Seasonality and Human Mobility along the Georgia Bight

Elizabeth J. Reitz,
Irvy R. Quitmyer, and
David Hurst Thomas

Editors and Contributors

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SEASONALITY AND HUMAN MOBILITY ALONG THE GEORGIA BIGHT

ELIZABETH J. REITZ, IRVY R. QUITMYER,

AND

DAVID HURST THOMAS

EDITORS AND CONTRIBUTORS

WITH CONTRIBUTIONS BY

C. FRED T. ANDRUS, SARAH G. BERGH, NICOLE R. CANNAROZZI, GWENDOLYN D. CARROLL, CAROL E. COLANINNO, BRENDAN J. CULLETON, CHESTER B. DEPRATTER, KANDACE D. HOLLENBACH, DOUGLAS S. JONES, DEBORAH ANN KEENE, DOUGLAS J. KENNETT, CHARLES W. LAMBERT, J.W. MOAK, BRUCE M. SAUL, C. MARGARET SCARRY, GREGORY A. WASELKOV, AND ELIZABETH S. WING

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CONTENTS

TABLES

FIGURES

ABSTRACT

Some of the most enduring and fundamental questions in archaeology relate to site seasonality. During which seasons did people occupy coastal archaeological sites? Why is "seasonality" important to our understanding of human behavior? What does this knowledge tell us about life in dynamic estuarine systems? What methods and technologies are available to address key issues of seasonality? Archaeological seasonality is uniquely linked to settlement patterns, resource availability, environmental relationships, anthropogenesis, landscapes, and social complexity.

Archaeologists working in coastal settings typically recover multiple biological proxies that are well suited to explicating questions of human seasonal behavior. The Fifth Caldwell Conference was convened to discuss and report on practiced methods for reading the seasonality record found in common biological proxies. These researchers spoke of how they are applying various methods grounded in the natural sciences to estimate seasonality with particular reference to the archaeology of St. Catherines Island and the Georgia Bight. These methods include stable isotope analysis, ^{14}C dating, longitudinal studies of animals (molluscs and fishes), zooarchaeology, and archaeobotany. The research shows that all plant and animal remains found in a midden contain a record of human behavior.

The authors of these 13 chapters agree that multiple indicators of site seasonality provide the most robust picture of the annual settlement cycle. These papers were initially presented at the Fifth Caldwell Conference, cosponsored by the American Museum of Natural History and the St. Catherines Island Foundation, held on St. Catherines Island, Georgia, May 14–16, 2010.

PARTICIPANTS IN THE FIFTH CALDWELL CONFERENCE ST. CATHERINES ISLAND, GEORGIA, MAY 14–16, 2010

C. Fred T. Andrus (Associate Professor, Department of Geological Sciences, University of Alabama)

Sarah G. Bergh (Ph.D. student, Department of Anthropology, University of Georgia)

Elliot Blair (Ph.D. student, Department of Anthropology, University of California, Berkeley)

Rachel Cajigas (Material Culture Analyst, Nels Nelson North American Archaeology Laboratory, American Museum of Natural History)

Nicole R. Cannarozzi (Ph.D. student, Department of Anthropology, University of Florida)

Carol E. Colaninno (Ph.D., Department of Anthropology, University of Georgia)

Christina Friberg (at the time, St. Catherines Island Assistant Archivist, American Museum of Natural History)

Royce Hayes (Superintendent, St. Catherines Island)

Christa Hayes (St. Catherines Island)

Kandace D. Hollenbach (Ph.D., Archaeological Research Laboratory, Department of Anthropology, University of Tennessee, Knoxville)

Douglas J. Kennett (Professor, Department of Anthropology, the Pennsylvania State University)

Matthew Napolitano (Assistant Laboratory Supervisor, Nels Nelson North American Archaeology Laboratory, American Museum of Natural History)

Alexandra Parsons (Ph.D. student, Florida State University)

Lorann S.A. Pendleton (Director, Nels Nelson North American Archaeology Laboratory, American Museum of Natural History)

Irvy R. Quitmyer (Environmental Archaeology Collection Manager, Florida Museum of Natural History)

Elizabeth J. Reitz (Professor of Anthropology, Georgia Museum of Natural History, University of Georgia)

David Hurst Thomas (Curator of Anthropology, American Museum of Natural History)

C. Margaret Scarry (Associate Professor and Director of Undergraduate Studies, Department of Anthropology, University of North Carolina at Chapel Hill)

Gregory A. Waselkov (Professor, Department of Sociology, Anthropology, and Social Work, University of South Alabama)

Elizabeth S. Wing (Curator Emeritus, Environmental Archaeology, Florida Museum of Natural History)

Participants in the Fifth Caldwell Conference, standing in front of the Carriage House Archaeological Laboratory on St. Catherines Island, May 14–16, 2010: (top row, left to right) Fred Andrus, Christina Friberg, Sarah Bergh, Carol Colaninno-Meeks, Lori Pendleton, Margaret Scarry, Betsy Reitz, Matthew Napolitano, Rachel Cajigas, and Elizabeth Wing; (bottom row, left to right) Kandace Hollenbach, Greg Waselkov, Alexandra Parsons, Irvy Quitmyer, Royce Hayes, Christa Hayes, Doug Kennett, David Hurst Thomas, Nicole Cannarozzi, and Elliot Blair.

PREFACE

ELIZABETH J. REITZ, IRVY R. QUITMYER, AND DAVID HURST THOMAS

Archaeological excavations at coastal sites typically recover multiple biological proxies for seasonal behavior of plant and animal resources and of people. Questions of seasonality are embedded in much of archaeological research, with answers linked to many aspects of cultures and environments, including why seasonality is important to the study of human behavior and what seasonality can tell us about life in dynamic estuarine systems. The Fifth Caldwell Conference was organized to explore aspects of seasonality found in common biological remains and substantive applications with particular reference to the archaeology of St. Catherines Island and the Georgia Bight (USA).

Issues of seasonality and mobility are fundamental to much archaeological research, even when not made explicit. These questions are linked to resource availability, subsistence strategies, economic institutions, and social complexity. But the settlement pattern issue is too often reduced to a dichotomy between mobility on the one hand and sedentism on the other, as though they were mutually exclusive options. As Bar-Yosef and Rocek (1998: 1, italics theirs) argue: "The fact is *all* societies have a mobility component; the issue is what the form of that mobility is, not whether it exists." As with most human institutions, residential patterns as well as resource acquisition come in many variations for many different reasons.

Archaeological excavations along the Georgia Bight typically recover thousands of potential "seasonal indicators." Aten (1981) identifies five characteristics commonly used to study seasonality in animals: presence or absence of skeletal elements (e.g., bones of migratory birds), demography (e.g., changes in the sizes of estuarine fishes as they mature through the annual cycle), morphology (changes in shell contour through the annual cycle, e.g., marsh clams [*Rangia cuneata*]), structure (changes in shell microstructure correlated with the seasons of the year, e.g., growth phases in hard clams [*Mercenaria* spp.]), and chemistry (changes in shell composition, e.g., shifting oxygen and carbon isotopes in *Mercenaria*).

Regardless of approach, these techniques can reveal only when an organism died and some information about environmental conditions prevailing during that individual's life or at the time of death. Judgments regarding season of availability, procurement, and location (as defined by Monks, 1981) must rest on ecological analogy, which typically requires monitoring modern patterns to correlate hard tissue growth and other aspects of seasonality with annual cycles. The fact that a particular clam died on St. Catherines Island in November/December is, by itself, of limited use in testing theories of seasonality and mobility with regard to the use of resources and locations over time. To articulate season of death with broader inferences requires arguments demonstrating that the death of an organism was contemporaneous with (and relevant to) specific behaviors, cultural institutions, interactions with neighboring groups, site functions, and site histories. Without such linkage arguments, seasonal estimates tell us very little about people.

We believe it is important not to conflate patterns of seasonal site occupation (reflecting mobility strategies), seasonal patterns of resource procurement (reflecting foraging and/or farming strategies), site function, and relationships with people on neighboring islands and the mainland (e.g., Quitmyer et al., 1997: 826). These are very different—if interrelated—facets of human behavior.

The chapters in this volume address specific issues (such as inconsistencies in the ethnohistoric record, refinements in dating archaeological deposits, intersite and intrasite variability, and regional settlement patterns) associated with biological proxies used to assess aspects of seasonality and mobility along the Georgia Bight generally, and on St. Catherines Island in particular. They were originally presented at the Fifth Caldwell Conference, cosponsored by the American Museum of Natural History and the St. Catherines Island Foundation and held on St. Catherines Island, Georgia, May 14–16, 2010.

The first chapter in the volume, by David Hurst Thomas, discusses sampling and inferential problems raised when linking seasonality studies to our understanding of mobility patterns and paleoclimatic change. The author recaps how issues of seasonality and mobility have dominated archaeological research and related discourse on

St. Catherines Island, as well as the rest of the Georgia Bight. He specifically reviews efforts to systematically collect archaeological evidence to resolve the conflicting ethnohistoric interpretations of the Georgia coastline (the so-called Guale problem). For the Late Archaic period, inquiry has centered on whether the massive shell ring settlements represent episodic aggregations or long-term, year-round occupations (or both). For the Late Prehistoric period, the "Guale problem" has highlighted contrasting views of residential and logistic mobility for these coastal people.

Douglas J. Kennett and Brendan J. Culleton present a Bayesian chronological framework as a way to determine contemporaneity within and among sites, a procedure essential for assessing seasonal rounds, residential mobility, and determining whether specific sites used during different or the same seasons are coeval. These authors note that seasonality studies depend upon defining culturally meaningful analytical units and analyzing and interpreting seasonality data within the broader context provided by these units. Chronology building is an essential part of defining these analytical units. The authors observe that Bayesian analysis of radiocarbon dates from archaeological sites is routine in Britain, and programs like OxCal provide prepackaged statistical tools with which to develop robust archaeological site chronologies. Custom-built Bayesian statistical environments that analyze and model spatiotemporal patterns in the archaeological record are also being developed, including tools potentially useful for integrating the multiscalar chronological measures necessary for establishing site seasonality and inferring mobility patterns. The authors then provide a new Bayesian chronological framework for interpreting seasonality data on St. Catherines Island, combining stratigraphic information and other prior knowledge with radiocarbon dates to establish more precise and accurate chronological models. This paper concludes that changes in material culture observed at the two Late Archaic shell rings on St. Catherines Island could have occurred within less than a decade. The authors argue that more precise AMS ^{14}C dates could provide additional insights into the cultural processes in play.

The next chapter addresses one of the major kinds of evidence available to archaeologists interested in understanding seasonality along the Georgia coastline—fish. In chapter 3, Elizabeth J. Reitz, Bruce M. Saul, J.W. Moak, Gwendolyn D. Carroll, and Charles W. Lambert compare and contrast seasonal evidence obtained from research on modern and archaeological fishes along the Georgia Coast. Estuarine fishes are a mixture of endemic, marine, and freshwater species attracted to estuaries as nursery grounds and feeding areas. The potential of estuaries to fill these roles varies seasonally, raising the possibility that fishes can serve as proxies for seasonal patterning in human fishing strategies. In this study, the spatial and seasonal habits of modern and archaeological fishes are evaluated for evidence of seasonal fishing strategies. These authors find that fishing was highly selective and that some fish taxa in the archaeological record are not markedly seasonal, limiting the value of simple presence or absence to provide seasonal fishing information.

In chapter 4, Carol E. Colaninno evaluates data from oxygen isotopic profiles and seasonally sensitive vertebrate remains as evidence for year-round occupation at Late Archaic shell rings on the Georgia coast. Specifically, seasonal occupation at five Late Archaic (4200–3100 B.P.) shell rings is explored using oxygen isotopic evidence from hardhead catfish (*Ariopsis felis*) and Atlantic croaker (*Micropogonias undulatus*) otoliths. Combined with knowledge of seasonal availability, Colaninno's results demonstrate that these fishes were captured during multiple seasons at each of the five Late Archaic shell rings; all four seasons are represented at several sites. This suggests that some portion of the human population occupied these sites throughout the year during this period.

Sarah G. Bergh discusses intrasite variability in seasonal occupation at Back Creek Village (A.D. 1200–1600) on St. Catherines Island. These archaeological shell middens likely accumulated outside structures occupied by sedentary households. Bergh evaluates the degree to which intra- and intermidden variation reflects specific modes of shell accumulation. This study uses annual cycles in fishes and hard clam (*Mercenaria* spp.) growth habits to explore seasonal patterns of midden deposition, which can be linked to site function and mobility. Bergh argues that villagers relied heavily on vertebrate resources present in the estuary throughout the year, suggesting that seasonal mobility to exploit animal resources was not a factor in the settlement system.

In chapter 6, C. Fred T. Andrus presents an integrated, programmatic approach to assessing seasonality and sedentism on the Georgia Bight. Andrus notes that most molluscan sclerochronology research in the southeastern United States focuses on Eastern oyster (*Crassostrea virginica)* and quahog (or hard clam [*Mercenaria* spp.]), the two most common taxa in archaeological middens from this area. But he argues that several other molluscs likewise show varying degrees of promise as proxies for season of capture. While these other taxa may not be as abundant as oysters and quahogs, their analysis may provide insight into human behavior in a varied range of ecosystems and offer a more complete picture of subsistence activities. This paper surveys relevant literature and presents new data concerning the development of novel season of capture proxies. Key areas of concern include taxon-specific properties of biomineralization, shell structure, seasonal growth, taphonomy, and geochemistry. The goal is to foster expansion of the current suite of sclerochronological tools available to archaeologists in this region and encourage modern proof-of-concept research.

In chapter 7, Irvy R. Quitmyer and Douglas S. Jones discuss annual incremental shell growth patterns in hard clams (*Mercenaria* spp.) recovered in archaeological contexts from St. Catherines Island. Hard clams grow by mantle-mediated precipitation of calcium carbonate forming a predictable alternating pattern of opaque (white) and translucent (gray) shell increments corresponding to seasonal changes in water temperature. This research applies sclerochronological techniques to document the annual periodicity of shell formation in modern populations of hard clams from St. Catherines Island and applies this model to the interpretation of Archaic-period archaeological assemblages. Their results demonstrate that hard clams recovered from the St. Catherines and the McQueen shell rings were intensively harvested during the late winter and spring seasons. These authors explicitly address two companion issues associated with high levels of sedentism: the extent to which natural and anthropogenic processes impact these resources, and whether there is evidence of resource management strategies. They clearly demonstrate that knowing something about cultural activity is to know something about the biology and ecology of the animals that were used.

Douglas S. Jones, Irvy R. Quitmyer, and Chester B. DePratter present oxygen isotope validation of annual macroscopic shell growth increments in modern and zooarchaeological hard clams (*Mercenaria* spp.) from the Litchfield Beach Estuary, South Carolina. They note that the periodicity of incremental shell growth in *Mercenaria* spp. is a powerful tool for estimating the season of resource procurement and anthropogenic impact on zooarchaeological resources. The seasonal pattern of shell formation in modern populations is well documented throughout their range, but recent research suggests that changes in the marine environment can quickly and significantly alter patterns of growth within a region. The research analyzes the variability of oxygen isotope ratios ($^{18}O/^{16}O$) in shell carbonate to validate the seasonal periodicity of incremental shell growth in modern and zooarchaeological specimens recovered from Litchfield Beach. The data verify the hypothesis that the periodicity of incremental shell growth has not changed over the past 2000 years, allowing the population dynamics of modern and ancient populations in the region to be assessed. The authors document significant changes in the composition of the ontogenetic age classes of pre-Hispanic hard clam populations' top down impact on hard clam beds.

In chapter 9, Deborah Ann Keene reevaluates the use of impressed odostomes (*Boonea impressa*) as proxies for season of capture for eastern oysters (*Crassostrea virginica*) recovered from middens along the Georgia Bight. The potential for zooarchaeological research was first explored by Russo (1991) who hypothesized that determining the season of death for *Boonea impressa* would reveal the season of death for the oysters to which they were attached. By assuming that most *Boonea impressa* are born at the same time of year, live for about one year, and grow steadily throughout that year, Russo argued that their season of death, as well as season of collection for oysters, could be estimated from odostome size. To test his hypothesis, he collected and measured modern samples of *Boonea impressa* from the northeast coast of Florida for 14 months, then developed a model of their yearly growth based on shell length. Keene notes that whereas additional data have been collected on the growth, reproduction, and behavior of *Boonea impressa* in North Carolina, we still do not understand how reproduction and growth are affected by environmental factors, meaning that studies using *Boonea impressa* to determine season of capture require deeper inquiry to establish a more reliable model to assess the season of oyster harvest. Keene proposes several potential ways to evaluate accuracy, and concludes that the cost effectiveness and ease of this method for determining season of death means that it should not yet be abandoned.

Nicole R. Cannarozzi evaluates the potential of the Eastern oyster (*Crassostrea virginica*) as a proxy for seasonality using zooarchaeological collections from St. Catherines Island. She discusses how determining the season of collection of oysters in the Georgia Bight is complicated by the dynamic nature of the estuaries these molluscs inhabit. Environmental changes may cause unpredictable biological responses, including the formation of multiple shell growth breaks. Currently, stable isotope geochemistry is the most effective method for determining seasonality of oyster harvest in the area. Morphological data show that different habitats were exploited and/or oyster habitats on St. Catherines have changed considerably over time. She includes in her study measurements of impressed odostomes (*Boonea impressa*), which indicate year-round collection with the greatest number of individuals collected during cool months.

In chapter 11, C. Margaret Scarry and Kandace D. Hollenbach examine the question of whether plant data derived from archaeological samples provide reliable evidence of seasonality in the past. In most environments, plants have predictable cycles of flowering and fruiting, for example, and seem likely candidates for estimating the season(s) of occupation. The potential to delay harvest and to store many plants, however, complicates direct associations between harvest seasons and seasonal residential patterns. The authors, instead, consider seasonal subsistence rounds from the perspective of operational chains involved in acquiring, processing, and consuming key plant resources. To do this, they draw upon species inventories from archaeological sites throughout the region as well as ethnographic and ethnohistoric information. They conclude that their hypothetical round of plant handling could be conducted from marshside settlements on St. Catherines Island without requiring seasonal settlement relocation.

Gregory A. Waselkov discusses more general implications of seasonality and mobility in coastal research. He notes that coastal archaeologists have refined their studies of subsistence remains for evidence of resource intensification and seasons of resource use and residential patterns. Seasonality, in particular, is far more complex than earlier models suggested. But Waselkov warns that current archaeological methods employed to document and interpret subsistence seasonality (which is our principal portal to the multiple facets of residential mobility and sedentism) have many shortcomings. Although even our best available methods have real limitations on seasonal resolution, Waselkov suggests that a higher standard of analysis can provide a firmer basis for models of coastal sedentism and mobility.

In the concluding paper, Elizabeth S. Wing discusses the papers presented at the Fifth Caldwell Conference, noting that many challenges exist in documenting the seasonal foraging patterns of the past. She emphasizes the expansion of archaeological techniques available for examining seasonal change over the past few years and encourages further integration of data from such diverse sources as charcoal, tree rings, growth increments in mollusc shells and fish otoliths, and fish faunal assemblages. Wing states that these techniques provide a more complete understanding of human conditions in the past. She also underscores the difficulty of integrating data from plants with those from animals due to the relatively poorer preservation of plant remains, and suggests that the recovery of additional plant remains from waterlogged conditions could help meld these two datasets. Wing notes that the bioarchaeological remains discussed in these papers derive from excavated archaeological deposits and points to the importance of documentary evidence in providing (sometimes conflicting) firsthand glances at the past foraging activities of people living along the Georgia Bight.

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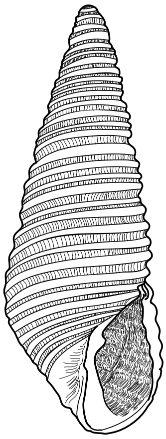


CHAPTER 1
SEASONALITY AND MOBILITY ON THE GEORGIA BIGHT: WHY SHOULD WE CARE?

DAVID HURST THOMAS[1]

Three years ago, our team published a three-volume, 1136-page monograph called *Native American Landscapes of St. Catherines Island* (Thomas, 2008), presenting the data and synthesizing all of our previous research on St. Catherines Island (except for the archaeology of Mission Santa Catalina de Guale). The American Museum of Natural History's program in archaeology on St. Catherines Island has always been about teamwork, and the *Native American Landscapes* volumes clearly reflects this broad-based, interdisciplinary bias, with more than two dozen contributors to the final publication.

Four decades of archaeological research, encapsulated in *Native American Landscapes*, addressed aboriginal lifeways of indigenous St. Catherines Islanders in terms of four deceptively simple questions (after Thomas, 2008: iii):

How and why did the human landscape (reflected in settlement patterns and land use) change through time?

To what extent were subsistence and settlement patterns shaped by human population increase, intensification, and competition for resources?

What factors can account for the emergence of social inequality in Georgia's Sea Islands?

Can systematically collected archaeological evidence resolve the conflicting ethnohistoric interpretations of the aboriginal Georgia coastline (the so-called Guale problem).

In this chapter, I focus on the fourth of these research objectives.

A critical element in the scientific enterprise, I believe, is the right to be wrong. Given the objectives guiding the Fifth Caldwell Conference, it seems worthwhile to explore the pivotal relationship between seasonality of site occupation and human mobility strategies. To understand how seasonality inferences were embedded within the St. Catherines Island archaeological program, I'll first summarize the previous findings, then deconstruct the *Native American Landscapes* volumes specifically with respect to seasonality (Thomas, 2008). The idea is to highlight some shortcomings in our previous work and anticipate some ways to improve our understanding of site seasonality and its impact on the estuarine systems of the Georgia Bight.

WHAT'S THE 'GUALE PROBLEM'?

The Guale Indians of the interior Georgia Bight were among the first indigenous peoples met by Europeans exploring north of Mexico. After brief contact with the Spanish in 1526, this Muskhogean-speaking group later encountered the French in 1562–1563. Then, beginning in 1566, the Guale experienced a sustained period of Spanish colonization and missionization.[2] By 1684, the gradual southern withdrawal of the Spanish coupled with the southward expansion of the Carolina colony fostered relocation and reorganization of the vastly reduced Guale population.[3]

CONFLICTING VIEWS

Building on Swanton's (1922) landmark synthesis *The Creek Indians and Their Neighbors*, Lewis Larson (1969, 1980) contrasted the Guale with apparently more sedentary peoples of Apalachee Florida. Concluding that coastal

Georgia environments seriously constrained and hampered aboriginal lifeways, Larson argued that only a highly dispersed, seasonally mobile population could have survived there.

Particularly critical to this interpretation were ethnohistoric documents from the central Georgia Bight during the 1560s (Larson, 1969: 293–297), especially the accounts by Fr. Jean Rogel at Orista (Sturtevant, 1964: 170), Fr. Antonio Sedeño (who described coastal Georgia as "the most miserable thing ever discovered" (Zubillaga, 1946: 424), and René Laudonière (Bennett, 1975: 121), who recorded similar impressions in 1564 at Outina (a Timucuan settlement located just west of the St. Johns River in northeastern Florida (see Worth, 1998: 21 and Thomas, 2008: chap. 11). These (and other) documents convinced Larson (1980: 209, 218) that the infertile and patchy soils of coastal Georgia were "the primary reason for the scattered and small size of the agricultural production unit." He concluded that along the Guale coast "permanent settlements were not the rule, for long seasonal junkets in pursuit of game mitigated against a settled populace" (Larson, 1978: 122; see also 1969: 293–297, 1980: 206–209). Despite some modifications in the mid-1980s (addressed in Thomas, 2008: chap. 11), Larson's perspectives on Guale subsistence and settlement were accepted and amplified by a number of investigators (esp. Crook, 1984, 1986; see also Wallace, 1975: 265–271; Pearson, 1977: 62–63; Reitz and Scarry, 1985: 46; Reitz, 1988, 1991; see also Thomas, 2008: chaps. 11 and 35).

Likewise, arguing long-term, high residential mobility, Crook (1986: 17–20, fig. 2, 2004; see also Crook, 1984: 260, 1986: 18–20; Larson, 1980) proposed a *"purely aboriginal" fission-fusion settlement model for the precontact Guale people*. Crook defined the Guale wintertime settlement (mid-December through mid-March) as "minimal settlements" consisting of a single matrilineage, dispersed "adjacent to tidal streams which permitted access to the estuarine system" (1986: 22).[4] Crook (1986: 53) summarized his "Annual Model" this way: "large villages primarily occupied during the summer, smaller settlements occupied either multi-seasonally or during the fall–winter season, and small sites occupied for very short periods of time do exist" (see also Thomas, 2008: table 11.6).

Ethnohistorian Grant Jones (1978, 1980) came to a quite different conclusion after his own close reading of the same documentary sources: "On the empirical level I believe that [the conventional wisdom] has led to an overstatement of the isolation of the Guale from the interior, the unproductivity of Guale horticulture, and the scattered quality of Guale settlements" (Jones, 1978: 189). Jones (1978: 179, 191, 194) believed that the Jesuit reports deliberately exaggerated the "misery" of the land, and proposed instead that the Guale lived in "dispersed towns … there is no doubt that there was a town center with a large round community building, a chunky field, and some residential structures. The regular presence of some form of mortuary structure is likely. The town center was surrounded by dispersed households practicing shifting horticulture. Intergroup and intragroup economic exchanges and redistribution systems, in a context of considerable resource variability contributed toward a dependable food supply that probably required little regular seasonal residential mobility" (Jones, 1978: 200).[5]

Jones (1978: 209) summarized his position this way: "Larson's … reliance on the Jesuit view of the sixteenth century Guale … led him to consider the Guale as an isolated, distinctive adaptation. While it is significant that the Guale were adapted to special environmental conditions, I have argued that these conditions neither created isolation nor impeded the development of a complex level of sociocultural integration.… Despite their environmental and adaptive differences, the Guale and the interior groups shared such basic features as chiefdoms, military federations, matrilineality, and dual aspects of organization. … [I]t is of considerable theoretical importance that such an exploration eventually be attempted, for the Guale case seems to demonstrate that more than one set of adaptive conditions may well combine to create highly similar features."

These are vastly different interpretations of the ethnohistoric record for the Georgia coastline, and the so-called Guale problem became the central research question addressed in the *Native American Landscapes* volumes (Thomas, 2008; see also 1987: 57–64, Worth, 1999; Saunders, 2000b; Ruhl, 2003: 188–189; Keene, 2004: 672).

Competing Hypotheses and Logical Consequences

The Guale problem turns on the twin issues of residential mobility and economic intensification, which I believe can be succinctly expressed in two competing hypotheses extracted from the ethnohistoric record:

The Jesuit hypothesis: Guale Indians were egalitarian, highly nomadic, mostly nonfarming foragers who lived in low-density, small, seasonal aggregations;

The Franciscan hypothesis: Guale Indians were a hierarchical, ranked society; they relied heavily on maize cultivation, rarely moved their residences, and lived in high-density "dispersed towns."

Native American Landscapes of St. Catherines Island (Thomas, 2008) was all about testing these two hypotheses.

The truth, of course, is that scientists don't really test their hypotheses—what we test are the logical implications of our hypotheses. Essentially, hypotheses are abstract, inductive statements that must be translated (through deductive reasoning) into logical, empirical, material consequences. Such deductive arguments generally take the form of "if ... then" statements: *If* the hypothesis is true, *then* we will expect to observe the following outcomes. Bridging the gap from *if* to *then* is the tricky step.

With respect to the Guale problem, we framed the following logical consequences from the two competing hypotheses:

The Jesuit hypothesis: *If* the Jesuit observations correctly reflect mid-17th century Guale settlement patterns, *then* the resulting archaeological record should reflect a palimpsest of some four-season settlements and several seasonally specific settlements. The most concentrated occupations should occur during the summer, with a dispersed series of archaeological accumulations during the early fall, followed by moderate occupational intensity from the late fall through winter. From the fall through springtime, the Guale were residentially mobile foragers who should have produced an archaeological record of (1) dispersed oak forest settlements (fall and springtime occupations only) and (2) dispersed marshside settlements (late fall–winter and springtime occupations only).

The Franciscan hypothesis: *If* the Franciscan observations correctly reflect mid-17th century Guale settlement patterns, *then* the resulting archaeological record should reflect a basic strategy of low residential mobility centered on "dispersed towns," generally positioned along the maritime forest/marsh margin. Whereas some Guale may have shifted their winter residence to be closer to hunting, fishing, or shellfish patches, most St. Catherines islanders maintained four-season residence in a single community. Hunting, fishing, and wood-collecting trips took individuals away from the community on a temporary basis. Guale dispersed towns were located mostly along the margins between maritime forest and saltwater marshes. These forager farmers (or, perhaps, farmer foragers), lived in large, relatively stable residential central places, out of which logistical forays of small "task groups" brought plants and animals back home. This strategy of minimal residential mobility should produce a distinctive archaeological record, characterized by sustained, four-season occupations of *marshside* settlements, with only minimal evidence of single- or biseasonal occupations elsewhere.

ARCHAEOLOGY AND THE GUALE PROBLEM

The American Museum of Natural History harnessed a broad array of field and analytical techniques to test the Jesuit and Franciscan hypotheses (esp. Thomas, 2008: chaps. 7–12). We situated this fieldwork within the general paradigm of human behavioral ecology, grounded in three basic models (Thomas, 2008: chaps. 7–10). The *diet-breadth (or prey choice) model* addressed the issue of which foods an efficient forager should harvest from all those available on St. Catherines Island. Diet-breadth models predict that foragers will optimize the time spent capturing prey, and employ the simplifying assumptions that all resources are randomly distributed (without patches) and that "capture/handling" and "search" times represent the sum total of all time spent foraging. We also applied the *patch choice model*, which, combined with the central limit theorem, predicts that foraging efforts will correlate directly with efficiency rank order, meaning that foragers should spend more time working the higher-ranked patches and less time in patches with lower energetic potential. Using the *central place foraging* model, we investigated the time/energy spent processing resources at temporary camps before transport to a residential base. For several years, we have also conducted a series of optimal foraging experiments, specifically addressing procurement and return rates for key marine and terrestrial resources that would have been available to aboriginal foragers on St. Catherines Island.

We conducted a 20% probabilistic transect survey of St. Catherines Island, walking and probing for buried sites across a series of 31 east–west transects, each 100 m wide (fig. 1.1). This procedure generated a sample of 122 archaeological sites, which we tested with more than 400 1 m × 1 m units. Because the transect sam-

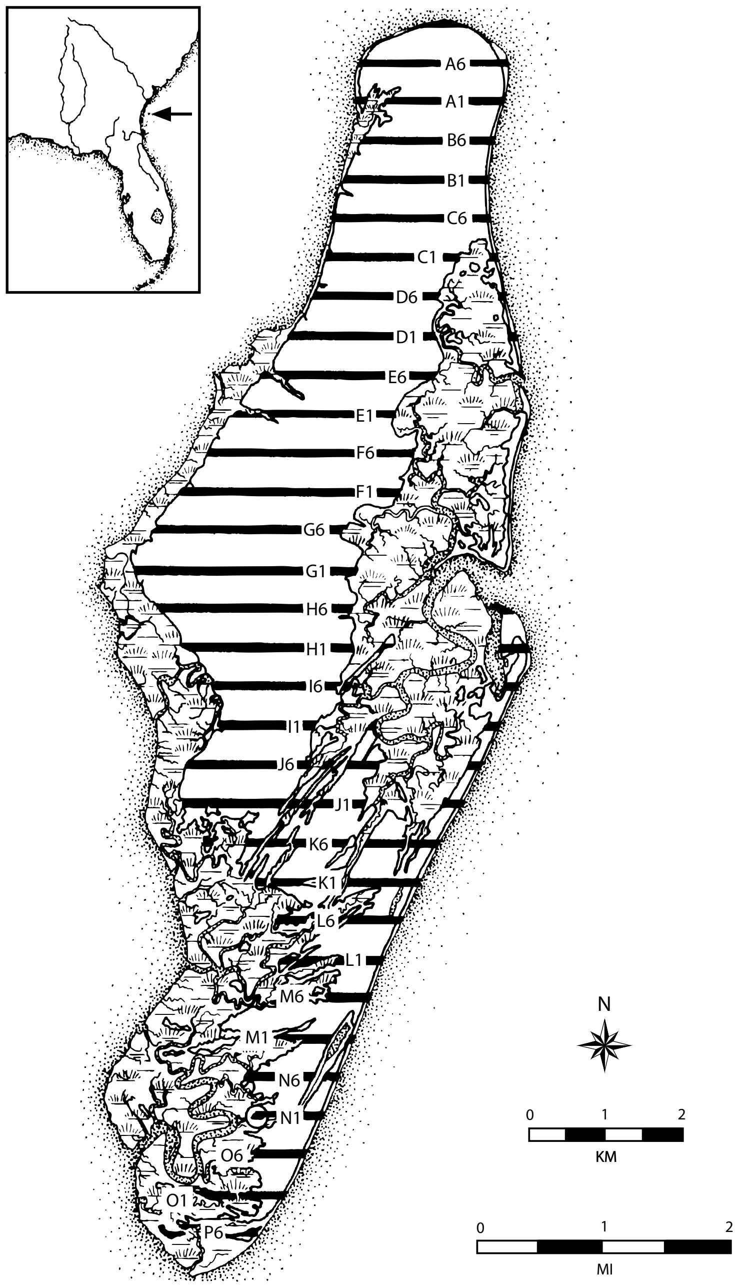


Fig. 1.1. The randomized transect research design employed in the island-wide survey of St. Catherines Island (after Thomas, 1987: fig. 22).

pling was heavily biased toward sites with marine shell, we also conducted a systematic shovel testing program and augmented these systematic surveys with a direct shoreline reconnaissance (mostly following the late Holocene surfaces), recording an additional 84 shoreline sites. By plotting the distribution of these known-age sites across the Holocene beach ridges, we developed a detailed sequence documenting the progradation and erosion of beach ridge complexes adjacent to tidal estuaries and coastal shorelines on St. Catherines Island.

These data in hand, we turned next to the analytical tools necessary to make sense of this archaeological record, beginning with chronological controls.

DEVELOPING MULTISCALAR CHRONOLOGIES

> Chronology is at the root of the matter, being the nerve electrifying the dead body of history.
>
> –Berthold Laufer (1913: 577)

A century ago, addressing the annual meeting of the American Anthropological Association, ethnographer Berthold Laufer pretty much got it right—chronology really does lie at the heart of the matter. Archaeologist Alfred Tozzer (1926: 283) subsequently expressed similar sentiments about archaeological data having "an inert quality, a certain spinelessness when unaccompanied by a more or less definite chronological background" (see also O'Brien and Lyman, 1999: chap. 1).

Laufer (1913: 576) went on to suggest that whereas archaeology and ethnology are "inseparably one and the same—emanations of the same spirit, pursuing, as they do, the same ideal, and working to the same end," they operate at different timeframes. "When archaeology and ethnology have drawn up each its own chronology, then the two systems may be pieced together and collated, and the result cannot fail to appear." This observation is important because Laufer explicitly recognized that chronology typically operates at multiple levels—what today we might call a "multiscalar" approach to chronology control.

Today, we understand that archaeology's initial objective must always be chronological—reflecting the necessity of establishing a firm grasp on *time* before attempting to reconstruct ancient lifeways or addressing more processual matters. In our St. Catherines Island research, we have approached chronology in the multiscalar fashion anticipated by Berthold Laufer a century ago:

The Hour Hand: The St. Catherines Island ceramic sequence provided the "little hand" on the clock, generally providing temporal controls at a submillennial level of resolution.

The Minute Hand: The radiocarbon sequence became the "big hand" on the clock, generating temporal controls at a century level of resolution.

The Second Hand: Site seasonality studies offer microchronological controls at the resolution of months or even weeks.

Below, we discuss how this multiscalar approach to chronology allowed us to evaluate the Guale problem on St. Catherines Island, especially as it relates to site seasonality studies.

The St. Catherines Island Ceramic Chronology: Reading the Hour Hand

The regionalized random sampling of St. Catherines Island generated more than 15,000 potsherds from 122 archaeological sites (Thomas, 2008: tables 20.3 and 20.5). Perceived as "index fossils," these diverse ceramic assemblages provided the initial (and most coarse-grained) chronological controls.

All of the aboriginal ceramics recovered from St. Catherines Island were initially classified according to the northern Georgia coast ceramic chronology, as refined by Chester DePratter (1979: table 30; as updated in DePratter, 1991: table 1; see also Thomas, 2008: chap. 14 and 15). In this synthesis, DePratter relied on temper, surface decoration, rim form, and vessel form that demonstrably vary "asynchronously" (DePratter, 1979: 122). DePratter's chronological sequence contained seven major cultural *periods*, subdivided into nearly two dozen archaeological *phases* (table 1.1.) This coarse-grained approach to chronology provided temporal estimates accurate at the submillennial level.[6]

Radiocarbon Dating: Reading the Minute Hand

Monitoring radioactive emission from organic specimens by determining the current rate of ^{14}C breakdown, the radiocarbon method estimates the length of elapsed time since the death of a plant or animal. Within the last couple of decades, physicists have discovered that the atmospheric level of radiocarbon has changed somewhat over the last several millennia, enabling archaeologists to "correct" their radiocarbon dates using an absolute chronology based on radiocarbon dating of known-age bristlecone pine samples. New advances in accelerator-based radiocarbon methods permit archaeologists to use extremely small samples, vastly stretching the potential of the method.[7]

By itself, the radiocarbon method tells us nothing about human activities in the past. A ^{14}C date merely estimates when a certain hickory nut dropped to the ground or a specific hard clam died. In each case, the event being dated must be demonstrated to be coeval with a behavioral (cultural) event of interest.

Throughout the St. Catherines Island research, we have emphasized the importance of radiocarbon dating in both archaeological and geological perspectives. The St. Catherines Island archaeological research is currently grounded in a database of roughly 300 ^{14}C determinations, most of them processed on "cultural" samples recovered from documented archaeological contexts on St. Catherines Island,[8] primarily burial mounds and shell middens. We have an additional suite of ^{14}C dates from noncultural contexts, primarily organics and marine shell samples collected in conjunc-

TABLE 1.1
Comparison of Northern Georgia Coast and St. Catherines Island Chronologies
(Northern Georgia coast after DePratter, 1979: table 30, as modified by DePratter, 1991: table 1. St. Catherines Island after Thomas, 2008: table 15.3.)

Phases	Northern Georgia coast chronology age (uncalibrated)	Northern Georgia coast chronology age (calibrated)	St. Catherines Island chronology age (calibrated)
	A.D. 1700[1]	—	A.D.1700[2]
Altamaha			
	A.D. 1580	—	A.D. 1580[2]
Irene			
	A.D. 1325	A.D. 1310–1390	A.D. 1300
Savannah			Savannah phase deleted
	A.D. 1200	A.D. 1280	A.D. 1300
St. Catherines			
	A.D. 1000	A.D. 1050–1150	A.D. 800
Wilmington			
	A.D. 500	A.D. 630	A.D. 350
Deptford			
	400 B.C.	400 B.C.	350 B.C.
Refuge			
	1100 B.C.	1360 B.C.	1000 B.C.
St. Simons			
	2200 B.C.	2750–2860 B.C.	3000 B.C.

[1]Beginning and ending age estimates for the Altamaha period in the northern Georgia coast chronology are based on historical documentation, not ^{14}C dating.
[2]Uncalibrated.

tion with vibracore sampling and surface geological reconnaissance (see Bishop et al., 2011: appendix 1 for a compilation of these dates). Each radiocarbon date was calibrated according to the conventions and protocols discussed in Thomas (2008: chap. 13).

Radiocarbon dating provides temporal estimates generally accurate at the level of centuries, sometimes even at the decades level.

Site Seasonality: Reading the Second Hand

So far, we have emphasized the importance of grounding St. Catherines Island archaeology within a solid *macrochronological* framework—an ordering of events within segments of millennia, centuries, and even decades. But addressing the Guale problem requires more fine-grained temporal controls—certainly on the order of seasons, perhaps even months or weeks. Literally thousands of potential "seasonal indicators" were recovered during our excavations on St. Catherines Island and (following Aten, 1981) we explored several commonly employed methods for determining seasonality in such sites: presence or absence of skeletal elements (such as bones from migratory species), demography (changing size of estuarine fishes as they mature through the annual cycle), morphological changes in shell contour during the annual cycle, microstructural changes correlated with the seasons of the year, and chemical changes in shell composition (such as shifting oxygen and carbon isotopes).

The Incremental Growth Sequence in *Mercenaria:* As we developed the archaeological research design for St. Catherines Island, we recognized the potential for determining the seasonality of harvest by analyzing growth increments in the shell of hard clams (*Mercenaria mercenaria*), which occur in some abundance in the local shell middens (O'Brien and Thomas, 2008). Such studies were in their infancy in the mid-1970s, with only a limited literature then available (esp. Clark, 1968, 1974; Weide, 1969; Coutts, 1970, 1975; Coutts and Higham, 1971; Ham and Irvine, 1975; Kennish and Olsson, 1975; Koike, 1975).

Most of these pioneering studies emphasized the importance of modern controls for understanding the variability introduced by changing water temperatures and salinity, tides, predation, spawning, and other environmental factors. On St. Catherines Island, we began collecting a modern control sample of *Mercenaria mercenaria* in 1975, a process that continued, somewhat sporadically, over a nine-year interval; an independent sample of modern *Mercenaria* was also collected between April 1994 and March 1995, in support of the oxygen isotope study (Andrus and Crowe, 2008).

Working with George R. Clark II (1979), we began a program of seasonal analysis by analyzing *Mercenaria* recovered from Johns Mound, Marys Mound, and McLeod Mound (see also Thomas and Larsen, 1979; Larsen and Thomas, 1982: 338). Clark concluded that most hard clams interred in these mortuary sites had been harvested during the winter months, probably December and January. But because these zooarchaeological samples were recovered from a secondary, nonmidden context, the complex formation processes involved precluded actual seasonal dating of the mortuary activities. Still, we were encouraged that seasonal patterns were indeed evident in the ancient *Mercenaria* samples recovered archaeologically, and we moved on to consider hard clam seasonality in the various occupational sites of St. Catherines Island.

Initial laboratory observations of growth increments along the ventral margins, compiled mostly between the late 1970s and mid-1980s, were expressed in Clark's descriptive terminology (e.g., "early gray," "early-mid white," "probably end of white," and so forth). Since that time, considerable progress has been made on the seasonal analysis of molluscs. O'Brien and Thomas (2008) made use of the then-standardized, six-part subdivision of annual shell growth (Jones, 1980; Quitmyer et al., 1985, 1997: 830), but converted to a four-stage scale, which was then (fig. 1.2) correlated with approximate season of harvest:

O_{1-2} (initial to intermediate opaque increment): Winter (mid-December–mid-March)

O_3 (terminal opaque increment): Early spring (mid-March–mid-April)

T_1 (initial translucent increment): Spring (mid-April–mid-June)

T_{2-3} (intermediate to terminal translucent increment): Summer and fall (mid-June–mid-December)

Figure 1.2 summarizes the modern control sample, pooled from both St. Catherines Island collection sites (after O'Brien and Thomas, 2008: fig. 17.4).

Mercenaria suitable for seasonal analysis were recovered from nearly 85% (110 of 130) of

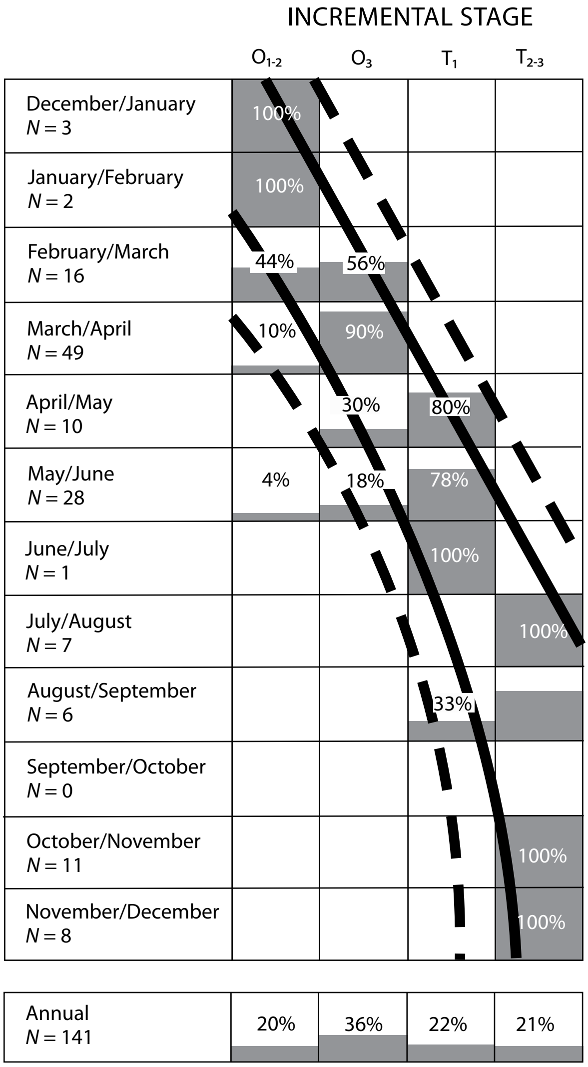


Fig. 1.2. Interpolated estimates of incremental growth stages for the modern control sample of *Mercenaria* collected from St. Catherines Island.

the sites sampled in the island-wide survey, and we saved every single undamaged clam ventral margin for potential seasonal analysis. O'Brien and Thomas (2008: 484–486) elaborate the various ways in which these valves were processed for analysis, including blind testing and additional quality controls employed.

Because such analysis was time-consuming and labor intensive, we instituted a sampling scheme to narrow down the number of clams to be analyzed, while still avoiding the introduction of bias in the winnowing process. After the ceramics from the survey sites were analyzed (using the St. Catherines Island ceramic chronology, discussed above)—and we could classify most sites according to archaeological period(s)—we applied a series of sampling conventions to select appropriate *Mercenaria* for seasonal analysis:

Single-component sites: If fewer than 25 readable clams were available, all clams were analyzed. If more than 25 suitable clams were recovered, the available valves (or fragments) were numbered sequentially, and a sample of 25 was selected using a table of random numbers. Some "single component" sites also contained evidence of secondary occupations during other ceramic periods. When this happened, *Mercenaria* samples were taken whenever possible from "temporally discrete" test pits and/or excavation levels (from those units and levels containing only one ceramic complex) by randomly selecting from within these relatively homogeneous intrasite areas.

Double-component sites: Each component was sampled independently by targeting relatively homogeneous test pits (and/or specific levels) from each major temporal component. We then selected up to 25 clams from each component (randomly sampling in the case of $N > 25$).

Multiple-component sites: We wanted to analyze 25 valves from each of the identified components, but in practice, we never recovered sufficient *Mercenaria* to do this. As a result, we analyzed whatever clams were recovered and attempted to determine the archaeological age of each specimen by charting associated potsherds.

Undated components: Several sites contained sufficient *Mercenaria* for seasonal analysis, but too few potsherds to assign a probable period of occupation. The seasonal estimates were included in the overall, island-wide total, but not in the period-by-period tallies.

Although this sampling procedure is, admittedly, a bit mechanistic, we were seeking a way to generate a relatively uniform, representative sample of hard-shelled clams selected for analysis by reducing the overall number of analyzed specimens to approximately 2000 individual *Mercenaria* valves (or fragments). Of these, 1771 individual specimens (or fragments) provided usable growth increment estimates, enabling us to address seasonal patterns during the 5000 years of human history (O'Brien and Thomas, 2008).[9]

Russo (1991) has also published estimates of seasonality in oyster collection on St. Catherines Island by employing measurements of impressed odostome (*Boonea impressa*) recovered from Meeting House Field. His analysis of *Boonea* determined that oyster collection took place primarily during the fall, with summer as a secondary collection period (Russo, 1991: 219). Russo's correlative study of seasonality in *Mercenaria* at Meeting House Field (Russo and Saunders, 2008) employed the Kings Bay, Georgia control sample (Quitmyer, Hale, and Jones, 1985) to analyze the zooarchaeological specimens from Meeting House Field. Overall, these data suggest a year-round site occupation, though the evidence for summer occupation is limited. Of particular interest was the difference in oyster collection and quahog collection in the fall, although both species were collected in varying amounts throughout the year.

Assessing Season of Capture in Nonhuman Vertebrate Remains: The island-wide transect survey produced an extensive and diverse set of vertebrate faunal remains collected systematically from archaeological sites tested across the entire island. Elizabeth Reitz and her colleagues analyzed this vertebrate faunal assemblage, which contains at least 586 individuals represented by 14,970 vertebrate specimens (Reitz, 2008; Reitz and Dukes, 2008). Reitz (2008: 623–624, 660–663, table 22.72) has discussed the presence of numerous seasonal indicators in the vertebrate zooarchaeological samples recovered from archaeological sites on St. Catherines Island—especially (1) unshed deer antlers, (2) juvenile deer dentition, (3) presence of shark remains, and (4) presence of sea catfish remains.

Seasonality and the Guale Problem

With this multiscalar, three-tiered approach to chronology, we synthesized the evidence from the island-wide archaeological survey, documenting residential mobility and human population increase between 3000 cal B.C. and cal A.D. 1300 (Thomas, 2008: chaps. 32–34). Overall, these data demonstrate (1) an exponential increase in human population through time, and (2) a low degree of residential mobility throughout the entire aboriginal period. This pattern continued through the late prehistoric (Irene) period, characterized by the largest and most frequent archaeological occupations recorded in the island-wide survey. Irene occupations accumulated at an extremely rapid rate (34 occupations/century) and the number of recorded archaeological components skyrocketed to 52 (for an average of 17.33 components/century; Thomas, 2008: table 30.1). This is, by far, the densest concentration of archaeological remains recorded for any aboriginal period on St. Catherines Island. The Irene period also had the largest proportion of "large" sites and the smallest proportion of "small" sites (see definitions in Thomas, 2008: table 30.2) recorded during the probabilistic survey.

We generated seasonality estimates for 42 Irene-period components (representing 124 seasonally specific occupations; see fig. 1.2). More than 40% of these Irene components had all four seasons represented and another 36% were occupied in (at least) three seasons. Conversely, only four Irene components represented a single season (each of these being a winter-only occupation). Throughout this discussion, we cautioned against equating a four-season archaeological occupation with "sedentism" (in the conventional ethnographic and ethnohistoric usage).[10]

With respect to the implications derived from human behavioral ecology, the upshot was simple and conclusive: Optimal foraging considerations strongly militate in favor of logistical, rather than residential, mobility. Even factoring in the shifting shape of St. Catherines Island over the past five millennia, it is clear that all habitats on the island could have been systematically searched and exploited by individual foragers who could easily return home daily. These biogeographic constraints suggest that St. Catherines Island foragers could have pursued a strategy of logistic procurement and low residential mobility (at least during times of relatively favorable climatic conditions).

The vast preponderance of archaeological evidence supports a collector strategy of low residential mobility. For most of the time, Irene populations apparently did live, year round in dispersed towns located along the forest-marsh margin (per Jones, 1978: 193–194). Expressed in terms of expectations from central place foraging theory, more than 80% of the archaeological components encountered on St. Catherines Island (for *all* temporal periods) fit the model of sustained and multiseasonal *marshside* settlements. Only limited evidence exists for (1) single- or biseasonal occupations or (2) inland, special-purpose, short-term settlements.

To conclude, the combined evidence from the island-wide archaeological survey, coupled with recent ethnohistoric interpretations and modeling from human behavioral ecology would seem to resolve the Guale problem, overwhelmingly rejecting the Jesuit hypothesis, at least on St. Catherines Island. The Franciscan hypothesis, on the other hand, is entirely consistent with the newly available evidence, confirming and amplifying ethnohistorian Grant Jones's (1978, 1980) perception of the contact-period Guale people: These were largely sedentary foraging farmers who lived in optimally positioned marshside dispersed towns, grew significant quantities of maize and other domesticated crops (at least late during the Irene period), and maintained a complex chiefdom level of social organization with centralized, inherited leadership and long-distance trade networks with the interior (Thomas, 2008: chap. 35).

BUT DID THE JESUITS GET IT WRONG?

Given the compelling evidence for supporting low residential mobility and significant maize cultivation among the coastal Guale people, one must ask: What happens to the French and Jesuit accounts? These eyewitness accounts consistently describe high residential mobility, seasonal dispersal, infertile soils, and minimal horticultural productivity during the 1560s along the central Georgia Bight.

Did the Jesuits and the French simply get it wrong? Probably not.

Blanton and Thomas (2008) discussed the relevance of recent paleoclimatic research on bald cypress (*Taxodium distichum*) in the American southeast (Stahle and Cleaveland, 1992; Anderson, 1994: 277–289; Anderson, Stahle, and Cleaveland, 1995; Stahle et al., 1998; Blanton, 2000, 2004). The period of extended dryness during the latter part of the 16th century is particularly relevant to the present discussion—a time when "megadrought" conditions plagued much of North America (Stahle et al., 2000). During the early European contact period, Stahle et al. (1998: 545) document "a prolonged drought from 1562 through 1571 that was most severe from 1565 to 1569." Whereas this intensely warm and dry interval (between about A.D. 1565 and 1569) has been little discussed in the recent literature, it signals an extraordinarily difficult time for forager–farmers along the Georgia coastline—one of many challenges facing Europeans and Native Americans alike. We can now see that the Jesuit missionaries of Georgia and Carolina were facing a prolonged drought, the driest interval of the entire 16th century (Worth, 1999; Saunders, 2000b).

Still smarting from their public failures in Spanish Florida, the Jesuit friars may have exaggerated their accounts regarding the poverty of the Georgia Bight (Jones, 1978, 1980; Worth, 1999). But when combined with the tree-ring evidence from this same area, these accounts gain considerable credibility because they document how these coastal chiefdoms adapted their normal seasonal and annual routines to accommodate environmental challenges and social stress.

Judging from the combined tree-ring records and surviving ethnohistoric accounts, it seems that the foraging farmers of Guale also adapted their provisioning strategies, sometimes using backup tactics to exploit relatively drought-resistant prey taxa. Additional research is required to understand how the logistic and residential strategies might vary in different localized landscapes across the Sea Islands and how they might respond to short-term climatic fluctuations—despite the fact that these coastal foragers pursued identical hunt types across identical patch types using identical technologies.[11]

SOME CONCLUSIONS AND IMPLICATIONS

This is where things stood with the publication of *Native American Landscapes of St. Catherines Island* (Thomas, 2008). We concluded that the

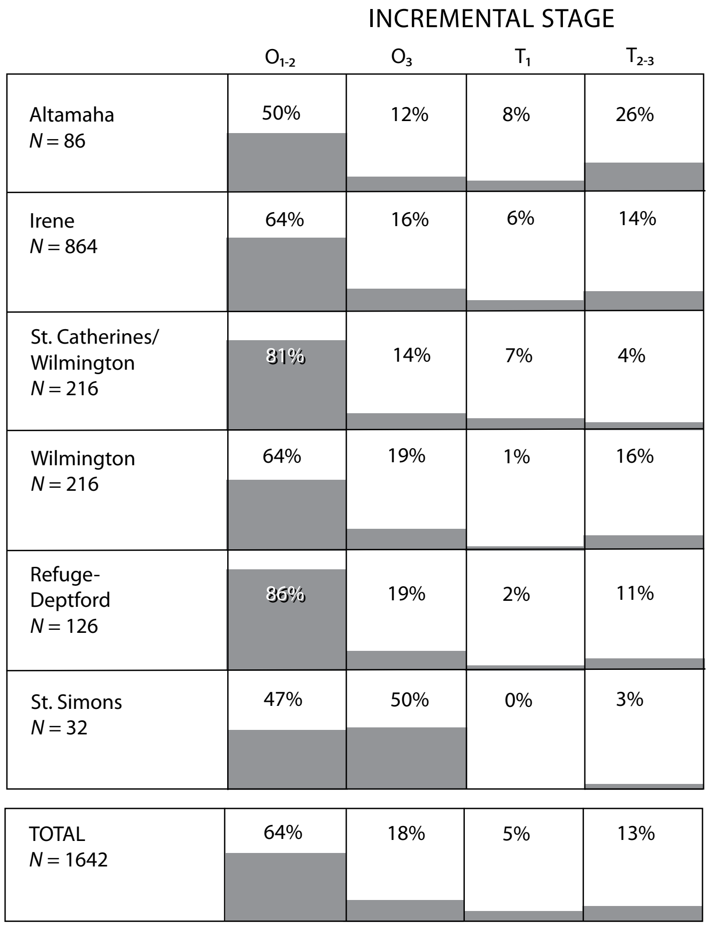


Fig. 1.3. Position of growth surface within major increments at time of harvest: modern control sample of *Mercenaria* collected between 1975 and 1984 on St. Catherines Island.

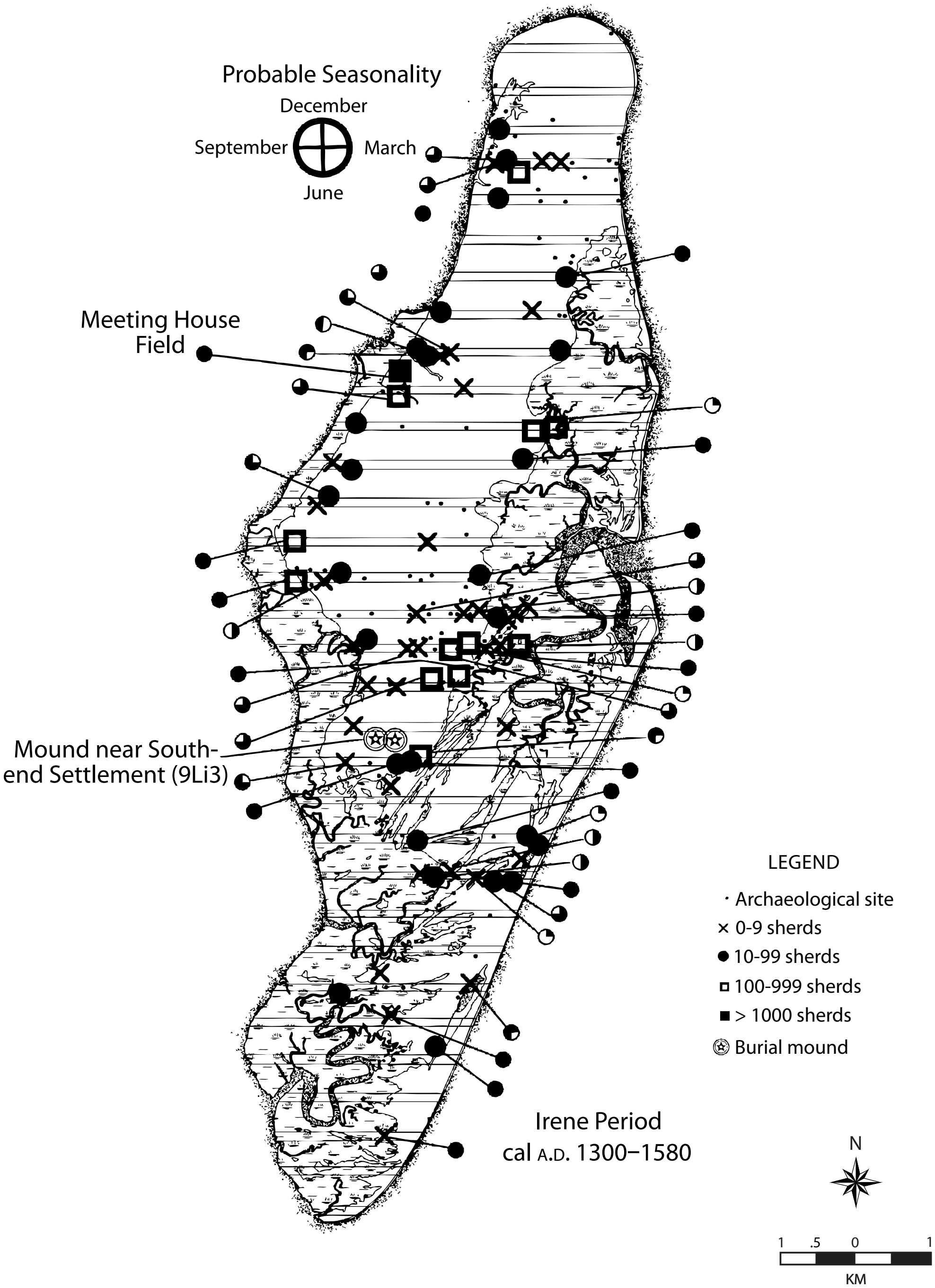


Fig. 1.4. Map of probable seasonality on St. Catherines Island during the Irene period.

modeling from human behavior ecology, newer ethnohistoric interpretations, and archaeological evidence from the island-wide survey were quite consistent with the Franciscan hypothesis: during the mid-16th century, Guale society was hierarchical and ranked, relying heavily on maize cultivation and centered on relatively high density, low-mobility "dispersed towns." (i.e., the Franciscan hypothesis). But we did suggest that alternative, backup mobility strategies (consistent with the Jesuit hypothesis) seemed possible (even likely) during the dramatic drought episodes known to have taken place during the 16th and 17th centuries.

Since the publication of *Native American Landscapes,* we have continued intensive archaeological research on St. Catherines Island, pursuing two primary goals. One project flowed directly from our previous interest in the Guale problem. Emphasizing remote sensing and large-scale excavations, we are currently studying the settlement structure and household patterning at several late prehistoric (Irene) sites, especially Meeting House Field (9Li21). We think that these large sites are likely the "dispersed Guale towns" discussed by Jones (1978).

We have also launched a long-term program investigating the McQueen Shell Ring (9Li1648) and St. Catherines Shell Ring (9Li231), two large Late Archaic sites. The study of such Late Archaic rings has provoked lively discussions within the archaeological community (e.g., Russo and Heide, 2001; Marquardt, 2010a, 2010b; Russo, 2004, 2008; Sassaman, 2004, 2006; Thomas and Sanger, 2010). Ceramic production first occurs during the Late Archaic, spurring archaeologists to question the motives behind this technological advancement. Similarly, some of the earliest evidence for extended sedentism is found in such Late Archaic sites, begging questions into the cultural, sociological, and economic ramifications of such a shift in settlement pattern. The presumed planning and investment represented in Late Archaic shell rings also raises important questions regarding power, control, and hierarchy. With these issues in mind, we have conducted detailed mapping and extensive remote sensing operations at both sites, likewise excavating numerous test units and several large block excavations (Sanger and Thomas, 2010; see also Thomas and Sanger, 2010).

Although the Late Archaic and late precontact periods are separated by three millennia, both research designs require a thorough investigation of site seasonality. This is why we believe it necessary to deconstruct and to improve upon our previous work on St. Catherines Island.

The St. Catherines Island Research Design

Previous approaches to site seasonality on St. Catherines Island can be improved in numerous ways. For one thing, we used ¼ in. screens throughout most of the island-wide archaeological survey.[12] As Reitz (2008: 656) and others have noted, the use of such coarse-grained recovery techniques discriminates against smaller taxa, especially the smaller fishes (Reitz and Quitmyer, 1988; Quitmyer and Reitz, 2006; Reitz et al., 2010: 54). We should note that in all our excavations since 1982, we have only used ⅛ in. (or finer) screens, and in many cases, the deposits were water-screened as well. In our analysis of incremental growth in *Mercenaria,* we failed to distinguish left from right valves, creating the possibility that some of the randomly sampled specimens came from the same individuals (thereby weakening the assumption of independent sampling). Although we have modified our procedures in subsequent research on St. Catherines Island, we cannot currently assess the degree to which these shortcomings have biased the estimates of site seasonality in the *Native American Landscapes of St. Catherines Island* (Thomas, 2008).

We also created certain analytical ambiguities when interpreting the specific incremental patterns observed in the *Mercenaria* samples recovered for seasonal analysis. When framing the temporal parameters for *Native American Landscapes of St. Catherines Island,* we generally followed Clark's (1979) seasonal estimates, which divided the annual growth cycle into phases observable through thin-section microscopy: winter (mid-December through mid-March), spring (mid-March through mid-June), summer (mid-June through mid-September), and fall (mid-September through mid-December). For phases of fast growth, our gradations of the "white" zone were translated to stages of "opaque" growth (scaled from O_{1-3}); for episodes of slow growth, our observations on the "gray" increments were expressed as increments of "translucent" zonation. Even though we significantly expanded the modern *Mercenaria* control sample beyond what was available to Clark and we switched over to the six-stage growth incremental criteria of Quitmyer et al. (1985), our regrouped and reconfigured seasonal boundaries remain imperfect. Specifically with reference to the St. Catherines Island control sample, we found that growth stages T_2 and T_3 were almost entirely coterminous. This means that T_2 and T_3 specimens significantly overlapped in samples collected between mid-August and mid-December. Because of this overlap, we felt it necessary to group these two incremental stages into a single analytical category (denoted as T_{2-3}). Similarly, because we found almost complete temporal overlap in growth stages O_1 and O_2, we decided to group these readings into a single category, denoted as O_{1-2}. This is why we employed a four-part subdivision of annual shell growth in *Mercenaria* from St. Catherines Island (Mayer and Thomas, 2008). This is an imperfect solution and more recent studies (e.g., Quitmyer, Jones, and Andrus, 1997; Andrus and Crowe, 2008; Thompson and Andrus, 2010) have employed more fine-grained and better-defined criteria, standards that need to be applied throughout the St. Catherines Island project.

Other issues of basic sampling also arise from the island-wide transect survey. By relying on probabilistic, randomized sampling strategies, we were attempting to maximize the observed variability while minimizing sampling bias (Thomas, 2008: chaps. 11 and 19). Specifically, we generated a large sample of archaeological sites and loci, deliberately sampling across the range of soil types, site sizes, and time periods. We did this by using systematic transects, excavating hundreds of 1 × 1 m test pits, augmented by a shovel-testing program. Shovel-testing was a relatively unfamiliar technique during the late 1970s, when we conducted the island-wide survey and, in retrospect, we should have significantly expanded the shovel-testing aspect of the survey (because, we believe, we overlooked many nonshell sites, thus biasing the overall representativeness of the sample).

Reitz (2008: 617) has already commented on the difficulties in computing Minimum Number of Individuals, for instance, in the "aggregated" samples resulting from the island-wide survey sampling. Similarly, with respect to assessing site seasonality, our strategy of test-unit excavation also introduced an unanticipated degree of bias. When an archaeological "locus" was discovered, we excavated several (usually four to eight) 1 m^2 test pits, working in 10 cm levels and proceeding down into sterile deposit. We saved all cultural and zooarchaeological materials encountered, collecting potential ^{14}C samples in the process. We have already discussed the biases introduced by our selection procedures in radiocarbon dating (Thomas, 2008: 442–446). Specifically, when we examined our motives in sampling the radiometric record of St. Catherines Island, we found a significant bias created by our two rather basic sampling strategies, attempting to pinpoint chronostratigraphic central tendencies and trying to define the temporal range of ceramic variability. We concluded that the very process of selecting appropriate radiocarbon samples introduced a significant, nonrandom bias into the cumulative ^{14}C histogram of all available radiocarbon dates, likely influencing our attempt to define the temporal range of ceramic time-markers. This bias could readily result in peaks that correspond to the middle range of a ceramic type and a gap separating temporally contiguous ceramic types.

Accordingly, in 2006, we processed an additional 49 radiocarbon determinations from contexts in the island-wide survey, attempting to "close the gaps" introduced by such biased sample selections (Thomas, 2008: 451–474). Among other findings, we ran 15 additional ^{14}C samples, each apparently associated with fiber-tempered ceramics. Surprisingly, only 40% of these determinations fell into the expected age range, with more than half of the marine shell samples producing significantly later ages than the St. Simons period. We know this bias is unidirectional because *none* of the additional 34 samples associated with later ceramic types produced St. Simons age dates (Thomas, 2008: chap. 16). In other words, there is a clear-cut tendency of St. Simons period ceramics to be commingled with marine shell from later time periods. Many of the marine shell samples apparently associated with St. Simons and early Refuge-Deptford period ceramics actually produce much later ^{14}C age estimates. This systematic error seems to reflect the general lack of shell deposits dating to the time span 1350 cal B.C.–200 cal B.C. (despite the presence of fiber-tempered and Refuge-Deptford period ceramics). The presence of Woodland period molluscs associated with Late Archaic ceramics creates obvious interpretive difficulties and biases when assessing matters of site seasonality.

We now believe that similar biases could have been introduced in our analysis of growth increments in hard clams. Earlier in this chapter, we reiterated the randomized procedures used to select specific *Mercenaria* for analysis. By deliberately attempting to assure "a relatively uniform distribution of hard-shell clams" (O'Brien and Thomas, 2008: 490), we likely "averaged out" some of the seasonal variability we were seeking. That is, we probably introduced some bias, as we did when selecting only "top and bottom" samples for ^{14}C dating biased the macrochronological profiles resulting from radiometric dating. We think the sample selection process for *Mercenaria* probably skewed some of the resulting seasonal estimates for certain sites.

In subsequent fieldwork, we have emphasized the importance of defining microstratigraphic units for both radiometric and seasonality sampling, attempting to process multiple samples throughout these small-scale units (encountered in both large-scale excavations and column samples). In this way, we hope to avoid the problem of "averaging out" the variability we are seeking.

Correlative problems arise with modern techniques of isotopic analysis. As the results in seasonality studies become increasingly sophisticated and fine grained, we run the risk of "learning more and more about less and less." As the precision increases, sample sizes become progressively smaller, raising the risk, again, that we are seriously underestimating the seasonal variability we are seeking. Ideally, the fine-grained, small-sample methods of isotopic analysis can be balanced against the larger-scale (if less precise) methods of growth increment documentation. Thompson and Andrus (2010) provide an excellent example of this procedure in practice, and we believe that their research provides a model for increasing precision while simultaneously addressing the need for maintaining large sample sizes.

Potential Problems with Proxy Populations

Modern control samples are critical as proxy populations for calibrating estimates of seasonal harvest in the remote past. The control sample of *Mercenaria* collected in the waters surrounding St. Catherines Island has some obvious strengths and weaknesses (O'Brien and Thomas, 2008: 481). Because the *Mercenaria* were collected over a nine-year interval, we hoped that this "longitudinal aspect" would help buffer the skewing effects of unique seasonal events, such as phases of exceptionally cold or warm temperatures, spawning, or storms. Because the control sample was collected in conjunction with ongoing archaeological fieldwork, the collection was particularly strong for the late winter and spring months; but our sampling strategy was sporadic and somewhat seasonally biased, especially during the summer months, when our archaeological field crew was generally deployed elsewhere for fieldwork, and also during the middle winter months, when we rarely excavated on St. Catherines Island. More recent studies (e.g., Quitmyer, Jones, and Andrus, 1997; Andrus and Crowe, 2008) have demonstrated the value of collecting larger, more systematic samples. Several chapters in this volume report on more recent research that has considerably improved the modern control sampling on St. Catherines Island.

Use of proxy population studies is also important when employing nonhuman vertebrate remains to reconstruct seasonality, on St. Catherines Island and elsewhere. Although noting that sharks and sea catfishes are expected to be relatively abundant during warm weather and are relatively rare in colder weather, Reitz (2008: 660–663) cautioned that "Vertebrates are not the best seasonal indicators … the absence of a seasonal marker can in no way be interpreted as evidence that the site was unoccupied at that time (Reitz and Wing, 1999: 259–261) … As with most research, negative evidence is not helpful." There are also biases in preservation that militate against the recovery of juvenile specimens.

When estimating postencounter return rates for fish species common to the Georgia coast (Thomas, 2008: 113–135), I relied heavily on fisheries studies (esp. Dahlberg, 1972, 1975), significantly augmented by ichthyofaunal surveys conducted for a dozen years (on a monthly basis) on St. Catherines Island under the direction of Bruce Saul, of Augusta State University (Saul, 2002, 2003, 2004). In *Native American Landscapes of St. Catherines Island,* I discussed the seasonal availability of hardhead (*Arius felis*) and gafftopsail (*Bagre marinus)* catfish, noting Saul's concern about the declining numbers between 2002 and 2004. Three years later, both catfish had virtually disappeared from the waters surrounding St. Catherines Island (Lambert, 2007; Bruce Saul, personal commun.). This surprising turn of events prompted Lambert (2007) to ask "where have they gone and why?" Perhaps this is a short-term natural cycle, or maybe a virus took out the population. Pollution is an obvious possibility, with some speculating that perhaps intake of heavy metals might be responsible.[13]

Whatever the cause, the mysterious disappearance of catfish near St. Catherines Island underscores the complex ecological dynamics involved in collecting control (proxy) samples for site seasonality studies. It is a mistake to assume that any single "modern collection" is an accurate proxy reflection of species biogeography or pattern of seasonal distribution. There are also issues, I believe, that must be addressed with respect to all aspects of control/proxy collections.

Consider, for example, the problems of changing hydrological regimes and their impact on levels of seawater salinity. Based on soil distributions and the dendritic pattern of relic groundwater outflows that once drained St. Catherines Island, Hayes and Thomas (2008) reconstructed a large freshwater lagoon they believe once dominated the central reaches of the island (see also Bishop et al., 2007: 40, fig. 6). During the aboriginal period, freshwater was always abundant on St. Catherines, available in numerous places, except during periods of extreme drought. The extensive central depression was powered by the Floridan aquifer, one of America's most productive groundwater reservoirs, which extends from South Carolina to Florida and reaches inland as far as Alabama. The deep confined aquifer discharged artesian water to the ground's surface in many places, and elsewhere, a relatively shallow well could tap the surficial reservoir of nonartesian water.

This was the hydrological regime available to the first St. Catherines islanders. Discharge from this system remained in approximate equilibrium so long as the upper Floridan aquifer was recharged by rainfall in the interior of the coastal plain, where it lay near the ground surface. These artesian conditions created natural seeps, with water flowing to the surface in springs and seeping into rivers, ponds, wetlands, and other surface-water bodies throughout most of coastal Georgia. But over the past century, groundwater pumping has significantly lowered the water level in the upper Floridan aquifer throughout the entire coastal area.

Recent research at colonial Jamestown (VA) highlights the potential of studying estuarine drought conditions by coupling fine-grained archaeological and paleoclimatic investigation (Harding et al., 2010). By comparing bivalve geochemistry (particularly oxygen isotope data) between modern oysters to those discarded in early 17th century wells, these investigators have successfully quantified estuarine salinity, seasonality of oyster collection, and annual shifts in drought conditions in the Chesapeake Bay ecosystem.

It is difficult for the modern observer to appreciate the magnitude of the hydrological change over this past century. But by looking closely at the historical sources and tracing out the surviving geomorphological evidence, we believe it is possible to reconstruct what St. Catherines Island looked like before the deep drilling so significantly changed the hydrology.

We think that shifting hydrologies over the past century have significantly impacted the American (or eastern) oyster, *Crassostrea virginica*, still found in abundance within intertidal estuaries, along saltwater rivers and tidal creeks that dissect the expansive *Spartina* marsh. Within a given locality, oyster growth depends on bottom conditions, degree of salinity, water temperature, and tidal movement. A century ago, coastal Georgia was among the world's leading oyster harvesters, rivaling the celebrated, oyster-rich waters of the Chesapeake (e.g., Irving, 1902; see also Thomas, 2008: chap. 7): By the 1880s, overharvesting and pollution threatened Georgia's shellfishery. The headwaters of these oyster-bearing rivers were also once fed by freshwater aquifers, which dried up due to the lowering of water tables over the past century. Walker and Cotton (2001) suggest that this loss of freshwater headwater could account for gradual movement of oysters away from places like the Duplin River (off St. Simons Island) over time.

Cannarozzi and Quitmyer (2007) have discussed the monthly collection of oysters from St. Catherines Island, continuing since 2006. As these modern control samples are amassed for isotopic study, one must wonder about whether shifting hydrological and salinity patterns could have impacted the biochemical processes in modern oysters. There is also the possibility that ongoing global climate change—especially with respect to sea level and water temperature—could impact modern oyster growth patterning.

One potential avenue of inquiry into molluscan proxy populations might be available through the study of century-old bivalves. In *Native American Landscapes of St. Catherines Island* (Thomas, 2008: chap. 13), we discussed the issues surrounding reservoir correction calculations, and the necessity of obtaining known-age, prebomb mollusc samples for ^{14}C dating. We knew that a commercial oyster industry had once flourished in the waters surrounding St. Catherines Island (Thomas, 2008: chap. 6). In the late 19th century, Augustus Oemler erected an oyster factory on the south end of St. Catherines Island. Oysters, collected by hand from nearby creeks and marshes, were prepared in a large boiler connected to the southern end of the island by a causeway. Two additional boilers were added later. The apparently inexhaustible supply of oysters disappeared during the 1920s, forcing the once flourishing oyster factories of St. Catherines Island to close. Today, the rusting boilers and massive spoil heaps of oyster shell remain visible evidence of this industry. Since virtually all of the shells within these factory middens derived from *Crassostrea* individuals harvested between about 1900 and 1920, we collected numerous samples and used them in the reservoir correction computations for St. Catherines Island.

We think that a similar approach might be useful in considering the effects of hydrological change and shifting salinity over the past century. Not only could we collect oysters that lived under the previous (artesian) hydrological regimen, but we have recently discovered that occasional *Mercenaria* were also (accidentally) harvested at the oyster factories, providing another potential source of samples to explore this issue. For St. Catherines Island (and the rest of the Georgia coastline), we have detailed salinity measurements taken between October 1888 and February 1889 (Drake, 1891). We think a comparison of modern and century-old salinity levels and mollusc proxy samples could help determine the nature of recent hydrological and salinity shifts over the past century. It might be that the century-old molluscs provide more accurate "modern controls" than proxy specimens collected in the past few years (see Thomas, n.d., for more recent data on this issue).

We pose these two case studies to suggest some potential new refinements in site seasonality studies. For decades, reconstructing site seasonality has been the warp and the weft of St. Catherines Island archaeology. So far, so good (I believe). But we must do much better ... and that's what the Fifth Caldwell Conference is all about.

NOTES

1. I gratefully acknowledge the assistance of Lorann Pendleton Thomas, Chelsea Graham, and Diana Rosenthal in preparing this manuscript.

2. In 1562 and 1564, the French established two colonial forts (Charlesfort and Fort Caroline) at opposite ends of the central Georgia Bight. Each fort was occupied for about a year, and the subsequent Spanish towns of St. Augustine and especially Santa Elena—in roughly the same territory—continued an even more significant contact with local Indian populations after 1565. Following a brief period of Jesuit mission activity (in 1569–1570), the Franciscans launched a more concerted effort in 1574–1575. But Mocamo was not truly missionized until 1587, and the major Guale missions were established in 1595–1605 (Jones, 1978; Worth, 1998, 2004, 2007).

3. The most important sources addressing the nature of Guale coastal adaptations include Swanton (1922, 1946), Sturtevant (1962), Larson (1969, 1978, 1980), Jones (1978), and Worth (2004, 2007); see also Bushnell (1990), Crook (1986), Jones (1873), Hann (1986a, 1986b), and Saunders (2000a, 2000b).

4. By this interpretation, the Guale dispersed still further in the springtime into nuclear family settlements spread throughout the oak forest, located near swidden plots of maize, beans, and squash. In Crook's "Annual Model" the Guale "resided in towns from the first part of July until the middle of September when they dispersed to gather nuts" (Crook 1986: 20), after which they once again dispersed, probably into a "matrilineage segment with four or five nuclear families forming the social core," several related families living together in dispersed settlements located throughout the oak forest, subsisting on acorns, hickory nuts, and communal deer hunts, with occasional aggregation for feasting (Crook, 1986: 21). Fall settlements were basically chiefly compounds "defined by towns composed of temporary and changing populations, as opposed to the seasonally stable population of the summer towns."

5. Whereas Fr. Rogel reported that the Guale dispersed seasonally to gather acorns, Jones (1978: 193) questioned whether it was necessary to abandon the "dispersed town" in order to harvest the mast. With respect to shellfish, Jones notes that whereas some important Guale towns lay beyond the oyster beds, "there is no documentary evidence that [the Guale] spent seasonal periods downstream or along the inland waterways to exploit the oysters." Citing Robert Sandford's 1666 account for the North Edisto River (South Carolina), Jones suggests that concentrations of oysters were sufficiently close to the maize fields "that the beds could be exploited without seasonal shifts in residence" (Jones, 1978: 193).

6. Specifically with regard to the island-wide survey sites, we also compared the existing ceramic and ^{14}C chronologies for St. Catherines Island (Thomas, 2008: chap. 15). A total of 189 radiocarbon dates had been processed on archaeological samples from St. Catherines Island, and 110 of these dates—from 31 distinct mortuary and midden sites—were directly associated with datable ceramic assem-

blages from the aboriginal phase. This diverse sample of ^{14}C dates, which spanned more than four millennia, provides a workable set of radiometric controls on the ceramic chronology currently available for St. Catherines Island. The results fine-tune, yet overwhelmingly, confirm the previous research on the ceramic chronology for Georgia's north coast, particularly the work of Joseph Caldwell, Antonio Waring, and Chester DePratter.

7. Some years ago, we reported the results of our excavations of several Refuge-Deptford-Wilmington burial mounds on St. Catherines Island (Thomas and Larsen, 1979). We analyzed 29 radiocarbon dates, nearly one-quarter of them processed on marine shell. Although aware of potential problems associated with radiocarbon dates on sea shells, we followed the lead of Joseph Caldwell, who had also worked on St. Catherines Island. Caldwell concluded that "radiocarbon determinations made from oyster shell do not appear to differ significantly from determinations made from charred wood" (Caldwell, 1971: 1). Today, we understand that this assumption was incorrect. A significant reservoir effect is operating here because, relative to the atmosphere, ocean water is depleted in ^{14}C, transmitting this deficiency to marine organisms. This means that ^{14}C determinations processed on marine samples will routinely appear to be older (in many cases, several centuries older) than ^{14}C dates run on contemporary terrestrial samples. We found it necessary to derive a unique reservoir correction for St. Catherines Island and the results of this fieldwork and analysis are reported in Thomas (2008: chap. 13; see also Thomas, Sanger, and Hayes, n.d.).

8. This apparent discrepancy arises because, in order to derive an accurate and reliable local reservoir correction, we processed a dozen radiocarbon dates on modern time prebomb samples.

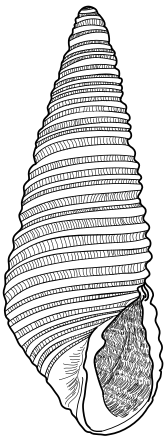
9. This study is reinforced by an oxygen isotope study of modern and ancient clams from St. Catherines Island (Andrus and Crowe, 2008).

10. "To repeat: The available archaeological evidence does not permit the conclusion that Irene populations were sedentary (although we certainly believe that such was the case). But sticking to the documented archaeological specifics, the data regarding site seasonality are conclusive: (1) single-season sites are extremely rare during Irene times (as they are rare throughout the entire aboriginal period on St. Catherines Island) and (2) three-quarters of the known Irene components on St. Catherines Island were occupied during three or more seasons" (Thomas, 2008: 1098).

