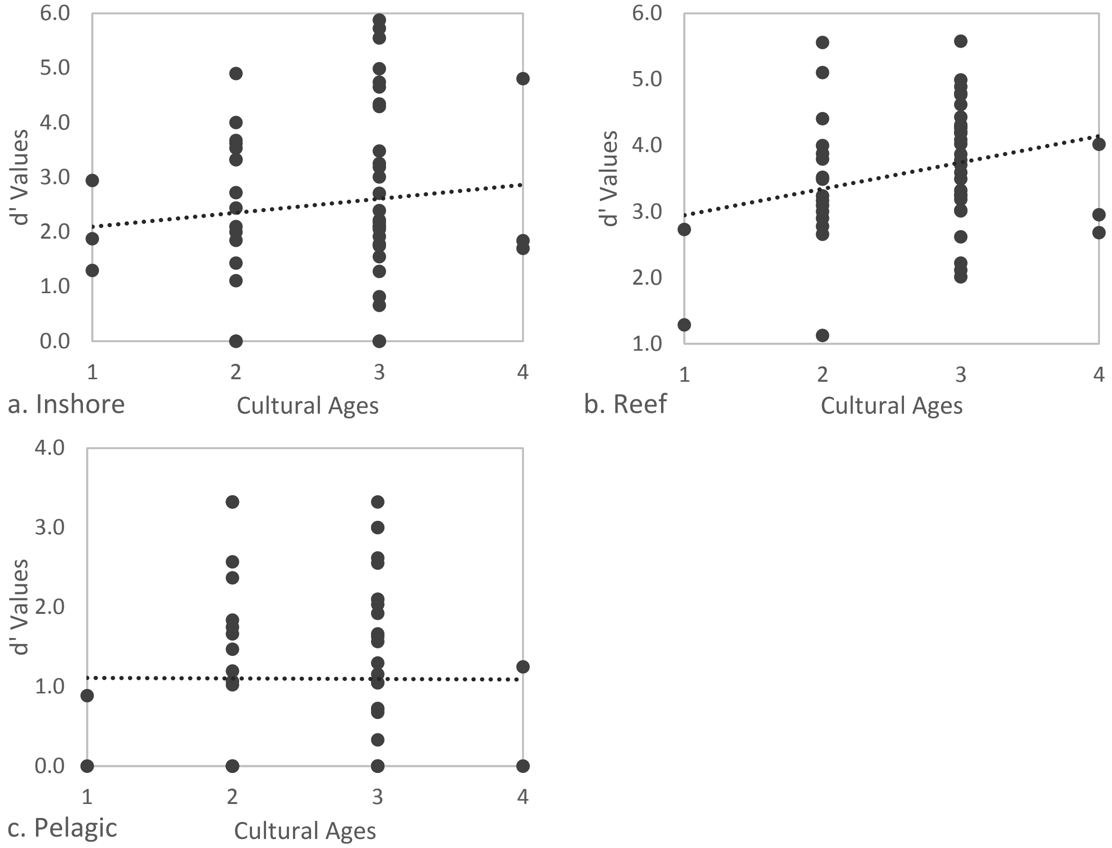


Figure 23. Trans-Caribbean Family Richness through Time: (a) Inshore Values, (b) Reef Values, (c) Pelagic Values.

include more fishes when return rates decreased in the other patches.

Heterogeneity. The Shannon index, combining evenness and richness, demonstrates a decline from the Archaic to the proto-Historic era (Figure 24). The relationship between eras and heterogeneity is significant based on a Spearman's *rho* test (r_s = -.278, *p* = .022). In addition, the differences in heterogeneity values between the Ceramic and Formative periods is significant (*U* = 166.5, *z* = -2.068, *r* = -.302, *p* = .039). The results for heterogeneity oppose my prediction, but are similar when compared to Bluefields Bay *H'* values.

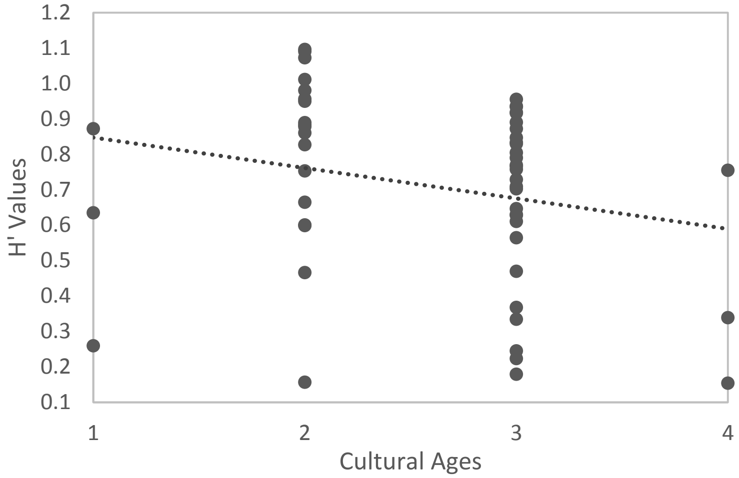


Figure 24. Trans-Caribbean Heterogeneity through Time (1 = Archaic Age, 2 = Ceramic Age, 3 = Formative Age, 4 = proto-Historic Age).

The trend in decreasing heterogeneity reflects a shift in fish diversity that may be unrelated to resource availability. In fact, all the changes observed thus far could be due to a change in cultural practices, such as shifts in dietary preference, political and/or ritual structure, horticulture practices, or fishing technology. In addition, changes in climate could alter fish populations and account for the changes I have presented. Unfortunately, not many researchers have studied the fluctuating climate and environment of Quaternary Jamaica (Allsworth-Jones 2008).

One study, performed by Cooper and Peros (2010), provides a model of human responses to climate change throughout the entire Caribbean. They use data collected on rising sea levels, variation in precipitation, and the frequency and intensity of hurricane activity throughout the migration and occupation of the region. The data they use can also help determine marine fish responses to similar climate changes. Such changes could have negative effects on one species and positive effects on another. These naturally shifting relative abundances and fish populations would still appear in my analyses, but my hypothesis would need to be rejected. Ruling out climate change is beyond the scope of this thesis project, but such a study would strengthen the interpretations I have made.

An archaeobotanical study would aid in determining if Caribbean foragers were relying more heavily on domesticated crops. Lee Newsom (Newsom and Wing 2004) provides such data for Puerto Rico and Hispaniola in the Greater Antilles but not for Jamaica itself. Her results suggest an intensification of plant production based on terraces and other landscape changes that flatten the ground. In addition, she observed a shift from family gardens to a greater emphasis on domesticated taxa, at least in Haiti and Puerto Rico. If an intensification of plant production occurred in Jamaica as well, then that may account for the shifts I observed in marine fishes. An archaeobotanical study is again, outside the reach of this thesis project.

However, a study within the scope of this thesis is one that investigates changing fishing technology, specifically technology that increased the return rates of low ranked prey items (Butler 2001; Madsen and Schmitt 1998). If there are changes in technology, such as the capture of individual fish to mass harvesting of multiple fishes at one time, then another measure besides size declines is required. Butler (1994, 2001), Keegan (1986), and others (Leach and Intoh 1984; Masse 1986; Wing and Reitz 1982; Wing and Scudder 1983) suggest using the behavioral ecology of prey such as what and how fish eat, to interpret how humans captured them.

In general, carnivorous fishes have relatively large jaws, with teeth designed to capture prey, because they consume active prey such as other fish and mobile invertebrates. These fishes are attracted to baited hooks. In contrast, omnivore/ herbivores have small, terminal mouths with reduced or modified teeth, as they prey on slow-moving invertebrates or graze on the reef directly. These fish often ignore baited hooks and are caught using mass capture methods.

A ratio of groupers (Serranidae) to parrotfish (Scaridae) indicates the relative importance of netting versus angling. This is because serranids are largely caught in deeper waters where baited hooks are required, while scarids, being herbivores, are caught in shallow waters where netting can be used (Butler 1994; Leach and Intoh 1984). In addition, ethnographic research across Micronesia identified serranids and lutjanids (snappers) as most often caught by hook-and-line, while scarids and acanthurids (surgeonfish) were most often caught with nets (Masse 1986). Therefore, if fishing technology shifted towards mass harvesting, I expect an increase in the relative abundance of herbivores through time (Butler 1994, 2001). If fishing technology remained the same, and is not a factor in the trends observed for Taíno foraging efficiency, then I expect the index to remain consistent from lower to upper levels.

To determine if fishing technology changed at the Bluefields bay site, I calculated a carnivore/herbivore index using the equation:

$$\sum carnivores \,/ \sum (carnivores + herbivores)$$

where *carnivores* include all genera and species of Serranidae (NISP values) and *herbivores* include all genera and species of Scaridae (NISP values). Table 17 provides the raw data and the index values of both units. I combined the units and observed a clear decrease in the relative abundance of herbivores over time (Figure 25). A Spearman's *rho* test shows the relationship between levels and RAI values is not significant ($r_s = .353$, $p = .063$), and the difference between upper (1-5) and lower (6-10) levels is also not significant ($U = 41.5$, $z = -.609$, $r = -.14$, $p = .542$).

The implications of these results suggest the Bluefields Bay Taíno may have either intensified their use of hook and line fishing or shifted away from mass harvesting. This shift in fishing technique may influence the trends observed in ichthyofaunal

Table 17. Carnivore/Herbivore Index Results for the Bluefields Bay Sample.

Level	1	2	3	4	5	6	7	8	9	10	11
Unit 5 RAI	**0**	**.77**	**.75**	**.63**	**.49**	**.5**	**.56**	**.33**	**.67**	**1**	**0**
Serranidae	0	10	3	10	20	9	10	2	2	2	0
Scaridae	0	3	1	6	21	9	8	4	1	0	0
Unit 8 RAI	**.33**	**.33**	**.8**	**.48**	**.38**	**.43**	**.38**	**.57**	**.67**	**.75**	**1**
Serranidae	1	3	8	10	15	13	12	4	2	3	1
Scaridae	2	6	2	11	24	17	20	3	1	1	0

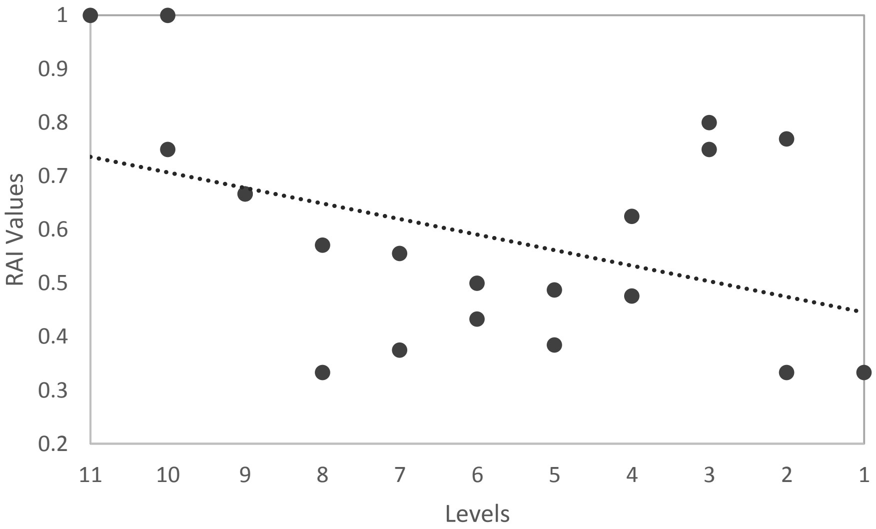


Figure 25. Carnivore/Herbivore Index Results for the Bluefields Bay Sample (Both Units).

diversity such as the evenness and richness index. That is because an increased use of hooks over nets targets carnivorous species that are more abundant in the reef habitat and possibly accounts for changes in the reef patch.

