CHAPTER 16
GEOMORPHOLOGY, SEA LEVEL, AND MARINE RESOURCES: ST. CATHERINES ISLAND

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The abundance, diversity, and accessibility of marine resources available to the prehistoric Native American populations of St. Catherines Island were certainly influenced by a myriad of interacting geomorphological, sedimentological, and ecological processes, played out within the context of sea level change.[1] Any discussion of prehistoric foraging strategies must be ultimately constrained by the accumulation of observational data. Several avenues of ongoing research now offer opportunities for some degree of discriminatory heuristic modeling of temporal changes in the St. Catherines Island marine resource base. This chapter discusses a largely empirical interactive integration of rate and magnitude of sea level change, tidal amplitude, sedimentary dynamics, and developmental evolution of bay and marsh habitats, and how these variables may have influenced the shellfish resources on St. Catherines Island.

OVERVIEW OF LATE PLEISTOCENE SEA LEVEL CHANGE ALONG THE GEORGIA COAST

The shallow Georgia embayment currently extends eastward over 100 km into the Atlantic. There is general agreement that St. Catherines Island and the other Georgia Sea Islands were constructed during the Silver Bluff submergence when sea level rose to 1–3 m above present-day level; these data have been summarized elsewhere (Thomas, 2008: chap. 4; see also chap 1, this volume). The age of the Silver Bluff transgression remains elusive. Although conventional opinion places the last Pleistocene sea level high-

stand at about 125 ^{14}C ka B.P., numerous radiocarbon dates along the eastern U.S. coast have come in at between 25 and 40 ^{14}C ka B.P. Attempts to explain these younger than expected dates in terms of contamination by "young" carbon have not been successful, as the distribution of these dates shows a consistently tight pattern and not the expected array of varying degrees of contamination. Moreover, the number of finite dates zeroing in on 25 to 40 ^{14}C ka B.P. would be less than the number of infinite dates, if contamination were the sole explanation. Either these dates are valid, or explainable in terms of local tectonism, or perhaps, as suggested by Dockal (1995) the rate of past ^{14}C production has not been constant and was influenced by an increase of cosmic ray flux at about 60 ^{14}C ka B.P.

Vibracores completed on St. Catherines Island, along North Beach, Cracker Tom, and at the St. Catherines Shell Ring have likewise produced a number of dates in the range of 25–40 ^{14}C ka B.P. (Linsley, 1993; Bishop et al., 2007; Linsley, Bishop, and Rollins, 2008). Vento and Stahlman (2008; see also chap. 4, this volume) dated the A horizon of a basal paleosol exposed at Yellow Bluff along North Beach at about 22,820 years ^{14}C yr B.P. Fiddler crab burrows in that soil horizon provide evidence of a washover deposit more or less penecontemporaneous with a shell lag date of 22,600 ^{14}C yr B.P. from a vibracore taken along North Beach transect A–A′ (Linsley, 1993) and confirm its proximity to the paleoshore at that date (Martin and Rindsberg, 2008; see also Martin and Rindsberg, this volume, chap. 5).

There is also general agreement that 18,000 ^{14}C years ago much of this was subaerially ex-

posed as sea level was about 100 m lower than at present. Pilkey et al. (1981) reported the results of two vibracore transects, extending into the embayment, one located just opposite the present-day Savannah River. These cores, although widely spaced, penetrated the very thin (about 4 m thick) offshore sedimentary veneer and demonstrated that the initial Holocene transgression following the Wisconsinan sea level lowstand involved an extensive westward movement of barrier island facies. The cores, however, were too widely spaced to permit detailed reconstruction of that migration of the barrier island facies tract, but did provide clear evidence that barrier islands tracked sea level rise, and were not constructed only following achievement of present sea level stability about 5–7 ^{14}C ka B.P. A few vibracores described in the Pilkey et al. (1981) report, completed in their northern transect off Cape Romain, penetrated the earlier Pleistocene and contained some in situ oyster shells that were radiocarbon dated at 22,590 ^{14}C yr B.P. and 25,070 ^{14}C yr B.P., again nicely within the range of the Silver Bluff chronology.