11. "Patch types" reflect the way in which food resources were clumped or aggregated across the landscape (Thomas, 2008: 63). Specific "hunt types" are variously associated with one or more particular prey species, particular microhabitats ("patch type"), specialized methods of search or capture, specialized transport or foraging technology, and certain seasons or environmental conditions (Thomas, 2008: 71).

12. On occasion, as at Little Camel New Ground Field 5 (9Li206), we did employ 1⁄16 in. screens to sample the extremely dense concentration of fish bones encountered (Thomas, 2008: 519). But ¼ in. hardware was primarily used in the island-wide survey. We note, parenthetically, that Rochelle Marrinan made extensive use of fine-mesh screens in 1973–1975, while excavating two Late Archaic shell rings on St. Simons Island (Marrinan, 1975, 2010). In this respect, she was considerably ahead of her time.

13. In chapter 3 in this volume, E.J. Reitz, B. Saul, J.W. Moak, G.D. Carroll, and C.W. Lambert assess the value of the modern ichthyofaunal survey data as an archaeological proxy for St. Catherines Island.



CHAPTER 2
A BAYESIAN CHRONOLOGICAL FRAMEWORK FOR DETERMINING SITE SEASONALITY AND CONTEMPORANEITY

Douglas J. Kennett and Brendan J. Culleton

In the previous chapter, Thomas outlined a multiscalar approach for determining seasonal resource exploitation strategies and, by extension, for reconstructing mobility patterns in the past. On St. Catherines Island this involves: (1) ceramic typologies for establishing submillennial temporal resolution (the hour hand); (2) radiocarbon dating to control century-level resolution (the minute hand); and (3) site seasonality studies to provide seasonal or monthly resolution (the second hand). This hierarchy of chronological measures is essential when inferring mobility patterns from seasonality data from multiple sites. The crux of the matter is whether or not sites used during different or the same seasons are coeval. Chronology really does make a difference when interpreting seasonality data and inferences regarding prehistoric mobility patterns. If changes in mobility and resource extraction are detected, then finer grained chronological information is also required to determine if these changes were influenced by paleoenvironmental change and/or other mechanisms (e.g., population growth, resource intensification, or competition for resources).

In this chapter we argue that a Bayesian statistical environment provides a coherent framework for integrating these multiscalar chronological measures. The Bayesian analysis of radiocarbon dates from archaeological sites is now becoming routine in Britain (Bayliss and Bronk Ramsey, 2004; Buck, 2004; Bayliss et al., 2007) and programs like OxCal (Bronk Ramsey, 1995, 2001, 2005) provide a prepackaged set of Bayesian statistical tools to help develop more robust archaeological site chronologies. Custom-built Bayesian statistical environments to analyze and model spatiotemporal patterns in the archaeological record are also being developed including tools potentially useful for integrating the multiscalar chronological measures necessary for establishing site seasonality and inferring mobility patterns (Buck, 2004; Steele, 2010; Winterhalder et al., 2010). In this chapter we emphasize the development of a Bayesian chronological framework for interpreting seasonality data on St. Catherines Island. We begin with a basic overview of the approach.

BAYESIAN ESSENTIALS

Classical statistical analysis has dominated archaeological inquiry and is well suited to a wide range of observations made by archaeologists (Thomas, 1986; Shennan, 1997; Drennan, 2010). However, there are certain contexts where a Bayesian approach may be better suited and we argue that the types of data acquired in seasonality studies fall into this category. In contrast to classical statistics, Bayesian statistical analysis derives posterior information (a posteriori) by combining prior information (a priori), a likelihood function (a particular probability function), and the available data (Buck and Millard, 2004b: VII). The best examples in archaeology come from chronology building where a variety of nonquantitative contextual information (e.g., stratigraphic position, diagnostic artifact assemblages) can be integrated with probability distributions from radiocarbon dates (Bayliss and Bronk Ramsey, 2004; see below).

Emphasis is placed on chronological model building based on prior knowledge and the available radiocarbon dates followed by iterative data collection to make adjustments. The major benefits of this approach are that: (1) a statistical environment is created that incorporates a wider range of observations and knowledge (e.g., relative and absolute chronology), and (2) these models can be used to direct research and make sampling decisions. Using *a priori* information can make some researchers uneasy (see Steier and Rom, 2000), but if care and transparency are used it provides a framework to formalize assumptions and to build and test multiple models with new data. Shell middens are particularly complex (Stein, 1992), but agreement indices (*A*) provide a way of determining how each alternative model fits with the available data, and are generated for the posterior distributions of each radiocarbon date in a model, as well as the overall model itself (Bronk Ramsey, 2000: 201). Agreement indices falling below a critical value ($A'c$ = 60%) indicate a poor fit of data with the model, and can be used to identify potential outlier dates or problematic stratigraphic assumptions in the model. It should be noted that, strictly speaking, when $A > A'c$ (i.e., there is agreement between model and dates) it *does not* mean that the model assumptions and structure *are correct*. It simply tells us that we have no reason based on the data at hand to reject the model as it stands.

BUILDING SITE CHRONOLOGIES

The first step in developing a coherent picture of site seasonality is establishing a viable chronology and determining the contemporaneity of different sites. When combined with seasonality data this allows for the reconstruction of changing patterns of resource extraction at one location. Broader patterns of settlement and land use are often inferred from these data when combined with other regional datasets. The accurate reconstruction of mobility patterns at the regional level is dependent upon whether sites were used or occupied during the same interval. This highlights one of the first-order decisions necessary when building a Bayesian chronological model for seasonality studies: finding a meaningful definition of contemporaneity (Bayliss and Bronk Ramsey, 2004). On St Catherines Island this could be defined as the "Archaic period" or it could be taken to be the same century or even the same decade.

The hypothetical example in figure 2.1 demonstrates the importance of high-precision dating for interpreting seasonality data. The low-resolution site chronology displayed in the first panel (A) shows six "contemporary" sites dating to between A.D. 800 and 1000. The one larger village site shows evidence for hard clam (*Mercenaria*) exploitation and processing during all seasons along with evidence for a variety of other activities. The five other sites are more ephemeral shell middens showing hard clam harvesting and processing during different seasons. One interpretation of this would be year round occupation of the larger site with logistical exploitation of hard clams throughout the year by a certain segment of the larger social group (B). A finer grained chronology is shown in panels C and D, revealing an alternative model of higher residential mobility between A.D. 800 and 900 followed by greater sedentism at one locality between A.D. 900 and 1000. The combination of high-resolution chronological and seasonality data has a major impact on the socioeconomic and evolutionary inferences made from these data.

Establishing precise chronologies is no simple matter and is done best within a Bayesian statistical framework. English Heritage has used the approach since the mid-1990s as a cost effective way of building site chronologies (Bayliss and Bronk Ramsey, 2004). The computer program OxCal provides a preexisting Bayesian environment to build and refine chronologies. Model building and testing is completed in an interactive fashion with new data informing and refining chronological models for individual sites. Precise dating is dependent upon: (1) careful stratigraphic excavation and the exact recording of ^{14}C samples within the depositional sequence, (2) the selection of short-lived organisms for AMS radiocarbon dating (e.g., carbonized seeds, twigs, marine shells, or animal bones), (3) proper chemical protocols for processing samples, and (4) an understanding of taphonomic processes affecting potential radiocarbon samples. Outdated radiocarbon dates with high error ranges from previous excavations may be used as an initial guide for model development along with stratigraphic information. They may contribute to the final chronological model, but they could also be eliminated as outliers. This is largely dependent upon the research question being asked. When high precision is required, as is the case with seasonality studies, it is often necessary to start over with a clear idea of site stratigraphy, sample types and locations, and the low analytical error afforded by adaptations to the latest generation of Accelerator Mass Spectrometers (Beverly et al., 2010). Even with the best technological and procedural protocols in place, chronological control is ultimately constrained by the vagaries of the calibration curve, which afford different levels of precision throughout time depending upon atmospheric radiocarbon production and ocean circulation (see e.g., Blackwell, Buck, and Reimer, 2006).

TRIMMING CONFIDENCE INTERVALS

We start with a simple advantage afforded by Bayesian analysis: the trimming of calibrated ^{14}C radiocarbon confidence intervals using the stratigraphic position of samples. This is based on the simple combination of relative and absolute chronological information. The variety of factors influencing measurement errors in radiocarbon dating and fluctuations in the calibration curve can result in substantial

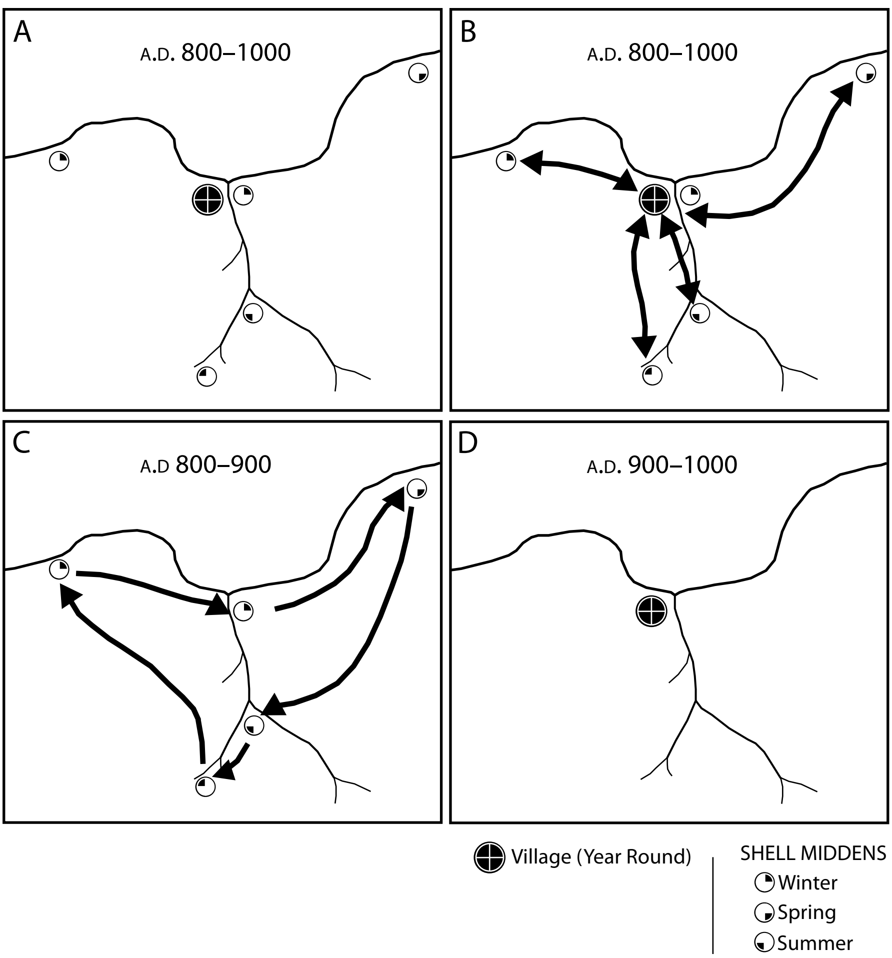


Fig. 2.1. Hypothetical seasonality and settlement data (**A**) along with differing interpretations of these data based on low (**B**) and high (**C** and **D**) resolution chronologies for these sites.

overlap of calibrated distributions even if two events are known not to be contemporary based on the stratigraphic record. Take, for example, two radiocarbon dates on charred hickory nuts from the McQueen Shell Ring on St. Catherines Island, table 2.1: one near the base of the shell midden deposit (Beta-251767; 3680 ± 40 B.P., N243E233; 40 cmbs) and the other closer to the top (Beta-251761, 3710 ± 40 B.P., N243E233; 10 cmbs) (Sanger and Thomas, 2010). The calibrated 2σ probability distributions for these two dates broadly overlap (outlined probability distribution in fig. 2.2), but from the law of superposition we can argue that the lowest part of the sequence accumulated first, followed by the upper materials. This stratigraphic information can be used to create *a posteriori* distributions for these same dates (filled probability distributions) that assume that the hickory nut at 40 cmbs *must* be older than the one at 10 cmbs. The model fit with the data satisfies the threshold for acceptance (A = 99.9%, $A'c$ = 60%). In other words this model is viable and indicates that this part of the deposit accumulated rapidly between 2100 and 2000 cal B.C.

Probability distributions of marine shell dates from the same deposit show a similar story (see table 2.1). The upper two dates are associated with the radiocarbon dates on charred hickory nuts and the third date is stratigraphically below the lowest of the two. The calibrated probability distributions of these dates also overlap in figure 2.3. Applying the same stratigraphic assumptions as above, the calibrated probability distributions are trimmed and the dates fall into an acceptable stratigraphic order between 2100 and 1900 cal B.C. (A = 83.8%). The smoother probability distributions and larger calibrated ranges for marine shell, relative to associated carbonized seeds, result from the mixing model used to derive the Marine09 calibration curve from the IntCal09 atmospheric curve (which, for most of the Holocene, are identical to the 2004 versions), and propagation of uncertainty in the ΔR estimate (following Stuiver, Pearson, and Braziunas, 1986).

Considering the same three dates in two additional contexts can show the importance of reasoned stratigraphic interpretation for forming the priors in Bayesian chronological modeling. First, let's say that we had reason to infer that the entire deposit was laid down in one event, or for practical purposes within a single year or a few years. In that case we would assume that all the shells should be the same age, and scatter in conventional ^{14}C ages arises from simple measurement error. These dates could then be *combined* following the procedure of Ward and Wilson (1978), with a resulting averaged age of 3860 ± 25 B.P. A chi-squared test indicates that

TABLE 2.1
Radiocarbon Dates from McQueen Shell Ring, N243E233

Beta no.	Provenience[1]	Material	Conventional ^{14}C age	2σ cal age	2σ cal age as sequence	2σ cal age as phase
251761	4.5–4.4 m	charred hickory nut	3710 ± 40	2280–1970 B.C.	2150–1960 B.C.	
251767	4.4–4.3 m	charred hickory nut	3680 ± 40	2200–1940 B.C.	2210–2030 B.C.	
251762	4.5–4.4 m	*Mercenaria* shell	3820 ± 50	2180–1850 B.C.	2100–1820 B.C.	2150–1880 B.C.
251768	4.4–4.3 m	*Mercenaria* shell	3910 ± 40	2280–1960 B.C.	2150–1940 B.C.	2220–1940 B.C.
251769	4.3–4.2 m	*Mercenaria* shell	3830 ± 40	2160–1870 B.C.	2210–1980 B.C.	2150–1900 B.C.

[1]Note that elevations are *above* an arbitrary 0 m datum.

there are no outliers in this group of dates (χ^2 = 2.757; df = 2; T' = 5.991) and we can infer that the shells were deposited sometime between 2180 and 1930 cal B.C. (at 2σ). Alternatively, if the stratigraphic relationships among the three dates were unclear in the field, the dates could be modeled as a *phase* rather than a *sequence*, with *boundaries* placed as estimates of two undated events: the start and end of shell deposition. Modeling as a *phase* might be more appropriate for dates within a stratum that appears to be distinct and in order within the larger stratigraphic sequence, but could have been mixed before being buried. Another application would be dates from multiple discrete shell lenses or hearths deposited on a common living surface, where the depositional order among them cannot be discerned from the stratigraphy. If the three shell dates are modeled as an unordered *phase*, we find that the stratum was deposited over a *span* potentially as long as 800 years, from ca. 2600 to 1550 cal B.C. (*A* = 105.9%). All that differs between these three scenarios are the prior assumptions that are used to model the three shell dates: the first assumes an ordered stratigraphic *sequence*; the second assumes a single deposition event; the third assumes an unordered group of dates, or a *phase*. That the resulting chronological data can differ so greatly based on a simple assumption drives home the fact that proper stratigraphic interpretation in the field is of primary importance. The agreement indices provide no guidance in these scenarios as to which assumptions are more reasonable (nor does Ward and Wilson's χ^2 test), so it rests upon the fundamental archaeological skill of interpreting stratigraphy and site-formation processes.

TOWARD BUILDING A BAYESIAN MODEL FOR THE McQUEEN SHELL RING

Funding is often limited for archaeological projects and precision AMS radiocarbon dating is expensive. How precise a chronology needs to be is directly related to the research question at hand and for site seasonality, high precision is generally required if the ultimate goal is to reconstruct mobility patterns. Seasonality studies themselves are also time consuming and expensive. It makes sense to establish a precise site chronology prior to conducting seasonality work in order to define the relevant sampling units and to avoid oversampling a particular interval at the expense of other units that may be more interesting or significant chronologically.

Figure 2.4 shows the north wall profile of a unit excavated on the eastern side of the McQueen Shell Ring (N243E233). The sequence is between 40 and 50 cm deep in this area and dominated by a dense deposit of shell (~30 cm thick) overlying a medium brown sand containing no shell and a thinner deposit of shell and bone (labeled clam "floor"). The samples discussed above come from the thicker shell deposit and their stratigraphic position is shown along with our first attempt at building a chronological model for this part of the site. In this model the dates are ordered in a sequence and the start and end dates for the sequence are modeled from the available data. Marine shell samples are available for dating from the shell deposit and the clam "floor" and ongoing work will determine if charred seeds or twigs will also be available for study. In certain contexts ^{14}C dating marine shell is preferable to other materials and it is often the only material available from certain stratigraphic contexts (Kennett et al., 2002; Thomas, 2008). It is also short-lived and material deposited during a single year or season can be sampled (but see Culleton et al., 2006, for complicating factors in areas with high upwelling).

This Bayesian chronological framework provides a guide for future work. One or two dates are needed to determine the age of the clam "floor" and they will help constrain the age of the intervening sterile medium brown sand lens (along with the shell date just above it [Beta-251769]). An additional date from the uppermost layers in the shell deposit will help constrain the terminal age of the deposits in this part of the site. Dating a marine shell may be preferable in this instance due to the contamination of surface deposits with modern carbonized plant material (see discussion of precision below). The presence of pitting in other parts of the site suggests horizontal stratigraphy that should also be explored with additional dates. The decision to add more data to the modeled chronology is based on the ability of new data to refine the model. The method calls for continued AMS radiocarbon dating of quality materials from known stratigraphic units until the model can no longer be improved. In reality, there is often a trade off between model quality (precision and accuracy), available funds, and time to publication.

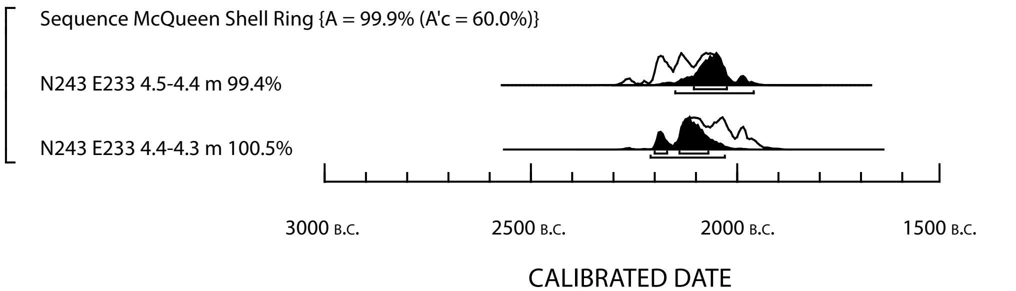


Fig. 2.2. Calibrated results of a *sequence* of two ^{14}C dates on hickory nuts from McQueen Shell Ring using OxCal 3.01. Standard calibration is shown in open outline (prior distribution); modeled calibration incorporating stratigraphic information (posterior distribution) is depicted as a solid fill. The *agreement index* (A = 99.9%) above the critical value ($A'c$ = 60.0%) indicates good agreement between the data and the model.

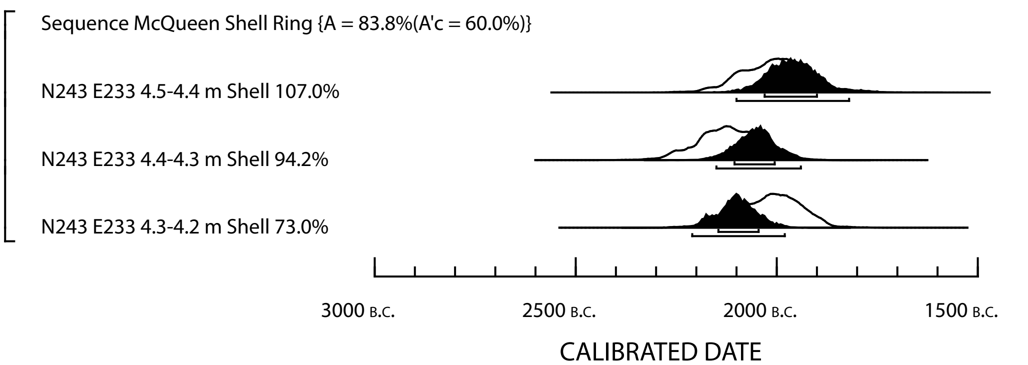


Fig. 2.3. Calibrated results of a *sequence* of three ^{14}C dates on *Mercenaria* shells from McQueen Shell Ring using OxCal 3.01. Standard calibration is shown in open outline (prior distribution) and modeled calibration incorporating stratigraphic information (posterior distribution) is depicted as a solid fill. The *agreement index* (A = 83.8%) higher than the critical value ($A'c$ = 60.0%) indicates good agreement between the data and the model.

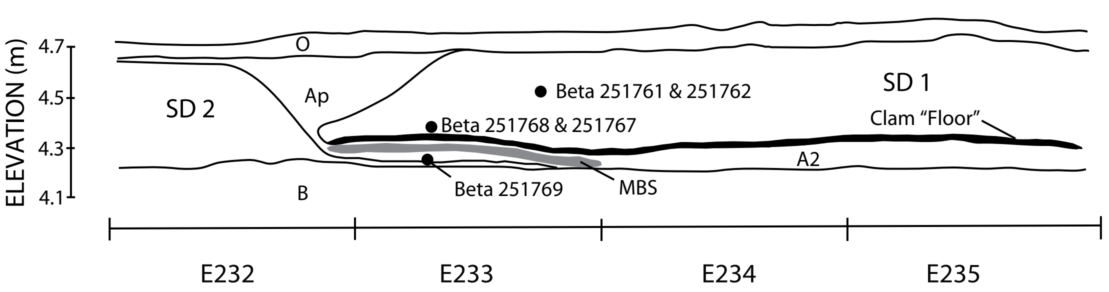


Fig. 2.4. Profile of the N243 trench north wall, McQueen Shell Ring (AMNH 696, 9Li1648), showing the depositional sequence discussed in the text (courtesy of Matt Sanger). **O** high organic, dark brown sand; **Ap** plowed A, dark brown sand, shell flecking; **A2** buried A, dark brown, no shell; **B** medium yellow brown, no shell; **MBS** medium brown sand; **SD** shell deposit.

A NOTE ON PRECISION ^{14}C AND SEASONALITY STUDIES

The larger age ranges evident in the marine shells from the McQueen Shell Ring point to the importance of precision and accuracy in building site chronologies. Radiocarbon dates with large analytical error reflect poor precision, but also undermine accuracy by increasing the range of actual calendar ages that could produce the measured age. This compromises our ability to determine if two sites with seasonality data are contemporary or not. One crucial way in which this occurs can be illustrated with the Ward and Wilson test described earlier, which is essentially a test of contemporaneity between conventional ^{14}C ages. Taking two McQueen shell dates, Beta-251769, 3830 ± 40 B.P., and Beta-251768, 3910 ± 40 B.P., the χ^2 test does not reject the sample as containing outliers, so they may be contemporary ($\chi^2 = 2.000$; df = 1; T' = 3.841). However, if the same dates had better precision, say ± 20 ^{14}C yr, the same two dates are strongly rejected as unlikely to be contemporary ($\chi^2 = 8.000$; df = 1; T' = 3.841). Put simply, low-precision dates are more likely to appear contemporaneous, even with a generally robust statistical test, than high-precision dates. Although Stuiver, Pearson, and Braziunas (1986) have argued that the relative smoothness of marine calibration curves (caused by propagating multiple layers of statistical uncertainty) reduces "wiggles" and the frequency of multiple intercepts, it is at the cost of wider calibrated ranges that make it more difficult to distinguish true contemporaneity. Analytical precision can be improved with modifications to the latest generation of Accelerator Mass Spectrometers (Beverly et al., 2010). Samples in the age range of the McQueen Shell Ring could be reduced to ± 15 and 20 ^{14}C years with this approach (Kennett et al., 2011). However, the precision and accuracy of marine samples will always be lower than paired terrestrial samples because of the mixing models and the ΔR estimates used in the calibration process.

Bayesian statistical tools may provide one possible way of improving the precision and accuracy of marine shell dates to make them more comparable to terrestrial samples. The approach would rely on the visible and predictable incremental changes in hard clam (*M. mercenaria*) shells and the "wiggles" in the marine calibration curve. Visible incremental change in the growth of hard clams has already provided an important source of seasonality data on St. Catherines Island (O'Brien and Thomas, 2008). The benefits of working with hard clam shells include their ubiquity in island archaeological deposits of all ages, the resistance of their thick shells to decomposition, and a clear growth structure that responds to water temperature and associated changes in the marine system in predictable ways. These same characteristics provide an opportunity for precision AMS ^{14}C dating and therefore a link between the centennial resolution of radiocarbon dating and the seasonal or monthly data provided by seasonality studies.

If greater precision and accuracy are required to establish a chronological model for an archaeological site, then additional AMS ^{14}C dates within the same hard shell can be combined with the counting of annual growth increments to obtain a more precise age. The known chronological separation between samples based on ring counting is incorporated into OxCal and a *defined sequence* is used to "wiggle match" the radiocarbon ages to the calibration curve to improve precision and accuracy (Bronk Ramsey, van der Plicht, and Weninger, 2001). This approach has been used to obtain a very precise and accurate age on a prehistorically constructed subcircular ring of oak timbers discovered in the intertidal zone in Norfolk, England (Bayliss et al., 1999). In the Norfolk case, six contiguous samples of 20 years' growth were precisely dated and a Bayesian model incorporating these dates and the known gaps between them was used to establish the date of construction at 2050 cal B.C.

In the case of hard clams on St. Catherines Island, the time elapsed between radiocarbon samples in a single hard clam shell can be determined with annual growth increments. Modern specimens from protected areas along the southeastern coast are known to live up to 30 years (Ansell, 1968; Quitmyer and Jones, chap. 7, this volume), but the maximum age of individuals from prehistoric contexts on St. Catherines is about 10 years with most in the 3–4 year range (see fig. 7.9 in Quitmyer and Jones, this volume). This increment just satisfies the minimum required to match the resolution of the calibration curve (3–4 years; Bronk Ramsey, van der Plicht, and Weninger, 2001: 388). Hard clam shells are composed of alternating white (opaque under tungsten light) and dark (translucent under tungsten light) bands that represent sequential annual cycles. Growth rates are faster in winter and spring (white growth) and slower during the summer months (dark growth). Water temperature and associated biotic shifts appear to influence growth rates (Henry and Cerrato, 2007; Jones, Arthur, and Allard, 1989; Jones and Quitmyer, 1996; Quitmyer and Jones, chap. 7, this volume, Cannon, and Jones, 1985; Quitmyer, Jones, and Arnold, 1997) and this has been confirmed with stable isotopic studies (Andrus and Crowe, 2008; Quitmyer and Jones, chap. 7, this volume). The growth rings are clearly visible and can be counted to determine a clam's age at the time of harvest. A couplet of one opaque and one translucent increment represents one year of life.

Figure 2.5 shows a cross section of a fictitious hard clam shell displaying incremental growth. This clam was 10 years old when it was harvested during the winter (O1, white [opaque], December through January). From the perspective of seasonality, we are interested in establishing a precise age for this and associated hard clam shells. AMS ^{14}C dating the carbonate near the terminal growth margin of the shell (sample A) will accomplish this, assuming that the marine reservoir does not fluctuate radically throughout the annual cycle as it does in other parts of the world (Kennett et al., 1997; Culleton et al., 2006). This assumption needs to be empirically tested, but it seems a reasonable working hypothesis since marine upwelling (a source of old carbon) along the coast of St. Catherines appears to be minimal given the bathymetry, and the negative local reservoir offset ($\Delta R = -134 \pm 26$ ^{14}C yr) indicates better than average mixing of atmospheric carbon compared to the global marine model age. We use a fictitious set of dates here based on the marine shell dates from the McQueen Shell Ring discussed above. The calibrated age of the terminal growth margin ranges between 2090 and 1960 cal B.C. (130 yrs at 1σ, shown as outline in fig. 2.5). Adding two additional dates (B and C) 5 and 10 years earlier in the growth of the clam creates a sequence of dates that can be used to wiggle match with the marine calibration curve to get a more precise age. In OxCal this is accomplished by creating a *defined sequence* with an established set of known age gaps based on counted growth increments (Bronk Ramsey, 2001: 383). The posterior or modeled age distribution for the terminal growth margin, based on wiggle matching, is reduced to 1980–1910 cal B.C. (70 yrs at 1σ, shown as a solid distribution in fig. 2.5). This is comparable in age to a carbonized seed of the same age and calibrated with the atmospheric calibration curve.

Running multiple AMS ^{14}C dates on the same clam shell is costly and this would only be warranted if associated carbonized twigs or seeds were not available. However, marine shells are short lived, so dating the shells would be preferable to ^{14}C dating wood charcoal or bulk sediments (see Sanger and Thomas, 2010, regarding problems with ^{14}C dating bulk sediments). Depending upon the age of the shell, and the character of the marine calibration curve at that time, a substantial improvement may be obtained with just one additional measurement. In the case of wiggle matching, more wiggly parts of the curve are actually more of a boon than a bane because they constrain the match more tightly. To evaluate the potential for wiggle matching, terminal growth margins should be ^{14}C dated first and then a *defined sequence* may be modeled with OxCal using that date plus a number of *simulated dates* at specified *gaps* to determine if (or how many) additional dates from the shell would be worthwhile (the above example was created in this way). The specific advantage of working with hard clams is that this provides a close linkage between the subcentennial scale precision of AMS ^{14}C dating and the seasonal data provided by hard clam growth increment studies.

CONTEMPORANEITY AND ARCHAIC PERIOD SHELL RINGS

Most applications of Bayesian models for chronology building have focused on single locations where the relationship between samples is known and stratigraphic context is built into the model. The ultimate goal of most seasonality studies is to reconstruct prehistoric mobility across a landscape. This is dependent upon determining whether two archaeological sites are contemporary or not. More sophisticated models that add this spatial component are now being developed (Buck, 2004; Winterhalder et al., 2010), but these types of studies are in their infancy and require custom-built Bayesian statistical environments not available in prepackaged programs (e.g., OxCal).

As a starting point for work on St. Catherines, we investigate the contemporaneity of the McQueen and St. Catherines shell rings within a Bayesian statistical framework. Shell rings are relatively common in the American southeast and are often the oldest sites found in coastal regions (Russo, 2006). They generally date to the Late Archaic period (4000 to 1000 cal B.C.). Two of these shell rings have been identified on St. Catherines Island: the St. Catherines and McQueen shell rings. The St. Catherines Shell Ring is positioned on the west coast of the island and has been excavated extensively. A series of ^{14}C dates are available for study (Thomas, 2008: 370). The McQueen Shell Ring is located on the east coast of the island and is currently being excavated, but preliminary results are now available for comparison (Sanger and Thomas, 2010: 62–63). A comparison of ^{14}C summed probability profiles from these two sites suggests that both were occupied from ca. 2600 to 1800 cal B.C. However, the material culture differs substantially at these sites, particularly in the types of ceramic decorations identified and the relative proportions of groundstone and decorative items found at each site (Sanger and Thomas, 2010: 67). If the two sites are contemporary and seasonality studies demonstrate year-round occupation, then this observation has interesting social and political implications.

Summed probability distributions are useful heuristic devices and can be helpful in focusing research questions, though their statistical meaning actually remains poorly understood. We have no metric to evaluate how much overlap in two summed distributions constitutes contemporaneity or temporal disjunction. In the present case, it suggests the potential for simultaneous occupation of the two shell rings over a broad period, which runs counter to the observation of different material culture assemblages at each site that could suggest two temporally distinct occupations. With a Bayesian model, we can take the prior knowledge of the differing assemblages as a basis for arguing that one shell ring precedes the other, and there is no overlap in the occupations. At a first pass, we simply model the cul-

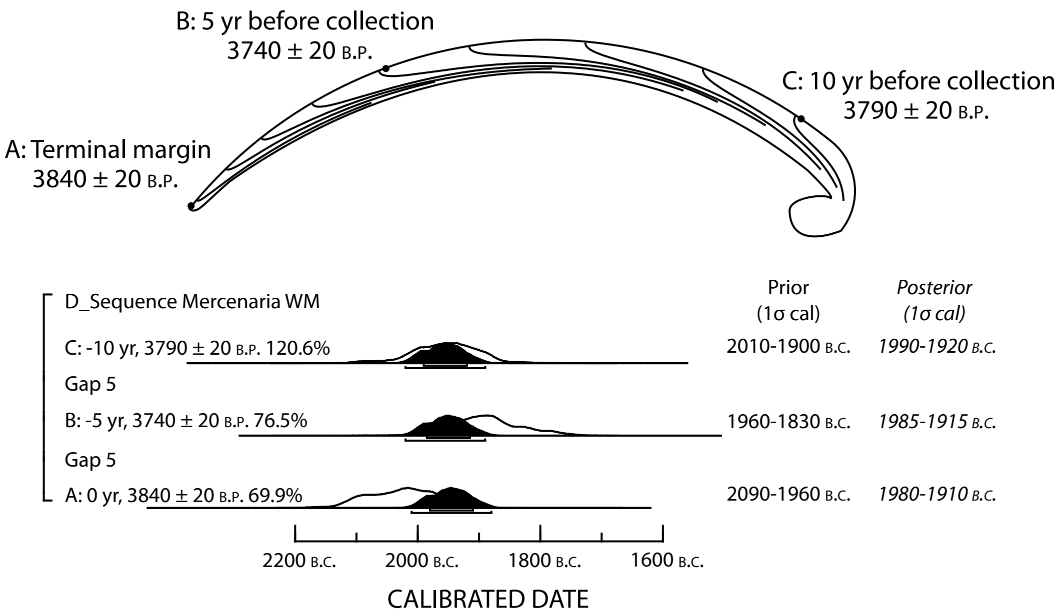


Fig. 2.5. Schematic cross section of a hypothetical *Mercenaria* valve showing annual growth increments and three ^{14}C dates used in a *defined sequence* to wiggle match the terminal date (A). Results of the wiggle match, performed with OxCal 3.01, are depicted below. Standard calibrations are shown in open outline (prior distribution) and modeled calibrations incorporating known five-year *gaps* in the *defined sequence* (posterior distribution) are depicted as a solid fill.

turally relevant and reliable ^{14}C dates from St. Catherines and McQueen as two *phases* (groups of unordered dates) within a *sequence* that forces the St. Catherines phase to precede the McQueen phase. The advantage to this approach is that an agreement index (*A*) is calculated that gives a measure of model fit, and provides a statistical basis for accepting or rejecting the model and its assumptions. Perhaps unsurprisingly, this model thoroughly fails to accommodate the data (A = 22.6%; $A'c$ = 60.0%), which means we must reject the assumption of sequential and discrete occupations of each shell ring. While this may seem a minor insight in light of the overlap observed in the summed probabilities, it may also suggest that the differing cultural assemblages in each shell ring may not be as temporally diagnostic as thought, or that their associations with the dated materials could be reconsidered.

Further steps in refining this analysis depend on more detailed stratigraphic models for St. Catherines and McQueen shell rings. For St. Catherines the ^{14}C dates that are acceptable (based on the excavators' knowledge of the deposits) can be grouped into three categories: Pre-Ring; Ring; and Interior Plaza. The first two groups have an intuitive temporal relationship implied in their names, and the third represents a more temporally ambiguous group, where the spatial association with the rest of the shell ring doesn't allow a firm stratigraphic argument to be made with respect to the other two groups of dates. Leaving the Interior Plaza aside for the moment, we can treat the Pre-Ring and Ring dates as *phases* in a sequence, similar to our treatment of St. Catherines vs. McQueen shell rings above. In this case, the assumed order is based on stratigraphic relationships rather than diagnostic artifact assemblages, but the model structure is similar. *Boundaries* are modeled representing the beginning of Pre-Ring deposition, the transition from Pre-Ring to Ring deposition (i.e., the initial construction of the St. Catherines Shell Ring), and the end of Ring deposition. The Interior Plaza dates can be grouped into a separate phase independent of the other two, with boundaries for its beginning and end. The results of these models are depicted in figure 2.6 and from the agreement index of A = 84.6% we can see that the assumption of all the Pre-Ring dates preceding the Ring dates appears to be a reasonable one, based on the data at hand. The boundaries, which are estimates of additional undated events, also provide interesting information. The start of Pre-Ring phase cultural deposition is placed at 3100–2450 cal B.C., the beginning of Ring phase deposition at 2430–2200 cal B.C., and the end of Ring phase deposition is at 2210–1780 cal B.C. The Interior Plaza phase overlaps considerably with both the Pre-Ring and Ring phases, being estimated to start between 2980 and 2500 cal B.C. and to end between 2400 and 1800 cal B.C. This result accords with descriptions of the Interior Plaza deposits as appearing to be more mixed, and potentially being a locus for deposition through both phases of site use.

The depositional sequence of the McQueen Shell Ring is in some ways more complicated. Focusing on a series of dates from three excavation units (TPII, N243E233, and N272E200), we can build a nested model of sequences and phases for the shell ring. The overall period of deposition is considered a *phase*, which includes an unordered group of three *sequences* comprising the dates in each unit. We do this because we are making no assumptions about the stratigraphic relationships between units, only within units. Within two of the unit sequences we have pairs of shell and charcoal dates in a few levels; these pairs are treated as *phases* within the unit *sequence*s, again because they are unordered with respect to each other, though they both should postdate those below and predate those above. This is a somewhat involved model for a relatively small number of dates, but its structure actually reflects a fairly conservative set of stratigraphic assumptions, all of which are open to evaluation. Figure 2.7 shows the modeled results, and we are immediately alerted by a poor agreement index (A = 17.8%) for the overall model. Phase models are more accommodating than sequences, so we would expect the problems to lie in one of the three unit sequences, and from the individual agreement indices it's clear that the upper and lower dates in TPII (A = 7.2% and 10.9%, respectively) are problematic. The dates in this unit appear to be completely reversed, and our assumed depositional sequence appears to be incorrect. This information could direct the excavators to reevaluate the context from which the dated shells were taken, sample selection criteria, or even to recheck the sample labels or artifact inventories. For the time being, however, we can revise the model by removing these three dates and see if it behaves differently.

Without the dates from TPII, the agreement

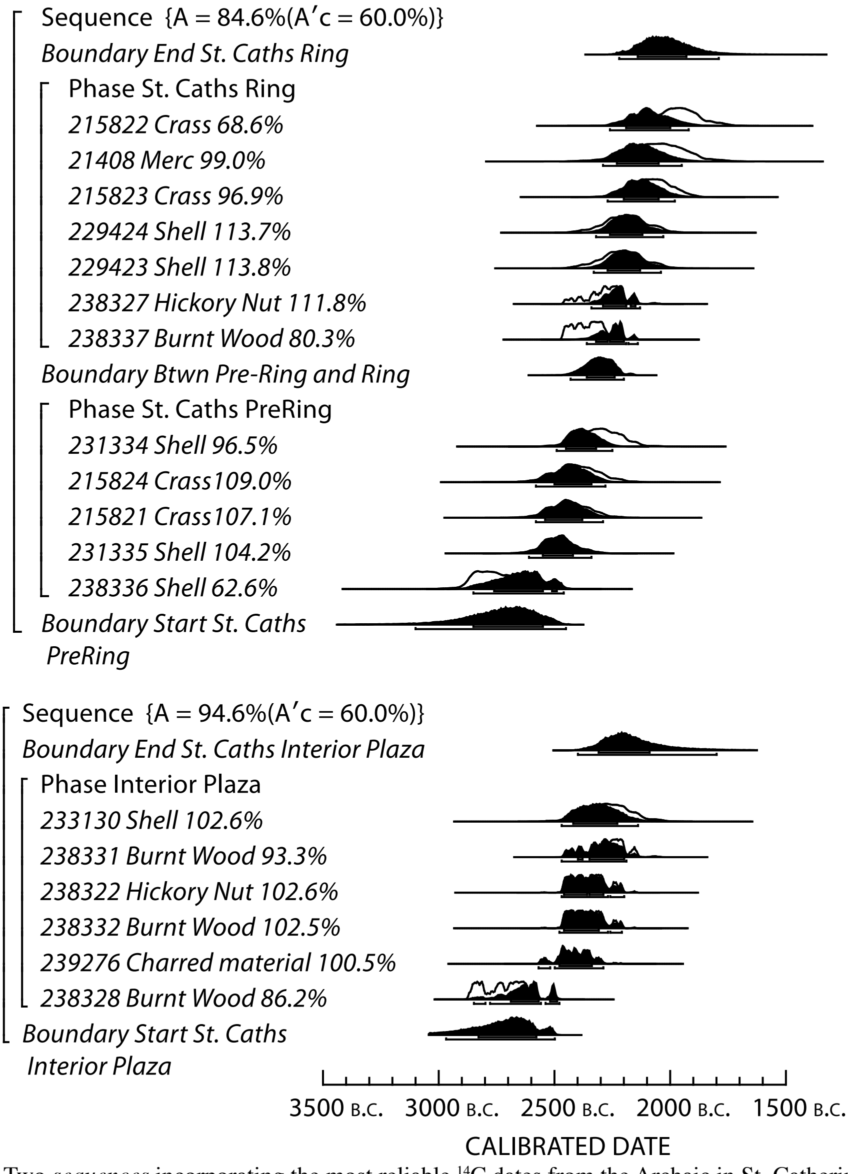


Fig. 2.6. Two *sequences* incorporating the most reliable ^{14}C dates from the Archaic in St. Catherines Shell Ring. The first models two *phases* (unordered groups of dates) defined as "Pre-Ring" or "Ring" within a *sequence* that assumes no overlap between the two *phases* and are separated by a *boundary*. Standard calibration is shown in open outline (prior distribution) and modeled calibration incorporating phase designations (posterior distribution) is depicted as a solid fill. The *agreement index* (*A* = 84.6%) higher than the critical value (*A′c* = 60.0%) indicates good agreement between the data and the model. Below, a third group is placed in an independent *phase* of Interior Plaza dates, with *boundaries* to estimate the beginning and end of that phase of deposition. Substantial overlap with both Pre-Ring and Ring phases supports the view of continued deposition in the Interior Plaza in both phases. See Sanger and Thomas, 2010, for raw data.

index for the revised McQueen model is *A* = 85.4%, indicating a good fit between the observed data and the model. Also, the overall distribution of dates and boundaries is not greatly altered by removing the three problematic dates, other than making the boundary estimates for the beginning and end of deposition a bit broader, as they are constrained by fewer dates. The start of McQueen Shell Ring deposition is estimated between 2520 and 2100 cal B.C., and the ending between 1970 and 1580 cal B.C., which overlaps substantially with the Ring phase at St. Catherines (starting at 2430–2200 cal B.C.) though McQueen likely persisted past the end of the Ring phase as currently modeled. If the set of McQueen dates included in the model is representative of the site,

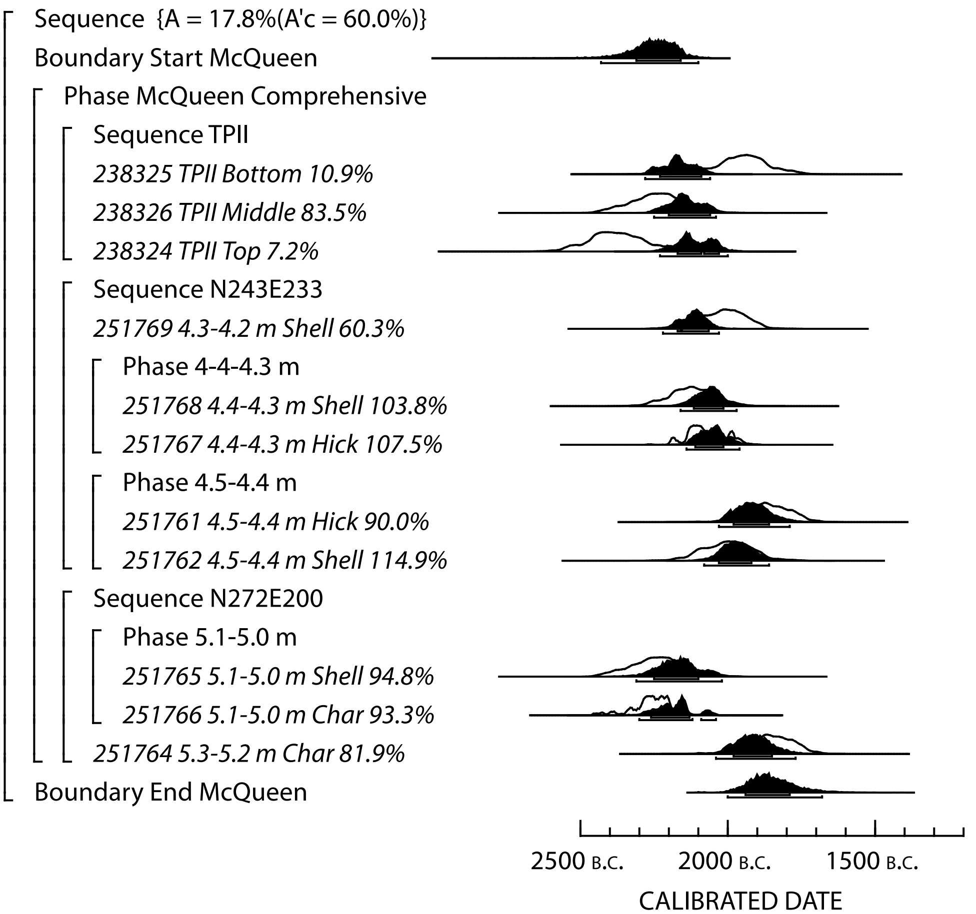


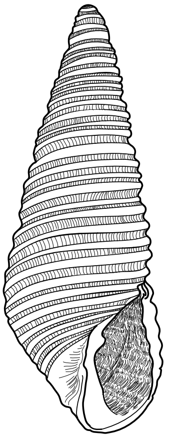
Fig. 2.7. A *phase* of nested *sequences* incorporating the most reliable ^{14}C dates from the Archaic in McQueen Shell Ring. Dates from within individual units can be placed in *sequences* based on their stratigraphic relationships, but the three units cannot be cross-correlated, so they are collectively modeled as an unordered group of sequences, i.e., a *phase*. Standard calibration is shown in open outline (prior distribution) and modeled calibration incorporating phase designations (posterior distribution) is depicted as a solid fill. The *agreement index* (*A* = 17.8%) well below the critical value (*A′c* = 60.0%) indicates poor agreement between the data and the model. Low individual agreement indices point to reversals in unit TPII, which should be removed from subsequent analyses and the context reconsidered in the field. See Sanger and Thomas, 2010, for raw data.

it would appear that there is no occupation contemporary with the St. Catherines Pre-Ring phase at McQueen. Further dates from McQueen and a refined stratigraphic picture may improve our interpretations, both by constraining the depositional boundaries and adding more relationships between dates in the various excavation units, which should provide a more detailed sense of occupational changes through time.

CONCLUSIONS

Seasonality studies depend upon defining culturally meaningful analytical units and analyzing and interpreting seasonality data within the broader context provided by these units (Monks, 1981: 223). Chronology building is an essential part of defining these analytical units. We argue that the Bayesian approach defined in this chapter provides a viable statistical framework for combining stratigraphic information and other prior knowledge with radiocarbon dates to establish more precise and accurate chronological models for archaeological sites on St. Catherines Island. It also provides a set of tools and indices for determining if the various sites on the island are contemporary or not, critical information when comparing seasonality data and inferring past land use and mobility patterns.

One of the benefits of the approach is that it provides a framework for future research and, most importantly, for establishing and testing alternative chronological models. We have examined whether or not the two Late Archaic period shell rings on St. Catherines are contemporary between 2430 and 2200 cal B.C. within this framework. Based on the available data we argue that they are most likely contemporary. This is a similar result to the summed probability approach used by Sanger and Thomas (2010), and adds strength to this hypothesis. However, the changes in material culture defined by Sanger and Thomas could have occurred in under a decade during the Late Archaic and more precise AMS ^{14}C dates could provide additional insights into the cultural processes in play. We argue that these chronological improvements are best accomplished in an iterative fashion within the Bayesian statistical framework established in this chapter.



CHAPTER 3
INTERPRETING SEASONALITY FROM MODERN AND ARCHAEOLOGICAL FISHES ON THE GEORGIA COAST

Elizabeth J. Reitz, Bruce M. Saul, J.W. Moak, Gwendolyn D. Carroll, and Charles W. Lambert[1]

Estuarine fishes are a mixture of endemic, marine, and freshwater species attracted to estuaries as nursery grounds and feeding areas. The potential of estuaries to fill these roles varies seasonally, raising the possibility that fishes can serve as indicators or ecological groups that can be used to consider seasonal patterning in human fishing strategies. In this chapter, modern spatial and seasonal habits of fishes on the Georgia coast (USA) are used by analogy to assess seasonal fishing activities in the archaeological past. Despite problems common to all ecological analogies, we find that fishing was highly selective, that the most ubiquitous fish taxa in the archaeological record of the Georgia Bight are not markedly seasonal, and that the overall record is marked by stability rather than change. This limits the value of fish presence and ubiquity to provide information about seasonality in human behavior and changes in that behavior over time. Although settlement patterns should not be inferred uncritically from season of availability, the evidence that the fish taxa most ubiquitous in the archaeological record generally are available throughout the year within these estuaries raises doubts about the ability of unicausal economic, residential, and foraging models to capture the complexity of human life in such environments.

In his seminal review of seasonality studies, Gregory Monks (1981) critiques common methodologies used to study seasonality and offers a framework for integrating such studies. He argues that seasonality studies should begin by asking the question: seasonality of what? Monks identifies three major responses to this question: season of availability, season of activity, and season of location. He suggests that season of availability and season of activity are linked, but cautions against associating these with season of location, specifically season of site occupation and settlement patterns.

Despite Monks's caution, it is likely that more seasonality studies have focused on season of location and seasonal components of political, economic, and other social institutions than on season of availability or activity. This leaves the impression that seasonal aspects of availability and activity are resolved, whereas it is more likely that fishing strategies in the past specifically targeted fish communities and populations available throughout the year, albeit vulnerable to a variety of techniques in different estuarine habitats. Questions of availability and activity are subtle and unlikely to be answered by examining fish population characteristics such as seasonal variations in population structure, abundance, biomass, diversity, dominance, distribution, or body size without collaborative evidence from other sources.

The first of Monks's (1981) three aspects of seasonality, the availability of fishes, is the focus of this chapter. Our goal is to associate the niches and habitat preferences of modern fishes with those of high-ubiquity fishes present in the archaeological record to derive season of availability using modern data from St. Catherines Island and Cumberland Sound, located behind Cumberland Island (fig. 3.1). The modern data from these locations show a clear seasonal pattern in fish availability measured by the number of fish individuals (fig. 3.2). Thus, we approach the question of seasonality of fishing on the premise that fishing strategies were informed by seasonal migratory patterns though these may be difficult to interpret when viewed through the lens of the archaeological record. This leaves the season of activity and season of location unresolved, though we have some thoughts on those as well.

Monks (1981) reviews much of the direct and indirect evidence used to study seasonality. In his discussion of indirect evidence, he critiques the many cultural variables that circumscribe season, activity, and location (see also, Morales Muñiz, 1998). His review of these variables is thorough, and is not repeated here, other than to emphasize that the archaeological record is a cultural one. Likewise, many of the biases associated with archaeofaunal data from sites associated with aquatic ecosystems, especially coastal ones, are reviewed elsewhere (e.g., Erlandson, 2001; Butler and Campbell, 2004; Reitz and Wing, 2008; Broughton, 2010; Campbell and Butler, 2010) and these critiques are not repeated here. The complexity of seasonality in anthropogenic contexts extends far beyond basic, descriptive data.

This study relies on Harry Kenward and Allan Hall's (1997: 665) definitions of indicator groups and taxa. Indicator or ecological groups are combinations of organisms defined taxonomically or by some other common element (e.g., habitat, seasonal preference). Kenward and Hall (1997: 665) define an indicator taxon as "one which reliably carries the implication of the occurrence of some event, activity, or ecological condition in the past" and an indicator group as "a natural grouping of organisms selected because it includes a range of stenotopic species which together encompass a wide spectrum of ecological conditions or human activities relevant to the aims of the study being carried out." Indicator taxa, single species typical of, perhaps even restricted to, specific niches may not be as useful as indicator groups for studying environments or human behavior. Estuarine organisms with strong preferences for specific combinations of temperature, oxygen levels, water depths, or other characteristics are more informative than are eurytopic organisms with broad tolerances.

Monks advocates an integrated, multiproxy, regional approach, termed by Kenward and Hall (1997: 665) as indicator packages, which they define as "a collection of recordable data of any kind which, when occurring together, can be accepted as evidence of some past state or activity." Indicator packages are far more useful than an indicator taxon or indicator groups, but such complex data are unavailable for the current study.

Interpretation of archaeological evidence relies on ecological and ethnographic analogy; both of which should be used with caution. Ecological analogy uses behaviors of organisms in response to critical environmental parameters that can be observed today to infer habitats and niches in the past. Ethnographic analogies accomplish a similar goal using recent, observable human activities to interpret former behaviors. Changes in the anthropogenic, biogeochemical, and hydrologic environments affect all aspects of the ecological and archaeological record, and, consequently, all analogies must be viewed skeptically.

ESTUARIES AND FISHES

Our focus is on the section of the southern U.S. coast of the Atlantic Ocean known as the Georgia Bight, a large embayment extending along the coast from Cape Fear, North Carolina, to Cape Canaveral, Florida (fig. 3.1; Hayes, 1994). A series of barrier or sea islands forms a boundary between the coastal waters of the Atlantic and lagoons (locally known as estuaries). The distance between a barrier island and the mainland can be as much as 7 km. Barrier islands share similar Pleistocene and Holocene histories, as well as archaeological, biological, and physiographic characteristics (Hoyt, 1967; Hoyt and Hails, 1967; Johnson et al., 1974: 11; Thomas et al., 1978; Oertel, 1979; Howard and Frey, 1985; Frey and Howard, 1986; Hayes, 1994; Thomas, 2008; Bishop, Rollins, and Thomas, 2011). Barrier islands are between 5 and 17 km long and 1 and 6 km wide (Hubbard, Oertel, and Nummedal, 1979). Island elevations generally are less than 7 m, though individual dunes may be higher (Johnson et al., 1974: 11). St. Catherines and Cumberland islands are two of the largest barrier islands in this area.

The central portion of the Georgia Bight, corresponding with the Georgia coast, is characterized by large, complex, highly productive estuaries. These semienclosed lagoons have access to the ocean through deep sounds that separate the barrier islands from each other. Fresh waters from large, perennial rivers draining the mainland mix with ocean water through tidal action, resulting in biogeochemical properties that are intermediate between salt water and fresh water and change during each tidal cycle (Odum and Barrett, 2005:

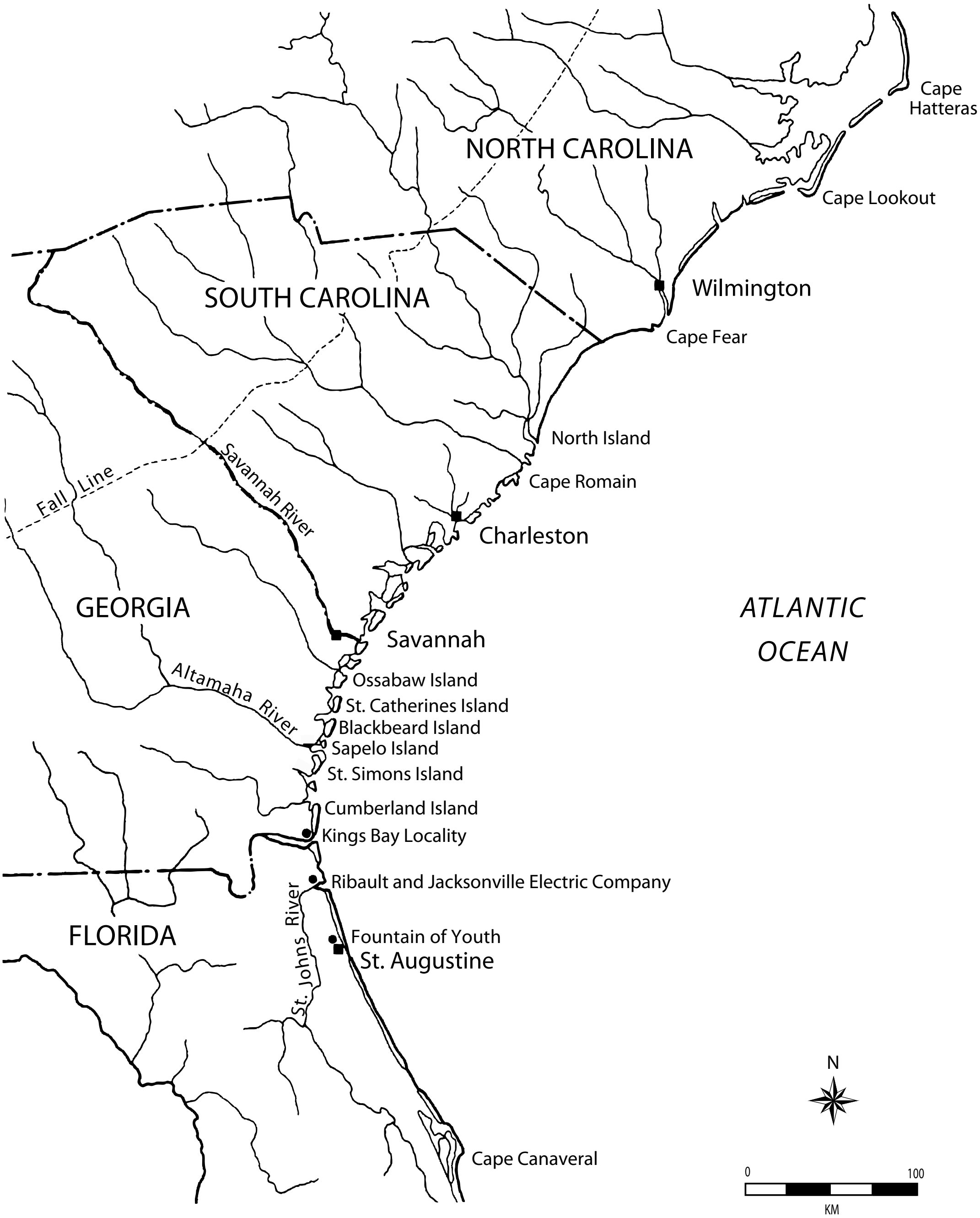


Fig. 3.1. Location of sites mentioned in this study. Modern cities are indicated by blocks and archaeological sites by circles.

421). This coastline is considered a low-energy to moderate-energy, mesotidal system (Hubbard, Oertel, and Nummedal, 1979). Estuaries in this area have the lowest energy levels in the Georgia Bight due to shoreline alignment, wind direction, and the broad continental shelf (Johnson et al., 1974: 89; Frey and Howard, 1986). Wave height is less than 0.1 m, somewhat larger toward the northern and southern ends of the Bight (Hubbard, Oertel, and Nummedal, 1979). Inlets and marshes along the Georgia coast experience the greatest tidal ranges in the Georgia Bight because these back-barrier lagoons are larger and more complex than those in South Carolina or Florida (Hubbard, Oertel, and Nummedal, 1979). The average tidal range is 2 m with a range of 1 to 3 m in spring (Schelske and Odum, 1961; Hubbard, Oertel, and Nummedal, 1979; Howard and Frey, 1985). A spring high tide may produce a 50% increase over mean tide level (Frey and Howard, 1986). A neap tide is absent in some areas, particularly in high marshes adjacent to the mainland. Surface water temperature extremes occur in January and August. In the estuaries associated with Sapelo and St. Catherines Islands, water temperatures range from 8° to 32° C, with an average of 20° C (Dahlberg, 1972; Dahlberg, 1975: 7–8). The turbid inshore waters of the Georgia Bight are generally no more than 10 m deep.

A distinction is made between estuaries and coastal waters. Coastal waters are divided into inshore waters and offshore waters. Inshore waters extend eastward from the mouths of sounds and the sandy beaches of barrier islands (Johnson et al., 1974: 86). Beaches bordering the seaward sides of barrier islands extend east to ca. 1–2 m depths. On St. Catherines Island, the beach zone extends seaward as much as 1000 m from North Beach and as little as 100 m from South Beach (fig. 3.3). Temperatures range from 7° to 29° C and salinities range from 25 to 31 ppt except when floodwaters reduce salinity (Dahlberg, 1972; Dahlberg, 1975: 113).

Estuaries are characterized by mosaics of tidal creeks, sounds, salt marshes, and marsh islands. Estuaries are divided into major habitats by salinity, water depth, dissolved oxygen, temperature, turbidity, and bottom topography, as well as other biogeochemical and hydrological properties (Schelske and Odum, 1961; Dahlberg, 1972; Dahlberg, 1975: 4–11; DEIS, 1978: D-411; Frey and Howard, 1986). One of these habitats

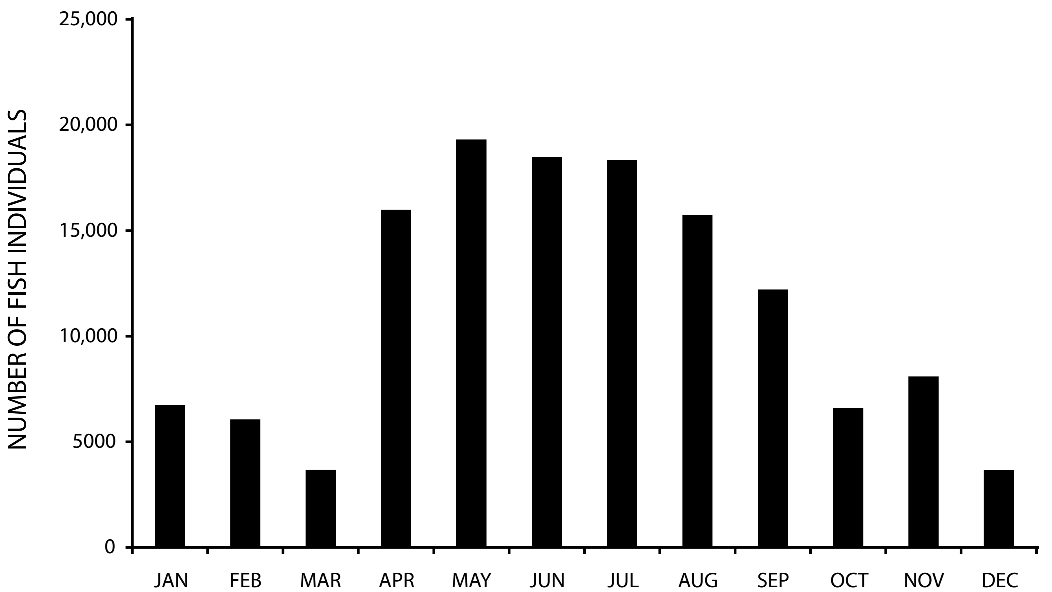


Fig. 3.2. Monthly total catch, North and South beaches.

is the lower reach of each estuary, including the sounds that separate barrier islands from each other and provide access to the sea. These are the widest and deepest habitats. Waters are polyhaline; salinities range from 18 to 32 ppt and temperatures from 8° to 32° C (Dahlberg, 1972; Dahlberg, 1975: 113). The high marsh includes the salt marshes and creeks of the upper littoral zone. Salinity levels in high marsh range from 15 to 30 ppt (Dahlberg, 1975: 7). Middle and upper reaches of estuaries primarily are composed of narrow, shallow creeks and marshes with salinity ranges between 0.3 and 29 ppt and temperature ranges from 8° to 32° C (Dahlberg, 1972; DEIS, 1978: D-412). Salinity increases in oligohaline creeks with rising tides but is diluted by freshwater runoff and rainfall. Salinity ranges from 0 to 14 ppt and temperatures range from 4° to 32° C (Dahlberg, 1972; Dahlberg, 1975: 7, 114). Freshwater creeks and ponds lie beyond the tidal reach. These generally are on the mainland, though the barrier islands also have freshwater sources. The final two habitats are low-salinity and high-salinity tidal pools. Low-salinity pools receive more freshwater runoff and are flooded only during high tide, whereas high-salinity pools are flooded regularly by tides and rarely receive fresh water. Salinity ranges in these pools are 0 to 34 ppt and temperatures range from 7° to 32° C (Dahlberg, 1972). Some high-salinity pools are associated with beaches, filling at high tide and perhaps isolated from the ocean at low tide, trapping some fish within them.

Characteristics that underlie seasonal patterns in feeding, growth, and reproduction include water temperature, dissolved oxygen, turbidity, salinity, predation, nutrients, and similar biogeochemical and hydrological properties. Many are highly variable on daily, seasonal, and annual cycles and organisms that live in estuaries are adapted to significant and frequent changes in such properties. For example, when freshwater discharge from mainland rivers is reduced by droughts, high-salinity waters and associated organisms may be found as far as 40 km inland (Frey and Howard, 1986) and the reverse is true during freshwater floods. The lower reaches of estuaries, closer to the ocean, are more saline than the upper reaches and less subject to the coldest temperatures (Johnson et al., 1974: 86, 89; Dahlberg, 1975: 7). Variations associated with each tidal cycle approach seasonal and annual ranges (Dahlberg, 1972; DEIS, 1978).

These habitats serve as nurseries and feeding areas for endemic, marine, and freshwater species so that population structure, numbers of species and individuals, and the average size of fishes vary seasonally within fish communities (Dahlberg and Odum, 1970; Conover and Ross, 1982; Rogers, Targett, and Vansant, 1984; Levin et al., 2001). Young fishes are more flexible and better able to tolerate the wide variations in estuarine conditions than are adults, which may be able to use the estuary only for short periods of time. Many species are not permanent residents of estuaries; they spawn in the ocean or in fresh water and their young use estuaries as nursery grounds. Some species live offshore as adults and only use estuaries as feeding grounds. Very few spend their entire life cycle within an estuary. The function of estuaries as nurseries for the annual crop of juvenile fishes presents an important feeding opportunity to predators, though properties such as salinity and temperature discourage some potential predators from taking advantage of this opportunity. Young fishes also are protected from many diseases and parasites by the extremes presented within estuaries. The seasonal dynamics of these roles reinforce the premise that fishes can serve as proxies for seasonal patterning in human fishing strategies.

The use of salt marshes and nearshore zones by fishes is often dependent on spawning cycles (Conover and Ross, 1982). Nearshore areas along barrier island beaches are breeding grounds for small prey fishes, such as mummichogs (*Fundulus heteroclitus*), which then attract larger predators (Martin et al., 2004). Food species, such as bay anchovies (*Anchoa mitchilli*) and Atlantic menhadens (*Brevoortia tyrannus*), spawn either in winter or early spring months, replenishing the food supply for larger predatory fishes that move into estuaries during the warmer months (Reis and Dean, 1981; Conover and Ross, 1982; Fives, Warlen, and Hoss, 1986). One of Georgia's important predatory species, both now and in the past, is the red drum (*Sciaenops ocellatus*), which exemplifies this behavior. Red drums spawn offshore, inshore, and in estuaries between mid-August and October, typically in areas with salinities above ca. 30 ppt (Lowerre-Barbieri et al., 2008). Lowerre-Barbieri et al. (2008) report that many red drums are associated with deeper pools instead of shallower shoreline areas. Juvenile red drums subsequently mature in estuarine and shallow nearshore waters while schools of adults move between inshore and offshore areas. Rogers, Targett, and Vansant (1984) report that numerous species use upper estuarine nursery areas near freshwater river discharges in the Ossabaw Sound estuary, at the northern end of Ossabaw Island. Other patterns may be related to river discharge, temperature, food availability, or depth (Rogers, Targett, and Vansant, 1984; Smith and Wenner, 1985; Jassby et al., 1995). St. Catherines is different from most barrier islands because it does not receive a significant influx of fresh water from a nearby large river, contrasting with such islands as Ossabaw, Sapelo, St. Simons, and Cumberland that receive inputs of fresh water from rivers such as the Ogeechee, Altamaha, and St. Marys (Oertel, 1979; Howard and Frey, 1985).

BACKGROUND PREMISES

Modern data from both St. Catherines and Cumberland islands show clear seasonal patterns in the abundance of fish individuals, with different patterns for beaches compared to estuarine reaches that probably reflect the seasonal migrations of juvenile and adult fishes. Thus, we approach the question of seasonality and fishing based on the background premise that fishing strategies were informed by migratory patterns that define season of availability, though we cannot prove this empirically. Archaeological indicator groups, organisms with similar requirements, may provide evidence of temporal or spatial choices, or indicate a specific collection strategy.

The other background premise is that a basic fishing strategy was followed within the Georgia Bight and was a major aspect of economic life (see references in table 3.1). This strategy changed remarkably little over the millennia despite changes in Holocene climates and other aspects of biogeochemical and hydrological parameters. The fishes that form the core of this fishing strategy are present in most, if not all, archaeological collections. This indicator group of fishes generally dominates archaeological collections in terms of minimum number of individuals (MNI) and biomass. Fishes in this indicator group move within estuaries or between estuaries and offshore habitats in response to a suite of seasonal variables associated with reproduction and feeding. The presence of this indicator group in an archaeological deposit could be evidence that specific environmental parameters prevailed when, and where, these animals were captured.

Although we can define membership in this indicator group, and do so in this chapter, we do not know where the preferred fishing grounds were within each estuarine system when the archaeological site under study was occupied because of the ever-changing nature of the estuarine environment itself in response to changes in climate, sea level, sedimentation, spit formation, dune building, freshwater hydrology, and other geomorphic processes that affect biological processes (Blanton and Thomas, 2008; Bishop, Rollins, and Thomas, 2011; chap. 1, this volume).

METHODS

Modern fish samples from St. Catherines Island are from collection sites on the North and South beaches (fig. 3.3). These beaches lie on the exposed seaward side of the island. The samples were taken between 1998 and 2009. Sites were selected to provide representative samples from the entire maximum accessible area and to incorporate as many differences in bottom topography as possible. Initially four sites were selected on each beach. One site on North Beach was eliminated and another was occasionally inaccessible due to shifting mud, snags, and oyster beds, phenomena that undoubtedly have always influenced fishing in this and other coastal areas. Each site was sampled on a monthly basis during the three-hour period before low tide, allowing for collection in morning, midday, evening, night, and predawn periods. Samples were collected under all weather conditions, excluding lightning storms, extreme cold, and rough surf, which would endanger the health and safety of the research team or make sampling impractical.

Species composition was assessed at each site by towing seines in a standard quarter-haul fashion from the beach. Two hauls were made using a 30.5 m monofilament seine, with a 2.5 cm mesh, and two hauls were made with an 18.3 m cotton mesh bag seine of 0.3 cm mesh (Hillman, Davis, and Wennemer, 1977). Each tow was offset 9 to 18 m from the previous one to reduce the effects of population disbursement associated with the previous pull.

The 0.3 cm mesh net used in the bag seine was designed to collect all sizes of all possible game and nongame species. Differences in nets in the modern St. Catherines Island study likely do not pose a bias in this study. The 0.3 cm mesh used in the modern study captured all but the very small-

TABLE 3.1
Summary of Archaeological Sites and Vertebrate Collections[1]

Sites	Location	Time period	Screen size (mm)	NISP	MNI	No. taxa	No. fish taxa
Back Creek Village, Mississippian (Irene) 9Li207	St. Catherines Island, GA	A.D. 1300–1580	3.18	14,881	449	53	27
Bourbon Field, Mississippian (Savannah) 9Mc71	Sapelo Island, GA	A.D. 1000–1350	6.35	15,331	563	35	19
Cathead Creek, Mississippian (Savannah) 9Mc360	Darien, GA	A.D. 1200–1500	0.5	2,248	84	34	16
Cathead Creek, Woodland (Swift Creek) 9Mc360	Darien, GA	A.D. 300–700	0.5	1,610	74	27	19
Fountain of Youth Park, Archaic 8SJ31	St. Augustine, FL	1450–500 B.C.	1.59	215	28	15	11
Fountain of Youth Park, Miss. (St. Johns IIc) 8SJ31	St. Augustine, FL	A.D. 1513–1565	1.59	14,891	218	36	27
Jacksonville Electric Authority, Miss. (Savannah) 8Du634, 8Du669	Duval Co., FL	A.D. 1000–1500	1.59	7,380	179	30	16
Kenan Field, Mississippian (Savannah) 9Mc67	Sapelo Island, GA	A.D. 1000–1500	6.35	0	397	44	15
Kings Bay Locality, Mississippian (Savannah) 9Cam171a, 9Cam177	Kings Bay Locality, GA	A.D. 1200–1500	1.59	36,667	903	57	26
Kings Bay Locality, Woodland (Swift Creek) 9Cam171a, 9Cam177	Kings Bay Locality, GA	A.D. 300–700	1.59	37,530	1,704	46	27
McQueen Shell Ring, Archaic 9Li1648	St. Catherines Island, GA	2300–1950 B.C.	3.18	43,240	1,153	58	36
Meeting House Field, Mississippian (Irene) 9Li21	St. Catherines Island, GA	A.D. 1300–1520	various	6,193	105	23	7
Mission Sta. Catalina de Guale (Historic) 9Li13	St. Catherines Island, GA	A.D. 17th century	various	43,206	204	54	16
Pueblo Sta. Catalina de Guale (Historic) 9Li8	St. Catherines Island, GA	A.D. 17th century	various	14,493	167	50	14
Ribault Clubhouse, Archaic 8Du76	Duval Co., FL	2000 B.C.	3.18	2,885	144	37	26
St. Catherines Shell Ring, Archaic 9Li231	St. Catherines Island, GA	2540–2030 B.C.	3.18	49,587	1,249	69	31
St. Simons Cannon's Point (Marsh) Ring, Archaic 9Gn57	St. Simons Island, GA	2240–1815 B.C.	3.18	19,970	345	45	25
St. Simons West Ring, Archaic 9Gn76	St. Simons Island, GA	2320–1970 B.C.	3.18	9,453	251	31	16
Sapelo Shell Ring III, Unit 9, Archaic 9Mc23	Sapelo Island, GA	2332–1740 B.C.	1.59	12,132	182	27	21

[1]NISP refers to number of identified specimens (vertebrates only). MNI refers to minimum number of individuals (vertebrates only); "No. taxa" refers to the total number of vertebrate taxa each collection; and "No. fish taxa" is the number of fish taxa in each collection. Data are from the following sources: Bourbon Field (Crook, 1978, 1984; Reitz, 1982); Cathead Creek site (Reitz and Quitmyer, 1988; Quitmyer and Reitz, 2006); Fountain of Youth site (Reitz, 1991); Jacksonville Electric Authority site (Lee et al., 1984; Reitz, Quitmyer, and Marrinan, 2009); Kenan Field (Crook, 1978); Kings Bay Locality (Reitz and Quitmyer, 1988; Quitmyer and Reitz, 2006); McQueen Shell Ring (Colaninno, 2010: 153–155; Sanger and Thomas, 2010); Meeting House Field (Reitz and Dukes, 2008); Back Creek Village (Bergh, this volume); Mission (Eastern Plaza Complex) Santa Catalina de Guale (Reitz et al., 2010); Pueblo Santa Catalina de Guale (Reitz et al., 2010); Ribault Clubhouse (Quitmyer and LeFebvre, 2004; Reitz, Quitmyer, and Marrinan, 2009); St. Catherines Shell Ring (Colaninno, 2010: 116–119; Sanger and Thomas, 2010); St. Simons Cannon's Point (Marsh) and West Rings (Marrinan, 1975; Reitz, Quitmyer, and Marrinan, 2009; Colaninno, 2010: 95–97, 100–101; Marrinan, 2010); and Sapelo Shell Ring (Thompson, 2006; Colaninno, 2010: 104–105). Descriptions of each site, the methods used during excavation, and the original zooarchaeological studies of each collection are found in the above sources. All of these materials were identified using the comparative skeletal collections at the Florida Museum of Natural History and the Georgia Museum of Natural History. Swift Creek is a Woodland period; Savannah, Irene, and St. Johns IIc are Mississippian periods. Human MNI estimates are excluded.

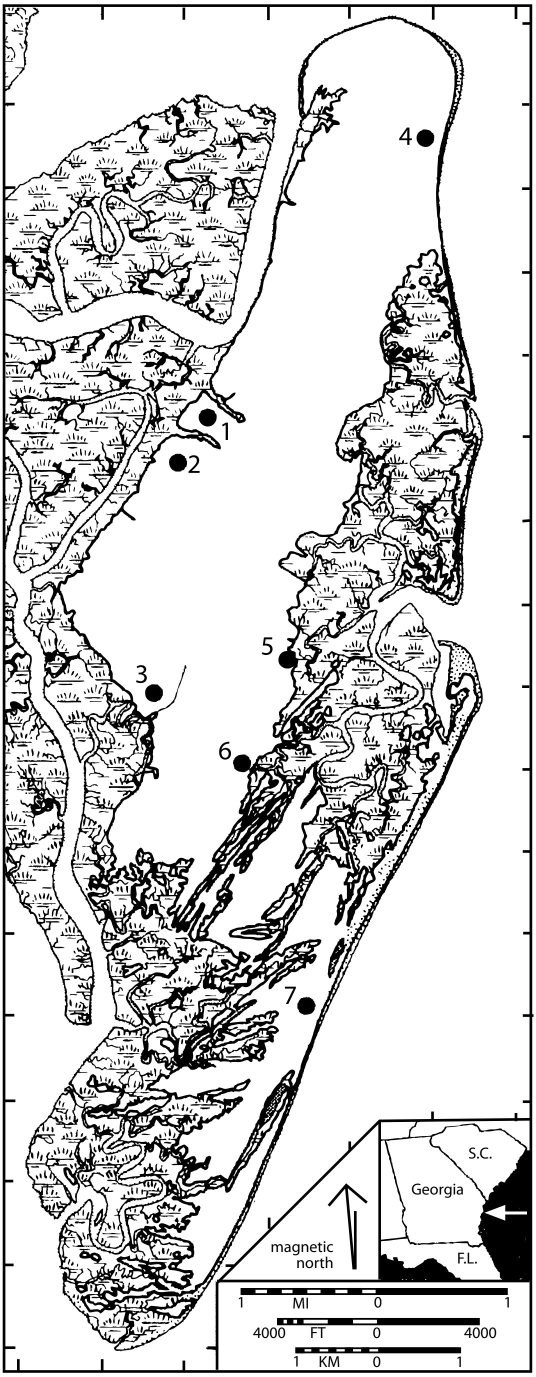


Fig. 3.3. Map of St. Catherines Island, showing North and South beaches. Key to sites: **1**, Meeting House Field; **2**, St. Catherines Shell Ring; **3**, Santa Catalina de Guale mission and pueblo; **4**, North Beach; **5**, McQueen Shell Ring; **6**, Back Creek Village; **7**, South Beach.

est juvenile fishes. Zooarchaeological collections, of course, only contain skeletal elements and not live, whole fish; thus archaeological excavations must use a smaller screen size to recover the remains of the same small taxa that can be captured live using a larger mesh. For example, the largest, intact, skeletal element of a mummichog with a total length of 86 mm is 12.5 mm. As a live fish, this mummichog would be captured in the bag seine used in the modern study.

The fishes in each haul were identified, enumerated, and measured. Larger specimens, particularly if part of a breeding cohort, were measured first and returned to the water to reduce sampling mortality rates. Measurements were taken using a Wildco fish measuring board with 1.0 cm divisions (Wildlife Supply Company, Yulee, FL). Specimens that could not be identified in the field were taken to the lab and preserved in a 10% formalin solution. Fishes were identified to species using marine field guides (Breder, 1929; Dahlberg, 1975; Robins et al., 1986; Hoese and Moore, 1998). A representative sample of all sizes was measured when a large number of specimens of a single species were collected (≥ 25) and the remaining specimens were counted.

The following discussion generally focuses on data from South Beach because, thus far, relatively few archaeological sites have been found in the North Beach area (Thomas, 2008: 546). Most of the archaeological sites on the eastern side of the island are closer to South Beach, though very few sites are actually adjacent to either North or South Beach.

Because South Beach data are from a seaward beach, they are supplemented with data from Cumberland Sound, a complex back-barrier system landward of Cumberland Island, for which similar quantified modern data are available (figs. 3.1, 3.4). This enables us to assess seasonal pulses in the shallow waters behind a barrier island (DEIS, 1978). Fishes were collected quarterly at four stations along each transect using a 5 m semiballoon otter trawl and at shallow water stations (A, C, X, D, E, F, G, I, J, K, L, M, N) using a 50 ft bag seine. Migratory fish collections were made in winter and spring quarters using three 100 ft gill nets with ¾ in., 1½ in., and 3 in. meshes set near transects D and E for a complete tidal cycle (DEIS, 1978: D-192). The methods used in the Cumberland Sound study are described in more detail in the Draft Environmental Impact Statement for Cumberland Sound (DEIS, 1978: 186, 192–193). Occasionally, specific reference is made to biological sampling stations D and E, located in that part of the sound known as Kings Bay.