However, the same increased use of baited hooks would also restrict the number of fish species available to Taíno fishers, suggesting increased evenness and richness are still indicators of a broadening diet. Moreover, the carnivore/herbivore index suggests the vertebrae size declines occur within a few concentrated taxa that are more easily caught with baited hooks. Fewer taxa caught by the Taíno means the fish size results are accurately depicting actual size declines, rather than an increase in smaller fish species. As the carnivore/herbivore shows, the Taíno were shifting away from mass capture techniques and I would expect there to be fewer small fishes in the sample.

However, other interpretations of the data include evidence of group size or socioeconomic structure influencing the productivity of different strategies. Socioeconomics take into account the social organization of both angling, which is largely solitary, and netting, which is cooperative (Butler 1994). The Taíno depositing fishes in the Bluefields Bay midden may have experienced reduced group size, increasing the use of hook and line fishing. Additionally, the carnivore/herbivore index could provide evidence of the habitat structure of Bluefields Bay, in that baited hooks are preferable as netting may catch in the coral reefs where fish reside.

I propose the results indicate a possible increase in hook and line fishing, but acknowledge the problems associated with using family level generalizations of feeding tendencies. These generalizations exclude detail and mask the fact that not every species within a family acts the same. In addition, there are accounts of some fishers catching parrotfish with baited hooks. However, Keegan and Carlson (2008) suggest that traps account for the high numbers of parrotfish in the archaeological record, not hook and line fishing. In conclusion, the carnivore/herbivore index reveals the complexity of interpreting faunal materials and the need for multiple studies that account for various scenarios. The carnivore/herbivore study allowed me to explore a different scenario that may account for some of the trends found within this thesis.

In summary, the comparison study using diversity measures suggest the greater Caribbean experienced shifts in community composition similar to the Bluefields Bay site. Trans-Caribbean evenness values offer evidence that foragers experienced declining foraging efficiency in the reef and pelagic patches. Richness offers a similar perspective but with changes seen in the inshore and reef patch. Although I did not predict a declining heterogeneity, the decrease is seen in both the Bluefields Bay site and sites across the Caribbean.

The RAI dataset and Reef Fish Relative Abundances

For the second study, I calculated a new set of relative abundance indices from four Caribbean sites. I focused exclusively on reef fishes and used body-size to rank fishes. The RAI dataset contains reports published by Blick (2007), Colten and Worthington (2014), Quitmyer (2003), and Steadman and Jones (2006). I narrowed the RAI study to these papers as they reported multiple occupational levels or layers, allowing me to observe trends through time for a particular site. I focused on reef fishes and excluded fishes living in other habitats, because the Bluefields Bay diversity indices signaled resource depression in the reef patch and because archaeologists conducting comparison studies suggests Caribbean foragers targeted reef fishes in various island settings (Carlson and Keegan 2004; Newsom and Wing 2004; Wing and Wing 2001).

Data. The archaeofaunal material reported by Blick (2007) comes from San Salvador in the Bahamas. Blick's data comes from his excavations at Minnis-Ward (SS-3), which is on the northwest corner of San Salvador. John Goggin first excavated Minnis-Ward in 1960 and later, Winter extended excavations in the 1980s. Blick excavated a 5 x 5 m block to a depth of 40 cm. Minnis-Ward is classified as an open village site dating from A.D. 963 to A.D. 1426. Two fish families, Scaridae and Serranidae, dominate the archaeofaunal sample.

Colten and Worthington (2014) present data from the site Vega del Palmar, located on the south central coast of Cuba within the Greater Antilles. Vega del Palmar is a refuse midden located on a hilltop near Rio Arimao. Hahn excavated the site in the 1950s, with the data Colten and Worthington use coming from a single 2 m^2 unit excavated to a depth of 1.5 m. Colten and Worthington present two radiocarbon dates for the site, with the date from the 15-30 cm level being 1750 +/- 30 BP (Beta-318170; shell; δ13 = 2.6 0/00), estimated at A.D. 630 and the date from the 120-135 cm level being 2570 +/- 30 BP (Beta 318171; shell; δ13 = -3.0 0/00), estimated at 350 B.C..

Quitmyer (2003) presents the zooarchaeological remains from Cinnamon Bay, St. John, located in the U.S. Virgin Islands. The site contains a sequential record of human habitation and immigration beginning with the first occupation in cal A.D. 1000 to the abandonment of the site in cal A.D. 1490. Cinnamon Bay served as a ceremonial site that evolved into a Classic Taíno chief offering place. The site contains three ceramic styles constrained in stratigraphic sequence; the latest is the Monserrate style, observed between 70 and 100 centimeters below surface (cmbs). The next stratum corresponds to the Santa Elena pottery style and found within the 30 to 70 cmbs levels. The earliest stratum corresponds to the Chican Ostionoid style and observed between 30 cmbs and ground surface. The Chican Ceramic Period is generally attributed to the Taíno, with the other earlier styles representing the Taíno ancestors.

Data reported by Steadman and Jones (2007) comes from the island of Tobago located in the Southern Caribbean, north of Trinidad. Steadman and Jones excavated two sites from different parts of the island. Each site dates to different cultural periods. Milford I (TOB3) dates to the Archaic period, and the other site, Golden Grove (TOB13), dates to the Ceramic period. TOB3 is located 60 m from a small beach at Milford Bay with two adjoining 1 m^2 units placed in the densest portion of the midden. TOB-13 is 3.8 km northeast of TOB-3 and was a circular plaza village characteristic of Taíno design. Materials were water-screened using 1/16-inch mesh. Although calibrated radiocarbon dates suggest layer IV and III were occupied during the same time (cal A.D. 690-900), the law of superposition suggests layer IV is older than layer III. Relative dating of the layers appears logical when one lays on top of the other and I use this distinction in my interpretation of the data.

Methods. To calculate RAI values, I first define rank order of taxa in the faunal samples. As previously mentioned, zooarchaeologists often use body size as a proxy measure for average net return rates and I do the same here. Reef large bodied fishes include groupers (Serranidae) and parrotfish (Scaridae) (Newsom and Wing 2004). Within the groupers, genera *Epinephelus* and *Mycteroperca* are the largest piscivores. Genera *Scarus* and *Sparisoma* contain the largest parrotfish species. For wrasse (Labridae), most of the species are small. However, wrasses have considerable variation in size, body shape, and behavior (Humann and DeLoach 2002). The largest wrasses are hogfish (*Lachnolaimus maximus*). Therefore, highest ranked fishes derive from genera *Epinephelus*, *Mycteroperca*, *Scarus*, *Sparisoma*, and *Lachnolaimus*. Families of fishes representing low-ranked prey include surgeonfish (Acanthuridae), triggerfish (Balistidae), porcupinefish (Diodontidae), grunts (Haemulidae), squirrelfish (Holocentridae), snappers (Lutjanidae), pufferfish (Tetraodontidae), angelfish (Pomacanthidae), and other genera of wrasses, groupers, and parrotfish.

The index I use is the proportion of high-ranked taxa to high-ranked plus low-ranked taxa (Bayham 1979; Broughton 1994, 2002; Nagaoka 2002). A larger index value means the assemblage contains a greater proportion of large-bodied taxa. If resource depression is occurring, I expect to see declines in the relative abundance of higher ranked taxa through time.

Results. I combined all the sites in the study into one table (Table 18). The results adhere to predictions I made, although not quite in the way expected. Within the Golden Grove site (TOB13) and the Minnis-Ward (SS-3) site, the expected decline in high-ranked genera is evident. Golden Grove RAI values (layer IV = .72, layer III = .64, and layer II = .49) decline through time, and at Minnis-Ward the same trend is evident (stratum 3 = .67, stratum 2 = .60, and stratum 1 = .58).

However, there were some unexpected results. The first unexpected result centers on the Archaic sites, where the RAI values are the lowest of the calculations (Milford I = .28 and Vega del Palmar Lower = .29). This is unexpected, as I assumed it would be the highest of the four calculations. The low Archaic RAI values conform to previously stated observations that Archaic peoples practiced different foraging strategies from the later Ceramic peoples by focusing on terrestrial rather than marine resources (Keegan 1994; Wing 1989).

Table 18. Relative Abundances by Site, Caribbean Dataset.

Site	Period	Calibrated Date (2σ)	High	Low	Total	RAI
Milford I/Layer II	Archaic	1000-820 B.C.	102	264	366	**.28**
Golden Grove/Layer IV	Ceramic	A.D. 690-900	129	52	181	**.71**
Golden Grove/Layer III	Ceramic	A.D. 690-900	240	144	384	**.63**
Golden Grove/Layer II	Formative	A.D. 980-1060	258	341	599	**.43**
Cinnamon Bay/L10	Formative	A.D. 1029-1290	14	13	27	**.52**
Cinnamon Bay/L4	Formative	A.D. 1300-1485	324	127	452	**.72**
Cinnamon Bay/ L2	Formative	A.D. 1290-1475	145	90	235	**.62**
Minnis-Ward/Stratum 3	Formative	A.D. 950–1150	6	3	9	**.67**
Minnis-Ward/Stratum 2	Formative	A.D. 1150–1300	6	4	10	**.60**
Minnis-Ward/Stratum 1	Formative	A.D. 1300–1450	7	5	12	**.58**
Vega del Palmar/Lower	Archaic	350 B.C.	10	24	34	**.29**
Vega del Palmar/Upper	Ceramic	A.D. 630	36	21	57	**.63**

The other unexpected result comes from Cinnamon Bay. The RAI values appear to increase through time, beginning with a low RAI value for the early period (Level 10 =

.52), then a high RAI for the middle period (Level 4 = .72) and a decline in the RAI value in the latest period that is still higher than the earliest RAI value (Level 2 = .62). The results for Cinnamon Bay may have to do with the sites use as a ceremonial center, with the RAI values reflecting the sites importance rather than actual foraging efficiency.

Conclusion. The unique case of calculating RAI from published research shows that although not every site had signals of resource depression, the questions: can foragers alter marine resources in island settings, and can zooarchaeological data provide insights into these alterations, has been answered in the affirmative. I have also shown that taking into consideration a sites use is important for determining anomalies in the relative abundance of certain species, as is the case with the ceremonial site discussed here.

To conclude this chapter, I have shown through the calculation of RAI values, specific element measurements, and three diversity indices that resource depression, in the form of reduced encounter rates with high-ranked fishes, was occurring at the Bluefields Bay site and beyond. The pan-Caribbean studies provided both a comparison to the Bluefields Bay site and a detailed look at changing subsistence strategies across larger spatial and temporal scales. Moreover, I discussed alternatives to human caused resource depression that could account for the trends observed, such as changes in climate, cultural practices, and fishing technology. I included a study with results demonstrating an intensification of hook and line fishing. The study used a carnivore/herbivore index that ruled out changes in fishing technology, at least among the

Bluefields Bay Taíno. In essence, each measure provided nuanced results suggesting resource depression is not ubiquitous within a site, nor an island.