The relative rate of sea level rise following the Wisconsinan regression, on average, must have been slow enough to permit barrier island construction as backbarrier lagoonal deposits and fauna, including the oyster *Crassostrea*, occur in many of the cores. Core spacing was too coarse, however, to determine whether sea level rose gradually or episodically, and whether the barrier island/lagoon facies track moved seamlessly or in a stepwise manner characterized by short-term stability followed by "spurts" of rapid rise. In any case, by between 5 ^{14}C ka B.P. and 3 ^{14}C ka B.P. sea level hovered within a few meters of its present position and the transgressive barrier island/lagoon facies tract lodged against the relict Silver Bluff escarpment. The Silver Bluff escarpment, by this time, was likely erosionally diminished in comparison to its earlier stature. Paleosol 5A on Yellow Bluff, dated at 22,820 ^{14}C yr B.P. (Vento and Stahlman, this volume, chap. 4) is penecontemporaneous with the 22,600 ^{14}C yr B.P. date reported by Linsley (1993) on a cojacent subtidal marine shell lag in core 3, transect A–A′ (Linsley, 1993; Linsley, Bishop, and Rollins, 2008). The paleosol represents an interval of extensive temporal stability and its vertical separation from the shell lag approximates 8 m, providing a crude estimation of the relief of the Silver Bluff escarpment in this area at that time.

Moreover, such a steep gradient suggests that this area of the coast at that time was possibly wave dominated, not tidally dominated. What was earlier a labile facies tract marching (albeit, perhaps, in episodic spurts) over a low relief coastal plain was transformed, by "fusion" to an anchored river-dissected relict shoreline, into a sedimentary regime characterized by imposition of ebb tidal dominance and a type of stability leading to lagoonal/marsh infilling.

OVERVIEW OF HOLOCENE GEOMORPHOLOGY AND SEA LEVEL CHANGE

Thomas (2008: chap. 4; see also chaps. 1, 8, and 9, this volume) summarizes the previous work on Holocene sea level change along the Georgia coast, and details a scenario for concomitant geomorphologic modification, Native American occupation, and resource exploitation on St. Catherines Island, in particular. Highlights of this pattern include:

(1) About 18 ^{14}C ka B.P. the shoreline that fronts present-day St. Catherines Island was around 100 km eastward of its present position and sea level was about 100 m below present MSL.

(2) A relatively rapid early Holocene sea level rise of 1 cm/yr, slowing to about 3 mm/yr occurred by about 7 ^{14}C ka B.P. (7900 cal B.P.).

(3) According to Crusoe and DePratter (1976), extensive oyster beds only developed behind the Sea Islands when sea level flooded freshwater lagoons (5000–4000 ^{14}C yr B.P.; 3780–2530 cal B.C. [5730–4480 cal B.P.]) and the earliest recognizable shorelines (associated with St. Simons artifacts and Late Archaic shell rings) date to this time interval and represent occupation on both sides of the Sea Islands (DePratter and Howard, 1980). Sea level was, at this time, 1–2 m below present level, evidenced by observations of the shell ring basal strata below present marsh surface (DePratter and Howard, 1980; Thomas, 2008; see this volume: fig. 1.5). Zooarchaeological evidence from several shell rings along the Georgia and Florida coasts demonstrates a fully developed estuarine environment during this period (e.g., Marrinan, 1975, 1976, 2010; Russo, 1998, 2002; Quitmyer and Jones, 2000; Russo and Heide, 2001, 2002; Russo, Heide, and Rolland, 2003; Sanger and Thomas, 2010).

(4) This was accompanied by reduction in stream gradients, wetter climate, bay filling, in-

let straightening, narrowing, and deepening, and the development of an extensive salt marsh tidal prism with tidal creeks and estuaries. In addition, this may mark an initial transition from a wave-dominated to tidal-dominated coast similar to, but predating, the scenario postulated by Chowns et al. (2008) accompanying the ~2600 B.P. lowstand and subsequent ~2500 B.P. transgression that resulted in formation of the modern Sapelo, St. Catherines, and Ossabaw inlets.