Differences in sampling location and sampling gear for the modern St. Catherines Island and Cumberland Sound collections limit our ability to directly compare modern data from these two locations. The modern collection strategies were not designed to replicate each other or human behavior in the past. The St. Catherines Island modern data are from a collection locality that may not have been frequently used by islanders (seaward beaches), but the collection gear (manual seines) is probably similar to what was used in the past. The Cumberland Sound data

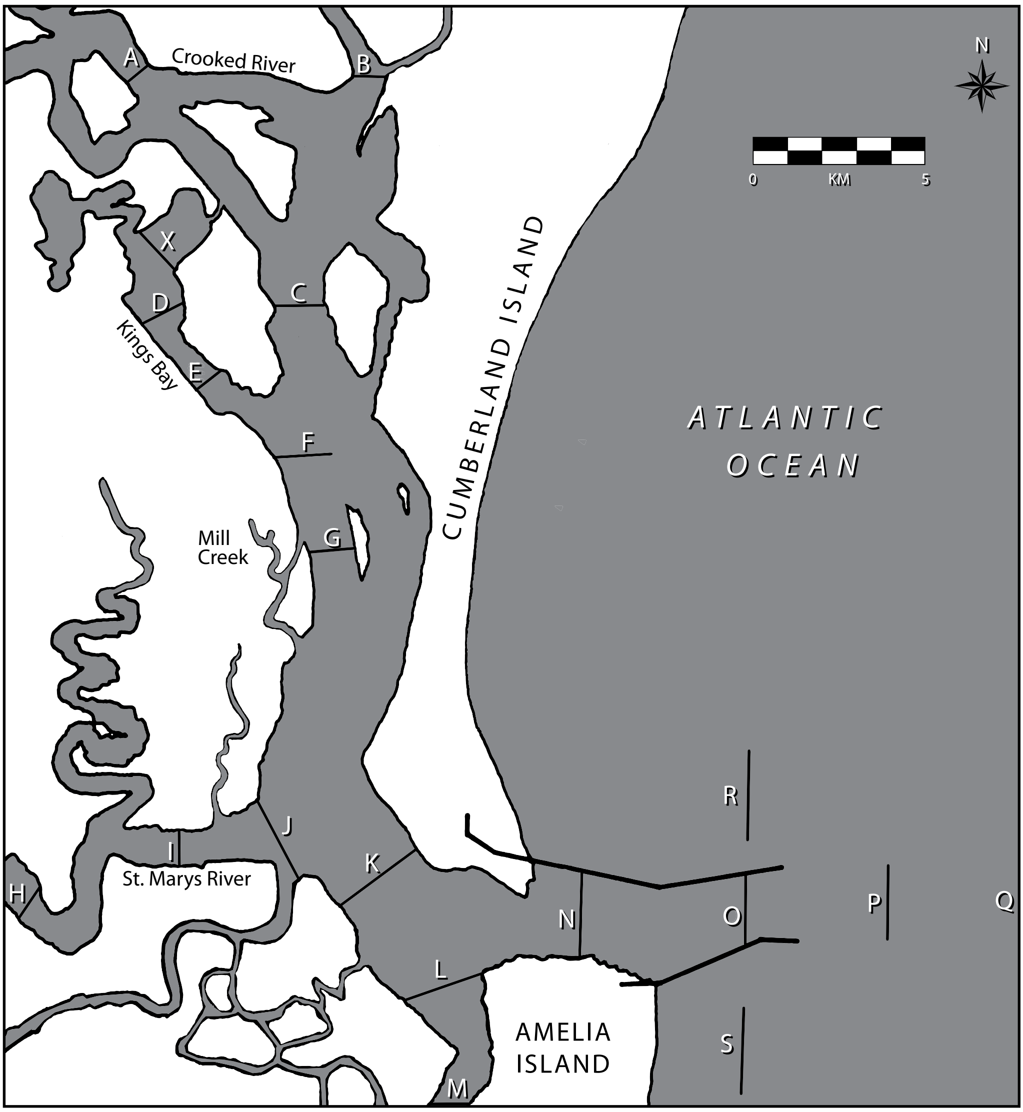


Fig. 3.4. Aquatic biological sampling stations in Cumberland Sound (modified from DEIS, 1978: D-187).

represent a collection locality similar to that used by people living in this region (back bay waters and tidal creeks), but using a modern collection gear (mechanized trawls) unknown until recently. From an archaeological perspective, it would be highly desirable to collect modern samples from archaeologically probable collection localities using probable collection gear.

The archaeological collections are from 19 sites or temporal components of multicomponent sites between St. Catherines Island and Anastasia Island, Florida (table 3.1; fig. 3.1). Five of these sites (McQueen Shell Ring, Back Creek Village, Bourbon Field, St. Simons Cannon's Point [Marsh] Ring, and St. Simons West Ring) are from the seaward side of barrier islands. The Bourbon Field and the St. Simons Island sites are protected from the ocean by additional, smaller, barrier islands (Blackbeard and Little St. Simons islands) and two St. Catherines Island sites are adjacent to an inlet (McQueen) and a marsh (Back Creek Village) on the seaward side of the island. Other barrier island sites (St. Catherines Shell Ring, Meeting House Field, Mission and Pueblo Santa Catalina de Guale, Sapelo Ring III, and Kenan Field) are located on the landward sides of barrier islands. The remaining sites are mainland sites (Cathead Creek, Kings Bay, Ribault, Jacksonville Electric Authority, and Fountain of Youth). Archaeological collections were deposited between ca. 2560 B.C. and A.D. 1680. In the case of sites occupied prior to the onset of the First Spanish period (A.D. 1565), it is not known if any were contemporaneous or what relationships among each site's occupants might have occurred. Establishing contemporaneity is clearly required to link seasonality in the resource base with residential patterns (see Kennett and Culleton, chap. 2, this volume).

Monks (1981) identifies presence-absence of seasonally available species as the simplest, oldest, and most common methodology and this is one of the methods used in the archaeological part of this study. Presence-absence relies upon ecological analogy, using the seasonal habits of fishes today to infer seasonal behaviors in the past. Fishes are expected to move within estuaries or between estuaries and either freshwater or offshore habitats in response to a suite of seasonally sensitive variables associated with reproduction and feeding. The presence of a fish in an archaeological deposit could be evidence that a specific suite of parameters prevailed when, and where, the animal was captured. The absence of any resource, or the absence of evidence that a resource was used during a specific season, as we all know, is more problematic (e.g., Balasse et al., 2003). To emphasize this point, we refer only to "presence" henceforth, using presence of taxa as reported in zooarchaeological reports (table 3.1). We focus on those fishes that form our hypothesized core group in the Georgia Bight fishing strategy (Quitmyer and Reitz, 2006; Reitz, Quitmyer, and Marrinan, 2009; Reitz et al., 2010). Variables that affect presence will be revisited below.

An ideal study would combine presence with information about fish size and other indicators of age, such as increments. The tidal and seasonal movement of fishes within estuaries and between estuarine and coastal waters is closely associated with age and body size. Age cohorts are seasonal markers in fishes because habitats and niches change as individuals grow larger and reach reproductive size. Members of an age cohort of a given species not only are roughly the same size at the same time, they also occupy similar habitats and niches at the same time, and are susceptible to capture with similar fishing gear. As their size changes with maturity, so too do the habitats and niches of the fishes, and the fishing strategy likely to efficiently capture them. These variables are likely to be somewhat different among those members of a taxon that occupy ideal habitats and those that occupy the slightly less optimal edges of the species biogeographical range. Sadly, too few measurements of archaeological fish remains, or associations of size with age, are available for the Georgia Bight to use in this study. Morphometric and incremental studies should become routine in all future archaeological projects.

Both the modern South Beach and the archaeological fishes are examined using ubiquity analysis and Shannon-Weaver diversity indices. Ubiquity analysis of modern fishes involves dividing the number of samples in which an individual fish species is present by the total number of samples. Ubiquity analysis of archaeological data involves dividing the number of archaeological collections in which a specific fish taxon is present by the total number of archaeological collections in this application ($N = 19$). Only those taxa for which MNI is estimated are used in the archaeological ubiquity analysis. This approach controls for the diverse attribution levels in the archaeological species lists and is similar to the ubiquity analysis of modern collections, which is based on individual fishes.

The Shannon-Weaver diversity index is estimated for each modern and archaeological site using the following function: $H' = -\Sigma P_i \log P_i$, where P_i is the proportion of individuals in the *i*-th species (Dahlberg and Odum, 1970). Shannon-Weaver is also estimated for the combined archaeological assemblage by adding the indices for all of the archaeological collections in table 3.1 together and dividing by the total number of collections (*N* = 18), excluding Kenan Field for which MNI is unavailable. Shannon-Weaver allows us to compare proportions and not numbers, accommodating characteristics in the data and differences in techniques (see Reitz and Wing [2008: 110–113] for a review of this method). A t-test compares the overall archaeological diversity and modern diversity. Analysis of variance (ANOVA) compares seasonal differences of modern data and archaeological collections.

CAVEATS

It bears repeating that comparisons of modern and archaeological data rely on the premise that relationships exist among the organisms studied, their environmental preferences, environmental conditions at the site, and human behavior. This premise underlies the use of ecological analogies to infer relationships in the past and is basic to studies that associate season of availability with other aspects of human behavior. In the Georgia Bight, long-term processes operate within an ecosystem in which populations and communities accommodate daily variations during each tidal cycle. Coastal landscapes are highly dynamic, which means that environmental proxies and ecological analogies must be used cautiously.

Many analogies assume that organisms have not changed their habitats and niches during the intervening centuries, a premise that is unlikely to be true (e.g., (Webb, Hedges, and Robinson, 1998). In the case of St. Catherines Island, geological and climatological processes have altered the structure and function of aquatic and terrestrial environments (Blanton and Thomas, 2008; Bishop et al., 2011; Rich, Vega, and Vento, 2011). Many nonanthropogenic phenomena are associated with environmental change, such as floods, storms, plant successions and other ecosystem processes, coastal remodeling, and climatic cycles. These have both short- and long-term outcomes. Routine ecological processes (e.g., competition, predation, community transformations) alter the composition and physical location of populations and communities. All of these processes can occur without human intervention; but it is likely that the structure and productivity of estuaries in the Georgia Bight have been impacted by human fishing strategies for millennia (Reitz, 2004).

Thus, the suite of estuarine organisms found at a specific time and place may change, either for a long time or a short time, sometimes within a matter of hours. Organisms previously common in a specific fishing ground may now be rare and taxa formerly absent from a location may now be abundant there. In reference to the present study, however, it is important to recognize that we may not know what the landscape at the time of occupation was or which specific habitats were exploited from a specific site at a given point in time. This, of course, is the conundrum faced by all diachronic and synchronic studies of seasonal behaviors, ecosystems, and environments.

Biological surveys typically define seasons by the lunar calendar: January–March, April–June, July–September, and October–December. Many characteristics are associated with seasons beyond the lunar calendar and these vary within a range from one year to the next. It is likely that storms, climate cycles, and other dynamics influenced cultural and ecological systems at several organizational, spatial, and temporal scales during the millennia encompassed in this review (Redman, Grove, and Kuby, 2004; Reitz, Quitmyer, and Marrinan, 2009). Fishing strategies, residential patterns, and behaviors of fishes themselves undoubtedly responded to these changes but might not occur precisely during the winter, spring, summer, and fall months defined by the Gregorian calendar.

This diachronic ambiguity is compounded by synchronic Holocene changes in sea levels, sedimentation, distance from fluvial sources, shoreline configurations, littoral drift, aeolian sand accumulations, migrations of tidal inlets, storm-related topographic changes, biogeochemical properties, and sea surface temperatures, among other changes (Dolan, Hayden, and Lins, 1980; Liu, 2004; Reitz, Quitmyer, and Marrinan, 2009; Bishop, Rollins, and Thomas, 2011). The broad general similarities among fish populations and communities in both modern and archaeological collections suggest that fish taxa represented in today's estuaries were able to endure synchronic changes just as they are able to endure diachronic ones. Certainly, however, ecosystem structures and processes were impacted by synchronic changes, which are variables in this record of seasonal patterning; one of many reasons why it is difficult to associate seasonal aspects of resource availability with human behavior in the past using ecological analogies.

The present study is only possible if one presumes that the overall estuarine characteristics required by aquatic animals were met someplace within the environment, though the exact physical and morphological aspects with regards to the archaeological sites investigated are unknown. At the risk of a circular argument, while we cannot define the temperature/salinity regime that prevailed at a specific time and place, or specify where inlets, tidal creeks, sounds, salt marshes, marsh islands, and shallow waters were, the suite of fishes recovered from St. Catherines Island shows remarkable richness as well as continuity. The dominant fish taxa, those in the indicator group of fishes, are specifically those known for behavioral flexibility, a characteristic necessary for all organic life in the Georgia Bight, including people.

Fish biologists identify most of their catch to species and zooarchaeologists rarely do. It is species that respond to daily, seasonal, and annual variations, not genera or families; but species-level identifications often elude zooarchaeological studies. Thus, we may know we have a sea catfish (Ariidae) in an archaeological collection, but not which of two possible sea catfish species (*Ariopsis felis*, *Bagre marinus*). Much more information is available about the habitat preferences of the hardhead catfish (*A. felis*), for example, than for the family Ariidae. Likewise, mullet (*Mugil* spp.) specimens in archaeological collections almost always are attributed only to the genus *Mugil* because it is difficult, if not impossible, to distinguish between striped mullets (*M. cephalus*) and white mullets (*M. curema*). It is equally difficult to distinguish between the two species of mullets in modern, live-collected fishes, many of which are present in the modern South Beach collection.

Recovery method is a well-known source of bias in archaeological analyses. Four of the 10 fishes with ubiquity above 0.44 in the modern South Beach collection are small-bodied taxa, defined as having an adult total length of less than ca. 250 mm today (Reitz, Quitmyer, and Marrinan, 2009; Reitz et al., 2010: 234–237). Large-bodied taxa are ones with an adult total length over 250 mm. The mean total length (TL) of inland silversides (*Menidia beryllina*) is 79 mm, bay anchovies 54 mm, striped killifishes (*Fundulus majalis*) 62 mm, and striped anchovies (*A. hepsetus*) 73 mm in the modern St. Catherines Island collection (table 3.2; Augusta State University field notes; see also, Jorgenson and Miller, 1968). It is unlikely that these four taxa would be represented in an archaeological collection if a screen size of more than 3 mm was used during archaeological fieldwork. Many of the archaeological collections were recovered using mesh sizes too large to catch the small bones of these small-bodied taxa. For this reason, and because of the susceptibility of small fish elements to site formation processes, it is possible, if not probable, that very small taxa, as well as small individuals of large-bodied taxa, are underrepresented in the archaeological record. Without measurements and body size estimates for all fishes in all of the archaeological collections merged in this study, it is not possible to know which specific archaeological individuals were large or small, unless the specimen is from a biologically small fish taxon.

Another limitation of all fishery studies is the question about how people used small fishes, if they did. Today, we eat anchovies and other small fishes, bones and all, and it is possible that people did so in the past. Very small fishes, however, could have been used as bait instead of food. We question whether bait fish would be present at an archaeological site; it is more likely that bait was used shortly after capture, or tossed into the water at the end of the fishing expedition. Additionally, as this and other contributions in this volume demonstrate, small-bodied fishes can be prominent components of archaeological collections from the Georgia Bight, too prominent to be dismissed as gut contents of predators, given that many of these presumed predators are themselves rare or absent in the archaeological record. Regardless of whether or how small fishes were used, the season of availability would be informative of human behavior.

Differences between modern seines and devices used in the past are highly important sources of bias. Such differences grow in significance when one recognizes that gear is tailored to prey, with specific gear used for specific purposes. Gear dif-

TABLE 3.2
Seasonal Total Length (TL) Ranges (in mm) for High-Ubiquity Taxa from South Beach

		Winter				Spring				Summer				Fall			
Common name	Scientific name	Min	Mean	Max	*N*	Min	Mean	Max	*N*	Min	Mean	Max	*N*	Min	Mean	Max	*N*
Inland silverside	*Menidia beryllina*	6	82	122	2151	10	90	121	3327	6	71	121	1699	32	73	102	1246
Bay anchovy	*Anchoa mitchelli*	40	58	85	1543	15	62	520	2384	24	48	480	2878	20	50	83	1860
Southern kingfish	*Menticirrhus americanus*	30	101	365	223	20	106	372	220	1	65	520	1776	19	68	370	544
Striped mullet	*Mugil cephalus*	22	99	446	275	19	121	452	67	19	127	362	829	29	166	455	778
Striped killifish	*Fundulus majalis*	39	57	81	56	44	70	135	188	20	59	113	870	34	61	95	100
Florida pompano	*Trachinotus carolinus*	41	74	254	55	14	35	227	466	10	75	245	3954	15	63	419	1222
Silver perch	*Bairdiella chrysoura*	116	143	232	113	45	148	270	203	129	160	199	18	112	143	195	84
Star drum	*Stellifer lanceolatus*	21	43	97	49	19	47	160	42	19	78	440	420	26	105	167	22
Striped anchovy	*Anchoa hepsetus*	59	89	120	18	43	63	118	347	26	60	122	443	32	81	116	137
Hardhead catfish	*Ariopsis felis*	292	292	292	1	226	331	421	69	42	130	550	345	280	333	384	11
Spot	*Leiostomus xanthurus*	82	188	271	9	60	100	182	16	70	154	231	49	115	208	262	32
Atlantic bumper	*Chloroscombrus chrysurus*	0	0	0	0	78	97	111	13	8	63	162	621	32	69	147	480
Red drum	*Sciaenops ocellatus*	370	509	723	33	405	507	640	14	20	367	535	15	350	508	680	15
Atlantic menhaden	*Brevoortia tyrannus*	114	179	235	24	125	164	443	11	61	134	212	150	142	177	283	40
Gulf kingfish	*Menticirrhus littoralis*	64	254	467	40	29	199	370	21	62	152	262	18	60	255	411	13
Atlantic needlefish	*Strongylura marina*	275	402	470	7	127	359	445	8	212	302	423	22	260	394	495	40
Bluefish	*Pomatomus saltatrix*	29	73	160	3	18	61	345	95	35	150	280	20	34	172	257	3

ferences are particularly profound when modern trawl data, taken from sounds, are used to interpret archaeological fishing strategies. Anticipating the results of this study, there is no evidence that offshore habitats or deep inshore sounds were used in the past. Net size does influence catch, but nets used in the modern St. Catherines collection, at least, were selected purposefully to catch a large variety of species of all sizes. The merit of the St. Catherines modern study is that seines were used to sample two localities whose parameters are similar to some of those probably used in the past: near-shore shallow waters into which students could safely wade. The Cumberland Sound data are less than ideal in this regard.

Ideally, modern fishes would be collected using gear more similar to that surmised for the past in locations likely to have been routinely used in the past. Early societies would have used multiple methods of capture to maximize their efforts, probably in shallow waters. Experiments that test the seasonal quantity and variety of fishes that might be captured using fishing gear and locations hypothesized to have been used in the past would greatly improve our understanding of many aspects of this study. Arguments that infer archaeological fishing strategies in the archaeological past using modern fishing strategies are, by their nature, circular. This issue plagues all ecological and ethnographic analogies.

There are no obvious solutions to any of these caveats; but it is in recognition of these issues that statistical tests of significance are avoided; they would confer on the results of this study an aura of legitimacy that is unwarranted. Clearly, well-designed, regional, multiproxy studies designed to contribute to definitions of indicator packages would make substantial contributions to resolving some of the problems with ecological analogies encountered in this study; but it is likely that most cannot be resolved without a time machine. Having acknowledged this, however, it is clear from the data in this volume and in other volumes in the American Museum of Natural History series on St. Catherines Island that we do know a great deal about life on this island and in the Georgia Bight.

RESULTS

Modern South Beach and Cumberland Sound Data

A total of 134,895 individual fish representing 102 species were collected from North and South beaches between 1998 and 2007 (*N* = 208; table 3.3). A total of 79 species were collected from

TABLE 3.3
Total Catch by Year for North Beach and South Beach (*N* = 208)

Year	North (*N* = 107)	South (*N*= 101)	Total
1998	4,126	12,587	16,713
1999	9,088	9,423	18,511
2000	6,093	16,571	22,664
2001	5,392	10,783	16,175
2002	2,506	2,912	5,418
2003	2,484	1,865	4,349
2004	3,367	9,265	12,632
2005	5,954	9,696	15,650
2006	6,539	6,554	13,093
2007	6,609	3,081	9,690
Total	52,158	82,737	134,895

TABLE 3.4
Mean Catch per Unit Effort (CPUE) by Year for North Beach and South Beach

Year	North (*N* = 1196)	South (*N* = 1554)	Average
1998	32.5	71.5	55.2
1999	64.5	54.5	59.0
2000	41.2	104.2	73.8
2001	37.4	56.5	48.3
2002	27.2	27.0	27.1
2003	32.3	16.1	22.5
2004	25.9	48.3	39.2
2005	46.9	55.1	51.7
2006	49.9	42.0	45.6
2007	83.7	28.8	52.1
Average	44.1	50.4	47.4

TABLE 3.5
Fishes with Ubiquity ≥ 0.25, North Beach and South Beach Data Combined

Family	Common name	Scientific name	Ubiquity (*N* = 101)
Atherinopsidae	Inland silverside	*Menidia beryllina*	0.98
Engraulidae	Bay anchovy	*Anchoa mitchelli*	0.93
Sciaenidae	Southern kingfish	*Menticirrhus americanus*	0.89
Mugilidae	Striped mullet	*Mugil cephalus*	0.85
Fundulidae	Striped killifish	*Fundulus majalis*	0.71
Carangidae	Florida pompano	*Trachinotus carolinus*	0.67
Sciaenidae	Silver perch	*Bairdiella chrysoura*	0.51
Sciaenidae	Star drum	*Stellifer lanceolatus*	0.49
Engraulidae	Striped anchovy	*Anchoa hepsetus*	0.44
Ariidae	Hardhead catfish	*Ariopsis felis*	0.36
Sciaenidae	Spot	*Leiostomus xanthurus*	0.36
Carangidae	Atlantic bumper	*Chloroscombrus chrysurus*	0.32
Sciaenidae	Red drum	*Sciaenops ocellatus*	0.30
Clupeidae	Atlantic menhaden	*Brevoortia tyrannus*	0.29
Sciaenidae	Gulf kingfish	*Menticirrhus littoralis*	0.28
Belonidae	Atlantic needlefish	*Strongylura marina*	0.26
Pomatomidae	Bluefish	*Pomatomus saltatrix*	0.25

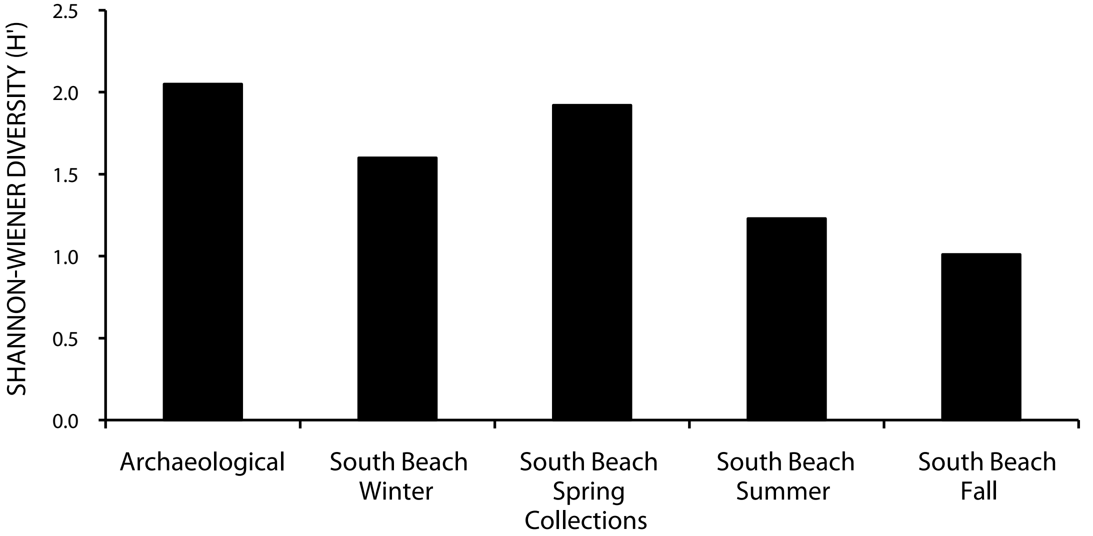


Fig. 3.5. Comparison of archaeological and South Beach fish diversity.

TABLE 3.6
Fishes Collected from South Beach with Ubiquity ≥ 0.25

Family	Common name	Scientific name	Ubiquity (*N* = 101)
Atherinopsidae	Inland silverside	*Menidia beryllina*	0.96
Engraulidae	Bay anchovy	*Anchoa mitchelli*	0.91
Sciaenidae	Southern kingfish	*Menticirrhus americanus*	0.89
Mugilidae	Striped mullet	*Mugil cephalus*	0.81
Fundulidae	Striped killifish	*Fundulus majalis*	0.72
Carangidae	Florida pompano	*Trachinotus carolinus*	0.67
Sciaenidae	Red drum	*Scianops ocellatus*	0.44
Engraulidae	Striped anchovy	*Anchoa hepsetus*	0.43
Sciaenidae	Silver perch	*Bairdiella chrysoura*	0.41
Carangidae	Atlantic bumper	*Chloroscombrus chrysurus*	0.33
Ariidae	Hardhead catfish	*Ariopsis felis*	0.31
Sciaenidae	Spot	*Leiostomus xanthurus*	0.30
Sciaenidae	Star drum	*Stellifer lanceolatus*	0.30
Sciaenidae	Gulf kingfish	*Menticirrhus littoralis*	0.29
Pomatomidae	Bluefish	*Pomatomus saltatrix*	0.25

North Beach and 66 species were collected from South Beach. In terms of catch composition, 10 species are present in over 95% of the total catch and 75% of the total number of fishes caught consists of four species: bay anchovies, inland silversides, striped mullets, and Florida pompanos (*Trachinotus carolinus*). Mean catch per unit effort (CPUE), a measure of the number of fishes caught per seine haul, was slightly higher for South Beach than for North Beach (table 3.4). With respect to gear, 121,425 fish were caught with the bag seine and 13,470 were caught with the monofilament seine. The average total length (TL) of fish caught with the bag and monofilament seines was 68 mm and 132 mm, respectively. No fish had a ubiquity of 1.0 (i.e., was present in every sample) in the combined North Beach and South Beach data (table 3.5). Inland silversides and bay anchovies have the highest ubiquity in the combined data, followed closely by southern kingfishes (*Menticirrhus americanus*) and striped mullets. The number of fish individuals is lowest in the colder months and highest in warm months (fig. 3.2). A large pulse is clearly visible from April to September, followed by a decline in October. The average size of fishes is another aspect of population structure related to seasonality (table 3.2).

Inland silversides and bay anchovies also have the highest ubiquity in the South Beach collection, followed closely by southern kingfishes and striped mullets (table 3.6). The ubiquity of fishes collected per quarter from South Beach has a distinctly seasonal pattern (table 3.7). Average ubiquity is highest in summer, followed by fall, spring, and winter. Species diversity on South Beach is highest in the spring collection and lowest in the fall collection (fig. 3.5). Summer and winter are the only seasons that show significantly different diversity in the modern data (table 3.8).

Cumberland Sound data represent fish seasonality in a back-barrier location. The stations near Kings Bay are the most productive areas in terms of fish abundance and biomass (fig. 3.6; DEIS, 1978: D-436, D-448–451, D-456). This may reflect the abundance of food and other nursery characteristics in these shallow waters.

Cumberland data show seasonal pulses in the number of fish individuals as fishes in different parts of their life cycles migrate in and out of the sound (fig. 3.7; DEIS, 1978: D-437, D-448–451). Large numbers of fish are uniformly distributed during summer and fall though they concentrate in shallow waters near shore in the summer and in midchannel locations in the fall. In winter, fish are more abundant in the warmest, deepest parts of the estuary. Many of the species present in winter are year-round residents, but other taxa leave the estuary altogether. In spring, fish abundance is greatest near freshwater creeks. The number of fishes present in the estuary, however, is lowest during the colder months.

This does not convey the complexity of fish behavior because habitat preferences change as individuals mature. Members of each age cohort have distinct habitat and niche preferences, which change as animals mature during the annual cycle. Most juveniles are more tolerant of estuarine conditions than are most adults, which prefer more stable offshore waters. Larger, more mature fishes are present in fall collections, and dominate winter ones, because juveniles have left to mature elsewhere. Spring collections contain young of the year, in addition to larger individuals. The annual influx of juveniles reduces the average weight per fish in each sample. Juveniles grow larger as they mature, thereby increasing the average weight per individual. Thus, the average weight per fish is highest in winter samples, declines in spring and summer samples, and is lowest in fall samples (DEIS, 1978: D-480–481).

The spawning cycle and use of Cumberland Sound by juvenile fishes are reflected in changes in the average weight of fishes (biomass) during the year at specific locations (fig. 3.8; DEIS, 1978: D-458, D-474–475, D-477–478). Changes in biomass have a general association with the seasonal movement of adult and juvenile fishes in and out of the estuary. During summer, fish biomass is distributed throughout the estuary, but concentrated at the mouth of the estuary and near the confluence of two freshwater rivers. In fall the greatest concentration of biomass is in and near Kings Bay, which is also where penaeid shrimp are abundant. The concentration of fish biomass around Kings Bay also reflects the influx of juvenile fishes into this shallow part of the estuary.

Community structure in the summer and fall is essentially the same, but somewhat different from that in spring and very different from that in winter (DEIS, 1978: D-492; see also, Dahlberg and Odum, 1970). Larger fishes, more mature ones, are present in fall (DEIS, 1978: D-523). Larger fishes are much more common in winter, when small juveniles have left the area

TABLE 3.7
Seasonal Ubiquity of Fishes Collected from South Beach

Common name	Scientific name	Winter	Spring	Summer	Fall	Average
Inland silverside	*Menidia beryllina*	1.00	0.96	0.96	0.92	0.96
Bay anchovy	*Anchoa mitchelli*	0.84	0.92	0.96	0.92	0.91
Southern kingfish	*Menticirrhus americanus*	0.80	0.85	0.96	0.96	0.89
Striped mullet	*Mugil cephalus*	0.88	0.58	0.88	0.92	0.81
Striped killifish	*Fundulus majalis*	0.52	0.69	1.00	0.67	0.72
Florida pompano	*Trachinotus carolinus*	0.20	0.50	1.00	1.00	0.68
Red drum	*Sciaenops ocellatus*	0.52	0.42	0.46	0.33	0.43
Striped anchovy	*Anchoa hepsetus*	0.16	0.38	0.65	0.50	0.42
Silver perch	*Bairdiella chrysoura*	0.64	0.46	0.19	0.33	0.41
Atlantic bumper	*Chloroscombrus chrysurus*	0.00	0.08	0.73	0.50	0.33
Hardhead catfish	*Ariopsis felis*	0.04	0.31	0.62	0.25	0.30
Spot	*Leiostomus xanthurus*	0.24	0.19	0.42	0.33	0.30
Star drum	*Stellifer lanceolatus*	0.36	0.31	0.35	0.17	0.30
Gulf kingfish	*Menticirrhus littoralis*	0.28	0.27	0.31	0.29	0.29
Bluefish	*Pomatomus saltatrix*	0.08	0.42	0.35	0.13	0.24
Average ubiquity		0.44	0.49	0.66	0.55	

TABLE 3.8
Comparison of Archaeological and Modern South Beach Fish Diversity

Comparison	Diff. of means	t	*P* value	Critical level	Significant?
Archaeological vs. South Beach winter	1.030	4.54	<0.001	0.005	Yes
Archaeological vs. South Beach spring	0.824	3.52	0.002	0.006	Yes
South Beach summer vs. South Beach winter	0.912	3.05	0.005	0.006	Yes
South Beach summer vs. South Beach spring	0.697	2.33	0.028	0.007	No
Archaeological vs. South Beach fall	0.377	1.57	0.133	0.009	No
South Beach fall vs. South Beach winter	0.593	1.98	0.059	0.01	No
South Beach fall vs. South Beach spring	0.377	1.26	0.219	0.013	No
South Beach summer vs. South Beach fall	0.320	1.07	0.296	0.017	No
South Beach spring vs. South Beach winter	0.215	0.72	0.478	0.025	No
Archaeological vs. South Beach summer	0.127	0.52	0.612	0.05	No

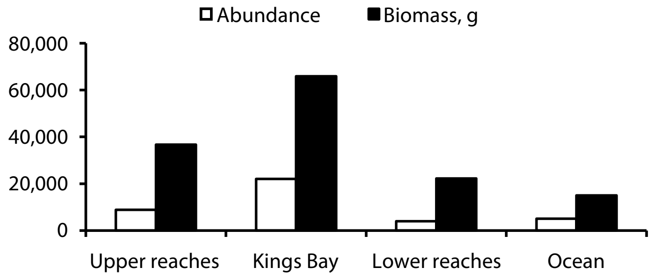


Fig. 3.6. Abundance and biomass values for Cumberland Sound (DEIS, 1978: D-456). Upper reaches include data from stations A, B, and C; Kings Bay includes data from stations X, D, E, and F; lower reaches include data from stations G, K, N, and O; ocean includes data from stations P, Q, R, and S; shown on fig. 3.4. Data from DEIS (1978: D-456).

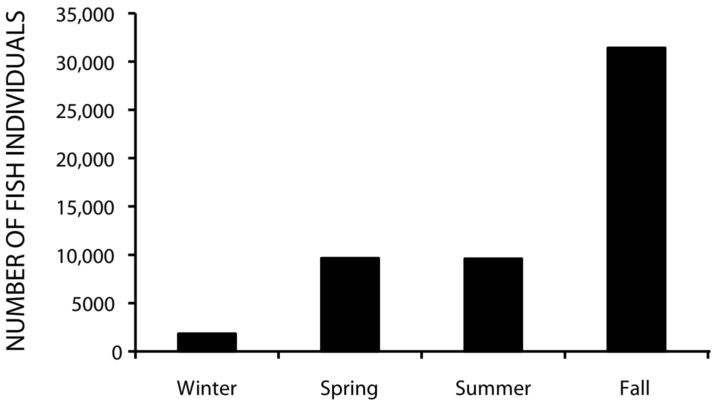


Fig. 3.7. Overall abundance for Cumberland Sound (DEIS, 1978: D-437).

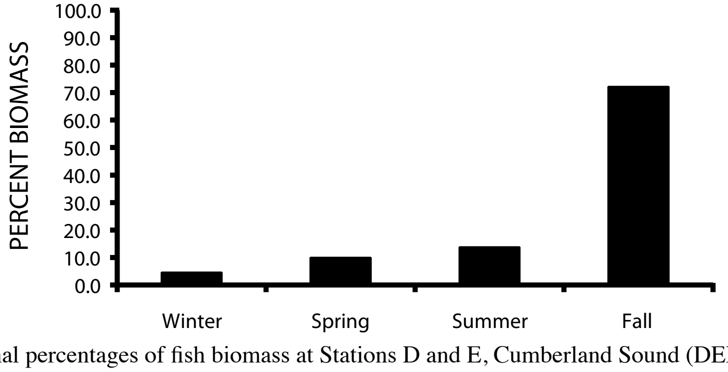


Fig. 3.8. Seasonal percentages of fish biomass at Stations D and E, Cumberland Sound (DEIS, 1978: D-458).

to mature elsewhere. In spring, larger fishes are joined by small individuals, probably young of the year. The annual influx of juveniles reduces the average weight per fish; as these mature and grow larger the average weight increases. Thus, the average weight of individual fish is highest in winter (10.9 g/fish), declines in spring (4.7 g/fish) and summer (3.5 g/fish), and is lowest in fall (2.8 g/fish). Many of the species present in winter are year-round residents (DEIS, 1978: D-483).

Diversity has a seasonal pattern as fishes respond to spawning cycle, salinity, water depth,

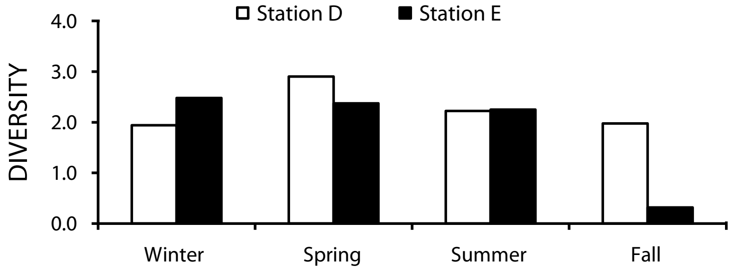


Fig. 3.9. Seasonal variations in fish diversity at Stations D and E, Cumberland Sound (DEIS, 1978: D-489).

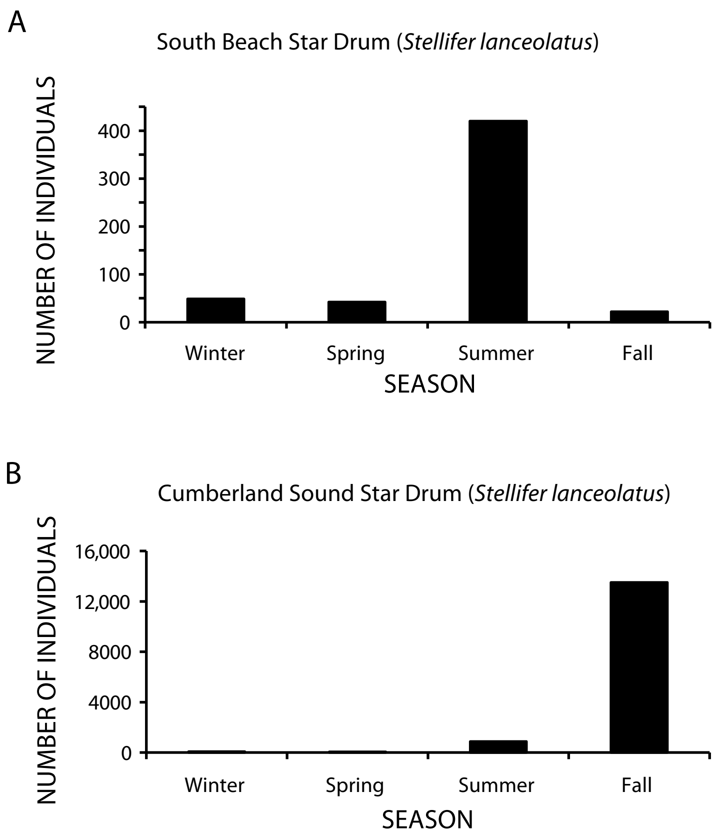


Fig. 3.10. Abundance of star drum (*Stellifer lanceolatus*) individuals per season: (A) South Beach and (B) Cumberland Sound collections. Cumberland Sound data from DEIS (1978: D-439, D-441, D-443, D-445).

and water temperature (fig. 3.9; DEIS, 1978: D-484–489). Although the nursery aspects of the estuary are complex, there is a relationship between diversity and the spawning cycle. Young fishes enter estuaries for the nursery aspects, adults enter to feed and spawn, and both adult and newly mature fishes leave for inshore and offshore waters. During summer and fall, the highest diversities are found in areas with the lowest salinity values. This does not hold true for winter, when water temperatures decline and fishes move from shallower waters into deeper, warmer areas. In spring, both low and high salinity areas have high species diversity, though estuarine waters may be too cool for some species, which remain offshore in warmer waters.

Modern data from South Beach and Cumberland Sound have different patterns of seasonal abundance (figs. 3.2, 3.7). Although these differences could be the result of different modern catch technologies used in the South Beach and Cumberland Sound studies, they also can be explained by differences in habitat sampled. It is likely that the more exposed, higher-salinity South Beach location represents a portion of life cycles of high-ubiquity fishes that is less common in Cumberland Sound. This difference may reflect the seasonal migration of fishes into and out of the back-barrier reaches lying between sea islands and the mainland as part of their growth and reproduction cycles. Star drums (*Stellifer lanceolatus*) are most abundant in the South Beach catch in the summer (fig. 3.10A), but they are most abundant in the Cumberland Sound catch in the fall (fig. 3.10B; DEIS, 1978: D-438–447, D-459–473), for example. We use star drums in this example because they constitute 27% of fishes individuals captured in Cumberland Sound and 15% of the biomass in Cumberland Sound. They are the most abundant species in Dahlberg and Odum's (1970) study of Sapelo and St. Catherines sounds and have an archaeological ubiquity of 0.84. This is always a small-bodied fish (TL range 7.5–102.5 mm) despite indeterminate growth (table 3.2; Dahlberg and Odum, 1970).

Dahlberg and Odum (1970) elaborate upon the seasonal aspect of fishes in the back-barrier areas. They report that 29 of the 70 fish species "were collected at estuarine stations in all seasons or at least in both winter and summer" (Dahlberg and Odum, 1970: 384). Only eight of the 20 species were restricted to the colder months and seven species were collected only in warmer months. Seasonal trends are most pronounced in the sounds and least in the upper marsh creeks (Dahlberg and Odum, 1970). Dahlberg and Odum (1970) do not report significant differences in diversity of fishes in sounds and tidal creeks behind St. Catherines Island, however. They did not specifically sample habitats for the smaller fish species (e.g., silversides, mummichogs, and mullets), or sample the seaward beach on the island.

Well-versed anglers understand these changes in fish behavior, as well as the accompanying variations in potential capture rates. Today, fishing strategies take advantage of local knowledge of seasonal patterns, derived from decades of experience, oral traditions passed down through generations, and experts such as boat captains, guides, and recreational fishermen (Murray, Neis, and Johnsen, 2006). These insights are used for subsistence, economic gain, and recreation (Matthews, 1928; McClanahan and Cinner, 2008). Such local knowledge undoubtedly informed earlier fishing strategies in the Georgia Bight and can be used to develop current and historical conservation management plans (Murray, Neis, and Johnsen, 2006; Silvano et al., 2006; McClanahan and Cinner, 2008).

Archaeological Data

A total of 6912 fish individuals representing 72 taxa are present in the archaeological collections (table 3.9). The most ubiquitous fishes (≥ 0.83) are, in order of ubiquity: seatrouts (*Cynoscion* spp.), mullets, gars (*Lepisosteus* spp.), Atlantic croakers (*Micropogonias undulatus*), hardhead catfishes (*Ariopsis felis*), gafftopsail catfishes (*Bagre marinus*), flounders (*Paralichthys* spp.), red drums, and star drums. The sea catfish family is as ubiquitous as seatrouts (1.0), but the archaeological reports of St. Simons Cannon's Point and West rings and Bourbon Field record these taxa at the family level, reducing the ubiquity of the two species.

Comparison

Most high-ubiquity fishes in the modern South Beach collection also are present in Georgia Bight archaeological collections (fig. 3.11). The taxa in figure 3.11 are arranged in order of their ubiquity in the South Beach collection. The taxa labeled 1, 2, and 8 are small-bodied fishes (*Menidia beryllina, Anchoa mitchelli, Anchoa hepsetus*) that could be discriminated against by site formation processes or during archaeological excavations.

TABLE 3.9

Ubiquity of Fishes Identified in Some Georgia Bight Archaeological Collections[a]

		Sapelo Ring III	St Cat	Mc-Queen	Marsh Ring	West Ring	Ribault	FOY A	Cathead Ck	Kings Bay	Ke-nan	Bour-bon	Cat-head Ck	Kings Bay	JEA	FOY SJ	MHF	Back Ck	EPC	Pueb-lo	
		Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Sw Creek	Sw Creek	Sav	Sav	Sav	Sav	Sav	SJ	Irene	Irene	17th c	17th c	
Richness	71	21	31	36	25	16	26	11	19	27	15	19	16	26	16	27	7	26	16	14	
Taxon	Ubiq-uity																				Total
Cynoscion spp.	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Mugil spp.	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Lepisosteus spp.	0.95		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Micropo-gonias undulatus	0.89	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	17
Ariopsis felis	0.84	1	1	1			1	1	1	1	1		1	1	1	1	1	1	1	1	16
Bagre mari-nus	0.84	1	1	1			1	1	1	1	1		1	1	1	1	1	1	1	1	16
Paralichthys spp.	0.84	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1	1		16
Sciaenops ocellatus	0.84	1	1	1	1	1	1		1	1	1	1		1	1	1		1	1	1	16
Stellifer lanceolatus	0.84	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1		16
Archosargus probato-cephalus	0.79	1	1	1		1	1	1		1	1	1		1	1	1		1	1	1	15
Clupeidae	0.79	1	1	1	1	1	1		1	1	1	1	1	1	1	1		1			15
Pogonias cromis	0.79		1	1	1	1	1	1	1		1	1	1	1		1		1	1	1	15
Bairdiella chrysoura	0.74	1	1	1	1	1	1		1	1		1	1	1		1		1	1		14
Leiostomus xanthurus	0.68	1	1	1	1	1	1			1		1	1	1	1	1		1			13
Ariidae	0.47				1	1			1	1	1	1		1				1		1	9
Elops saurus	0.47		1	1	1	1	1			1	1					1		1			9

TABLE 3.9 — (*Continued*)

		Sapelo Ring III	St Cat	Mc-Queen	Marsh Ring	West Ring	Ribault	FOY A	Cathead Ck	Kings Bay	Ke-nan	Bour-bon	Cat-head Ck	Kings Bay	JEA	FOY SJ	MHF	Back Ck	EPC	Pueb-lo	
		Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Sw Creek	Sw Creek	Sav	Sav	Sav	Sav	Sav	SJ	Irene	Irene	17th c	17th c	
Richness	71	21	31	36	25	16	26	11	19	27	15	19	16	26	16	27	7	26	16	14	
Taxon	Ubiq-uity																				Total
Menticirrhus spp.	0.47	1	1	1	1		1			1				1		1		1			9
Pomatomus saltatrix	0.42		1	1	1					1		1		1		1		1			8
Rajiformes	0.42						1		1	1	1	1	1	1	1						8
Carangidae	0.32			1	1	1	1							1				1			6
Carcharhini-dae	0.32		1				1	1				1		1						1	6
Ictalurus spp.	0.32						1		1	1			1	1	1						6
Opsanus sp.	0.32	1	1	1	1											1		1			6
Amia calva	0.26		1	1	1				1				1								5
Anguilla rostrata	0.26	1	1	1			1											1			5
Cyprinodon-tidae	0.26	1	1	1	1													1			5
Dasyatidae	0.26	1	1	1					1							1					5
Fundulus sp.	0.26								1	1			1	1			1				5
Lagodon rhomboides	0.26		1	1	1		1											1			5
Peprilus spp.	0.26	1		1						1				1		1					5
Ameiurus sp.	0.21		1	1	1													1			4
Dasyatus spp.	0.21											1	1						1	1	4
Myliobatidae	0.21		1		1	1		1													4
Belonidae	0.16			1			1											1			3
Brevoortia spp.	0.16						1			1				1							3
Chloroscom-brus chrysurus	0.16									1				1		1					3

TABLE 3.9 — (*Continued*)

		Sapelo Ring III	St Cat	Mc-Queen	Marsh Ring	West Ring	Ribault	FOY A	Cathead Ck	Kings Bay	Ke-nan	Bour-bon	Cat-head Ck	Kings Bay	JEA	FOY SJ	MHF	Back Ck	EPC	Pueb-lo	
		Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Sw Creek	Sw Creek	Sav	Sav	Sav	Sav	Sav	SJ	Irene	Irene	17th c	17th c	
Richness	71	21	31	36	25	16	26	11	19	27	15	19	16	26	16	27	7	26	16	14	
Taxon	Ubiq-uity																				Total
Chondrich-thyes	0.16														1	1				1	3
Citharichthys spp.	0.16	1	1	1																	3
Orthopristis chrysoptera	0.16	1		1														1			3
Chaetodip-terus faber	0.11			1												1					2
Diodontidae	0.11						1					1									2
Eleotridae	0.11											1				1					2
Galeocerdo cuvier	0.11				1														1		2
Ictaluridae	0.11		1													1					2
Prionotus sp.	0.11	1			1																2
Acipenser spp.	0.05															1					1
Carcharhi-nus spp.	0.05																		1		1
cf. Chlo-roscombrus chrysurus	0.05									1											1
cf. Lamnidae	0.05																		1		1
Chaenobryt-tus gulosus	0.05		1																		1
Cyprinidae	0.05																	1			1
Esox spp.	0.05								1												1
Larimus fasciatus	0.05			1																	1

TABLE 3.9 — (*Continued*)

		Sapelo Ring III	St Cat	Mc-Queen	Marsh Ring	West Ring	Ribault	FOY A	Cathead Ck	Kings Bay	Ke-nan	Bour-bon	Cat-head Ck	Kings Bay	JEA	FOY SJ	MHF	Back Ck	EPC	Pueb-lo	
		Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Ar-chaic	Sw Creek	Sw Creek	Sav	Sav	Sav	Sav	Sav	SJ	Irene	Irene	17th c	17th c	
Richness	71	21	31	36	25	16	26	11	19	27	15	19	16	26	16	27	7	26	16	14	
Taxon	Ubiq-uity																				Total
Lepomis spp.	0.05		1																		1
Lobotes suri-namensis	0.05													1							1
Menticirrhus americanus	0.05		1																		1
Menticirrhus saxatilis	0.05									1											1
Odontaspis taurus	0.05																		1		1
Ophidiidae	0.05			1																	1
Peprilus paru	0.05			1																	1
Raja eglan-teria	0.05			1																	1
Rhinoptera bonasus	0.05			1																	1
Sardinella sp.	0.05						1														1
Sciaenidae	0.05																			1	1
Serranidae	0.05															1					1
Sparidae	0.05														1						1
Sphyrna sp.	0.05				1																1
Symphurus spp.	0.05			1																	1
Trichiurus lepturus	0.05									1											1
Trinectes spp.	0.05									1											1
Fish MNI		176	1121	1112	318	235	126	23	64	1672	231	398	61	853	157	204	32	334	75	54	7246

[a]See table 3.1 for references.

However, taxon 5 is also a small-bodied fish (killifish, *Fundulus majalis*) and taxon 3 (southern kingfish) is generally a large fish when found in Georgia Bight archaeological collections. Mullets, taxon 4, are often small-bodied fishes in archaeological collections (e.g., Colaninno 2010: 51); though they grow to much larger sizes as adults, the larger size is more typical of Hispanic collections from sites further south, such as those from St. Augustine, than they are of pre-Hispanic collections. Mullets in many coastal archaeological collections are about the size of taxa 1, 2, 5, and 8, which are absent or rare in archaeological collections. Thus, recovery technique is not the only explanation for this pattern.

Instead, it appears that many of the fishes most ubiquitous in the South Beach collection are animals less commonly used in the past; supporting our premise that fishing was highly selective; fishes with lower modern ubiquity were favored over fishes with higher modern ubiquity by earlier fishing strategies. This conclusion is underscored by taxon 23. Taxon 23 is gar, a fish found in 95% of the archaeological collections

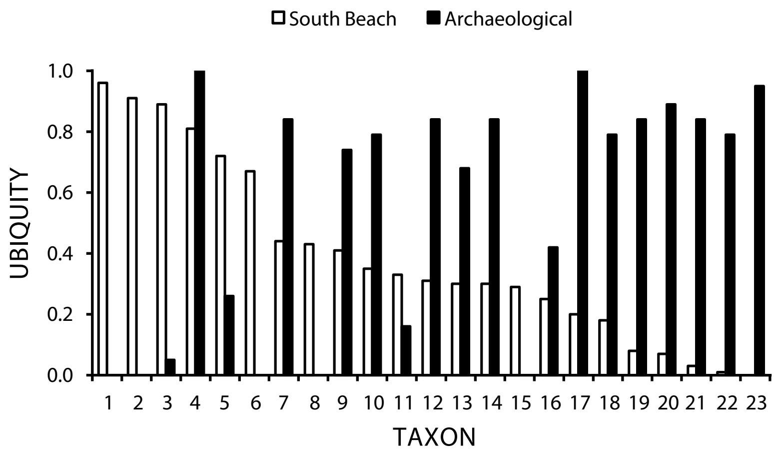


Fig. 3.11. Comparison of South Beach and archaeological fish ubiquity. **1,** *Menidia beryllina;* **2,** *Anchoa mitchelli;* **3,** *Menticirrhus americanus;* **4,** *Mugil cephalus;* **5,** *Fundulus majalis;* **6,** *Trachinotus carolinus;* **7,** *Sciaenops ocellatus;* **8,** *Anchoa hepsetus;* **9,** *Bairdiella chrysoura;* **10,** Clupeidae; **11,** *Chloroscombrus chrysurus;* **12,** *Ariopsis felis;* **13,** *Leiostomus xanthurus;* **14,** *Stellifer lanceolatus;* **15,** *Menticirrhus littoralis;* **16,** *Pomatomus saltatrix;* **17,** *Cynoscion* spp.; **18,** *Pogonias cromis;* **19,** *Bagre marinus;* **20,** *Micropogonias undulatus;* **21,** *Paralichthys* spp.; **22,** *Archosargus probatocephalus;* **23,** *Lepisosteus* spp.

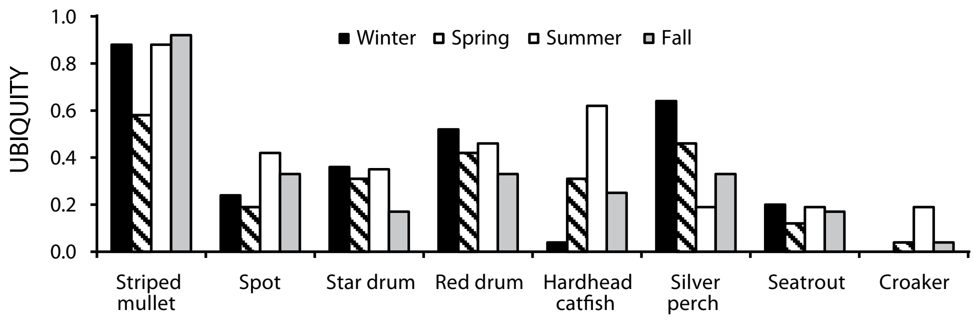


Fig. 3.12. Seasonal ubiquity of selected fish taxa in the South Beach collection.

from every time period and every location within the Georgia Bight. Gars are absent in the South Beach catch and rare in the Cumberland catch. Perhaps the conclusion to be drawn from figure 3.11 is that people did not often fish on the seaward side of barrier islands, where gars are rare or absent, but they did fish often in back-barrier locations, where longnose gars (*Lepisosteus osseus*) are found throughout the year (Dahlberg, 1972). It also is possible that this difference is a reflection of the lower freshwater input at St. Catherines, or may be an indication that more freshwater habitats once existed between St. Catherines Island and the mainland and on the island itself, particularly if the island once extended further east than it does today.

Figure 3.12 shows the present-day seasonal ubiquity of eight fishes with high ubiquity in either the modern South Beach (≥ 0.30) or archaeological (≥ 0.68) collections. The first observation is that all but one of these fishes is present throughout the year; the primary pattern is a seasonal shift in relative ubiquity. The standard seasonal markers that may be used elsewhere fail in this context. The second observation is that some fishes are more ubiquitous than are others during one or more season. Mullet, red drums, and star drums are unlikely to be helpful as seasonal markers, whereas hardhead catfishes might be strong markers for warmer waters and silver perches (*Bairdiella chrysoura*) moderately strong markers for cooler waters. Similar ubiquity data are not available for Cumberland Sound but most taxa with ubiquity ≥ 0.68 in the archaeological record are present during at least three, if not four, of the seasons at Station E in the Kings Bay area (fig. 3.13; DEIS, 1978: D438–D445).

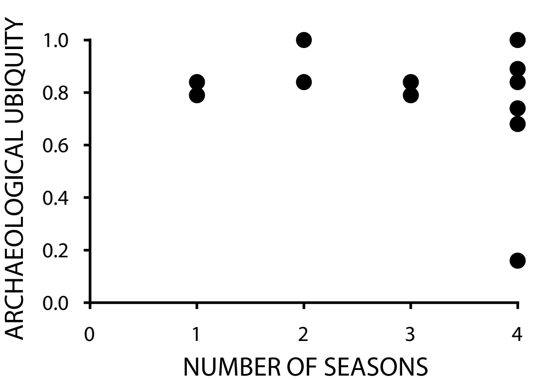


Fig. 3.13. Number of seasons in which fishes with archaeological ubiquity ≥ 0.68 are present at Station E, Cumberland Sound (DEIS, 1978: D-438–D-445).

Species diversity of archaeological data (H' = 2.06) is significantly higher than modern South Beach data (H' = 1.48). Diversity of the archaeological collections is significantly different than the diversity of modern winter and spring South Beach collections, but not when compared with the fall and summer samples (table 3.8; fig. 3.5).

DISCUSSION

The purpose of this chapter is to consider evidence for season of availability in modern fishes as a means of clarifying season of activity and location for people living in the Georgia Bight in the past. Although this study focuses on those fishes that form the core of the Georgia Bight fishery, many other organisms, including fungi, plants, invertebrates, reptiles, mammals, and birds, supplemented these fishes. This flexible subsistence strategy is reflected in a moderate vertebrate diversity (H' = 2.890, MNI) and high vertebrate equitability (V' = 0.841, MNI) before the advent of the First Spanish period in A.D. 1565 (Reitz et al., 2010: 63, 72, 233–234).

In this study, modern data show clear seasonal patterns in the availability of fishes. Characteristics such as abundance, biomass, diversity, dominance, distribution, ubiquity, and body size, however, are relative rather than absolute and may depend on location and gear as much as on season. Organisms characteristic of estuaries are those best able to withstand the biogeochemical and hydrological conditions that define estuaries. Resource seasonality does occur in the Georgia Bight, but many fishes identified in archaeological collections are present somewhere in estuarine waters throughout the year, depending on whether they are young fishes using estuaries as nurseries or adults using them as feeding grounds.

Fishing in the Georgia Bight was highly selective, focused specifically on a core group of indicator taxa that occupy estuarine waters throughout the year. Many of these core fishes either school or form large aggregations, making them susceptible to mass-capture techniques (Reitz, Quitmyer, and Marrinan, 2009; Reitz et al., 2010: 234–237). These same high-ubiquity, core fishes generally are not high-ubiquity taxa in standard fishing samples taken under modern conditions, however. Although this may be strong evidence that major environmental changes in estuarine ecosystem functions have occurred, it is also true that the ability of ecological analogies using fish presence and ubiquity to provide answers to questions of season of human activity and location is limited. The answer to season of availability, however, is that taxa in the core fishing group were available somewhere in the upper or lower reaches of the estuary throughout the year.

Difficulties in correlating resource availability with the synchronic biogeochemical and hydrological properties that define seasons are compounded by diachronic changes in the niche and habitat preferences of fish individuals as they mature. Age cohorts are mobile and seek out preferred environmental properties throughout the estuary and beyond during an annual cycle. This produces patterns such as those observed in the mean total length of star drum on South Beach (fig. 3.14). Mean total length of this small fish increases substantially in the fall, as mature individuals leave the estuary, even as their abundance decreases (fig. 3.12). Young fishes are more tolerant of estuarine conditions than are most adult fishes. Combining presence data with measurements of fishes may be more productive than presence and ubiquity analysis in assessing season of availability by considering the seasonal aspects of age cohorts, though one would still need to know location of capture for larger and smaller fishes and the influence of gear on this evidence for season of availability.

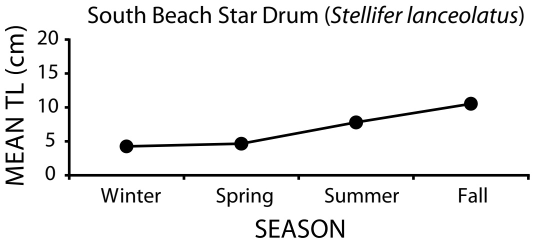


Fig. 3.14. Seasonal aspects of mean total length (in cm) of star drum (*Stellifer lanceolatus*) in the South Beach collection.

Modern studies suggest that shallow, warm, low-energy waters with salinity and nutrient levels typical of middle and upper reaches were preferred fishing grounds. Beaches were used less frequently than were back-barrier areas. Although modern data clearly indicate when and where fishing would be productive today, it is unlikely that these precise locations were equally productive in the past because the topography of each estuary probably has changed. Identifying specific places where fishing occurred is unlikely.

Where fishing took place and the gear used undoubtedly changed during the annual cycle given the different locations the most ubiquitous fishes occupy within estuaries during the year. Fishing, likely using watercraft, probably followed the preferred, targeted fish taxa within each estuary (e.g., Ames, 2002). The distances are not great, probably no more than 10–12 km depending on where the fishing party started and where it was going. We suggest "party" intentionally because many ubiquitous fishes are susceptible to technologies such as weirs and nets that are most effective in shallow waters where tidal ranges are large enough to overtop the enclosure at high tide. Such facilities usually require several people to work and frequent repairs, but the labor of people of all ages and abilities would be useful. Although the distance from most places on St. Catherines Island to daily or annually productive fishing grounds would not have been great, fishing parties would have to be mindful of going against strong incoming or outgoing tides.

Embedded in the archaeological literature is the assumption that coastal life is difficult and coastal residence must be forced upon people by necessity (for reviews of these perceptions see Erlandson, 2001 and Ames, 2002). Despite Monks (1981) admonition that residential patterns are not clearly related to season of availability, it is typically presumed that people lived on the coast only during the warmer months, residing elsewhere during the remainder of the year. The assumption that fishing communities must be mobile fundamentally links season of availability with season of location. Thus resource availability, subsistence schedules, residential habits, political institutions, and social complexity are merged in many models. Residential patterns themselves are often reduced to a dichotomy of mobility on the one hand and sedentism on the other, as though these were mutually exclusive options. As Bar-Yosef and Rocek (1998: 1, italics theirs) argue: "The fact is *all* societies have a mobility component; the issue is what the form of that mobility is, not whether it exists." As with most cultural institutions, the forms, causes, and consequences of resource acquisition and residential patterns are diverse.

Interpretations of coastal life labor under a particularly inflexible assumption that a farming subsidy is required to support people throughout an annual cycle or to support complex social institutions. Although it has been demonstrated repeatedly that nonfarmers with complex social institutions did exist in coastal settings (e.g., Kennett and Kennett, 2000; Builth, 2006), the question remains unresolved in the minds of many. A quarter of all the fish taxa present in Georgia Bight archaeological collections is present in over 60% of the collections, regardless of whether the site is an Archaic shell ring or a 17th-century Spanish mission. This suggests that the kinds of fish, though perhaps not the technology, have been little altered over the centuries, regardless of the cultural matrix of which fishing was but one aspect (Reitz, 2004). This is not to suggest that there were no changes either in the resource base or in the cultural use of that base; we know that there were. Throughout the period, however, fishing was a major and consistent aspect of daily life; drawing upon the ability of both the fishes in the core group and people to be flexible in an environment that changes with each tide.

A suite of concepts draws upon human behavioral ecology, specifically optimal foraging theory, to interpret fishing strategies (e.g., Habu, 2002; Ugan, 2005; Winterhalder and Kennett, 2006; Culleton, Kennett, and Jones, 2009). In archaeological applications, these concepts are important because it is essential to distinguish between anthropogenic and nonanthropogenic impacts on biological resources to assess causality in environmental change and resilience in specific fisheries, important issues in conservation biology and fisheries management (e.g., Butler and Delacorte, 2004; Broughton, 2010).

Among these concepts are those that distinguish between subsistence-settlement systems of foragers and collectors (e.g., Binford, 1980; Bettinger, 1991: 68; Habu and Fitzhugh, 2002; Broughton, 2010). Although "forager" is often used as a substitute for "hunter-gatherer," in many optimal foraging models foraging forms one end of a continuum with collecting at the other end. When used in this sense, foraging systems are said to occur in areas with high productivity and resources that are seasonally and spatially homogeneous. Collector systems occur in areas with low productivity and resources that are seasonally or spatially uneven. Foragers acquire food each day near their residential base and are residentially mobile; all members move to another location when resources are judged to be inadequate. Such opportunistic foraging is only feasible if resources can be transported over a short distance. Collectors, on the other hand, implement planned, logistic strategies that may exploit resources over a larger area, usually produce larger yields, and are implemented by specialized task groups. Such logistically mobile collectors bring resources back to the residential base, where they may be stored. A foraging radius, therefore, is close to the base camp and a logistic/collecting radius is further away. Collectors, too, may move their residential bases seasonally, though storage may reduce the scope of this mobility. Coastal foragers, therefore, should be characterized by low logistical mobility and high residential mobility and coastal collectors by high logistical mobility and low residential mobility.

Some research in coastal settings, however, suggests that considerably more flexibility and variety than a simple dichotomy between foragers and collectors characterize fishing in such areas (Ames, 2002; Habu, 2002; Habu and Fitzhugh, 2002; Butler and Campbell, 2004). Fishing in the Georgia Bight appears to be another example not easily accommodated in either of these models. Generalizing broadly, the Georgia Bight could be considered a high productive area with resources that are seasonally and spatially uneven.

The estuaries of the Georgia Bight are among the most productive and complex on the Atlantic coast, with about four times as much marsh per kilometer of coastline as other areas of the Atlantic seaboard (Schelske and Odum, 1961; Hayden and Dolan, 1979: 1063; Frey and Howard, 1986). Resources, however, are not seasonally or spatially homogeneous; they are spatially and temporally patchy in addition to being highly mobile in the case of vertebrates. Neither are they likely to be depleted within an annual cycle to such an extent that it would stimulate residential mobility because the fishery is renewed with each tidal cycle. It is entirely possible that the fishery could be, and was, depressed by overfishing or other drivers of long-term environmental change from time to time (e.g., Reitz, 2004; Quitmyer and Reitz, 2006; Reitz, Quitmyer, and Marrinan, 2009), but the broad features of the core fishing strategy persisted, nonetheless. A similar conclusion is reported for other fisheries (Butler and Campbell, 2004).

People likely did fish more or less each day and return the food to a residential base but are unlikely to have moved elsewhere if fishing deteriorated at a favored fishing ground; the distances on any of the islands or within estuaries would be well within the 30 km estimated for a coastal foraging radius (Ames, 2002). More likely the travel distance for fishing was much less throughout the year. It is entirely likely that fishing would be less productive at a specific location during the year given the preferences of fish age cohorts, populations, and communities for different locations during the annual growth and reproductive cycles of each species, but it is unlikely that all fishes in the core strategy would move so far away that they could not be reached from any residential base within most estuaries in the Georgia Bight. Likely only task groups were involved in each fishing foray. The potential exists for large quantities of fish to be taken, though storing fish may not have been appealing in this subtropical, humid region.

We suspect good places to build homes, secure water craft, shelter from wind and sand fleas, and dry nets might be limited and highly prized. These would be abandoned with great reluctance in response to such larger factors as a reconfiguration of the coastline after a storm, but not because of factors that are said to characterize either opportunistic foragers or logistical collectors.

Another key concept is the role of plant domestication. Plants and animals provide different types of nutrients. It is unlikely that a sustainable coastal economy was based exclusively on either plant or animal nutrients. Plants and animals also provide different types of raw materials and play different roles in social life. Thus, people living in the Georgia Bight, as broad-spectrum omnivores, undoubtedly used both plants and animals, some of which were terrestrial and some aquatic. When or whether some plants were at least tended if not domesticated is poorly known for the Georgia Bight, but eventually some domestic plants did enter the economy (see Scarry and Hollenbach, chap. 11, this volume). This does not appear to have altered the fishing strategy in any measurable way, though it may have impacted residential and fishing decisions as scheduling conflicts were resolved (e.g., Flannery, 1968).

Sarah Campbell and Virginia Butler (2010) argue that beliefs and social institutions (such as ownership, regulations, rituals, and monitoring) might foster resilience in coastal ecosystems. They report a 7500-year-long record of stability in a Pacific Northwest salmon fishery that may be evidence for the regulation of salmon fishing by cultural institutions in the region, thereby encouraging persistence in the fishery. A similar long-term fishery is seen in the Georgia Bight. It is probable that kin groups or other social units owned the rights to specific fishing grounds and the facilities constructed at each. We consider it unlikely that fishing networks would fail to safeguard their rights to such valuable assets, even during brief absences for social or economic reasons (e.g., Nishimura, 1975; Builth, 2006). The possibility that members of these fishing communities intentionally modified estuarine conditions to encourage a variety of estuarine plants and animals, much as they might manipulate habitats preferred by terrestrial organisms, is intriguing (e.g., Erickson, 2000; Builth, 2006; Campbell and Butler, 2010). As Butler and Campbell (2004: 373) report for Pacific coast salmon fishing, the core fishes in Georgia Bight archaeological collections are among the most widespread and abundant fish prey. Their role in the fishery persisted from ca. 2560 B.C. until the beginning of the First Spanish period, in fact, continuing to be prominent components of subsistence strategies in EuroAfrican colonial towns and plantations thereafter (Reitz, 1994; Reitz et al., 2010). This fishery undoubtedly experienced cycles of crisis and recovery, but it was sufficiently flexible and resilient to endure despite cultural and environmental changes over the millennia.

Other factors complicate studies of season of availability in the Georgia Bight. Many animals used in the past are available throughout the year at several different locations. Although they may move, reproduce, or grow seasonally, these details are difficult to determine from zooarchaeological observations such as taxonomic identifications, taxonomic frequencies, element distribution, measurements, age at sexual maturity, and season of death. Isotopic ratios and growth increments may demonstrate that an organism died during one part of the annual temperature or growth cycle; but not the contemporaneity of other sites that might be part of a seasonal round. Technologies and other aspects of subsistence strategies can leave vertebrate evidence that diverges widely from background resource bases, as seen in this study. Storage, production, and exchange systems could leave little unambiguous evidence at the site under study. Exchange networks within an extended family or on a broader scale have the purpose of rounding the shortfalls associated with poor weather, poor skills, and bad luck.

Estuaries are characterized by continuity and stasis rather than change in large part because of the inherent flexibility of organisms that use estuaries as nursery grounds. Such taxa could withstand significant exploitation, and alterations associated with top-down and bottom-up processes regardless of the cause. That many estuarine organisms are no longer able to maintain former population sizes and community structures, and now are in decline, should be cause for alarm among coastal resource managers.

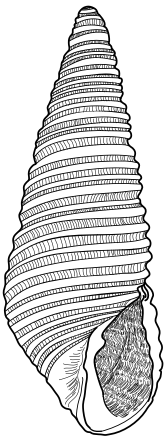
CONCLUSION

Estuarine fishes are attracted to back-barrier reaches as nursery grounds and feeding areas. The potential of estuaries to fill these roles varies seasonally. Our analysis indicates that the fish communities and populations forming the core fishing strategy into the 17th century are available in shallow waters throughout the year, albeit in different locations and probably vulnerable to different capture techniques. Seasonality in the Georgia Bight appears to be more a question of where and how rather than what or when.

In order to engender hope for determining season of activity and location, studies must combine observations for *communities* of organisms with information about the biogeochemical and hydrological properties preferred by ubiquitous taxa. Indicator groups are useful for studies such as the one in this chapter, however, syntheses of biotic, abiotic, and cultural data to form indicator packages are needed before we can address the questions of where and how. Indicator packages are difficult to develop and seldom achieved. The first step toward this goal is to ensure that a wide range of evidence is included in the research project through thoughtful fieldwork and multiproxy studies. The full suite of environmental studies should be performed with equal rigor at all sites that might be part of a seasonal round, exchange network, kin group, or other social unit to systematically explore how sites of different sizes and functions fit into the overall landscape, and how patterns of season, activity, and location change through time and space.

NOTES

1. We gratefully acknowledge the long-term research support of the Edward John Noble Foundation and the St. Catherines Island Foundation. We thank David Hurst Thomas, American Museum of Natural History, for his support of zooarchaeology on St. Catherines Island, the opportunity to study the St. Catherines Island animal remains, and for facilitating the publication of this issue of the American Museum of Natural History Anthropological Papers. Funding was provided in part by NSF Award No. BCS-1026167. Over 100 Augusta State University undergraduate students have helped with the St. Catherines Island sampling. We are grateful to them all even if we cannot list them by name. We are also grateful to the diverse group of archaeologists who provided the opportunities to study the vertebrate collections listed in table 3.1, particularly to Carol Colaninno-Meeks and Sarah Bergh for permission to use unpublished dissertation data. An earlier version of this paper was presented at the 75th annual meeting of the Society for American Archaeology, St. Louis.



CHAPTER 4
EVALUATING $\delta^{18}O$ PROFILES OF HARDHEAD CATFISH AND ATLANTIC CROAKER OTOLITHS AS A METHOD OF DETERMINING SEASONAL USE OF FISHES

CAROL E. COLANINNO[1]

Documenting seasonal resource use among human populations is a central aspect of archaeological research. For coastal locations of the southeastern United States, studies of seasonal resource use have focused on molluscs, and for good reason. Molluscs, including oysters (*Crassostrea virginica*) and hard clams (*Mercenaria* spp.), generally are abundant at these locations; there is a correlation between incremental formation and yearly, seasonal environmental oscillations; and shell $CaCO_3$ (calcium carbonate) precipitates in oxygen isotope equilibrium with the ambient water in which shell forms (Grossman and Ku, 1986; Quitmyer, Jones, and Arnold, 1997; Andrus and Crowe, 2000; Andrus and Crowe, 2008). This allows researchers to examine patterns in incremental formations and the ratio of stable oxygen isotopes ($^{18}O/^{16}O$, expressed as $\delta^{18}O$) at the terminal band and in prior bands to determine the season in which people captured the organism (Quitmyer, Hale, and Jones, 1985; Quitmyer, Jones, and Arnold, 1997; Andrus and Crowe, 2000, 2008; O'Brien and Thomas, 2008; Thompson and Andrus, 2011). These studies were instrumental in documenting year-round occupations, as well as locations used seasonally (Quitmyer, Jones, and Arnold, 1997; Andrus and Crowe, 2008; Thompson and Andrus, 2011).

Although oyster and hard clam studies are essential for characterizing seasonal resource use, they do so for only two organisms, oysters and clams. Zooarchaeological research at coastal southeastern sites shows that over a hundred different animals were used in the past, in addition to oysters and clams (Colaninno, 2010; Reitz et al., 2010: 54–57; Reitz et al., chap. 3, this volume). These resources include a diverse array of estuarine fishes along with numerous other aquatic and terrestrial animals. Investigating seasonal use of nonmolluscan taxa, particularly fishes, provides further information about past land and estuarine use patterns, resource intensification, and social complexity. It is an area of research that largely is unexplored in the southeastern United States.

This chapter examines seasonal use of two fish species: hardhead catfish (*Ariopsis felis*) and Atlantic croaker (*Micropogonias undulatus*). I examine $\delta^{18}O_{otolith}$ profiles of modern hardhead catfishes and Atlantic croakers to determine whether $\delta^{18}O_{otolith}$ profiles track seasonal temperature oscillations. Seasonal temperature oscillations observed in modern $\delta^{18}O_{otolith}$ are applied to archaeological $\delta^{18}O_{otolith}$ to determine past seasonal temperature oscillations and the season in which people captured these fishes. The archaeological otoliths are from four Late Archaic shell rings (2550–1500 cal B.C.) located on the Georgia coast: the Cannon's Point (9GN57) and West rings (9GN76) of St. Simons Island, and the St. Catherines (9Li231) and McQueen shell rings (9LIi648) of St. Catherines Island (fig. 4.1).

Shell rings are complex structures having intricate stratigraphic sequences representing multiple cultural and natural processes (Marrinan, 2010: 80; Sanger and Thomas, 2010: 55; Kennett and Culleton, chap. 2, this volume; Thompson and Andrus, 2011). Radiocarbon dates indicate that otoliths from the Cannon's Point Ring were deposited between 2760 ± 120 cal B.C. and 2200 ± 140 cal B.C. (Marrinan, 2010: 81). Dates from the West Ring indicate deposition between 2320 ± 120 cal B.C. and 1970 ± 160 cal B.C. (Marrinan, 2010: 81); however, dates were not obtained from locations where otoliths were sampled. Deposition from the location in which otoliths were sampled from the St. Catherines Shell Ring dates between 2580 and 1770 cal B.C. (Sanger and Thomas, 2010: 62). Dates from the McQueen Shell Ring suggest deposition between 2460 and 1850 cal B.C. (Sanger and Thomas, 2010: 63); however, materials were not dated from locations where otoliths were sampled.

METHODS

I chose hardhead catfishes and Atlantic croakers because their otoliths are ubiquitous in these four shell ring collections (Colaninno, 2010). Additionally, these two species have relatively large otoliths that are identifiable to species and easily handled.

Seasonal use of archaeological hardhead catfishes and Atlantic croakers is estimated by analyzing the seasonal variation recorded in $\delta^{18}O_{otolith}$ in relation to environmental oscillations. The original research design was to capture modern hardhead catfishes and Atlantic croakers each month for one year to ensure that $\delta^{18}O_{otolith}$ profiles track seasonal temperature fluctuations. Unfortunately, monthly fishing trips did not always result in the capture of a fish. To supplement the modern otolith study, I selected hardhead catfish and Atlantic croaker otoliths for isotopic analysis from individuals with known dates and locations of capture and biological measurements curated in the zooarchaeological comparative collection of the Georgia Museum of Natural History and the environmental archaeology program of the Florida Museum of Natural History. I analyzed 24 modern otoliths, 12 from each species (appendix 4.1).

I selected 42 archaeological otoliths for $\delta^{18}O$ analysis using several criteria. Archaeological otoliths first were examined for evidence of burning or leaching. These taphonomic processes affect $\delta^{18}O$ of preserved $CaCO_3$ (Andrus and Crowe, 2002). Additionally, only complete otoliths with lengths greater than 7.0 mm were selected because it is difficult to section smaller otoliths without destroying them. Otherwise, I sampled the full size range of otoliths in each archaeological collection. Only left otoliths of both archaeological and modern individuals were sampled. For the archaeological specimens this ensured that each otolith represents a different individual. Unfortunately, these criteria excluded many otoliths, and more otoliths were sampled from some shell rings than from others (appendix 4.2).

The archaeological otoliths were immersed in distilled water for 24 hours and then brushed with a nylon-polyester blend bristled toothbrush to remove adhering sediments from the exterior surface before they were cross-sectioned. I immersed the modern otoliths in 30% H_2O_2 solution for 12 hours and rinsed them in distilled water to remove organic contaminates. After all otoliths were cleaned, I cross-sectioned each otolith along the transverse plane through the center of the core with a Buehler Isomet low-speed diamond-wafering saw model 11-1280-160 to expose the otolith's cross section. I then attached each otolith section to a glass microscope slide with crystal bond, polished the otolith section to a flat surface, again rinsed the specimen with distilled water, and allowed each specimen to air dry completely.

Isotopic analysis of fish otoliths was conducted at the University of Alabama stable isotope laboratory with a New Wave/Merchantek micromill. Multiple drilling paths were interpolated across the cross-sectioned surface. Several drilling paths were sampled from some growth bands, depending on the size of the band. In some cases, however, growth bands were too small to drill a single isolated band and two bands were included in one drilling path sample. Drilling paths were spaced across the cross-sectioned surface of the otolith at regular intervals of approximately 0.1–0.2 mm. This method of drilling sampled growth bands through reserved ontogenic sequence; that is from the terminal edge through the core (all $\delta^{18}O_{otolith}$ are plotted through ontogeny in the figures). For hardhead catfish otoliths, I sampled the entire cross-sectioned surface (fig. 4.2). For Atlantic croaker otoliths, I sampled the medial surface (surface with sulcus) to the center core (fig. 4.3). I did not sample the lateral surface of Atlantic croaker otoliths because portions of the knobby texture on the lateral surface often were not present on archaeological specimens. The complete length, width, and medial surfaces were present on all studied otoliths. I noted the location of each drilling path within the otolith and within the growth band during isotopic sampling when

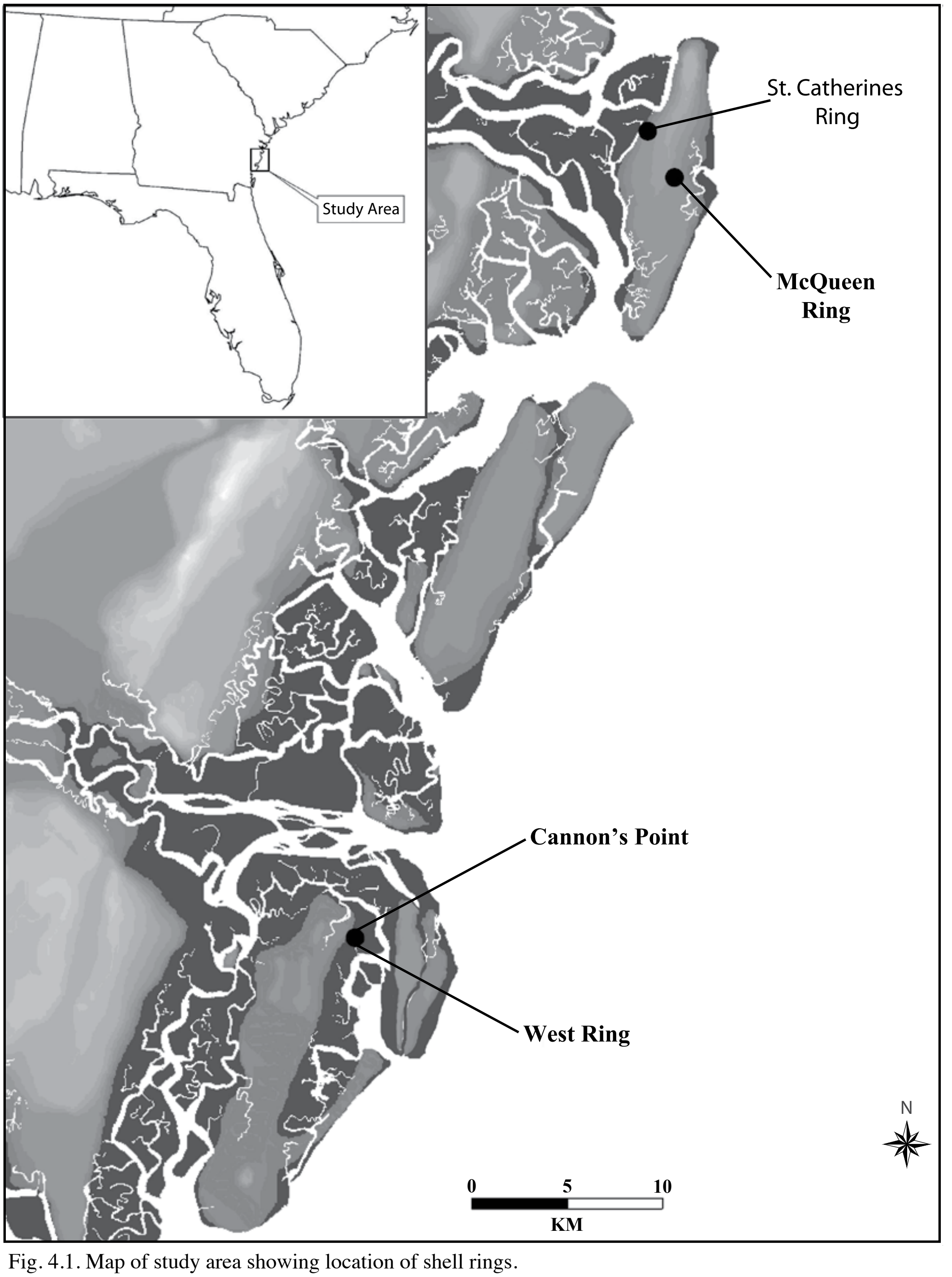


Fig. 4.1. Map of study area showing location of shell rings.

incremental bands clearly were definable and visible using the microscopic feature of the New Wave/Merchantek micromill.

Micromilling the sectioned surface of the otolith produced a powdered sample. I cleaned the microdrill with compressed air after every sample to prevent cross-contamination. These samples were exposed to phosphoric acid to generate CO_2 gases, which were processed by a Finnigan Mat Delta-E isotope ratio mass spectrometer. Working standards also were processed after every seventh sample to ensure precision and accuracy of the mass spectrometer.

Results of this analysis yielded raw oxygen isotopic signatures that were processed and reported in per mil (‰) units with respect to VPDB (Vienna Pee Dee Belemnite Standard). Precision was estimated and data were calibrated to VPDB through analysis of the NBS-19 standard. Precision ranges from 0.08‰ and 0.37‰. Averaged precision of all samples is 0.17‰ (1σ).

Temperatures (T) are calculated with $\delta^{18}O_{otolith}$ using the Grossman and Ku (1986) aragonite precipitation equation where T is temperature in degrees Celsius:

$$\delta^{18}O_{otolith\ (PDB)} = [(T-20.6/-4.34)] + \delta^{18}O_{water\ (SMOW)}.$$

I use several values for $\delta^{18}O_{water\ (SMOW)}$, which are stated in the various temperature estimates.