CHAPTER 8

REVIEW OF THESIS RESEARCH

To review, my thesis sought to answer the broad questions: can foragers alter marine resources in tropical and island settings and can zooarchaeological data provide insight into these changes? To answer these questions, I narrowed my focus to a faunal sample from the Bluefields Bay archaeological site in western Jamaica. The Bluefields Bay site lies near the small town of Belmont and dates to the late Taíno occupation of Jamaica, known as Meillacan Ostionoid (cal A.D. 900 to 1500). Within the context of my thesis research, a zooarchaeological study offered clear links to the pre-Columbian Bluefields Bay environment. My central hypothesis suggested the Bluefields Bay Taíno targeted large bodied, high-ranked fishes. This caused declines in the relative abundances and body size of these prey types, altering the ichthyofaunal community composition.

My research made explicit use of the prey choice model and provided signals of resource depression. Resource depression reflects the consequences of predator behavior in the direct reduction of prey capture rates (Charnov et al. 1976). Zooarchaeologists document the effects of resource depression by measuring changes in foraging efficiency (the net return per unit of time). This requires researchers to determine changes in prey choice and prey size (Broughton 2002; Grayson and Cannon 1999; Nagaoka 2002).

Using the primary data I generated of ichthyofaunal taxa and quantities, I generated secondary data. My results suggest the Bluefields Bay Taíno altered their local marine ecosystem by decreasing the overall size of fishes captured, known as growth overfishing and may have reduced the capture rates of inshore fishes causing them to shift to reef fishes. In addition, the comparison of the Bluefields Bay faunal sample to faunal data across the Caribbean yielded similar signals of resource depression and declining foraging efficiency. The trans-Caribbean data suggested the diet broadened to include lower-ranked fishes as shown by increasing evenness and richness in the reef patch. The changes in marine fish diversity offer evidence for possible ecosystem overfishing.

From the Bluefields Bay baseline data, I can suggest management targets for the local fishery and aid the Fisherman's Friendly Society. As Taíno catches included large carnivorous species of groupers (Serranidae) and snappers (Lutjanidae), then a return of such species in terms of both abundance and size indicates improvements to the Bay's stock. In addition, an increased diversity of grouper and snapper species, especially the larger species, would also indicate improvements to the overall ecosystem (Hawkins and Roberts 2004).

These results add to the growing body of literature providing data on the impacts small-scale societies have had on marine ecosystems. However, some remaining gaps in knowledge exist. A study providing the effects of climate change on fish productivity and population sizes would strengthen or disprove my conclusions. Another such study looking at archaeobotanical remains would also provide evidence on shifting horticulture practices that would influence marine exploitation. Additional studies would offer evidence besides human caused impacts to the marine ecosystem.

In addition, a study of all Jamaican archaeofaunal collections would improve our understanding of the islands Taíno subsistence strategies. A Jamaican archaeofaunal study would provide details on possible differences between exploited areas, as well as supply a longer time scale. In addition, research that included other marine fauna, terrestrial fauna, and bivalves would corroborate the trends seen in the ichthyofauna. Furthermore, access to a larger comparative collection could provide lower taxonomic identifications within the Bluefields Bay faunal sample. Increases in the number of species identified would allow a study using the distant patch model (Broughton 2002), and could alter some of the conclusions I have drawn here.

In conclusion, my thesis research offers evidence that the Taíno, who occupied the Bluefields Bay area, experienced resource depression as their subsistence patterns decreased the encounter rates with high-ranked fishes, leading them to introduce lower-ranked taxa into the diet. The Bluefields Bay Taíno experience similar trends as foragers across the greater Caribbean. I can answer in the affirmative that foragers alter marine resources in tropical and island settings, and that zooarchaeological data can provide insight into these changes.

REFERENCES CITED

Allsworth-Jones, Philip
2008 *Pre-Columbian Jamaica: Caribbean Archaeology and Ethnohistory*. University of Alabama Press, Tuscaloosa.

Atkinson, Lesley-Gail
2006 *The Earliest Inhabitants: The Dynamics of the Jamaican Taíno*. University of the West Indies Press, West Indies.

Baisre, Julio A.
2010 Setting a Baseline for Caribbean Fisheries. *Journal of Island & Coastal Archaeology* 5:170-172.

Bayham, Frank
1979 Factors Influencing the Archaic Pattern of Animal Utilization. *Kiva* 44:219-235.

Bellwood, David R.
1994 A Phylogenetic Study of the Parrotfish Family Scaridae (Pisces: Labroidea), with a Revision of Genera. *Records of the Australian Museum, Supplement* 20:1-86.

Bellwood, David R. and J. Howard Choat
1989 A Description of the Juvenile Phase Colour Patterns of 24 Parrotfish Species (family Scaridae) from the Great Barrier Reef, Australia. *Records of the Australian Museum* 41:1-41.

Blick, Jeffery P.
2007 Pre-Columbian Impact on Terrestrial, Intertidal, and Marine Resources, San Salvador, Bahamas (A.D. 950–1500). *Journal of Nature Conservation* 15:174-183.

Bobrowsky, Peter T. and Bruce F. Ball
1989 The Theory and Mechanics of Ecological Diversity in Archaeology. In *Quantifying Diversity in Archaeology*, edited by Robert D. Leonard and George T. Jones, pp. 4-12. Cambridge University Press, New York.

Boomert, Arie
2000 Trinidad, Tobago and the Lower Orinoco Interaction Sphere: An Archaeological/ Ethnohistorical Study. Ph.D. dissertation, Department of Anthropology, Leiden University, Leiden.

Broughton, Jack M.
1994 Late Holocene Resource Intensification in the Sacramento Valley, California: The Vertebrate Evidence. *Journal of Archaeological Science* 21:501-14.

1997 Widening Diet Breadth, Declining Foraging Efficiency, and Prehistoric Harvest Pressure: Ichthyofaunal Evidence from the Emeryville Shellmound, California. *Antiquity* 71:845-862.

2002 Prey Spatial Structure and Behavior Affect Archaeological Tests of Optimal Foraging Models: Examples from the Emeryville Shellmound Vertebrate Fauna. *World Archaeology* 34:60-83.

Broughton, Jack M., Michael D. Cannon, Frank E. Bayham, and David A. Byers
2011 Prey Body Size and Ranking in Zooarchaeology: Theory, Empirical Evidence, and Applications from the northern Great Basin. *American Antiquity* 76:403-428.

Bruggemann, J. Henrich, Madeleine J. H. van Oppen and Anneke M. Breeman
1994 Foraging by the Stoplight Parrotfish *Sparisoma viride.* I. Food Selection in Different, Socially Determined Habitats. *Marine Ecology Progress Series* 106:41-55.

Butler, Virginia L.
1994 Fish Feeding Behavior and Fish Capture: The Case for Variation in Lapita. *Archaeology in Oceania* 29:81-90.

2001 Changing Fish Use on Mangaia, southern Cook Islands: Resource Depression and The Prey Choice Model. *International Journal of Osteoarchaeology* 11:88-100.

2010 Seeking Balance in "Human Impacts" Research. Comment on Julio Baisre's "Setting a Baseline for Caribbean Fisheries." *Journal of Island & Coastal Archaeology* 5:148-151.

Butler, Virginia L. and Sarah K. Campbell
2004 Resource Intensification and Resource Depression in the Pacific Northwest: A Zooarchaeological Review. *Journal of World Prehistory* 18:327-405.

Byers, David A., Craig S. Smith, and Jack M. Broughton
2005 Holocene Artiodactyl Population Histories and Large Game Hunting in the Wyoming Basin, USA. *Journal of Archaeological Science* 32:125-142.

Cannon, Debbi Yee
1987 *Marine Fish Osteology: A Manuel for Archaeologists*. Archaeology Press, Burnbay, B.C.

Cannon, Michael D.
2000 Large Mammal Relative Abundance in Pithouse and Pueblo Period Archaeofaunas from Southwestern New Mexico: Resource Depression among the Mimbres-Mogollon. *Journal of Anthropological Archaeology* 19:317-347.

Cannon, Michael D. and Jack M. Broughton
2010 Evolutionary Ecology and Archaeology: An Introduction. In *Evolutionary Ecology and Archaeology: Applications to Problems in Human Evolution and Prehistory*, edited by Jack M. Broughton and Michael D. Cannon, pp. 1-12. University of Utah Press, Salt Lake City.

Carder, Nanny, Elizabeth J. Reitz, and John G. Crock
2007 Fish Communities and Populations during the post-Saladoid period (AD 600/800-1500), Anguilla, Lesser Antilles. *Journal of Archaeological Science* 34:588-599.

Carlson, Lisbeth A., and William F. Keegan
2004 Resource Depletion in the Prehistoric Northern West Indies. In *Voyages of Discovery: The Archaeology of Islands*, edited by Scott M. Fitzpatrick, pp. 85-107. Praeger Publishers, Westport.

Charnov, L. Eric and Gordon H Orians
1973 Optimal Foraging: Some Theoretical Explorations. Ph.D. dissertation, Department of Anthropology, University of Washington, Seattle. University of New Mexico Repository, Albuquerque.

Charnov, L. Eric, Gordon H. Orians, and Kim Hyatt
1976 Ecological Implications of Resource Depression. *The American Naturalist* 110:247-259.

Choat, J. Howard and David R. Bellwood
1998 Wrasses and Parrotfishes. In *The Encyclopedia of Fishes*, edited by John R. Paxton and William N. Eschmeyer, pp. 211-215. Academic Press, San Diego.

Colley, Sarah M.
1990 The Analysis and Interpretation of Archaeological Fish Remains. *Archaeological Method and Theory* 2:207-253.

Colten, Roger H., Elizabeth Terese Newman, and Brian Worthington
2009 Preceramic Faunal Exploitation at the Las Obas Site, Cuba. Bulletin of the Peabody Museum of Natural History Vol. 50, No. 1. Yale University, New Haven.

Colten, Roger H. and Brian Worthington
2014 Faunal Remains from the Archaic and Archaic Ceramic Site of Vega del Palmar, Cuba. *Journal of Caribbean Archaeology* 14:23-49.

Cooper, Jago and Mathew Peros
2010 The Archaeology of Climate Change in the Caribbean. *Journal of Archaeological Science* 37:1226-1232.

Cruz-Uribe, Kathryn
1988 The Use and Meaning of Species Diversity and Richness in Archaeological Faunas. *Journal of Archaeological Science* 15:179-196.

Daly, Patricia
1969 Approaches to Faunal Analysis in Archaeology. *American Antiquity* 34:146-153.

deFrance, Susan D.
2010 Valuing the Archaeological Record of Human Impacts on Caribbean Fisheries. Comment on Julio Baisre's "Setting a Baseline for Caribbean Fisheries." *Journal of Island & Coastal Archaeology* 5:156-158.

deFrance, Susan D., William F. Keegan, and Lee A. Newsom
1996 The Archaeobotanical, Bone Isotope, and Zooarchaeological Records from Caribbean Sites in Comparative Perspective. In *Case Studies in Environmental Archaeology*, edited by Elizabeth J. Reitz, Lee A. Newson, and Sylvia J. Scudder, pp. 289-304, Plenum Press, New York.

DeLoach, Ned and Paul Humann
2007 *Reef Fish Behavior: Florida, Caribbean, Bahamas*. New World Publishers, Jacksonville.

Dulvy, Nicholas K., Yvonne Sadovy, and John D. Reynolds
2003 Extinction Vulnerability in Marine Populations. *Fish and Fisheries* 4:25-64.

Erlandson, Jon M. and Torben C. Rick
2010 Archaeology Meets Marine Ecology: The Antiquity of Maritime Cultures and Human Impacts on Marine Fisheries and Ecosystems. *Annual Review of Marine Science* 2:165-185.

Eschmeyer, William N.
2014 Catalog of Fishes at the California Academy of Sciences. Electronic document, http://www.calacademy.org/scientists/projects/catalog-of-fishes, accessed December 2, 2014.