(5) Present-day sea level was attained in this area by about 3000 cal B.P. (1050 cal B.C.) when shoreward transgression of an early- to mid-Holocene barrier island facies tract anchored against the older (Pleistocene) Silver Bluff shoreline. DePratter and Howard (1981) provided additional evidence of this sea level highstand and Thomas (2008) emphasized its role in expansion of intertidal resources, such as oyster patches. Brooks et al. (1989) reported that, in the South Carolina area, shell middens extensively occur more inland between 3000 cal B.P. and 800 cal B.P. (1050–1150 cal B.C.) due to estuarine expansion (Thomas, 2008; see also chap. 1, this volume). More recent research at middens at Litchfield Beach estuary (just south of Murrells Inlet) produced dates ranging from about 2100 to 600 cal B.C. (Irvy Quitmyer and Chester DePratter, personal commun.).

(6) An interval of sea level lowering and shoreline regression occurred in the late Holocene. DePratter and Howard (1980) indicated that this event occurred about 2500 ^{14}C yr B.P. (550 cal B.C.) and involved a 4 m drop below modern MSL. Transgressions correlate with the breaching of inlets. Thus the original inlets (Blackbeard and Guale) probably date from the highstand prior to 3000 B.P. (?5000–4000 B.P., items 3 and 5 above), the spits date to the lowstand (~2600 B.P.), and the modern inlets (Sapelo, St. Catherines, Ossabaw) date to resumed transgression (~2500 B.P. onward; item 9 below). From the available dates these three breaches all fall between middle Refuge and late Wilmington (Chowns, personal commun.). This postulated regression was also supported by Brooks et al. (1989), who indicated that sea level in the South Carolina area was 3 m to 4 m below present MSL about 3000 cal B.P. (1050 cal B.C.), but rose again between 2400 cal B.P. and 1700 cal B.P. (450 cal B.C. to cal A.D. 250; Thomas, 2008: 44–47). According to DePratter (1977a), this resulted in a significant hiatus in shellfishing, between 3000 ^{14}C yr B.P. and 2700

^{14}C yr B.P. (1260–820 cal B.C.; 3210–2770 cal B.P.) By 2600 ^{14}C yr B.P. (800 cal B.C.; 2750 cal B.P.), sea level again rose and extensive oyster beds reformed (Crusoe and DePratter, 1976).

(7) Detailed studies in Murrells Inlet, South Carolina, by Gayes et al. (1992) and Scott, Gayes, and Collins (1995) focus on a late Holocene sea level highstand between 5300 cal B.P. and 4300 cal B.P. (3350–2350 cal B.C.), followed by a 2 m fall between 4300 cal B.P. and 3600 cal B.P. (2350–1650 cal B.C.). Gayes et al. (1992) also suggest, if their Santee Delta data are included, that the lowstand might actually date somewhat later, roughly 2600 cal B.P. (650 cal B.C.). The highstand reached about 1.5 m below present day MSL indicating that sea level 2650 ^{14}C yr B.P. (700 cal B.C.) was a bit more than 3 m below present level. Relative sea level rise (RSLR) was about 50 cm per century during this event, but slowed to about 10 cm per century after 3600 ^{14}C yr B.P. (1650 cal B.C.) until present (i.e., less than the global average of 18 cm per century; Scott, Gayes, and Collins, 1995: 616).

(8) Thomas (2008: 45) stressed that "high-ranking marine patches" would be negatively impacted during this late Holocene regression, and any midden material would likely be either "eroded away" or "buried beneath 2 m of more recently deposited salt marsh sediments." Over an interval of only seven centuries, salt marsh would have been eliminated from the western side of St. Catherines Island. Oceanward, however, formation of a new barrier island (Guale Island) afforded an eastern source of interisland marsh resources (Thomas, 2008: chaps. 32, 34).

(9) The 10 cm per century rise in sea level following the late Holocene regression led to overtopping and erosion of Guale Island and an eventual renaissance of more westerly estuarine marshland resources. This led Thomas (2008: chap. 4) to predict the existence of few Late Archaic and Refuge-Deptford sites on the northeast side of St. Catherines Island (see also chap. 1, this volume).