$\delta^{18}O_{otolith}$ FRACTIONATION FACTORS AND ESTUARINE ENVIRONMENTS

Otoliths precipitate in oxygen isotopic equilibrium with ambient waters in which the otolith forms (Devereux, 1967; Hoefs, 1997; Thorrold et al., 1997). $\delta^{18}O_{otolith}$ covaries with water temperature and $\delta^{18}O_{water}$. If $\delta^{18}O_{water}$ can be held constant, $\delta^{18}O_{otolith}$ can be used to estimate the water temperature in which the fish lived (Thorrold et al., 1997; Andrus et al., 2002). When $\delta^{18}O_{otolith}$ is plotted through ontogeny, seasonal temperature oscillations should be observed, and the $\delta^{18}O_{otolith}$ samples prior to and at the terminal edge of growth can determine the approximate temperature the fish experienced when it was captured.

For estuarine environments, such as those surrounding Georgia Sea Islands, $\delta^{18}O_{water}$ cannot be held constant and temperature calculations from $\delta^{18}O_{otolith}$ will not be the actual temperature. This is because inputs of fresh water, with lower salinities compared to sea water, alter $\delta^{18}O_{water}$. Estuaries are, by definition, areas of partly enclosed water with freshwater inputs. In some regions of the world, freshwater inputs are seasonal and $\delta^{18}O_{otolith}$ tracks these seasonal changes in salinity, which can indicate season of capture (Kennett and Voorhies, 1996). In other regions, freshwater influxes are erratic, complicating $\delta^{18}O_{water}$.

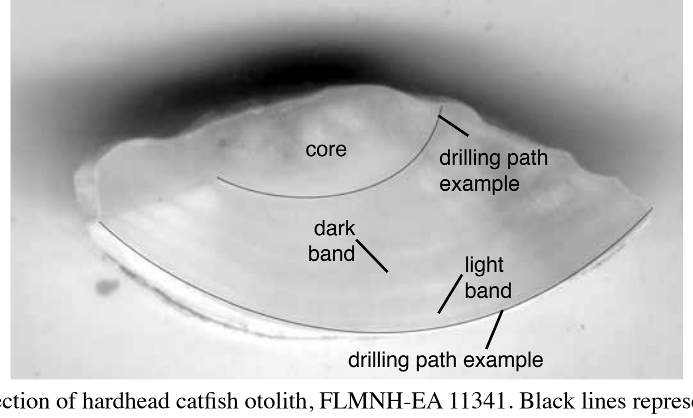


Fig. 4.2. Cross section of hardhead catfish otolith, FLMNH-EA 11341. Black lines represent drilling path examples for $\delta^{18}O$ sampling. Multiple drilling paths were taken from each otolith. For example, 28 drilling paths were sampled from FLMNH-EA 11341 across the entire surface of the otolith, within incremental bands.

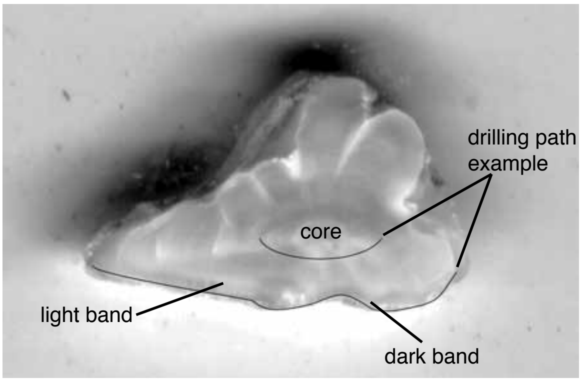


Fig. 4.3. Cross section of Atlantic croaker otolith, FLMNH-EA 11319. Black lines represent drilling path examples for $\delta^{18}O$ sampling. Multiple drilling paths were taken from each otolith. Nine drilling paths were sampled from FLMNH-EA 11319 across the medial surface (surface with sulcus) to the center core, within incremental bands.

To understand oscillations in $\delta^{18}O_{otolith}$, modern oscillations in temperature and salinity for Georgia estuaries must be considered. Water temperatures of Georgia estuaries (fig. 4.4) generally oscillate over a seasonal range of approximately 20°C (http://cdmo.baruch.sc.edu/ data from Marsh Landing, Sapelo Island water data year 2003; Andrus and Crowe, 2008). Warmest temperatures occur from June to August, and coolest temperatures occur from December to February (http://cdmo.baruch.sc.edu/ data from Marsh Landing, Sapelo Island water data year 2003; Andrus and Crowe, 2008). Freshwater inputs and salinity also vary, both spatially and temporally. Monthly average salinity generally ranges between approximately 16‰ and 31‰ (http://cdmo.baruch.sc.edu/ data from Marsh Landing, Sapelo Island, water data, years 1996 and 2003), although lower salinity values are reported (Thompson and Andrus, 2011). Unlike temperature oscillations, salinity does not vary seasonally and no regular salinity cycle is observed, apart from those associated with daily tidal cycles (fig. 4.4).

Unpredictable salinity fluctuations make accurate temperature estimations with $\delta^{18}O_{otolith}$ problematic. If $\delta^{18}O_{water}$ values can be held constant (e.g., seawater), $\delta^{18}O_{otolith}$ could accurately estimate temperatures. The $\delta^{18}O_{otolith}$ sample of the terminal increment combined with the sample just prior to the terminal increment could establish seasonal temperature fluctuations and the season in which people captured the fish. I demonstrate this using data from Andrus and Crowe (2008) and the Grossman and Ku (1986) aragonite precipitation equation. With recorded temperature, salinity, and a constant $\delta^{18}O_{water}$ value as the average water value of –0.9‰ from monthly collections, estimates of $\delta^{18}O_{otolith}$ are calculated (Andrus and Crowe, 2008).

As seen in figure 4.5, when $\delta^{18}O_{water}$ is held constant, $\delta^{18}O_{otolith}$ accurately reflects seasonal temperature oscillations. That is, the most enriched $\delta^{18}O_{otolith}$ would precipitate during coolest months, winter, while the most depleted $\delta^{18}O_{otolith}$ would precipitate during warmest months, summer.

Figure 4.5 models the ideal circumstance for using $\delta^{18}O_{otolith}$ to estimate season of capture, but this does not occur in estuarine waters of the Georgia coast. $\delta^{18}O_{water}$ fluctuates due to both seasonal temperature oscillations and erratic salinity fluctuations. Thus, the $\delta^{18}O_{otolith}$ profiles are more complex than figure 4.5 suggests.

Using actual monthly measured $\delta^{18}O_{water}$ (range from –2.2‰ to 0.4‰) from Andrus and Crowe (2008), a model (fig. 4.6) is generated based on the Grossman and Ku (1986) aragonite precipitation equation. From figure 4.6, a semisinusoidal pattern in estimated $\delta^{18}O_{otolith}$ is seen. Estimated $\delta^{18}O_{otolith}$ values are depleted during warmest months, while enriched values form during coldest months. Salinity complicates estimated $\delta^{18}O_{otolith}$ values, however. For example, in October, the temperature is 22.8°C, but $\delta^{18}O_{water}$ is depleted due to low salinity levels from fresh water, generating more depleted $\delta^{18}O_{otolith}$ values.

To examine effects of fluctuating $\delta^{18}O_{water}$ on $\delta^{18}O_{otolith}$, I examined modern otoliths for seasonal $\delta^{18}O_{otolith}$ oscillations, converting $\delta^{18}O_{otolith}$ to temperature in degrees Celsius, with a constant $\delta^{18}O_{water}$ of –0.9‰ (the yearly average $\delta^{18}O_{water}$ from waters surrounding St. Catherines Island [Andrus and Crowe, 2008]). These temperature values are approximations of the actual temperature the fish experienced.

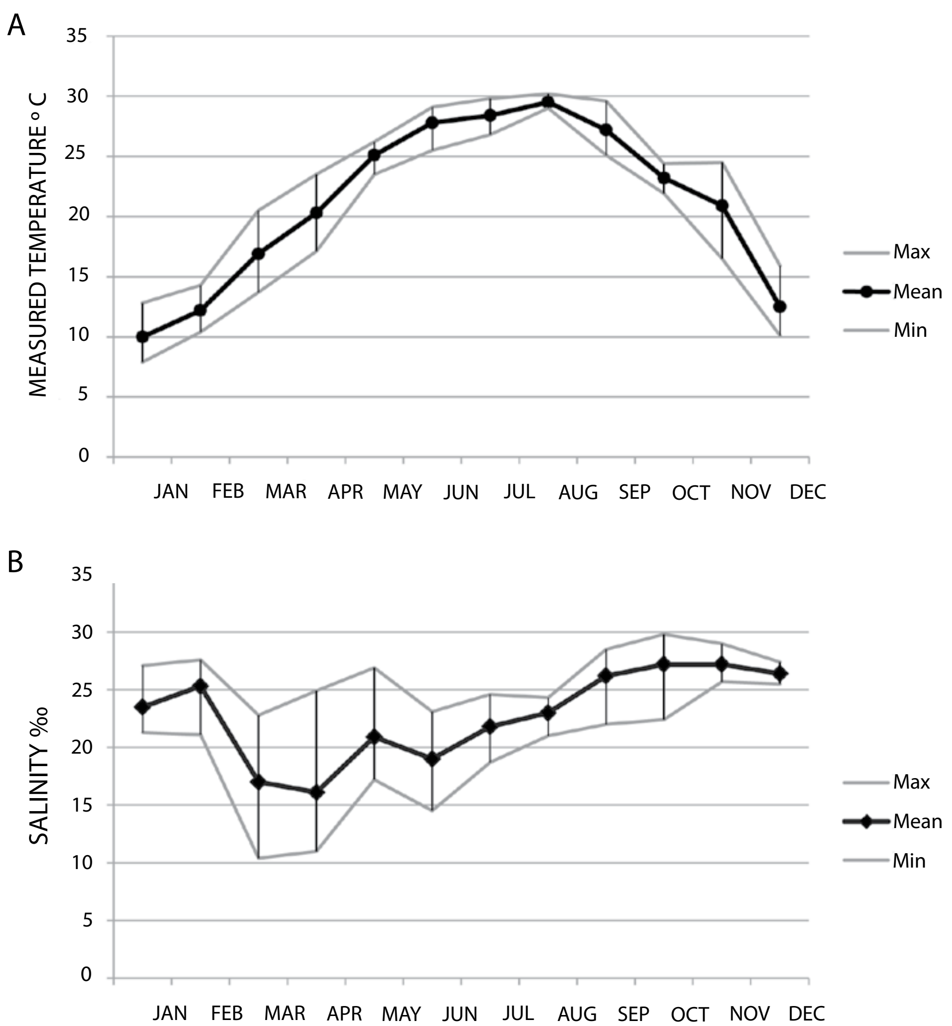


Fig. 4.4. **A.** Mean temperature per month for 2003 with recorded temperature maximums and minimums at Sapelo Island Marsh Landing. **B.** Mean salinity per month for 2003 with recorded salinity maximums and minimums. See http://cdmo.baruch.sc.edu/ for Marsh Landing, Sapelo Island, water data.

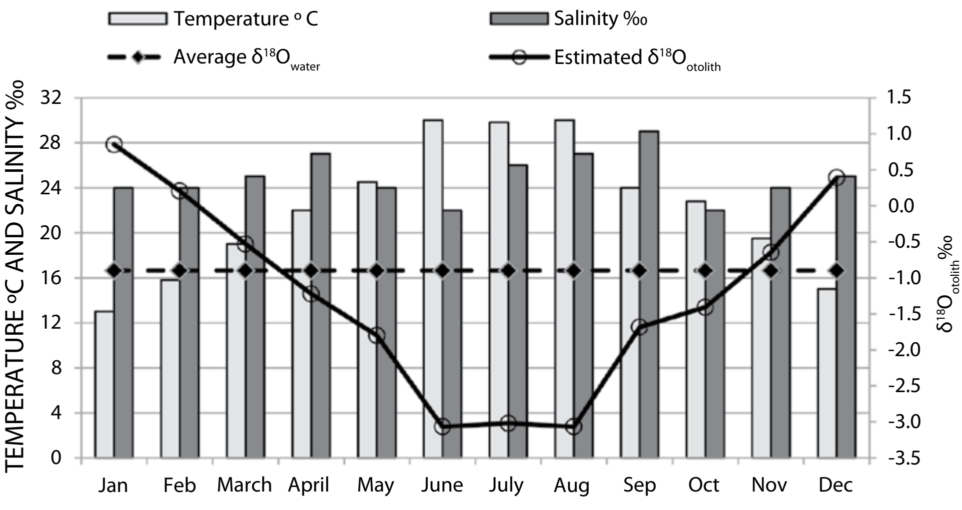


Fig. 4.5. Annual cycle of temperature oscillation and salinity fluctuations for the McQueen Inlet of St. Catherines Island, Georgia (Andrus and Crowe, 2008). Estimated $\delta^{18}O_{otolith}$ is based on an average and constant $\delta^{18}O_{water}$. Calculation based on Grossman and Ku (1986).

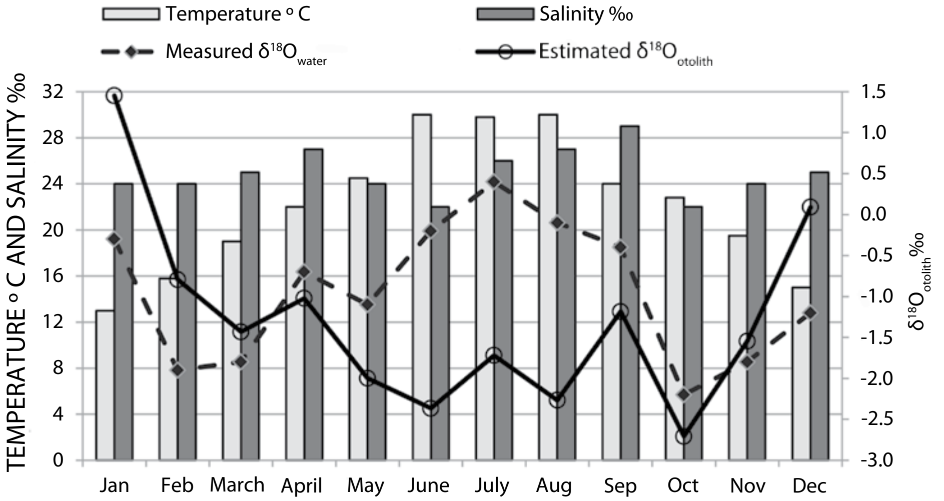


Fig. 4.6. Annual cycle of temperature oscillation and salinity fluctuations for the McQueen Inlet of St. Catherines Island, Georgia (Andrus and Crowe, 2008). Estimated $\delta^{18}O_{otolith}$ is based on a recorded $\delta^{18}O_{water}$ (Andrus and Crowe, 2008). Calculation based on Grossman and Ku (1986).

$\delta^{18}O$ OF MODERN OTOLITHS

When the modern hardhead catfish $\delta^{18}O_{otolith}$ are plotted through ontogeny, oscillations in $\delta^{18}O_{otolith}$ are observed, reflecting seasonal temperature oscillation (fig. 4.7A). In 75% of the examined otoliths, the terminal and penultimate $\delta^{18}O_{otolith}$ values record seasonal temperature fluctuations correlating with the expected season in which the hardhead catfish was captured (table 4.1).

Like the modern hardhead catfish $\delta^{18}O_{otolith}$, the modern Atlantic croaker $\delta^{18}O_{otolith}$ show semisinusoidal oscillations in $\delta^{18}O_{otolith}$ when plotted through ontogeny, recording seasonal temperature oscillations (fig. 4.7B). The modern

TABLE 4.1
Modern Hardhead Catfish Otolith Season of Capture and Estimated Season of Capture

Catalog no.	Date captured	Season captured	Estimated season captured $\delta^{18}O_{otolith}$
GMNH 2172	5/10/81	Spring	Spring
GMNH 4457	6/27/09	Summer	Spring
GMNH 1732	7/25/80	Summer	Summer
GMNH 4269	7/31/03	Summer	Summer
FLMNH-EA 11162	8/9/79	Summer	Summer
FLMNH-EA 11271	8/9/79	Summer	Summer
FLMNH-EA 11341	8/9/79	Summer	Summer
GMNH 4472	8/22/09	Summer	Summer
GMNH 4470	8/22/09	Summer	Summer
GMNH 4295	9/16/03	Summer	Spring
GMNH 4469	9/19/09	Summer	Summer
GMNH 4468	9/19/09	Summer	Summer

TABLE 4.2
Modern Atlantic Croaker Otolith Season of Capture and Estimated Season of Capture

Catalog no.	Date captured	Season captured	Estimated season captured $\delta^{18}O_{otolith}$
GMNH 1075	3/1/80	Winter	Winter
GMNH 4475	4/25/09	Spring	Spring
GMNH 4458	5/23/09	Spring	Spring
GMNH 3762	5/29/87	Spring	Spring
GMNH 4462	6/27/09	Summer	Spring
FLMNH-EA 11313	8/8/79	Summer	Summer
FLMNH-EA 11318	8/8/79	Summer	Summer
FLMNH-EA 11319	8/8/79	Summer	Summer
GMNH 4473	8/27/09	Summer	Summer
GMNH 4474	8/27/09	Summer	Summer
GMNH 4471	9/18/09	Summer	Indeterminate
GMNH 4476	9/18/09	Summer	Summer

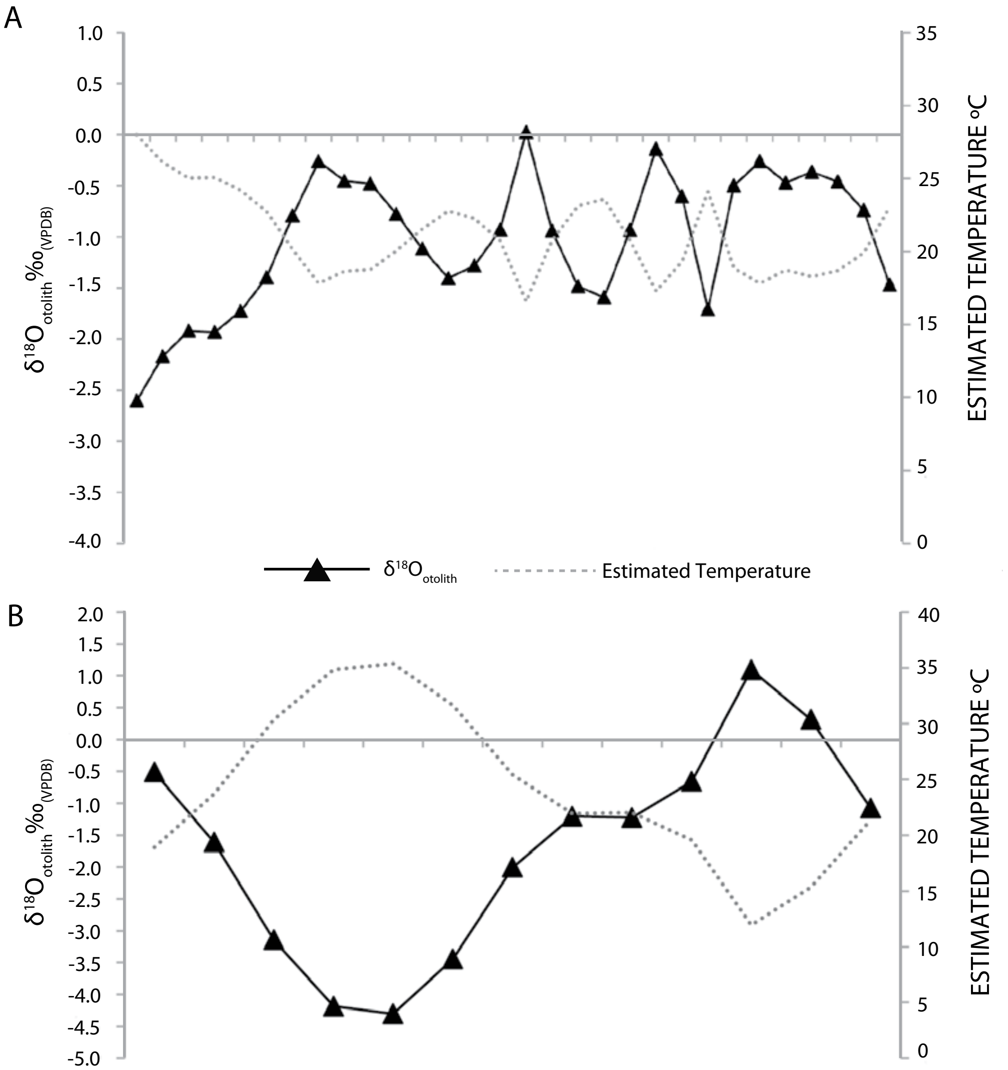


Fig. 4.7. **A.** Modern hardhead catfish (FLMNH-EA 11271) $\delta^{18}O_{otolith}$ captured in August 1979, Walburg Creek, St. Catherines Island. $\delta^{18}O_{otolith}$ indicates that this individual was captured when water temperatures were warm. **B.** Modern Atlantic croaker (GMNH-EA 4462) $\delta^{18}O_{otolith}$ captured in June 2009, North Beach, St. Catherines Island. $\delta^{18}O_{otolith}$ indicates that this individual was captured when water temperatures were warm.

Atlantic croaker $\delta^{18}O_{otolith}$ correctly predicted the season of capture in 83% of the sample, which is a higher level of accuracy compared to hardhead catfish $\delta^{18}O_{otolith}$ (table 4.2).

$\delta^{18}O$ OF ARCHAEOLOGICAL OTOLITHS

In 75% of modern hardhead catfish otoliths and 83% of modern Atlantic croaker otoliths, modern $\delta^{18}O_{otolith}$ accurately indicated the season in which the fish died. As such, $\delta^{18}O_{otolith}$ profiles of archaeological specimens can indicate the season in which people captured the fish. The archaeological $\delta^{18}O_{otolith}$ sample just before terminal growth and at terminal growth, in addition to $\delta^{18}O_{otolith}$ fluctuations experienced through ontogeny, are used to characterize temperature fluctuations occurring when the fish died. Little to no temperature difference is noted between seasonal transitions, for example March 20 (the last day of winter) and March 21 (the first day of spring) (http://cdmo.baruch.sc.edu/ data from Marsh Landing, Sapelo Island water data years 1996 and 2003). The application of seasonal classification using archaeological $\delta^{18}O_{otoliths}$ does not directly equate to the actual season, but rather, winter is indicated by cold temperatures, spring is suggested by the transition of cold to warm temperatures, summer is indicated by warm temperatures, and fall is suggested by a warm to cold temperature transition. If all four seasons are represented in the archaeological $\delta^{18}O_{otolith}$ profiles from a site, fishing likely occurred during all four seasons. The Grossman and Ku (1986) aragonite precipitation equation is used to convert $\delta^{18}O_{otolith}$ to temperature in degrees Celsius, with the constant $\delta^{18}O_{water}$ of –0.9‰ for the following analysis (fig. 4.8A–D and 9).

The Cannon's Point Ring

Only one of the two otoliths examined from the Cannon's Point Ring yielded conclusive results, FLMNH-EA 01550585 (table 4.3). This Atlantic croaker otolith indicates that the fish died while temperatures were cold, suggesting that people fished at least during winter (fig. 4.8A).

The West Shell Ring

I analyzed two hardhead catfish and six Atlantic croaker otoliths for $\delta^{18}O_{otolith}$ profiles from the West Ring (table 4.3). People who formed this ring captured one hardhead catfish during summer (FLMNH-EA 01610161) and one during fall (FLMNH-EA 01610027). One Atlantic croaker otolith yielded inconclusive results (FLMNH-EA 01610231). Three Atlantic croakers were captured during winter (FLMNH-EA 01610169, 01610194, and 01610214), one was captured in the spring (FLMNH-EA 01610214), and one was captured during fall (FLMNH-EA 01610169). These data suggest that fishing occurred during all four seasons (fig. 4.8B, D).

The McQueen Shell Ring

Two hardhead catfishes and five Atlantic croakers were analyzed for $\delta^{18}O_{otolith}$ profiles. All otoliths from the McQueen Shell Ring yielded seasonal results (table 4.3). One hardhead catfish was captured during spring (GMNH 02420216), while the other was captured during fall (GMNH 02420047). Two Atlantic croakers were captured in winter (GMNH 02420227 and 02420261), two were captured in spring (GMNH 02420057 and 02420100), and one was captured in summer (GMNH 02420187). These data suggest that people fished during all four seasons.

The St. Catherines Shell Ring

I sampled 16 hardhead catfish otoliths and nine Atlantic croaker otoliths from the St. Catherines Shell Ring for isotopic analysis (table 4.3). Sixteen of the archaeological $\delta^{18}O_{otolith}$ yielded profiles that provide evidence of season of capture. One $\delta^{18}O_{otolith}$ from a hardhead catfish indicates that people captured this fish during winter (GMNH 02381373), four hardhead catfish (GMNH 02380115, 02381373, and two otoliths from 02380118) were captured in spring, and two were captured in fall (two otoliths from GMNH 02381373). $\delta^{18}O_{otolith}$ from archaeological Atlantic croakers (fig. 4.8C) indicate that people captured one individual in winter (GMNH 02381348), two in spring (GMNH 02381477 and 02381554), four in summer (GMNH two from 02381444, and one each from 02380999 and 02381886), and two were captured in fall (GMNH 02381203 and 02381516). These data suggest that people fished during all four seasons.

Summary

$\delta^{18}O_{otolith}$ profiles of archaeological specimens indicate that people fished during all four seasons at the West, McQueen, and St. Catherines shell rings. The limited sample from the Cannon's Point Ring prevents a comprehensive understanding of seasonal fishing behaviors at this site.

$\delta^{18}O_{otolith}$, ESTUARINE ENVIRONMENTS, AND ARCHAEOLOGICAL IMPLICATIONS

Modern $\delta^{18}O_{otolith}$ Problems and Areas of Future Research

In most cases, modern $\delta^{18}O_{otolith}$ accurately determined the season in which the fish died, however, there are some problems.

Shackleton (1973) outlines six requirements for a successful archaeological application of $\delta^{18}O_{carbonate}$ to determine season of capture. To paraphrase Shackleton's requirements, he notes that: (a) the species must form their carbonate structure in isotopic equilibrium with the ambient water; (b) the isotopic composition of the water in which the carbonate structure forms must remain

TABLE 4.3
Archaeological Otolith Estimated Season of Capture

				$\delta^{18}O$ ‰$_{(VPDB)}$		
Catalog no.	Ring	Species	Otolith no.	One before terminal	Terminal	Estimated season captured
FLMNH-EA 01551061	Cannon's Point	*A. felis*	Cannon's-1	–0.93	—	Indeterminate
FLMNH-EA 01550585	Cannon's Point	*M. undulatus*	Cannon's-3	0.47	1.28	Cold
FLMNH-EA 01610027	West	*A. felis*	West-1	–0.70	–0.70	Warm/cold transition
FLMNH-EA 01610161	West	*A. felis*	West-2	–0.44	–0.96	Warm
FLMNH-EA 01610169	West	*M. undulatus*	West-3	–1.90	–1.28	Warm/cold transition
FLMNH-EA 01610169	West	*M. undulatus*	West-4	–0.30	1.51	Cold
FLMNH-EA 01610194	West	*M. undulatus*	West-5	–0.39	1.19	Cold
FLMNH-EA 01610214	West	*M. undulatus*	West-8	0.21	–0.71	Cold/warm transition
FLMNH-EA 01610214	West	*M. undulatus*	West-9	–0.14	1.12	Cold
FLMNH-EA 01610231	West	*M. undulatus*	West-10	0.84	0.62	Indeterminate
GMNH 02420216	McQueen	*A. felis*	McQueen-1	–0.31	–0.43	Cold/warm transition
GMNH 02420047	McQueen	*A. felis*	McQueen-3	–0.86	–0.68	Warm/cold transition
GMNH 02420227	McQueen	*M. undulatus*	McQueen-2	1.05	0.31	Cold
GMNH 02420187	McQueen	*M. undulatus*	McQueen-4	–1.52	–1.62	Warm
GMNH 02420261	McQueen	*M. undulatus*	McQueen-5	–0.75	0.69	Cold
GMNH 02420057	McQueen	*M. undulatus*	McQueen-6	0.28	–0.81	Cold/warm transition
GMNH 02420100	McQueen	*M. undulatus*	McQueen-7	0.51	–0.45	Cold/warm transition
GMNH 02380115	St. Catherines	*A. felis*	0115-O1	–0.73	–0.54	Indeterminate
GMNH 02380115	St. Catherines	*A. felis*	0115-O2	–0.39	–0.95	Cold/warm transition
GMNH 02380118	St. Catherines	*A. felis*	0118-O3	–0.69	–0.76	Cold/warm transition
GMNH 02380118	St. Catherines	*A. felis*	0118-O4	–1.39	—	Indeterminate
GMNH 02380118	St. Catherines	*A. felis*	0118-O5	–0.59	–0.46	Indeterminate
GMNH 02380118	St. Catherines	*A. felis*	0118-O6	0.02	–1.01	Cold/warm transition
GMNH 02380122	St. Catherines	*A. felis*	0122-O7	–0.66	—	Indeterminate
GMNH 02380120	St. Catherines	*A. felis*	0120-O8	0.06	—	Indeterminate
GMNH 02381373	St. Catherines	*A. felis*	1373-O4	–0.14	–0.18	Warm/cold transition

TABLE 4.3 — (*Continued*)

				$\delta^{18}O$ ‰$_{(VPDB)}$		
Catalog no.	Ring	Species	Otolith no.	One before terminal	Terminal	Estimated season captured
GMNH 02381373	St. Catherines	*A. felis*	1373-O5	–0.28	–0.33	Cold/warm transition
GMNH 02381373	St. Catherines	*A. felis*	1373-O6	–0.30	–0.28	Warm/cold transition
GMNH 02381373	St. Catherines	*A. felis*	1373-O7	0.12	0.40	Cold
GMNH 02381437	St. Catherines	*A. felis*	1437-O8	—	–0.08	Indeterminate
GMNH 02380494	St. Catherines	*A. felis*	0494-O14	–0.67	—	Indeterminate
GMNH 02380989	St. Catherines	*A. felis*	0989-O17	–0.23	—	Indeterminate
GMNH 02381037	St. Catherines	*A. felis*	1037-O19	—	–1.11	Indeterminate
GMNH 02381348	St. Catherines	*M. undulatus*	1348-O3	–0.17	0.32	Cold
GMNH 02381444	St. Catherines	*M. undulatus*	1444-O9	–1.97	–1.90	Warm
GMNH 02381444	St. Catherines	*M. undulatus*	1444-O10	–0.53	–1.07	Warm
GMNH 02381477	St. Catherines	*M. undulatus*	1477-O11	–0.81	–0.74	Cold/warm transition
GMNH 02381516	St. Catherines	*M. undulatus*	1516-O12	–1.34	–0.75	Warm/cold transition
GMNH 02381554	St. Catherines	*M. undulatus*	1554-O13	0.63	–0.74	Cold/warm transition
GMNH 02380999	St. Catherines	*M. undulatus*	0999-O21	–1.07	–1.28	Warm
GMNH 02381203	St. Catherines	*M. undulatus*	1203-O25	–1.41	–0.08	Warm/cold transition
GMNH 02381886	St. Catherines	*M. undulatus*	1886-O26	–1.74	–2.67	Warm

constant through a season; (c) the water temperature in which the carbonate structure forms must be sea temperature; (d) the organism must deposit the carbonate structure throughout the year; (e) growth in the carbonate structure must be great enough to allow for discrete sampling of increments covering no more than a few weeks; and (f) the habitat in which the organism lives must undergo large and regular seasonal temperature oscillations. Although hardhead catfish and Atlantic croaker otoliths meet requirements a, c, and f, otoliths from these two species do not meet requirements b, d, and e. This may explain why some of the modern $\delta^{18}O_{otolith}$ did not indicate the correct season of capture.

Firstly, $\delta^{18}O_{water}$ in which the fish lives does not remain constant through the season (Shackleton, 1973: requirement b). It is clear from the zooarchaeological record of the Georgia coast that estuarine fishes were an important subsistence resource (Reitz, Quitmyer, and Marrinan, 2009; Colaninno, 2010; Reitz et al., 2010: 54–57). People fished estuarine fishes heavily, but they did not fish in offshore areas where $\delta^{18}O_{water}$ values are more stable. To characterize seasonal fishing efforts in inshore settings, this requirement must be met. It is possible that a more comprehensive environmental understanding of Georgia estuaries can generate accurate $\delta^{18}O_{otolith}$ models that account for temperature, salinity, and $\delta^{18}O_{water}$ (see Surge and Walker, 2005; Andrus and Crowe, 2008; Culleton, Kennett, and Jones, 2009). Monthly analysis of $\delta^{18}O_{water}$ in conjunction with $\delta^{18}O_{otolith}$ from several locations surrounding St. Catherines Island may resolve this issue.

Fishes are mobile animals and movement of fishes confounds fluctuations in $\delta^{18}O_{water}$, again violating Shackleton's (1973) requirement b. Both hardhead catfishes and Atlantic croakers move within estuaries and outside estuaries (Dahlberg, 1972; Muncy and Wingo, 1983; Hare and Able, 2007). Fish movement complicates documenting environmental oscillations within Georgia estuaries. Each individual fish may experience different environmental parameters with movement. Alternatively, these species may have a specific set of preferred environmental conditions, including temperature and salinity, within which the fish swims as these parameters move with tides and seasons. This behavior, known as thermoregulatory movement, is documented in other fish species (Jones and Campana, 2009) and could be practiced by hardhead catfishes and Atlantic croakers. Developing better models to predict $\delta^{18}O_{otolith}$ through further study of $\delta^{18}O_{water}$, temperature, and salinity may resolve some of the confounding factors of temperature and salinity fluctuations on $\delta^{18}O_{water}$, but seasonal temperature oscillations will be difficult to detect in fishes with thermoregulatory movement.

Shackleton (1973: requirement d) also notes that formation of the carbonate structure used to determine seasonality must form throughout the year. Growth in fish otoliths may violate this requirement. Researchers note stoppage of otolith growth in other fish species (Fowler, 1995) and this could occur in hardhead catfishes and Atlantic croakers. This is particularly likely for hardhead catfishes. Males of this species gestate their eggs

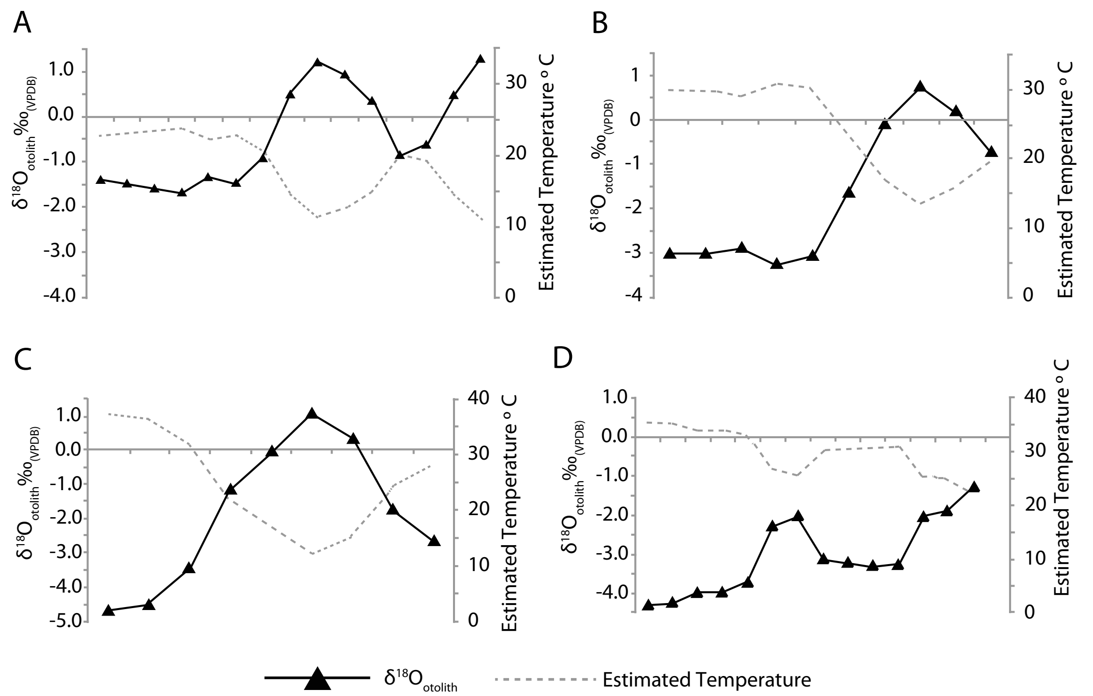


Fig. 4.8. $\delta^{18}O_{otolith}$ through ontogeny. **A.** Atlantic croaker (FLMNH-EA 01550585) $\delta^{18}O_{otolith}$ profile indicating cold temperatures, or winter season of death from the Cannon's Point Ring. **B.** Atlantic croaker (FLMNH-EA 01610214) $\delta^{18}O_{otolith}$ profile indicating a cold to warm temperature transition, or spring season of death from the West Ring. **C.** Atlantic croaker (GMNH 02381886) $\delta^{18}O_{otolith}$ profile indicating a warm, or summer season of death from the St. Catherines Shell Ring. **D.** Atlantic croaker (FLMNH-EA 01610169) $\delta^{18}O_{otolith}$ profile indicating a warm to cold temperature transition, or fall season of death from the West Ring.

and young in their mouth for approximately 60 to 80 days after spawning (Dahlberg, 1972). Oral gestation occurs during the late spring through early fall (Gunter, 1947; Ward, 1957). During this period, males do not eat and somatic growth may not occur. The fact that only one archaeological hardhead catfish otolith had a terminal increment that formed in summer further suggests that otolith growth is not continuous throughout the year. Hardhead catfish are most abundant in Georgia estuaries during summer (Dahlberg, 1972), making the limited evidence for summer-captured hardhead catfish surprising. Nonetheless, modern hardhead catfish $\delta^{18}O_{otolith}$ generally do form otolith increments in warmer months. Additional modern sampling of both males and females, in known states of reproduction, is required to understand consequences of reproduction on somatic growth and otolith formation.

Shackleton (1973: requirement e) also observes that growth rates of the carbonate structure must be large enough to sample isolated increments covering no more than a few weeks of growth. Some archaeological otoliths do not meet this requirement, particularly otoliths from older fishes. This problem is noted when peaks in $\delta^{18}O_{otolith}$ profiles are examined in conjunction with the number of incremental bands in each otolith. Theoretically, fish form growth bands through ontogeny in response to environmental and biological conditions such as temperature, food availability, and reproductive efforts (Pannella, 1971, 1980; Wootton, 1998:111–116; Van Neer, Löugas, and Rijnsdorp, 2004). Major fluctuations in environmental and biological conditions that the fish experiences generally occur annually, causing fish to grow quickly and then slowly within an annual cycle. This process produces two visually distinct bands per year (dark and light growth bands). As such, the number of bands in an otolith should correlate to the number of isotopic peaks in $\delta^{18}O_{otolith}$ profile when plotted through ontogeny (figs. 4.7, 8A–D, and 9). This is not always the case, however. In some otoliths, the number of increments is equal to the number of seasonal peaks in the $\delta^{18}O_{otolith}$ profile. In other otoliths, there are more increments than peaks. This suggests that either too little growth occurred in these otoliths to discretely sample each season using the sampling method I employed, or increment formation does not correlate to seasonal temperature oscillations in every case.

The effect of growth increments that cover no more than a few weeks also is seen in FLMNH-EA 01610231 (fig. 4.9). This individual was 18.5 ontogenic years at death and formed 1.07 mm of noncore otolith (from the terminal edge of the otolith to the outer edge of the core). As-

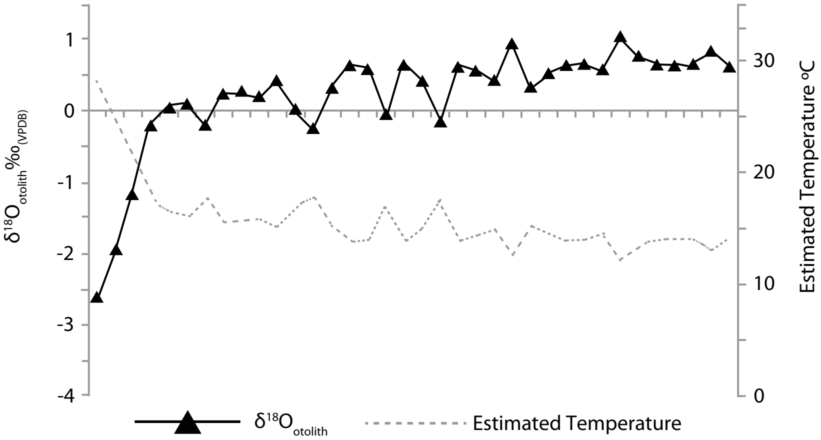


Fig. 4.9. Archaeological $\delta^{18}O_{otolith}$ of an Atlantic croaker (FLMNH-EA 01610231) approximately 18.5 years of age. $\delta^{18}O_{otolith}$ during 17.5 years of noncore growth ranges between –0.25‰ and 1.05‰ or a 5.7°C difference in experienced temperature.

suming an average growth rate over the 17.5 years of noncore growth, only 0.06 mm of otolith formation occurred per year or 0.01 mm every three months (i.e., per season). I spaced isotopic drilling paths for both modern and archaeological otoliths between 0.1 and 0.2 mm apart. It is impossible to isolate season of capture for older individuals with such little growth each season. Because fish generally grow most rapidly during their first few years of life (Wootton, 1998: 116), otoliths from younger individuals should provide higher-resolution trends in temperature oscillations experienced by the fish.

Researchers also use visual characterization of the terminal band type of otoliths to determine seasonality. If the type of banding, that is dark or light bands, is known to occur during specific seasons for a species, the terminal band can be used to infer the season in which the fish was captured (Smith, 1983; Hales and Reitz, 1992; Erlandson, 1994: 103; Higham and Horn, 2000). Currently, this method yielded inconclusive results for both hardhead catfishes and Atlantic croakers. For modern hardhead catfishes, individuals were captured only during five months of the year (May, June, July, August, and September), representing two seasons: spring and summer. All hardhead catfishes in the sample had dark or fast, terminal growth bands when they were captured. Although this indicates that hardhead catfish likely form dark growth bands in the spring and summer, these data do not indicate whether dark growth occurs continuously throughout the spring and summer and when light growth bands form. Season of death for Atlantic croakers in the modern sample includes croakers that died in spring and summer. Only one croaker captured in spring was in noncore growth and this individual was forming a dark growth band. Otoliths from Atlantic croakers captured in summer had both dark and light growth terminal bands. One otolith was in light growth formation and four were in dark growth formation. These data indicate that dark bands generally form during spring and summer; however, without direct evidence that light bands occur in winter and fall, it is impossible to draw this conclusion.

Characterizing the terminal band in otoliths may provide an additional method to determine season of capture, but more modern sampling is needed to understand seasonal timing of band formation in these two species. Overall results from the modern $\delta^{18}O_{otolith}$ indicate that oscillations in $\delta^{18}O_{otolith}$ can estimate temperature oscillations fishes experienced just prior to and at death and thus, season of capture. Further research is needed to understand the full seasonal range of environmental oscillations, particularly correlations among temperature, salinity, and $\delta^{18}O_{water}$ in Georgia estuaries, and biological and environmental factors that affect otolith growth and incremental banding in these two species.

Archaeological Implications

Researchers have conducted analyses of clam and oyster incremental formation and $\delta^{18}O$ profiles at several Late Archaic shell rings, including the shell rings in this otolith study (Quitmyer, Hale, and Jones, 1985; O'Brien and Thomas, 2008; Thompson and Andrus, 2011). These mollusc studies concluded that people harvested shellfish during multiple seasons (Marrinan, 1975: 99; Thompson and Andrus, 2011), and in some instances, throughout the year (Quitmyer, Hale, and Jones, 1985; Thompson, 2006; Thomas, 2008: 927; Thompson and Andrus, 2011). These data suggest a model of year-round shellfish harvesting at most, although not necessarily at all, shell rings (Thompson and Andrus, 2011).

This archaeological $\delta^{18}O_{otolith}$ study also suggests a year-round model for fishing. At the West, McQueen, and St. Catherines shell rings, $\delta^{18}O_{otolith}$ profiles just prior to and at death indicate that people captured these two fish species during all four seasons in conjunction with multiseason harvesting of shellfishes (table 4.3). Researchers in other coastal areas document a similar pattern of year-round resource use by coastal peoples in the past (Yesner, 1980; Russo, 1998; Keene, 2004; Orr, 2007).

Although $\delta^{18}O_{otolith}$ profiles define a pattern of year-round fishing at the West, McQueen, and St. Catherines shell rings, this does not mean the entire population associated with each shell ring lived there continuously. Segments of the population could be absent occasionally on collecting and hunting trips, social visits, or ritual activities for longer or shorter lengths of time. Such seasonal patterns of movement by only segments of a population are documented among modern hunter-gatherer populations (Meehan, 1982: 31–41; Kelly, Poyer, and Tucker, 2005) and likely characterize the behavior of archaeological populations.

Admittedly, evidence that people fished Georgia estuaries and deposited the fish remain at these shell rings during all four seasons does not directly equate to a year-round, sedentary population occupying shell rings. Temperature regimes at time of capture represent a discrete time interval during a period of three to four months. Archaeological $\delta^{18}O_{otolith}$ profiles are not sufficiently precise to identify patterned, but brief, absences or presences of fishing activities. It is possible that people only fished and deposited fish remains at these shell rings for a day, week, or month of the three to four month period defined using archaeological $\delta^{18}O_{otolith}$. Given the large quantity of faunal remains (Colaninno, 2010), depth of deposits at these sites, and the multiseason harvesting practices documented in mollusc samples (Quitmyer, Hale, and Jones, 1985; O'Brien and Thomas, 2008; Thompson and Andrus, 2011), an extended, year-round occupation is probable.

SUMMARY AND CONCLUSIONS

This study is one of the first to use archaeological fish otoliths to determine the seasonality of fishing in the southeastern United States (for seasonal studies that used otoliths in other regions see, Erlandson, 1994: 103; Van Neer, Löugas, and Rijnsdorp, 1999; Van Neer et al., 2004; Hufthammer et al., 2010). Although initial results of this analysis are promising, further research is needed. Factors that control $\delta^{18}O_{otolith}$ for Georgia estuaries, as well as biological and environmental factors that control otolith formation must be better understood. Despite these shortcomings, modern $\delta^{18}O_{otolith}$ profiles indicate that $\delta^{18}O_{otolith}$ determines the season in which people captured the fish in most cases.

These data indicate that people fished hardhead catfishes and Atlantic croakers during multiple seasons. At the West, McQueen, and St. Catherines shell rings, people fished during all four seasons. With these data, future archaeological research can focus on patterns in the horizontal and vertical distributions of seasonal deposits within each shell ring and across the region, as well as other spatial, temporal, and behavioral scales. Additionally, seasonal data from molluscs can be examined in conjunction with data from fish otoliths to view seasonal resource use involving several taxa (Walker and Surge, 2006). Multiproxy studies may provide a better prospective on Late Archaic seasonal resource use patterns and settlement patterns than single-proxy studies.

NOTES

1. Isotopic analysis of modern, Cannon's Point, West, and McQueen otoliths is funded by the National Science Foundation Doctoral Dissertation Improvement Grant BCS-0912176. Isotopic analysis for the St. Catherines Shell Ring is funded by the American Museum of Natural History and Edward J. Noble Foundation. I would like to thank all those who have helped me with this research: David Hurst Thomas, Matthew C. Sanger, Ginessa Mahar, and the crew at the American Museum of Natural History for allowing me to work with the St. Catherines Island collections, Rochelle Marrinan for allowing me to work with the St. Simons material, Bruce Saul, Charles Lambert, and their students at Augusta State University for collecting fishes, Irvy Quitmyer for helping me collect fishes and aiding me at the Florida Museum of Natural History, Fred Andrus for allowing me to work at the University of Alabama, Joe Lambert for processing my isotopic samples, John A. Turck for the map, Julia K. Orr for processing the modern fishes, and Betsy Reitz for the insightful comments. This research could not have taken place without your support, so thank you. The author is responsible for all contents, including the errors and any misinterpretation of the data herein.

APPENDIX 4.1
Modern Otoliths Sampled for Isotopic Analysis

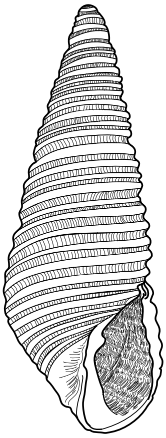
Catalog #	Location	Captured	Collector	Length, mm	Breadth, mm	Width, mm	Thickness, mm	Weight, g
GMNH 2172	Edisto Island, SC	5/10/81	Lisa Osteen	11.53	10.23	9.62	4.97	0.57
GMNH 4457	St. Catherines Island, Ga	6/27/09	Bruce Saul, Carol Colaninno	8.61	7.68	6.72	3.59	0.22
GMNH 1732	Sapelo Island, Caretta Beach, Ga	7/25/80	Besty Reitz	11.28	10.12	9.72	4.65	0.54
GMNH 4269	Camachee Island, St. Johns County, Fl	7/31/03	Kelly Orr	10.81	9.79	8.83	4.15	0.40
FLMNH 11162	St. Catherines Sound, SCI2, Ga	8/9/79	Richard Casteel	9.55	8.21	8.01	3.72	0.29
FLMNH 11271	St. Catherines Walburg Creek, Ga	8/9/79	Richard Casteel	10.73	9.58	9.13	3.82	0.39
FLMNH 11341	St. Catherines Island SCI1, Ga	8/9/79	Richard Casteel	10.20	8.85	8.33	3.85	0.33
GMNH 4472	St. Catherines Island, Ga	8/22/09	Bruce Saul, Carol Colaninno	8.82	7.81	7.15	3.75	0.25
GMNH 4470	St. Catherines Island, Ga	8/22/09	Bruce Saul, Carol Colaninno	12.29	10.90	10.55	5.34	0.73
GMNH 4295	Vilano Bridge, St. Johns County, Fl	9/16/03	Kelly Orr	12.10	10.62	9.98	5.70	0.75
GMNH 4469	St. Catherines Island, North Beach Seine, Ga	9/19/09	Bruce Saul, Carol Colaninno	11.10	9.79	9.13	4.51	0.48
GMNH 4468	St. Catherines Island, North Beach Seine, Ga	9/19/09	Bruce Saul, Carol Colaninno	12.80	11.31	10.78	5.25	0.73
GMNH 1075	Skidaway Island, Ga	3/1/80	D. Miller	8.91		6.63	3.60	0.17
GMNH 4475	Ossabaw Estuary Trawl, Ga	4/25/09	Carol Colaninno	7.72		5.65	3.40	0.11
GMNH 4458	St. Catherines Island Trawl, Ga	5/23/09	Carol Colaninno	11.39		8.56	4.84	0.39
GMNH 3762	Gloucester, Middlesex Co., Va	5/29/87	J. Gayner	11.04		8.14	5.19	0.39
GMNH 4462	St. Catherines Island, North Beach Seine, Ga	6/27/09	Carol Colaninno	8.98		6.64	3.63	0.19
FLMNH 11318	St. Catherines McQueen Inlet, Ga	8/8/79	Richard Casteel	7.36		5.39	3.42	0.10
FLMNH 11319	St. Catherines McQueen Inlet, Ga	8/8/79	Richard Casteel	7.28		5.17	2.80	0.08
FLMNH 11313	St. Catherines Island SCI2, Ga	8/9/79	Richard Casteel	7.46		5.55	3.29	0.10
GMNH 4473	St. Catherines Island, Ga	8/27/09	Bruce Saul, Carol Colaninno	8.57		6.37	3.61	0.17
GMNH 4474	St. Catherines Island, Ga	8/27/09	Bruce Saul, Carol Colaninno	9.99		7.23	4.32	0.25
GMNH 4471	St. Simons Estuary trawl, Ga	9/18/09	Bruce Saul, Carol Colaninno	7.98		5.60	3.42	0.13
GMNH 4476	St. Simons Estuary trawl, Ga	9/18/09	Bruce Saul, Carol Colaninno	7.91		5.56	3.22	0.12

APPENDIX 4.2
Archaeological Otoliths Sampled for Isotopic Analysis

Catalog no.	Ring	Species	Otolith no.	Unit	Level	Length, mm	Breadth, mm	Width, mm	Thickness, mm	Weight, g
FLMNH 01551061	Cannon's Point	*A. felis*	Cannon's 1	18N, 0E	25	9.85	8.80	8.19	3.61	0.294
FLMNH 01550585	Cannon's Point	*M. undulatus*	Cannon's 3	18N, 0E	12	9.39		7.30	4.48	0.253
FLMNH 01610027	West	*A. felis*	West 1	5S, 30E	ZII L1	10.52	9.34	8.80	4.52	0.442
FLMNH 01610161	West	*A. felis*	West 2	5S, 30E	6	10.71	9.49	8.88	4.05	0.407
FLMNH 01610169	West	*M. undulatus*	West 3	5S, 30E	6	8.60		6.57	4.06	0.176
FLMNH 01610169	West	*M. undulatus*	West 4	5S, 30E	6	8.16		6.32	3.34	0.126
FLMNH 01610194	West	*M. undulatus*	West 5	5S, 30E	7	8.62		6.22	3.39	0.149
FLMNH 01610214	West	*M. undulatus*	West 8	5S, 30E	8	8.96		6.31	3.98	0.178
FLMNH 01610214	West	*M. undulatus*	West 9	5S, 30E	8	12.14		10.00	5.00	0.500
FLMNH 01610231	West	*M. undulatus*	West 10	5S, 30E	9	19.94		15.07	8.25	2.225
GMNH 02420216	McQueen	*A. felis*	McQueen 1	N263 E179	5.6–5.5	8.85	7.93	7.5	3.52	0.247
GMNH 02420227	McQueen	*M. undulatus*	McQueen 2	N263 E179	5.6–5.5	8.14		5.98	3.33	0.142
GMNH 02420047	McQueen	*A. felis*	McQueen 3	N213 E179	4.6–4.5	8.08	7.25	6.78	3.72	0.215
GMNH 02420187	McQueen	*M. undulatus*	McQueen 4	N263 E179	5.7–5.6	10.85		9.22	4.84	0.356
GMNH 02420261	McQueen	*M. undulatus*	McQueen 5	N263 E179	5.5–5.4	7.61		5.83	3.00	0.113
GMNH 02420057	McQueen	*M. undulatus*	McQueen 6	N213 E198	4.6–4.5	11.37		8.45	4.65	0.357
GMNH 02420100	McQueen	*M. undulatus*	McQueen 7	N213 E198	4.5–4.4	10.38		7.41	4.42	0.302
GMNH 02380115	St. Catherines	*A. felis*	0115-O1	N789 E801	10–20 cm	9.36	8.29	7.82	3.56	0.270
GMNH 02380115	St. Catherines	*A. felis*	0115-O2	N789 E801	10–20 cm	9.73	8.87	8.41	4.33	0.373
GMNH 02380118	St. Catherines	*A. felis*	0118-O3	N789 E801	20–30 cm	7.99	6.87	6.49	3.38	0.179

APPENDIX 4.2 — (*Continued*)

Catalog no.	Ring	Species	Otolith no.	Unit	Level	Length, mm	Breadth, mm	Width, mm	Thickness, mm	Weight, g
GMNH 02380118	St. Catherines	*A. felis*	0118-O4	N789 E801	20–30 cm	9.27	7.79	7.43	4.39	0.292
GMNH 02380118	St. Catherines	*A. felis*	0118-O5	N789 E801	20–30 cm	8.53	7.32	6.85	3.64	0.218
GMNH 02380118	St. Catherines	*A. felis*	0118-O6	N789 E801	20–30 cm	8.53	7.32	6.85	3.64	0.218
GMNH 02380122	St. Catherines	*A. felis*	0122-O7	N789 E801	30–40 cm	8.87	8.08	7.78	4.13	0.265
GMNH 02380120	St. Catherines	*A. felis*	0120-O8	N789 E801	40–50 cm	8.49	7.39	6.93	3.69	0.224
GMNH 02381348	St. Catherines	*M. undulatus*	1348-O3	N784 E797	10–20 cm	8.70		6.82	3.69	0.178
GMNH 02381373	St. Catherines	*A. felis*	1373-O4	N784 E797	20–30 cm	10.29	8.95	8.52	4.09	0.374
GMNH 02381373	St. Catherines	*A. felis*	1373-O5	N784 E797	20–30 cm	9.64	8.56	8.21	4.11	0.344
GMNH 02381373	St. Catherines	*A. felis*	1373-O6	N784 E797	20–30 cm	9.70	8.17	7.92	3.77	0.290
GMNH 02381373	St. Catherines	*A. felis*	1373-O7	N784 E797	20–30 cm	10.13	8.73	8.38	4.02	0.367
GMNH 02381437	St. Catherines	*A. felis*	1437-O8	N784 E797	40–50 cm	8.76	8.07	7.55	3.83	0.274
GMNH 02381444	St. Catherines	*M. undulatus*	1444-O9	N784 E797	40–50 cm	9.17		7.03	3.96	0.198
GMNH 02381444	St. Catherines	*M. undulatus*	1444-O10	N784 E797	40–50 cm	8.66		6.33	3.41	0.162
GMNH 02381477	St. Catherines	*M. undulatus*	1477-O11	N784 E797	50–60 cm	9.64		7.62	4.05	0.232
GMNH 02381516	St. Catherines	*M. undulatus*	1516-O12	N784 E797	60–70 cm	7.67		5.16	3.17	0.109
GMNH 02381554	St. Catherines	*M. undulatus*	1554-O13	N784 E797	70–75.5 cm	10.32		7.62	4.35	0.284
GMNH 02380494	St. Catherines	*A. felis*	0494-O14	N784 E801	30–40 cm	8.31	7.23	6.77	3.84	0.228
GMNH 02380989	St. Catherines	*A. felis*	0989-O17	N784 E811	20–30 cm	9.36	8.39	8.06	3.55	0.282
GMNH 02381037	St. Catherines	*A. felis*	1037-O19	N784 E811	30–40 cm	10.06	8.89	8.30	4.18	0.367
GMNH 02380999	St. Catherines	*M. undulatus*	0999-O21	N784 E811	20–30 cm	8.93		6.44	3.93	0.179
GMNH 02381203	St. Catherines	*M. undulatus*	1203-O25	N784 E811	60–70 cm	8.15		6.16	3.56	0.163
GMNH 02381886	St. Catherines	*M. undulatus*	1886-O26	N771 E819	2.5–2.4	9.24		7.06	4.24	0.207



CHAPTER 5
LATE PREHISTORIC SETTLEMENT PATTERNS: ZOOARCHAEOLOGICAL EVIDENCE FROM BACK CREEK VILLAGE, ST. CATHERINES ISLAND

SARAH G. BERGH[1]

Despite more than three decades of archaeological research on St. Catherines Island, there are still questions about the residential mobility of late prehistoric populations. Ethnohistoric accounts of late 16th-century coastal Georgia societies are open to interpretation; some researchers posit that the Guale people moved residences on a seasonal basis following available resources, while others suggest Guale lived in dispersed but permanent settlements. This debate also applies to the late prehistoric period (A.D. 1300–1580), when it is assumed Guale or their direct ancestors occupied the coast. This chapter presents the results of zooarchaeological analysis of recently excavated materials from Back Creek Village, a large, late prehistoric site on St. Catherines Island. These data are applied to the "Guale Problem" (Thomas, chap. 1, this volume), and provide new insight, as the materials were fine-screened, recovered from multiple middens at a single site, and yield a large sample of vertebrate remains and multiple seasonal indicators that speak to seasonality of site occupation.

SEASONALITY IN FAUNAL ASSEMBLAGES

Zooarchaeological remains are often used to address seasonal occupation of sites (Monks, 1981). Life histories of many animal species involve behavioral and physiological events that occur in response to seasonal changes in temperatures, vegetation, sunlight, and rainfall, among other factors. These phenological events are often visible in the archaeological record. Some species follow seasonal rounds, occupying estuarine waters only during certain seasons. Sea turtles, for example, spend most of the year offshore, but females lay their eggs on the beaches during the summer months. Sharks, too, tend to stay offshore except for the warmer months when they enter estuaries and nearshore waters. Some migratory birds stop along the Georgia coast in the spring and fall to rest and refuel. Reproductive cycles of many species are driven by seasonal events. The white-tailed deer (*Odocoileus virginianus*) breeding season is generally October–January and young are born in May and June. Fishes have specific spawning seasons, which vary by species. Fish of the same species born in the same year form a cohort, and each age cohort may have different food and habitat preferences. The location of preferred habitats and food may change on a seasonal basis, causing cohorts to move to different parts of the estuary or out of the estuary. Mollusc growth is mostly dependent on environmental conditions, such as temperature and salinity, and these often change on a seasonal basis. All these phenological events can be used to interpret the season in which an animal in the archaeological record died. It is important to remember, however, that there will always be individual variation and that the environmental conditions that trigger phenological events may not always occur on a regular, seasonal schedule—storms and unusually warm, cold, wet, or dry seasons can alter animal behavior and physiology.

The assumptions that follow the interpretation of an archaeological animal's season of death—that humans killed the animal, the animal's remains were deposited at the site about the time the animal was killed, and the site was therefore occupied by humans about the time the animal was killed—can be disputed in some cases. On St. Catherines Island, however, some evidence supports these assumptions. Abundant cultural material throughout the middens reported here supports the assumption that humans killed the animals and deposited the remains. Although a more tenuous assumption, the bones and shells deposited at most sites were likely collected and deposited while people occupied the site. Although storage of meat is certainly possible, it is less likely that meat was stored on the bone or shell and transported among sites on a regular basis. The bones and shells are heavy and bulky and the same animals are available in most other locations along the coast. It is important to remember, however, that the presence of animals killed in all seasons does not necessarily mean that the site was occupied permanently throughout the year; it is possible that the site was reoccupied intermittently over the course of a single or multiple years. The absence of animals killed in a season also is not necessarily evidence that the site was abandoned during that season, only that the archaeological excavations failed to unearth any animals that definitely died in that season. It is only possible to estimate season of death for a small portion of the individuals recovered at a site.

THE 'GUALE PROBLEM'

The "Guale Problem" essentially sets up two different models, defined by economic potential and residential mobility (Thomas, 2008: 239). This chapter does not address economic potential, in terms of maize production, as there is no quantified study of botanicals from the late prehistoric period on St. Catherines. One maize kernel was found at Back Creek Village, the site discussed in this chapter, so the plant was utilized to some extent during the late prehistoric period by the people who lived at the site (Ruhl, 2008). The faunal evidence, instead, speaks to patterns of residential mobility. The model proposed by Larson (1980: 206–209, 221–228) and Crook (1986: 11–28), based on their interpretation of Jesuit missionary accounts for the region, suggests a residentially mobile society that was unable to support permanent settlements with maize grown on small patches of poor agricultural soils. The maize harvest in late summer allowed the population to aggregate for a time in towns, but throughout the rest of the year, households dispersed into small sets of households (i.e., matrilineages), moving residences seasonally among habitats with the most productive resources—oak forests in the fall to collect mast and hunt deer, marshside in the winter to collect molluscs, and near swidden plots in the spring for planting maize (Crook, 1986: 18). The model proposed by Jones (1978: 190–194), based on his interpretation of Jesuit accounts as exaggerated and other descriptions of southeastern Indians, suggests that Guale lived in dispersed, permanent settlements, each of which had access to mast and shellfish resources without the need for seasonal, residential mobility. In addition, although Jones also understood Guale to use a swidden system of maize cultivation, he proposed that maize plots were scattered around the settlement, new fields being cleared in the vicinity when necessary, without moving to a new site.

This debate about the Guale settlement-subsistence system also applies to the late prehistoric period, as it is assumed that Guale or their direct ancestors inhabited the coast at this time. A better understanding of the late prehistoric settlement-subsistence system may, therefore, shed light on the "Guale Problem." The 1970s transect survey of the island addressed settlement-subsistence systems on an island-wide scale (Thomas, 2008). Sites, in general, and large sites in particular, are more numerous during the late prehistoric period than earlier (Thomas, 2008: 877), suggesting larger communities, and more of them. The sites tend to be located at the margins of marsh and forest habitats (Thomas 2008: 929–933). This would seem to support the Jones model. Faunal samples, however, were small, not fine-screened, and the samples of seasonal indicators from each site were also small (Reitz, 2008: 617, 656–663). The data generated by the survey were appropriate for addressing macroscale questions, but not for site-level questions about intrasite variability in subsistence and seasonality. The recent excavations at Back Creek Village were designed to address these site-level questions. Fine-screened faunal collections and the resulting large samples of vertebrates and clams from multiple middens from Back Creek are used to address the question of whether late prehistoric sites were occupied on a seasonal basis for the purpose of exploiting seasonally available resources, or if they were occupied on a permanent basis. The latter scenario allows for the movement of groups of people for subsistence, political, or social activities, but not residential movement of entire communities on a seasonal basis.

MATERIALS AND METHODS

Back Creek Village (9Li207) is located on the seaward side of the island, just inland from the marsh formed by McQueen Inlet (fig. 5.1). Thomas (2008: 520, 534) classified the site as large, defined as having an inferred subsurface area greater than 500 m^2. Numerous discrete shell middens are visible, and others have been located through a probe survey. The middens surround a large depression that was possibly man-made and may once have held water. Middens vary in size—most are several meters in diameter, though others are more amorphous and cover a larger area. The site was identified during the 1970s transect survey of the island and five middens were tested (Thomas, 2008: 584). In the 1990s, another midden was tested. The materials recovered in those excavations indicate that the site was occupied during the Irene phase (A.D. 1300–1580). Excavations in 2008 retested five of the previously excavated middens as well as two additional middens, one of which was a large, amorphous mound (fig. 5.2). Two one-by-one meter units were excavated into each of the seven middens. The tested middens were given the letter designations A–H, though E was not excavated in 2008. Deposits were water screened through nested screens, ⅛ inch mesh being the smallest. Vertebrate remains were sorted in the field and sent to the Zooarchaeology Laboratory, Georgia Museum of Natural History, University of Georgia, for analysis. All whole hard clam valves (*Mercenaria* spp.) also were retained for analysis.

Identification of the vertebrate remains and clam valves used the comparative collection of the Georgia Museum of Natural History, following standards established in Reitz and Wing (2008: 151–181). Specimens were counted and weighed to aid in establishing relative abundances of taxa. Fish otoliths and atlases were measured using lab standards; namely, greatest width for atlases, and greatest length, greatest width, and thickness for otoliths. Age estimates for deer were based on epiphyseal fusion and tooth eruption. Sex was not evaluated, as none of the elements appropriate for such designation were present in the sample.

NISP (number of identified specimens), MNI (minimum number of individuals), and biomass were estimated for each midden. MNI, based on symmetry and age, was estimated for the lowest taxonomic level possible, usually at the species or genus level, except in cases where more individuals were present at the family level. NISP assumes that each specimen is from a different animal, which overestimates the contribution of taxa that have large numbers of elements or particularly identifiable elements. MNI assumes that the entire animal was present at the site and tends to overemphasize the relative importance of small species since it gives equal weight to all species, though small species have less meat to contribute to the diet (Reitz and Wing, 2008: 212–213). Biomass was estimated from specimen weight using allometric formulas published in Reitz and Wing (2008: 68). This measure is based on the allometric principle that skeletal weight scales to body size as an animal gets larger, and may be a more accurate reflection of dietary contribution because it only assumes the presence at the site of the bones found, and estimates meat contribution from those elements (Reitz and Wing, 2008: 239). It must be noted, however, that skeletal weight is subject to diagenic processes, so specimen weight does not necessarily reflect the weight of the specimen when the animal was alive.

Data were further summarized in a number of ways. They were assigned to higher taxonomic categories based largely on class and order; this summary was done at the site level, merging the data for each midden. Richness, diversity, and equitability were estimated for each midden and for the site as a whole. Richness is the number of species present in the species list, not including commensals (Anura, Caudata, Lacertilia, Soricidae, Talpidae, Sigmodontinae). Diversity, using the Shannon-Weaver index, is an index of the relative contribution of each species to the overall diet and equitability measures the degree of evenness with which the species were used (Reitz and Wing, 2008: 110–113). The diversity index ranges from 0 to 5 and is calculated using the formula: $H' = -\Sigma (p_i) (\log_e p_i)$, where p_i is the relative abundance of each taxon, in this case MNI and biomass estimated from specimen weight. The equitability index ranges from 0 to 1 and is calculated using the formula: $V' = H'/\log_e S$ where S is the number of taxa for which MNI and biomass were estimated.

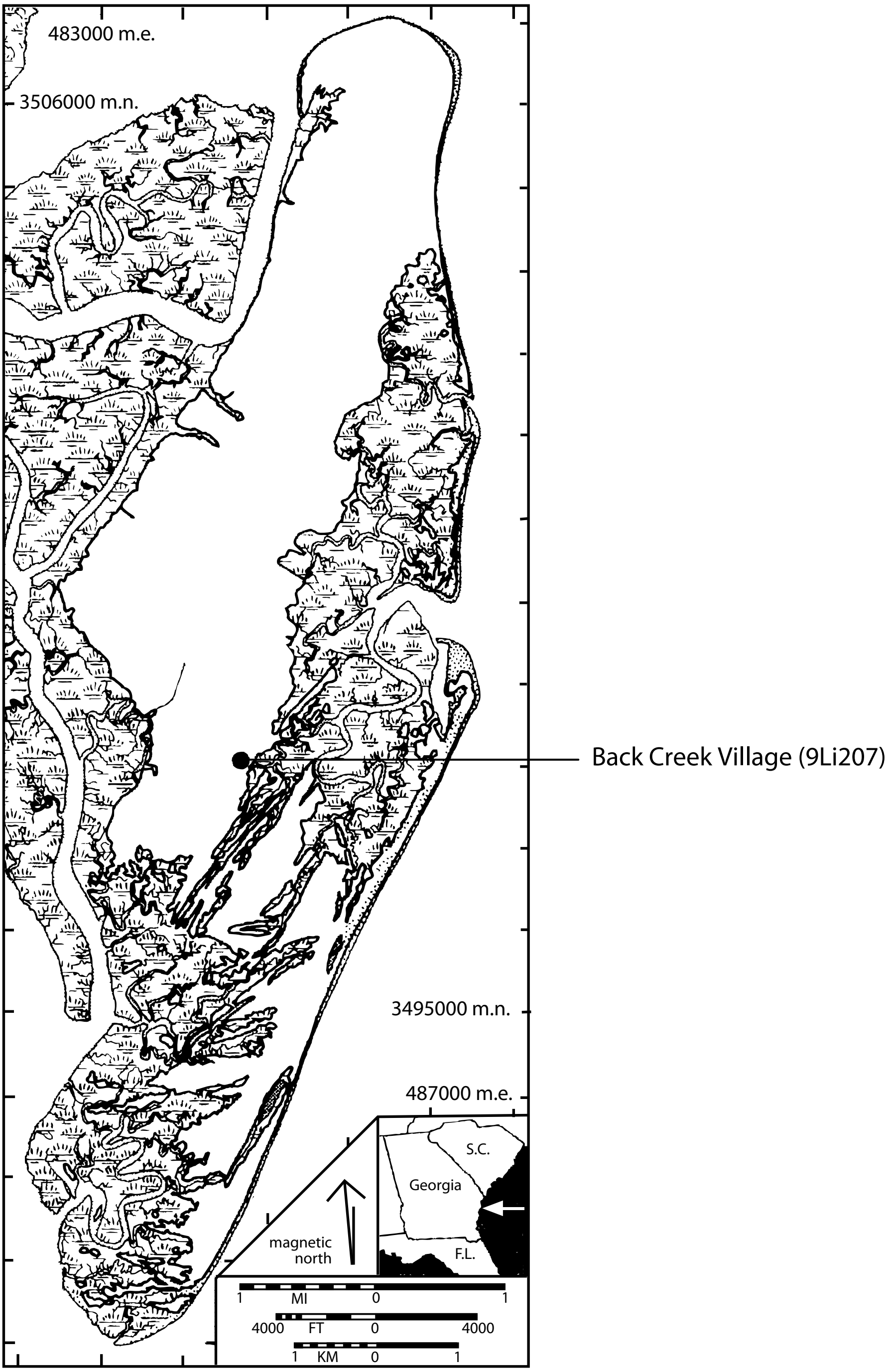


Fig. 5.1. Location of Back Creek Village on St. Catherines Island, Georgia.

Hard clams grow incrementally throughout the year by adding carbonate to the margins of each valve. In southeastern populations, an annual cycle is represented by a translucent, slow growth increment laid down in the summer and an opaque, fast growth increment laid down in the late winter–spring (Quitmyer, Jones, and Arnold, 1997). Using an established six-part sequence of growth (Jones, 1980; Quitmyer, Jones, and Arnold, 1985; Quitmyer, Jones, and Arnold, 1997; Quitmyer and Jones, chap. 7, this volume) and modern seasonal growth patterns (Quitmyer, Jones, and Arnold, 1997; Andrus and Crowe, 2008; O'Brien and Thomas, 2008; Quitmyer and Jones, chap. 7), it is possible to estimate season of death for the clams recovered at Back Creek Village. Andrus and Crowe (2008: 507–517) found that opaque growth began around November or December in St. Catherines clams and translucent growth began around March. Growth is most influenced by temperature, though other environmental variables, such as salinity, dissolved oxygen, and food availability, can cause variations in growth

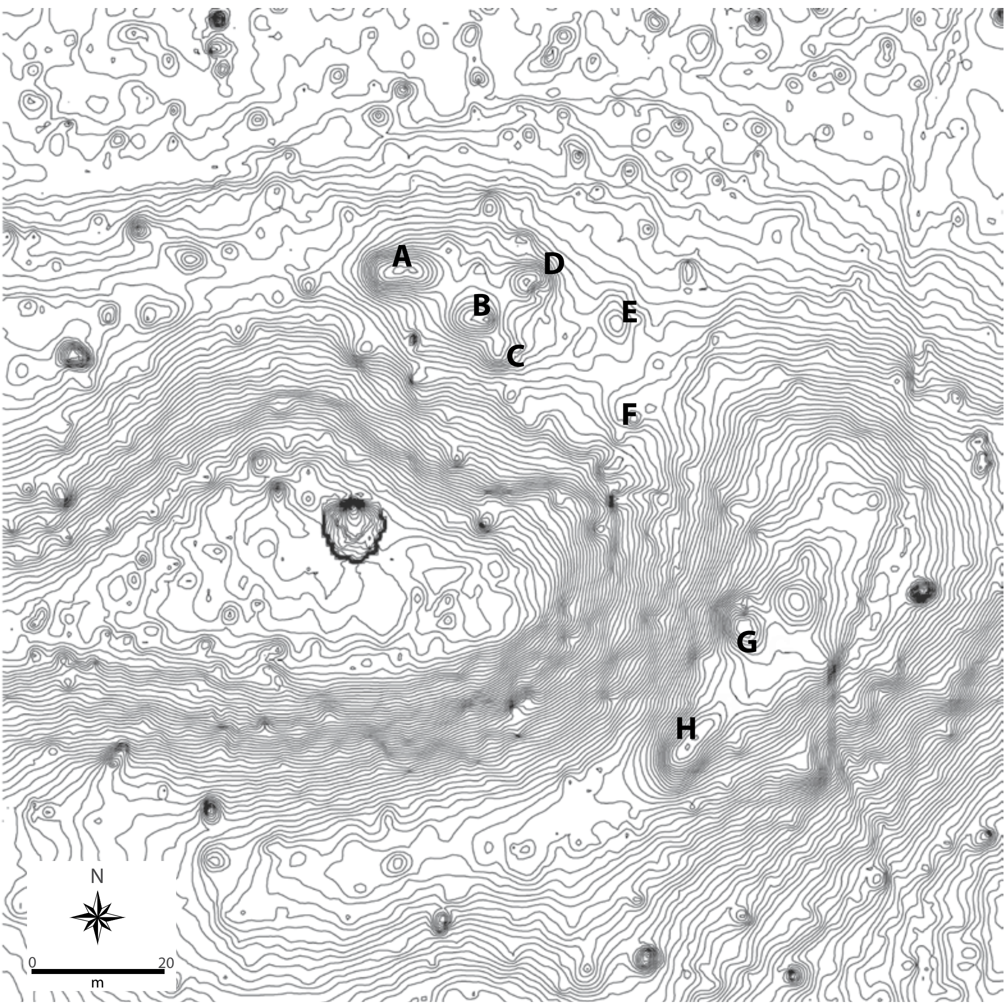


Fig. 5.2. Topographic map of Back Creek Village showing the location of the middens excavated in 2008.

patterns (Andrus and Crowe, 2008: 499–502). In addition, there are physiological conditions that cause variations in this pattern—most specifically, older individuals lay down much thinner increments and may be more sensitive to environmental stresses (Andrus and Crowe, 2008: 499). Looking at multiple clams from a single context can help account for individual variation within an archaeological population.

Seventy-five percent of the left valves from each unit were selected for analysis using a random number table. In units with 10 or fewer left valves, all left valves were selected. Each valve was sectioned radially from the umbo to the edge, along the margin of greatest growth, with a Buehler Isomet low-speed saw. Thick sections were visually inspected to determine the final growth phase. Histograms comparing the percentage of specimens assigned to each growth phase were constructed for each unit and for the site as a whole, to illustrate the range and distribution of growth phases present in each context

Fish size estimation can be useful for determining season of death in two ways. Modern trawl data record the frequency of different size classes of fishes caught on a monthly basis. The size of archaeological fishes can then be compared to the modern data to estimate the time of year the fishes were captured. Trawl data are available for a number of localities along the Georgia Coast (DEIS, 1978; Nelson et al., 1991) including the landward side of St. Catherines Island (Dahlberg, 1972). Back Creek Village, however, is located on the seaward side and the modern data may not be directly comparable. Fish size is generally related to fish age. If growth rates are known for the species in a region, then individuals can be classified as juveniles, subadults, or adults. This information can then be used to estimate seasonality for species in which different age cohorts have distinct seasonal movements within or out of the estuary.

Standard length for Back Creek Village fishes was reconstructed from allometric formulas (table 5.1) using measurements of otoliths and atlases. Growth of these elements scales allometrically with fish size. Modern comparative collections were used to generate regression formulas relating otolith length or width and atlas width to standard length that were applied to the archaeological measurements (Colaninno, personal commun.; Reitz and Wing, 2008: 68). Standard length was estimated for nine taxa: sea catfishes (Ariidae), mullets (*Mugil* spp.), silver perch (*Bairdiella chrysoura*), seatrout (*Cynoscion* spp.), spot (*Leiostomus xanthurus*), kingfish (*Menticirrhus* spp.), Atlantic croaker (*Micropogonias undulatus*), black drum (*Pogonias cromis*), and red drum (*Sciaenops ocellatus*). Standard length was estimated for the most common element of each taxon present in each unit.

RESULTS

A total of 14,881 vertebrate specimens were identified, for a total weight of 2049.296 g, and a total of 449 individuals. The results are presented by midden in tables 5.2 through 5.8. Hardhead catfish (*Ariopsis felis*), mullets, killifishes (Cyprinodontidae), snakes (Serpentes), rabbits (*Sylvilagus* spp.), and deer are 100% ubiquitous. Herrings and shad (Clupeidae), silver perch, seatrout, spots, red drums, flounders, mud turtles (Kinosternidae), diamondback terrapin (*Malaclemys terrapin*), birds (Aves), and raccoon (*Procyon lotor*) are present in over half the middens. Overall, fishes dominate the MNI (84%) and contribute a large portion of the biomass (37%) (table 5.9). Deer contribute the most biomass (43%), but only a small percentage of the MNI. Turtles and other wild mammals contribute more to the MNI than deer, though pond turtles are the only taxon besides fishes and deer to contribute a significant portion of the biomass. Birds and snakes contribute a small percentage of the MNI and biomass. Killifishes contribute the largest number of individuals to the fish MNI, though sea catfishes contribute the largest portion of the fish biomass. Drums make up the next largest portion of fish biomass, but sea catfishes, drums, and mullets contribute roughly similar numbers of individuals. Other fishes are not an insignificant portion of the MNI, but contribute little to the total biomass.

Richness, diversity, and equitability results are presented in figure 5.3. Richness for the whole site was 36, but for the middens it ranged from 14 in midden G to 26 in midden D, with a mean of 19. Diversity, estimated from MNI, ranged from 1.89 in midden F to 2.46 for midden D, and for the site as a whole, was 2.55. Diversity, estimated from biomass, ranged from 1.49 in midden F to 2.18 in midden C, and for the site as a whole, was 1.81. Equitability, estimated from MNI, was 0.71 for the site, and ranged from 0.68 in midden F to 0.85 in midden B. Equitability, estimated from

TABLE 5.1
Fish Size Regression Formulas

Otolith Width (mm) to Standard Length (mm)				
Taxon	*N*	Slope (b)	Y-intercept (log a)	r^2
Ariidae	337	1.13	1.31	0.7
Bairdiella chrysoura	68	1.09	1.32	0.92
Otolith Length (mm) to Standard Length (mm)				
Taxon	*N*	Slope (b)	Y-intercept (log a)	r^2
Cynoscion spp.	94	1.27	0.94	0.95
Menticirrhus spp.	45	1.27	1.13	0.97
Micropogonias undulatus	65	1.19	1.06	0.95
Pogonias cromis, Sciaenops ocellatus	75	1.238	1.05	0.91
Leiostomus xanthurus	86	1.39	1.06	0.86
Atlas Width (mm) to Standard Length (mm)				
Taxon	*N*	Slope (b)	Y-intercept (log a)	r^2
Mugil spp.	55	0.852	1.803	0.96
Sciaenidae	152	0.61	1.93	0.65

biomass, was 0.5 for the site, and ranged from 0.48 in midden H to 0.81 in midden G.

A total of 331 clam valves were sectioned for this study, but the growth phase of the final increment could only be determined for 308 valves. All growth phases were represented (T1–T3 and O1–O3) in the observed final increments (fig. 5.4). For the site as a whole there is a normal distribution around O1 growth, and the percentage in each phase ranges from 10% to 23%, a relatively equal representation of each phase. A similar distribution is seen in middens C (*N* = 26) and G (*N* = 48). All growth phases are also present in middens D (*N* = 53) and A (*N* = 66), though these middens have a small spike in T2 growth and another in O1 or O2 growth. Midden F (*N* = 27) is dominated by O1 growth and T2 is absent, midden B (*N* = 43) is dominated by O2 growth and T2 is absent, and midden H (*N* = 39) is dominated by O2 though T1 growth and T2 is absent.