Field, Andy
2013 *Discovery Statistics Using SPSS*. 4th ed. Sage Publications Inc., Los Angeles.

Fitzpatrick, Scott M.

2010 Viewing the Sea from the Reefs. Comments and Forum Synthesis on Julio Baisre's "Setting a Baseline for Caribbean Fisheries." *Journal of Island & Coastal Archaeology* 5:173-178.

Fitzpatrick, Scott M., William F. Keegan, and Kathleen Sullivan Sealey

2008 Human Impacts on Marine Environments in the West Indies during the Middle and Late Holocene. In *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, edited by Torben C. Rick and Jon M. Erlandson, pp. 147-164. University of California Press, Berkeley.

Gallucci, Frank J.

1985 The Geophysics and Cultural Aspects of the Greater Antilles. Electronic document, http://www.yale.edu/ynhti/curriculum/units/1985/4/85.04.04.x.html, accessed March 31, 2013.

Gibran, Fernando Zaniolo

2007 Activity, Habitat Use, Feeding Behavior and Diet of Four Sympatric Species of Serranidae (Actinopterygii: Perciformes) in southeastern Brazil. *Neotropical Ichthology* 5:387-398.

Gilmore, Raymond M.

1949 The Identification and Value of Mammal Bones from Archaeological Excavations. *Journal of Mammalogy* 50:163-169.

Gordon, Marvel

2011 Fish Sanctuaries Working. *Jamaican Observer* 03 July. Kingston

Gosline, William A.

1984 Structure, Function, and Ecology in the Goatfishes (Family Mullidae). *Pacific Science* 38:312-323.

Grayson, Donald K.

1979 On the Quantification of Vertebrate Archaeofaunas. In *Advances in Archaeological Method and Theory,* edited by Michael B. Schiffer, pp. 199-237. Academic Press, New York.

1981 The Effects of Sample Size on Some Derived Measures in Vertebrate Faunal Analysis. *Journal of Archaeological Science* 8:77-88.

2001 The Archaeological Record of Human Impacts on Animal Populations. *Journal of World Prehistory* 15:1-68.

Grayson, Donald K. and Michael D. Cannon
1999 Human Paleoecology and Foraging Theory in the Great Basin. In *Models for the Millennium*, edited by Charlotte Beck, pp. 141-151. University of Utah Press, Salt Lake City.

Grayson, Donald K. and Francoise Delpech
1998 Changing Diet Breadth in the Early Upper Paleolithic of Southwestern France. *Journal of Archaeological Science* 25:1119-1129.

Gurven, Michael
2006 Human Behavioral Ecology. In *Encyclopedia of Anthropology,* edited by H. James Birx, pp. 773-777. SAGE Publications, Thousand Oaks.

Hardesty, Donald L.
1980 The Use of General Ecological Principles in Archaeology. *Advances in Archaeological Method and Theory* 3:157-187.

Hawkins, Julie P. and Callum M. Roberts
2004 Effects of Artisanal Fishing on Caribbean Coral Reefs. *Conservation Biology* 18:215-226.

Heemstra, Phillip C., William D. Anderson, and Phillip S. Lobel
2003 Groupers (Seabasses, Creolefish, Coney, Hinds, Hamlets, Anthiines, and Soapfishes). In *The Living Marine Resources of the Western Central Atlantic,* edited by Kent E. Carpenter pp. 1308-1369. FAO Species Identification Guide for Fishery Purposes. Vol. 2: Bony fishes part 1 (Acipenseridae to Grammatidae). Electronic document, http://www.fao.org/3/a-y4161e.pdf, accessed February 18, 2015.

Helfman, Gene S.
2007 *Fish Conservation: A Guide to Understanding and Restoring Global Aquatic Biodiversity and Fishery Resources*. Island Press, Washington, D.C.

Helfman, Gene S., Bruce B Collette, Douglas E. Facey, and Brian W. Bowen
2009 *The Diversity of Fishes: Biology, Evolution, and Ecology*. 2nd ed. Wiley-Blackwell Ltd. Publication, Hoboken.

Howard, Hildegarde
1930 A Census of the Pleistocene Birds of Rancho La Brea from the Collections of the Lost Angeles Museum. *The Condor* 32:81-88.

Hughes, Terence P.
1994 Catastrophes, Phase Shifts, and Large-Scale Degradation of a Caribbean Coral Reef. *Science* 265:1547-1551.

Humann, Paul and Ned DeLoach
2002 *Reef Fish Identification: Florida, Caribbean, Bahamas*. New World Publications, Jacksonville.

Jacks, Phillipa
2011 'The Fish Can Done:' a Marine Sanctuary Project in Jamaica's Bluefields Bay. Electronic Document, http://philippajacks.co.uk/2011/01/the-fish-can-done-a-marine-sanctuary-project-in-jamaicas-bluefield-bay/, accessed September 25, 2012.

Jackson, Jeremy B. C.
1997 Reefs since Columbus. *Coral Reefs* 16:23-32.

Jackson, Jeremy B. C. and Michael X. Kirby, Wolfgang H. Berger, Karen A. Bjorndal, Louis W. Botsford, Bruce J. Bourque, Roger H. Bradbury, Richard Cooke, Jon Erlandson, James A. Estes, Terence P. Hughes, Susan Kidwell, Carina B. Lange, Hunter S. Lenihan, John M. Pandolfi, Charles H. Peterson, Robert S. Steneck, Mia J. Tegner, and Robert R. Warner
2001 Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science* 293:629-638.

Johnson, G. David and Anthony C. Gill
1998 Perches and Their Allies. In *The Encyclopedia of Fishes,* edited by John R. Paxton and William N. Eschmeyer, pp. 181-195. Academic Press, San Diego.

Johnson, Jan
2005 Fisheries and Aquaculture Topics, Small-Scale and Artisanal Fisheries, Topics Fact Sheet. In *FAO Fisheries and Aquaculture Department*. Electronic Document http://www.fao.org/fishery/topic/14753/en, accessed April 23, 2015.

Jones, Sharyn
2010 Considerations for Advancing a Dialogue Pre-Modern Marine Exploitation in the Caribbean and Beyond: Comment on Julio Baisre's "Setting a Baseline for Caribbean Fisheries." *Journal of Island & Coastal Archaeology* 5:159-161.

Keegan, William F.
1986 The Ecology of Lucayan Arawak Fishing Practices. *American Antiquity* 51:816-825.

1994 West Indian Archaeology. 1. Overview and Foragers. *Journal of Archaeological Research* 2:255-284.

Keegan, William F.

2000 West Indian Archaeology. 3. Ceramic Age. *Journal of Archaeological Research* 8:135-167.

2010 From Faunal Remains to Baselines: Comment on Julio Baisre's "Setting a Baseline for Caribbean Fisheries." *Journal of Island & Coastal Archaeology* 5:162-164.

Keegan, William F. and Lesley-Gail Atkinson

2006 The Development of Jamaican Prehistory. In *The Earliest Inhabitants: The Dynamics of the Jamaican Taino,* edited by Lesley-Gail Atkinson, pp. 13-29. University of the West Indies Press, West Indies.

Keegan, William F. and Lisabeth A. Carlson

2008 *Talking Taíno: Caribbean Natural History from a Native Perspective*. University of Alabama Press, Tuscaloosa.

Keegan, William F., Roger W. Portell, and John Slapcinsky

2003 Changes in Invertebrate Taxa at Two pre-Columbian Sites in Southwestern Jamaica, AD 800–1500. *Journal of Archaeological Science* 30:1607-1617.

Kelly, Robert L.

1995 *The Foraging Spectrum*. Smithsonian Institute Press, Washington.

Klein, Richard G. and Kathryn Cruz-Uribe

1984 *The Analysis of Animal Bones from Archaeological Sites*. University of Chicago Press, Chicago.

Leach, Bryan Foss and Mishiko Intoh

1984 An Archaeological Fishbone Assemblage from the Vitaria Site, Rurutu, Austral Islands. *Journal de la Societe des Oceanistes* 78:75-77.

Lee, Wendy A.

2006 Notes on the Natural History of Jamaica. In *The Earliest Inhabitants: The Dynamics of the Jamaican Taíno,* edited by Lesley-Gail Atkinson, pp. 89-96. University of the West Indies Press, West Indies.

LeFebvre, Michelle J.

2007 Zooarchaeological Analysis of Prehistoric Vertebrate Exploitation at the Grand Bay Site, Carriacou, West Indies. *Coral Reefs* 26:931-944.

Lyman, R. Lee

2003 The Influence of Time Averaging and Space Averaging on the Application of Foraging Theory in Zooarchaeology. *Journal of Archaeological Science* 30:959-610.

Lyman, R. Lee
2008 *Quantitative Paleozoology*. Cambridge University Press, New York.

MacArthur, Robert H.
1972 *Geographical Ecology: Pattern in the Distribution of Species*. Princeton University Press, Princeton.

MacArthur, Robert H. and Richard Levins
1967 The Limiting Similarity, Convergence, and Divergence of Coexisting Species. *The American Naturalist* 101:377–385.

MacArthur, Robert H. and Eric R. Pianka
1966 On Optimal Use of a Patchy Environment. *The American Naturalist* 100:603-609.

Madsen, David B. and Dave N. Schmitt
1998 Mass Collecting and the Diet Breadth Model: A Great Basin Example. *Journal of Archaeological Science* 25:445-455.

Magurran, Anne E.
2004 *Measuring Biological Diversity*. Blackwell Science Ltd., Malden.

Map of Life
2015 *Pharyngeal Jaws in Teleost Fish*. Electronic document, http://www.mapoflife.org/topics/topic_361_Pharyngeal-jaws-in-teleost-fish/, accessed April 24, 2015.

Margalef, Ramon
1968 *Perspectives in Ecological Theory*. University of Chicago Press, Chicago.

Masse, W. Bruce
1986 A Millennium of Fishing in the Palua Islands, Micronesia. In *Traditional Fishing in the Pacific: Ethnographical and Archaeological Papers from the 15th Pacific Science Congress*, edited by Atholl Anderson, pp. 85-117. Pacific Anthropological Records No 37, Bernice P. Bishop Museum, Honolulu.

Matsuura, Keiighi and James C. Tyler
1998 Triggerfishes and their Allies. In *The Encyclopedia of Fishes*, edited by John R. Paxton and William N. Eschmeyer, pp. 229-233. Academic Press, San Diego.

McClenachan, Loran, Marah Hardt, Jeremy Jackson, and Richard Cooke
2010 Mounting Evidence for Historical Overfishing and Long-term Degradation of Caribbean Marine Ecosystems: Comment on Julio Baisre's "Setting a Baseline for Caribbean Fisheries." *Journal of Island and Coastal Archaeology* 5:165-169.

McKillop, Heather

1984 Prehistoric Maya Reliance on Marine Resources: Analysis of a Midden from Moho Cay, Belize. *Journal of Field Archaeology* 11:25-35.

Miloclavich, Patricia and Eduardo Klein

2004 Linking Marine Biodiversity Research and Conservation in the Caribbean. *Proceedings of the Caribbean Marine Biodiversity Workshop* 1:1-17. Isla de Margarita.

Morrison, Alex E. and Terry L. Hunt

2007 Human Impacts on the Nearshore Environment: An Archaeological Case Study From Kaua'I, Hawaiian Islands. *Pacific Science* 61:325-345.