We can expect that the aforementioned scenario of change would lead to significant perturbations in the abundance, distribution, and exploitation potential of the St. Catherines Island shellfish resources over time. But we hasten to add that these observations have yet to be tested against comprehensive zooarchaeological analysis of the vertebrate and invertebrate remains from these sites (although considerable

research in this direction is currently ongoing). Further, the nuances that are associated with relative rates of sea level change, wave versus tidal dominance, temporal span of causality, and sedimentological and biological responses have yet to be fully analyzed.

Historically, the availability and utilization of marine shellfish resources along the Sea Islands of Georgia have depended upon the dynamic interaction of several factors. At the risk of oversimplification, this interaction can be categorized.

ECOLOGICAL DIMENSIONS AND CONSTRAINTS OF THE RESOURCES

Shellfish taxa exhibit habitat specificity. This is rather obvious in a comparison of major nearshore between-habitat biotopes, such as shoreface, marsh, and estuarine environments, but it is also applicable to proximal within-habitat situations, such as intramarsh oyster patches, tidal creek clam beds, and higher marsh streamside mussel clumps. The proximity of salt marsh resources to those of the terrestrial hinterland greatly influenced Native American foraging strategies along coastal Georgia, and has become a focus of the analysis of resource exploitation on St. Catherines Island (Thomas, 2008: chap. 10).

GEOMORPHOLOGICAL DIMENSIONS ENGENDERING RESOURCE CHANGE AND AVAILABILITY

Several factors regulate maintenance of salt marsh ecosystems and useful discussions and reviews can be found in Frey and Basan (1985), Fletcher et al. (1993), Jennings, Carter, and Orford (1995), Donnelly and Bertress (2001), Torres et al. (2006), Ward et al. (2008), among others. The most important controls are considered to be those that allow the dominant marsh macrophytes (e.g., *Spartina alterniflora*) to retain their elevational habitat, usually a rather restricted portion of the intertidal range. Specifically, the long-term controls on this dynamic equilibrium involve interactions among sea level, substrate elevation, primary productivity, and sedimentary accretion rate. Geomorphological influence on this equilibrium includes change in tidal amplitude and wave intensity and lateral (along strike) variation in sediment supply and antecedent topography. In the sediment-rich salt marsh estuaries of the southeastern United States, the critical rate of sea level rise, beyond which the *Spartina* growth will be inhibited, is thought to be about 1.2 cm/yr—more than 3.5 times the current long-term rate of sea level rise (Morris et al., 2002). Kirwan and Temmerman (2009) note, however, that the position of a marsh in the tidal frame and the range of tidal amplitude may determine whether a given relative rate of sea level change leads to marsh deterioration or survival. The interplay of controls on marsh growth and survival can perhaps be best viewed in those areas, such as coastal Louisiana and certain other sites along the northern Gulf of Mexico, where the impact of sea level rise is exacerbated by land subsidence, due to tectonic downwarping, sediment compaction, and human impact (Shirley and Battaglia, 2006).

There is a tendency to think about coastal retreat and advance simplistically, in terms of rate and amplitude of sea level change but, in fact, these may not be the primary drivers of change along many shorelines. For example, relative availability of fluvial sediment due to proximal riverine estuaries, along mesotidal to macrotidal low gradient coasts, may determine whether a shoreline exhibits progradation or retrogradation.

ECOLOGICAL DIMENSIONS OF SHELLFISH RESOURCES

For the past three years, zooarchaeologist Nicole Cannarozzi (working with Irvy Quitmyer, Florida Museum of Natural History) has been analyzing column samples from the Late Archaic shell rings on St. Catherines Island (Sanger and Thomas, 2010). Similarly, Sarah Bergh (working with Elizabeth Reitz, University of Georgia) has been studying shellfish frequencies in the late prehistoric middens of St. Catherines Island. But in both cases, this research is ongoing and the results remain preliminary.