Fish size was estimated for a total of 155 fishes (fig. 5.5). Age was estimated using biological studies of growth rates and size and age at maturity for each taxon. Size was estimated for a total of 41 sea catfishes from seven middens. The size ranges from 137 mm to 403 mm, with an average of 260 mm. Based on modern data for sea catfishes, these are all at least in their second year of life, and most are probably mature adults (Muncy and Wingo, 1983). Size was estimated for a total of 62 mullets from six middens. The size ranges from 88 mm to 201 mm, with an average of 135 mm. These individuals are likely under three years of age, and not mature (Collins, 1985). Size was estimated for a total of 17 silver perch from five middens. The size ranges from 95 mm to 180 mm, with an average of 140 mm. No data are available to address age. Size was estimated for a total of 20 seatrout from five middens. The size ranges from 149 mm to 521 mm, with an average of 352 mm. Seatrout can reach 150 mm by the end of the first year, and even 200

TABLE 5.2
Back Creek Village, Midden A: Species List

Taxa		NISP	MNI	% MNI	Weight (g)	Biomass (kg)
Actinopterygii	Indeterminate bony fishes	1185	—	—	18.951	0.356
Elops saurus	Ladyfish	10	1	1.3	0.082	0.004
Anguilla rostrata	American eel	2	1	1.3	0.050	0.003
Siluriformes	Catfishes	44	—	—	3.551	0.069
Ameiurus natalis	Yellow bullhead	1	1	1.3	0.039	0.001
Ariidae	Sea catfishes	17	—	—	7.012	0.131
Ariopsis felis	Hardhead catfish	27	1	1.3	4.051	0.046
Bagre marinus	Gafftopsail catfish	23	2	2.6	2.788	0.055
Mugil spp.	Mullets	480	10	12.8	7.427	0.171
Cyprinodontidae	Killifishes	152	16	20.5	1.207	0.041
Sciaenidae	Drums	83	—	—	3.645	0.104
Bairdiella chrysoura	Silver perch	1	1	1.3	0.006	0.001
Cynoscion spp.	Seatrout	241	15	19.2	25.374	0.559
Leiostomus xanthurus	Spot	1	1	1.3	0.050	0.004
Menticirrhus spp.	Kingfish	3	1	1.3	0.243	0.014
Micropogonias undulatus	Atlantic croaker	1	1	1.3	0.270	0.015
Sciaenops ocellatus	Red drum	2	1	1.3	0.376	0.019
Paralichthyidae	Flounders	8	1	1.3	0.485	0.015
Anura	Frogs and toads	37	—	—	0.656	—
Anaxyrus spp.	North American toads	10	2	2.6	0.301	—
Scaphiopus holbrookii	Eastern spadefoot toad	22	3	3.8	0.648	—
Rana sp.	Bullfrog	1	1	1.3	0.010	—
Caudata	Newts and salamanders	6	1	1.3	0.128	—
Testudines	Indeterminate turtles	150	—	—	27.224	0.362
Kinosternidae	Mud turtles	10	2	2.6	2.340	0.070
Emydidae	Pond turtles	15	—	—	13.957	0.227
Malaclemys terrapin	Diamondback terrapin	31	3	3.8	19.740	0.290
Lacertilia	Indeterminate lizards	14	4	5.1	0.136	—
Anolis carolinensis	Green anole	1	(2)	—	0.019	—
Serpentes	Indeterminate snakes	43	—	—	2.443	0.034
Nerodia spp.	Water snakes	14	1	1.3	2.262	0.031
Zenaida macroura	Mourning dove	1	1	1.3	0.052	0.001
Passeriformes	Perching birds	6	1	1.3	0.116	0.003
Mammalia	Indeterminate mammals	193	—	—	73.483	1.346
Scalopus aquaticus	Eastern mole	1	1	1.3	0.097	0.003
Sylvilagus spp.	Cottontail rabbit	4	1	1.3	0.703	0.019
Sigmodontinae	New World mice and rats	11	—	—	0.173	0.006
Sigmodon hispidus	Hispid cotton rat	1	1	1.3	0.040	0.001
Procyon lotor	Raccoon	2	1	1.3	4.153	0.096
Odocoileus virginianus	White-tailed deer	29	2	2.6	95.908	1.708
Vertebrata	Indeterminate vertebrates	—	—	—	52.786	—
Total		2883	78	100	372.982	5.805

TABLE 5.3
Back Creek Village, Midden B: Species List

Taxa		NISP	MNI	% MNI	Weight (g)	Biomass (kg)
Actinopterygii	Indeterminate bony fishes	389	—	—	5.899	0.139
Clupeidae	Herrings and shads	4	1	2.2	0.015	0.002
Siluriformes	Catfishes	152	—	—	9.453	0.171
Ariidae	Sea catfishes	51	7	15.6	47.294	0.789
Ariopsis felis	Hardhead catfish	7	(1)	—	0.903	0.018
Bagre marinus	Gafftopsail catfish	142	(4)	—	14.558	0.257
Mugil spp.	Mullets	45	2	4.4	0.644	0.024
Cyprinodontidae	Killifishes	49	9	20.0	0.385	0.016
Orthopristis chrysoptera	Pigfish	1	1	2.2	0.021	0.001
Pomatomus saltatrix	Bluefish	1	1	2.2	0.021	0.001
Sciaenidae	Drums	9	—	—	0.150	0.012
Bairdiella/Stellifer	Small drums	11	—	—	0.086	0.007
Bairdiella chrysoura	Silver perch	30	7	15.6	1.227	0.055
Micropogonias undulatus	Atlantic croaker	6	2	4.4	1.086	0.041
Pogonias cromis	Black drum	2	1	2.2	0.010	0.001
Sciaenops ocellatus	Red drum	1	1	2.2	0.672	0.029
Paralichthyidae	Flounders	1	1	2.2	0.014	0.001
Anura	Frogs and toads	25	—	—	0.369	—
Anaxyrus spp.	North American toads	7	2	4.4	0.189	—
Scaphiopus holbrookii	Eastern spadefoot toad	7	2	4.4	0.122	—
Caudata	Newts and salamanders	10	1	2.2	0.032	—
Testudines	Indeterminate turtles	66	—	—	7.042	0.146
Malaclemys terrapin	Diamondback terrapin	2	1	2.2	0.821	0.028
Lacertilia	Indeterminate lizards	18	2	4.4	0.123	—
Serpentes	Indeterminate snakes	59	1	2.2	0.645	0.009
Mammalia	Indeterminate mammals	13	—	—	4.837	0.116
Soricidae	Shrews	2	1	2.2	0.014	0.001
Sylvilagus sp.	Cottontail rabbit	1	1	2.2	0.158	0.005
Odocoileus virginianus	White-tailed deer	1	1	2.2	15.089	0.303
Vertebrata	Indeterminate vertebrates	—	—	—	18.308	—
Total		1112	45	100	130.187	2.172

TABLE 5.4
Back Creek Village, Midden C: Species List

Taxa		NISP	MNI	% MNI	Weight (g)	Biomass (kg)
Actinopterygii	Indeterminate bony fishes	453	—	—	5.701	0.138
Lepisosteus spp.	Gars	15	1	1.5	0.549	0.020
Cyprinidae	Carp and minnows	1	1	1.5	0.014	0.001
Siluriformes	Catfishes	71	—	—	2.836	0.056
Ariidae	Sea catfishes	7	—	—	5.095	0.096
Ariopsis felis	Hardhead catfish	46	4	6.2	5.146	0.097
Bagre marinus	Gafftopsail catfish	33	1	1.5	5.109	0.097
Mugil spp.	Mullets	297	10	15.4	4.038	0.103
Cyprinodontidae	Killifishes	225	22	33.8	1.734	0.051
Lagodon rhomboides	Pinfish	1	1	1.5	0.005	0.000
Sciaenidae	Drums	4	—	—	0.040	0.004
Bairdiella/Stellifer	Small drums	12	2	3.1	0.159	0.012
Bairdiella chrysoura	Silver perch	8	(1)	—	0.366	0.020
Cynoscion spp.	Seatrout	4	2	3.1	1.311	0.063
Leiostomus xanthurus	Spot	8	2	3.1	0.065	0.006
Paralichthyidae	Flounders	1	1	—	0.011	0.000
Anura	Frogs and toads	14	—	—	0.329	—
Anaxyrus spp.	North American toads	13	2	3.1	0.336	—
Scaphiopus holbrookii	Eastern spadefoot toad	13	3	4.6	0.276	—
Testudines	Indeterminate turtles	63	—	—	8.119	0.157
Malaclemys terrapin	Diamondback terrapin	3	1	1.5	3.420	0.089
Lacertilia	Indeterminate lizards	13	3	4.6	0.178	—
Serpentes	Indeterminate snakes	113	—	—	2.050	0.029
Nerodia spp.	Water snakes	2	1	1.5	0.027	0.000
Aves	Indeterminate birds	30	1	1.5	2.067	0.040
Passeriformes	Perching birds	1	1	1.5	0.010	0.000
Mammalia	Indeterminate mammals	75	—	—	30.351	0.640
Didelphis virginiana	Opossum	1	1	1.5	0.229	0.007
Sylvilagus spp.	Cottontail rabbits	2	1	1.5	0.562	0.016
Sciurus sp.	Squirrels	1	1	1.5	0.126	0.004
Sigmodontinae	New World mice and rats	3	1	1.5	0.023	0.001
Procyon lotor	Raccoon	3	1	1.5	0.553	0.017
Odocoileus virginianus	White-tailed deer	6	1	1.5	17.736	0.373
Vertebrata	Indeterminate vertebrates	—	—	—	26.206	—
Total		1542	65	100	124.777	2.138

TABLE 5.5
Back Creek Village, Midden D: Species List

Taxa		NISP	MNI	% MNI	Weight (g)	Biomass (kg)
Actinopterygii	Indeterminate bony fishes	1013	—	—	14.190	0.289
Lepisosteus spp.	Gars	3	1	1.1	0.141	0.006
Elops saurus	Ladyfish	1	1	1.1	0.010	0.001
Anguilla rostrata	American eel	4	1	1.1	0.051	0.003
Clupeidae	Herrings and shads	55	3	3.2	0.254	0.010
Siluriformes	Catfishes	150	—	—	9.428	0.174
Ariidae	Sea catfishes	147	—	—	16.646	0.296
Ariopsis felis	Hardhead catfish	165	11	11.6	31.425	0.543
Bagre marinus	Gafftopsail catfish	32	4	4.2	2.694	0.052
Opsanus sp.	Toadfish	1	1	1.1	0.023	0.001
Mugil spp.	Mullets	538	27	28.4	8.264	0.176
Belonidae	Needlefish	1	1	1.1	0.013	0.001
Cyprinodontidae	Killifishes	79	16	16.8	0.575	0.023
Carangidae	Jacks	1	1	1.1	0.033	0.002
Sciaenidae	Drums	13	—	—	0.540	0.029
Bairdiella/Stellifer	Small drums	2	—	—	0.020	0.002
Bairdiella chrysoura	Silver perch	10	3	3.2	0.418	0.025
Cynoscion spp.	Seatrout	4	1	1.1	0.071	0.006
Leiostomus xanthurus	Spot	13	3	3.2	0.095	0.008
Micropogonias undulatus	Atlantic croaker	3	1	1.1	0.449	0.026
Pogonias cromis	Black drum	3	1	1.1	0.066	0.005
Sciaenops ocellatus	Red drum	1	1	1.1	0.739	0.031
Paralichthyidae	Flounders	6	1	1.1	0.413	0.013
Anura	Frogs and toads	10	—	—	0.208	—
Scaphiopus holbrookii	Eastern spadefoot toad	8	1	1.1	0.172	—
Rana sp.	Bullfrog	1	1	1.1	0.033	—
Testudines	Indeterminate turtles	554	—	—	122.871	0.989
Kinosternidae	Mud and musk turtles	1	1	1.1	0.061	0.005
Emydidae	Pond turtles	50	—	—	33.127	0.413
Malaclemys terrapin	Diamondback terrapin	129	4	4.2	98.558	0.841
Lacertilia	Indeterminate lizards	3	1	1.1	0.067	—
Serpentes	Indeterminate snakes	46	—	—	0.487	0.006
Colubridae	Nonvenomous snakes	2	1	1.1	0.008	0.000
Viperidae	Venomous snakes	1	1	1.1	0.012	0.000
Aves	Indeterminate birds	3	1	1.1	0.666	0.015
Mammalia	Indeterminate mammals	82	—	—	41.056	0.795
Didelphis virginiana	Opossum	1	1	1.1	0.173	0.005
Scalopus aquaticus	Eastern mole	10	1	1.1	0.707	0.019
Sylvilagus sp.	Cottontail rabbit	1	1	1.1	0.124	0.004
Sigmodon hispidus	Hispid cotton rat	1	1	1.1	0.015	0.001
Procyon lotor	Raccoon	1	1	1.1	0.134	0.004
Odocoileus virginianus	White-tailed deer	21	1	1.1	78.322	1.384
Vertebrata	Indeterminate vertebrates	—	—	—	73.884	—
Total		3170	95	100	537.243	6.203

TABLE 5.6
Back Creek Village, Midden F: Species List

Taxa		NISP	MNI	% MNI	Weight (g)	Biomass (kg)
Actinopterygii	Indeterminate bony fishes	327	—	—	13.577	0.279
Lepisosteus sp.	Gars	1	1	1.6	0.126	0.005
Siluriformes	Catfishes	55	—	—	2.562	0.051
Ariidae	Sea catfishes	23	—	—	2.783	0.055
Ariopsis felis	Hardhead catfish	43	4	6.6	6.025	0.113
Bagre marinus	Gafftopsail catfish	2	1	1.6	0.227	0.005
Mugil spp.	Mullets	205	5	8.2	2.651	0.075
Cyprinodontidae	Killifishes	120	27	44.3	0.853	0.031
Sciaenidae	Drums	3	—	—	0.351	0.021
Cynoscion spp.	Seatrout	3	1	1.6	0.268	0.017
Pogonias cromis	Black drum	11	1	1.6	8.416	0.188
Sciaenops ocellatus	Red drum	3	1	1.6	0.371	0.019
Paralichthyidae	Flounders	1	1	1.6	0.058	0.002
Anura	Frogs and toads	44	—	—	1.108	—
Anaxyrus spp.	North American toads	28	4	6.6	0.200	—
Scaphiopus holbrookii	Eastern spadefoot toad	10	2	3.3	0.824	—
Testudines	Indeterminate turtles	201	—	—	40.414	0.474
Kinosternon spp.	Mud turtles	3	1	1.6	0.276	0.013
Emydidae	Pond turtles	6	—	—	16.480	0.244
Malaclemys terrapin	Diamondback terrapin	69	3	4.9	113.474	0.947
Lacertilia	Indeterminate lizards	30	1	1.6	0.426	—
Serpentes	Indeterminate snakes	52	—	—	1.758	0.024
Colubridae	Nonvenomous snakes	59	1	1.6	10.535	0.149
Aves	Indeterminate birds	1	—	—	0.165	0.004
Rallidae	Coots and rails	4	2	3.3	0.492	0.011
Passeriformes	Perching birds	1	1	1.6	0.018	0.001
Mammalia	Indeterminate mammals	90	—	—	66.578	1.232
Scalopus aquaticus	Eastern mole	16	1	1.6	0.730	0.020
Sylvilagus spp.	Cottontail rabbit	2	1	1.6	1.432	0.036
Sigmodontinae	New World mice and rats	1	1	1.6	0.006	0.000
Odocoileus virginianus	White-tailed deer	17	1	1.6	79.288	1.438
Vertebrata	Indeterminate vertebrates	—	—	—	66.438	—
Total		1431	61	100	438.91	5.454

TABLE 5.7
Back Creek Village, Midden G: Species List

Taxa		NISP	MNI	% MNI	Weight (g)	Biomass (kg)
Actinopterygii	Indeterminate bony fishes	1183	—	—	6.414	0.148
Clupeidae	Herrings and shads	1	1	2.6	0.006	0.001
Siluriformes	Catfishes	85	—	—	2.290	0.046
Ariidae	Sea catfishes	36	8	20.5	7.435	0.138
Ariopsis felis	Hardhead catfish	57	(4)	—	4.438	0.085
Mugil spp.	Mullets	191	5	12.8	2.872	0.078
Cyprinodontidae	Killifishes	68	11	28.2	0.483	0.019
Sciaenidae	Drums	1	—	—	0.020	0.002
Bairdiella chrysoura	Silver perch	2	1	2.6	0.038	0.003
Cynoscion spp.	Seatrout	6	2	5.1	1.970	0.091
Leiostomus xanthurus	Spot	3	1	2.6	0.050	0.005
Paralichthyidae	Flounders	2	1	2.6	0.305	0.009
Anura	Frogs and toads	15	—	—	0.405	—
Anaxyrus spp.	North American toads	5	1	2.6	0.157	—
Scaphiopus holbrookii	Eastern spadefoot tad	5	1	2.6	0.184	—
Testudines	Indeterminate turtles	26	—	—	2.548	0.073
Kinosternon spp.	Mud turtles	4	1	—	1.646	0.044
Emydidae	Pond turtles	2	—	—	0.373	0.016
Malaclemys terrapin	Diamondback terrapin	3	1	2.6	3.941	0.097
Lacertilia	Indeterminate lizards	6	1	2.6	0.035	—
Serpentes	Indeterminate snakes	32	1	2.6	0.743	0.010
Mammalia	Indeterminate mammals	43	—	—	19.952	0.406
Sylvilagus spp.	Cottontail rabbit	2	1	2.6	1.759	0.044
Procyon lotor	Raccoon	3	1	2.6	2.212	0.054
Odocoileus virginianus	White-tailed deer	1	1	2.6	4.910	0.110
Vertebrata	Indeterminate vertebrates	—	—	—	23.518	—
Total		1782	39	100	88.704	1.479

TABLE 5.8
Back Creek Village, Midden H: Species List

Taxa		NISP	MNI	% MNI	Weight (g)	Biomass (kg)
Actinopterygii	Indeterminate bony fishes	1022	—	—	17.898	0.332
Elops saurus	Ladyfish	1	1	1.5	0.005	0.000
Clupeidae	Herrings and shads	2	1	1.5	0.010	0.001
Siluriformes	Catfishes	397	—	—	1.248	0.251
Ariidae	Sea catfishes	203	—	—	11.269	0.202
Ariopsis felis	Hardhead catfish	309	11	16.7	39.689	0.666
Mugil spp.	Mullets	287	14	21.2	5.731	0.138
Cyprinodontidae	Killifishes	190	14	21.2	1.247	0.040
Archosaurgus probatocephalus	Sheepshead	4	1	1.5	0.618	0.010
Lagodon rhomboides	Pinfish	1	1	1.5	0.006	0.000
Sciaenidae	Drums	14	—	—	0.196	0.014
Bairdiella chrysoura	Silver perch	3	1	1.5	0.099	0.008
Cynoscion spp.	Seatrouts	23	2	3.0	2.074	0.087
Leiostomus xanthurus	Spot	5	1	1.5	0.055	0.006
Menticirrhus spp.	Kingfish	40	3	4.5	1.849	0.073
Paralichthyidae	Flounders	6	1	1.5	0.323	0.010
Anura	Frogs and toads	9	—	—	0.198	—
Anaxyrus spp.	North American toads	2	1	1.5	0.067	—
Scaphiopus holbrookii	Eastern spadefoot toad	3	2	3.0	0.040	—
Caudata	Newts and salamanders	3	1	1.5	0.011	—
Testudines	Indeterminate turtles	168	—	—	16.022	0.231
Kinosternidae	Mud and musk turtles	11	1	1.5	0.522	0.029
Malaclemys terrapin	Diamondback terrapin	48	2	3.0	42.325	0.444
Serpentes	Indeterminate snakes	79	—	—	1.504	0.021
Colubridae	Nonvenomous snakes	1	1	1.5	0.149	0.002
Mammalia	Indeterminate mammals	70	—	—	26.075	0.530
Soricidae	Shrews	9	1	1.5	0.247	0.007
Sylvilagus sp.	Cottontail rabbit	1	1	1.5	0.957	0.025
Sciurus spp.	Squirrels	3	1	1.5	1.084	0.028
Peromyscus spp.	Deer mice	20	2	3.0	0.377	0.011
Odocoileus virginianus	White-tailed deer	27	2	3.0	132.961	2.290
Vertebrata	Indeterminate vertebrates	—	—	—	51.637	—
Total		2961	66	100	356.493	5.457

TABLE 5.9
Back Creek Village: Summary

	NISP	MNI	% MNI	Biomass (kg)	% Biomass
Deer	102	9	2.0	6.09	43.2
Other wild mammals	28	15	3.3	0.32	2.3
Birds	47	8	1.8	0.07	0.5
Snakes	503	8	1.8	0.32	2.3
Pond turtles	358	15	3.3	1.90	13.5
Mud turtles	29	6	1.3	0.09	0.6
Sea catfishes	1370	55	12.2	3.44	24.4
Mullets	2043	73	16.3	0.46	3.3
Killifishes	883	115	25.6	0.13	0.9
Drums	593	61	13.6	1.11	7.8
Other fishes	137	30	6.7	0.11	0.8
Commensal taxa[1]	467	54	12.0	0.07	0.5
Total	6560	449	100	14.11	100

[1]Biomass not calculated for frogs, toads, lizards, and salamanders.

mm, depending on the environment. These individuals probably range in age from one year to six years (Johnson and Seaman, 1986). Size was estimated for a total of five spots from two middens. The size ranges from 137 mm to 187 mm, with an average of 157 mm. Based on modern data, these individuals are likely in their second year, and most are probably not mature (Hales and Van Den Avyle, 1989). Size was estimated for a total of two kingfish from two middens. The standard lengths for these two individuals were 263 mm and 326 mm. There are no data available to address age, though based on growth rates for other drums, these are probably adults. Size was estimated for a total of five Atlantic croakers from three middens. The size range was 145 mm to 203 mm, with an average of 180 mm. These individuals are probably in their second year, and likely not yet mature (Lassuy, 1983). Size was estimated for one black drum. The standard length for this individual was 87 mm. This individual is a juvenile, probably about half a year old (Sutter, Waller, and McIlwain, 1986). Size was estimated for two red drums from two middens. The standard lengths for these two individuals were 378 mm and 400 mm. These individuals are likely mature adults (Reagan, 1985).

DISCUSSION

The vertebrate taxa recovered from Back Creek Village are available year round in the estuary. Seasonally available resources, such as sea turtles, sharks, and migratory birds are completely absent. Terrestrial mammals, such as deer, raccoon, squirrels, opossums, and rabbits, live on the island, and although the mainland is close enough for some exchange between populations, there is no population-scale migration of these taxa off the island at any time of year. Modern studies of southeastern estuarine fishes demonstrate that the most common fish taxa from Back Creek—

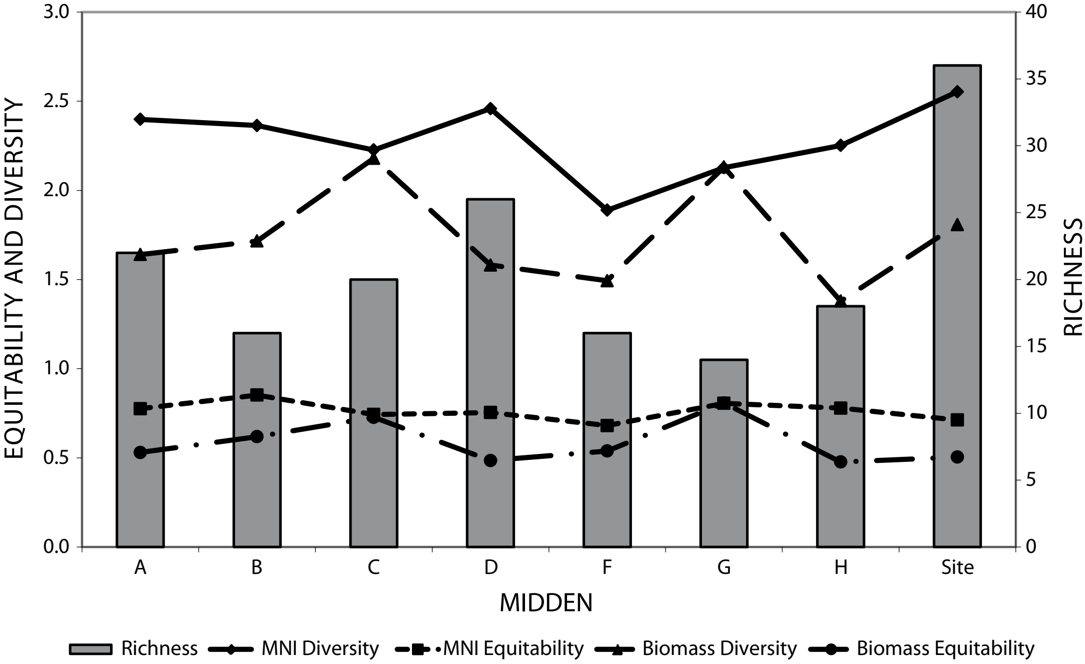


Fig. 5.3. Richness, diversity, and equitability estimates for Back Creek Village, presented for each midden and for the site as a whole.

sea catfishes, mullets, killifishes, drums, and flounders—are present in the estuary throughout the year. The age cohorts and locations of each taxon may change, but the taxon itself is present all year some place in the estuary (Dahlberg, 1972; DEIS, 1978; Nelson et al., 1991). The less abundant fishes in the Back Creek collection are also available for at least most of the year. This suggests a subsistence strategy that targeted consistently available animal resources.

The subsistence strategy also appears to have been generalized, not focused on single taxa or habitats. Mammals, fishes, shellfishes, estuarine and mud turtles, and terrestrial and water birds are all found in the same middens. Richness varies among middens, but it roughly correlates with NISP for the midden, and the same common taxa are present in all or most middens. Diversity estimated from MNI is consistently higher than diversity estimated from biomass, suggesting that although a range of taxa were exploited in any given midden, a small number of these taxa contributed most of the meat to the diet. Equitability for MNI is quite high in all middens (over 0.68), indicating that the hunting strategy targeted a range of taxa on a relatively equal basis. Equitability estimated from biomass is lower in most cases because deer, the largest animal identified in the collection, dominates the biomass. In middens C and G, equitability is the same for MNI and biomass. In midden C, this is because both MNI and biomass are dominated by a single taxon (killifishes in the case of MNI and deer in the case of biomass), and in midden G, this appears to be because no taxa dominate the MNI or biomass. The variability among middens can probably be accounted for by the different sample sizes recovered and by the fact that the specific species caught on any given fishing or hunting trip will vary.

The fish size and age data suggest a focus on fishing during the warmer months, though size could only be estimated for a handful of the fish individuals present at the site and the modern

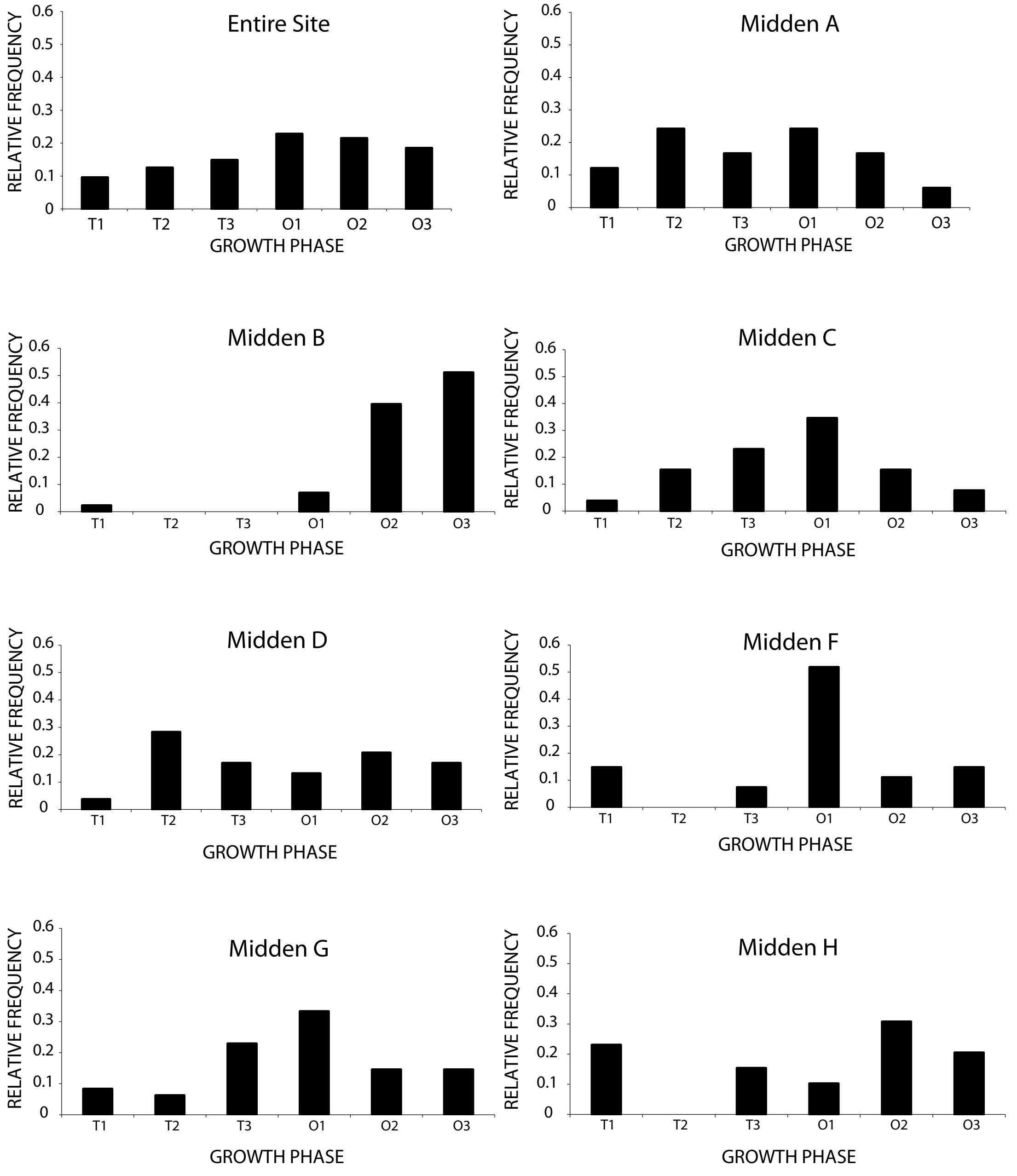


Fig. 5.4. Relative frequencies of final growth phases for hard clams (*Mercenaria* spp.) from Back Creek Village, presented for the site as a whole (top left graph) and for each midden.

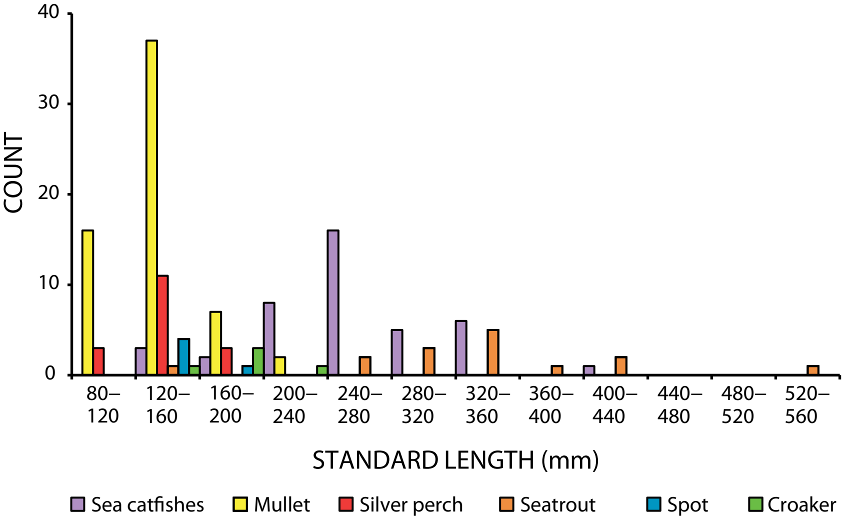


Fig. 5.5. Fish size estimates for selected fishes from Back Creek Village, presented for the site as a whole.

data used to estimate age and seasonality are not precise. The size of the black drum individual from midden D suggests an age of about half a year. The black drum spawning season is in the late winter/early spring (Sutter, Waller, and McIlwain, 1986), which could suggest a late-summer or fall occupation for midden D, though juvenile black drums are present in the estuary year-round (Nelson et al., 1991). Size was estimated for sea catfishes at the family level, since otoliths of the two species can be very similar. The individuals at Back Creek are all probably over a year old. They are all within the size ranges of hardhead catfish captured during the summer in modern trawls (Dahlberg, 1972). Size was estimated for seatrout at the genus level, as otoliths and atlases can look very similar. However, most of the individuals are probably spotted seatrout (*Cynoscion nebulosus*), and all but one are probably over two years of age. Juveniles and adults of this species are present in the estuary year-round (Nelson et al., 1991). Adults of the other species, weakfish (*Cynoscion regalis*), are present from April to December, and juveniles are present all year. Although there are no age estimates for the silver perch, the size of individuals from middens B, C, and G are in the range, or larger, than those caught only in summer in modern trawls. The individuals in middens D and H are in the range caught all year (Dahlberg, 1972). The spots in midden G are in the range of those caught in the summer and fall in modern trawls, while those in midden G are into the range of those caught all year (Dahlberg, 1972). The size of the kingfish at Back Creek is larger than those caught in the modern trawls, but is closest to those caught in the fall and early winter (Dahlberg, 1972). The Atlantic croaker individuals from middens A, B, and D are in or above the size range captured during the summer and early fall (Dahlberg, 1972). Adult red drums, croakers, kingfish, and spots are present in the estuary at least from April to December (Nelson et al., 1991). Size was estimated for mullets at the genus level because the skeletal elements of the species found on the Georgia coast are very similar. The mullets ranged from under a year to two years. As striped mullet juveniles and adults are present in the estuary year-round (Dahlberg, 1972; Nelson et al., 1991), this does not provide any seasonal evidence. Back Creek is located on the seaward marsh, and the modern trawl data are from the landward marsh, so the comparability of the two data sets is uncertain. In addition, trawling as a method of capture may not replicate the methods or locations used by past human populations. The consistency among the middens and among the fish taxa, however, does suggest fishing was especially important during the warmer months.

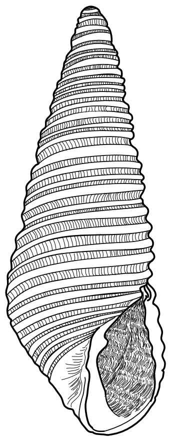
The results from clam incremental analysis indicate that clams were collected during all seasons at Back Creek Village. The distribution of final increments for the site as a whole is relatively even, though weighted a little toward the cold season, with a peak at O1 growth. Middens C and G have a similar distribution. Middens A and D are equally weighted toward cold and warm season growth, with small peaks at T2 and O1 or O2 growth, also suggesting that clams were collected in all seasons. Midden F is dominated by O1 growth and may suggest more of a fall–winter collection. Midden B is dominated by O2 and O3 growth, and might represent more of a winter–spring collection. Midden H is missing only T2 growth and may be a fall–spring collection. In all cases, except for midden B, both cold and warm season growth are represented. This may suggest a focus on molluscs, such as clams, during the colder seasons when many other animals are lean or less abundant and plant materials are less abundant.

CONCLUSION

The zooarchaeological evidence is more consistent with the Jones model of settlement than with the Larson and Crook model. The late prehistoric subsistence strategy represented at Back Creek Village relied heavily on vertebrate resources that are present in the estuary throughout the year, suggesting that seasonal movement to exploit animal resources was not a structuring principle of the settlement system. The same suite of vertebrate resources is present in all middens and the seasonal indicators suggest that all middens were utilized during multiple seasons. Although this is not proof that people occupied the site on a permanent basis, there is no evidence they occupied it on a strictly seasonal basis. The middens themselves may represent contemporary households or different occupations by one, or a few, households over time, but they do not appear to be a series of seasonal occupations. Animal taxa in a temperate estuarine environment vary in their abundance and location on a variety of temporal scales. Daily tides, fluctuations in timing and strength of tides during the year, rainy or dry periods in the interior or on the coast, stormy times of year, and temperature changes all influence resource abundance. Different taxa are affected by and respond to these environmental changes differently. The Georgia coast, then, is not a place where seasonality of resource availability is simply a matter of fall, winter, spring, and summer. Subsistence-settlement systems, instead, exploited the constant changes in availability of each resource—focusing on taxa that are reliably present in the estuary and emphasizing those that are most abundant during a time of year, such as fishes in the summer and fall and invertebrates in the winter and spring.

NOTES

1. I gratefully acknowledge the funding of archaeological research on St. Catherines Island by the Edward John Noble Foundation and the St. Catherines Island Foundation. I also want to acknowledge Dr. Elizabeth J. Reitz, Dr. David Hurst Thomas, and Irvy R. Quitmyer for their support in this research, Carol Colaninno-Meeks and Siavash Samei for their help in the lab, Maran Little for her enormous help sectioning clams, and Lori Pendleton Thomas, Elliot Blair, Anna Semon, and the rest of the 2008 St. Catherines Island archaeology staff and crew for excavating and sorting these materials.



CHAPTER 6
MOLLUSCS AS OXYGEN-ISOTOPE SEASON-OF-CAPTURE PROXIES IN SOUTHEASTERN UNITED STATES ARCHAEOLOGY

C. Fred T. Andrus

Oxygen isotope measurements in mollusc shells (fig. 6.1) are increasingly used to determine season of capture (SOC) in southeastern U.S. archaeological sites (e.g., Keene, 2004; Quitmyer, Jones, and Andrus, 2005; Andrus and Crowe, 2008; Thompson and Andrus, 2011). The basic rationale was initially outlined by Shackleton (1969; 1973, drawing from Emiliani et al., 1964). The method relies on the systematic variation of oxygen isotopes (expressed as $\delta^{18}O$ values in parts per mil: ‰) in shells during ontogeny as a function of water temperature and local water $\delta^{18}O$. In turn, local water $\delta^{18}O$ values are a function of fresh and salt water mixing and/or evaporation. Therefore, seasonal oscillations in shell $\delta^{18}O$ can be detected in areas with consistent variation in seasonal water temperature and/or precipitation (assuming that these two variables do not interact to obscure a seasonal signal in a shell).

If only one of those two variables controls shell $\delta^{18}O$ in a particular habitat, then SOC analysis is fairly simple (i.e., along desert coasts with almost no variation in $\delta^{18}O_{water}$ or tropical areas with little temperature variation but a pronounced rainy season leading to seasonal changes in $\delta^{18}O_{water}$). In those comparatively rare coastal environments, a small number of $\delta^{18}O$ samples near the edge of the shell can be analyzed for both absolute value and trend, and then a SOC estimate can be made (e.g., Jones et al., 2008). Most other coastal mollusc habitats are subject to regular variation in temperature and irregular variation in $\delta^{18}O_{water}$, thus complicating interpretation of shell $\delta^{18}O$ data. In many regions tidal variation between geographically adjacent zones makes absolute $\delta^{18}O$ values nearly useless for assessing SOC (e.g., Andrus and Crowe, 2008; Thompson and Andrus, 2011). In these cases, a seasonal trend in $\delta^{18}O_{shell}$ must be reconstructed through ontogeny and the most recent $\delta^{18}O$ value (at the growing shell edge) can be assessed relative to the particular seasonal cycle experienced by the shell as it grew (for a more complete explanation of one method using this approach, see Andrus and Crowe, 2008, and Thompson and Andrus, 2011. This approach is depicted in fig. 6.2). In most habitats along the southeastern coast of North America (Atlantic and Gulf of Mexico), local $\delta^{18}O_{water}$ is highly variable and is not reliably seasonal (see data at http://cdmo.baruch.sc.edu/ for examples from the Atlantic coast, and http://www.mymobilebay.com/ for examples from the Gulf coast). Therefore, the more expensive and time-consuming sequential sampling approach is required.

Early in the use of isotope sclerochronology, it was noted that careful study of modern living examples of each species (or close analogs) is necessary to ensure correct interpretation of archaeological SOC data (e.g., Bailey, Deith, and Shackleton, 1983). Different mollusc species have characteristics that may render their isotope profiles more or less useful as seasonal proxies (i.e., if the shape of the $\delta^{18}O$ curve becomes non-sinusoidal, seasons cannot be determined). $\delta^{18}O$ values in most biogenic carbonates are influenced by multiple variables in addition to temperature and ambient $\delta^{18}O_{water}$. These factors may include metabolic/kinetic effects (e.g., Owen, Kennedy, and Richardson, 2002), shell mineralogy (e.g., Cusack et al., 2008), shell structure (e.g., Cusack et al., 2008; Jones, 2010), variable growth rate,

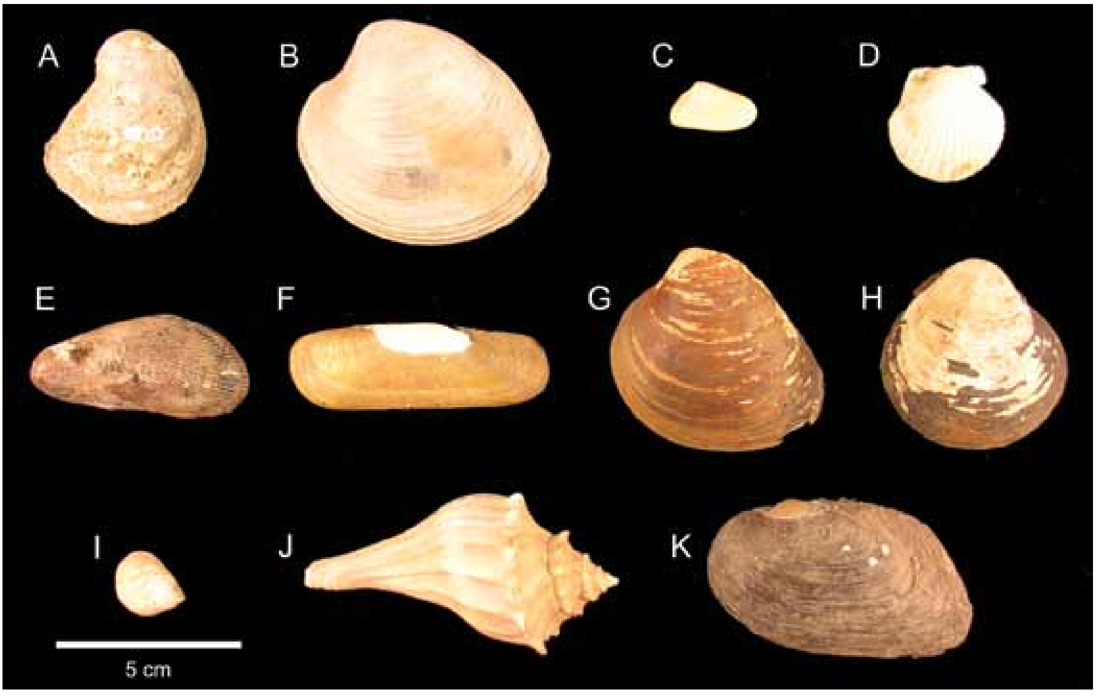


Fig. 6.1. Examples of taxa described in this chapter. **A**, American oyster (*Crassostrea virginica*); **B**, quahog (*Mercenaria mercenaria*); **C,** coquina (*Donax variabilis*); **D**, bay scallop (*Argopecten irradians*); **E**, ribbed mussel (*Geukensia demissa*); **F,** stout razor clam (*Tagelus plebeius*); **G**, marsh clam (*Rangia cuneata*); **H**, Carolina marsh clam (*Polymesoda caroliniana*); **I**, periwinkle (*Littorina irrorata*); **J**, knobbed whelk (*Busycon carica*); **K,** freshwater mussel (Unionidae).

and growth cessations (e.g., Goodwin, Schöne, and Dettman, 2003) to name a few.

To illustrate, consider that molluscs commonly cease growing for portions of each year (e.g., Goodwin, Schöne, and Dettman, 2003; Schöne, 2008; Jones et al., 2010a). If molluscs in a midden were collected during a prolonged period in which there was no shell growth, then the SOC estimate would be inaccurate. If the growth cessation periods are brief and do not interrupt the general seasonal trends in $\delta^{18}O$, then the shell isotope profile can still be a useful SOC proxy. This may, however, limit the precision of the estimates. Large numbers of growth breaks may preclude effective use of the shell as an SOC indicator by distorting the seasonal $\delta^{18}O$ oscillation to the point where it is not recognizably sinusoidal. Some growth cessations are regular and linked to a particular time of the year (e.g., Jones et al., 2010a), and thus may aid in the interpretation of $\delta^{18}O$ profiles. Others may be arrhythmic (e.g., Cobb, Andrus, and Etayo-Cadvid, 2009) and may cause significant ambiguity in $\delta^{18}O$ interpretations.

These and other complications need to be assessed for each taxon prior to making SOC estimates from archaeological contexts. This is usually accomplished by detailed growth and geochemical analyses of modern controlled collections of specimens. Such baseline data are time-consuming and expensive to collect, thus the accumulation of SOC proxy methods for species in a region may be slow. A number of useful SOC taxa are needed to assess a wide range of human subsistence practices and to reconstruct possible seasonal-round movements across habitats. For example, it must be remembered that an SOC estimate from a particular taxon does not necessarily equate to the total season(s) of site occupation. It is plausible that some resources would only be exploited seasonally in an otherwise permanent occupation, perhaps due to dietary prohibitions, comparative abundance of other food sources, seasonal changes in taste and condition of molluscs, or a number of other factors. In such cases, a single-taxon SOC study would yield erroneous conclusions. Furthermore, multispecies SOC data would also be useful in assessing regional subsistence strategies. For example, prehistoric people in the coastal southeastern United States exploited a wide range of habitats (e.g., Thomas, 2008). Few mollusc species are present in all of these habitats. To gain a more complete picture of regional site occupation patterns, data would be required from sites from all habitat zones.

To accomplish this broader approach in the southeastern United States, not only do we need an understanding of the abundant coastal marine/lower estuarine species like oyster and quahog, but also brackish and freshwater taxa. If reliable methods can be established for multiple taxa, then widespread and more cost-effective application of SOC estimates can be made, thus building a regional understanding of subsistence practices.

DISCUSSION

The goal of this chapter is to review published literature pertinent to oxygen isotope SOC assessment methods in the southeastern U.S. coastal zone. Each relevant taxon (fig. 6.1) will be discussed individually. In most cases these taxa have not been used to measure SOC yet, so their potential utility will be evaluated based on published literature and new data pertinent to key variables such as biogeography, taphonomy, shell structure and mineralogy, seasonal growth, and geochemistry. This is not meant to be a complete list of all molluscs found in southeastern middens, but rather focuses on taxa that are comparatively common in archaeological sites, display some potential for use as SOC indicators, and cover a wide range of ecosystems relevant to coastal subsistence. Not all of these species are present in St. Catherines Island middens, but all are found within nearby coastal ecosystems. For the purposes of this chapter, the "southeastern U.S. coast" includes all tidally affected water from the northernmost barrier islands of the Carolinas south to the semitropical zones of southern Florida, and in the Gulf of Mexico coast from semitropical Florida west to Mexico.

Oyster (*Crassostrea virginica*)

The oyster (see A in fig. 6.1) is the most common mollusc found in southeastern U.S. coastal middens (for examples see Pearson, 1977; Crook, 1992; Russo and Heide, 2001; Keene 2002; Quitmyer and Reitz, 2006; Thomas, 2008; Thompson and Andrus, 2011). Five studies have been

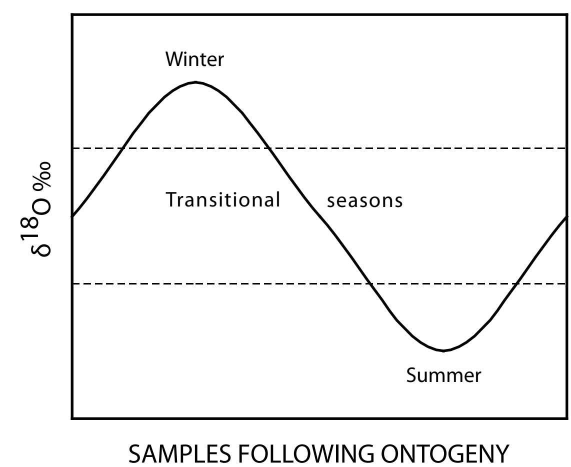


Fig. 6.2. Idealized representation of seasonal $\delta^{18}O$ oscillations in a mollusc through ontogeny.

published on oxygen isotope analyses in modern populations, Kirby, Soniat, and Spero (1998) Andrus and Crowe (2000) and Surge, Lohmann, and Dettman (2001), Harding et al. (2010) and Cannarozzi (chap. 10, this volume), as well as three isotopic SOC analyses of archaeological sites, Keene (2004), Harding et al. (2010), and Thompson and Andrus (2011).

Oysters present several significant challenges unique among common southeastern U.S. midden molluscs. Most obvious is their highly variable morphology. Whereas most molluscs grow in generally predictable rates and shapes like *Mercenaria* spp. (see Quitmyer, Jones, and Arnold, 1997; compare A and B in fig. 6.1), oysters do not have a specific growth geometry (see Kent, 1982). As such, oysters are not typically sampled for oxygen isotopes across the valve length as is the case in most taxa, but rather are bisected along the chondrophore (fig. 6.3) and then sequentially sampled along the hinge area (e.g., Surge, Lohmann, and Dettman, 2001; Keene, 2004; Thompson and Andrus, 2011).

Another complication is their lack of reliably rhythmic growth increments. In cross section along the chondrophore, dark and dense calcite alternates with light and chalky calcite in what appear to be growth increments. Surge, Lohmann, and Dettman (2001) found no regular seasonal pattern to increments in an estuary on the Gulf coast of Florida. Based on a sample of oyster shells from Georgia, Andrus and Crowe (2000) argued that while most increments seen in cross section were related to seasonal extremes, bands were also associated with nonseasonal events. Kirby, Soniat, and Spero (1998) found that ligamental increments were seasonal in Mississippi and Chesapeake Bay samples. Other studies in the Chesapeake Bay area have also shown regular banding (e.g., Kent, 1992; Herbert and Steponaitis, 1998). It may be that there are regional differences in growth patterns. Further studies across a broad geographic range are needed to clarify this discrepancy. As such, it is difficult to confidently estimate age and growth rate prior to sequential isotope sampling, thus limiting estimates of time-averaging and sampling resolution.

This sampling difficulty in turn may contribute in part to nonsinusoidal $\delta^{18}O$ profiles, sometimes described as "saw-tooth" in pattern. In Andrus and Crowe (2000) these patterns were likely exaggerated by the laser sampling method whereby a single pit was ablated into each increment, leaving significant spaces of unanalyzed shell in between adjacent pits, thus increasing the likelihood of signal aliasing and the appearance of sudden variation in $\delta^{18}O$. Likewise, the laser method and the microenvironments at that

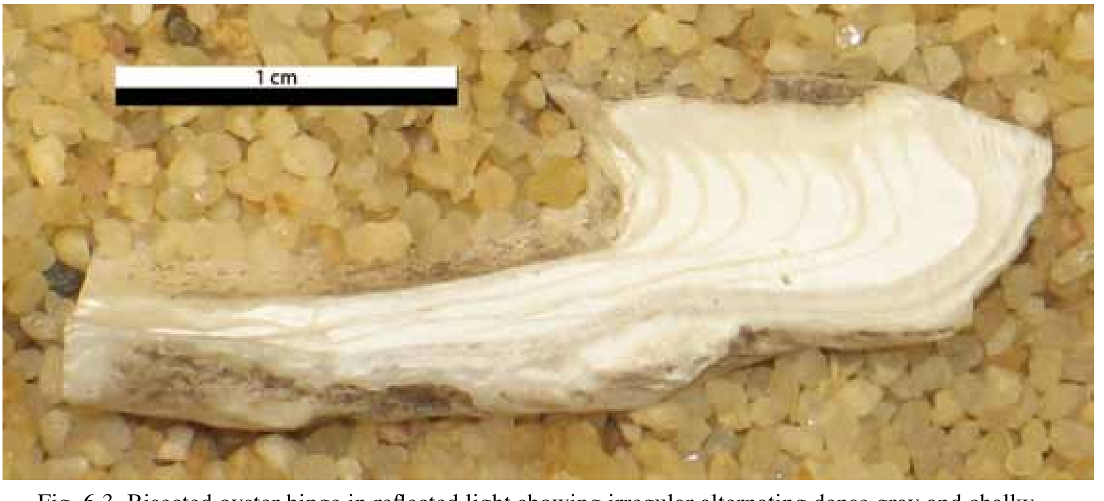


Fig. 6.3. Bisected oyster hinge in reflected light showing irregular alternating dense gray and chalky white banding.

collection site likely contributed to wider amplitudes of seasonal oscillations and more variable absolute values due to comparatively poor analytical precision and standardization. This method has since been abandoned, yet these saw-tooth patterns and variability between profiles are still seen even in finely micromilled samples analyzed with high precision (see Surge, Lohmann, and Dettman, 2001, Keene 2002; Harding et al. 2010; Thompson and Andrus, 2011). There may be several related explanations for this.

Periods of growth cessation are noted in oysters (e.g.,Kirby, Soniat, and Spero, 1998; Surge, Lohmann, and Dettman, 2001), and even short gaps may lead to abrupt changes in $\delta^{18}O$ values if temperature and $\delta^{18}O_{water}$ change rapidly. Also, unlike most other taxa discussed here, oysters are completely sessile, epibenthic, and frequently found in intertidal zones. This means that oysters are not insulated by any sediment, have no means of avoiding temperature and salinity extremes other than closure, and may be exposed to diurnal and tidal temperature extremes that create abrupt changes in $\delta^{18}O$ and frequent brief growth cessations. Furthermore, oysters cluster and create growing beds in ways that may promote the formation of changeable microenvironments.

The net result of these issues in terms of SOC estimates is that nonsinusoidal $\delta^{18}O$ profiles may be commonly seen and be difficult or impossible to interpret. As a result, a comparatively high percentage of analyzed shells may not yield trustworthy data, thus adding uncertainty, cost, and time to the overall site analysis (e.g., Thompson and Andrus, 2011). It may also lead to decreased overall accuracy in SOC estimates.

In summary, even though several modern studies exist and midden oysters are already in use as SOC proxies, more baseline data are needed to better understand many key aspects of oyster growth and geochemistry. Such additional work is warranted because oysters are the dominant taxon in middens in the region and cover a wide range of habitats. The research presented in this volume by Cannarozzi (chap. 10) represents an important contribution to this progress and adds detail and new data to the description given here.

Quahog, or Hard Clam (*Mercenaria* spp.)

Quahogs, or hard clams (*Mercenaria mercenaria, M. campechiensis*, and hybrids [B in fig. 6.1]), are the most studied of all midden molluscs in the southeastern United States with respect to oxygen isotopes and growth increments. Modern baseline incremental oxygen isotope analyses in hard clams were pioneered by Jones, Arthur, and Allard (1989) and Jones and Quitmyer (1996). Other modern baseline studies followed, including Elliot et al. (2003), Walker and Surge (2006), Surge and Walker (2006), and Andrus and Crowe (2008). Comparisons of isotope data to visual growth band analysis and modern control collections showed that, unlike some other taxa in the region, quahog growth increments form with good seasonal regularity (fig. 6.4) and can be used to assess SOC (Clark, 1979; Quitmyer, Hale, and Jones, 1985, 1997; Arnold et al., 1991; Jones and Quitmyer, 1996; Andrus and Crowe, 2008; O'Brien and Thomas, 2008; Parsons, 2008; Russo and Saunders, 2008; Thompson and Andrus, 2011; Quitmyer and Jones, chap. 7; and Jones, Quitmyer, and DePratter, chap. 8 in this volume). The two species and their hybrids are difficult to differentiate using only shell morphology; however, they can be safely treated as identical in terms of their $\delta^{18}O$ records according to Surge et al. (2008), who made detailed comparisons of each and found no differences that would complicate their use as SOC proxies.

These clams are arguably the best and most reliable sources of sclerochronological SOC data in the region. This is due to their well-studied, regular growth patterns, temperature-dependent oxygen isotope fractionation, large size that permits easy sampling, good preservation, abundance in many middens in the region, and wide environmental tolerance. The principal limitations of these clams are that they are less abundant than oysters in archaeological sites in the region, and that they do not range into brackish and freshwater environments. Geriatric individuals may also present challenges in that banding at the shell margin is very thin and may not permit adequate sampling density to resolve seasonal shifts in $\delta^{18}O$ (e.g., Andrus and Crowe, 2008; Parsons, 2008).

$\delta^{18}O$ data can be used to augment incremental (structural) SOC methods (Quitmyer, Jones, and Arnold, 1997; Andrus and Crowe, 2008; Jones, Quitmyer, and DePratter, chap. 8, this volume) in that latitudinal (Jones and Quitmyer, 1996) and temporal (Henry and Cerratto, 2007) variation in increment precipitation has been noted. $\delta^{18}O$ profiles compared to increments in midden clams can assess the stability of growth patterns through

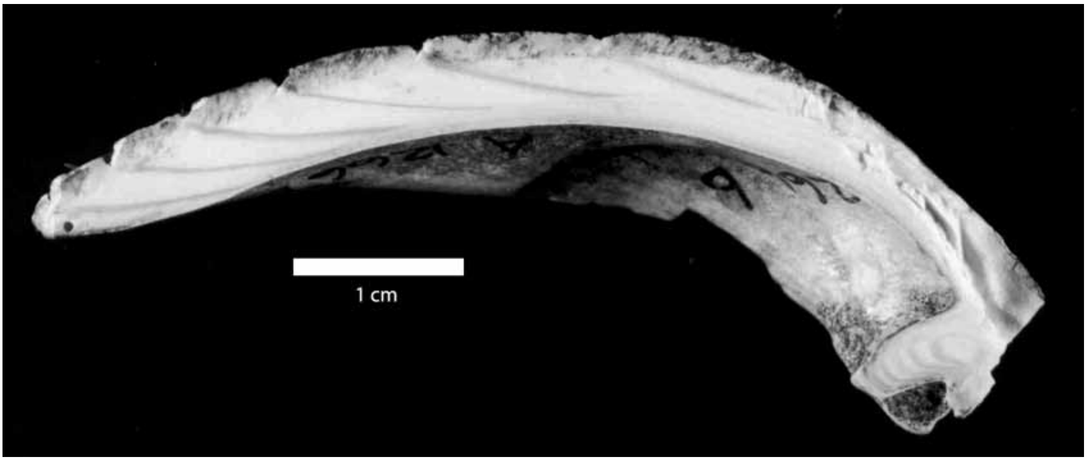


Fig. 6.4. Bisected quahog valve in reflected light showing regular alternating light and dark bands.

time and space. Thus, large numbers of shells can be visually analyzed cheaply and quickly with a few complementary isotope profiles to build confidence in the method. Application of this general approach is growing (e.g., Andrus and Crowe, 2008; O'Brien and Thomas, 2008; Thompson and Andrus, 2011) and will hopefully expand over time. Quitmyer and Jones (chap. 7) and Jones, Quitmyer, and DePratter (chap. 8, this volume) expand on these baseline data and provide more detail on the analysis of clam shells.

Coquina Clam (*Donax variabilis*)

Coquinas are not as common in most middens as oysters and quahogs but are very abundant in some archaeological sites (e.g., Quitmyer, Jones, and Andrus, 2005), typically in sites near the clam's littoral habitat. These are small clams (C in fig. 6.1) that inhabit the surf zones of open beaches, living by burrowing in the sand and riding waves in and out with the tides. This habitat drew the attention of researchers because $\delta^{18}O_{water}$ in beach environments is typically far more stable than the habitats of other midden molluscs (Jones, Quitmyer, and Andrus, 2004). Three papers have been published on modern and archaeological coquinas (Jones, Quitmyer, and Andrus, 2004, 2005; Quitmyer, Jones, and Andrus, 2005). These papers took advantage of the stable $\delta^{18}O_{water}$ to reconstruct past sea surface temperatures (Jones, Quitmyer, and Andrus, 2004, 2005). SOC estimates have also been made using these clams (Quitmyer, Jones, and Andrus, 2005; Price, 2008).

The small size of these clams (often 1–2 cm along the longest axis) presents some challenges in sampling. Micromilling an intact valve from the outer surface is the method most often used (Jones, Quitmyer, and Andrus, 2004, 2005; Quitmyer, Jones, and Andrus, 2005; Etayo-Cadavid, 2010) and this fine-scale sampling can result in submonthly resolution. The resulting $\delta^{18}O$ profiles generally produce smooth sinusoidal curves amenable to seasonal interpretation. In many respects $\delta^{18}O$ profiles in these clams represent ideal SOC proxies and useful coastal marine paleoclimate proxies. The principal limitation appears to be their comparative rarity in sites in the region and their restricted habitat. Additional research into the periodicity of increments, shell structure, and environmental tolerances may improve this proxy.

Bay Scallop (*Argopecten irradians*)

Scallops (D in fig. 6.1) are not common in all ecosystems across this region; thus their appearance in middens is somewhat localized (Russo and Quitmyer, 1996, 2008; Withers and Hubner, 2009). *Argopecten irradians concentricus* is the dominant subspecies found in the southeastern U.S. Atlantic and Gulf coasts (MacKenzie, 2008). This scallop is extensively well studied with respect to basic biology (see MacKenzie, 2008, for a recent review), but no published analysis of oxygen isotope shell data exists. Archaeological analyses of these scallops have focused on SOC estimates using shell length measurements (Russo and Quitmyer, 1996, 2008) and changes in shell morphology (Marelli and Arnold, 2001).

Examination of the shell structure and mineralogy suggests that there may be several challenges to overcome when measuring $\delta^{18}O$ profiles in these scallops. For example, the shell is composed of two calcite layers separated by an aragonite layer. Such a configuration makes micromilling single-mineral samples difficult. Prior knowledge of sample mineralogy is necessary to generate and interpret $\delta^{18}O$ data from bimineralic shells because aragonite and calcite have differing phosphoric acid fraction factors (Kim, Mucci, and Taylor, 2007) and potentially different original isotopic enrichments (Cusack et al., 2008). Undetected mixing of mineral samples could alter the seasonal $\delta^{18}O$ profile and complicate assignment of SOC.

Additional alteration of scallop $\delta^{18}O$ profiles can be due to seasonally episodic growth. Significant winter mortality occurs in this species in at least part of its range after the first year of growth (Russo and Quitmyer, 1996, 2008). This suggests that sublethal exposure to seasonal temperature extremes may lead to diminished or paused shell growth and result in truncation of seasonal $\delta^{18}O$ oscillations. Although these growth and structural issues need to be addressed, sequential isotopic analysis in morphologically similar scallops has been successful in measuring seasonal environmental variation (e.g., Jones et al., 2007).

Ribbed Mussel (*Geukensia demissa*)

Although ribbed mussels (E in fig. 6.1) are found in southeastern U.S. shell middens (e.g., Keene, 2002; Quitmyer and Reitz, 2006; Parsons, 2008) and are abundant in regional salt marshes, no sequential oxygen isotope data have been published for this species. However, fairly extensive geochemical, mineralogical, and microstructural analysis has been performed on closely related species from similar coastal environments (Jones and Kennett, 1999; Vander Putten, 2000; Gillikin et al., 2006; Wanamaker et al., 2006, 2007; Cusack et al., 2008; Jones et al., 2008; Ford et al., 2010; Jones, 2010). One study (Lécuyer, Reynard, and Martineau, 2004) analyzed bulk (no time series data) $\delta^{18}O$ samples from Caribbean ribbed mussels and noted temperature-dependent oxygen isotope distributions. Collectively, these studies demonstrate that making isotopic estimates of SOC is likely possible, but as with the bay scallops, there are several potential problems that need to be addressed before these mussels can be analyzed with confidence.

First among these concerns is a need to have a detailed understanding of the shell microstructure and mineralogy. Lécuyer, Reynard, and Martineau (2004) performed Raman analyses on one shell and detected only aragonite; however, some mussels like *Mytilus edulis* (Vander Putten et al., 2000) and *Choromytilus chorus* (Jones, 2010) also contain calcite. More detailed mineralogical and microstructural analysis is required because $\delta^{18}O$ data from bimineralic mussels presents a similar situation as described above for bay scallops. Furthermore, in some other mussels, different textures and crystal habits of the same mineral are present across shell layers and contain different isotopic values (Cusack et al., 2008; Jones, 2010).

Shell growth rate in this species is not uniform throughout the year in the southeastern United States (Borrero and Hilbish, 1988). Growth cessations and significant changes in growth rate over ontogeny have been seen to impact $\delta^{18}O$ profiles in related taxa (e.g., Jones, 2010). Studies of modern populations of ribbed mussels are needed to fully assess whether growth rate impacts their utility as SOC indicators. Seasonal $\delta^{18}O$ profiles may also be impacted by damage to the fragile valves during life (Hillard and Walters, 2009).

If absolute temperature reconstructions are desired, it may also be necessary to develop a species-specific isotope temperature equation. Other mussels such as *Mytilus edulis* (Wanamaker et al., 2006, 2007) and *Mytilus californiensis* (Ford et al., 2010) have slightly different slopes and significantly different *y*-intercepts to their respective isotope/temperature relationships. The only published $\delta^{18}O$ data from this species (Lécuyer, Reynard, and Martineau, 2004) lack adequate environmental monitoring to assess which, if any, published equation is suitable.

The biggest obstacle to the use of ribbed mussels for SOC analysis may be taphonomy. Compared to oysters and quahogs, their shells are quite thin and fragile. They are typically excavated in fragments that may be too small to generate a seasonal sinusoidal curve with which to compare the edge values. Because they live in similar habitats to the oyster and thus experience highly variable $\delta^{18}O_{water}$, such complete sinusoids are necessary to measure SOC.

Stout Razor Clam (*Tagelus plebeius*)

Razor clams (F in fig. 6.1) are often present in middens in the Southeast (e.g., Pearson, 1977; Keene, 2002; Quitmyer and Reitz, 2006; Parsons, 2008), but little SOC research has been conducted on them. No published studies exist regarding seasonal growth in their shells or oxygen isotope distributions. These large, robust clam valves preserve comparatively well in middens and would be technically straightforward to sample sequentially. Morphologically similar razor clams have been analyzed for sequential isotope data in Peruvian and Chilean middens (e.g., Carré et al., 2005, 2009; Jones et al., 2010b). These South American shells produced regular, seasonal sinusoidal patterns, with abrupt summer shifts in shell $\delta^{18}O$ values indicating subseasonal warm temperature growth cessations (Carré et al., 2005; Jones et al., 2010b). The Pacific coast of South America has a far narrower range in seasonal water temperatures and very little variation in $\delta^{18}O_{water}$ as compared to the southeastern United States; therefore, direct analysis of modern *T. plebeius* is required to assess the seasonality of shell growth.

Research on modern populations in South Carolina by Holland and Dean (1977) suggest that these razor clams contain annual growth bands and grow most rapidly in summer and fall with variation between habitats and tidal zones. Lomovaskya, Gutiérrez, and Iribarnea (2005) note that specimens of *T. plebeius* commonly display evidence of shell damage and repair around the valve edge (>70% in their samples). Similar to periods of growth cessation or diminishment, this may have significant impact on the shape of the seasonal $\delta^{18}O$ profiles and should be assessed with controlled modern studies.

Marsh Clam (*Rangia cuneata* and *Polymesoda caroliniana*)

Unlike the other taxa thus far discussed, marsh clams live in brackish to nearly fresh water environments and thus may provide insight into subsistence activities and seasonal timing outside the immediate coast. *Rangia cuneata* (G in fig. 6.1) is the dominant marsh clam in habitats and middens along the Gulf of Mexico coast, and *Polymesoda caroliniana* (H in fig. 6.1) is more abundant on the Atlantic coast. While *R. cuneata* is frequently the most abundant species in Gulf middens (e.g., Aten, 1981; Carlson, 1987), *P. caroliniana* is less often found in either coast.

There are three published $\delta^{18}O$ studies of *R. cuneata* (Lécuyer, Reynard, and Martineau, 2004; Andrus and Rich, 2008; Cobb, Andrus, and Etayo-Cadavid, 2009); however, they do not focus directly on measuring SOC; rather, they examine basic sclerochronological concerns such as isotope fractionation and growth rates and patterns. *R. cuneata* precipitates aragonite shells in or near oxygen isotope equilib-

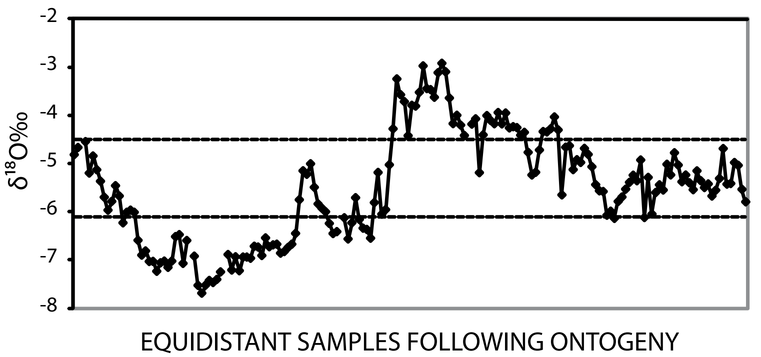


Fig. 6.5. Sequential $\delta^{18}O$ data from *R cuneata* valve (0608.2) collected from Chocolatta Bay where it enters Mobile Bay, AL (30°40′36″S and 87°58′21″W) collected on June 8, 2006. Ontogeny runs left to right, with sample from valve edge on right of plot. Dashed lines divide the seasonal range in $\delta^{18}O$ into equal thirds. $\delta^{18}O$ analytical precision is finer than ± 0.1‰ (based on analysis of NBS-19 average across all runs). Following the methods outlined in figure 6.2, the SOC estimate is spring.

rium, which supports its use for SOC determinations (Lécuyer, Reynard, and Martineau, 2004; Andrus and Rich, 2008). However, it appears that these shells are prone to frequent growth cessations that are neither rhythmic nor consistent within a population (Cobb, Andrus, and Etayo-Cadavid, 2009). These growth cessations are often visible in the shell structure and are described as partly seasonal in some locations (Fairbanks, 1963; Carlson, 1987). This irregular growth may be a result of the highly variable environments of upper estuaries where temperature, salinity, turbidity, and other factors rapidly and unpredictably change. These growth cessations may result in nonsinusoidal $\delta^{18}O$ profiles that complicate SOC assessments. However, $\delta^{18}O$ profiles thus far analyzed (fig. 6.5) contain predictable sinusoidal oscillations. The irregular growth breaks likely contribute to subseasonal abrupt changes in $\delta^{18}O$ but may not obscure the overall seasonal trends.

In contrast, no published $\delta^{18}O$ studied of *P. caroliniana* exist, but similar growth habit and environments suggest that it may share general sclerochronological properties with *R. cuneata* and other closely related clams. For example, *Polymesoda radiata* was measured for shell $\delta^{18}O$ to assess seasonality of rainfall and SOC in midden samples from Pacific Mexico (Kennett and Voorhies, 1995, 1996).

While more research may be required before confident SOC estimates can be made from upper estuarine species such as these, the results may warrant the effort. Currently, sclerochronological analysis in the southeastern United States focuses on marine and lower estuarine species, thus human subsistence activities in fresh and brackish water habitats are less well understood. This means archaeologists may be blind to a significant portion of a seasonal subsistence round or resource area.

Freshwater Mussels (Unionidae)

Moving further up the estuaries of the region, marine and brackish species give way to freshwater mussels (K in fig. 6.1). These clams thus become more common in archaeological sites deeper into the interior coastal plain. However, there has been little research into $\delta^{18}O$ sclerochronology in these taxa. Carroll, Romanek, and Paddock (2006) measured oxygen and hydrogen isotope variation in Savannah River watershed mussels and Peacock and Seltzer (2008) examined the elemental geochemistry of shell fragments in ceramics as a means to examine paleoenvironmental conditions, but no work focused on SOC measurements has been done. $\delta^{18}O$ analysis has been conducted in some western U.S. and European unionids (e.g., Dettman, Reische, and Lohmann, 1999; Goewert et al., 2007; Versteegh et al., 2009, 2010). These studies suggest that while unionid $\delta^{18}O$ values reflect seasonal environmental changes, there are sometimes significant periods in which shell growth stops. Long cessations may limit these mussels' utility as SOC proxies, but further baseline studies are needed before this can be concluded.

Other challenges may impede the use of these species as well. These shells are very fragile and are often deposited in acidic soils that contribute to recrystallization of their aragonite. Although recrystallization is relatively easy to detect, other taphonomic concerns create additional problems. In particular, these shells tend to fragment and spall along growth increments, and inner layers of the shells foliate cleanly, leaving what appears to be a pristine shell that in fact is missing its innermost layers. This property is common enough that it has been exploited to aid in ontogenetic sampling of mussel shells (Nelson, 1964; Sterrett and Sayville, 1974). Such break-

Fig. 6.6. Archaeological Unionidae clam valve. The preservation of this specimen is typical of sites in the region. Note the spalling occurring on the right. Entire shell layers have been noted to foliate along growth increments, potentially leaving what appears to be an intact valve. Such taphonomic issues could lead to erroneous season-of-capture estimates.

age may occur during site formation or excavation, and if undetected may lead to erroneous SOC estimates (fig. 6.6).

Species-specific issues may exist as well. Some unionids are quite long-lived and grow slowly late in life with very thin increments that make sequential sampling at seasonal resolution difficult (e.g., Schöne et al., 2004; Versteegh, 2009). However, sampling resolution adequate to assess SOC has been achieved in some freshwater mussels (Goewert et al., 2007). Even if species-specific baseline studies are conducted to address concerns of differential growth rate and cessation, species identification is sometimes difficult in archaeological mussel shells. This is especially true of fragmentary specimens, which might be expected in middens or those that have eroded or broken hinge areas.

Habitat-specific concerns exist as well. $\delta^{18}O_{water}$ values can vary according to a number of factors that may complicate interpretation of mussel $\delta^{18}O$ profiles. For example, small, shaded, spring-fed streams may have little differences in $\delta^{18}O_{water}$ from season to season, but slower, shallow, and exposed bodies of water subject to seasonal evaporation may have wide variation in $\delta^{18}O_{water}$.

In summary, freshwater mussels represent one of the most complex challenges in terms of developing new taxa for isotopic SOC studies. However, the lack of alternative taxa in interior sites may warrant the effort and provide insight into links between coastal and inland subsistence strategies.

Gastropods

There are no published oxygen isotope studies of archaeological southeastern U.S. gastropods. Some relatively common midden gastropods include the whelks *Busycon carica* (J in fig. 6.1), *Busycon sinistrum*, *Busycon spiratus*, *Busycotypus canaliclatum*, and the periwinkle, *Littorina irrorata* (I in fig. 6.1). Gastropods have been analyzed for oxygen isotopes from other archaeological contexts in other regions (e.g., Mannino, Spiro, and Thomas, 2003; Mannino et al., 2007; Colonese et al., 2009), and presumably the southeastern U.S. species would be similar in at least some respects.

Busycon whelks are particularly important in southeastern archaeology as they were modified and traded as utilitarian objects and gorgets, and as such their geochemistry has been used to assess provenance (Claassen and Sigmann, 1993). While these other uses may complicate their interpretation as subsistence remains in middens, it magnifies the importance of their potential as seasonality indicators in that insight into trade and tool procurement practices may be possible. Unfortunately, little baseline data exist concerning the specifics of whelk isotope geochemistry or sclerochronology.

The work that has been done underlines the importance of baseline studies. For example, mark and recapture data suggest that shell growth rates are highly variable, that some shells may not grow for extended periods, and that shell abrasion is common along the aperture edge (e.g., Eversole, Anderson, and Isely, 2008). Growth rates may also vary between sexes (Power, Sellers, and Walker, 2009), and habitat (Walker et al., 2008). Unlike most bivalves, whelks in this study area migrate, often with different patterns between species (e.g., Walker et al., 2008). These factors can complicate the interpretation of seasonal oscillations in $\delta^{18}O$ by altering both the seawater temperature and the $\delta^{18}O_{water}$ experienced by the snails. Furthermore, other gastropods, notably the queen conch (*Strombus gigas*) are offset from oxygen isotope equilibrium (Wefer and Killingley, 1980). Such offsets do not preclude SOC estimates, but suggest the need for species-specific baseline analyses.

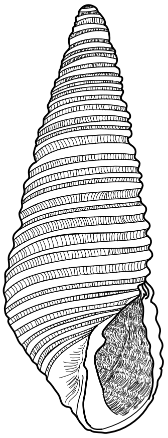
Periwinkles (*Littorina irrorata*) are common at some sites (e.g., Quitmyer and Reitz, 2006), but no isotope sclerochronology has been performed on this species. However, the calcite shells of the closely related *Littorina littorea* have been studied in both modern and archaeological contexts, and the resultant $\delta^{18}O$ records show promise because the periwinkle oxygen isotope fractionation is temperature dependent and at least some populations record the full seasonal range of temperatures (Andreasson, Schmitz, and Jönsson, 1999; Burman and Schmitz, 2005; Burman and Påsse, 2008). Key questions remain concerning the continuity of growth, shell margin damage, and other issues that need to be addressed with local modern baseline data.

CONCLUSIONS

This review illustrates some of the reasons why the expansion of isotope sclerochronology in midden analysis is slow and expensive. Each potentially useful species requires fundamental baseline studies before archaeological application can be considered reliable. Even some of the most extensively studied molluscs such as quahogs and oysters still demand further research. Progress toward expanding the range of SOC indicator species will likely occur piecemeal, with different taxa being studied according to relative abundance in key regions and their utility in answering archaeological questions.

Currently, oysters, quahogs, and coquina clams have been studied adequately enough to allow at least some application of SOC analyses in the southeastern United States. *Rangia* clams will likely soon join this list because new studies are underway. An effective means to expand the number of SOC indicator species applicable to the southeastern United States would be to target those organisms having close relatives that have been used in other regions. For example, scallops, razor clams, and mussels from other parts of the world have been successfully utilized in archaeological research. Building on these preexisting studies may partially limit the extent of needed baseline research on local species. To my mind, the most important knowledge gap to address is in freshwater habitats. Unfortunately, molluscs in these environments may also present some of the greatest analytical challenges.

Finally, I hope this review highlights the need to conduct comprehensive analyses of human dietary remains. While isotope sclerochronology may be too expensive and specialized for many archaeological purposes, simple and low-cost approaches may yield similar conclusions. Mollusc shells need not be relegated to the back-dirt pile but should be retained, identified, and at least roughly quantified. These data can be greatly strengthened when integrated into vertebrate and botanical analyses. By having a large repertoire of seasonality indicators, with different biases and sources of error, we may more confidently reconstruct not only season of exploitation, but also more complex questions of occupation patterns, site formation processes, and overall subsistence strategies. This integrated approach has yielded broadly significant results on St. Catherines Island over the past decades and may serve as a template for others.



CHAPTER 7
ANNUAL INCREMENTAL SHELL GROWTH PATTERNS IN HARD CLAMS (*MERCENARIA* SPP.) FROM ST. CATHERINES ISLAND, GEORGIA: A RECORD OF SEASONAL AND ANTHROPOGENIC IMPACT ON ZOOARCHAEOLOGICAL RESOURCES

Irvy R. Quitmyer and Douglas S. Jones

> Sclerochronology is the study of physical and chemical variations in the accretionary hard tissues of organisms, and the temporal context in which they formed. Sclerochronology focuses primarily upon growth patterns reflecting annual, monthly, fortnightly, tidal, daily, and subdaily increments of time entrained by a host of environmental and astronomical pacemakers. Familiar examples include daily banding in reef coral skeletons or annual growth rings in mollusc shells. Sclerochronology is analogous to dendrochronology, the study of annual rings in trees, and equally seeks to deduce organismal life history traits as well as to reconstruct records of environmental and climatic change through space and time.
> —1st International Sclerochronology Conference, 2007

Historically it has been recognized that a diverse number of plant and animal taxa form repeating growth structures in their skeletons (Rhoads and Pannella, 1970; Rhoads and Lutz, 1980; Jones and Gould, 1999). Many times these structures represent physiological responses to environmental stimuli that can be regarded as biorecordings of the life and times of an organism (Jones and Quitmyer, 1996). It was not until the last half of the 20th century that scientists realized the potential of asking and answering natural history questions through the study of these structures (Wells, 1963; Buddemeier, Maragos, and Knutson, 1974; Hudson et al., 1976). In concert with natural historians, zooarchaeologists seized on sclerochronology as a tool to address one of the fundamental questions posed by archaeologists—during which seasons did people occupy a given archaeological site (Weide, 1969; Coutts, 1970, 1975; Coutts and Higham, 1971; Ham and Irvine, 1975; Koike, 1975)? The answer to such a question helps to define settlement patterns, and subsistence strategies. Such definitions expand our understanding of cultural complexity found in the archaeological record.

There is an emerging body of zooarchaeological inquiry that is examining the intensity of resource use, resource management strategies, and natural and anthropogenic changes in the environment. Methods grounded in sclerochronology are helping to explore whether prehistoric peoples were good ecologists, conservationists, both, or neither (Quitmyer, Hale, and Jones, 1985; Thomas, 1987; Quitmyer and Jones, 2000; Marcello and Thomas, 2002; Quitmyer, 2003; Peacock, Haag, and Warren, 2004; Hames 2007; Rick and Erlandson, 2008; Erlandson et al., 2008; Szabó and Quitmyer, 2008)? The literature also identifies instances where there are changes in zooarchaeological assemblages that are not anthropogenic in origin, but related to a changing environment (e.g., Bailey and Craighead, 2003).

In southeastern North America, sclerochronology of hard clams (*Mercenaria* spp.) as a zooarchaeological indicator of season of resource harvest first emerged from archaeological research conducted on St. Catherines Island, Georgia (Clark, 1976a, 1976b; O'Brien and Thomas, 2008). These early researchers showed that hard clams are suitable taxa for such work and are ubiquitous in the shell middens. Sclerochronology of hard clams has become an integral part of St. Catherines Island archaeological research and has influenced zooarchaeological research throughout southeastern North America (Claassen, 1982; Quitmyer, Hale, and Jones, 1985; Quitmyer, Jones, and Arnold, 1997; Andrus and Crowe, 2008).

This research represents the third year of a five-year study of modern incremental shell growth in St. Catherines Island hard clams (*Mercenaria mercenaria*) that was undertaken by the authors in collaboration with David Hurst Thomas, American Museum of Natural History. Our first goal is to establish longitudinal growth frequency profiles of incremental shell growth among living populations of St. Catherine Island hard clams. We seek to assemble a robust sample that is systematically collected to document the annual periodicity of incremental shell formation. These data augment earlier research by O'Brien and Thomas (2008) that started during the mid to late 1970s and more recent research conducted by Andrus and Crowe (2008). We apply the modern model of incremental shell growth to zooarchaeological hard clams excavated from the Late Archaic at St. Catherines Shell Ring (ca. 4500 B.P.), and McQueen Shell Ring (4450 B.P.) (general levels and "floor" feature). We note that the McQueen "floor" archaeological feature is constructed of a sand base covered with a modest number of hard clam shells (Thomas, personal commun.). Relative to the general levels of the two St. Catherines Island Archaic period sites, the "floor" feature represents a distinct period in time at McQueen. We also include previously published data from nearby Cannon's Point Shell Ring (ca. 4500 B.P.), St. Simons Island, GA (Marrinan, 1975; Quitmyer, Hale, and Jones, 1985).