Mullon, Christian, Pierre Freon, and Philippe Cury

2005 The Dynamics of Collapse in World Fisheries. *Fish and Fisheries* 6:111-120.

Nagaoka, Lisa

2001 Using Diversity Indices to Measure Changes in Prey Choice at the Shag River Site, Southern New Zealand. *International Journal of Osteoarchaeology* 11:101-111.

2002 Explaining Subsistence Change in Southern New Zealand Using Foraging Theory Models. *World Archaeology* 34:84-102.

Nelson, Joseph S.

2006 *Fishes of the World*. 4th ed. John Wiley & Sons, Inc., Hoboken.

Newsom, Lee A. and Elizabeth S. Wing

2004 *On Land and Sea: Native American Uses of Biological Resources in the West Indies*. University of Alabama Press, Tuscaloosa.

Odum, Eugene P. and Gary W. Barrett

2005 *Fundamentals of Ecology*. Thomson Learning Incorporated, Belmont, California.

Olsen, Stanley J.

1968 *Fish, Amphibian and Reptile Remains from Archaeological Sites: Southeastern and Southwestern United States*, Appendix: The Osteology of the Wild Turkey. Vol. 56. Peabody Museum Press, Cambridge.

1971 The Relative Value of Fragmentary Mammalian Remains. *American Antiquity* 26:538-540.

Orchard, Trevor J. and Susan Crockford
2010 Size Estimation of Pacific Cod (*Gadus microcephalus*) Remains from Shemya Island. In *The People at the End of the World: The Western Aleutians Project and the Archaeology of Shemya Island*, edited by Debra G. Corbett, Dixie Lee West, and Christine Lefebvre, pp. 93-98. Alaska Anthropological Association, Anchorage.

Orians, Gordon H.
1969 On the Evolution of Mating Systems in Birds and Mammals. *The American Naturalist* 103:589-603.

Paris, Claire B., Robert K. Cowen, Rodolgo Claro, and Kenyon C. Lindeman
2005 Larval Transport Pathways from Cuban snappers (Lutjanidae): Spawning Aggregations Based on Biophysical Modeling. *Marine Ecology Progress Series* 296:93-106.

Pauly, Daniel
1995 Anecdotes and the Shifting Baseline Syndrome of Fisheries. *Trends in Ecology and Evolution* 10:430-430.

Pauly, Daniel, Villy Christensen, Johanne Dalsgaard, Rainer Froese, and Francisco Torres Jr.
1988 Fishing Down Marine Food Webs. *Science* 279:860-863.

Peet, Robert K.
1974 *The Measurement of Species Diversity*. Annual Review of Ecology and Systematics Vol. 5. Annual Reviews, Palo Alto.

Quitmyer, Irvy R.
2003 *Zooarchaeology of Cinnamon Bay, St. John, US Virgin Islands: Pre-Columbian Overexploitation of Animal Resources*. Bulletin of the Florida Natural History Museum, Vol. 44, No. 1. Florida Natural History Museum, Gainsville.

Randall, John E.
1998 Groupers, Seabasses, and their Allies. In *The Encyclopedia of Fishes*, edited by John R. Paxton and William N. Eschmeyer, pp. 195-199. Academy Press Inc., San Diego.

Reitz, Elizabeth J.
2001 Fishing in Peru between 10000 and 3750 BP. *International Journal of Osteoarchaeology* 11:163-171.

2004 “Fishing Down the Food Web:” A Case Study from St. Augustine, Florida, USA. *American Antiquity* 69:63-83.

Reitz, Elizabeth J., Irvy R. Quitmyer, H. Stephen Hale, Sylvia J. Scudder, and Elizabeth S. Wing
1987 Application of Allometry to Zooarchaeology. *American Antiquity* 53:304-317.

Reitz, Elizabeth J. and Elizabeth S. Wing
2008 *Zooarchaeology*. Cambridge University Press, New York.

Ringrose, Trevor J.
1993 Bone Counts and Statistics: A Critique. *Journal of Archaeological Science* 20:121-157.

Roberts, Callum M. and Julie P. Hawkins
1999 Extinction Risk in the Sea. *Trends in Ecological Evolution* 14:241-46.

Rosello, E. V. Vasquez, A. Morales, and T. Rosales
2001 Marine Resources from an Urban Moche (470-600 AD) Area in the 'Huacas del Sol y del la Luna' Archaeological Complex (Trujillo, Peru). *International Journal of Osteoarchaeology* 11:72-87.

Rouse, Irving
1989 Peopling and Repeopling of the West Indies. In *Biogeography of the West Indies*, edited by Charles A. Wood, pp. 119-127. Sandhill Crane Press, Gainesville.

1992 *The Tainos: Rise and Decline of the People Who Greeted Columbus*. Yale University Press, New Haven.

Russ, Garry R.
1991 Coral Reef Fisheries: Effects and Yields. In *The Ecology of Fishes on Coral Reefs,* edited by Peter F. Sale, pp. 601-635. Academic Press, San Francisco.

Sary, Zsolt, John L. Munro, and Jeremy D. Woodley
2003 Status Report on Jamaican Reef Fishery: Current Value and Costs of Non-Management. *Gulf and Caribbean Fisheries Institute* 54:98-146.

Schoener, T. W.
1971 Theory of Feeding Strategies. *Annual Review of Ecological Systems* 11:369-404.

Sciberras, Marija, Stuart R. Jenkins, Rebecca Mant, Michel J. Kaiser, Stephen J. Hawkins, and Andrew S. Pullin
2015 Evaluating the Relative Conservation Value of Fully and Partially Protected Marine Areas. *Fish and Fisheries* 16:58-77.

Scudder, Sylvia
2006 Early Arawak Subsistence Strategies: The Rodney's House Site of Jamaica. In *The Earliest Inhabitants: The Dynamics of the Jamaican Taino*, edited by Lesley-Gail Atkinson, pp. 113-128. University of the West Indies Press, West Indies.

Shannon, Claude E and Warren Weaver
1949 *The Mathematical Theory of Communication*. University of Illinois, Urbana.

Simms, Steven R.
1985 Pine Nut Use in Three Great Basin Cases: Data, Theory and a Fragmentary Material Record. *Journal of California and Great Basin Anthropology* 7:166-175.

Smith, Eric A.
1983 Anthropological Applications of Optimal Foraging Theory: A Critical Review. *Current Anthropology* 24:625-651.

Smith, Eric A. and Bruce Winterhalder
1992 Natural Selection and Decision Making: Some Fundamental Principles. In *Evolutionary Ecology and Human Behavior*, edited by Eric A. Smith and Bruce Winterhalder, pp. 25-60. Aldine de Gruyter, New York.

Steadman, David W. and Sharyn Jones
2006 Long-Term Trends in Prehistoric Fishing and Hunting on Tobago, West Indies. *Latin American Antiquity* 17:316-334.

Stephens, David W. and John R. Krebs
1986 *Foraging Theory*. Princeton University Press, New Jersey.

Stiner, Mary C. and Natalie D. Munro
2002 Approaches to Prehistoric Diet Breadth, Demography, and Prey Ranking Systems in Time and Space. *Journal of Archaeological Method and Theory* 9:181-214.

Stiner, Mary C., Natalie D. Munro, Todd A. Surovell, Eitan Tchernov, and Ofar Bar-Yosef
1999 Paleolithic Population Growth Pulses Evidences by Small Animal Exploitation. *Science* 283:190-194.

Stock, Chester
1929 A Census of the Pleistocene Mammals of Rancho la Brea, Based on the Collections of the Los Angeles Museum. *Journal of Mammalogy* 10:281-289.

Wake, Thomas A., Douglas R. Doughty, and Michael Kay
2013 Archaeological Investigations Provide Late Holocene Baseline Ecological Data For Bocas del Toro, Panama. *Bulletin on Marine Science* 89:1-21.

Watters, David R.
1989 Archaeological Implications for Lesser Antilles Biogeography: The Small Island Perspective. In *Biogeography of the West Indies*, edited by Charles A. Wood, pp. 153-166. Sandhill Crane Press, Gainsville.

Westneat, Mark W.
1999 *Scaridae*. The Living Marine Resources of the Western Central Pacific: FAO Species Identification Sheets for Fishery Purposes. Family Labridae. Food and Agriculture Organization of the United Nations 6:3381–3467.

Wheeler, Alwyne and Andrew K.G. Jones
1989 *Fishes: Cambridge Manuals in Archaeology*. Cambridge University Press, New York.

White, Theodore E.
1953 A Method of Calculating the Dietary Percentage of Various Food Animals Utilized by Aboriginal Peoples. *American Antiquity* 19:396-398.

Wilkinson, Laurie
2001 Impact of Hunting on Jamaican Hutias (*Geocapromys brownii*) Populations: Evidence from Zooarchaeology and Hunter Surveys. In *Biogeographies of the West Indies: Patterns and Perspectives*, 2nd ed., edited by Charles A. Woods and Florence Sergile, pp. 529-545, CRC Press, Boca Raton.

Wilson, Samuel M.
2007 *The Archaeology of the Caribbean*. Cambridge University Press, New York.

Wing, Elizabeth S.
1975 Hunting and Herding in the Peruvian Andes. In *Archaeozoological Studies: Papers of the Archaeozoological Conference 1974, held at the Biologisch-Archaeologisch Instituut of the State University of Groningen*, 1st ed., edited by Anneke T. Clason, pp. 302-308. American Elsevier, New York.

1989 Human Exploitation of Animal Resources in the Caribbean. In *Biogeography of the West Indies: Past, Present, and Future*, edited by Charles A. Woods, pp. 137-152. Sandhill Crane Press, Gainesville.

2001 Native American Use of Animals in the Caribbean. In *Biogeography of the West Indies: Patterns and Perspectives*, 2nd ed., edited by Charles A. Wood and Florence E. Sergile, pp. 481-518. CRC Press, Boca Raton.

Wing, Elizabeth S. and Elizabeth J. Reitz
1982 Prehistoric Fishing Communities of the Caribbean. *Journal of New World Archaeology* 5:13-32.

Wing, Elizabeth S. and Sylvia J. Scudder
1983 Animal Exploitation by Prehistoric People Living on a Tropical Marine Edge. In *Animals and Archaeology Vol. 2 Shell Middens, Fishes and Birds,* edited by C. Grigson and J. Clutton-Brock, pp. 197-210. BAR International Series 183, Oxford.

Wing, Steve R. and Elizabeth S. Wing
2001 Prehistoric Fisheries in the Caribbean. *Coral Reefs* 20:1-8.

Woolwine-Moen, Christina and John Moen
2011 Caribbean Islands. Electronic document, http://www.worldatlas.com/webimage/countrys/carib.htm, accessed March 30, 2013.

Wootton, Robert J.
1998 *Ecology of Teleost Fishes*. 2nd ed. University of Wales, Boston.

Zeanah, David W. and Steven R. Simms
1999 Modeling the Gastric: Great Basin Subsistence Studies since 1982 and the Evolution of General Theory. In *Models for the Millennium: Great Basin Anthropology Today*, edited by Charlotte Beck, pp. 118-140. University of Utah Press, Salt Lake City.

APPENDICES

APPENDIX A

ADDITIONAL DATA FROM THE BLUEFIELDS BAY SITE

Table 19. Element Abbreviations.