Lacking these empirical results based on zooarchaeological data, we have (for present purposes) selected five shellfish known to occur in the St. Catherines Island middens: the quahog *Mercenaria mercenaria*, the eastern oyster *Crassostrea virginica*, the Atlantic ribbed mussel, *Geukensia demissa*, the periwinkle *Littoraria irrorata*, and the knobbed whelk *Busycon carica* (and other busyconine species). All of these (and others such as the stout tagelus, *Tagelus plebius*, and possibly the eastern mudsnail, *Ilyanassa obsoleta*, have been harvested as food resources by Native Americans on St. Catherines Island

(Thomas, 2008: esp. chap. 7).

Mercenaria mercenaria (quahog)

The northern quahog *M. mercenaria* ranges today from Canada to the Gulf of Mexico and archaeological evidence suggests that this latitudinal distribution has existed for millennia. To the south it is replaced by *Mercenaria campechiensis*, the more offshore, subtidal southern quahog. *M. mercenaria* exhibits a notable cross-latitude change in habitat preference. From North Carolina to Canada it generally occurs intertidally and subtidally in open embayments, whereas to the south (South Carolina to Florida) it prefers shallow subtidal to intertidal portions of salt marsh tidal creeks and oyster patches. This pattern correlates strongly with the change from a wave-dominated coastline north of Cape Fear, North Carolina to one of tidal domination along the southeast U.S. Atlantic coast. Moreover, this has led to extensive commercial harvesting of this resource to the north, where its occurrence is more predictable and subject to mechanical harvesting but, to the south along the Georgia coast, it is subject to the vagaries of hydrodynamic tidal flow associated with salt marsh creeks; it is thus a less predictable resource, exploitable only by hand-picking or raking (Rollins, Prezant, and Toll, 2008), even though densities may reach more than 100 individuals per square meter (Walker, 1987).

Quahogs exhibit variation in growth rate associated with habitat (Jones et al., 1990; Quitmyer and Jones, 2000) and, in general, larger individuals are found in the more subtidal populations. They are shallow infaunal organisms, burrowing into shell, sand, silt, or mud, but can also occur clustered around *Spartina* rhizomes or nestled among oyster valves. Life spans can approach 40 years but *M. mercenaria* can reach harvestable size in the southeastern United States in only two to three years.

A multiyear study of *M. mercenaria* at Engineers Point, St. Catherines Island, demonstrated the "top-down" environmental forcing mentioned above on populations of this species in such tide-dominated regimes (Prezant, Rollins, and Toll, this volume, chap. 12). In this study, three intertidal clam stations exhibiting varying substrate conditions were repeatedly sampled over a three-year period. All clams were harvested from all sites, and they were replaced after marking and measuring. Even though only marked clams were replaced after each defaunation, by the time

of the next harvest, all of the sites contained a mix of both marked and unmarked clams. The sampled clam populations were repopulated by recruits, due to hydrodynamic movement of adult clams and not by larval settlement. The greatest rate of clam movement in this mesotidal regime occurred at the site experiencing the greatest amount of hydrodynamic change (determined by laser level measurement of substrate change). Only a few years after this study, recruitment at this site ceased apparently due to hurricane-induced change. A similar experiment, at the same time, was performed in a tidal creek on the eastern side of St. Catherines Island. In that situation, a point-bar population of quahogs subjected to even stronger tidal flow (up to 1.1 m/sec) was selected for mark and recapture. In such ebb tidal environments the "downstream" side of point bars typically harbor flanking lower energy runnels sandwiched between the point bar and marsh and this serves as a catchment for dislodged clams. Marked clams were only lost from the point bar, not from the runnel, demonstrating again the prevalence of top-down hydrodynamic winnowing and adult recruitment in this regime. These processes could be expected to result in a paucity of multisized cohorts and relatively uniform sized valves in shell middens; this might easily be incorrectly attributed to selective harvesting of this resource. Description of the methodologies and more detailed results of these studies are presented in chapter 12 (Prezant, Rollins, and Toll, this volume).