Our second research objective is to examine the population dynamics of the three Archaic period assemblages. We apply commonly used fisheries statistics that help to evaluate and manage living hard clam populations by quantifying their size classes, survivorship, and ontogenetic age (Fegley, 2001). In so doing we are able to assess relative harvesting pressure during the Archaic period on St. Catherines Island and at Cannon's Point.

METHODS

Modern Hard Clams

Hard clams form alternating white and gray (or purple) shell growth increments that may be seen in cross sections of their shells using direct (fig. 7.1A) or transmitted light (fig. 7.1B). Backlit radial thin sections of the shells show that the white increment is opaque while the gray (or purple) increment is translucent, allowing the transmission of light (fig. 7.1B). The two increments represent distinct differences in the shell microstructures that are known to be periodic and associated with physiological responses to environmental changes in the annual cycle (Clark, 1976a; Quitmyer, Jones, and Arnold, 1997; Fritz, 2001: 60–61). We use the terms translucent and opaque to characterize the shell growth increments in this chapter (figs. 7.1B and 7.2).

We follow the methods of Quitmyer, Jones, and Arnold (1997) to establish a chronology of annual incremental shell formation in living St. Catherines Island hard clams. Approximately 40 living hard clams were collected monthly for one year (2007–2008) from a shallow tidal creek in King New Ground that flows into McQueen Creek. The specimens were collected by hand from sandy mud and shell substrate around the base of oyster bars. This represents typical hard clam habitat as reported in the literature (Walker and Tenore, 1984; Fegley, 2001). The specimens were transported to the St. Catherines Island compound where they were quickly frozen in a commercial grade freezer. Following transport back to the Florida Museum of Natural History, the specimens were thawed and eviscerated. The valves were washed, dried, numbered, and stored for later analysis.

Historical sea surface temperature (SST) and salinity (PSU) data were obtained from the National Estuarine Research Reserve System monitoring station (SAQG1) at nearby Sapelo Island, Georgia. These data represent a close approximation of estuarine SST and salinity for the region during 2008.

The size and age data provide significant information about the natural history of hard clams and the interpretation of their use by Native Americans (see Jones, Quitmyer, and DePratter, chap. 8, this volume). The anterior to posterior length of the right valve of each specimen was measured using digital calipers attached to a personal computer (Jones, Quitmyer, and DePratter, chap. 8).

A radial cross section of the right valve, from the umbo to the ventral margin, was facilitated with a water-cooled lapidary saw equipped with a Mark V alumina oxide blade (Quitmyer, Jones,

Fig. 7.1. Radial cross section of a hard clam (*Mercenaria campechiensis*) to expose its growth increments (**A**) and a backlit thin section (**B**) showing the alternating opaque and translucent shell growth increments.

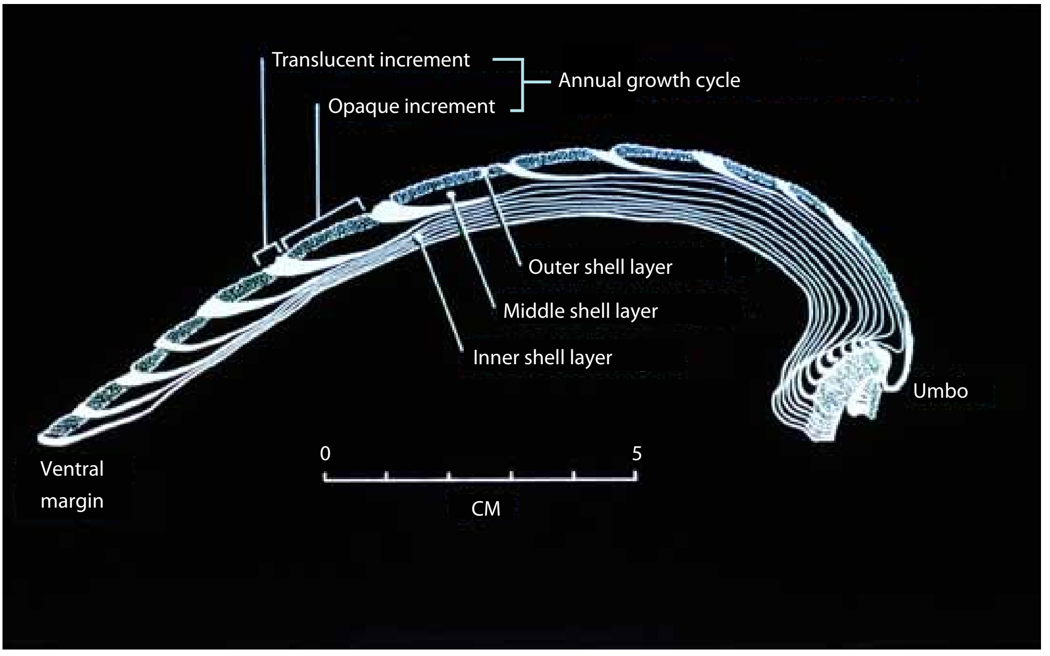


Fig. 7.2. The location of the translucent and opaque shell growth structures showing a count of the ontogenetic age (years) of a specimen.

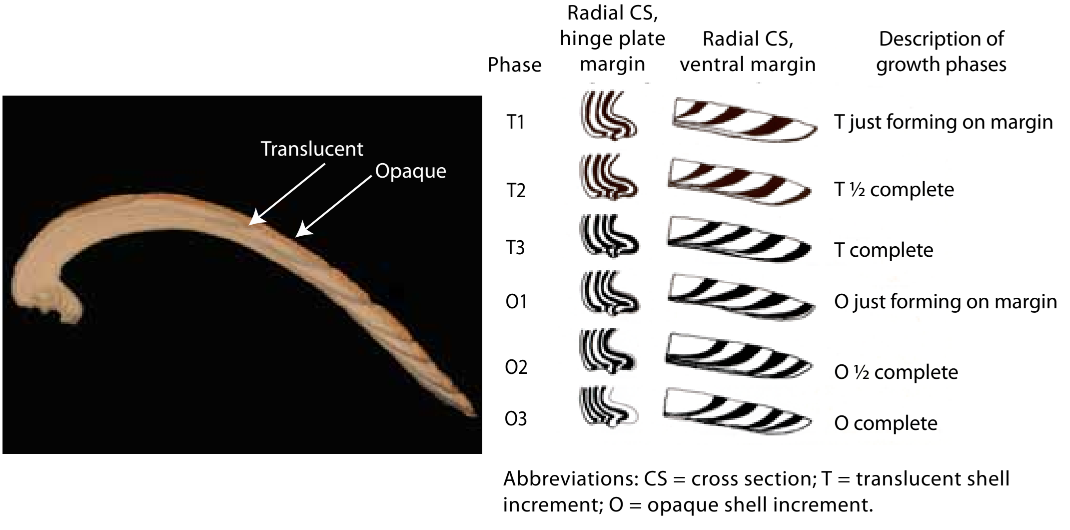


Fig. 7.3. Six-part division of translucent and opaque annual shell growth increments in hard clam (*Mercenaria* spp.) shells.

and Arnold, 1997). The blade produced a polished surface where the incremental growth structures could be evaluated with the unaided eye and/or microscopically (10–20×) with transmitted light (Rhoads and Lutz, 1980; Quitmyer, Hale, and Jones, 1985; Ropes, 1987; Jones et al., 1990: 217; Quitmyer and Jones, 1992).

It is generally agreed that hard clams living in the southeastern part of their range form a couplet of opaque and translucent shell growth increments each year (fig. 7.2; Jones and Quitmyer, 1996; Quitmyer, Jones, and Arnold, 1997; Fritz, 2001; Andrus and Crowe, 2008). A count of the paired increments provides a direct method of assessing the longevity of hard clam assemblages (Jones and Quitmyer, 1996; Fegley, 2001; Jones, Quitmyer, and DePratter, chap. 8, this volume).

At a finer seasonal scale, the size of opaque or translucent shell increments at the growing margin of the shell may be used to estimate the season in which a hard clam was harvested (Jones and Quitmyer, 1996; Quitmyer, Jones, and Arnold, 1997). A six-part subdivision of the annual shell growth cycle was used to establish a seasonal growth model in order to resolve the season of harvest of the zooarchaeological hard clams (fig. 7.3). The formation of the translucent growth increment was divided into three stages or phases: (a) translucent 1 (T1)—translucent increment just starting to form; (b) translucent 2 (T2)—translucent increment approximately one-half the size of the previous year's translucent increment; (c) translucent 3 (T3)—translucent increment equal to or greater than the previous translucent increment. The formation of the opaque growth increment was similarly divided into three growth phases: (a) opaque 1 (O1)—opaque increment just starting to form; (b) opaque 2 (O2)—opaque increment approximately one-half the size of the previous year's opaque increment; (c) opaque 3 (O3)—increment nearly completed, almost equal in size to the previous year's opaque increment. It should be noted that early in ontogeny the T3 and O3 growth phases are relatively more common. With increasing age it becomes increasingly less likely that T3 and O3 phases would exceed those of the previous year. Nonetheless, this provides a temporal profile of incremental shell growth in the hard clam population.

The frequency of individuals in each of the various phases of incremental shell growth was calculated for each month and each season, to document an annual pattern that is presented as a histogram for each of the four seasons. This simple, straightforward technique accurately characterizes seasonal incremental shell growth (Claassen, 1990; Quitmyer, Jones, and Arnold, 1997).

The zooarchaeological samples were prepared and analyzed in accordance with the methods outlined for the modern comparative collection of hard clams. The St. Catherines Island modern analog of incremental shell growth was used to evaluate the zooarchaeological assemblages. We note that zooarchaeological season of harvest does not rest on the shell growth of a single hard clam, but on a population approach where all individuals contribute to a seasonal pattern of incremental shell growth. The growth frequency profiles constructed from our 2007–2008 longitudinal study are used to evaluate zooarchaeological hard clams excavated from St. Catherines Shell Ring, McQueen Shell Ring (general levels and "floor" feature), and Cannon's Point Shell Ring, St. Simons Island, Georgia.

RESULTS

Modern Cycle of Incremental Shell Growth

Our results are based on a numerically robust sample of a population of modern St. Catherines Island hard clams. Because the various phases of individual incremental shell formation may be observed in most months of the year, an individual's shell growth does not describe the overall pattern of growth in a modern or zooarchaeological population. It is tempting to use these proxy data to interpret the zooarchaeological shells at monthly or subseasonal levels (e.g., late spring); however, hard clam populations are responsive to various environmental stimuli that are variable across space and time. Such is the nature of most biological populations.

Figure 7.4 presents a sclerochronological comparison of opaque and translucent shell growth through an annual cycle. This is simply meant to show the monthly progression of the two shell growth increments in the population. Translucent shell growth is present in at least some of the individuals during every month; it becomes the dominant increment during the summer and fall seasons. Opaque shell growth is most prevalent during the winter and extends into the spring. This pattern correlates with previous studies in southeastern North America, such as Kings Bay, Georgia (fig. 7.4; Quitmyer, Jones,

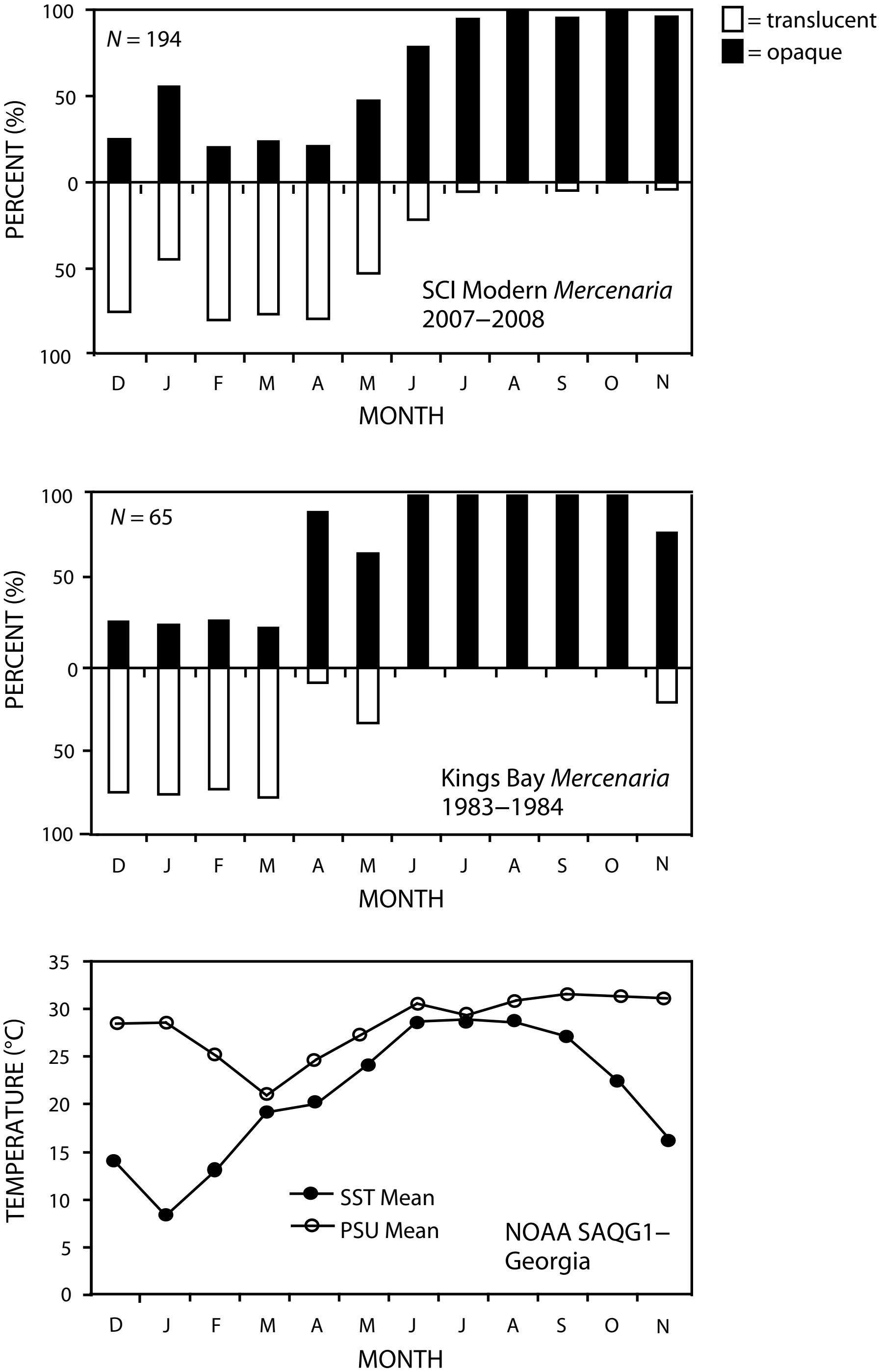


Fig. 7.4. The relationship of sea surface temperature (°C) and monthly formation of translucent and opaque growth in modern hard clams collected live from St. Catherines Island and Kings Bay.

and Arnold, 1997; Fritz, 2001; Henry and Cerrato, 2007) and Litchfield Beach, South Carolina (Jones, Quitmyer, and DePratter, chap. 8, this volume). Previous researchers have reported that the sequential formation of opaque and translucent shell is a physiological response to seasonal changes in temperature or factors related to temperature (Ansell, 1968). Temperatures ranging between 15° C and 20° C are regarded as optimal: the range in which the animal attains maximum growth rates (Fegley, 2001). Near the thermal maximum and minimum, 31° C and 7° C, respectively, growth abates, then stops. A similar relationship between temperature and shell growth exists in the St. Catherines population (fig. 7.4). Opaque shell growth is most prevalent when SST is at the animal's thermal optimum during the late winter and spring (fig. 7.4). As SST reaches the thermal maximum (31° C) for the organism, translucent shell growth dominates the seasonal profile. In fact, Quitmyer, Jones, and Arnold (1997) observed this same shell growth profile in five modern populations occurring along the Atlantic and Gulf coasts between Litchfield Beach, South Carolina, and Cedar Key, Florida (also see Andrus and Crowe, 2008).

At the seasonal scale, 34.8% of the St. Catherines Island population is forming T3 shell growth in the winter, while around 65% is in the O1 (17.4%), O2 (21.7%), and O3 (26.1%) shell growth phases (fig. 7.5). In the spring season T3 shell growth is observed in 30% of the specimens, while 70% of the individuals are forming the opaque growth increments: O1, 8.3%; O2, 31.7%; and O3, 30%. By the summer season 87% of the population has reached T3 shell growth and a similar pattern extends into the fall season. Contrary to previous studies where the six-part subdivision of seasonal growth has been used to distinguish all four seasons, only two halves of the year can be confidently identified in the St. Catherines population: winter/spring and summer/fall (fig. 7.5).

Zooarchaeological Hard Clams—Season of Resource Procurement

The modern SCI six-part subdivision of incremental shell growth (fig. 7.5) is used as a model to evaluate the zooarchaeological season of hard clam collection from St. Catherines Shell Ring ($N = 117$), McQueen Shell Ring (general levels $N = 68$; "floor" feature, $N = 54$), and Cannon's Point Shell Ring ($N = 35$) (fig. 7.6). The data from the four sites show that the majority of the zooarchaeological specimens were forming opaque shell growth (figs. 7.5 and 7.6). The best fit with the modern growth frequency profiles suggests the zooarchaeological hard clams were harvested in late winter and spring (fig. 7.5). Relative to St. Catherines and McQueen, the greater frequency of the T3 shell growth phase in the Cannon's Point assemblage suggests a harvest period that was more active during the winter, albeit still in the winter/spring seasons. This is the time when the modern specimens have transitioned out of T3 shell growth phase and undergo rapid opaque shell formation (fig. 7.4). It is also the time when the population begins their major spawning event.

Population Dynamics—Modern Ontogenetic Age and Survivorship

As we note above, a combination of one opaque and one translucent or opaque increment represents one year of life (fig. 7.2). Thus, a count of the translucent growth increments yields an accurate account of the ontogenetic age (years) of each individual. The question arises, why go to the trouble of sectioning and counting the growth increments to assess hard clam population dynamics? Why not use size as a proxy for age and simply measure each specimen? Figure 7.7 presents a plot of shell length, anterior to posterior (mm), against ontogenetic age (years) for the modern St. Catherines and zooarchaeological McQueen hard clams. As we have observed elsewhere (Jones, Quitmyer, and DePratter, chap. 8, this volume) there is considerable overlap in size versus age relationships in hard clams (see also Walker and Tenore, 1984; Fegley, 2001). For example, the shell lengths of a six-year-old modern cohort overlap those of 12-year-old clams (fig. 7.7). Further, a 30-year-old clam can be the same size as a three-year-old clam. Researchers have found that the growth of same-aged individuals may be affected by genetic and environmental variables (Fegley, 2001). Environmental variables may include water quality, substrate type, and predator-prey relationships. At best, size is a coarse proxy for age and direct age-determined models provide greater confidence in assessing hard clam population dynamics (fig 7.7; Fegley, 2001). Because of the overlap in size and age observed in the samples, the use of population age dynamics dispenses with the possibility of modern or zooarchaeological size-specific collection inefficiency that may occur during the course of harvesting (Haddon, 2001).

Survivorship curves are commonly used in fisheries biology to examine the health of animal populations (Fegley, 2001). The percentage of hard clams surviving each year for living populations collected from Kings Bay, and St. Catherines Island, Georgia, serve as an example (fig. 7.8; table 7.1). Like many other hard clam populations living along the Georgia coast, the Kings Bay assemblage may be considered unimpacted or in equilibrium (Walker, 1989). The Kings Bay specimens were sampled (1983–1984) from a military reserve where harvesting was prohibited for over 40 years. The Kings Bay and St. Catherines Island hard clam survivorship curves show great similarity with a gradual loss of individuals with time. Between 31% and 40% of the two populations can expect to live at least 10 years. There is also great similarity in the mean ages of the St. Catherines Island (9.4 years) and Kings Bay (10.4 years) populations (fig. 7.9). In fact, a plot of the 95% confidence intervals around the means overlap and indicate that the two sample assemblages could have been derived from the same population (fig. 7.9). These data also confirm previous research showing that hard clam beds are typically dominated by older, larger individuals (Walker and Tenore, 1984).

Population Dynamics—Zooarchaeological Mean Age and Survivorship

The curves for the zooarchaeological specimens from the St. Catherines Shell Ring and McQueen Shell Ring show a dramatic loss of individuals during the first four years of life (fig. 7.8).

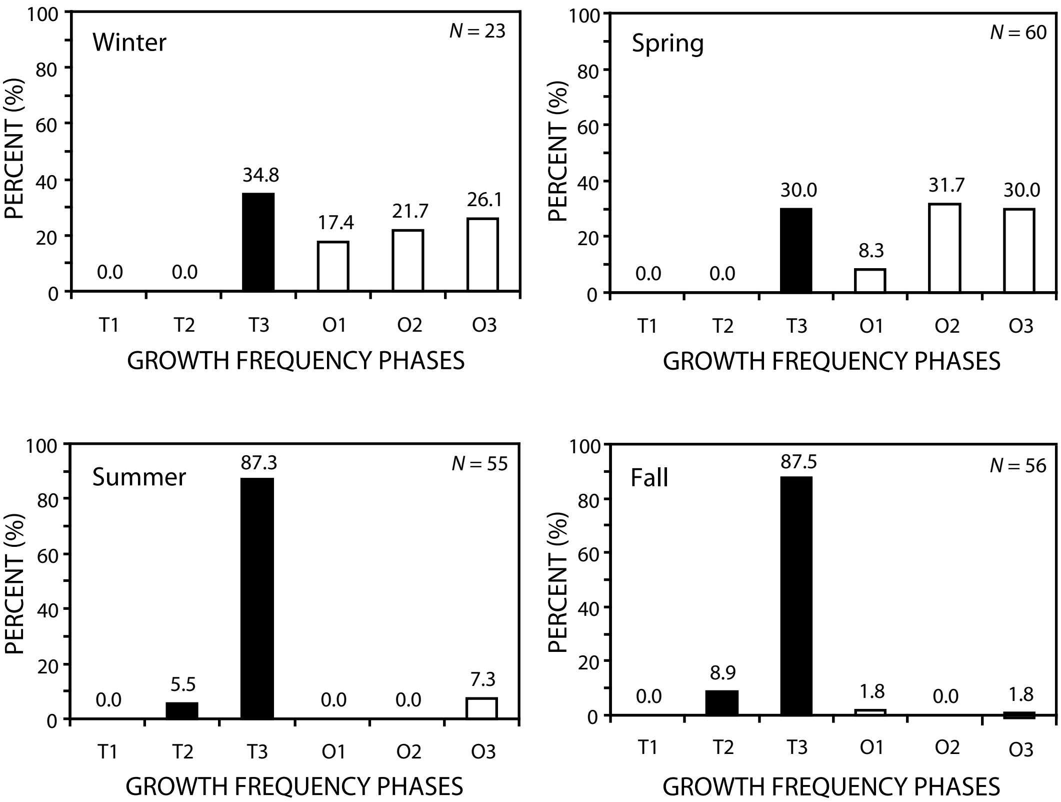


Fig. 7.5. Seasonal growth frequency patterns of modern hard clams (*Mercenaria*) collected live from St. Catherines Island, 2007–2008.

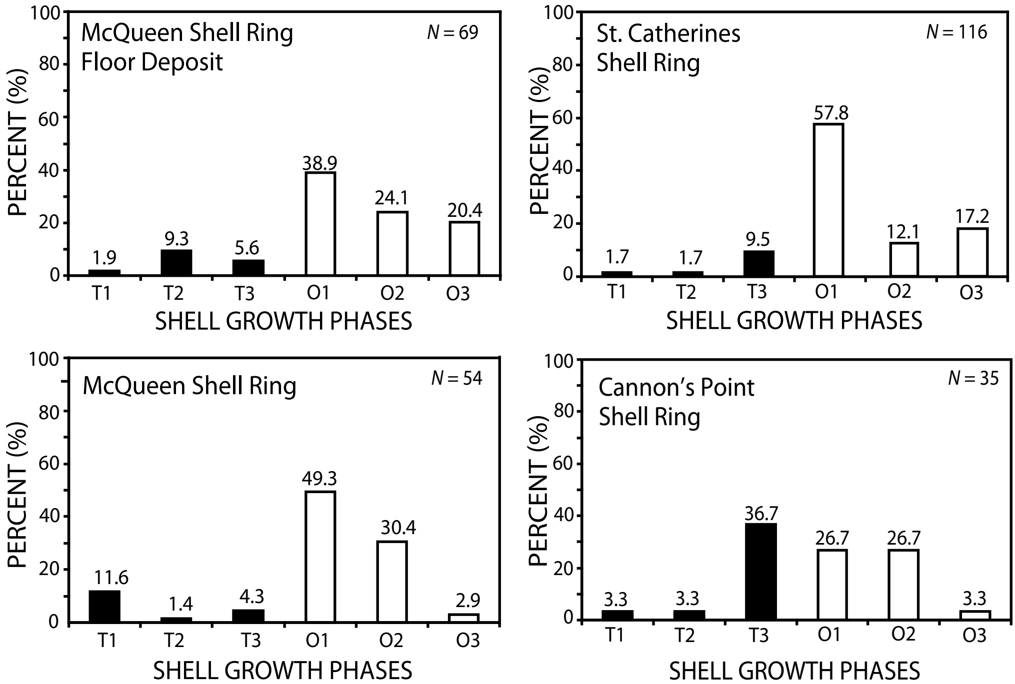


Fig. 7.6. Growth frequency profiles of zooarchaeological hard clams collected from St. Catherines Island and Cannon's Point, representing the Archaic period.

In contrast to the two modern populations, fewer than 11% of the zooarchaeological hard clams attained 10 years of age (fig. 7.8). The mean ontogenetic ages of all three St. Catherines Island zooarchaeological samples is around three years (fig. 7.9). The 95% confidence intervals around the means all overlap, indicating that they could have been collected from the same living population (fig. 7.9). The mean age of the St. Simons shells is six years and the 95% confidence interval does not overlap with the modern or St. Catherines Island assemblages (fig. 7.9).

DISCUSSION

In the archaeological literature the term *seasonality* refers to questions of variability in the seasonal round of settlement behavior. Such studies are in their infancy (Russo and Quitmyer, 1996) and they are typically biologically based. As such, they require long-term field and laboratory analysis of modern taxa before the zooarchaeological record can be interpreted. Zooarchaeologists sometimes erroneously refer to these as site seasonality studies; but, seasonal site occupation and seasonal patterns of resource procurement (e.g., shellfish collection) represent two different kinds of human behavior (Deith, 1983: 423). Unless a single taxon represents all seasons of resource procurement, site seasonality cannot be confidently determined. Repeated sampling and analysis of multiple indicators of resource procurement may provide a more confident indication of seasonal or year-round site occupation (Quitmyer, Jones, and Arnold, 1997). This research is intended to extend our knowledge of the sclerochronology of the hard clam as one tool that may be used to interpret human interaction with the environment.

The application of the six-part subdivision of incremental shell growth in monthly collections of St. Catherines Island hard clams does not provide unique profiles of shell growth that can be used to identify all of the four seasons of

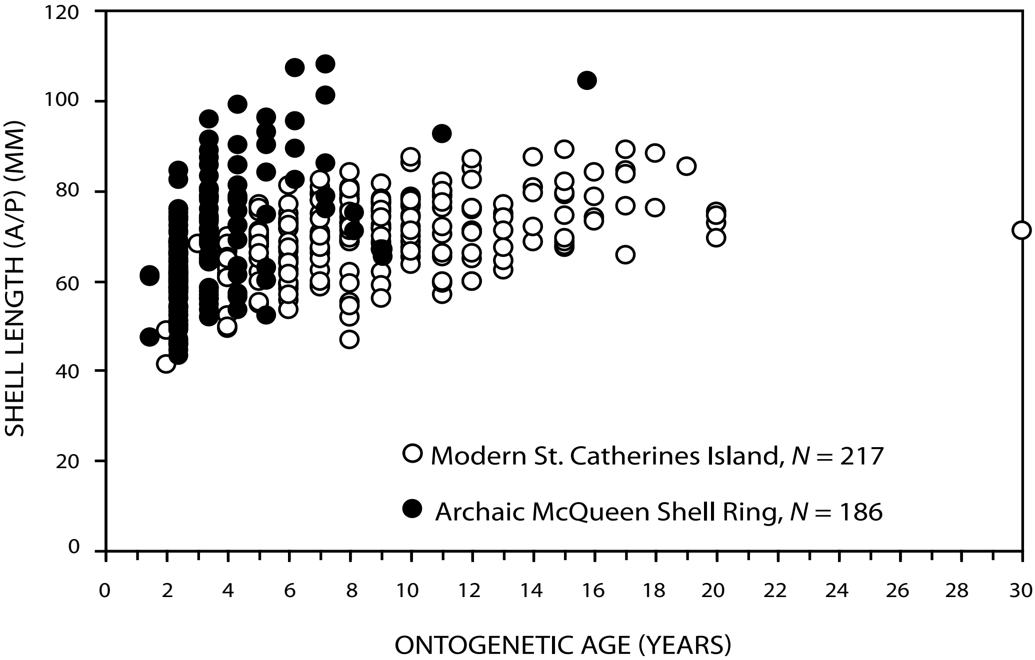


Fig. 7.7. A comparison of shell length (mm) to ontogenetic age (years) of modern and zooarchaeological hard clams from St. Catherines Island.

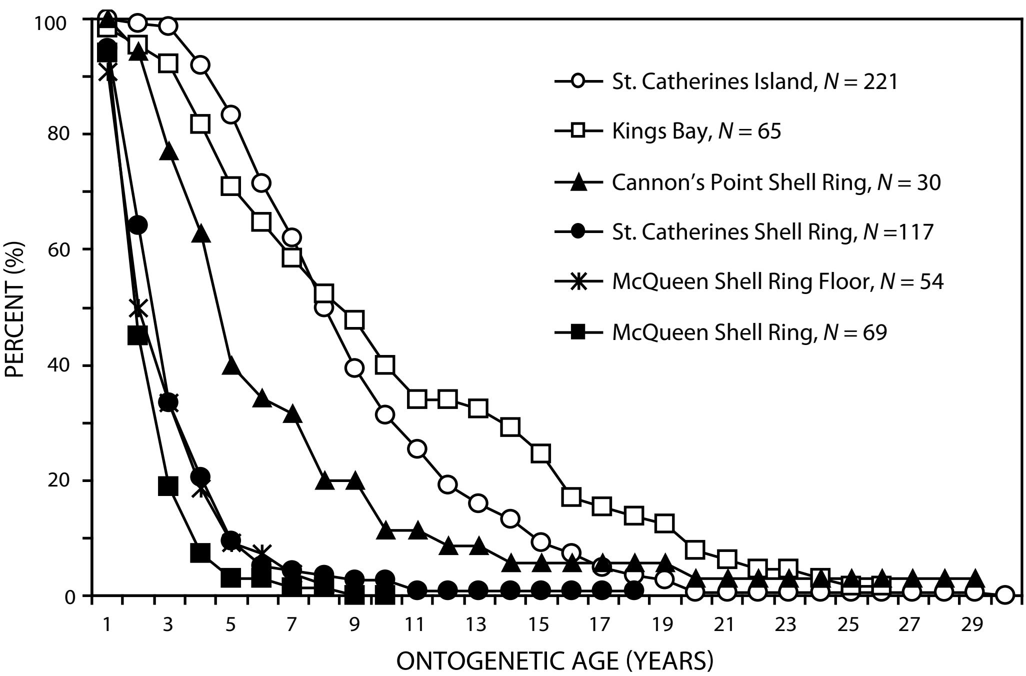


Fig. 7.8. Survivorship curves characterizing modern and zooarchaeological hard clams from St. Catherines Island, Cannon's Point, and Kings Bay.

the year (fig. 7.5). However, the modern analog provides a basis to distinguish winter/spring from summer/fall collection of zooarchaeological hard clams. When the St. Catherines Island modern profile of seasonal shell growth is applied to the zooarchaeological assemblages from St. Catherines Shell Ring, McQueen Shell Ring general levels, McQueen Shell Ring floor deposit, and from Cannon's Point Shell Ring, a clear winter/spring pattern of hard clam harvest is evident. In fact, all four of the zooarchaeological growth frequency profiles have elevated levels of Opaque 1 growth phase (fig. 7.6) relative to the other growth phases. This represents the onset of rapid shell growth during the winter and spring seasons where water temperature approaches optimal (15° C–20° C) (Ansell, 1968). Such a pattern suggests an intensive period of harvest as opaque shell growth forms.

This winter/spring pattern of hard clam procurement is prevalent across space and time for zooarchaeological assemblages along the southeastern Atlantic coast. Nearly half of the 26 sites (48%) reported by Quitmyer, Jones, and Arnold (1997) contained hard clams that were specifically harvested during the winter/spring seasons. These represent a diverse number of archaeological cultures that date between 550 and 4500 B.P. We do not attempt to explain this long period of preferentially harvesting hard clams during the winter and spring seasons in this chapter. This is a subject for future inquiry. However, it is clear that during the Archaic period on St. Catherines Island and at Cannon's Point, hard clams were intensively harvested during the winter and spring seasons.

Here we question how the population dynamics of the Archaic period hard clams might have been affected by intensive harvesting pressure as seen through their biology and ecology. First, we note that the modern Kings Bay population is at or very near equilibrium because that locality has been closed to harvesting for several decades. Although technically the St. Catherines population is not closed to harvest, it experiences negligible recreational clamming as a private island and as a consequence has a similar age class frequency distribution when compared to the Kings Bay assemblage. In fact, many beds throughout coastal Georgia have experienced very little harvesting and have some commonality with our two modern populations (Walker,

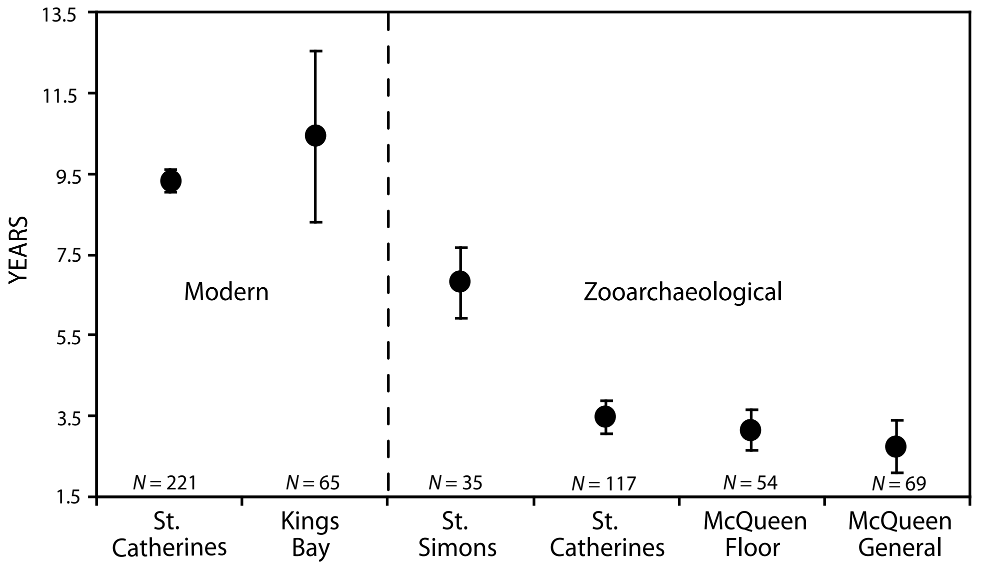


Fig. 7.9. Mean age (years) and 95% confidence intervals plotted for modern and zooarchaeological hard clams from St. Catherines Island, Cannon's Point, and Kings Bay.

TABLE 7.1
Modern and Zooarchaeological Survivorship Data of *Mercenaria* spp. Sampled from St. Catherines Island, St. Simons Island, and Kings Bay, Georgia

Ontogenetic age (years)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Modern St. Catherines Island (*N* = 221)																														
Total number of deaths per year	0	2	1	15	19	26	21	27	23	18	13	14	7	6	9	4	5	3	2	5	0	0	0	0	0	0	0	0	0	1
Total number remaining in each age group	221	219	218	203	184	158	137	110	87	69	56	42	35	29	20	16	11	8	6	1	1	1	1	1	1	1	1	1	1	0
Percent of individuals remaining in each age group	100	99.1	98.6	91.9	83.3	71.5	62.0	49.8	39.4	31.2	25.3	19.0	15.8	13.1	9.1	7.2	5.0	3.6	2.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0
Modern Kings Bay (*N* = 65)																														
Total number of deaths per year	1	2	2	7	7	4	4	4	3	5	4	0	1	2	3	5	1	1	1	3	1	1	0	1	1	0	1			
Total number remaining in each age group	64	62	60	53	46	42	38	34	31	26	22	22	21	19	16	11	10	9	8	5	4	3	3	2	1	1	0	0	0	0
Percent of individuals remaining in each age group	98.5	95.4	92.3	81.5	70.8	64.6	58.5	52.3	47.7	40.0	33.8	33.8	32.3	29.2	24.6	16.9	15.4	13.8	12.3	7.7	6.2	4.6	4.6	3.1	1.5	1.5				
Archaic Period, St. Simons (*N* = 35)																														
Total number of deaths per year	0	2	6	5	8	2	1	4	0	3	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Total number remaining in each age group	35	33	27	22	14	12	11	7	7	4	4	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	0
Percent of individuals remaining in each age group	100	94.3	77.1	62.9	40.0	34.3	31.4	20.0	20.0	11.4	11.4	8.6	8.6	5.7	5.7	5.7	5.7	5.7	5.7	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	
Archaic, St. Catherines Shell Ring (*N* = 117)																														
Total number of deaths per year	6	36	36	15	13	5	1	1	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total number remaining in each age group	111	75	39	24	11	6	5	4	3	3	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Percent of individuals remaining in each age group	94.9	64.1	33.3	20.5	9.4	5.1	4.3	3.4	2.6	2.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9												

TABLE 7.1 — (*Continued*)

Ontogenetic age (years)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Archaic, McQueen Shell Ring floor deposit ($N = 54$)																														
Total number of deaths per year	5	22	9	8	5	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number remaining in each age group	49	27	18	10	5	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percent of individuals remaining in each age group	90.7	50.0	33.3	18.5	9.3	7.4	3.7	1.9																						
Archaic, McQueen Shell Ring general levels ($N = 69$)																														
Total number of deaths per year	4	34	18	8	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number remaining in each age group	65	31	13	5	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percent of individuals remaining in each age group	94.2	44.9	18.8	7.2	2.9	2.9	1.4	1.4	0.0	0.0																				

1989; Fegley, 2001). For these reasons our two modern populations serve as baselines when we assess the age frequency of the four zooarchaeological assemblages.

Our age-based analysis of the three St. Catherines Island zooarchaeological populations are all dominated by individuals that are between two and six years old (fig. 7.7). In contrast to our two modern baselines and previously published biological data for the Georgia coast (Fegley, 2001), the zooarchaeological hard clams are nearly devoid of specimens older than six years (fig. 7.7). In fact, specimens from the two modern baseline populations average around 10 years old while the St. Catherines Island zooarchaeological specimens are approximately three years old (fig. 7.9). The zooarchaeological survivorship curves are representative of a population where there is great mortality in early in life with very few individuals reaching full longevity (fig. 7.8; Deevey, 1947). Such a pattern is not typical of hard clam populations in southeastern North America that may be considered in equilibrium. These data suggest a population where intensive harvesting has occurred.

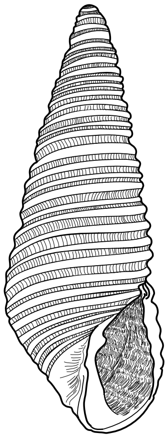
As we have outlined in another chapter in this volume (Jones, Quitmyer, and DePratter, chap. 8), the biology and ecology of hard clams make them susceptible to measurable harvesting pressure. In southeastern North America, most populations occur in densely circumscribed beds that are easily collected from their preferred habitats in shallow tidal creeks. These beds are usually dominated by older, larger specimens that are easily located by hand collection. Once the larger specimens are removed, the smaller individuals become more susceptible to natural predation. Intensive harvest of hard clams during their peak spawning period (spring) would have further deleterious impact on the beds.

In many cases, humans manage their subsistence resources by limiting the sizes of animals that they hunt and gather (Kraeuter and Castagna, 2001), thus leaving mature and productive individuals to replenish the population. Size-class selection does not appear to be the strategy that was used in the harvest of hard clams at St. Catherines Island. For example, the McQueen hard clams are dominated by individuals that are between two and six years old (figs. 7.7 and 7.8), but their sizes exceed the maximum and minimum of all age classes, up to 30 years old in the modern St. Catherines assemblage (fig. 7.7). Again, there is a great deal of overlap in the physical size of individuals within a population of multiple ages. Protracted and intensive harvest would have eventually removed the older individuals in the population.

CONCLUSION

On St. Catherines Island, the timing of modern hard clam incremental shell growth correlates with the winter/spring (opaque growth) and summer/fall (translucent growth) seasons and may be used to effectively assess the season of hard clam harvest during the Archaic period. Zooarchaeological hard clams from Cannon's Point, St. Catherines Shell Ring, and McQueen Shell Ring were collected during the winter/spring seasons when opaque growth was at its highest frequency. This is a pervasive pattern that has been documented among many cultural groups living along the southeastern coast of North America. At this level of research, we cannot account for the choice to collect or harvest during the winter/spring seasons.

The life curves and ontogenetic age data provide evidence for intensive exploitation of hard clams from McQueen and Cannon's Point shell rings. All of the zooarchaeological assemblages represent populations where large, older specimens have been removed from the populations and there is high mortality early in life. This pattern is not characteristic of most southeastern hard clam populations that are in equilibrium. These data are indicative of intensive harvest of the resource.



CHAPTER 8

VALIDATION OF ANNUAL SHELL INCREMENTS AND SHIFTING POPULATION DYNAMICS IN MODERN AND ZOOARCHAEOLOGICAL HARD CLAMS (*MERCENARIA MERCENARIA*) FROM THE LITCHFIELD BEACH REGION, SOUTH CAROLINA

Douglas S. Jones, Irvy R. Quitmyer, and Chester B. DePratter

Hard clams (*Mercenaria* spp.) form an alternating pattern of opaque (light) and translucent (dark) growth increments that can be seen in radial cross sections of their shells (fig. 8.1). These increments are thought to represent an annual cycle of growth and reflect changes in shell microstructure and chemistry associated with physiological responses to variations in water temperature or factors related to temperature (Ansell, 1968; Jones and Quitmyer, 1996).

Biologists, paleobiologists, and zooarchaeologists alike have documented the annual periodicity of incremental shell growth in *Mercenaria mercenaria* populations from the Atlantic coast of North America (Jones, Arthur, and Allard, 1989; Quitmyer, Jones, and Arnold, 1997; Fritz, 2001). These seasonally formed shell increments have been used to estimate the season of hard clam procurement in archaeological sites—zooarchaeological seasonality (Clark, 1979; Quitmyer, Jones, and Arnold, 1997; O'Brien and Thomas, 2008). Less commonly attempted in zooarchaeology are analyses of ancient hard clam population dynamics based on annual shell increments. This approach provides an empirical way to assess potential anthropogenic effects of hard clam harvest on natural populations (Quitmyer, Hale, and Jones, 1985; Quitmyer and Jones, 2000). Such techniques are widely used to monitor the effects of harvesting on modern shellfish beds (Deevey, 1947; Hallam, 1972; Fegley, 2001). In this investigation we explore whether the natural distribution of ontogenetic age classes was disrupted by pre-Hispanic harvesting pressure on hard clam beds in the Litchfield Beach region.

As noted above, shell growth is strongly associated with ambient water temperature. Ansell (1968) demonstrated that optimal shell growth occurs at ~20° C and growth slows as water temperatures approach 9° C or 32° C. The seasonal timing of translucent and opaque incremental shell formation is also known to change across the geographic range of the animal from the Gulf of St. Lawrence to the Bay of Campeche (Fritz, 2001). In the southern part of its range (e.g., South Carolina to Florida) hard clams form the translucent increment during the summer and fall, while opaque shell growth occurs during the late winter and early spring. In the northern latitudes (e.g., mid-Atlantic to New England) this pattern is reversed—translucent increments form in the winter and opaque in the summer. Although the pattern of shell increment differs between northern and southern populations, the preponderance of baseline research demonstrates that a couplet of one opaque plus one translucent increment comprises one year of life.

Within the last decade, some exceptions to these observations have been reported (Fritz, 2001). In a zone between New Jersey and Virginia researchers discovered hard clam populations that deposit four increments during an annual period during certain years—one opaque increment in the spring and another in the fall, plus one translucent increment in the summer and another in the winter (Fritz, 2001). The conventional wisdom of the shell growth literature would seem to indicate that annual increment formation in hard clams could be used to assess the population dynamics and season of harvest of zooarchaeological hard clams throughout their latitudinal range. However, reports of variability in the periodicity of shell formation across space and time indicate a need for caution (Fritz, 2001).

In a more recent study Henry and Cerrato (2007) reported that the timing of formation of shell increments can quickly change within a single locality. Their work reviewed hard clam research published by Jones, Arthur, and Allard. (1989) from Narragansett Bay, Rhode Island, reporting translucent shell increment formation during the winter and opaque increment formation during the summer. These patterns were confirmed by the analysis of oxygen isotope ratios ($^{18}O/^{16}O$) found in the translucent and opaque increments (Jones, Arthur, and Allard, 1989). In

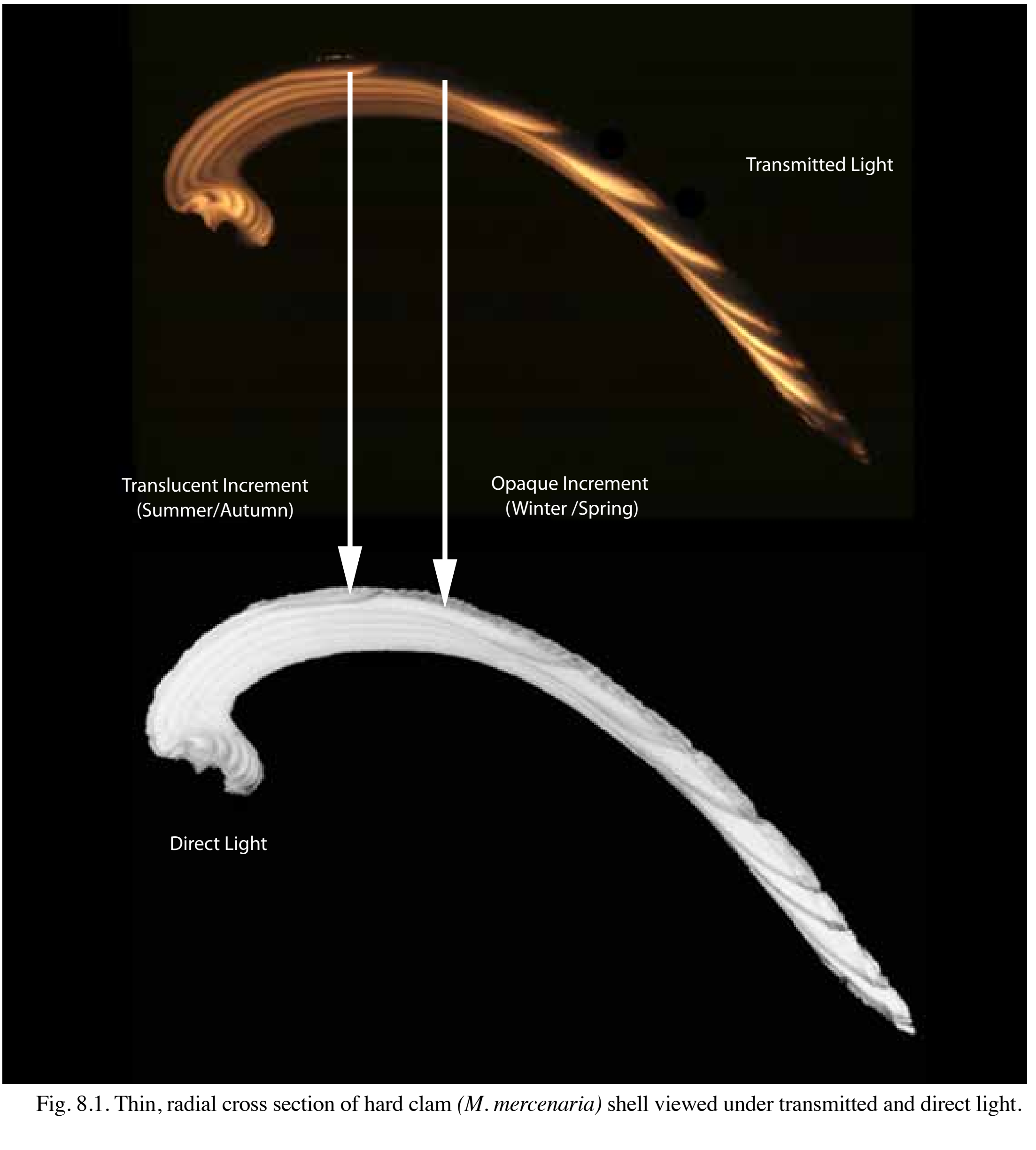


Fig. 8.1. Thin, radial cross section of hard clam *(M. mercenaria)* shell viewed under transmitted and direct light.

this case, a count of the translucent increments yields the ontogenetic age (in years) of each animal. A size analysis of the age-corrected annual shell increments documented the growth of Narragansett Bay specimens living between 1958 and 1983 (Jones, Arthur, and Allard, 1989).

Henry and Cerrato (2007) found a quite different annual periodic pattern in incremental shell formation in their analysis of shell oxygen isotopes collected from Narragansett Bay in 2005–2006: a translucent increment formed during the winter, an opaque in the spring, a second translucent in the summer, and a second opaque in the fall. They hypothesize that the changes in periodic shell formation resulted from an increase in water temperature in Narraganset Bay (Henry and Cerrato, 2007). If they had relied on the Jones, Arthur, and Allard (1989) baseline interpretation, a count of the translucent increments would have resulted in an overestimate of the mean age of the population. They conclude:

> Future studies, even if they are conducted in geographic regions where the annual growth pattern of *M. mercenaria* has been previously defined, should confirm that the annual pattern has not changed over time due to local environmental fluctuations (Henry and Cerrato, 2007).

Their conclusion is particularly relevant to the study of zooarchaeological assemblages where baseline patterns of periodic shell growth have the potential of changing in response to local and worldwide climatic shifts such as those experienced during the Holocene by Native Americans who populated the coastal environments of the Southeast (Fagan, 2000, 2005). Given the right environmental conditions, the periodicity of incremental shell growth could have changed many times. Recent reports suggest that established baseline patterns of increment formation can even change within a single researcher's lifetime (Jones, Arthur, and Allard, 1989; Fritz, 2001; Henry and Cerrato, 2007).

In this study we establish a seasonal profile of incremental shell growth using cross sections of Litchfield Beach hard clam shells collected monthly in 2005–2007. These data help to frame the population dynamics of modern hard clams living in the Litchfield Beach estuary (fig. 8.2). We also examine hard clam shell growth in specimens from five zooarchaeological hard clam assemblages sampled from the marshes of the Litchfield Beach, South Carolina (Georgetown County). A sixth sample excavated from nearby Sewee, South Carolina (Charlestown County) is included. These shell middens date between 1690 B.P. and 250 B.P. (table 8.1).

In light of the findings by Henry and Cerrato (2007), we validate the periodicity of the opaque and translucent shell increments in the modern and zooarchaeological specimens by analyzing the ratio of oxygen isotopes ($^{18}O/^{16}O$) measured in the cross-sectioned shells. We use the annual incremental pattern established from this study to estimate the composition of the ontogenetic age classes of the hard clams contained in the modern and six zooarchaeological assemblages to chart temporal changes in their populations.

METHODS

Archaeological Sites

Chester DePratter and Jim Legg (South Carolina Institute of Archaeology and Anthropology) surveyed 18 shell middens located in the tidal marshes of the Litchfield Beach estuary (fig. 8.2) in 2005. With the exception of one eastern oyster shell (*Crassostrea virginica*) midden (8GE572), all of the sites were composed of hard clam shells with the isolated remains of Atlantic ribbed mussel (*Geukensia demissa*) and stout tagelus clam (*Tagelus plebeius*). Pottery sherds were rarely encountered, while carbon lenses were observed during the excavations. The middens are located in the salt marsh and some extend below the present high tide line, indicating that sea level was at a lower stand than it is today.

We report on only those sites where hard clam sample size is greater than 30 interpretable specimens and where the deposits were radiocarbon dated (tables 8.1 and 8.2). This represents a total of six archaeological sites in the Litchfield Beach locality (fig. 8.2; table 8.2). Twelve sites remain to be dated and analyzed (fig. 8.2).

Litchfield—Modern Proxy

A two-year reference collection of modern hard clams ($N = 1055$) was assembled by Chester and Kalla DePratter who collected approximately 45 live specimens each month over the two-year interval, March 2005–March 2007. The purpose of the study was to associate the timing and periodicity of incremental shell growth with the seasons of the year and to document the population dynamics (ontogenetic age distribution) of the hard clams living in the Litchfield Beach estuary. The annual patterns observed in these data are then used to provide a temporal assessment series of zooarchaeological hard clams from the five Litchfield Beach sites.

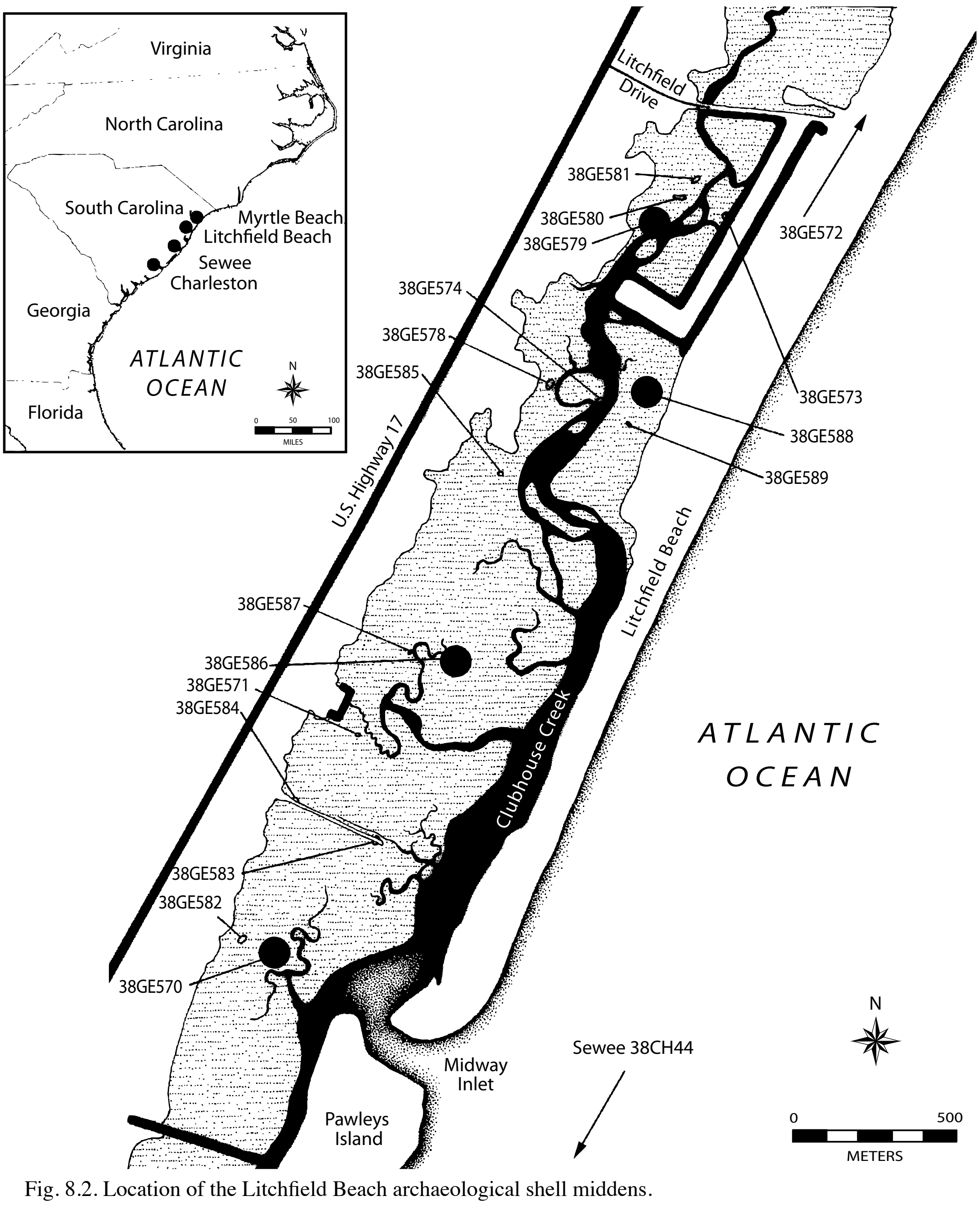


Fig. 8.2. Location of the Litchfield Beach archaeological shell middens.

TABLE 8.1
Radiocarbon Dates for Hard Clams (*M. mercenaria*)
from Litchfield Beach Shell Middens

Site no.	Beta no.	^{14}C dates 1 σ cal.	^{14}C dates (intercepts)	^{14}C sample depths
38GE570	220164	A.D. 850–1010 (1100–940 B.P.)	A.D. 920 (1030 B.P.)	30–50 cm bs
38GE572	209876	A.D. 180–360 (1170–1590 B.P.)	A.D. 260 (1690 B.P.)	1.4 m bs
38GE579	223880	A.D. 760–910 (1180–1040 B.P.)	A.D. 830 (1120 B.P.)	45–48 cm bs
38GE586	220165 220166	A.D. 1420–1490 (530–460 B.P.) A.D. 1310–1420 (640–530 B.P.)	A.D. 1450 (500 B.P.) A.D. 1390 (560 B.P.)	20–40 cm bs 40–60 cm bs
38GE588	223881	A.D. 1670–1810 (280–140 B.P.)	A.D. 1700 (250 B.P.)	ST, 35 cm bs
38CH44 Sewee clam	229579	A.D. 1420–1480 (530–470 B.P.)	A.D. 1450 (500 B.P.)	45–50 cm bs

TABLE 8.2
Descriptive Statistics of Ontogenetic Age (years) of Modern
and Zooarchaeological Hard Clams from the Litchfield Beach Region

	Litchfield	38GE588	38CH44	38GE586	38GE570	38GE579	38GE 572
	Modern	250 B.P.	500 B.P.	560 B.P.	1030 B.P.	1120 B.P.	1690 B.P.
Mean	7.88	7.48	6.83	3.17	4.95	5.00	7.75
Standard error	0.15	0.39	0.44	0.20	0.25	0.32	0.50
Median	8	7	6	3	5	5	8
Mode	7	7	5	2	5	4	8
Standard deviation	2.63	2.63	3.05	1.18	1.68	1.97	3.00
Sample variance	6.90	6.93	9.29	1.40	2.84	3.89	8.99
Range	13	11	14	4	6	9	12
Minimum	3	3	2	2	2	3	4
Maximum	16	14	16	6	8	12	16
Count	305	46	48	36	44	38	36
Confidence interval (95.0%)	0.30	0.78	0.89	0.40	0.51	0.65	1.01

Modern hard clams were hand collected live in the shallows of Clubhouse Creek. Scientific Permit #0984 was issued by South Carolina Department of Natural Resources because over the past 20 years the water quality of the estuary has not allowed for healthy commercial or recreational harvest of hard clams. We suggest that the modern Litchfield Beach assemblage may closely resemble a natural population because there had been no harvesting pressure over an extended period.

The specimens were frozen, allowed to thaw, cleaned of their soft tissue, and the shells were numbered and stored. Eventually the shells were transported to the Florida Museum of Natural History, Gainesville, for measurement and analysis. The anterior-to-posterior length of the right valve of each specimen was measured using digital calipers attached to a personal computer. This allowed for the direct input of shell measurement data into Microsoft Excel spreadsheets where all descriptive statistics were calculated.

We followed the methods of Quitmyer, Jones, and Arnold (1997) to expose and characterize the incremental shell growth patterns. The right valve of each specimen was radially cross-sectioned along the greatest growth axis, from the umbo to the ventral margin, using a water-cooled lapidary saw fitted with a Mark V alumina oxide blade (Quitmyer, Jones, and Arnold, 1997). The alumina oxide blade produced a polished cross-sectional surface that was examined with the unaided eye and/or microscopically (10×, 20×) with transmitted light.

For the purposes of our study, the frequency of individuals in either the translucent or opaque phase of shell growth was calculated for each month to document a pattern, or annual profile that is presented as a histogram for the modern hard clam assemblage. All of the zooarchaeological samples were prepared and analyzed in accordance with the methods outlined for the modern comparative collection of hard clams (Quitmyer, Jones, and Arnold, 1997; Quitmyer and Jones, 2000).

Isotopic Validation of Incremental Shell Growth Patterns

The seasonal variability in the oxygen isotope record contained in modern and zooarchaeological hard clams provides an independent method of validating the annual periodicity of incremental shell growth. Bivalves generally produce shell ($CaCO_3$) at or very near oxygen isotopic ($^{18}O/^{16}O$) equilibrium with the ambient seawater (Wefer and Berger, 1991). The exchange reaction is temperature dependent; thus, where the isotopic composition of ambient seawater remains relatively uniform, warm seawater temperatures are indicated where the oxygen isotopic composition ($\delta^{18}O$) is depleted, while cooler temperatures are indicated as the oxygen isotopic composition becomes enriched (Epstein and Lowenstam, 1953; Grossman and Ku, 1986). It is for this reason that we plot the isotopic values in an inverted fashion with negative (warm, up) to positive (cool, down) (Epstein et al., 1953).

Six zooarchaeological and two modern shells were randomly selected for isotopic analysis. The shells were radially cross-sectioned from the umbo to the ventral margin and glued to a glass petrographic microscope slide using two-part epoxy. Each specimen was then mounted on a Buehler Isomet saw equipped with a low concentration diamond wafering blade. A second radial cross section was made which produced a thick section for sampling. Between one and three samples of shell carbonate were milled from the opaque and translucent increments using a Merchantek Micromill equipped with a tungsten carbide bit. The samples were taken in ontogenetic sequence from the youngest to oldest part of the shell (i.e., umbo to ventral margin).

The isotopic analyses were conducted at the light stable isotope mass spectrometry laboratory, Department of Geological Sciences, University of Florida. The powdered shell samples were analyzed according to standard techniques, which involved an initial reaction in vacuo with 100% orthophosphoric acid at 70° C for 10 minutes. An online, automated, carbonate-preparation system (Kiel III) facilitated the production and purification of the evolved CO_2 gas. The isotopic differences between the derived CO_2 gas and the VPDB standard were determined with a Finnigan-MAT 252 isotope ratio mass spectrometer equipped with a Kiel III carbonate preparation system. All values are reported in standard δ notation where:

$$\delta^{18}O = [(^{18}O/^{16}O)_{sample}/(^{18}O/^{16}O)_{standard}-1] \times 10^3$$
per mil

The weight of the individual microsamples was so small that replicates of unknowns could not be run. However, variation among standards run before and after sample strings was less than ± 0.03 per mil (‰).

Ontogenetic Age

Based on the annual cycle of incremental shell growth observed in the shell cross section and validated from the isotopic study, the ontogenetic age (in years) of each modern and zooarchaeological hard clam was determined by counting the number of translucent shell increments seen in the radial cross section of the shells. The mean age and 95% confidence interval around the mean was calculated for each archaeological site. It was then possible to ascertain which of the sample sites were statistically different ($p <$

0.05) by noting whether or not their confidence intervals overlapped. This technique is straightforward, easily interpretable, and conservative.

Once the ontogenetic age was determined for every specimen, the rate of survivorship was calculated as the percentage of the population surviving during each year of life. These dynamic data were plotted as survivorship curves that facilitate the comparison of the modern and zooarchaeological samples (Deevey, 1947; Hallam, 1972; Cerrato, 1980).

RESULTS

Observed Incremental Shell Growth

Modern Hard Clams: Figure 8.3 presents the monthly frequency of individual clams ($N = 507$) forming the translucent and opaque increments in relation to annual monthly sea surface temperature (SST) and precipitation. The data show that during each month some proportion of the hard clam population is forming the translucent increment in their shells. Opaque shell growth is most prevalent between February and June. Thereafter, there is a distinct decline in opaque shell growth as SST increases toward summer maximum values. We note that precipitation in the region tracks SST and also reaches its maximum during the warm season. No opaque shell growth was observed in August and September when SST reached the annual maximum (August SST = 28° C). When all of the monthly data are pooled (fig. 8.3), annual translucent shell growth, relative to opaque, dominates the modern Litchfield Beach hard clam population.

Zooarchaeological Hard Clams: In contrast to the modern hard clams, the opaque shell increment is most frequently identified in all of the zooarchaeological assemblages (fig. 8.4). Because the $\delta^{18}O$ composition of the modern and zooarchaeological shells (figs. 8.5–8.7) indicate comparable temperature regimes (isotopic values ranging between –2.00 and +1.00 ‰), such a pattern most likely resulted from the preferential, seasonal harvest of hard clams during the winter and spring when opaque shell growth is most prevalent.

Isotopic Validation

The translucent and opaque shell growth increments were microsampled from two modern hard clams collected live in March 2005 and January 2007 (fig. 8.5). $\delta^{18}O$ values ranged between –1.75 and 1.48 in the 2005 specimen and between –2.40 and 1.63 in the 2007 shell. Figure 8.5 shows a pattern of growth where each translucent increment is characterized by depleted or light $\delta^{18}O$ values (warm SST) while the opaque increments are relatively enriched (cooler SST). These data confirm the monthly observations of marginal shell growth, which indicate that translucent increments are seasonally formed during the summer and autumn (figs. 8.1 and 8.3). Because only one translucent increment forms per year, the total number of translucent increments counted in a shell cross section yields the ontogenetic age (in years) of each specimen.

Carbon isotope ($\delta^{13}C$) profiles from the two modern shells range between –4.06 and –0.36. The $\delta^{13}C$ profiles weakly track the $\delta^{18}O$ values (fig. 8.5).

The results of the isotopic analyses from four zooarchaeological hard clams, excavated from three sites dating between 250 and 560 B.P., are presented in figure 8.6. The $\delta^{18}O$ values range between –2.20 and 1.51. In all cases, the translucent increment represents warmer SST (depleted $\delta^{18}O$), while the opaque increments formed in cooler conditions (enriched $\delta^{18}O$). $\delta^{13}C$ variation shows a positive correlation with the seasonal changes in the $\delta^{18}O$ composition (fig. 8.6). The correlation is much stronger than observed in the data from the modern specimens.

The three zooarchaeological hard clams from the sites that date between 1040 B.P. and 1690 B.P. share a similar oxygen isotopic pattern (fig. 8.7) with the modern shells and the other zooarchaeological shells. Among the three hard clams (fig. 8.7) the $\delta^{18}O$ values range between –2.04 and 1.70. The oxygen isotope data indicate that all translucent increments formed during the warm season and the opaque increments during cooler SST conditions. The $\delta^{13}C$ profiles also show a positive correlation with $\delta^{18}O$ as seen in the previous zooarchaeological specimens.

The isotopic data suggest there is a difference in the relationship between $\delta^{13}C$ and $\delta^{18}O$ in the modern versus the zooarchaeological shells. In all but one of the zooarchaeological shells (figs. 8.6 and 8.7), the correlation between $\delta^{13}C$ and $\delta^{18}O$ is stronger than in the modern specimens (fig. 8.5). This reflects the natural seasonal input of freshwater into the estuary, primarily during the wet season. In contrast, the modern estuary receives abundant freshwater year-round from septic tanks, irrigation, and storm water runoff.

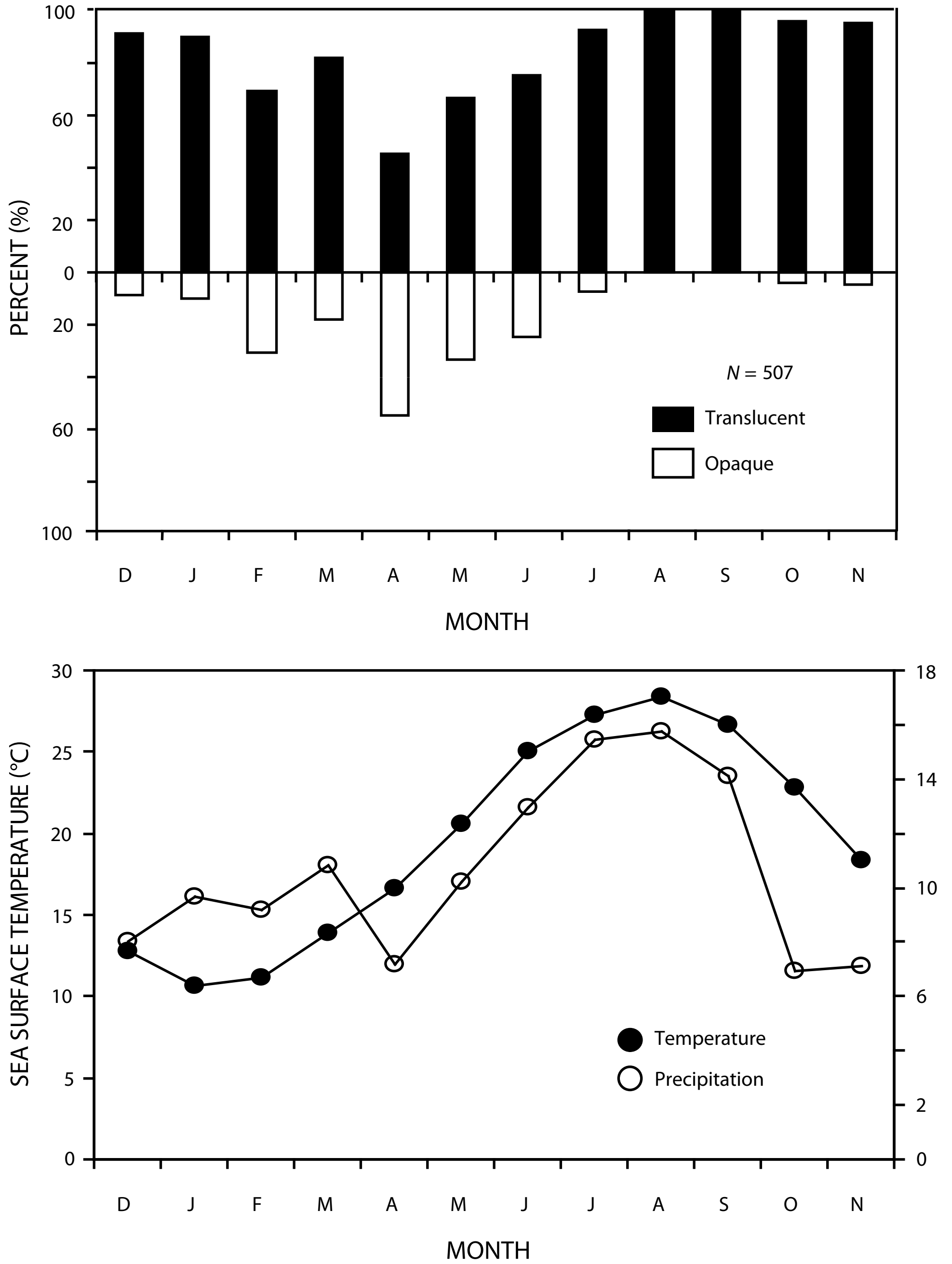


Fig. 8.3. Monthly frequency of specimens forming translucent or opaque shell growth increments from March 2005 to March 2007 in hard clams collected from the estuary at Litchfield Beach, SC. Sea surface temperature (°C) and precipitation (cm) from nearby North Myrtle Beach, SC.

Size vs. Age

Hard clam populations living in the Southeast display a great deal of variation in age among similar-sized individuals (Walker and Tenore, 1984; Quitmyer and Jones, 2000; Fegley, 2001). This pattern also exists in the modern Litchfield Beach hard clam population that was collected in 2005–2007. For example, the anterior to posterior range in size of the three-year-old clams encompasses a sizable proportion of all other age classes in the sample (see box in fig. 8.8). The shells range in age between three and 16 years (*N* = 305, mean = 7.9, S.D. ± 0.15), while the anterior-to-posterior length ranges between 64.3 and 84.5 mm (mean = 64.3 mm, S.D. ± 0.41).

Mean Ontogenetic Age and Survivorship

As noted above there is considerable overlap in the size range of consecutive age classes in each hard clam population. It is for this reason that we rely on ontogenetic age as a measure of the population dynamics of the modern and zooarchaeological assemblages. A plot of the mean age and 95% C.I. of the seven samples, in temporal order, shows a significant decline in the mean age between 1690 B.P. and 560 B.P. and a subsequent rebound to the present (table 8.2; fig. 8.9). The 95% C.I. of the three youngest samples and 38GE52 (1690 B.P.) overlap and are statistically indistinguishable; however, the samples from 1120 B.P. to 560 B.P. are statistically different.

A plot of the survivorship curves also shows temporal changes in the survivorship of the seven hard clam assemblages (fig. 8.10). The survivorship curves for the three samples dating between 1120 B.P. and 560 B.P. (solid symbols in fig. 8.10) show a substantial reduction in the mean survivorship and the right tail of the curve is truncated relative to the younger samples (500 B.P. to the present) or the earliest sample (1690 B.P.).

DISCUSSION

Documentation of the yearly pattern of growth increment formation in the shells of modern hard clams establishes a baseline proxy of an-

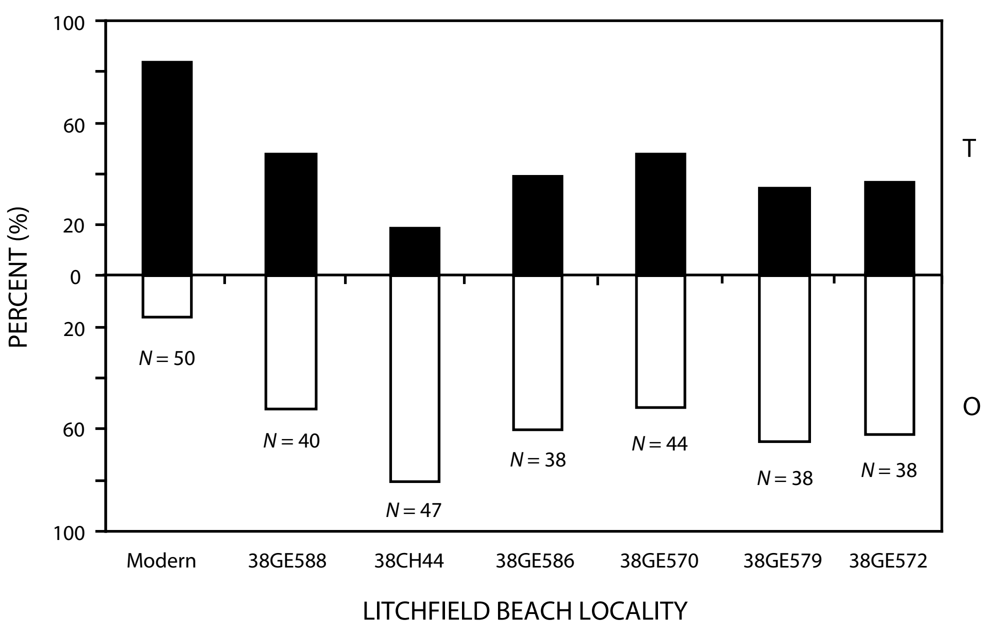


Fig. 8.4. Percentage of translucent and opaque incremental shell growth identified in modern and zooarchaeological hard clams from the Litchfield Beach region. Abbreviations: T = translucent shell growth; O = opaque shell growth.

nual incremental shell growth that can be used to evaluate the population dynamics of zooarchaeological hard clams excavated from the Litchfield Beach region. The shell microstructural data indicate that in the modern population the opaque increments form during a short seasonal interval

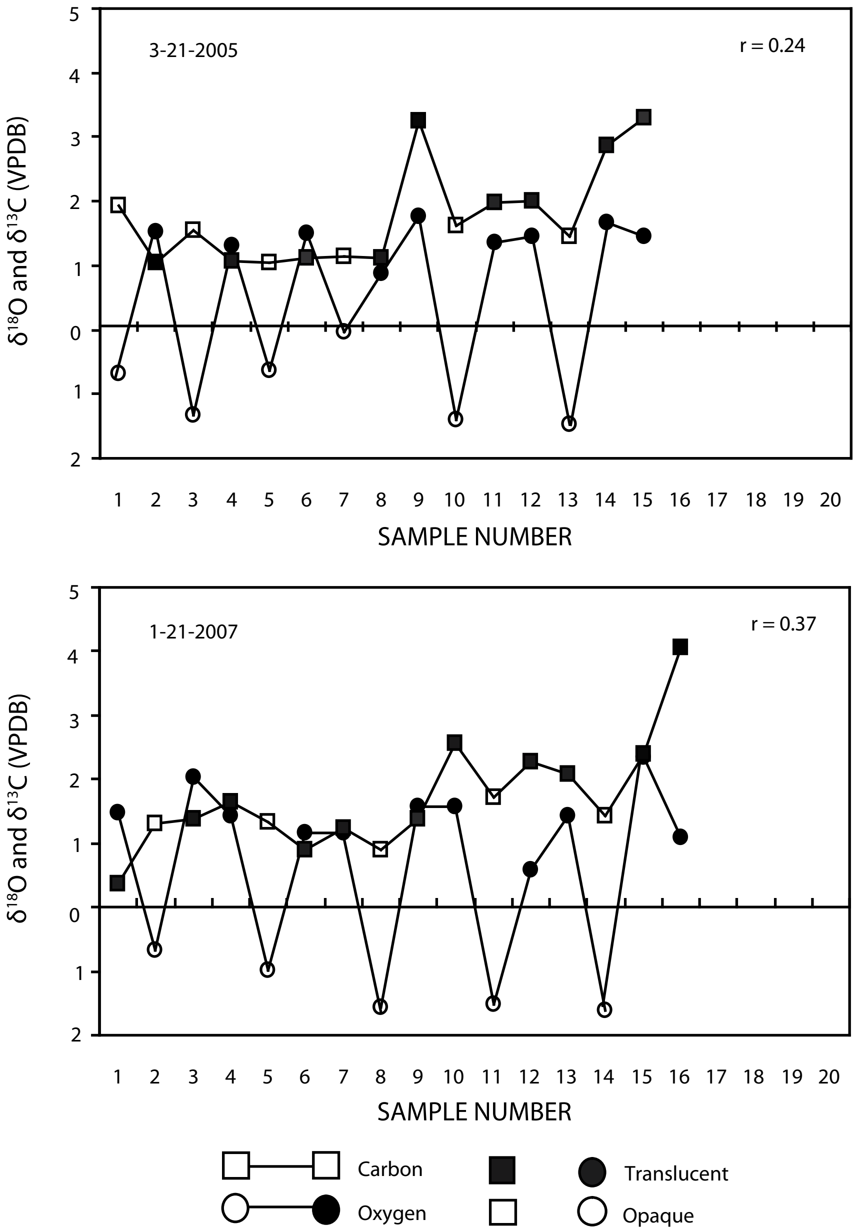


Fig. 8.5. Variation in oxygen ($^{18}O/^{16}O$) and carbon ($^{13}C/^{12}C$) isotopic composition in the translucent and opaque growth increments of modern hard clams from the Litchfield Beach region.

between late winter and spring. These alternate with translucent shell growth increments that are most pervasive during the summer and autumn as seawater temperature warms.

Analyses of oxygen isotopes ($\delta^{18}O$) in the modern and zooarchaeological shells independently verify the seasonal periodicity of the two alternating shell increments. In all cases, enriched values of $\delta^{18}O$ indicative of cool water conditions characterize the opaque increment and depleted $\delta^{18}O$ values (warm conditions) characterize the translucent increment. This periodic pattern (chemical and microstructural) is consistent with other modern seasonal and zooarchaeological studies of hard clams reported from the Southeast (Clark, 1979; Quitmyer, Jones, and Arnold, 1997; Fritz, 2001; Andrus and Crowe, 2008; O'Brien and Thomas, 2008). These findings verify that a couplet of one opaque and one translucent shell growth increment marks one year of life and justifies its use in characterizing the population dynamics of modern and zooarchaeological hard clam assemblages. Further, the data indicate that this pattern has remained constant in the Litchfield

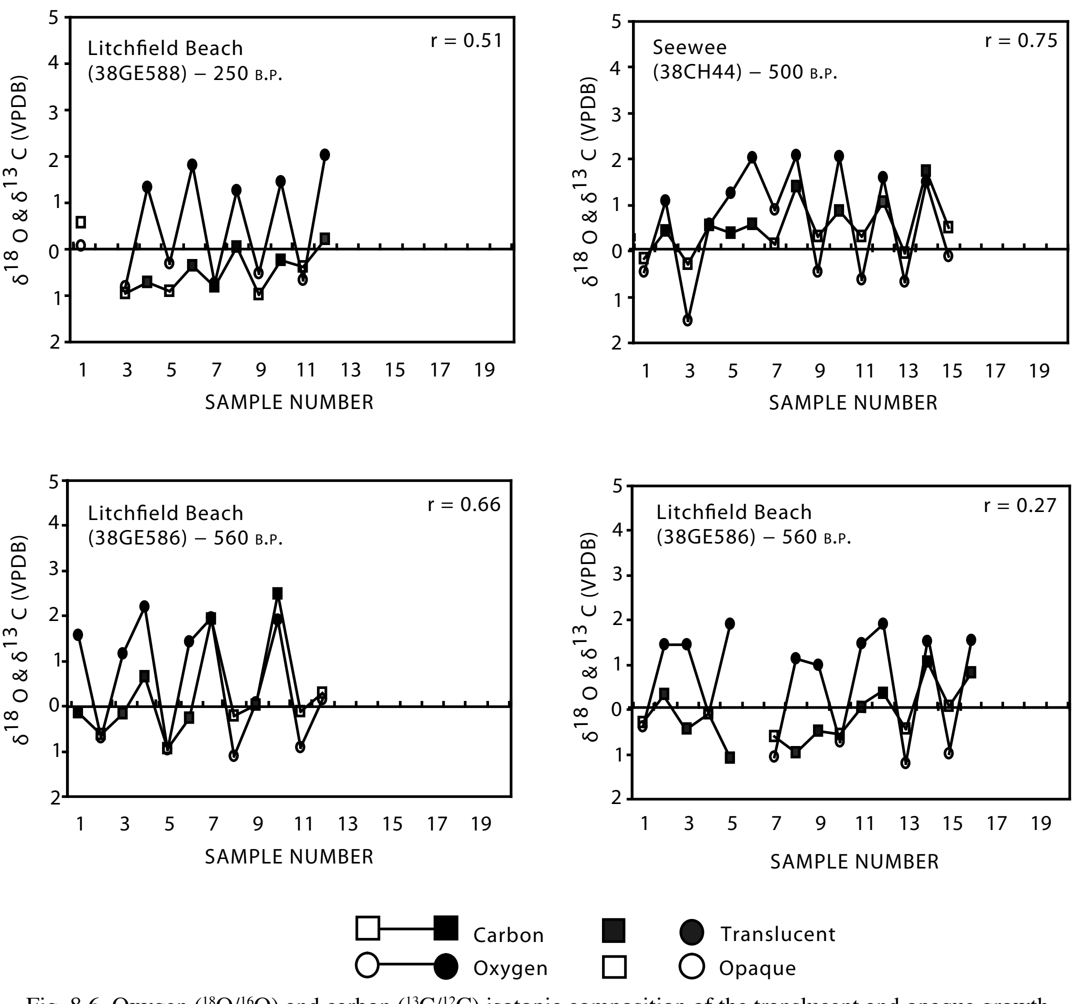


Fig. 8.6. Oxygen ($^{18}O/^{16}O$) and carbon ($^{13}C/^{12}C$) isotopic composition of the translucent and opaque growth increments from zooarchaeological hard clams *(M. mercenaria)* from the Litchfield Beach region.