Element	Abbreviation	Element	Abbreviation
Unidentified	UN	Fin Rays	FR
Non-Fish	NF	Vertebrae	Ve
Dentaries	De	Atlas	At
Premaxillae	Pm	Basioccipital	Bo
Maxillae	Mx	Certahyal	Ce
Angular	An	Epihyal	Ep
Vomer	Vo	Preopercle	Po
Parashenoid	Ps	Supraoccipital	So
Palatine	Pa	Scapula	Sc
Pharyngeals	Ph	Cleithrum	Cl
Quadrate	Qu	Supracleithrum	Sl
Hyomandibular	Hy	Ultimate Vertebra	UV
Dorsal Spine	DS	Postemporal	Pt
Spines	Sp	Frontal	Fr
Teeth	Te	Exocciptial	Eo
Opercle	Op		

Table 20. Element Counts for Unit 5, Level 1.

Taxon	Element	UN	Ve	Te	Fe	Σ
Rodentia				1		1
Geocapromys cf. *brownii*		1		1	1	3
Chondrichthyes			1			1
Osteichthyes			7			7
		1	8	2	1	11

Table 21. Element Counts for Unit 5, Level 2

	Element																			
Taxon	UN	NF	De	Pm	Ma	An	Vo	Ps	Pa	Ph	Qu	Sp	Te	FR	Ve	At	Bo	Ce	Po	Σ
Carnivora		2																		2
Reptilia		1																		1
Rodentia													1							1
Geocapromys cf. *brownii*	11	92											62		6					171
Chondrichthyes															1					1
Osteichthyes	8			1	1			1	2	1	2			60	213	8	1	1	1	300
Diodontidae												3								3
Haemulidae					1															1
Labridae										1										1
Lutjanidae					1	1	1													3
Scaridae										1										1
Sparisoma sp.			1							1										2
Serranidae			2	2	1															5
Σ	21		3	3	4	1	1	1	2	4	2	3	63	60	220	8	1	1	1	399

Table 22. Element Counts for Unit 5, Level 3

											Element										
Taxon	UN	NF	De	Pm	Mx	An	Ps	Pa	Qu	Hy	Sp	Te	Op	FR	Ve	At	Bo	Ce	Po	So	Sc	Σ
Aves		1																				1
Reptilia		1																				1
Carnivora		5																				5
Rodentia		3																				3
Geocapromys cf. *brownii*	5	94										59			13						4	175
Osteichthyes	23				4	2	2	2	1	1		2	1	83	207	4	1	3	2	2	1	341
Balistidae												1										1
Diodontidae											5											5
Haemulidae				5	2																	7
Lutjanidae			1	1	1																	3
Lutjanus synagris						1																1
L. jocu						2																2
Sparisoma sp.				1																		1
Serranidae			2		1																	3
Σ	35		3	7	8	5	2	2	1	1	5	62	1	83	220	4	1	3	2	2	5	452

Table 23. Element Counts for Unit 5, Level 4

	Element																								
Taxon	UN	NF	De	Rm	Mx	An	Vo	Ps	Pa	Ph	Qu	Hy	Sp	Te	Op	FR	Ve	At	Bo	Ce	Po	So	Sc	Cl	UV	Σ
Carnivora		2																								2
Rodentia		1																								1
Geocapromys cf. *brownii*	11	129												58			20						6			224
Chondrichthyes																	1									1
Osteichthyes	32				2	6		3	2	1	1	2			3	145	187	4	2	4	4	2		3	2	405
Balistidae				1										2												3
Carangidae				1																						1
Diodontidae													12													12
Haemulidae				7	2		1				2															12
Lutjanidae				1	5																					6
Lutjanus synagris			1																							1
Scaridae										1																1
Sparisoma sp.			2	1																						3
Serranidae			2	1	1	2					4															10
Σ	43	132	5	12	10	8	1	3	2	2	7	2	12	60	3	145	208	4	2	4	4	2	6	3	2	682

Table 24. Element Counts for Unit 5, Level 5.

	Element																											
Taxon	UN	FN	De	Pm	Mx	An	Vo	Ps	Pa	Ph	Qu	Hy	Sp	Te	Op	FR	Ve	At	Bo	Ce	Ep	Po	Sc	Cl	Sp	UV	Pt	Σ
Aves	1																											1
Carnivora	1																											1
Reptilia																	3											3
Rodentia		3																										3
Geocapromys cf. *brownii*	22	86												71			19						1					199
Chondrichthyes																	3											3
Osteichthyes	34		1			6		4	7	10	10	6			1	215	522	14	3	7	3	6	1	3	7	10	2	872
Balistidae				1										4														5
Carangidae					2	1	1					1																5
Diodontidae													80															80
Haemulidae			2	5	14	2					3																	26
Lutjanidae			2	6	3	1	2																					14
Lutjanus synagris			1			4																						5
L. jocu						4																						4
Scaridae			1		1	2		1		7																		12
Sparisoma sp.				7																								7
Serranidae			5	6	2	4																						17
Sparidae						1																						1
Σ	58	89	12	25	22	25	3	5	7	17	13	7	80	75	1	215	547	14	3	7	3	6	2	3	7	10	2	1258

Table 25. Element Counts for Unit 5, Level 6.

	Element																										
Taxon	UN	FN	De	Pm	Mx	An	Ps	Pa	Ph	Qu	Hy	Sp	Te	Op	FR	Ve	At	Bo	Ce	Ep	Po	Sc	Cl	So	UV	Pt	Σ
Aves		1																									1
Carnivora		3																									3
Reptilia																1											1
Rodentia	1	4																									5
Geocapromys cf. *brownii*	10	79											47			17						1					154
Chondrichthyes																2											2
Osteichthyes	29		1	5	2	3	6	3	2	6	3			4	136	396	10	8	4	2	1	1	2	1	5	3	633
Balistidae													1														1
Carangidae			1	1	1																						3
Diodontidae												9															9
Haemulidae				3	6	1				2																	12
Lutjanidae			1	2	5																						8
Lutjanus synagris						3																					3
L. jocu			1																								1
Scaridae									7																		7
Sparisoma sp.			1	1																							2
Serranidae			3	1	3	1					1																9
Sparidae				1				1																			2
Σ	40	87	8	14	17	8	6	4	9	8	4	9	48	4	136	416	10	8	4	2	1	2	2	1	5	3	856

Table 26. Element Counts for Unit 5, Level 7.

	Element																										
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ps	Ph	Qu	Hy	DS	Sp	Te	FR	Ve	At	Bo	Ce	Ep	Po	So	Sc	Sp	UV	Pt	Σ
Aves		1																									1
Carnivora		1																									1
Reptilia		3														1											4
Crustacea		2																									2
Geocapromys cf. *brownii*	23	80												34		18							2				157
Chondrichthyes																2											2
Osteichthyes	46		6	1		6		3	1	12	3				175	337	8	3	8	2	5	2		2	2	2	624
Balistidae												1															1
Diodontidae													3														3
Haemulidae			2	8	6		1	3		1	1																22
Labridae									1																		1
Lutjanidae				4	5	1					1																11
Lutjanus synagris			2			2																					4
L. jocu			2																								2
Scaridae			1	3																							4
Sparisoma sp.								1	3																		4
Serranidae			3	3	3	1																					10
Sparidae			1			1																					2
Σ	69	87	17	19	14	11	1	7	5	13	5	1	3	34	175	358	8	3	8	2	5	2	2	2	2	2	855

Table 27. Element Counts for Unit 5, Level 8.

	Element														
Taxon	UN	NF	De	Pm	Mx	Vo	Ps	Ph	Sp	Te	FR	Ve	Bo	Ce	Σ
Aves		1													1
Carnivora		1													1
Rodentia	1	3													4
Geocapromys cf. *brownii*	1	27								18					46
Osteichthyes	7				2		1				30	53	1	1	95
Diodontidae									2						2
Haemulidae				1	1										2
Lutjanidae				1											1
Scaridae								4							4
Serranidae			1			1									2
Σ	9	32	1	2	3	1	1	4	2	18	30	53	1	1	158

Table 28. Element Counts for Unit 5, Level 9.

	Element														
Taxon	UN	NF	De	Mx	Vo	Ps	Ph	Qu	Sp	Te	FR	Ve	At	Po	Σ
Rodentia										1					1
Geocapromys cf. *brownii*	10	26								6					42
Osteichthyes	6					1		1			30	62	3	2	105
Carangidae				1											1
Diodontidae									1						1
Haemulidae				1											1
Lutjanidae			1		1										2
Scaridae							1								1
Serranidae			2												2
Σ	16	26	3	2	1	1	1	1	1	7	30	62	3	2	156

Table 29. Element Counts for Unit 5, Level 10.

	Element											
Taxon	UN	NF	De	Pm	Mx	An	Pa	Ph	Te	FR	Ve	Σ
Aves		1										1
Carnivora		2										2
Geocapromys cf. *brownii*	8	10							3		5	26
Osteichthyes	4		2		1	1	1	1		16	19	45
Haemulidae				1								1
Lutjanidae				1	1							2
Serranidae				1	1							2
Σ	12	13	2	3	3	1	1	1	3	16	24	79

Table 30. Element Counts for Unit 5, Level 11.

	Element						
Taxon	UN	NF	Te	Op	FR	Ve	Σ
Geocapromys cf. *brownii*	1	1	1				3
Chondrichthyes						1	1
Osteichthyes	1					1	2
Σ	2		1	0	0	2	6

Table 31. Element Counts for Unit 8, Level 1.

	Element											
Taxon	UN	NF	De	Pm	Mx	Ph	Te	FR	Ve	At	Bo	Σ
Geocapromys cf. *brownii*	6	14					11		1			32
Osteichthyes	3			1				5	64	1	1	75
Balistidae			1				2					3
Scaridae						1						1
Sparisoma sp.			1									1
Serranidae					1							1
Σ	9		2	1	1	1	13	5	65	1	1	113

Table 32. Element Counts for Unit 8, Level 2.

	Element															
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ph	Qu	Hy	Te	FR	Ve	At	Sc	Σ
Aves		1														1
Carnivora		2														2
Geocapromys cf. *brownii*	7	57									30		4		1	99
Reptilia													1			1
Chondrichthyes													2			2
Osteichthyes	13		2	1	2	2				1	1	21	170	6	1	220
Balistidae											1					1
Haemulidae					2				1							3
Scaridae					1			2								3
Sparisoma sp.			2	1												3
Serranidae				1	1		1									3
Σ	20	60	4	3	6	2	1	2	1	1	32	21	177	6	2	338

Table 33. Element Counts for Unit 8, Level 3.

	Element																							
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ps	Pa	Ph	Qu	DS	Sp	Te	Op	FR	Ve	At	Bo	Ce	So	Sc	UV	Pt	Σ
Carnivora		1																							1
Crustacea		4																							4
Geocapromys cf. *brownii*	13	49												28			2					2			94
Reptilia		1																							1
Chondrichthyes														1											1
Osteichthyes	13		2	2	2	2		3	1		4			2	2	62	356	7	5	5	1		2	1	472
Balistidae				1								2		1											4
Carangidae					1																				1
Diodontidae													3												3
Haemulidae				3	5	1					1														10
Holocentridae			1		1																				2
Labridae																									0
Lutjanidae				3	2		1																		6
Lutjanus synagris			3			1																			4
L. jocu			2			2																			4
Pomacanthidae						1																			1
Scaridae								1		1															2
Serranidae			1	6	1	1																			9
Sparidae			1																						1
Σ	26	55	10	15	12	8	1	4	1	1	5	2	3	32	2	62	358	7	5	5	1	2	2	1	620

Table 34. Element Counts for Unit 8, Level 4.