Based on this study, Rollins, Prezant, and Toll (2008: 27) ventured the following a priori expectations: (1) "Shell middens in the coastal southeastern U.S. should often lack a significant quahog component, and display a temporal variation in quahog abundance, a result of the more stochastic distribution of southern quahog populations," (2) "Shell middens in the coastal southeastern U.S. should often exhibit stratigraphic zones with very high densities of quahog shells, reflecting extensive but intermittent exploitation of very localized high density populations," (3) "The more predictable northern populations of quahogs should have been more vulnerable to over-exploitation by humans (as they are today). One might expect a pattern of quahog distribution in shell middens that displays a dwindling of average valve size, perhaps followed by complete disappearance of the species from the record—the result of either extirpation of the resource or

abandonment of harvesting due to small return for investment of time," (4) "On the other hand, the more southerly quahog populations had a built-in resistance to over-exploitation … unpredictably distributed by hydrodynamic control and … protected by refugia," (5) "The relative lower stability of the southern quahog resource base might have led to lessened utilization of that species by Amerind populations of the southeastern U.S. and to intervals of greater dependence on other resources, either marine or terrestrial," and, finally, (6) "Analysis of size/age data of quahogs found in shell middens provides very little information about abundance of the food resource because there is a strong habitat control on size and growth rate. Thus, different sizes may not reflect age or abundance of quahogs but rather a change in harvested habitat…."

CRASSOSTREA VIRGINICA (EASTERN OYSTER)

Over four decades, archaeologists have systematically sampled aboriginal shell middens from all time periods on St. Catherines Island (Thomas, 2008: chap. 20), and considerable additional research is currently being undertaken by Irv Quitmyer, Nicole Cannarozzi, and Sarah Bergh. It is abundantly clear that oyster valves are the most common bivalves in these midden deposits. Beyond all doubt, this marine resource was heavily exploited by human populations over the past 5000 years (e.g., Marrinan, 1975, 2010; Quitmyer, 1985; Quitmyer, Hale, and Jones, 1985; Quitmyer, Jones, and Arnold, 1997; Reitz and Quitmyer, 1988; Russo, 1998, 2002; Quitmyer and Jones, 2000; Russo and Heide, 2002; Reitz, 2004; Quitmyer and Reitz, 2006). More recently there may have been a significant decline in the areal extent of oyster beds in coastal Georgia. Drake (1891) estimated an areal extent of 8.9 ha of oysters in the Duplin River (along the southwestern margin of Sapelo Island), whereas a more recent survey by Walker and Cotton (1981) reported only 4.4 ha of oyster beds. This loss is attributed to disease, lowered freshwater aquifers, and overfishing. But Walker and Cotton (1981) also suspect that Drake's estimation of oyster abundance may have been "unrealistically high."

Recent extirpation of oyster resources has occurred both north and south of coastal Georgia, as well. Oyster bar acreage in the Maryland portion of Chesapeake Bay apparently decreased more than 50% between 1907 and 1982, possibly due to the use of mechanical harvesters (instead of hand tongs) that destroy oyster reefs, although other factors, such as overfishing, increased susceptibility to pathogens, and environmental degradation may be involved. Independent lines of evidence indicate that oyster density in that region is now about 4% of what it was in 1884 (Rothschild et al., 1994). Harding, Mann, and Southworth (2008) noted, in addition, that oysters were dominant in Chesapeake Bay before European colonization, but "four centuries of harvest pressure, habitat degradation, … and disease activity…" have taken their toll. Moreover, in the Chesapeake James River region, "historic oysters had significantly faster growth rates than modern oyster populations" (Harding, Mann, and Southworth, 2008). Similarly, Gunter (1938) noted midden evidence that precolonial oysters harvested from coastal South Carolina were significantly larger (61% longer and 43% wider) than modern ones (cited in Thomas, 2008: 98). To the south, in the Canaveral National Seashore, Florida, a 57-year study record (1943–2000) identified about 60 oyster reefs with dead margins in proximity to navigation channels, an increase of 16.4% over this time interval (Grizzle, Adams, and Walters, 2002). Although water movement is essential to healthy oyster reefs, wave action can strongly affect the vertical growth and morphology of intertidal reefs; this interaction has apparently received very little study to date. Grizzle, Adams, and Walters (2002: 12) summarized the theoretical impediments posed to intertidal oyster reef development by excessive water movement, listing "vertical accretion of the reef surface to an elevation too high in the intertidal caused by waves, smothering and substrate instability caused by excessive sediment transport, and inhibited larval settlement caused by sediment ('grit') movement." They also indicated that a reef "can be physically moved by wave energies, resulting in a range of responses from slow migration to total destruction, much in the fashion that barrier islands migrate shoreward … under increased wave energies." In contrast to the dead margin phenomenon, the central areas of intertidal oyster reefs often exhibit dead oyster valves surrounded by living individuals (the so-called "senescent" stage of an oyster reef; Bahr and Lanier, 1981; Grizzle, Adams, and Walters, 2002).