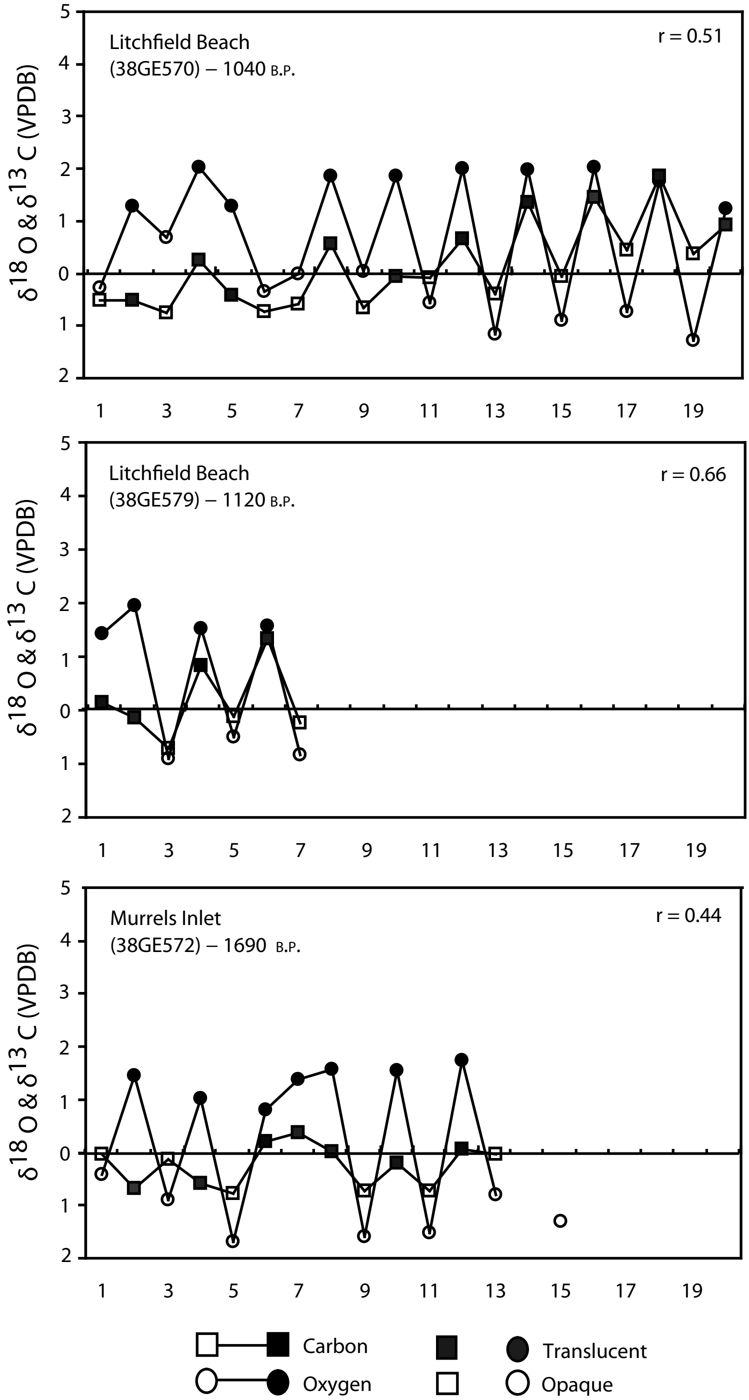


Fig. 8.7. Oxygen ($^{18}O/^{16}O$) and carbon ($^{13}C/^{12}C$) isotopic composition of the translucent and opaque growth increments from zooarchaeological hard clams *(M. mercenaria)* from the Litchfield Beach region.

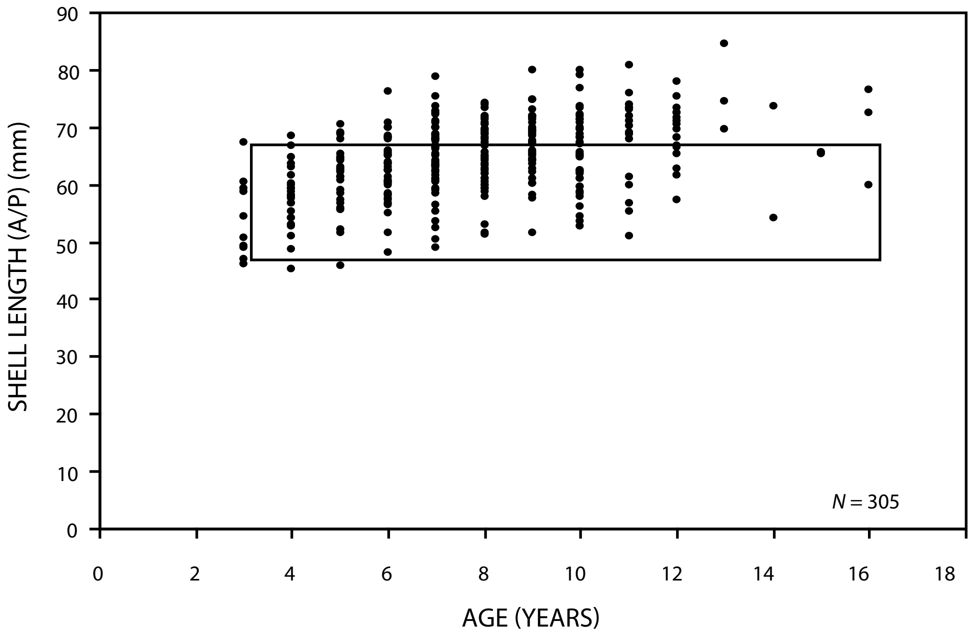


Fig. 8.8. A comparison of age (years) versus anterior-to-posterior (A/P) shell length in modern hard clams *(M. mercenaria)* from the Litchfield Beach estuary.

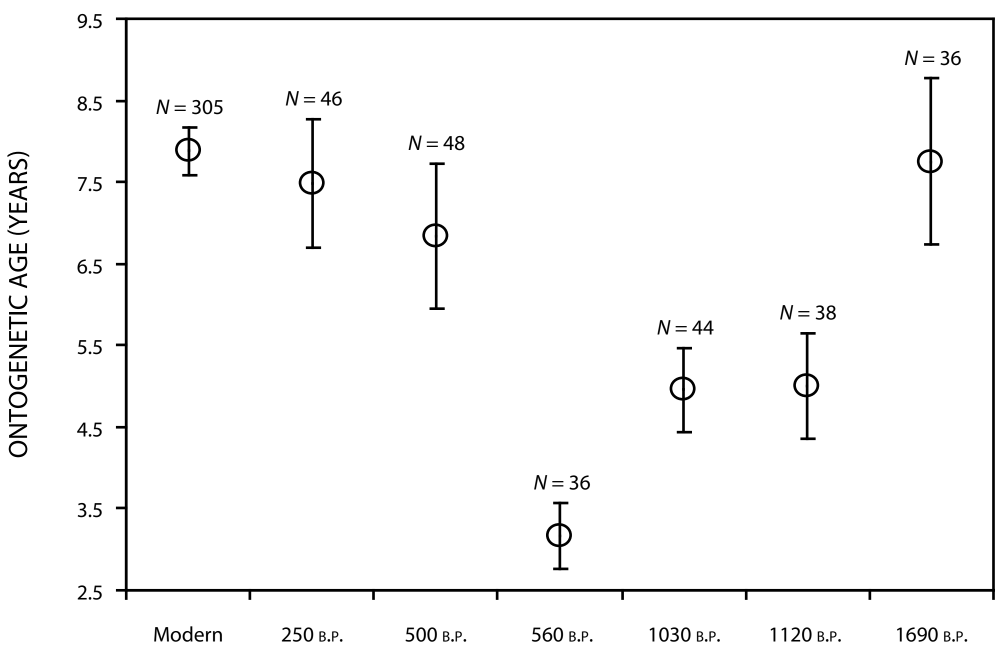


Fig. 8.9. The mean ontogenetic age and 95% confidence interval around the mean of modern and zooarchaeological hard clams *(M. mercenaria)* from the Litchfield Beach region.

Beach region for at least the last 1700 years.

The population dynamics of an organism like the hard clam are influenced by its ontogenetic age composition, growth rate, mortality (survivorship), and recruitment. Human harvesting pressure has been shown to alter the population dynamics of hard clam beds, in particular the mean ontogenetic age and survivorship (Walker, 1989). For example, Walker (1989) has shown that small, densely populated hard clam beds are easily overfished. In 1981 a small bed (90 m^2) containing 49 clams per square meter was illegally harvested (hand collecting) in the Wassaw Island National Wildlife Refuge of coastal Georgia. In a one-week period, the population declined to 22 individuals per square meter. In fact, hard clam populations of the southeastern United States are vulnerable to harvesting pressure because of their habitat preferences, recruitment, and distribution within those habitats.

Hard clams are one of the most abundant, large-bodied, infaunal suspension feeders living in soft substrates (Fegley, 2001). In the Southeast they generally occupy the intertidal zone of estuarine creeks where they tend to be restricted to heterogeneous substrates (Walker, 1989). They are typically found in densely packed, circumscribed beds among oysters, shell deposits, and to a lesser extent sand, mud, and sandy mud (Walker and Tenore, 1984; Fegley, 2001). Such a configuration facilitates rapid, intensive harvesting.

Recruitment is a gradual process that is inconsistent from year to year where very few individuals enter the adult stage (Malinowski, 1985). Because of sparse, sporadic settling of spat, major sets are rare and hard clam populations are dominated by larger individuals (Walker, 1989). Commercial harvesting along the Georgia and South Carolina coasts represents a minimal activity. Because of light harvesting pressure, it has been suggested that many of the beds resemble populations that are in equilibrium (Fegley, 2001). This may extend to other areas of the Southeast where harvesting is lim-

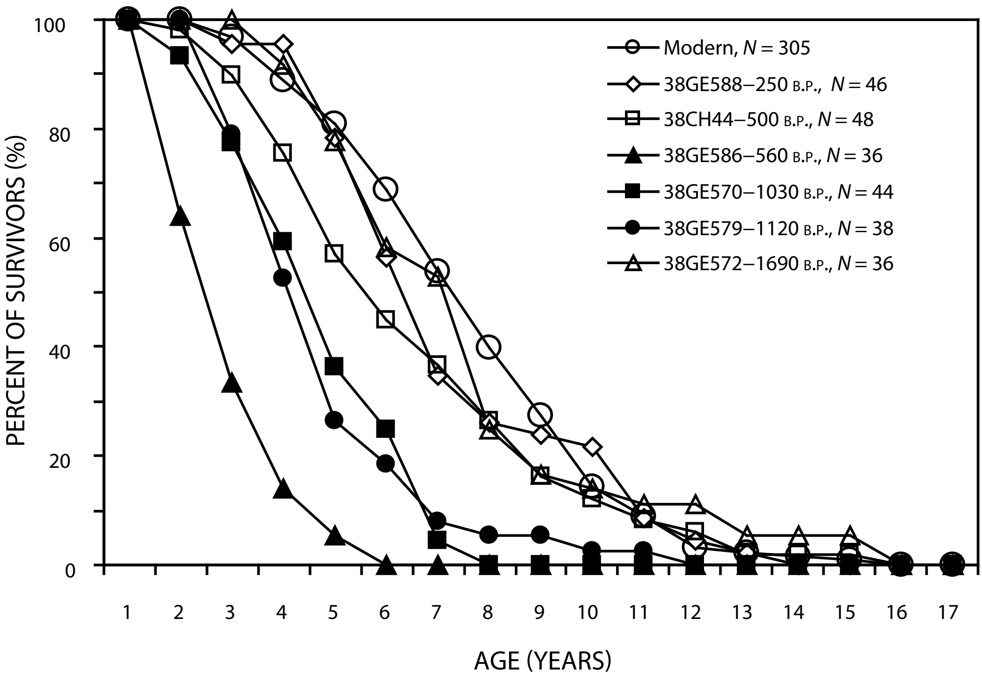


Fig. 8.10. Survivorship curves of modern and zooarchaeological hard clams *(M. mercenaria)* from the Litchfield Beach region.

ited. The Litchfield Beach hard clam population is one such example where harvesting has been limited or nonexistent for decades due to poor water quality.

Where hard clam beds are fished, larger individuals are at greater risk than small to medium-sized individuals (Fegley, 2001). It has been suggested that the larger hard clam shells shelter the smaller individuals from predators (Walker, 1989). As larger individuals are removed from their beds there may be an increase in predation on smaller specimens (Walker, 1989), which further reduces the number of individuals that might reach maximum age.

Although hard clam beds tend to be dominated by larger individuals, size classes may vary with habitat type, predator diversity, and density (Walker and Tenore, 1984). As we have shown above, there is considerable scatter in the size-versus-age relationship (Fegley, 2001). Because of this, variations in mean shell size are not a reliable indicator of hard clam population dynamics and their relationship to harvesting pressure.

In light of our understanding of hard clam biology and ecology, we can consider the ontogenetic age composition and survivorship of the hard clam assemblages that span nearly 1700 years at Litchfield Beach. The mean ontogenetic age of the earliest zooarchaeological assemblage (1690 B.P.) resembles that of the modern, unharvested beds. Between 1120 B.P. and 560 B.P. the data suggest the zooarchaeological hard clams were intensively harvested and the mean age of the population declined significantly. The survivorship curves also show a loss of younger individuals ranging between one and four years of life and fewer individuals reaching maximum age. After 560 B.P. there is a rebound in the ontogenetic age composition and survivorship that resembles the assemblages dating between 500 B.P. and the present. These are also similar to the earliest zooarchaeological sample (1690 B.P.).

The question might naturally be posed as to whether the diminished mean age composition of the ancient hard clam populations observed in this study could be the result of natural causes as opposed to human harvesting pressure (i.e., anthropogenic impact on the beds). Like many infaunal bivalve molluscs, hard clams refuge themselves in size from nonhuman predation pressures (e.g., fish, crabs, sea stars, boring gastropods, whelks), which are typically concentrated upon the smaller, juvenile components of the population (Walker, 1989). Intensification of natural predation pressure would therefore have the net opposite effect of what is observed in the zooarchaeological assemblages by increasing the mean ontogenetic age (size) of the population. In contrast, human exploitation that blindly extracts clams from the substrate puts the largest (generally oldest) individuals at greater risk of being collected. In the zooarchaeological assemblages that appear to have been impacted by intensive harvesting, the older members of the population are missing from the zooarchaeological assemblages (fig. 8.10).

We cannot fully reject unseen environmental conditions that could have affected the dynamics of the various Litchfield Beach hard clam populations. However, previous research has shown that the pattern of intensive hard clam exploitation is nonuniform over space and time in southeastern North America (Quitmyer and Jones, 2000). At some localities, the age class composition is diminished, while at other sites dating to the same time period, there are samples that seem to have been collected from unharvested beds. Quitmyer and Jones (2000) have also documented the reduction in the zooarchaeological age classes of hard clams in some locations in archaeological sites, while in other areas of the same sites there is no evidence for concentrated harvesting. Exposure time to humans and intensive harvesting are the two common variables that exist when heavy exploitation of hard clams is identified. Similar observations are well documented in the zooarchaeological record (Quitmyer, Hale, and Jones, 1985; Szabó and Quitmyer, 2008; Quitmyer and Jones 2000; Marcello and Thomas, 2002; Quitmyer, 2003; Peacock, Haag, and Warren, 2004; Erlandson et al., 2008; Rick and Erlandson, 2008).

This is the same pattern observed in the Litchfield Beach region. With exposure time to humans and evidence for intensive collecting, there is a clear and precipitous decline in the mean ontogenetic age (in years) between 1690 B.P. and 560 B.P. We cannot account for the subsequent increase in the mean age of the populations after 560 B.P., but it is clear that harvesting pressure was removed and the age class composition returned to what may be considered indicative of naturally occurring populations. This pattern may have been the result of intensive harvest in the region and a subsequent abandonment of the beds, thus allowing their age class compositions to equilibrate. Alternatively, could harvesting pressure have been abated by Hispanic incursion into the region? Shortly after 560 B.P., Hispanic explorers entered the Southeast, resulting in a profound disruption of the Native American population.

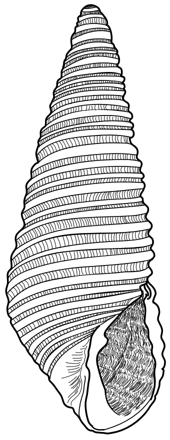
CONCLUSIONS

In this research we combine microstructural and oxygen isotopic approaches to document and validate the fundamental pattern of periodic, incremental shell growth for hard clams living in the Litchfield Beach region. The two-year longitudinal study of incremental shell growth (observational data) demonstrates that the opaque (light) growth increment forms in the late winter and spring when sea surface temperatures approach the optimum for hard clam growth (~20° C) and the translucent (dark) increment forms as the sea surface temperature increases toward the summer maximum (~32° C). The oxygen isotopic composition of the opaque and translucent shell increments validate the observational data. A couplet of one opaque and one translucent shell growth increment represents one year of life. These data also confirm a similar pattern in the zooarchaeological hard clam assemblages for the past 1700 years in the region. This periodic pattern of incremental shell growth is consistent with previous research from the southeastern Atlantic coast of the United States.

With these data in hand we can evaluate the season of hard clam harvest in the middens, ontogenetic age, and survivorship of the modern and zooarchaeological populations in the Litchfield Beach region. The data show that all of the zooarchaeological harvesting occurred during the winter and spring seasons. There was intensive harvesting pressure between 1690 B.P. and 560 B.P. where hard clams were consumed at an intensive rate. The mean ontogenetic age class composition declined from 7.8 years to 3.2 years. After 560 B.P., harvesting pressure was removed and the survivorship of the hard clam assemblages rebounded with the mean ontogenetic age rising to 7.9 years.

This pattern of intense exploitation appears to have occurred more than one time and in other geographic locations in the Southeast. Like many molluscan taxa, hard clams are sensitive indicators of harvesting pressure. Where there is evidence for dense human populations, evidence for sedentism, or in places where hard clams are a major focus of subsistence behavior, changes in the ontogenetic age classes and survivorship can be identified.

Pre-Hispanic harvest of hard clams extended across a wide temporal and geographic range. The decisions that resulted in the changes to the zooarchaeological hard clam population dynamics appear to be more intrinsic to the human species rather than associated with the level of cultural complexity.



CHAPTER 9
REEVALUATING THE USE OF IMPRESSED ODOSTOME (*BOONEA IMPRESSA*) AS A SEASON-OF-CAPTURE INDICATOR FOR OYSTERS

Deborah Ann Keene

Boonea impressa are small (less than 1 cm) parasitic gastropods that feed on oysters and are found along the Atlantic and Gulf coasts of North America (fig. 9.1). Although *B. impressa* were probably not deliberately gathered by humans as a food source, the oysters to which they were attached were gathered in large amounts. *B. impressa* are frequently found in archaeological middens, although a small screen size (0.7 mm) must be used to recover them all.

The use of *Boonea impressa* as a season-of-capture indicator for archaeological oysters was first devised by Russo (1991) and his ideas have laid the groundwork for others using this species (see Cannarozzi, chap. 10, this volume). Russo (1991) hypothesized that determining the season of death for *B. impressa* would reveal the season of death for the oysters to which they were attached. His hypothesis rests on the assumptions that the majority of *B. impressa* are born at the same time of year, live only for about one year, and increase in size throughout the year. Therefore, one could determine the season in which they died by their size. To test his hypothesis, he collected and measured modern samples of *B. impressa* from the northeastern coast of Florida for 14 months. He used these data to develop a model of yearly growth based on shell length. The growth curve is divided into shell length size classes representing spring, summer, autumn, late autumn, winter, and late winter (table 9.1). The shell length size classes were determined from the modal range, or the most common lengths collected during a particular season, rather than the average length of all the shells collected. Russo did this because, although most *B. impressa* are born at one time of the year, a smaller percentage is born throughout the year. Using a modal range theoretically isolates the larger birth cohort and negates any effects of the other birth cohorts in determining the season of death. He did not test his model on known samples, but did apply them to archaeological assemblages. Russo (1991) has carefully considered many of the drawbacks of assessing seasonality (i.e., mean length vs. mode size categories); however, there are several additional problems that must be addressed. These include variation between species in different environments, constant reproduction throughout the year, inconsistent growth patterns, feeding habits of juveniles, and lack of specific knowledge of many aspects of growth, reproduction, and behavior. Russo's application and these issues are the focus of this chapter.

LOCATION AND ENVIRONMENT

Morphological characteristics of *Boonea* differ among geographic locations and environments. White, Kitting, and Powell (1985) collected samples of *Boonea impressa* in October, December, March, May, and July (1981–1982) on Mud Island, Texas. These samples were compared to shells collected at Virginia Creek and Williston Creek, North Carolina. Multiple measurements of these collections indicated that the North Carolina specimens were larger overall (White, Kitting, and Powell, 1985: 42). However, no cause is suggested for this size difference. It may be due to temperature difference between North Carolina and Texas, or it may be that one collection was made in 1981–1982 while the other collections were made in the 1970s.

White, Kitting, and Powell (1985) counted sperm and oocytes in a laboratory sample of *Boonea impressa* collected from Big Slough, Texas, and found that sperm was present in all months but December. The authors suggest that the lack of sperm in December may be due to cold temperatures. If the cold temperatures in Texas can affect sperm production, it is likely that *B. impressa* in more northerly climates would not have the same birth seasons as populations in Texas and Florida. This means that *B. impressa* size classes would not be universal in determining season of capture. This is illustrated by Cannarozzi's (chap. 10) work from St. Catherines Island. Her size classes are markedly different from Russo's (1991) Florida size classes.

Morphological differences have also been observed in *Boonea impressa* populations that live in the same geographic location but in different environments within that location. Porter, Howie, and Deriso (1979) compared *B. impressa* and *Boonea seminuda* specimens from North Carolina estuaries with *B. seminuda* specimens from offshore environments. The estuarine samples of *B. impressa* and *B. seminuda* shared more selected characteristics than the *B. seminuda* from different environments did with each other (Porter, Howie, and Deriso, 1979: 44).

Both the White, Kitting, and Powell (1985) and Porter, Howie, and Deriso (1979) studies indicate that morphological differences in *Boonea* can be caused by environment and geography. However, the extent of these differences is not yet known, and more work needs to be done, especially with the effects of temperature on reproduction and growth. The available data indicate that size ranges to determine season of capture may only be useful in a small geographical area, highlighting the importance of developing ecological analogies using data collected as near as possible to the sites being studied (see Cannarozzi, chap. 10).

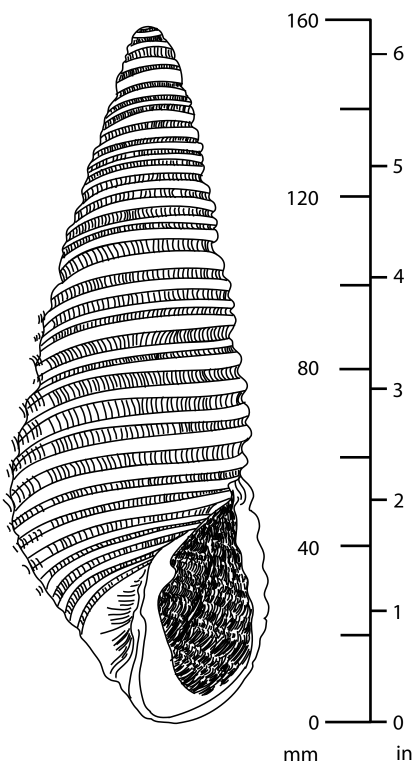


Fig. 9.1. Drawing of *Boonea impressa*.

REPRODUCTION

The *Boonea impressa* method relies on the assumption that the majority of individuals are born in late spring/early summer and live for approximately one year (Russo, 1991: 209). However, this assumption may not be supported by available data. Russo (1991: 208) cites two studies of *B. impressa* in addition to his own. The first is Wells (1959), and the second is White, Kitting, and Powell (1985).

The Wells (1959: 142) article states that "the largest collection of young were made in June and July, when they formed by far the most numerous class in the population." However, Wells (1959) does not report specific percentages. White, Kitting, and Powell (1985: 39) report percentages of young (0.5–1.0 mm wide) collected each month. July contained the largest number of young at 55%, however, December contained 22%, October contained 10%, and March 5%. The July sample may have been affected by climatic conditions and may be lower than normal, but this simply illustrates the point that the *Boonea impressa* demography is dynamic from one year to the next. Regardless, White, Kitting, and Powell (1985) show that a third of the population is born in seasons other than summer, and there is a fairly large birth rate increase in December, albeit smaller than the June/July increase.

This second reproductive peak in the annual growth curve (December) would cause many problems in interpreting archaeological assemblages by using *Boonea impressa* to determine season of capture. An archaeological assemblage consisting of a December population would consist of about 25% young *B. impressa*, about 55% middle-aged individuals, and about 20% of the individuals would reflect a variety of other age groups. This distribution would result in a bimodal growth curve suggesting spring and winter collection rather than just December. As these populations grow, the bimodal curve will continue to shift, producing a bimodal distribution that does not reflect the actual collection times of the *B. impressa*.

INCONSISTENT GROWTH PATTERNS WITHIN POPULATIONS

Two of the key assumptions needed when using *Boonea impressa* as a season-of-capture indicator is that "the average size … increases throughout the year" and that the lengths are comparable across time (Russo, 1991: 209). In Wells (1959), the collection of *B. impressa* takes place over a period of 18 months and 16 collections are made (fig. 9.2). Collections were taken during two successive years for the months of May, June, July, August, September, and October. One collection was taken for July/August in 1956; separate July and August collections were taken in 1955. As the length means from these collections would certainly differ from one another, they will not be included in this chapter. The mean length in May 1955 is approximately 2.5 mm, and the mean in May 1956 is approximately 4.25 mm. The mean length in June 1955 is approximately 1.5 mm and the mean in June 1956 is approximately 2.5 mm. The mean for September is about the same for both years. In October 1955, however, the mean is slightly over 3.0 mm, while in October 1956, the mean is nearly 4.0 mm. Clearly, the size means vary between years, in this case up to 1.75 mm, and this is precisely why Russo (1991) uses modal size ranges rather than mean. Modal sizes would do a good job of isolating a specific cohort, but if that cohort measured as little as 0.2–0.4 mm larger than it did in the previous year, Russo's (1991) particular modal size ranges would not accurately predict the season of capture.

The White, Kitting, and Powell (1985: 38) studies of *Boonea impressa* from Mud Island, Texas, contain data indicating that the growth patterns of their population of *B. impressa* do not match with the growth patterns seen in Russo's (1991) population. Although the width of the sample populations collected in October, December, March, May, and July increase throughout the year, a chi-square test indicated that there was not a significant difference in size between the March and May populations ($p < 0.05$). So although Russo's (1991) assumption that *B. impressa* generally grow larger throughout the year is supported, the month in which the older population dies and the new one takes over is variable. This conclusion is supported by the differences between Russo's (1991) and Cannarozzi's (chap. 10) size classes.

TABLE 9.1
Size Classes Formulated by Russo (1991)

Season designation	Calendar months included	Shell length (mm)
Spring	May, June	1.1–2.5
Summer	July, August	2.6–3.5
Autumn	September, October	3.6–4.0
Late autumn	October, November	4.1–4.5
Winter	November, December, January	4.6–5.0
Late winter	February, March, April	5.1–5.5

It is clear from these data that a population of *Boonea impressa* from the same area will have variable growth characteristics from year to year. If the growth of *B. impressa* is related to temperature, as suggested earlier, this would explain the changes in size from year to year and would seriously impact the use of *B. impressa* size to determine season of capture.

FEEDING HABITS

Another variable is the feeding habits of juvenile *Boonea impressa*. Powell et al. (1987) observed juvenile *B. impressa* frequently feeding on *Crepidula plana* and other *Crepidula* species in Texas. During a controlled experiment in which juvenile *B. impressa* were placed in a tank with oyster spat and *C. plana* for five days, all juveniles attached to the *C. plana* by the fifth day and none were found on the oyster spat. Adults always preferred the oyster. Although this is a particular instance indicating that juveniles and adults have different feeding habits, it demonstrates a general behavior that could affect distribution of *B. impressa* in archaeological assemblages. Feeding on any species other than oyster could skew the number of juveniles in a random sample, because the smallest *B. impressa* might not be brought to the archaeological site unless that species was present. Thus, the smallest size class would be underrepresented and larger individuals, those preferring oysters, would be numerically more common. This would result in consistently finding a larger number of mature individuals.

In fact, most applications that use *Boonea impressa* do find a larger number of mature individuals. When Russo (1991) applied the method to archaeological samples, all 13 of the features and middens contained *B. impressa* size classes representing late autumn or winter components (his larger size classes). Two features had smaller spring components, one had a smaller summer

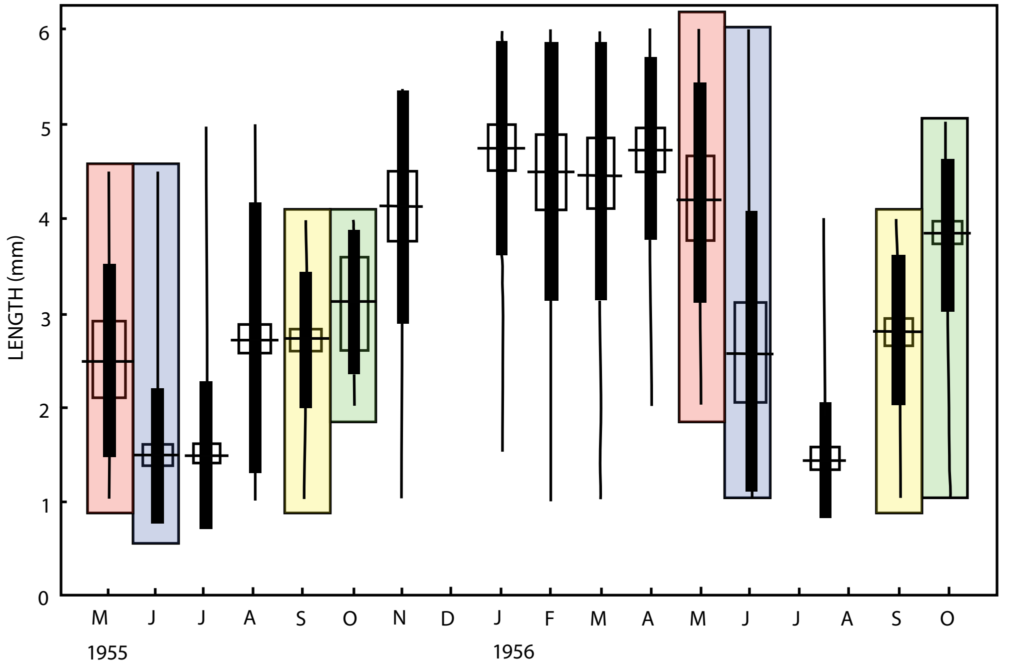


Fig. 9.2. Length distribution data from Wells (1959). Reprinted with permission. Colored highlights added by the author.

component, and one had a larger summer component. Fradkin (2008) measured over 6000 *B. impressa* from the Greenfield site, Florida, to determine season of capture. Again, all the components included autumn and late autumn captures (using Russo's [1991] size classes) with one having an additional summer capture. Cannarozzi (chap. 10) created her own size classes using local *B. impressa* near St. Catherines Island. The most numerous size class for both her archaeological samples was spring, which corresponds roughly in size to Russo's (1991) autumn, late autumn, and winter size classes (approximately 4–6 mm in length).

Russo's (1991) size classes were used by the author on samples of *Boonea impressa* taken from Grove's Creek Site, Skidaway Island, Georgia. The *B. impressa* shells were sorted from flotation samples taken from a 1 × 1 m midden unit and passed through 0.50 mm mesh. All shells were examined under a low-power microscope to confirm that they were unbroken. The length of each shell was measured with a pair of digital calipers. The measurements were taken from the apex to the abapical end and were divided into the modal length size classes outlined in Russo (1991). The data (N = 79) indicated primarily autumn season of capture (fig. 9.3). It should be noted that stable isotope analysis was performed on oysters recovered from the same excavation unit and none indicated an autumn season of capture (Keene, 2004). However, this discrepancy may be the result of small sample size (N = 8 oyster shells).

All four applications of the method described above find larger percentages of *Boonea impressa* in the 4–6 mm size class. This supports the hypothesis that primarily larger *B. impressa* are being recovered at greater rate than smaller *B. impressa*. Recovery bias may be due to feeding habits, but it may also be due to increased breakage of younger *B. impressa*, or recovery methods. With only four studies, these conclusions are preliminary. The Russo (1991) and Fradkin (2008) assemblages do contain significant numbers of spring and summer size classes. However, this could be due to reasons other than a spring or summer collection of oysters. First, multiple years might be represented in the archaeological sample, with one year producing smaller or larger adult *B. impressa* than another year. Second, a bimodal distribution of larger and smaller individuals might be caused by a population collected during the season when there is an influx of young *B. impressa* into an existing population of mature *B. impressa*.

CURRENT STATE OF KNOWLEDGE CONCERNING *BOONEA IMPRESSA*

The last issue has been mentioned throughout, and that is general lack of information about

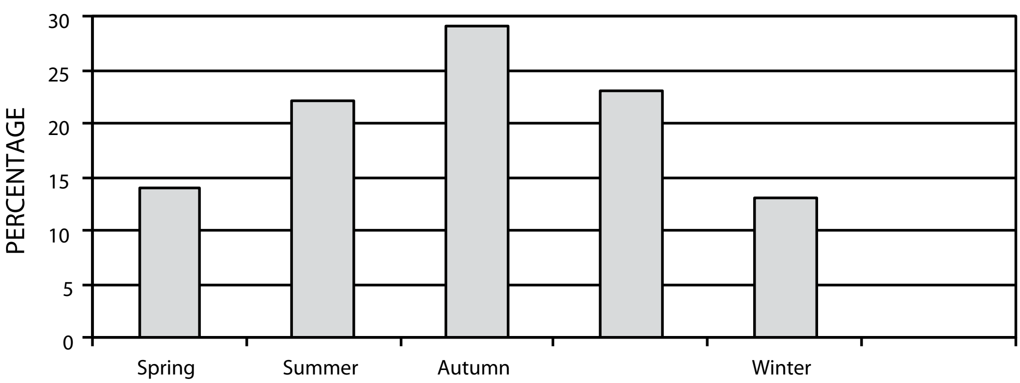
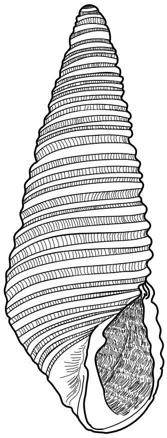


Fig. 9.3. Season of capture for Grove's Creek site *Boonea impressa* shells using Russo method with a 0.50 mm screen.

Boonea impressa growth, reproduction, and behavior. The major studies were conducted in North Carolina (Wells, 1959; Porter, Howie, and Deriso, 1979) and Texas (White, Kitting, and Powell, 1985; Powell et al., 1987). Some data indicate that these populations are morphologically distinct, but are insufficient to explain the degree of difference or why there are differences. Reproductive behavior may be affected by temperature (White, Kitting, and Powell, 1985), but this is inconclusive. Until we know how reproduction and growth are affected by environmental factors, using *B. impressa* as a method to determine season of capture for oysters may not be reliable, and it is clear that size classes are not universal.

There are several avenues that can be taken to evaluate the merits of this method for indirectly assessing season of capture for oysters. The first would be to recreate an archaeological midden sample with *Boonea impressa* from known collection dates. Shells from different years and months could be mixed and then measured by a person who does not know which seasons are included. Shells from the same month and different years should be tested similarly. Increased overall sample size as compared to previous studies is key. Modern collections need to be taken in several environmental zones over several years to record clinal variations in growth. Cannarozzi (chap. 10) has already done a multiyear collection at St. Catherines Island. If molluscan researchers and archaeologists from coastal universities collaborate, this project would not be as daunting as it may seem. Although there are certainly issues that need to be addressed, the cost effectiveness and ease of this method for determining season of capture indicate that it should not be abandoned.



CHAPTER 10
ESTIMATING THE SEASON OF HARVEST OF THE EASTERN OYSTER (*CRASSOSTREA VIRGINICA*) FROM ST. CATHERINES SHELL RING

Nicole R. Cannarozzi

Determining seasonal of use of the animals on St. Catherines Island is an important step toward understanding settlement and subsistence strategies through time. White-tailed deer, sharks, catfishes, hard clams (*Mercenaria* spp.), and impressed odostomes (*Boonea impressa*) have been used as proxies for seasonal procurement of resources on St. Catherines Island (Thomas, 2008: 877). Evidence from one or more of these animals for year-round use of resources, if not residence, is present for all cultural periods on St. Catherines Island. However, evidence for seasonal resource procurement when the St. Catherines Shell Ring was occupied is very rare for the St. Simons cultural period (3000 B.C.–1000 B.C.) (Thomas, 2008: 1001).

One of the primary ways in which the question of seasonal settlement of coastal sites has been addressed is through the measurement of annual growth increments of bivalve species such as the hard clam and, less frequently, the eastern oyster (*Crassostrea virginica)* (Claassen, 1986; Quitmyer, Hale, and Jones, 1985; Quitmyer, Jones, and Arnold, 1997; Quitmyer, Jones, and Andrus, 2005). Oysters are often the most numerous component in southeastern coastal shell middens, but have not been considered reliable proxies for seasonality because morphological features have not been found to correlate with seasons. Additionally, difficulties are encountered in interpreting the isotopic record of estuarine organisms due to mixing of freshwater and ocean water with varying salinities and oxygen isotopic signatures. Season of death studies using visual analysis of shell growth structures have been successful on subtidal and archaeological oysters in the Chesapeake Bay region where studies have shown that these oysters deposit identifiable winter growth breaks (Custer and Doms, 1990; Kent, 1992; Herbert and Steponaitis, 1998; Kirby, Soniat, and Spero, 1998). Techniques that measure growth structures are unsuitable for use on intertidal oyster populations in the Southeast because of the sensitivity of this species to extreme changes in the environment (Russo, 1991). Changes in water temperature and salinity, storm events, and even spawning may cause deposition of multiple growth breaks throughout the year (Kent, 1992; Shumway, 1996; Andrus and Crowe, 2000; McLusky and Elliott, 2004). Previous studies of oyster seasonality in the Southeast used shell length measurements of the impressed odostome, a predatory gastropod found among oyster reefs of the Gulf and Atlantic coasts (Russo, 1991; Fradkin, 2008). This demographic approach (size at season) measures shell lengths as estimates of oyster season of death. Recent studies on oysters in the Southeast have yielded positive results using stable isotope geochemistry (Kirby, 1998; Andrus and Crowe, 2000; Surge, Lohmann and Dettman, 2001). However, morphological seasonal indicators have not been consistently correlated with isotopic profiles in oysters (Andrus and Crowe, 2000; Surge, Lohmann and Dettman, 2001).

Environmental changes are recorded as changes in shell chemistry, shell microstructure, and physical morphology (Rhoads and Lutz, 1980). Certain criteria are required for both visual (structural) and isotopic analyses of modern and archaeological shells. The primary concerns are clear, visual delineation of growth increments, age of the animal, precipitation of $CaCO_3$ in isotopic equilibrium with water, minimal diagenetic effects, and growth throughout the annual temperature range (Shackleton, 1973; Killingley and Berger, 1979; Claassen, 1993).

The primary goal of this research is to determine whether intertidal oysters off the Georgia coast can be used as reliable proxies for estimating season of death in archaeological specimens on St. Catherines Island. Methods used include direct and indirect season of death estimations. Geochemical analysis of carbon and oxygen isotopes from modern and archaeological samples is used as a direct measure of oyster season of death. Shell length measurements of impressed odostomes from modern and archaeological contexts are indirect and are compared to geochemical data. Results on season of capture estimates using odostome shell length are also compared to results obtained by Russo (1991) for modern and archaeological sites. Morphometric analysis of oyster shell shape was applied to modern, historic, and archaeological shells to determine types of habitats from which Archaic oysters were collected (Kent, 1992).

OYSTER SEASONALITY STUDIES: A REVIEW

Oysters deposit carbonate in concentric rings along their shell margin. The oxygen isotopic composition of skeletal carbonate is primarily influenced by the isotopic composition of the water which is constrained by freshwater input and temperature. Shell carbon is influenced by dissolved inorganic carbon in the source water and metabolic processes (McConaughey and Gillikin, 2008). Therefore, carbonate samples taken from the dorsal to ventral margins of the umbo provide a record of environmental conditions and growth of that organism. Isotope sclerochronology has been extensively used to interpret past environmental conditions for many molluscs (Jones and Quitmyer, 1986; Quitmyer and Jones 2005, see also Andrus, chap. 6, this volume). Determination of season of death for oysters, however, has proved to be a more formidable endeavor. While clams exhibit a clear record of growth in the form of distinct light and dark bands, oysters do not. Oysters are composed primarily of calcite with layers of aragonite occurring on the hinge in the area of ligament attachment and also in the adductor muscle scar (Stenzel, 1694). In cross section, calcitic foliated shell microstructure is interrupted by irregularly sized, chalky shell islands, which have been described as light and dark bands, respectively (see fig. 10.2) (Andrus and Crowe, 2000, Carriker, 1996). However, these bands have not been correlated consistently to environmental causes such as temperature. Stable isotope geochemistry is currently the best method to understand and correlate growth band formation to environmental factors. This section reviews various methods applied in oyster seasonality studies.

Visual Methods

In his seminal work on subtidal oysters from the Chesapeake Bay in Maryland, Kent (1992) uses a method of analysis in which acetate peels magnify growth structures so that winter growth breaks can be distinguished from other breaks on the hinge area (Kennish, 1980). This produces an index that represents a measure of growth since the last growth break or winter season and can be used to retrodict season of death. Custer and Doms (1990) used this method on a modern control population in the Chesapeake Bay area and archaeological specimens in Delmarva Spring. Measurement of the most recent growth is divided by an average of growth over three or more previous years. Herbert and Steponaitis (1998) also used the acetate peel method for modern collections in Maryland and Early and Late Woodland archaeological assemblages with success. Most oyster seasonality studies on modern and archaeological samples in the United States have followed this method. The growth index is the most widely used method but has not been applied to oysters in the southeastern United States. It has been suggested that the growth index method may not be applicable to oysters in the Southeast because the fast growth observed in warmer waters allows oysters to reach edible size at younger ages (Shumway, 1996). Use of the growth index method requires three to five years of growth and oyster populations in the Southeast may reach edible size within two years. Southeastern oysters may even deposit breaks multiple times within a year during all seasons associated with extremes of heat and cold while exposed at low tide (Russo, 1991). The timing of increment formation varies by species and latitude. Kent (1992) notes that the interpretation of growth increments for southern oysters would be reversed—that distinctive breaks would be associated with heat stress. This phenomenon has been reported for hard clams and oysters in the Southeast (Jones and Quitmyer, 1996; Surge, Lohmann, and Goodfriend, 2003). Modern and archaeological oysters from Nueces Bay, on the central Texas coast, do not exhibit this reverse patterning, however. In Nueces Bay, oysters tend to form distinctive winter growth breaks due to water temperatures that average 8° C lower than the Florida Gulf coast (Cox, 1994). Cox (1994) posits that cooler water temperatures produce distinctive winter growth breaks and that this difference in average winter water temperatures may explain the lack of winter growth breaks in southern oyster populations.

Intertidal organisms are adapted to the conditions characteristic of their environments. Oysters are poikilothermic, euryhaline, and ecomorphic and thus able to tolerate variable extremes of temperature and salinity. Their variable morphology and wide geographical range make them highly adaptable to various environments (Van Sickle et al., 1976). It has been suggested that the rate of temperature change is more important for metabolic activities than is the level of temperature (Shumway, 1996). There are few studies on the effects of temperature and salinity on respiration but it has been reported that oyster tissues respond differently to stressors and environmental conditions (McConnaughey and Gillikin, 2008). It is reported that respiration for all tissues increases with warmer temperatures, and decreases with cooler temperatures (Shumway, 1996). However, gill function, the primary organ of respiration, is optimum at 25°–26° C (77–79° F) and stops completely at 5°–7° C (41°–45° F) (Galstoff, 1964; Eble and Scro, 1996). Intertidal oysters in the Southeast may record heat stress while exposed during low tides (Russo, 1991). Oysters are facultative anaerobes capable of closing their valves and reducing O_2 consumption to zero if necessary (Hammen, 1969). During the period of time that oysters are exposed at low tide, they may not respire but conserve O_2 until immersed again. If these events are recorded in oyster valves, it would be reflected in daily or subdaily tidal growth structures.

Geochemical Methods

Because of the problems associated with visual analysis, methods of determining season of death in southeastern oysters have relied on measurements of organisms associated with oyster populations, like impressed odostomes or stable isotope analysis of oyster shell carbonate. Kirby, Soniat, and Spero (1998) applied stable isotope geochemistry to modern and Pleistocene-aged oysters to reconstruct past estuarine conditions. Using modern oysters from the Mississippi Delta as a proxy for Pleistocene oysters from Chesapeake, Virginia, the authors found that oysters exhibit a seasonal record of water temperature. Additionally, they could establish that external growth structures on the hinge correlated with seasonal temperature changes. This work established some important baselines:

(1) Oysters precipitate shell in isotopic equilibrium with respect to the ambient environment.

(2) Growth increments are formed annually and reflect changes in seasonal water temperature.

(3) For this population, fast growth occurs during the spring/summer months, whereas growth is slowed during winter months.

Andrus and Crowe (2000) established similar baselines for intertidal oysters on Little Egg Island, Georgia. Sampling methods differed from those of Kirby and colleagues because southeastern intertidal oysters do not exhibit similar morphology in the hinge plate as those from the Mississippi Delta. Using laser ablation technology, Andrus and Crowe analyzed carbonate samples from alternating light and dark bands visible in cross section. They found that light bands were formed during warm months and dark bands during cool months. They noted that the primary factor affecting the oxygen isotope composition of oyster shell is temperature.

Surge, Lohmann, and Dettman (2001) studied intertidal oysters from the Blackwater River near Naples, Florida, to establish chemical controls on oyster shell chemistry. They established that all areas of the hinge are suitable for isotopic sampling, including chalky layers, as there was no statistical difference in the carbon or oxygen values. They reported that in these oysters, the chalky layers provide a larger sampling surface. Like Kirby, they found that shells precipitated in isotopic equilibrium with water; however, morphological features did not correlate with season. Also, in Naples samples, oysters exhibit fast growth in the winter, and slow growth during late summer and fall, though Surge, Lohmann, and Dettman (2001) did not confidently attribute the cause of growth cessation to temperature, as this is also the time that spawning occurs. They also found that temperature is more important than salinity in determining the oxygen isotope composition of oyster shell. These differences in methods and results outlined above reinforce the need to acquire historical baseline data of the environment. It is most desirable that historical data are collected as close as possible to the area of study due to regional variability in shell formation in these animals.

Seasonality Determination Using Impressed Odostomes

The impressed odostome is a small predatory gastropod common in oyster beds in the Atlantic and Gulf coasts of the United States (White and Wilson, 1996: 571). These animals attach to the soft tissues of adult and juvenile oysters and feed on body fluids. While these animals may parasitize a number of species, oysters are the primary host species (Powell et al., 1987). Impressed odostomes are reported to have a life span of approximately one year and research conducted over a wide geographical range agrees that spawning occurs continuously with peak reproduction and recruitment in late spring and early summer (Wells, 1959; White, Powell, and Kitting 1984; White, Kitting, and Powell, 1985; Russo, 1991). This initial cohort makes up the majority of the odostome population and members of the cohort increase in size throughout the year until death in spring of the following year. This expected growth pattern will be reflected in measurements of shell length through the year. The short life span, predictable growth rate, and close association with oyster populations make impressed odostomes a suitable proxy for the seasonality of oyster collection. Methods following Russo's (1991) seminal work on this species are applied to odostomes on St. Catherines Island. Keene (chap. 9, this volume) highlights important points to consider when using this technique. These are primarily related to establishing a sound understanding of growth, reproduction, and behavior of odostomes throughout their geographical range. In addition, the applicability of this method outside of northern Florida is called into question due to problems that arise when Russo's data are applied to populations outside of this region (Keene, chap. 9, this volume). This study attempts to resolve some of these uncertainties by applying modern proxy data collected on St. Catherines to archaeological odostome shells from St. Catherines Shell Ring.

OYSTER HABITAT ON ST. CATHERINES ISLAND

Oysters are located in inland and estuarine salt marshes on both the mainland and coastal sides of St. Catherines Island. These environments differ in that the tidal fluctuations in the estuarine salt marsh average greater than 2 m and occur two times a day (Thomas, 2008: 255–256). The marshes on the mainland side of the island are classified as high marsh (flooded twice monthly by spring tides) and low marsh (flooded twice daily by high tides). In addition, there are interior marshes that experience high tides twice daily but lack freshwater input other than local precipitation (Andrus and Crowe, 2008: 503). Oysters were collected for this study from an interior marsh. The status of St. Catherines Island as a conservation and research island means that no appreciable human pressure has been placed on these animals. As a result, they are generally longer lived than those in regularly harvested shellfisheries. This is an advantage when seeking seasonal patterns over multiple years of growth.

METHODS

Stable Isotope Analysis

Approximately 30 modern oysters were hand collected at low tide from Cemetery Road Marsh during the middle of each month from July 2006 to July 2008 to establish a modern analog for comparison. Cemetery Road Marsh is an inland marsh located on the Atlantic side of St. Catherines (fig. 10.1). Specimens were immediately frozen and subsequently transported to the Florida Museum of Natural History for processing and storage. They were hand cleaned with a brush and water and separated into singles from clusters when necessary. Soft tissue was removed manually and shells were dried in a desiccator. Measurements of water temperature and salinity were recorded and water samples taken at the collection site at the time of oyster collection. Salinity levels were measured using a refractometer and temperature was recorded using a digital thermometer. Two well-preserved archaeological specimens were selected from column samples excavated from St. Catherines Shell Ring. Specimens chosen were complete and free of evidence of fouling organisms and predation.

Prior to sampling for isotopic analysis, the left valve of each specimen was radially cross sectioned and mounted on glass slides with JB KWIK Weld and fixed to the sample stage of a Merchantek EO Micromill at the Florida Museum of Natural History stable isotope laboratory. Carbonate samples were drilled in ontogenetic (oldest to youngest) sequence from the calcitic, foliated layers of the bisected surface of the umbo only. Chalky layers were avoided because of the

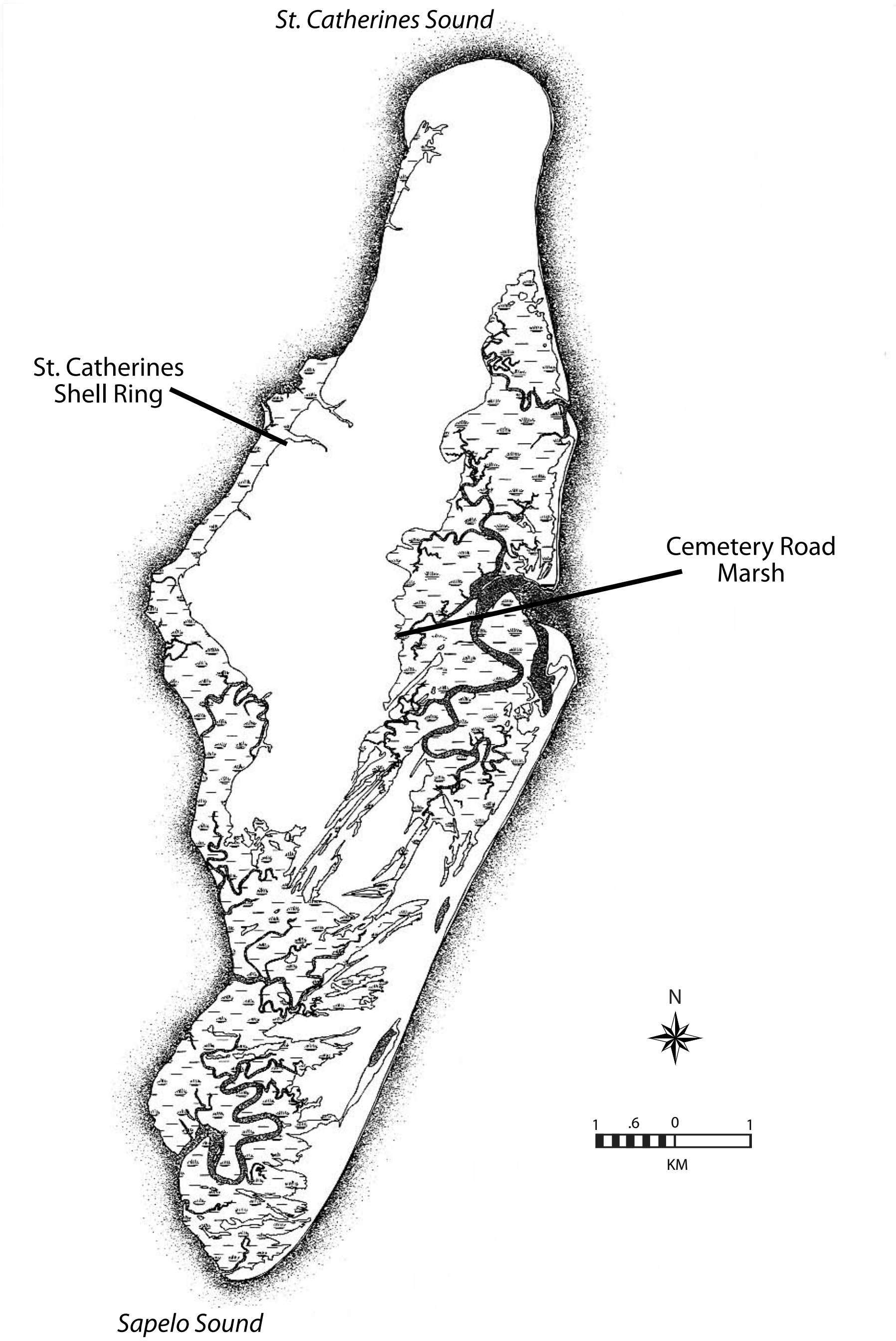


Fig. 10.1. Map showing location of the St. Catherines Shell Ring and oyster collection site (adapted from Thomas 2008).

irregularity in size and difficulty of microsampling these areas. Each drill hole measured approximately 50 μm in depth and the holes were 1 mm apart (fig. 10.2). The isotopic analyses were conducted in the light stable isotope mass spectrometry laboratory, Department of Geological Sciences, University of Florida. All samples were analyzed according to standard techniques (Jones and Quitmyer, 1996). All values are reported in standard notation where:

$\delta^{18}O = [(^{18}O/^{16}O)_{sample}/(^{18}O/^{16}O)_{standard}{}^{-1}] \times 10^3$ per mil (‰).

The temperature of the water in which the shell carbonate formed was calculated using the paleotemperature equation of Craig (1965) for the temperature-dependent fractionation of calcite in molluscs relative to seawater:

$T(°C) = 16.9 - 4.2\ (\text{shell}\ \delta^{18}O_{calcite} - \delta_{wSMOW}) + 0.13*(\delta^{18}O_{calcite} - \delta_{water})^2$.

Historical temperature data for the two-year collecting period (July 2006–July 2008) were obtained from the National Data Buoy Center station, 41008, located off the coast of Savannah (http://www.ndbc.noaa.gov/station_page.php?station=41008). Temperature measurements taken at the time of collection are not used because of consistent thermometer malfunction which did not allow for accurate temperature readings for some months.

Morphometric Analysis of Shell Shape

Oyster habitat can give insight into interpretations of the carbon isotopic signatures. Oyster shell shape is heavily influenced by the habitat in which it grows. The substrate, density of the oyster bed, the type and number of epibionts, as well as turbidity, salinity, and water depth all influence shell shape (Kent, 1992). The mor-

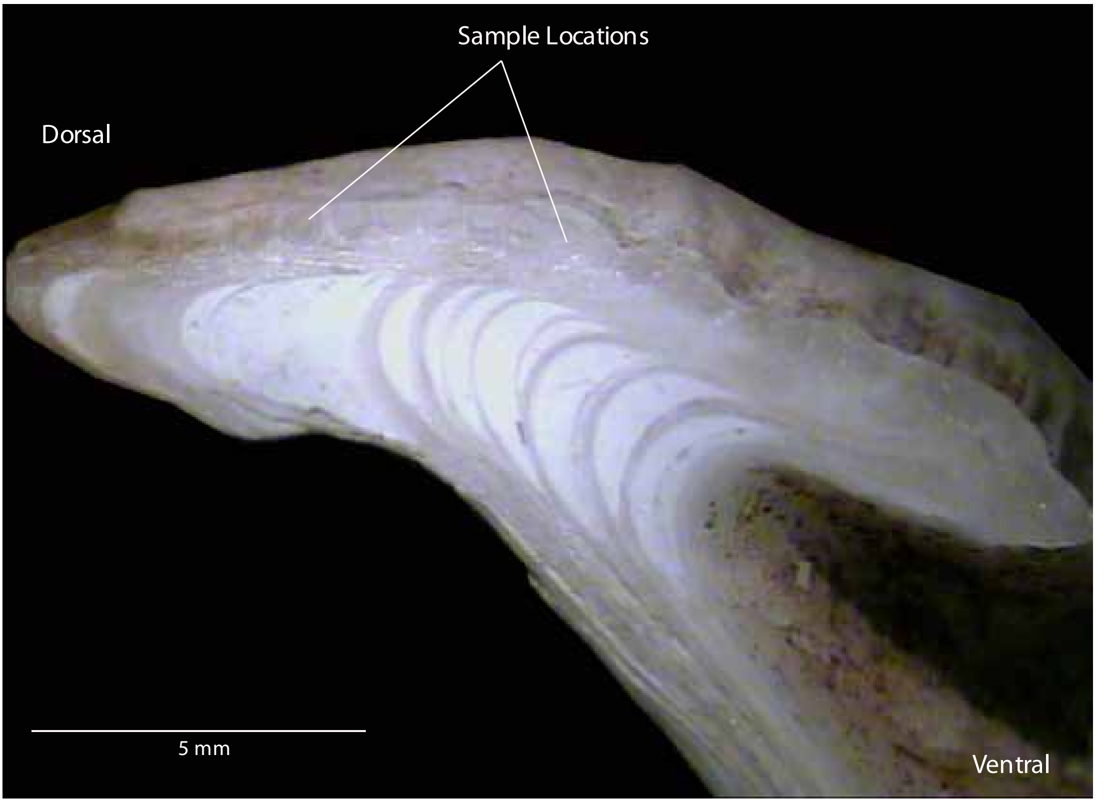


Fig. 10.2. Radial cross section of oyster showing sampling locations.

phometric analysis of oyster shells outlined by Kent (1992) provides a method with which to correlate oyster shell shape to habitat. Calculation of the height-length ratio (HLR) of the left valve is the simplest way to interpret habitat. The HLR is the height of the valve divided by the length (fig. 10.3). Mean HLR values of a sample population provide an accurate estimate of the habitat in which oysters grew. Measurements of oysters from modern, historical, and archaeological sites from the island were measured to determine habitat differences through time. Modern oysters measured were collected from Cemetery Road Marsh ($N = 30$) and Kings New Ground Marsh ($N = 30$). Oysters from Hokes Dock ($N = 28$) are remnants of an early 20th-century oyster boiler. Oysters ($N = 481$) from St. Catherines Shell Ring were obtained from column samples excavated by the author, during the 2007 field season, from excavation units W82S3 and 789N801E. Meeting House Field (9Li21) is an archaeological site that dates to the Irene cultural period ($N = 71$).

Shell Length Measurements Using *Boonea impressa*

Oyster clumps collected monthly from July 2006 to July 2008 (25 months) from the Cemetery Road Marsh site for stable isotope analysis were cleaned in buckets of water and sieved through 1.168 mm geological screens and dried. Archaeological specimens were obtained from the 1⁄16 in. portion of column samples excavated from two units (W83S2 and 789N801E) from St. Catherines Shell Ring. The shell length is described as the measurement from the tip of the apex to the abapical end (fig. 10.4). Shell length measurements were obtained using electronic calipers attached to a desktop computer (see Jones, Quitmyer, and DePratter, chap. 8, this volume). Following Russo (1991), data are presented as a seasonal frequency distribution of length size classes. For purposes of comparison with Russo's data, his six-season division has been applied to modern data from St. Catherines (table 10.1).

RESULTS

Stable Isotope Geochemistry

Figure 10.5 (A–D) shows the $\delta^{18}O$ and $\delta^{13}C$ values of the two modern and two archaeological shells. Each exhibits a cyclical pattern of shell formation. Low oxygen isotope values indicate warmer temperatures while high values indicate cooler temperatures. All samples were adequate for analysis with the exception of sample 11 in specimen arch-1, which was too small. The $\delta^{18}O$ profile from archaeological specimen arch-1 ($N = 27$) shows a semisinusoidal pattern of five complete cycles with values ranging from –1.35 to 1‰. Similarly, the $\delta^{18}O$ profile from archaeological specimen arch-2 ($N = 22$) shows five complete cycles with values between –1.87 and 1.30‰. Modern oyster CRM-July ($N = 26$) shows four complete cycles with $\delta^{18}O$ values between –1.97 and 1.24‰ and CRM-February ($N = 16$) shows two complete cycles with $\delta^{18}O$ values between –1.18 and 1.38‰.

The calculated temperature for modern oysters correlates well with the water temperature recorded by the buoy at the time of collection

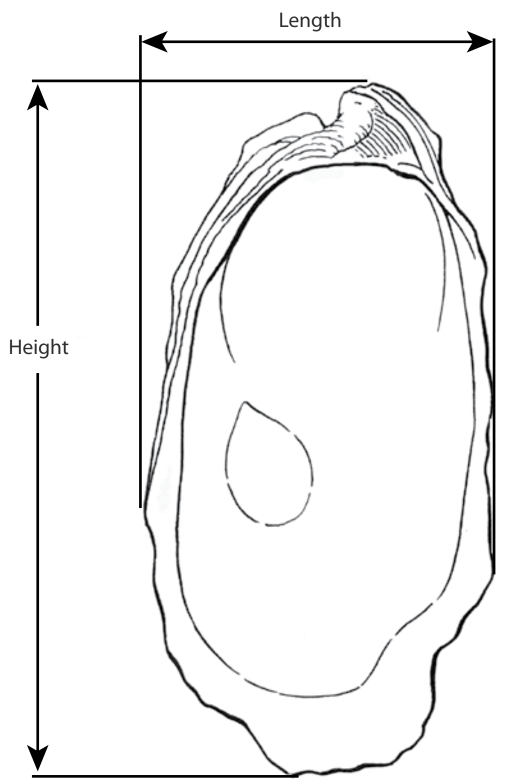


Fig. 10.3. Left oyster valve height and length measurements for HLR calculation.

with a difference of 4.85° C. Based on a comparison of modern sea surface temperatures with paleotemperatures, both archaeological samples were collected during warm months of the year. Arch-1 was collected during the spring, while arch-2 was collected during the late summer/early autumn (fig. 10.6). All oysters show a pattern of fast growth during the warm months and

Fig. 10.4. Impressed odostome shell length measurement.

TABLE 10.1
Seasonal Divisions and Sample Sizes for Modern and Archaeological Impressed Odostomes

Season	Months	Sample Size
Spring	May, June	73
Summer	July, August	20
Fall	September, October	1147
Late Fall	October, November	456
Winter	November, December, January	726
Late Winter	February, March, April	309
Excavation Unit	W83S2	196
	789N801E	132

slowed growth during cool months.

The carbon profiles of the modern and archaeological specimens are markedly different. The carbon profiles in the archaeological specimens track closely with oxygen. Values range from –1.44 to 0.51‰ in arch-1 and –2.03 to 0.60‰ in arch-2, an approximate variation of 2‰. No such pattern exists in the modern specimens where values range from –0.95 to 0.23‰ in CRM 2006 and –1.89 to 2.51‰ in CRM 2007, an approximate variation of 1‰.

Salinity measurements are consistent with a highly saline environment with the exception of two points in September 2007 and January 2008 that are lower than expected (fig. 10.7). All specimens appear to accurately record ambient temperatures throughout the growth period.

Morphometric Analysis of Oyster Shell Shape

The mean and 95% confidence interval of the HLR of oysters from the modern and archaeological sites were calculated for comparison (fig. 10.8). The 95% confidence interval on the mean HLR shows that the difference between modern, historic, and archaeological oysters is statistically significant. Based on HLR measurements, modern collected oysters are classified as channel/reef oysters. As summarized by Kent (1992), these oysters are densely clustered and elongated with an HLR greater than 2.0. They occur in deep channels and are frequently intertidal. This is confirmed by the habitat from which modern oysters were collected. The Cemetery Road Marsh collecting site is intertidal, with oysters densely clustered in soft mud. There was little difference (HLR = 0.01) between the HLR of the oysters in the units 789N801E and W83S2 from St. Catherines Shell Ring, thus the HLR was averaged. Based on the mean HLR, archaeological oyster samples are classified as bed oysters. Bed oysters have an HLR between 1.3 and 2.0 and occur in muddy sand in loose clusters or singly (Kent, 1992).

Shell Length Measurements of Impressed Odostomes

Measurements of modern impressed odostomes from St. Catherines Island follow a growth pattern of increasing shell length from the summer to spring months (fig. 10.9). Peaks in frequency of each size class represent the growth of the initial cohort through time. All size classes are represented in the archaeological samples, therefore all seasons are represented. However, approximately 30% of individuals from unit W83S2 and 27% of individuals from 789N801E correspond to winter/late winter/spring collections. When compared to Russo's data from Florida, on an annual scale of warm and cool months, both data sets show archaeological oysters were collected during cool months (fig. 10.10).

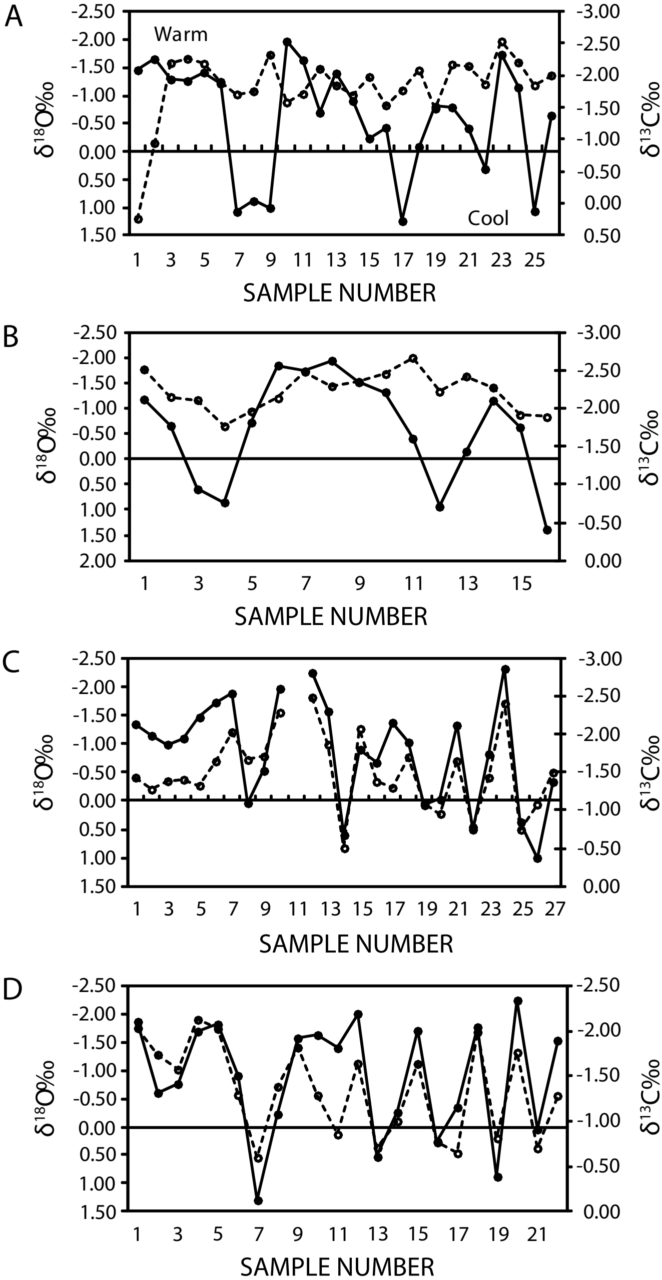


Fig. 10.5. $\delta^{18}O$ and $\delta^{13}C$ profiles across oyster specimens from earliest to most recent growth (dorsal to ventral edge of the umbo). Solid lines represent $\delta^{18}O$ values, dashed lines represent $\delta^{13}C$ values. (**A**) Modern oyster collected July 2006 from the Cemetery Road Marsh collection site. (**B**) Modern oyster collected February 2007 from the Cemetery Road Marsh collection site. (**C**) Archaeological oyster from unit WS83S2 of St. Catherines Shell Ring (arch-1). (**D**) Archaeological oyster from the St. Catherines Shell Ring unit number 789N801E (arch-2).

DISCUSSION

A record of ambient temperature can be detected chemically in the shells of modern and archaeological oysters from St. Catherines. This result is similar to that of Surge, Lohmann, and Dettman (2001) in their study of oysters from southwest Florida with the exception that seasons of fast and slow growth are reversed. Water temperature is the primary variable controlling iso-

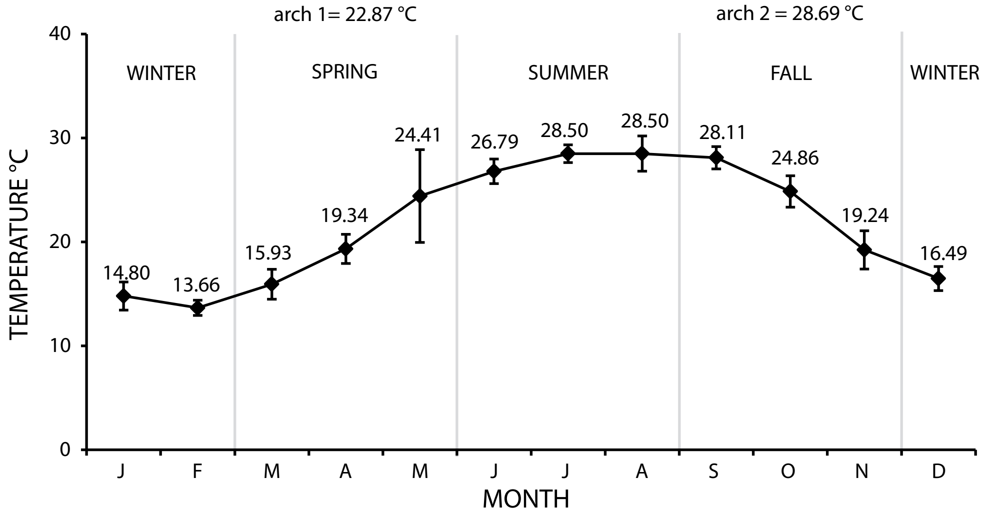


Fig. 10.6. Average monthly sea surface temperatures for the National Data Buoy Center Station, 41008 for 2006–2008.

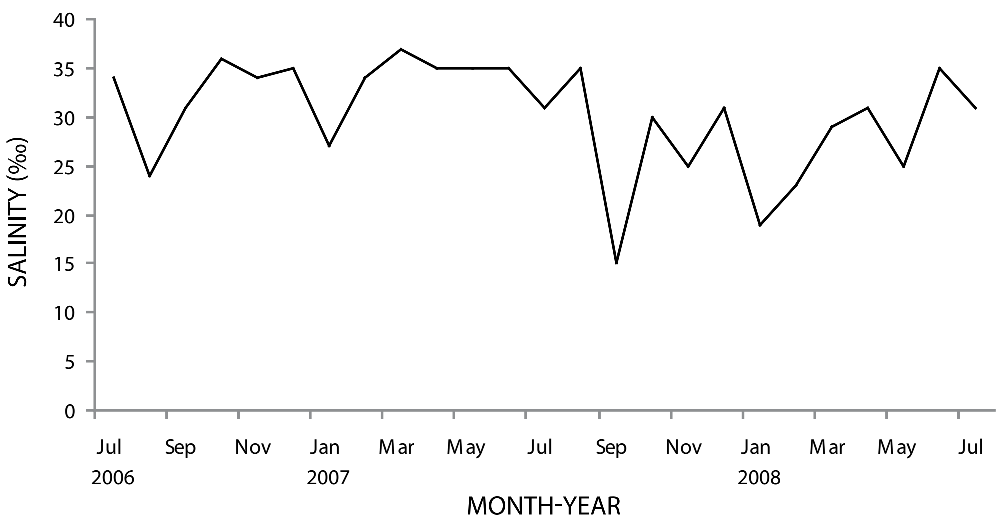


Fig. 10.7. Salinity measurements for July 2006–July 2008 from Cemetery Road Marsh collection site.

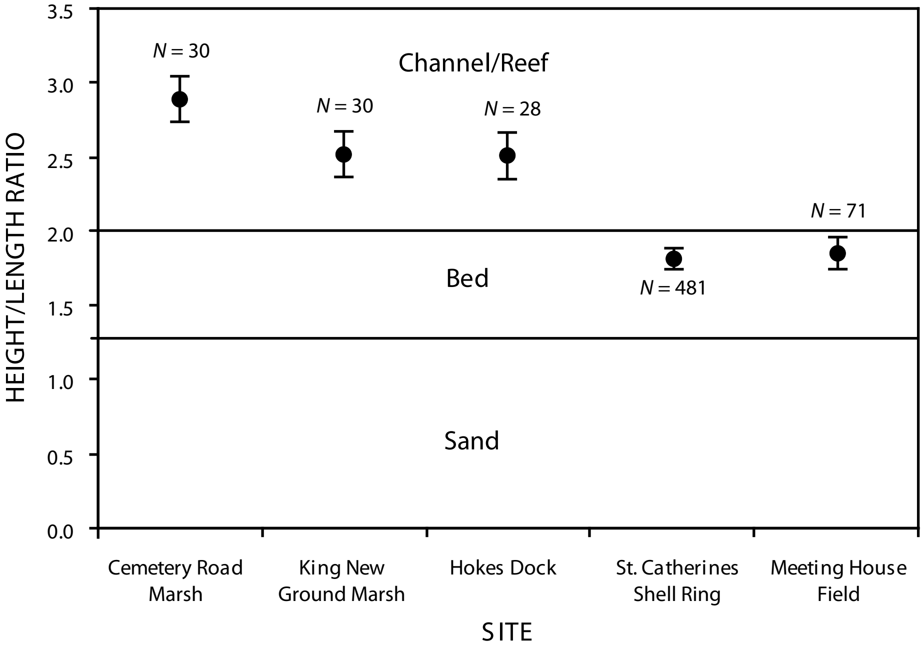


Fig. 10.8. A plot of the mean and 95% confidence interval of the shell height-to-length ratio (HLR) of oysters from modern, historic, and archaeological sites (after Kent, 1992).

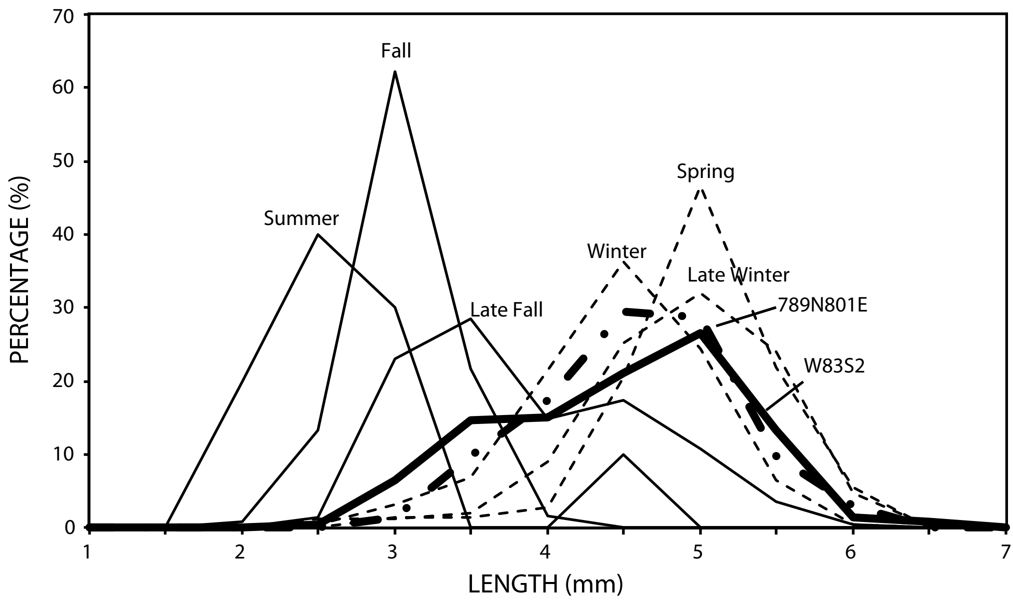


Fig. 10.9. Frequency distribution of impressed odostomes length size classes from units W83S2 and 789N801E plotted following Russo's (1991) six-season division.

topic variation in the oyster shell. The observed temperature at the time of collection is consistent with calculated temperatures and oxygen isotope variation in modern shells. The temperature range of all specimens does not exceed the range of modern monthly water temperature averages, which suggests that modern seasonal temperature ranges are similar to those during the Archaic occupation of St. Catherines Shell Ring.

Salinity is an important factor affecting oyster growth, particularly in estuarine environments where salinity can fluctuate rapidly and severely. Of particular concern in estuarine environments is lowered salinity which results in a decrease in

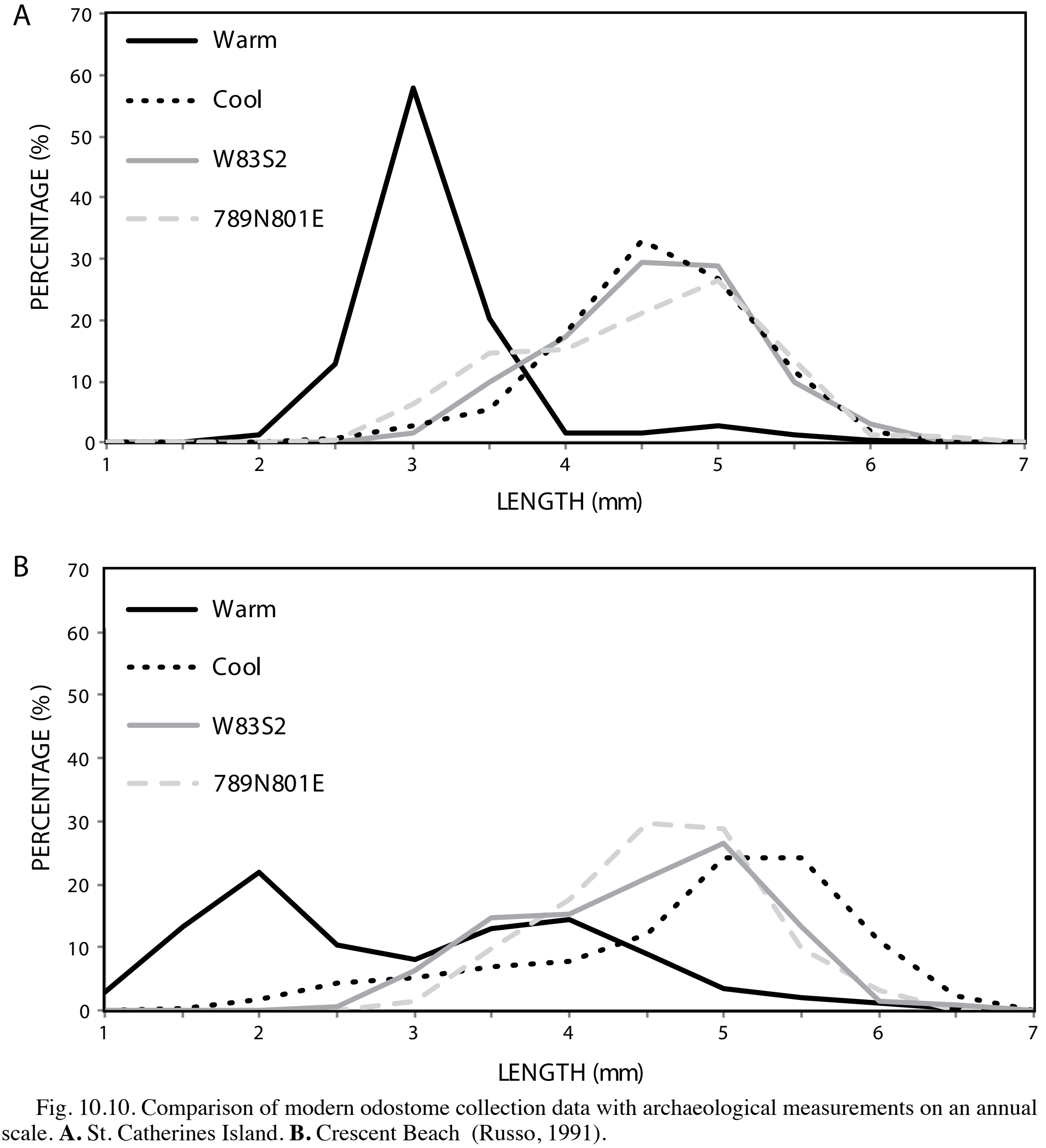


Fig. 10.10. Comparison of modern odostome collection data with archaeological measurements on an annual scale. **A.** St. Catherines Island. **B.** Crescent Beach (Russo, 1991).

the carbon and oxygen isotope ratios, producing a false temperature reading (Mook and Vogel, 1968). Decreased salinity occurs with the introduction of freshwater by rivers, streams, and precipitation in the estuary. Oysters are adapted to a wide range of salinities. Optimal salinity ranges exist though these vary geographically (Van Sickle et al., 1976; McLusky and Elliott, 2004). Lowered salinity in the estuary can invoke a number of physical and physiological responses in different classes of organisms, but for bivalves, particularly sessile ones like oysters, the response is typically to seal themselves within their shell. The ability of oysters to tightly close their shells allows the organism to protect itself from adverse environmental conditions, provided these are temporary (Galstoff, 1964). Upon closing the valves, an oyster can reduce its oxygen consumption until oxygen becomes available again (Hammen, 1969). It is possible that during times of stress such as salinity or temperature extremes, or when exposed to air, oysters respire anaerobically. These events are not likely to be recorded in the microstructure of the shell and therefore would have no bearing on isotopic composition (Schöne, 2008; Lutz and Rhoads, 1977). Andrus and Crowe (2000) suggest that variation in salinity could produce oxygen isotopic variation similar to what is produced by temperature but salinity would have to be seasonally variable. Salinity measurements from the Cemetery Road Marsh collecting site did not show seasonal variation. While oysters may record tidal cycles in their shells, the samples presented here show variation on a larger scale and fluctuations in salinity over tidal cycles are much more fine grained than what is represented in the oxygen isotope profiles for these specimens. The modern samples taken from the oyster bed on St. Catherines indicate a constant, highly saline environment with the exception of measurements made in September 2007 and January 2008. Precipitation records from Sapelo Island, located just south of St. Catherines, indicate that the island received 6.9 cm of rain over the two days prior to the September collection date and 3.4 cm of rain a day before the January collection date (climatological data for Georgia, National Climatic Data Center, 2009). The changes in salinity that occur during the tidal cycles in the estuary are not significant enough in duration or severity to account for the oxygen isotopic variation seen in the modern oyster shells.