	Element																									
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ps	Pa	Qu	Hy	DS	Sp	Te	FR	Ve	At	Bo	Ce	Ep	Po	So	Sc	UV	Fr	Σ
Aves		1																								1
Rodentia														1												1
Geocapromys cf. *brownii*	5	62												28		11							2			108
Reptilia		1														2										3
Cheloniidae		2																								2
Chondrichthyes														1		5										6
Osteichthyes	25		2		4	5		3	5	7	3				140	416	12	3	7	2	2	2	1	2	1	642
Balistidae												1		2												3
Diodontidae													1													1
Haemulidae				2	3					2																7
Labridae			1																							1
Lutjanidae				8	5		2																			15
Lutjanus synagris			3			2																				5
L. jocu			1																							1
Pomacanthidae						1																				1
Scaridae					2	2																				4
Sparisoma sp.			2	3																						5
Serranidae			1	3		2	3																			9
Sparidae			1		1				1																	3
Σ	30	66	11	16	15	12	5	3	6	9	3	1	1	32	140	434	12	3	7	2	2	2	3	2	1	818

Table 35. Element Counts for Unit 8, Level 5.

	Element																									
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ps	Pa	Ph	Qu	Hy	DS	Sp	Te	Op	FR	Ve	At	Bo	Ce	Ep	Po	Sc	Cl	Pt	Σ
Carnivora		11																									11
Crustacea		1																									1
Rodentia		3													1												4
Geocapromys cf. *brownii*	69	145													62			15						8			299
Iguanidae																		1									1
Chondrichthyes																		5									5
Osteichthyes	33		7	5	3	5	1	10	9	6	11	6			2	4	239	640	20	7	13	2	3	2	5	4	1037
Balistidae											1		2														3
Carangidae					1																						1
Diodontidae														4													4
Haemulidae				9	12	4	1	4			3					1											34
Labridae			1							1																	2
Lutjanidae				5	6		4																				15
L. synagris			4			6																					10
L. jocu			1			1																					2
Mugilidae					1																						1
Scaridae						1				12		1															14
Sparisoma sp.				2																							2
S. chrysopterum				1																							1
S. viride				1																							1
S. rubripinne				1																							1
Serranidae			3	5	2	5																					15
Sparidae			1	2		2						1															6
Σ	102	160	17	31	25	24	6	14	9	19	15	8	2	4	65	5	239	661	20	7	13	2	3	10	5	4	1470

Table 36. Element Counts for Unit 8, Level 6.

													Element													
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ps	Pa	Ph	Qu	Hy	Te	Op	FR	Ve	At	Bo	Ce	Ep	Po	Sc	Cl	UV	Pt	Σ
Carnivora		9																								9
Crustacea		1																								1
Geocapromys cf. *brownii*	12	80											27			19						3				141
Reptilia		1																								1
Cheloniidae	1																									1
Iguanidae																2										2
Chondrichthyes																6										6
Osteichthyes	27		10	2	6	2	4	9	10	6	8	8		4	187	418	12	9	9	3	4	2	5	4	2	751
Balistidae													6													6
Carangidae			1																							1
Haemulidae			1	10	14	5		1			6															37
Labridae				1						1																2
Lutjanidae			2	8			2				2															14
L. synagris			5			1																				6
L. jocu			2			4																				6
Scaridae								1		12																13
Sparisoma sp.			1	3																						4
Serranidae			5	1	2	2	2				1															13
Sparidae			1			1				1																3
Σ	40	91	28	25	22	15	8	11	10	20	17	8	33	4	187	445	12	9	9	3	4	5	5	4	2	1017

Table 37. Element Counts for Unit 8, Level 7.

	Element																										
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ps	Pa	Ph	Qu	Hy	DS	Sp	Te	Op	FR	Ve	At	Bo	Ce	Ep	Po	So	Sc	Sl	Σ
Aves		6																									6
Carnivora		3																									3
Crustacea		1																									1
Rodentia		2																									2
Geocapromys cf. *brownii*	22	116													56			31							3		228
Cheloniidae	1																										1
Chondrichthyes																		4									4
Osteichthyes	63		5	4	2	7		4	11	4	16	6			1	6	246	444	7	10	7	4	2	3	5	2	859
Balistidae													1		2												3
Carangidae			1		1	1						1															4
Diodontidae														3													3
Haemulidae			3	4	8	4		2			3																24
Labridae			1							1																	2
Lutjanidae				6	4	1																					11
L. synagris			5																								5
L. jocu			2																								2
Scaridae						1				13																	14
Sparisoma sp.			2	3																							5
Serranidae				4	2	1	5																				12
Sparidae			2						1																		3
Σ	86	128	21	21	17	15	5	6	12	18	19	7	1	3	59	6	246	479	7	10	7	4	2	3	8	2	1192

Table 38. Element Counts for Unit 8, Level 8.

	Element																							
Taxon	UN	NF	De	Pm	Mx	An	Vo	Ps	Pa	Ph	Qu	DS	Sp	Te	Op	FR	Ve	At	Bo	Ce	Ep	Po	Sc	Σ
Carnivora		1																						1
Rodentia														1			1							2
Geocapromys cf. *brownii*	15	67												31			10						3	126
Chondrichthyes																	2							2
Osteichthyes	12		3		2	1		1	3		6				1	79	192	8	5	5	1	1	2	322
Balistidae												2		2										4
Carangidae					1																			1
Haemulidae				1	1	1	1				1													5
Lutjanidae				1	2		1																	4
L. synagris			3			2																		5
L. jocu						1																		1
Scaridae										2														2
Sparisoma sp.			1																					1
Serranidae			1		1	1	1																	4
Sparidae			1																					1
Σ	27	68	9	2	7	6	3	1	3	2	7	2	0	34	1	79	205	8	5	5	1	1	5	481

Table 39. Element Counts for Unit 8, Level 9.

	Element														
Taxon	UN	NF	De	Pm	Mx	Vo	Qu	Hy	Te	FR	Ve	At	Bo	Ce	Σ
Aves		1													1
Carnivora		2													2
Rodentia		2													2
Geocapromys cf. *brownii*	7	39							7		4				57
Osteichthyes	15			1	2			1		33	58	1	1	2	114
Haemulidae					2	1	2								5
Lutjanidae				1											1
Lutjanus synagris			2												2
L. jocu			1												1
Sparisoma sp.			1												1
Serranidae				1				1							2
Sparidae			1												1
Σ	22	44	5	3	4	1	2	2	7	33	62	1	1	2	189

Table 40. Element Counts for Unit 8, Level 10.

	Element																	
Taxon	UN	NF	De	Pm	Mx	An	Vo	Pa	Ph	Qu	Te	FR	Ve	At	Bo	Ce	Sc	Σ
Carnivora		6																6
Crustacea		4																4
Rodentia		2																2
Geocapromys cf. *brownii*	2	29									13		5				1	50
Osteichthyes	16		1		1	2		2	1	1		22	60	3	1	1		111
Carangidae					1													1
Haemulidae				1														1
Lutjanidae				1			1											2
L. synagris			1			1												2
Sparisoma sp.			1															1
Serranidae				3														3
Σ	18	41	3	5	2	3	1	2	1	1	13	22	65	3	1	1	1	183

Table 41. Element Counts for Unit 8, Level 11.

	Element									
Taxon	NF	Mx	An	Te	FR	Ve	Ce	So	UV	Σ
Geocapromys cf. *brownii*	10			2		1				13
Osteichthyes		2			1	15	1	1	1	21
Haemulidae		2								2
Serranidae			1							1
Σ	10	4	1	2	1	16	1	1	1	37

APPENDIX B

DETAILS FOR THE TRANS-CARIBBEAN DATASET AND A DOMINANT GENUS AND SPECIES LIST

Trans-Caribbean Dataset

Table 42. Taxonomic Families and their preferred Habitat (Patch).

Shallow/Inshore	Coral Reef	Pelagic/Offshore
Albulidae	Acanthuridae	Belonidae
Carangidae	Baslistidae	Clupeidae
Centropomidae	Haemulidae	Exocoetidae
Eleotridae	Holocentridae	Scombridae
Elopidae	Labridae	
Gerreidae	Lutjanidae	
Gobiidae	Pomacanthidae	
Kyphosidae	Scaridae	
Malacanthridae	Serranidae	
Mugilidae	Diodontidae	
Ostrachiidae		
Sciaenidae		
Sparidae		
Sphyraenidae		

Table 43. Archaeological Sites in the Trans-Caribbean Dataset.

#	Site	Island	Age	Dates
1	Coralie GT-3	Grand Turk	Formative	AD 710-1170
2	MC-6	Middle Caicos	Formative	AD 1437
3	MC-12	Middle Caicos	Formative	AD 1040-1282
4	MC-32	Middle Caicos	Formative	AD 1284
5	CK-14	Crooked Island	Formative	
6	SM-2	Samana Cay	Formative	AD 950-1500
7	SM-7	Samana Cay	Formative	AD 950-1500
8	Palmetto Grove	San Salvador	Historic	AD 1410-1654
9	Minnis Ward	San Salvador	Formative	AD 1050-1287
10	Long Bay	San Salvador	Historic	AD 1460
11	Three Dog	San Salvador	Ceramic	AD 750
12	El Bronce	Puerto Rico	Formative	
13	Maisabel	Puerto Rico	Ceramic	
14	En Bas Saline	Hispaniola	Formative	
15	White Marl	Jamaica	Ceramic	AD 600
16	Pearls	Grenada	Ceramic	
17	Hillcrest 1	Barbados	Ceramic	
18	Chancery	Barbados	Ceramic	
19	Little Welches	Barbados	Ceramic	
20	Hillcrest 2	Barbados	Formative	
21	Silver Sands	Barbados	Formative	
22	Chancery Lane	Barbados	Formative	
23	Heywoods	Barbados	Formative	
24	Trants	Montserrat	Ceramic	
25	Hichmans	Nevis	Ceramic	
26	Sulphur Ghaut	Nevis	Formative	
27	Indian Castle	Nevis	Formative	
28	Golden Rock	St Eustatius	Formative	
29	Hope Estate -Early	St Martin	Ceramic	
30	Hope Estate -Late	St Martin	Ceramic	
31	Barnes Bay	Anguilla	Formative	AD 775-1400
32	Sandy Ground	Anguilla	Formative	AD 350-1500
33	Grand Bay	Carriacou	Formative	AD 400-1300
34	Santa Barbara	Curacao	Formative	A.D 800
35	Wanapa	Bonaire	Formative	A.D 800

Table 43. Continued.

#	Site	Island	Age	Dates
36	TOB 3/Layer II	Tobago	Archaic	1000-820 BC
37	TOB13/Layer IV-V	Tobago	Ceramic	AD 130-1060
38	TOB13/Layer IV	Tobago	Ceramic	AD 130-1061
39	TOB13/Layer III	Tobago	Ceramic	AD 130-1062
40	TOB13/Layer II	Tobago	Ceramic	AD 130-1063
41	Tutu-Early	St Thomas	Ceramic	
42	Tutu-Late	St Thomas	Formative	
43	Trunk Bay	St John	Formative	
44	Paraquita Bay	Tortola	Formative	
45	Cape Wright	Jost van Dyke	Formative	
46	Cinnamon Bay/ L2	St John	Historic	AD 1490
47	Cinnamon Bay/L4	St John	Formative	AD 1290-1450
48	Cinnamon Bay/L10	St John	Formative	AD 1000
49	Las Obas	Cuba	Archiac	AD 250-610
50	Vega del Palmar Upper	Cuba	Ceramic	A.D. 630
51	Vega del Palmar Lower	Cuba	Archaic	350 B.C.E
52	Bluefields Bay	Jamaica	Formative	AD 1336-1498
53	Bluefields Bay	Jamaica	Formative	AD 1103-1282

Table 44. Key for Date and Region Abbreviations.