Although environmental degradation and disease have likely affected the demography of recent oyster beds along the Atlantic coast, it is more difficult to accurately assess the sig-

nificance of historic changes in the size of individual oysters. The challenge for archaeologists investigating such patterns of historic change in size of oysters (and other molluscs, for that matter) has been whether to attribute the midden record of size change to the stress imposed by overexploitation, or to the harvesting of diverse habitats containing oysters exhibiting disparate growth rates.

Eastern oysters are, indeed, found today in diverse habitats, ranging from isolated patches in intertidal marsh muds to the firm substrates of more extensive subtidal reefs. From North Carolina to east-central Florida, intertidal oyster reefs predominate. In general, subtidal oyster shells are larger and rounder than the elongate shells growing in intertidal muds (Kent, 1992). Dame (1972) indicated that subtidal oysters contain about 40% more meat, by weight, than intertidal oysters of comparable size (cited in Thomas, 2008: 96). Growth rate in oysters positively correlates with salinity and larger shells afford allometrically increased surface area that effectively translates into a positive feedback where, in subtidal habitats, the larger oyster valves provide increased settlement area which, in turn, leads to larger patch size (increased resource potential; Kraeuter et al., 2009; Harding, Mann, and Southworth, 2008). A comparison of oyster "condition index" in five beds in Sapelo Island and Doboy Sound (Georgia) found that oysters living in rivers and sounds had significantly higher meat quality compared with those occupying sites with lower nutrient flux and width (i.e., tidal creeks; Mercado-Silva, 2005).

In coastal Georgia, oyster patch demography is affected by season of the year. Individual oyster beds typically experience rather stable numbers of living oysters during the winter months, with an increase in spring due to increased spat fall. But, in the fall, number of individuals decreases as the oyster disease *Perkinsus marinus* increases (Walker and Cotton, 2001). Lower intertidal and subtidal oysters are more vulnerable to predation (e.g., by whelks, pea crabs, etc.) and disease because many of these vectors of oyster mortality are ecologically excluded from the higher intertidal marshes and tidal creeks.

Oysters in coastal Georgia occur in diverse microhabitats. Crook (1992) described four types of oyster occurrence in Georgia marshes: "Singles" are small patches housing from two to six individual oysters found in mud substrate "with-

in the lower portion of the intertidal zone along small tidal creeks." "Clusters" are clumps of from 10 to 30 individuals attached to firmer substrates along tidal creek channels, or in mud on tidal flats. "Banks," he noted, consist of clusters of 30 or more attached oysters found along larger tidal creek levee margins forming "linear aggregations … from 2–4 metres wide" and "50 m or more in length." Finally, "reefs" are "very dense and closely spaced clusters of 30 or more oysters each, also located along larger tidal streams." Reefs are wider than banks, up to 20 m long, with more densely spaced individual oysters. Crook (1992) further noted that oyster shell morphology varied with intertidal microhabitat. He stated that single oysters occupying hard substrates tend to exhibit rounder shells but cluster, bank, and reef inhabitants tend to be "long and slender." Frey, Basan, and Smith (1987) had also mentioned that oyster individuals "dwelling on the salt marsh surface are diminutive and sparse relative to those along creek banks, and tend to be more rounded in shape." Crook (1992) sampled, as well, oysters from archaeological sites on Sapelo Island, and was able to statistically demonstrate that the microhabitat oyster growth forms were identifiable from shell middens (see also Kent, 1992).