Comparing the carbon isotope profiles reveals possible differences in water chemistry between the modern collection site and the archaeological setting. Modern signatures correlate to a stable habitat while the archaeological specimens may be from habitats that experience greater seasonal freshwater mixing. The incorporation of carbonate carbon in the mollusc shell is complicated by dual metabolic and environmental effects and, as such, has not been considered as reliable as oxygen as an environmental proxy (Grossman and Ku, 1986). Recent studies have confirmed that aquatic molluscs generally build shell carbonate from ambient dissolved inorganic carbon and, when carefully interpreted, shell carbonate can be an effective proxy for environmental conditions like salinity and magnitude of freshwater mixing (Fry, 2002; McConnaughey and Gillikin, 2008). It is possible that the carbon signatures in oysters from the shell ring reflect environments that experience greater freshwater input through streams or rivers. Modern oysters were collected from the Atlantic side of the island, which receives little freshwater input except in the form of precipitation (Andrus and Crowe, 2008). This consistently saline environment could account for the weak correlation between carbon and oxygen profiles of modern oysters. Oysters from the St. Catherines Shell Ring, located on the western side of the island, could have come from habitats closer to the ring that experience seasonal differences in freshwater input. The differences in carbon signatures between the modern and archaeological oysters cannot be interpreted without comparative water data from the western side of the island.

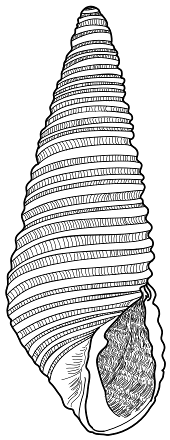
Morphometric analysis of shell shape indicates that modern and archaeological oysters lived in different habitats. The difference in shell morphology between the modern and archaeological oysters is supported by the carbon data that may also indicate different habitats. Differences in shell shape may reflect changes in island habitats due to anthropogenic effects. It may not be that Archaic peoples collected oysters from different habitats on the island, but that habitats on St. Catherines have changed through time. Rollins and Thomas (2011: 324–325) suggest that environmental degradation and disease have likely affected the oyster populations on and around St. Catherines but the authors note problems with interpretation of shell size changes in archaeological contexts. Future studies will couple morphometric analysis with additional habitat indicators such as type and frequency of oyster shell predation markers by boring sponges and other organisms.

Shell length measurements of the impressed odostomes indicate cool season collections for archaeological oysters. The combination of geochemical data and odostome measurements indicate year-round oyster collection for the St. Catherines Shell Ring. In comparison to Russo's data from Florida, the seasonal growth patterns of odostomes from St. Catherines are different, but both populations exhibit a trend of increasing size throughout the year. Additionally, modern winter collections in both data sets are represented by short, broad distributions. Russo explains that this is due to the secondary cohort that widens the size range of the most numerous size classes as the initial cohort dies off. This accounts for the absence of a single peak in the cool season sample. The increase in shell length from summer to spring for the 25-month period supports the hypothesis that a predictable pattern of annual growth exists for odostomes on St. Catherines Island. This hypothesis is challenged by Keene (chap. 9, this volume), who cites the need to better constrain key life history parameters such as variation in shell morphology, growth rate, reproduction, and behavior. While this is certainly true, collecting modern proxy data from environments closest to the archaeological site is essential for gathering such data. Variation in shell morphology, growth rate, and reproductive behavior are expected across geographic ranges and through time. Intraspecific shell shape plasticity associated with environmentally mediated growth patterns is common and documented for many molluscs (Kemp and Bertness, 1983, Martin-Mora et al., 1995; Zieritz, 2010; Marquez and van der Molen, 2011). Furthermore, growth patterns in species occupying the same locality can change over short periods of time (Henry and Cerrato, 2007). Proxy data collected over at least a full year, during all months of the year, are needed to assess growth patterns. Two or more years of collection will capture variation that occurs within a population over time. Once a local pattern of growth has been established, suitability of the proxy can be determined. However, frequent validation of known life history parameters over time and space is necessary if we are to confidently apply proxy species data to past animal populations (Jones, Quitmyer, and Andrus, 2004, Jones, Quitmyer, and DePratter, chap. 8, this volume). Shell length measurements of impressed odostomes from St. Catherines are suitable for determining archaeological season of oyster collection, provided appropriate proxy data are carefully applied.

CONCLUSIONS

Modern and archaeological oysters were evaluated as proxies for environmental conditions and season of oyster harvest on the Georgia coast using direct and indirect methods of season of death estimation. Geochemical records indicate that temperature is the primary variable influencing oxygen isotopic variation in the oyster shell. Although variations in $\delta^{18}O$ are consistent with variations in water temperature, more localized historical water chemistry data are needed to estimate seasonal temperature ranges and the range of variation that may occur within individual oysters and oyster beds. Future studies will be based on larger sample sizes and localized historical water temperatures for specimens currently being collected from St. Catherines Island. Analysis of modern oyster samples from the western side of the island, closer to the location of St. Catherines Shell Ring, are needed and may contribute to a better understanding of the carbon signatures. Morphological data show that different habitats were exploited and/or that oyster habitats on St. Catherines have changed considerably over time. Measurements of impressed odostomes indicate year-round collection, with the greatest number of individuals collected in spring. Measurements of this species remain the simplest and most cost-effective method for determining season of oyster collection.

It is possible to estimate the season of death of oysters from archaeological sites with appropriate proxy data. Currently, general estimates of seasonal use of oysters at the St. Catherines Shell Ring cannot be made due to the small sample size of oysters studied, however, future analysis of modern and archaeological specimens from the island will contribute to a better understanding of the role of oysters in the Archaic subsistence economy. Although geochemical methods remain the most effective for determining season of death of oysters, future work should focus on understanding the timing of visible growth structures on the interior umbo and correlating growth structures to geochemical signatures.



CHAPTER 11
WHAT CAN PLANTS AND PLANT DATA TELL US ABOUT SEASONALITY?

C. Margaret Scarry and Kandace D. Hollenbach

Contradictory descriptions by 16th- and 17th-century Jesuit and Franciscan missionaries, combined with comparatively sparse archaeological investigations, have led to ongoing debates among historians and archaeologists about the degree to which the Guale and their predecessors were seasonally mobile (Thomas, 2008). Were the Guale and other Native American communities living along the Georgia Bight mobile foragers, who visited the coast as part of their seasonal round? Or, were they sedentary central-base foragers—and in later times forager-farmers, who spent much, if not all, of the year on the coast or barrier islands? The American Museum of Natural History's program of systematic excavations and ecological studies, directed by David Hurst Thomas, on St. Catherines Island, has produced a corpus of data that we can bring to bear on questions relating to the Guale and their ancestors (Thomas, 2008; Reitz et al., 2010). But to understand fully the seasonal activities and mobility patterns of the island's residents, we need fine-grained data about the plants they collected or cultivated and consumed. Unfortunately, we lack systematic analyses of archaeobotanical data from St. Catherines Island (Thomas, 2008: 978) and there are relatively few detailed analyses from elsewhere along the coast to help fill in the picture. Nonetheless, it is possible to draw on patterns of plant use from the lower Southeast and the broader Georgia Bight to offer some thoughts about how plant data can contribute to understanding seasonal resource use and mobility patterns on St. Catherines Island and elsewhere along the coast.

USING PLANTS IN ANALYSES OF SEASONAL RESOURCE USE AND MOBILITY

Plants have predictable cycles of flowering and fruiting and generally grow in relatively distinct habitats. Thus, plants seem obvious sources of evidence about seasonality and mobility. We can certainly construct charts showing when plants identified in archaeological assemblages were ready for harvest and where gatherers could find those plants. However, inferring seasonal use or mobility patterns from such charts is far from straightforward. Some plant resources must be harvested as soon as they ripen, while others persist into later seasons and may be gathered when time allows. More problematic, most plant foods can be stored for later use. Some remains found in archaeological sites probably derive from plants deposited shortly after they ripened, but other remains may derive from plants processed or consumed long after they were harvested. Thus, ripening dates and habitat preferences by themselves are insufficient to explain people's seasonal uses of plants or how these relate to settlement and mobility patterns.

Optimal Foraging Models

A more promising approach is to consider the full range of decisions and activities people undertake as they obtain, process, and consume plants and animals. Gatherers do not simply embark on forays to collect whatever resources they happen upon during their day's walk. Instead they consider which plant foods are ready for harvest or which animal resources are prime for collecting, which patches would be best to visit first, which individuals should join a particular foraging party, and whose efforts might best be spent at camp processing plant and animal foods gathered previously. If we take into account the seasonal and spatial restrictions of plant resources as well as the practices and decisions involved in monitoring, cultivating, harvesting, collecting, processing, cooking, and storing plants—and animals—then we can model the seasonal activities and movements of gatherers.

Optimal foraging models are one avenue for addressing decisions and activities pertaining to resource choices. Models of optimal foraging differ in assumptions, variables, currencies, and computational formulas (Bettinger, 1991; Kaplan and Hill, 1992; Kelly, 1995). With the exception of nuts, plants tend to rank low in diet breadth models that use only calories or simplified return rates for predicting which resources should be targeted. More detailed linear programming models often include micronutrients in their consideration of resource value (Bettinger, 1991: 116–118; Kelly, 1995: 74–78). Models that incorporate micronutrients highlight the importance of fruits and greens because of the vitamins and minerals they contain, and depict relatively diverse diets, which appear to be preferred by most primates (Milton, 1993; Addessi et al., 2010).[1] Such linear programming models, however, require detailed information about nutrient composition that may not be available for many wild foods.

Plant foods fare better in optimal foraging models that separate activities of hunters, presumably men, from those of gatherers, presumably women and children (see Hawkes [1996] and Kelly [1995], for further discussions of the division of labor). These models incorporate assumptions that gatherers target foods that may deliver lower return rates but are predictable. Elston and Zeanah (2002) use this approach to construct diet breadth models for pre-Archaic hunter-gatherers in Railroad Valley, Nevada. Their results suggest that men's hunting opportunities determined residential mobility, while women's foraging opportunities determined site locations (Elston and Zeanah, 2002: 115). Closer to our area of interest, Hollenbach (2009: 69–97) applies a central-base foraging model to Late Paleoindian and Early Archaic data from Alabama. Among other things, she demonstrates that plants requiring minimal processing, such as early spring greens and summer fruits, can have high return rates when people collect them near camp but return rates decay rapidly with distance (fig. 11.1). As return rates for large game do not drop precipitously with distance, she argues that site locations and mobility patterns were organized around the seasonal and spatial availability of gathered resources.

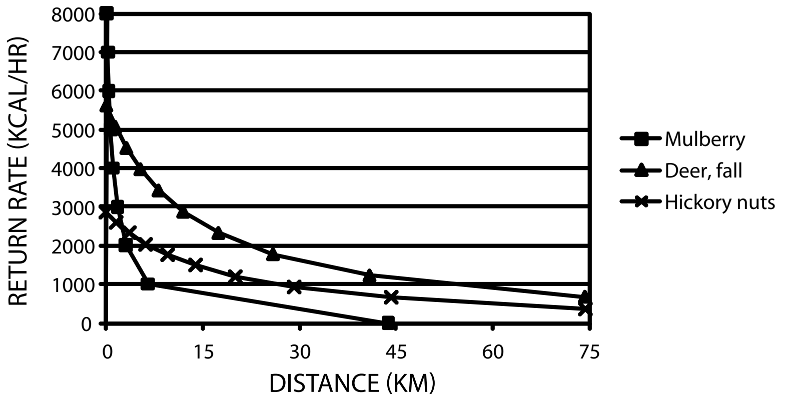


Fig. 11.1. Comparison of return rates for mulberries, hickory nuts, and deer (see Hollenbach, 2009, for full discussion).

Operational Chains

Some of the difficulty in applying optimal foraging models, or more broadly, human behavioral ecology models, stems from the problem that relatively little information about the decisions and activities associated with the use of plant resources is available or employed. One way we can remedy this is by constructing operational chains for potential foods. The study of operational chains (*chaînes opératoires*) was pioneered by Leroi-Gourhan (1964), who argued that operational sequences were deeply embedded in human behavior. Material culture, the organization of space, and subsistence strategies are the products of multiple technical choices (Leroi-Gourhan, 1993; Stark, 1998). Operational chains have been widely used to study the manufacture and use of stone tools and ceramics (e.g., Gosselain, 1998; Lemonier, 1986). A similar approach—though not always referred to as operational chains—is commonly used by archaeobotanists to study crop processing activities in Europe and Asia (Hillman, 1984; Jones, 1984; Fuller, Korisettar, and Venkatasubbaiah, 2001). While operational chains have not been used much to examine the food-related activities of Native Americans, we think they would yield important insights.

In constructing operational chains for subsistence activities, the goal is to identify the choices, activities, resources, tools, and refuse associated with each step in acquiring, processing, and consuming a particular food. Such an exercise can identify pertinent activities and decisions as well as the material signatures they would generate. It can also identify potential scheduling conflicts when decisions must be made to gather or pursue one plant or animal and forego another. Constructing operational chains for all of the food resources available to the inhabitants of St. Catherines Island through time is beyond the scope of this chapter. Here, we discuss some of the most relevant decisions and activities associated with key plant resources used by prehistoric peoples living in the Southeast. We then draw on what archaeobotanical data are available from the Georgia Bight to illustrate some of the seasonal activities and decisions associated with the use of these various plant resources. Table 11.1 sketches out activities, resources, and tools for gathering and processing hickory (*Carya* sp.) nuts, which were prominent foods for Native Americans in the Southeast. In the following paragraphs, we give a more general description of the considerations that must be addressed to construct operational chains for plants.

We first need a list of potential foods and information about their distribution, abundance, and predictability. We can assemble our list by combining species inventories from archaeological sites with ethnographic or ethnohistoric information about plant use, and knowledge about edible plants available in local fields and forests. People's use of diverse sets of seemingly low-ranking plants becomes more comprehensible when we take seasonal cycles into account and recognize that choices are based on what food resources are currently available and what can be stored for later use. Other factors, such as a predilection for a varied diet or human social considerations, also certainly affect people's food selections.

Monitoring/Cultivating: An initial step in building operational chains is to consider the level of human involvement in the growth of each plant. At the simplest level, in the course of their daily activities, gatherers monitor plants from flowering to fruiting. They make their decisions based on knowledge of what is ripe, where alternatives are located, and what will remain available in the future. Gatherers might also tend plants in various ways, including clearing underbrush, pruning, girdling or removing competing trees or plants, coppicing, or even transplanting (Shipek, 1989; Yen, 1989; Fowler, 2008). Acorn (*Quercus* sp.) and hickory mast (Gardner, 1997; Scarry, 2003) were important resources for southeastern foragers and remained important after crops were added to their repertoire. People gathering firewood, hunting, or simply passing through oak and hickory groves likely kept an eye on the impact of spring frosts, summer droughts, etc. on the flowers and developing nuts. They would know well before fall whether it was a good mast year and which trees and groves were most productive. Several researchers have suggested that people not only monitored nut groves but also managed them to enhance productivity (Munson, 1986; Gardner, 1997; Scarry, 2003).

Intensive agriculture stands at the other end of the spectrum, but cultivation of plants can be described as a continuum (Ingold, 1996; Smith, 2001). People's investment in cultivated plants may range from simply broadcasting seeds and harvesting those plants that survive through the growing season, to the much more intensive work of preparing beds, sowing seeds individually, weeding, and warding off predators. There are ethnohistoric accounts of southeastern farmers engaging in the full range of cultivation activities: from casually sowing chenopod (*Chenopodium berlandieri*) on exposed mudflats (Gilmore, 1931; Smith, 1992) to intensively preparing fields for maize (*Zea mays*) and other crops (Scarry, 2008; Swanton, 1946: 268, 274, 289, 292). The decision to sow on newly exposed ground has little impact on other plant resources. Preparation of more formal plots, however, involves choices about how to allocate time and labor as well as choices about where to locate the gardens, what plant resources will be removed and which, if any, will be allowed to remain. Descriptions of native fields (Bartram, 1928: 57) suggest that people left fruit trees such as plum (*Prunus* sp.) and persimmon (*Diospyros virginiana*) standing when they cleared the land. We speculate that they also avoided placing gardens in favored nut groves or at least left prolific trees to continue producing mast. Weeding was also likely selective; people probably tolerated and even tended plants that produced greens, medicines, or fruit (Scarry and Yarnell, 2006).

TABLE 11.1
Decisions, Activities, and Artifacts Associated with Hickory Nut Use[1]

Season	Task	Associated tools/features	Potential opportunity cost	Application to St. Catherines
Spring	Monitor spring flowering		Negligible if embedded in other activities	Likely embedded in spring forays to gather/collect/trap/fish other resources
Late summer	Monitor nut development		Negligible if embedded in other activities	Likely embedded in summer forays to gather/collect/trap/fish other resources
Early fall	Monitor timing of harvest		Negligible if embedded in other activities	Likely embedded in early fall forays to gather/collect/trap/fish other resources
Fall	Gather hickory nuts	Baskets, poles for knocking nuts from branches	Gather acorns	Hickories are interspersed among oaks on the island both nuts could be gathered simultaneously
	Decide size of work group		Collect shellfish	Can shellfish collection be delayed, or performed by others?
	Return to logistical camp or home base each night?		Hunt/trap animals that are putting on winter fat	Can hunting/trapping be delayed, or performed by others?
	Store hickory nuts	Large storage pits, baskets, bags	Other food procurement tasks	Can storage tasks be performed by a relatively small group?
	Store above or below ground?		Other maintenance tasks	
	Decide to parch first?	Baskets, pots, griddles	Minimal if hearth-dried, other food procurement tasks if parched	
	Decide near logistical or base camp?			Base camps likely within easy travel distance to tree groves
	Decide who controls stores—groups or families?			Storage pits may be located in public or private locales

TABLE 11.1 — (*Continued*)

Season	Task	Associated tools/features	Potential opportunity cost	Application to St. Catherines
Fall/ winter/ spring	Process hickory nuts		Other food procurement tasks	Stores are likely kept near base camp due to small travel distances on the island
	Decide size/ composition of work group?		Other maintenance tasks	Can processing tasks be performed by a relatively small group?
	Decide size of batch?		Other foods to eat	
	Decide tools used for initial cracking	Anvil, hammerstone, basket sieve, large nutshell fragments		Groundstone tools are likely to be recovered and may have residues amenable to lipid analysis
	Decide tools used for additional smashing	Mortar, pestle, smaller nutshell fragments		Groundstone tools are likely to be recovered and may have residues amenable to lipid analysis
	Decide discard of nutshell, primarily through burning	Carbonized nutshell fragments	Other fuels to burn	Carbonized nutshell is likely to be preserved and recovered through flotation; size of fragments may reflect processing stage
	Cook hickory nuts		Other foods to eat	What other foodstuffs (fresh or stored) are available? What is their nutritive/flavor content?
	Decide size of batch		Other maintenance tasks	Can cooking tasks be performed by a relatively small group?
	Separate nutmeats, or melt into oil			
	Decide method of heating: hot rock boiling or direct heat	Fire-cracked rock, hearths/cooking pits		Subsurface features are likely to be recognized during excavation but may have been used for various cooking/heating tasks
	Decide tools used for cooking	Skin-lined pit, ceramic vessel, scoop to skim nutmeats		Ceramic vessels are likely to be recovered and may have residues amenable to lipid analysis
	Discard nutshell, primarily through burning	Carbonized nutshell fragments	Other fuels to burn	Carbonized plant remains are likely to be preserved and recovered through floatation

[1]Sources: Swanton, 1946; Talalay, Keller, and Munson, 1984; Gardner, 1997; Fritz, Drywater Whitekiller, and McIntosh, 2001; Thomas, 2008; Roger Cain, personal commun. 2010.

The investment that gatherers make in tending or cultivating plant foods may vary from year to year, depending on the availability of other foodstuffs. If gatherers expect a poor yield from oak and hickory trees, which only produce sizeable crops every two to five years (Schopmeyer, 1974), they may devote more effort to the preparation and upkeep of garden plots or maize fields. Alternatively, if people anticipate poor crops because of drought, flood, frost or other inclement events, they may monitor and tend wild resources more carefully or plan foraging ventures that take them farther afield than usual.

HARVESTING/COLLECTING: Another consideration is when and for how long the edible portions of plants are available. When we model gatherers' and farmers' activities, to the extent possible, our estimates of when foods can be harvested should be based on local data. Besides when they can be collected, it is key to know how long foods stay edible and whether they are attractive to other animals. Knowledge about durability and competition guides gatherers' decisions about what they must collect immediately and what plants they can delay collecting. Fleshy fruits such as mulberries (*Morus rubra*) will spoil or be eaten by other animals, whereas dry fruits such as cabbage palm (*Sabal palmetto*) berries may linger on plants for weeks or months. Sweet acorns are prone to mold and insect infestations and they are favored browse for deer, turkeys, and other wildlife. Bitter acorns and thick-shelled hickories are more rot resistant and will be bypassed by wildlife when sweet acorns are available. Gatherers can defer collection of bitter and thicker-shelled nuts while they harvest those that need immediate attention. Knowledge of ripening periods of plants that are favored by wildlife also is important for hunters because the seasonal movements and locations of game are dependent on the plants they eat (Petruso and Wickens, 1984; Talalay, Keller, and Munson, 1984; Scarry, 2003; Hollenbach, 2009).

We also need to consider how the various seeds, nuts, fruits, and roots were collected and transported (Bettinger, Malhi, and McCarthy, 1997). Do the desired parts remain on trees, shrubs, and stalks or do they drop to the ground? How readily can they be seen and gathered if they are on the ground? Are tools needed for harvesting or can the plant foods be picked, stripped, or uprooted by hand? What kinds of containers are needed for collection and transport? Often there are alternatives to be weighed. For example, Hollenbach (2009: 87) shows that distance affects whether it makes more sense for gatherers to cut chenopod plants, tie them in bundles, and thresh them on return to camp or hand strip the seeds into baskets or bags and not transport the inedible stalks (fig. 11.2). For acorns and hickory nuts, gatherers must consider not only the cost of transporting the nuts in the shell but also loss of "shelf life" if they choose to shell nuts at the grove to reduce transport weight (see below).

PROCESSING/STORAGE: It is also important to know what processing is required for a given foodstuff. This question is inextricably connected to whether the food will be eaten immediately

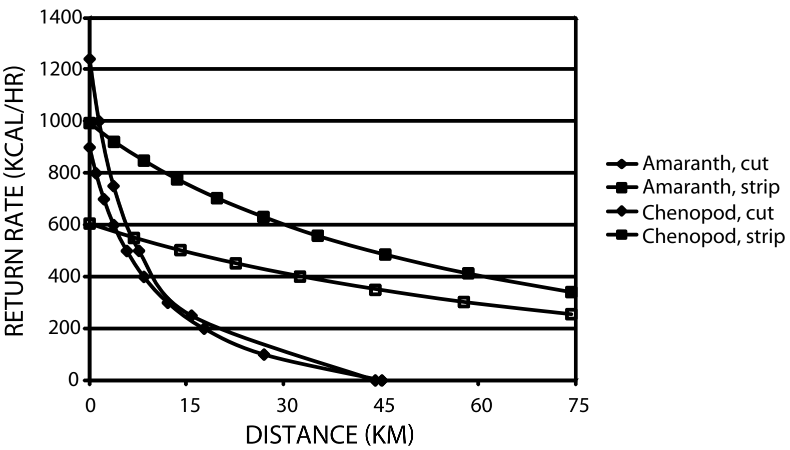


Fig. 11.2. Comparison of return rates for cutting and threshing versus hand-stripping for chenopod and amaranth (see Hollenbach, 2009, for full discussion).

or stored. If gatherers plan to use the food in the near future, their processing considerations revolve around what needs to be done to make the food edible or palatable and where to perform these activities. Do they eat the food on location or return to camp to cook it? If they decide to return to camp, do gatherers remove inedible portions at the collection site to reduce transport costs or maximize collection time and save "cleaning" for camp?

If gatherers intend to store their harvest, then their decisions about how, when, and where to process the food may be different. Decisions about how to handle foods destined for storage balance considerations about what, if anything, is needed to prevent spoilage, whether the shelf life is longer for a minimally handled or derived product, and whether deferring processing evens workloads or solves scheduling conflicts. Removing nutshells or grain chaff at the collection site may save transport costs but generally reduces the time a food can be kept without spoiling and eliminates the option of deferring labor. For example, to limit mold and insect damage, acorns must be dried or parched before they can be stored, but additional processing to make acorn flour, porridge, or soup can be delayed (Scarry, 2003). Thick-shelled hickory nuts are more impervious to infestations; they can be gathered and stored with little or no processing. Indeed, while the nuts may be placed near a fire to dry, it is better to defer other processing because the shelf life of hickory nut products is significantly shorter than that of unshelled nuts (Scarry, 2003). Once foodstuffs are in storage, there are further decisions to make. Are small quantities of foods removed and processed as they are needed for meals? Or are some episodically processed in bulk generating several weeks' supply? Households make such decisions based on the labor they have available and on what other activities require attention (Fuller, Korisettar, and Venkatasubbaiah, 2001).

Because they can be stored for extended periods, many plant foods have value beyond their immediate caloric returns. Storage can even out food availability and provide for anticipated lean seasons. As noted above, storage can also even out labor demands and help solve scheduling conflicts. Harvested nuts, grains, and fruits may need to be dried or parched to prevent spoilage, but further processing can often be deferred until there is a lull in other activities or the food is taken out of storage and cooked. Gremillion (2002) notes that starchy and oily seeds such as chenopod, maygrass (*Phalaris caroliniana*), sunflower (*Helianthus annuus*), and sumpweed (*Iva annua*) have relatively low return rates; however, they can be stored with chaff or hulls attached and processed in the winter when there are few foods to gather. She argues that this led not only to the regular incorporation of these foods into southeastern people's diets but also to the subsequent domestication of these starchy and oily seeded plants. The ability to store plants and defer some labor was an advantage for the people who collected, prepared, and ate those foods.

PROCESSING/COOKING: Finally, we need to consider how foods are cooked. What sorts of vessels or other tools are required? Are there multiple ways a food might be prepared and consumed? Depending on the desired dish, processing activities, cooking equipment, and labor demands may vary. Cracking hickory nuts to extract the meat is a labor-intensive task, which requires a nutting stone, a pick, and patience. Hickory nuts can be processed much more efficiently by pounding, dumping the mix of shell and meat into a vessel of water, boiling, and skimming to extract the oil. Or they can be pounded, sieved to remove the larger pieces of shell, pulverized, and then formed into *kenuchee* balls, which can be added to soups and stews. While the raw food is the same in all "recipes," the equipment, labor demands—and quite likely archaeological signatures—vary (Swanton, 1946; Talalay, Keller, and Munson, 1984; Gardner, 1997; Fritz, Drywater Whitekiller, and McIntosh, 2001; Thomas, 2008; Roger Cain, personal commun., 2010).

SEASONAL PLANT USE IN THE GEORGIA BIGHT

Constructing operational chains for multiple food items is a substantial challenge. If we are going to incorporate plant foods more fully into existing models of seasonal subsistence rounds for St. Catherines Island or the broader Georgia Bight, then there is a lot of work to be done. First and foremost, we need robust data about the plants that were collected, cultivated, and consumed. Unfortunately, while there are detailed analyses of animal remains from multiple sites and temporal contexts from St. Catherines Island, the only plant data come from a preliminary report on the mission assemblage (Thomas, 2008: 978).

Moreover, there have been far fewer systematic analyses of plant assemblages from elsewhere on the Atlantic coast than from the interior Southeast. Thus, we lack the archaeological basis for assessing the relative importance of various plant foods or for building detailed models of plant use on St. Catherines Island. We can, however, begin by compiling an inventory of plants that have been recovered from sites along the Carolina and Georgia coasts. This gives us a list of plants that might have been used on St. Catherines Island and provides a starting point for thinking about what foods were available to gather or take out of storage over the course of the year and what decisions and tasks were associated with their use.

For this chapter, we have culled presence data from Ruhl's plant list for Mission-period contexts on St. Catherines Island, with the omission of European-introduced species (Thomas, 2008: 978); from Hollenbach's analysis of late prehistoric plant remains from Keene's (2004) excavations of the Grove's Creek site (9CH71) on Skidaway Island, Georgia (Detwiler and Keene, 2003); and from 19 prehistoric or contact-era sites on the North Carolina coast that are reported in the contract literature (Scarry and Scarry, 1997) and in Kimberly Schaefer's (2011) dissertation. Most of the sites date after people began to grow maize on the coast, although six of the North Carolina sites also have earlier components. We do not present quantitative analyses or even calculate ubiquity, because only Grove's Creek and seven of the North Carolina sites have plant assemblages that were systematically collected (using flotation) and fully analyzed. Table 11.2 lists plants identified from the 21 sites.

Even a cursory inspection of table 11.2 is informative. We use the tabulations of species present and the probable collection dates for the various plant foods to sketch out a hypothetical seasonal round of plant-related activities and decisions for forager-farmers living on the lower Atlantic coast or one of the islands.

Spring

Few plant foods are available for collection in the early spring. At this time gatherers likely concentrated on plants with underground storage organs such as arum (*Peltandra virginica*), duck potato (*Sagittaria* sp.), and cattail (*Typha* sp.). Roots and tubers can be collected at virtually anytime, but are best harvested in winter or early spring when they are most tender and starch reserves are high (Scarry, 2003). Despite the fact that preservation of roots and tubers is generally uncommon, we have reports of greenbrier (*Smilax* sp.) (Thomas, 2008), Indian turnip (*Arisaema triphyllum*) (Jones, Espenshade, and Kennedy, 1997; Scarry and Scarry, 1997), and an unidentifiable tuber (Detwiler and Keene, 2003) from sites in our inventory. This suggests that roots were important resources for people living along the Carolina and Georgia coasts. Digging roots in the spring requires knowledge about where they can be found even when aboveground (or above water) leaves and vines are absent. It is also labor intensive and potentially uncomfortable when reaching the plants requires wading in cold mud or water. Gatherers' activities and conversations while digging aquatic or terrestrial roots likely disturbed game, fish, and fowl, making active hunting by the party unproductive. Trips to the marsh side could, however, be combined with setting or checking traps and trotlines for fish, turtles, and crabs as well as with digging clams or other molluscs. Once gathered, some tubers (e.g., duck potato) can be cooked with little processing, while others (e.g., arum) require pounding or grating before they are cooked (Messner, 2011: 20–26). Regardless of the labor, roots would provide a welcome source of carbohydrates at a time when there were few alternatives. In early spring, gatherers also could pick tender greens from plants such as chenopod, purslane (*Portulaca oleracea*), and poke (*Phytolacca americana*) that favor open ground and sprout in dormant garden plots and other disturbed soils. Greens eaten raw or stewed provide few calories but are important sources of vitamins and minerals and undoubtedly added welcome variety to meals.

As spring progressed, people would monitor the growth of grasses and the flowering of fruit and nut trees, anticipating and estimating the potentials for future gathering excursions. We have scant evidence for spring-ripening grains such as maygrass, little barley (*Hordeum pusillum*), or other grasses and sedges. Whether these were much used at coastal sites remains to be seen. If spring grasses were cultivated or gathered, then people must have made time for threshing and parching the grains. Once people began growing maize, beans (*Phaseolus vulgaris*), and squash (*Cucurbita pepo*), fields would need to be prepared so that planting could begin by mid-April. As they prepared for sowing and tended their early crops, women could continue to gather greens from volunteer plants.

TABLE 11.2
Plants Identified from Sites along the Georgia and Carolina Coasts

Common name	Taxonomic name	Season available	St. Catherines Island	Grove's Creek	North Carolina coast[1]
Crops					
Maize	*Zea mays*	summer	x	x	x
Bean	*Phaseolus vulgaris*	summer/fall	x	x	x
Squash	*Cucurbita pepo*	summer/fall	x	x	x
Bottle gourd	*Lagenaria siceraria*	summer/fall	x		
Starchy Seeds					
Little barley	*Hordeum pusillum*	spring/early summer			x
Maygrass	*Phalaris caroliniana*	spring/early summer		x	x
Vetch	*Vicia* sp.	summer			x
Wild rice	*Zizania aquatica*	mid summer/late summer			x
Amaranth	*Amaranthus* sp.	late summer/fall[2]	x	x	x
Chenopod	*Chenopodium* sp.	late summer/fall[2]	x	x	x
Knotweed	*Polygonum* sp.	late summer/fall[2]			x
Wild bean	*Strophostyles* sp.	late summer/fall	x	x	
Sedge family	Cyperaceae	mid summer/fall		x	x
Grass family	Poaceae		x	x	x
Oily Seeds					
Bearsfoot	*Smallanthus uvedalius*	late summer/fall		x	x
Ragweed	*Ambrosia* sp.	late summer/fall			x
Sumpweed	*Iva annua*	late summer/fall			x
Sunflower	*Helianthus annuus*	late summer/fall	x	x	
Nuts					
Acorn	*Quercus* sp.	fall	x	x	x
Hickory	*Carya* sp.	fall	x	x	x
Walnut	*Juglans nigra*	fall			x
Fruits					
Blackberry	*Rubus* sp.	summer	x	x	
Blueberry	*Vaccinium* sp.	summer		x	
Creeping cucumber	*Melothria pendula*	summer	x		
Grape	*Vitis* sp.	summer	x	x	x
Maypops	*Passiflora incarnata*	summer	x	x	x
Mulberry	*Morus* sp.	summer		x	
Plum/cherry	*Prunus* sp.	summer		x	
Elderberry	*Sambucus* sp.	late summer/fall	x		
Prickly pear	*Opuntia* sp.	late summer/fall			x
Wax myrtle	*Morella caroliniensis*	late summer/fall	x	x	

TABLE 11.2 — (*Continued*)

Common name	Taxonomic name	Season available	St. Catherines Island	Grove's Creek	North Carolina coast[1]
Black gum	*Nyssa sylvatica*	fall		x	x
Cabbage palm	*Sabal palmetto*	fall		x	
Saw palmetto	*Serenoa repens*	fall		x	
Palm family	Arecaceae	fall	x		
Persimmon	*Diospyros virginiana*	fall		x	
Dogwood	*Cornus* sp.	fall			x
Sumac	*Rhus* sp.	fall		x	x
Yaupon holly	*Ilex vomitoria*	fall		x	
Hackberry	*Celtis* sp.	fall/winter		x	x
Roots and Tubers					
Indian turnip	*Arisaema triphyllum*	all year[3]			x
Greenbrier	*Smilax* sp.	all year[3]	x		
Tuber or root		all year[3]		x	
Greens and Miscellaneous					
Bedstraw	*Galium* sp.			x	x
Carpetweed	*Molluga* sp.				x
Copperleaf	*Acalypha* sp.		x		x
Gromwell	*Lithospermum* sp.				x
Morning glory	*Ipomoea*/*Convolvulus* sp.			x	x
Mustard	*Brassica* sp.		x		x
Pokewee	*Phytolacca americana*		x	x	x
Purslane	*Portulaca* sp.		x	x	
Spurge	*Euphorbia* sp.		x		x
Stargrass	*Hypoxis* sp.			x	

[1]Presence data derived from 19 sites along the North Carolina coast.
[2]Season indicated is for ripe seeds. Greens would be available in spring/summer.
[3]Available all year but highest starch content is in winter/early spring.
[4] Sources: Abbott et al., 1999; Crites, 1999; Detwiler and Scarry, 1999; Gardner, 1984, 1990; Glazier, 1987; Green, 1984, 1986; Jones, Espenshade, and Kennedy, 1997; Loftfield, 1979; Marshall, 1986; Payne and Dahlin, 1987; Scarry and Scarry, 1997; Schaefer, 2011.

Summer

During the summer, people would continue to cultivate their crops. Depending on planting dates, maize, beans, and squash ripen from late June into August. Women would pick and cook some of the crops as soon as they were ripe. A significant portion of the crop, however, was likely left until fully mature. Maize would be allowed to dry on the stalk then picked; seed corn would be set aside, and the rest prepared for storage. Husking and shelling the maize would reduce storage bulk but it would increase immediate labor demands and decrease shelf life. Beans would be picked and shelled or the vines might be pulled and threshed to release the seeds. Fleshy squash would need to be cut and dried and the seeds parched or toasted. While waiting for their crops to ripen and after harvesting and preparing them for storage, people could pick and eat or dry a variety of summer-ripening fruit including blackberries (*Rubus* sp.), blueberries (*Vaccinium* sp.), mulberries, grapes (*Vitis* sp.), plums, and maypops (*Passiflora incarnata*). These have to be gathered as soon as they ripen or they rot or are eaten by animal competitors.

Fall

Late summer and early fall would bring an abundance of plant foods and work. Harvesting and preparing crops would continue into early fall. Chenopod, wild rice (*Zizania aquatica*), sunflower, and bearsfoot (*Smallanthus uvedalius*) would offer starchy and oily seeds that could be harvested and stored to be processed and eaten later. Fruits such as elderberry (*Sambucus* sp.), saw palmetto (*Serenoa repens*), cabbage palm, wax myrtle (*Morella caroliniensis*), and black gum (*Nyssa sylvatica*) would also ripen. Wild rice would need to be gathered before its seeds dropped and were dispersed by water. Elderberries would soon rot or disappear. Chenopod, the palms, wax myrtle, and gum have fruits that are persistent and less attractive to wildlife. Collection of these could probably be deferred.

In mid- to late fall, gatherers' attention would shift to nut mast with priority in collection and drying given to sweet acorns over thick-shelled hickories. Because of the dietary importance of these nuts, as well as their relatively short period of availability, nut-collecting parties may have been relatively large and included women, children, and men in order to maximize the group's gains. The size and composition of these task parties may have differed depending on the size of the nut crop that year.

To prevent spoilage, acorns would need to be parched for storage but shelling, leaching, and pounding into flour could be saved for later. Hickory nuts could be set in baskets near the hearth to dry but other processing (see table 11.1) could be deferred. Late fall fruits would include cabbage palm, saw palmetto, and persimmon.

Winter

Winter would bring few new plant foods, though roots, tubers, and persistent seeds and fruits could be gathered. Most attention at this time of year would turn to husking, shelling, cracking, and otherwise processing and cooking stored plant foods.

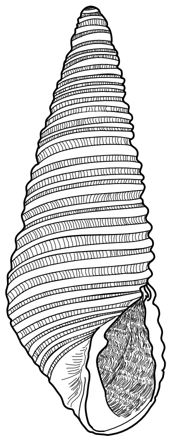
FINAL THOUGHTS

Much of the seasonal round we describe could fit almost any location in the Southeast. For the most part, we lack qualitative and quantitative data necessary to refine this picture for St. Catherines Island and distinguish the coast from the interior. We can offer several thoughts, however. First, while there is considerable debate about how heavily late prehistoric coastal people relied on crops, maize is consistently present and sometimes abundant at coastal sites. Second, there are several plant foods, notably bearsfoot nutlets and the fruits of black gum, cabbage palm, saw palmetto, and wax myrtle, which are seldom reported for interior sites but are common in coastal assemblages. The dietary role and processing requirements of these plants need attention. Third, our seasonal sketch focuses on plant foods, but gatherers often collect small game, shallow-water fish, and shellfish. During the summer and fall, people would have to weigh the merits of collecting fruit, nuts, turtles, shellfish, etc. When the mulberries or blackberries were ripe did people forgo a trip to the shore or berry patch? Or did they split their work parties and gather both fruit and clams? In this vein, we are intrigued by the data on shellfish collection (see chaps. 7, 8, and 10) that seem to indicate collection of clams and oysters in late fall and early spring when there were few plants to harvest and gatherers may have been collecting tubers from the marsh edges. Last but not least, St. Catherines Island, and quite possibly other island and coastal settings along the Georgia Bight, presents an interesting case for considering central-base foraging patterns. Thomas (2008) has argued that the size of St. Catherines Island and its geological and ecological configuration allowed camps to be located where they would provide access to key terrestrial and aquatic hunting and gathering grounds as well as agricultural soils without the need for seasonal relocation. People could have followed our hypothetical round of plant handling from marshside settlements without making more than brief forays away from camp.

The seasonal round we have sketched is a far cry from what might be possible if we practiced what we preached and examined operational chains and used optimal foraging models to juxtapose the plants and animals targeted by gatherers, gardeners, and hunters. To engage in such an exercise, however, we need additional, detailed, quantified analyses of plant remains, such as Hollenbach's (Detwiler and Keene, 2003) study of the Grove's Creek assemblage and Schaefer's (2011) analyses of coastal North Carolina assemblages.

NOTES

1. Recent experiments indicate that capuchins have a preference for dietary diversity. When offered choices, they select a variety of items over a greater quantity of their favorite food (Addessi et al., 2010).



CHAPTER 12
MAKING A CASE FOR COASTAL SUBSISTENCE SEASONALITY

GREGORY A. WASELKOV[1]

This chapter represents for me something of a rebirth as a coastal archaeologist. After dissertation research on a Potomac River oyster midden and publication of a worldwide review of shellfish gathering and shell midden archaeology (Waselkov, 1987), my career took a decades-long detour into the ethnohistory of southeastern North America and the archaeology of French colonists and historic Creek Indians. When an opportunity arose a few years ago to do some developer-funded investigations of Woodland shell middens on the Alabama coast, I felt akin to Rip van Winkle reawakening to a world changed greatly in the interim. While there are surely drawbacks to such a circuitous career path, my return after a long preoccupation elsewhere in the discipline has allowed me to see coastal archaeology with fresh eyes and envision some potentially fruitful paths forward. The invitation to join the Caldwell V conference on seasonality, where participants were immersed for a few days amid one of the most productive and innovative coastal archaeological projects underway anywhere in the world, offered the perfect venue for introspection.

Understanding seasonality seems, more than ever, to be essential to unraveling the rhythms and rationales of lives lived in coastal landscapes. More than an end in itself, though, seasonality is a portal through which we can grapple with questions of residential mobility, exploitative strategies, and many other facets of human existence along the world's estuaries. A good place to begin, therefore, is with a glance back at the shifting significance placed on seasonality by archaeologists concerned with coastal settings.

In the wake of the influential (and controversial) "Man the Hunter" symposium held in 1966 at the University of Chicago, Lee and DeVore famously offered "two basic assumptions about hunters and gatherers: (1) they live in small groups and (2) they move around a lot" (Lee and DeVore, 1968: 11). Both generalizations provoked criticism and an extensive literature now documents great variability in group size and mobility observed ethnographically among hunter-gatherers (Lee and Daly, 1999). Archaeologists participated in the ensuing debate in two ways, by developing the theoretical means to distinguish various kinds of residential mobility in the archaeological record and by recognizing that the archaeological record contains evidence for approaches to mobility unobserved in the modern world (Yesner, 1980).

Binford (1980, 1990) contributed substantially by contrasting the residential mobility of foragers who move as a group to their resources with the logistical mobility of collectors who exploit resources as individuals or specially organized task groups. He conceived of logistical and residential variability not "as opposing principles … but as organizational alternatives which may be employed in varying mixes in different settings" (Binford, 1980: 19). Nevertheless, many archaeologists have employed the collector/forager concepts as typological opposites or two extremes on a continuum without recognizing the multidimensional nature of the organizational possibilities they imply. Similarly Kelly (1992: 50, 60) has criticized archaeologists for the tendency to think in terms of a single scale of mobility leading toward sedentism that conflates the independent variables of individual and group mobilities (each with its own factors of age, gender, kin relations, and abilities), territorial shifts, and migrations. Among the many dimensions of mobility, he enumerates "seasonal movement of the residential base camp, movement of individuals around and between residences, movement of a group's yearly range or aggregation site ..., and permanence of facilities such as houses and fish weirs" (Kelly, 1995: 148–149; cf. Builth, 2006: 14–15).

Ames has explored the transformative role of watercraft in aquatic resource exploitation, particularly the possibilities for food production by easing acquisition and transport, as in opening new offshore habitats to exploitation and expediting collection of large amounts of small-sized taxa, which might not be a cost-effective strategy without boats even over short distances (Winterhalder, 2001; Ames, 2002: 34, 47). Selective resource exploitation assisted by watercraft could, of course, have seasonal mobility implications by enabling access to widespread habitats through broad dispersal of task groups or village movement. In some watery environments, canoes may at times have so transformed mobility that they became the residence, the ultimate in mobile central-place foraging.

A number of researchers have noted that gender and age distinctions may be reflected in archaeological food remains at coastal sites. In modern societies where shellfishing is conducted at a domestic nonindustrial scale, women and children are the most active shellfish gatherers (Meehan, 1982; Waselkov, 1987: 96–99; Claassen, 1998: 175–182; Klein, 1999; Bird and Bliege Bird, 2000). Ethnographic studies have repeatedly documented such age and gender disparities in foraging and collecting emphasis, with important dietary implications (particularly in protein and fat contributions to diet) for segments of society with limited access to hunted sources of meat (Bigalke, 1973; Meehan, 1982; de Boer, Pereira, and Guissamule, 2000; Thomas, 2002; Bird, Bliege Bird, and Richardson, 2004; cf. Voorhies, 2004: 129–141, for a nondomestic example). Precisely how this generalization translates to specific seasonal mobility patterns remains an open question for archaeologists, but one that should be considered in the development of seasonality models.

Coastal seasonality is playing an important role in reevaluations of the origins of cultural complexity. In recent decades, archaeologists have found early evidence of complexity in the relatively sedentary village sites of hunter-gatherers who occupied areas with abundant resources. In most parts of the world, it is now apparent, sedentism and cultural complexity preceded plant and animal domestication and in fact may have been preconditions for serious reliance upon domesticates. Not too many years ago, archaeologists considered coastal resources less reliable and less abundant than terrestrial and riverine resources (Cohen, 1977; Osborn, 1977), but that erroneous attitude was based on misunderstandings of estuarine environments, which are some of the most productive on earth (Rowley-Conwy, 1983, 1998; Brown, 1985; Marquardt, 1996; Costanza et al., 1997; Erlandson, 2001). Studies of cultural complexity in coastal locations are hampered to some extent by Holocene marine transgressions that inundated early coastlines. But worldwide evidence is revealing how substantial populations exploited estuarine resources, in some cases creating large sites interpreted as permanent, year-round villages of coastal hunter-gatherers organized in complex societies (Russo and Quitmyer, 1996; Russo, 1998; Keene, 2004; Thompson and Andrus, in press). Archaeologists need to understand how coastal strategies differed from interior strategies, which in so many instances led to reliance on agriculture. Brian Hayden concisely states the dilemma:

> One of the major conundrums of the domestication problem … is why domestication did not occur in certain neighboring regions or areas that seem to have been just as well endowed and as rich and environmentally variable as the initial hearths of domestication. In the eastern United States, for example, while people in the Ohio and neighboring valleys actively domesticated a number of species, nothing appears to have happened around the Louisiana floodplain or the Gulf Coast region until the introduction of efficient maize cultivation thousands of years later. California provides another example of a problem area with many diverse habitats and great resource variability. Australia is a problem area of even greater magnitude…. (Hayden, 1995: 297)

Archaeologists working along coastlines are rethinking this issue. In California, for instance, Kroeber's long-accepted view, that the natural complementary bounties of oak groves and coast made domesticates unnecessary, is being replaced by a more realistic grasp of local environmental uncertainties and a better appreciation of settlement and subsistence strategies that relied on diversification rather than specialization (Kroeber, 1925: 919–926; Raab, 1996; Glassow, 1997; Luby, Drescher, and Lightfoot, 2006; Jones et al., 2008; Lightfoot and Parrish, 2009). Builth (2006) argues for the development of social complexity along the temperate south coast of Australia based on evidence of landscape management and the development of a storage economy and trade in wild foods. Cases like these begin to dismantle long-standing assumptions about the rise of social complexity and challenge the presumed exceptionalism of California and Australia as ethnographic oddities, places where people inexplicably rejected agriculture and the monumentality that often followed the rise of social complexity elsewhere in the world.

I suggest that coastal regions routinely supported nonagricultural forms of resource use and permitted different trajectories of social complexity than are documented in noncoastal regions (also see Hayden, 1990; Jochim, 2006). One of Binford's principal conclusions in *Constructing Frames of Reference*, his massive analysis of ethnographically documented hunter-gatherer behavior, is his observation that subsistence intensification by hunter-gatherers eventually leads to one of two outcomes: dependence on aquatic resources or dependence on plant domesticates (Binford, 2001: 201, 357, 368, 443–444). In the absence of evidence for agriculture, archaeologists must refocus their energies on interpreting those plant and animal remains that reflect not only the changing targets of use, but the changing seasonalities of exploitation and settlement. Hayden's comment above, that "nothing appears to have happened around the Louisiana floodplain or the Gulf Coast region until the introduction of efficient maize cultivation thousands of years later," of course reflects our collective ignorance of what did happen in those areas during several thousand years of increasing population density and social complexity. We now know the earliest mound ceremonialism in North America appeared in the Mississippi floodplain around 5300 B.P. (Saunders et al., 1997), and the northern Gulf supported a series of vibrant nonagricultural societies culminating in Weeden Island, which disappeared coincident with the expansion of Mississippian maize farmers around A.D. 1250 (Brown, 2003). These thousands of years of nonagricultural existence were not insignificant footnotes to the rise of agriculture. Rather, they represent remarkably effective alternatives to the reliance on domesticates practiced by their neighbors and constitute an important but neglected part of the human past that we need to understand on its own terms.

But my task here is to focus on the problems facing archaeologists who wish to understand coastal seasonality. Seasonality of resource use and residential patterns is fundamental to many significant human behaviors. Managing or accommodating seasonal aspects of plant and animal physiology and habits underlies such diverse behaviors as rites of passage, calendrical rituals, political and economic organizations, harvest cycles, architectural designs, settlement patterns, and the density and size of human populations. Seasonality is fundamental to these phenomena because most of the organisms important for human life respond to cycles of temperature, moisture, and other variables that define seasons.

Unraveling the complexities of seasonality using archaeological data has proven extremely difficult. It is not uncommon for modern studies to extrapolate overall seasonality of resource use for entire sites from evidence provided by one or two species (each typically represented by a handful of specimens). In simplest form, seasonal preferences of species present in a sample are cited to establish which seasons are represented in the assemblage and which are not, thereby linking seasonal behavior of plants and animals with human residential patterns. This approach to deriving seasonality and reconstructing environments relies on analogy to modern species physiology and behavior, and on a further (doubtful) assumption, that climates, ecosystems, and organisms have remained unchanged throughout the Holocene. This approach fails to capture the complexity, diversity, and inherent flexibility of organisms, including people, on a daily, seasonal, annual, and long-term basis. Nonetheless, this remains the dominant archaeological method to assess season of site occupation in many parts of the world.

In addition to problems inherent in using modern ecological analogies, other problems exist in assessing seasonality at coastal archaeological sites using species presence/absence, quantified or not. In those cases where more than one site is studied, neither site locations nor artifact types provide the precision needed to verify or refute the presence of an asynchronous residential pattern due to seasonal availability of resources on a regional scale (e.g., Thomas, 2008). Radiocarbon dating has not yet provided fine enough temporal control to establish two or more sites as part of a seasonal round, or the contemporaneity of complementary special function sites, or the sequential reuse of a site on a year-to-year basis. (However, see Kennett and Culleton, chap. 2, this volume, for a possible resolution of the problem.)

Faunal evidence is equally challenging. Many animals are (and were) available throughout the year at different places along subtropical and tropical coasts. Although they may move, reproduce, and grow seasonally, the broad behavioral and physiological patterns visible in modern species are often unclear from archaeological taxonomic identifications, element distributions, measurements, ages at sexual maturity, and seasons of death, particularly when the ancient prey lived in different environmental conditions or different climatic regimes than exist currently. Ethnobotanists have similar problems. It does not help that fruits and grains have "seasons" when they are ripe, because in tropical and subtropical environments these seasons are fluid and can only be broadly defined. Both zooarchaeologists and ethnobotanists argue, too, that identified taxa could have been caught or collected in one season and stored for later use, or processed elsewhere in such a way that no evidence of their use reached the site being studied.

In sum, after more than a century of archaeological effort, we cannot yet prove that people lived at two different sites within the same year, let alone parse out the precise season in which each settlement was occupied, for what purpose, and by how many people. However, our inability to replicate the kind of observations made by ethnologists does not mean that archaeologists cannot address the seasonal nature of foraging behavior in the past. We do need to face up to current limitations of our analytical procedures, reassess the possibilities of our data, and consider where we can make better progress.

It is increasingly obvious that multiple lines of evidence (e.g., from radiocarbon dating, isotopic profiles, zooarchaeology, paleoethnobotany) ought to be pursued with equal rigor on a variety of sites that might have been part of a seasonal round, exchange network, kin group, or some other economic or social unit in order to assess variability in coastal settlement patterns. Ideally these methods ought to be performed in tandem at coastal *and* inland sites to explore entire settlement patterns and understand how sites of different sizes and functions in different locations fit into the overall landscape. In practical terms, however, as expressed by Bar-Yosef and Rocek (1995: 2), "the likelihood of recovering all of the sites in a settlement round is vanishingly small ... we must give up the idea of reconstructing the entire settlement pattern" of any ancient society. I share their skepticism on that score, given current limits of analytical methods, disparities in faunal preservation often observed between coastal and inland sites, and losses to modern development that disproportionately impact the world's coastal sites. Yet I maintain that we should apply our best analytical procedures more rigorously and more broadly to learn, as best we can, how patterns of subsistence and residential mobility changed over time.

You may take issue with my assessment of the progress archaeologists have made in determining seasonality of site occupancy, especially in light of recent widespread advances in the analysis of growth structures in shellfishes, fishes, and mammals. In fact, I am heartened that archaeologists are developing ever more powerful tools to establish seasonality of capture, and many of the Caldwell V conference participants have contributed to this effort (e.g., Quitmyer, Jones, and Arnold, 1997; Waselkov et al., 1998; Andrus and Crowe, 2000, 2008; Quitmyer, Jones, and Andrus, 2005; Reitz, Andrus, and Sandweiss, 2008; Thomas, 2008; Culleton, Kennett, and Jones, 2009). But most of this progress has been species specific. The biology of each target species is complex enough that the various techniques (e.g., those based on periodic changes in ontogenetic growth structures, oxygen isotopic profiles, population availability due to migrations) have had to be carefully crafted and tested in multiple locations to demonstrate their efficacy. Consequently, few archaeologists have applied more than one or two of these new analytical techniques to an assemblage, and they typically examine very few specimens per site. We, as a profession, have so far missed the opportunity to gather a broad range of evidence for complex seasonal activities undertaken by people who could plan and carry out more than one task at a time, different tasks in rapid succession, and tasks that changed in response not only to seasonal variation but to environmental fluctuations at longer time scales.

I will mention just two areas of inquiry I think are amenable to immediate improvement: (1) seasonality modeling that considers evidence of ontogenetic movement (that is, during the lifetime of an individual animal) between habitats; and (2) increasing resolution and confidence in seasonality estimates by statistical analysis of oxygen isotope and other temperature proxies.

HABITAT ANALYSIS

While oxygen isotope analysis has gained wide acceptance as a reliable means of determining season of capture for animals with calcium carbonate structures, the potential for stable isotope and elemental analyses to provide information on location of capture is barely explored, although this is obviously an aspect of season of exploitation (see Ishimaru et al., 2006; Lynch, Hamilton, and Hedges, 2008). Biologists are actively pursuing this line of inquiry for their own purposes (such as tracking migrations or tracing habitat environmental changes; see Hobson, 1999), and some of their findings and procedures have relevance and applicability to archaeology. Though not necessarily aimed squarely at seasonal questions, determining habitat of acquisition can inform seasonal interpretations in many contexts. Archaeological application is still experimental, but I think entirely feasible, as I've tried to demonstrate with a small pilot study focusing on white-tailed deer that examines carbon and nitrogen isotope analysis of bone collagen.

My original intent was to seek evidence of transport of deer elements between inland and coastal locations. Suspicion that such transport occurred was raised by the presence at the Late Woodland Bayou St. John site on the Alabama coast of hundreds of tools, mostly awls and spatulas, made almost exclusively from deer metapodials (Price and Waselkov, 2009). Analysis of all deer bones, worked and unworked, from Bayou St. John revealed disproportionate numbers of metapodials compared to other skeletal parts. Since movement of subsistence remains has important implications for the interpretation of site subsistence, seasonality of occupation, and regional economies, I devised an experiment to distinguish bones of coastal deer from bones of deer hunted at inland locations.

Analysis of stable isotope ratios of carbon and nitrogen in organic remains is based on their roles in two major biogeochemical cycles, the carbon cycle and the nitrogen cycle. A great many biological and chemical processes lead to variation in the relative proportions of these isotopes (for the basic science, see Hedges, Stevens, and Richards, 2004, 2005; Dawson and Siegwolf, 2007; Ferrio et al., 2007; Pollard et al., 2007: 176–189; Crawford, McDonald, and Bearhop, 2008). In particular, differences in human and animal bone collagen ratios of ^{12}C to ^{13}C ($\delta^{13}C$) and ^{14}N to ^{15}N ($\delta^{15}N$) have been interpreted as dietary indicators (DeNiro, 1985; Bocherens et al., 1999; Evershed et al., 2007; Goffer, 2007: 307–309; Koch, 2007). Both are closely tied to trophic level, so, for instance, carnivores are enriched in ^{15}N compared to their herbivore prey. Terrestrial herbivores from different habitats are frequently distinguishable on the basis of $\delta^{13}C$ and $\delta^{15}N$ values, which fluctuate in the plants upon which they feed. Archaeologists have mostly used this approach to document the importance of domesticates, particularly maize, in the diets of humans (or, indirectly, in their dogs; White et al., 2001), but there are other potential applications.

Five deer bone samples—three from the coastal Bayou St. John site and two from the Late Woodland Corps site situated inland in the Mobile-Tensaw delta—were submitted to Beta Analytic for collagen extraction and $\delta^{13}C$ and $\delta^{15}N$ analysis using procedures (Brown et al., 1988) standard for AMS radiocarbon dating of bone. The results (fig. 12.1) indicate ^{13}C depletion and ^{15}N enrichment in bones from the inland site compared to two bones from the coastal site. A third bone from the coastal site isotopically resembles the inland bones, suggesting transport of some deer parts to the coast, as anticipated. With additional testing, this approach may prove a valuable analytical tool for investigating the transport or exchange of subsistence materials between settlements, data that might otherwise be interpreted as evidence for seasonal task group activity.

A second approach to habitat analysis, applicable to shellfish valves and fish otoliths, involves elemental and isotopic analysis by laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) to obtain information on ontogenetic habitat changes of individual mobile fish (with their own seasonality implications) and to identify exploited habitats of mobile and sessile shellfish. Elements of interest include Ca, Mn, Sr, Ba, Pb, the lanthanide rare earths, Th, and U. Oxygen and carbon isotopes have also been used for habitat studies.

Multiple elemental and isotopic analyses of shellfish valves primarily reveal data on habitat of capture. Archaeologists previously have had little access to this kind of information. For instance, surface features and valve shape ("ecomorphism") of oysters have traditionally been regarded as indicative of habitat (i.e., bed, sand bottom, channel, and reef) (Galtsoff, 1964: 21–32; Kent, 1988: 28–38), but these can be ambiguous, and most species do not vary by habitat in simple morphological ways. Some biological research suggests that Ba/Ca profiles may reveal differences in environment of origin, and $\delta^{18}O$ analyzed for salinity may prove enlightening because salinity in estuaries should correlate with distance from passes to open water (Surge, Lohmann, and Dettman, 2001; Barats et al., 2009; Hobson et al., 2009).

Analysis of fish otoliths is likely to lead in unexpected directions. Within the last half century, biologists have built ever more complex fish life histories documenting migrations between shallow coastal estuarine habitats and open waters. In my research universe on the northern coast of the Gulf of Mexico, Livingston (1975, 1982, 1985) pioneered studies of estuaries, which he found to be not only geologically unstable, but highly dynamic in terms of seasonal and annual variations in temperature, salinity, nutrient flow, and grassbed compositions. Most fish become increasingly specialized in their food habits as they develop in estuarine nurseries, migrate to the open gulf, and return to the estuaries as adults. Livingston showed a progression of species entering and leaving estuaries through the year, and others have noted seasonal habitat preferences of different species (Rozas and Zimmerman, 2000; Rozas and Minello, 2001).

In recent years biologists have explored stable isotope relationships to these variables and have found, for instance, that $\delta^{15}N$ and $\delta^{87}Sr$ are enriched in fish moving from estuarine to deep water habitats, and $\delta^{13}C$ is enriched in seagrass habitats (Hobson, 1999: 320–321; Nagelkerken and van der Velde, 2004). Thus a chemical signature record of an animal's habitat changes is recorded in otoliths. A combination of light-stable isotope analysis ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$) and trace element analysis is likely to reveal information about habitats preferred for exploitation. Identifying collection habitats, and not ontogenetic movements, is typi-

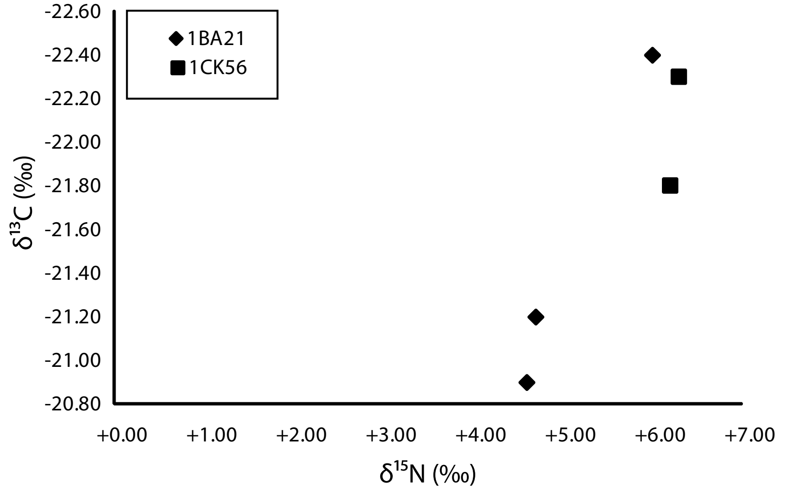


Fig. 12.1. Results of a trial carbon and nitrogen isotope analysis of deer metapodial bone collagen samples from two Late Woodland sites, the coastal Bayou St. John site (1BA21) and the inland Corps site (1CK56).

cally the focus of archaeologists, since they relate most directly to human residential mobility. But archaeological data on changes in fish species habitat preferences may correlate with data being gathered by marine biologists (see France, 1995; Hanson, Koenig, and Zdanowicz, 2004; Dorval et al., 2004; Kennedy et al., 2005; Martin and Thorrold, 2005; Surge and Walker, 2005; Comyns et al., 2008; Fodrie and Herzka, 2008; Fodrie et al., 2010; cf. Chittaro et al., 2005, 2006). In collaboration with Betsy Reitz and Fred Andrus, I have proposed a trial study of hardhead catfish and spotted seatrout otoliths. Catfish otolith chemistry is expected to reflect a limited habitat range of high-salinity mud/sand flats and channels, while seatrout could have been collected from a wider range of seagrass, oyster reef, channel, and salt-marsh habitats. In this sort of study, oxygen isotope analysis will enable us to calibrate the seasonal timing of habitat exploitation (reflected in other chemical signatures). The two analytical methods work in concert, which makes this a very powerful interpretive approach. As an ancillary benefit, gaining a means of analyzing shellfish and fish remains for habitat of capture should finally enable archaeologists to document and quantify dependency on canoe transport.

STATISTICAL ANALYSIS

Climatologists (e.g., Grimes et al., 2003) have suggested a need to apply statistical procedures to seasonality data, something both biologists and archaeologists have been reluctant to do. $\delta^{18}O$ data profiles of individual mollusc valves and otoliths are generally interpreted individually and very conservatively by attribution to broad seasonal divisions: spring, summer, fall, winter. I suspect this hesitancy to employ statistics is a consequence of the very small sample sizes available until recently in most seasonality studies. In the past it has not been uncommon for seasonality interpretations to be based on temperature proxy curves obtained from samples of one, two, or three shells per stratum or even per site. As our analytical methods mature and we acquire suites of data from larger archaeological samples, we are now beginning to see that temperature data profiles for individuals of the same species differ in ways that at least in part reflect natural variation around a mean with a calculable standard deviation. Earlier studies that relied on a few shells tended to interpret seasonality of harvest so conservatively because the natural variation was not well understood. Apparent differences in paleotemperatures at harvest were interpreted as evidence of harvest across seasons. But modern control studies of shellfish harvested monthly at many locations now thoroughly document how a single day's harvest can be represented by a substantial range in $\delta^{18}O$ values. Clearly we need to refine our seasonality interpretations in light of larger-scale modern control and archaeological studies, to narrow our seasonality estimates for specific collection events rather than continue to follow an overly conservative approach that yields three-month or six-month interpretations of archaeological deposits that, on the basis of other evidence, must have accumulated much more rapidly.

It is worth recalling that the preferred archaeological contexts for seasonality sampling were identified decades ago (Koike, 1979; Deith, 1986: 69; Waselkov, 1987: 142–144; Stein, 1992: 77; Stein, Deo, and Phillips, 2003; Claassen, 1998: 152). Gorski (2005) defined the smallest unit of analysis as the microstratum, the smallest visible "natural" stratum (a pocket or lens of midden). In deposits consisting largely of mollusc valves these are often interpreted as single episodes of cultural deposition—the contents of a fish boil or debris from a single shellfish roast or some other processing event, discarded as primary refuse and forming a discrete feature representing a moment in time. These micro contexts rightly turn our attention from a site as a generalized whole to the individual activities that, multiplied a thousand fold, created a site's deposits. By focusing analysis on micro contexts, they can give us meaningful insights on real behavior and help us move away from the deceptively simple (and simply deceptive) generalized "behavior" we think we see when our unit of seasonality analysis is an accreted midden or an entire site.

By comparison to modern control studies, we should be able (simplifying greatly) to calculate probability values that correlate increments of the $\delta^{18}O$ proxy curve to water temperature values. When we compare probability curves between species, the problem becomes more complex. However, we have an archaeological precedent for such an analysis in the method used to calibrate radiocarbon years to calendar years, which is an application of Bayesian statistical analysis (see Buck, Litton, and Smith, 1992; Buck, Cavanagh, and Litton, 1996; Buck and Millard, 2004a; Whittle and Bayliss, 2007). I have only begun to develop this idea, but Bayesian statistics offer a way to combine evidences of seasonality from our multiproxy studies. The protocol of monthly interval sampling followed in the most exacting oxygen isotope analyses allows conversion to rank-order data suitable for modeling (Heuzé and Braga, 2008). A very early application of Bayesian analysis to season of capture questions directed at fish otoliths (English and Freeman, 1981) demonstrates the appropriateness of the approach, but modern computer modeling of micromilled samples promises much finer seasonal resolution with an estimate of associated uncertainties (cf. Parnell et al., 2008).

In sum, we need thorough investigations of subsistence seasonality in specific locales occupied for limited periods of time to test the limits of our current range of analytical skills. Specifically, we need to apply traditional zooarchaeological methods, extensive oxygen isotope analyses (correlated by statistical analysis), incremental analysis, morphometrics, and related approaches to well-dated assemblages. Our goal should be to apply and refine the best techniques currently available to adequately sample and precisely define and model with confidence the seasonal component of coastal settlements, providing a platform upon which subsequent studies of other cultural variables and other environmental processes can be built.

NOTES

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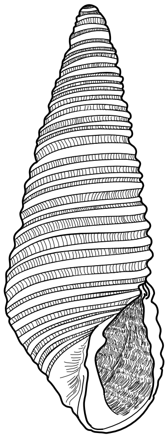

CHAPTER 13
DISCUSSION

ELIZABETH S. WING

The Fifth Caldwell Conference was held in a gorgeous setting free from commercial distractions, making it a pleasant and intellectually stimulating experience. The intent of the conference was to provide a forum for discussion of different aspects of the archaeological research being conducted on the island and directed by David Hurst Thomas over many years. The research has involved a large number of students and archaeologists committed to detailed longitudinal studies of the full array of materials excavated from archaeological sites on the island. St. Catherines Island was occupied for 5000 years, from the two Late Archaic period shell rings right up to the 17th-century Mission Santa Catalina de Guale and then into the plantation era. Archaeological deposits on this coastal island provide evidence for changing environmental conditions and successive cultures of people who inhabited it.

The focus of this year's conference was seasonality and mobility along the Georgia Bight. To be most effective in approaching these issues the research requires a multidisciplinary approach marshalling the specialized disciplines of biologists, zooarchaeologists, archaeobotanists, geochemists, sclerochronologists, and, of course, archaeologists. Such research requires detailed study of the local conditions of the island and its surrounding waters as well as year-long studies of seasonal changes in plant and animal growth to provide baseline data for interpreting evidence of seasonal changes seen in the archaeological remains of animals. The baseline studies would include, but not be limited to, shellfish incremental growth patterns and sizes, fish species compositional changes throughout the year, annual growth and reproductive cycles of game animals, and fruiting of plants. These present-day observations will, of course, show fluctuations from year to year in response to environmental changes such as temperature and rainfall variation, much as they did in the past. Consequently, it may not be possible to estimate seasons of harvest with great precision. However, the more we know about variability in life histories of the plants and animals used by people, the better our understanding of human adaptations to the dynamic coastal setting.

People are generally flexible in adapting to changes in resource availability (Reitz, Quitmyer, and Marrinan, 2009). Despite environmental variations, "data demonstrate the antiquity, flexibility, and richness of a well-established dynamic coastal fishing and hunting tradition in the southern Georgia Bight that existed for millennia before the 17th century" (Reitz et al., 2010: 76). The persistence of the Guale tradition is demonstrated by faunal assemblages deposited during the Mission period indicating that the "Spaniards altered their diet toward local Guale subsistence patterns far more than Guale members of the community altered theirs to conform with Spanish practices." (Reitz et al., 2010: 131).

Timing of events such as those rituals dictated by ecclesiastical calendars requires precision to the month and day of an archaeological deposit and may not be possible based on seasonality studies alone. Evidence of a feast in an archaeological deposit might correspond to a ritual event celebrating Christian commemoration of the holy days of Christmas or Easter. The signature in a deposit for a feast has to be carefully evaluated though it might be expected to include a large source of meat such as pig (*Sus scrofa*) or white-tailed deer (*Odocoileus virginianus*) and accompanied by sweet fruits and nuts.

Many challenges exist in documenting the seasonal foraging patterns of the past and, therefore, it is particularly important to have the opportunity provided by this conference to exchange ideas and describe new and innovative approaches to the complex issues of seasonality. Eleven papers, all involved with efforts to understand seasons of capture or collection of different resources based on material excavated from archaeological deposits, were presented at the 2010 conference. Most importantly, the past conferences have resulted in four publications in the American Museum of Natural History Anthropological Papers series. The papers presented at this conference are now published in this fifth volume of the series. These are landmarks in the progress of research on the archaeology of St. Catherines Island.

Five of the papers are concerned with sclerochronology of the growth increments in the shells of bivalves or otoliths of fishes. Irvy Quitmyer and Douglas Jones applied these studies to the hard clam (*Mercenaria mercenaria*) and validated the season of the increments by oxygen isotope analysis. Nicole Cannarozzi studied growth increments with stable oxygen isotope analysis along the hinges of oysters (*Crassostrea virginica*) and supporting evidence from the growth measurements of the impressed odostome (*Boonea impressa*). Carol Colaninno applied the techniques of sclerochronology to otoliths of hardhead catfish (*Ariopsis felis*) and Atlantic croaker (*Micropogonias undulatus*). Douglas Kennett and Brendan Culleton applied a Bayesian statistical framework for determining site seasonality and contemporaneity. They advocate combining stratigraphic information with multiple AMS ^{14}C dates. They apply this approach to the examination of the occupations of the two Archaic shell rings, St. Catherines and McQueen, and their contemporaneity.

Once clear criteria for seasonal changes are established, most participants advocated the use of multiple lines of evidence to better understand seasonal changes in foraging resources during pre-Hispanic and Mission periods. Multiple lines of evidence can strengthen conclusions or show variation in seasonal indicators. Elizabeth Reitz and Margaret Scarry examined the seasonal availability of a whole array of resources. Knowing when in a normal year buck deer shed their antlers, or fawns are born, or persimmons (*Diospyros virginiana*) ripen, provides clues about the season of capture or collection when the remains are recovered from archaeological deposits. Sarah Bergh also presented information on multiple seasonal indicators including data from hard clam sclerochronology, deer fusion sequences, and fish age and size classes, which the author suggests indicates year-round foraging of these animals. In addition to advocating use of multiple lines of evidence, Fred Andrus and Gregory Waselkov have legitimate concerns about adequacy of the sample sizes and the cost of some analyses.

The conference clearly achieved its purposes in stimulating lively debate and discussion about the accuracy of the methods used to estimate seasonal acquisition and uses of resources. It is, therefore, necessary to take the next step, as many of the authors have, and apply these techniques to gain a better understanding of the seasonal round of the people who lived on the island. The occupation at some sites was apparently of short duration. However, animal remains from these sites show use of resources throughout the year, indicating long-term occupations during each cultural period (Thomas, 2008: 878). Though clam sclerochronology data indicate that clams were gathered predominantly during the winter (mid-December to mid-March), a few clams were also gathered during other parts of the year (Thomas, chap. 1, this volume: fig. 1.3). When sources of seasonal information such as age of deer and the composition of the fish fauna in addition to the clam data are examined and combined for all cultural time periods, these catches appear to gradually decline through the year (seasonal indicators of winter catch are 32%, spring 28%, summer 24%, and fall 17% [Thomas, 2008: 878]). These samples are small, especially for the St. Simons period, and need further substantiation. However, if this is an accurate trend, one might expect a relatively greater dependence on plant resources collected during the summer and fall. Edible plants reported from the Mission era deposits are: chenopod (*Chenopodium* sp.), grape (*Vitis* sp.), blackberry (*Rubus* sp.), and elderberry (*Sambucus* sp.), available in the summer, and maize (*Zea mays*), acorns (*Quercus* sp.), and hickory (*Carya* sp.) nuts available in late summer and fall (Ruhl, 1993: table 15-11).

The difficulty in integrating data from plants with those from vertebrates and invertebrates lies in the relatively poorer preservation of plant remains. The only hopes for recovery of plant remains are when they were deposited in waterlogged conditions of wet sites such as a well or when they have been burned, which renders them into bits of fragile charcoal. The anatomical features of the plant may still be preserved in the charcoal. Integrating these data with those from the generally robust remains of shell and bone is difficult. Nevertheless, some assessment of the relative contribution of all remains to the past diet provides a more complete view of conditions in the past.

Other plants that must have been used but whose remains are invisible are fiber plants essential for making nets, baskets, and weirs. These must have been used to catch the small fishes and those species that are reluctant to bite a hook such as mullet (*Mugil* sp.) found in the faunal remains. Some pottery has net impressions on it, further substantiating the presence of netting in the past (Royce Hayes, personal commun.). There is a long tradition by the Gullah people living on the Georgia Sea Islands for making baskets out of sweet grass (*Muhlenbergia filipes*) stitched together with palm leaves (*Sabal palmetto*). These plants are available, as is bear grass (*Nolina* sp. or *Yucca* sp.), which may have been used for netting (Royce and Christa Hayes, personal commun.). Weirs and baskets might also have been made using cane (*Arundanaria gigantea*), which apparently became quite abundant in response to clearing during the Mission period (Donna Ruhl, personal commun.). Using fiber plants to make baskets and nets would have been essential to catch small fishes, and to carry and store plant and animal products.

In addressing issues of mobility, many important resources known to have been used throughout the year would have been within easy reach from the forest and shore margin. Or they would have been within the economic foraging distance of 10 km (Thomas, 2008: 245). Furthermore, transport would have been much easier with nets and baskets. Along the marine edge, access to fishes, shellfish, diamondback terrapin (*Malaclemys terrapin*), raccoon (*Procyon lotor*), and white-tailed deer is documented (Reitz et al., 2010). During the fall, the mast crop would have attracted both people and mammals such as deer and raccoon, creating an opportunity akin to garden hunting which might have made hunting more successful. The maize crop would also be subject to plunder from many animals and guarding the produce would be garden hunting in the original sense of the term (Reitz et al., 2010). During the Spanish period, sea catfishes (Ariidae) were very abundant in the faunal samples. As scavengers, they were probably attracted to the Spanish mission period disposal of trash in the estuary, another form of garden hunting (Reitz et al., 2010: 162).

Access to fishery resources greatly expands the carrying capacity of the dry land because tides and currents bring nutrients to fishing grounds from coastal waters (Odum, 1971). Likewise, domestic animals such as pigs concentrate nutrients making them available to people who consume the meat. Few remains of domestic mammals were recovered from the Mission period deposits, however (Reitz et al., 2010). Most surprising is the scarcity of dog (*Canis familiaris*) remains in the deposits. Dogs would be expected in both pre-Hispanic and Hispanic deposits and might have been useful hunting companions and assistants.

All of the remains discussed so far are based on excavated archaeological deposits. Every archaeologist wishes at some point to have a first-hand look at the activities of people who lived in the past. Documents written by Jesuits during the Mission period on the island described the situation as the most miserable thing ever discovered. The impression was that the people wandered about and that the soil was too poor to support a crop. The Jesuit mission attempt coincided with an extreme and extended drought, which resulted in a deteriorating resource base. The disruption of the normal subsistence strategies and the demands of the mission resulted in deteriorating health, disease, social and physiological stress, and demographic collapse (Reitz et al., 2010: 133). The short-lived Jesuit mission was followed by a more sustained Franciscan mission. The Franciscan view of the Guale people was quite different. They were portrayed as living in ranked society in sedentary towns and cultivating maize (Thomas, chap. 1, this volume). These two very different eyewitness accounts may both be accurate and reflect the conditions the writers saw during the very difficult climatic disruption while the Jesuits were on the island and the return to more normal, less threatening time during the Franciscan mission (Thomas, 2008).

The expansion of archaeological techniques such as those examining seasonal change in animals discussed at this conference and the further integration of data from such diverse sources as plant charcoal, tree rings, growth increments of mollusc shells and fish otoliths, and remains of fish faunal assemblages are providing ever more complete understanding of human conditions in the past. Eyewitness accounts are, of course, most valuable to have but must be “ground truthed” by archaeology for biases and partial understanding.

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Cover Design: Jennifer Steffey
Book Design and Layout: Kevin B. Havener

On the cover: Backlit thin section of a quahog (*Mercenaria campechiensis*) showing its alternating opaque and translucent shell growth increments. Quahogs, or hard clams (*M. mercenaria, M. campechiensis,* and hybrids), are the most studied of all midden molluscs in the southeastern United States with respect to oxygen isotopes and shell growth increments. These increments may be seen in cross sections of the shells; in the backlit radial thin section of the shell on the cover, transmitted light shows opaque and translucent increments that reflect the periodic differences in the shell microstructures associated with physiological responses to environmental changes in the annual cycle. Quahog growth increments form regularly according to the season and can be used to assess the time during which the bivalves were captured at southeastern U.S. archaeological sites, and surveys of quahog season-of-capture data and their localities can elucidate the movement of human populations throughout an annual cycle. Photograph by Irvy R. Quitmyer.

The St. Catherines Island research ... is a stellar example of what long-term, detailed, and interdisciplinary work can contribute to our understanding of the history and human ecology of coastal regions around the world. The Caldwell V conference proceedings extend earlier findings ... and the result is an impressive, informative, and well-focused volume about the archaeology of St. Catherines Island and the Georgia Bight—a book that will be of interest to a broad audience of coastal archaeologists interested in recent advances in seasonality and related issues in coastal settings.

Jon M. Erlandson, Professor of Anthropology, University of Oregon

The volume's strengths arise from its focus on a single set of problems, competing hypotheses about mobility patterns on St. Catherines Island, especially issues of seasonality and chronology. The volume will be very useful to any archaeologist grappling with mobility and seasonality since it presents a multistranded approach to data and the creation of evidence.

Kenneth M. Ames, Professor of Anthropology, Portland State University

Archaeological excavations at coastal sites typically recover multiple biological proxies for seasonal behavior of resources and of people. Questions of seasonality are embedded in much of archaeological research, with answers linked to many aspects of cultures and environments, such as: why is seasonality important to the study of human behavior? What does this knowledge tell us about life in dynamic estuarine systems?

Contributors to *Seasonality and Human Mobility along the Georgia Bight* believe that one must distinguish between patterns of seasonal site occupation (reflecting mobility strategies), seasonal patterns of resource procurement (reflecting foraging and/or farming strategies), site function, and relationships with people on neighboring islands and the mainland. These are very different—if closely interrelated—components of human behavior.

The chapters in the volume presented here address specific methodological issues (such as sample size, intersite and intrasite variability, dating, and defining regional settlement patterns) that remain to be resolved as investigators proceed with substantive applications to the archaeological record of the Georgia Bight. They were originally presented at the Fifth Caldwell Conference, cosponsored by the American Museum of Natural History and the St. Catherines Island Foundation and held on St. Catherines Island (Georgia), May 14–16, 2010.

ELIZABETH J. REITZ is a research associate of the American Museum of Natural History and Professor of Anthropology at the Georgia Museum of Natural History, University of Georgia.

IRVY R. QUITMYER is a specialist in the zooarchaeology of marine people and serves as Environmental Archaeology Collection Manager at the Florida Museum of Natural History, Gainesville, Florida.

DAVID HURST THOMAS is a curator in the Division of Anthropology at the American Museum of Natural History. He has conducted archaeological research on St. Catherines Island since 1974.

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