	Age		Region
1	Archaic	LA	Lesser Antilles
2	Ceramic	GA	Greater Antilles
3	Formative	BA	Bahamas
4	Proto-Historic	SC	Southern Caribbean
		VI	Virgin Islands

Table 45. Descriptive Statistics for Diversity Measure Values.

	N	Range	Min	Max	Mean	Std. Deviation
H’	51	.943	.154	1.097	.72933	.239900
e Inshore	50	1.051	.028	1.079	.24528	.232996
e Reef	51	.892	.072	.964	.57808	.226350
e Pelagic	43	.730	.002	.732	.18807	.165962
d’ Inshore	88	5.541	.425	5.966	2.65220	1.264304
d’ Reef	101	5.613	.873	6.486	3.64170	1.279015
d’ Pelagic	45	2.993	.329	3.322	1.70460	.859896

Table 46. Shannon Index (*H'*) and Evenness Index (*e*) for trans-Caribbean Dataset.

Site	Age	Region	*H'*	*e*		
				Inshore	Reef	Pelagic
Vega del Palmar -Lower	1	GA	.259	.928	.072	
Las Obas	1	GA	.635	.669	.331	
TOB 3/Layer II	1	SC	.872	.082	.599	.296
Pearls	2	LA	1.073	.308	.462	.269
Hillcrest 1	2	LA	1.011	.333	.500	.167
Chancery	2	LA	.861	.200	.667	.133
Little Welches	2	LA	.981	.278	.556	.167
Trants Site	2	LA	.601	.204	.776	.020
Hichmans	2	LA	.665	.036	.750	.214
Hope Estate	2	LA	.828	.222	.639	.083
Tutu –Early	2	VI	.890	.239	.642	.128
Maisabel	2	GA	1.091	.312	.420	.312
White Marl	2	GA	.754	.623	.464	.029
Vega del Palmar -Upper	2	GA	.599	.714	.286	
TOB13/Layer IV-V	2	SC	.950	.111	.311	.511
TOB13/Layer IV	2	SC	.883	.077	.318	.569
TOB13/Layer III	2	SC	.956	.118	.301	.514
TOB13/Layer II	2	SC	.878	.055	.332	.481
Coralie site	2	BA	.466	.158	.822	.002
Three Dog	2	BA	.156	.036	.964	
Santa Barbara	3	SC	.564	.189	.795	.016
Wanapa	3	SC	.917	.238	.619	.143
Hillcrest 2	3	LA	.956	.143	.571	.286
Silver Sands	3	LA	.918	.179	.616	.184
Chancery Lane	3	LA	.790	.077	.692	.231
Heywoods	3	LA	.709	.049	.220	.732
Sulphur Ghaut	3	LA	.848	.217	.659	.109
Indian Castle	3	LA	.628	.085	.798	.106
Golden Rock	3	LA	.834	.574	.369	.049
Hope Estate	3	LA	.935	.359	.538	.103
Barnes Bay	3	LA	.470	.028	.859	.107
Sandy Ground	3	LA	.729	.042	.704	.254
Grand Bay	3	LA	.872	.074	.587	.340
Tutu –Late	3	VI	.891	.260	.626	.114

Table 46. Continued.

Site	Age	Region	*H'*		*e*	
				Inshore	Reef	Pelagic
Trunk Bay	3	VI	.610	.116	.794	.065
Cinnamon Bay	3	VI	.758	.164	.727	.100
Paraquita	3	VI	.647	.167	.750	.042
Cape Wright	3	VI	.936	.191	.607	.191
Cinnamon Bay/L4	3	VI	.830	.185	.687	.125
Cinnamon Bay/L10	3	VI	1.097	.358	.333	.309
El Bronce	3	GA	.368	1.079	.474	.026
En Bas Saline	3	GA	.770	.259	.685	.056
Bluefields Bay –Upper	3	GA	.179	.044	.956	
Bluefields Bay –Lower	3	GA	.245	.067	.944	
MC-6	3	BA	.805	.541	.408	.031
MC-12	3	BA	.334	.104	.896	
MC-32	3	BA	.703	.492	.475	
SM-2	3	BA	.767	.088	.161	.124
SM-7	3	BA	.629	.033	.093	.164
Minnis Ward	3	BA	.224		.941	.059
Cinnamon Bay/ L2	4	VI	.755	.135	.739	.126
Palmetto Grove	4	BA	.154	.036	.964	
Long Bay	4	BA	.339	.099	.883	

Table 47. Margalef Richness Index (*d'*) for Trans-Caribbean Dataset.

Site	*d'*					
	Inshore		Reef		Pelagic	
	Family	Genus	Family	Genus	Family	Genus
Vega del Palmar -Lower	1.876	1.876	1.285	1.928		
Las Obas	1.294	1.294	.994	1.490		
TOB 3/Layer II	2.943	2.354	2.731	4.291	.886	1.772
Pearls	3.322	4.429	5.560	6.486	2.367	
Hillcrest 1		2.215	2.780	1.853	3.322	1.661
Chancery	2.096	2.096	4	4	3.322	3.322
Little Welches			3	4		2.096
Trants Site	2	2	3.165	3.798		
Hichmans			6.050	4.538	2.570	
Hope Estate	1.107		4.406	4.406		
Tutu-Early	3.534	2.120	3.794	4.336	1.745	
Maisabel	4.898	2.449	5.104	3.970	1.837	.612
White Marl	3.619	2.068	3.876	2.768	1.661	
Vega del Palmar -Upper	1.846	1.846	1.129	1.129		
TOB13/Layer IV-V	1.431		3.490	.873	1.469	.734
TOB13/Layer IV	2.434	1.217	2.658	1.772	1.195	2.390
TOB13/Layer III	3.671	5.966	3.096	5.804	1.065	2.486
TOB13/Layer II	4	3.5	3.240	5.761	1.021	1.702
Coralie GT-3	2.719	3.263	3.521	4.694		
Three Dog	3.322	3.322	2.900	2.900		
Santa Barbara	5.875	2.937	3.020	5.033	3.322	
Wanapa	5.723	2.861	3.591	4.489	2.096	
Hillcrest 2			4.429	2.215		
Silver Sands	.653	1.959	3.868	4.835	1.295	
Chancery Lane	2.096	2.096	4.192	4.192	2.096	
Heywoods			4.192	3.144	2.031	
Sulphur Ghaut	2.708	2.708	4.084	1.021	2.551	
Indian Castle	2.215	2.215	4.267	3.200	3	
Golden Rock	1.276	.425	3.707		1.564	
Hope Estate	1.745	2.618	3.782	2.269	1.661	
Barnes Bay	3.007	2.406	2.223	3.493		0.446
Sandy Ground	1.772	1.329	2.011	3.161	.329	0.658
Grand Bay	1.547	2.062	2.113	3.170	1.153	

Table 47 Continued.

Site	*d’*					
	Inshore		Reef		Pelagic	
	Family	Genus	Family	Genus	Family	Genus
Tutu-Late	4.651	1.993	4.771	5.301	2.618	
Trunk Bay	2.390	1.593	4.306	5.263	3	
Cinnamon Bay	3.187	1.593	4.204	4.729	1.921	
Paraquita Bay	4.983	3.322	5.576	6.373		
Cape Wright	3.251	1.625	4.618	5.772	1.625	
Cinnamon Bay/L4	1.917	1.438	3.013	3.013	1.045	
Cinnamon Bay/L10	2.051	.684	3.493	2.096	0.715	
El Bronce	4.340	3.100	3.187	3.187		
En Bas Saline	5.544	3.080	4.889	3.911	1.048	
Bluefields Bay –Upper	2.103	1.819	3.244	.483		
Bluefields Bay –Lower	1.173	2.173	2.619	.644		
MC-6	3.480	4.060	4.994	5.618		
MC-12	4.292	2.861	4.285	5.510		
MC-32	4.739	4.062	4.787	4.787		
SM-2	.813	1.625	4.023	2.012	.725	
SM-7		1.285	3.251	2.438	.677	
Minnis Ward			3.322	2.658		
Cinnamon Bay/ L2	1.837	1.224	2.952	3.374	1.248	
Palmetto Grove	1.701	1.701	2.682	2.682		
Long Bay	4.801	3.841	4.018	4.018		

Dominant Genus and Species Study

In addition to diversity indices, I calculated a dominant genus and species by location and cultural period; I present my findings in Table 48. As dominant species determine the primary biological characteristics of a community, and changes in dominant species often reflect fauna1 changes (Colvocoresses and Musick 1984), I computed the dominant genus and species for each region and cultural period. I took a relatively simple approach and calculated dominant genus and species by first dividing

Table 48. Dominant Genus and Species through Time.

Time	Genus	Zone	Species	Zone	Location
Lithic (1)	Sparisoma	Reef	Cephalopholis fulva	Reef	Southern Caribbean
	Centropomus	Inshore	Mugil curema	Inshore	Greater Antilles
Ceramic (2)	Haemulon	Reef	Albula vulpes	Inshore	Bahamas
	Caranx	Inshore	Dormitator maculatus	Inshore	Virgin Islands
	Lutjanus	Reef	Gobiomorus dormitor	Inshore	Greater Antilles
	Sparisoma	Reef	Selar crumenophthalmus	Inshore	Lesser Antilles
	Sparisoma	Reef	Euthynnus alletteratus	Inshore	Southern Caribbean
Formative (3)	Sparisoma	Reef	Mullus auratus	Inshore	Bahamas
	Sparisoma	Reef	Lachnolaimus maximus	Reef	Virgin Islands
	Sparisoma	Reef	Gobiomorus dormitor	Inshore	Greater Antilles
	Sparisoma	Reef	Sparisoma viride	Reef	Lesser Antilles
	Haemulon	Reef	Cephalopholis fulva	Reef	Southern Caribbean
			Sparisoma viride	Reef	Southern Caribbean
Historic (4)	Sparisoma	Reef	Epinephelus striatus	Reef	Bahamas

the data into region. I then totaled MNI and NISP for each site, thus giving me the dominant genus and species for the area.

Dominant genus has two inshore fishes in the earlier periods of the Archaic and Ceramic but all other genus are from reef environments. Also of note is the dominance of genus Sparisoma throughout the Caribbean in all four eras. Sparisoma is a genus of Scaridae (parrotfish), a large reef dweller, but not the largest nor most commercially exploited fish in modern times. Looking at dominant species, the Ceramic age has all inshore species, but this trend shifts to a dominance in reef species later in time. Also within dominant species, we see some regions remain constant while others change. For instance, the Great Antilles has an inshore dwelling species for all three ages, while the Virgin Islands, Lesser Antilles and Bahamas shift from inshore to reef species.

Interestingly, the Southern Caribbean begins with a dominant species inhabiting the reef zone, shifts to an inshore species during the Ceramic and again shifts to a reef species in the Formative era.

Sparisoma is the dominant genus of fishes throughout all eras of the Caribbean; this is most likely due to their abundance on coral reefs (Westneat 1999), and the fact that the genus contains several large species. Scarid abundance overall is due to their ability to sustain large population sizes and high growth rates on small food sources (Bruggemann et al 1994b). According to Bellwood (1994), parrotfishes are not a major commercial catch but are significant to artisanal fishers and are highly popular food fishes in some areas. Bellwood (1994) and Westneat (1999) note parrotfishes are usually caught with traps, gill nets, or by spearing. Scaridae flesh is relatively soft and does not keep well; therefore, parrotfishes are marketed and eaten fresh.