Frey, Basan, and Smith (1987) present a more detailed description of oyster morphology and habitat in Georgia salt marshes, noting that the species can be found mainly in the lower portion of the intertidal zone up to about one-half tide level but isolated clumps are found higher in the ponded marsh areas. They indicated that "oysters form small to large beds along Georgia tidal creek banks … and estuary margins … they also form small beds on small point bars … or within shallow creek channels…, and small isolated clusters in ponded water marshes (Frey, Basan, and Smith, 1987: 3). Subtidal oysters are, in their words, "riddled" with *Cliona* (sponge) borings and much more prone to predation by other organisms than are intertidal oysters. These observations provide the paleoecologist and archaeologist with a potential tool for identification of tidal depth of origin in both the fossil record and in midden materials (Wiedemann, 1972; Frey, Basan, and Smith, 1987). Detailed analyses of epibionts (such as *Cliona*) that inhabited harvested oyster and clam shells found in middens remains a potentially powerful tool for identification of exploited habitats—one that has, thus far, been barely utilized. By

the same token, some macropredators of shellfish (especially shell-boring gastropods) only attack subtidal to lower intertidal prey and rarely invade the more back-barrier marshland habitats. Shellfish valves often display a record of unsuccessful predation by these gastropods and evidence of unsuccessful (aborted) attacks are often visible on the shells in the form of incomplete boreholes caused by naticids and muricids, or the chip marks from apertural wedging by whelks. In the low intertidal to subtidal portions of larger St. Catherines Island tidal creeks, the boring pholad clam *Diplothyra smithii* can frequently be found clustered along the siphonal margins of large quahog shells. This infestation is visible today in the upper reaches of Seaside Inlet and similar occurrences on large quahog valves exhumed from the relict muds of the former Guale Marsh at North Beach provides additional evidence for the former existence of major tidal creeks in that area of the island. Clearly, detailed examination of shell midden material might provide significant clues to sites of shellfish harvesting.

Crassostrea virginica is a protandric hermaphrodite (that is, some older males become females) and the larger (shell length) individuals tend to be females. Under intense harvesting pressure, where larger individuals are preferentially taken, a populational decrease in the number of females occurs, with a concomitant decrease in average shell length (Kennedy, 1983; Rothschild et al., 1994).

Recruitment of oysters in the southeastern United States is highest in the intertidal zone (O'Beirn, Walker, and Heffernan, 1996). Recruitment of oysters in coastal Georgia is extended, lasting for six months (May through October), peaking between July and September (O'Beirn, Walker, and Heffernan, 1995). The distribution of oysters, whether intertidal or subtidal, is generally more predictable than that of clams especially in strong hydrodynamic regimes such as coastal Georgia. Unlike clams or many other species in the midden, oyster spat preferentially affix to the hard substrata afforded by other oyster valves, and oyster patches and reefs represent a long-term multigenerational resource. Oyster settlement is enhanced by water-soluble chemicals that are effective in strong hydrodynamic flow as well as in still water (Turner et al., 1994). Even so, there are notable differences between the resource potential of a small marsh mud cluster of oysters and the larger reefoid patches of open embayments.

Geukensia demissa (Atlantic ribbed mussel)

The Atlantic ribbed mussel is a major component of the salt marsh fauna of the eastern coast of the United States, ranging from Maine to northern Florida. In the Georgia Sea Islands this species is typically found in transitional and low-marsh back levee habitats where it is found attached by bysall threads in moundlike aggregations (Kuenzler, 1961; Smith and Frey, 1985; Frey, Basan, and Smith, 1987). *Geukensia* mounds, up to 15 cm high and 1 m in diameter, comprise as much as 7.8% of the area of back-levee ponded marsh environments, and the feces and pseudofeces of this species make up a large proportion of Georgia salt marsh mud deposits (Smith and Frey, 1985). Frey, Basan, and Smith (1987: 4) note that the vertical range of *Geukensia demissa* extends up to mean high water, and that it occurs only sparsely in the lower intertidal and subtidal areas, apparently due to increased predation pressures.

As is the case with many sessile marsh molluscs, the size, growth rate, and settlement of *Geukensia* decreases with increasing tidal height. On the other hand, predation intensity decreases with increased tidal height, and the moundlike aggregations afford additional protection (Bertness and Groshotz, 1985). The semiendobenthic habit of this species protects it from desiccation and temperature shock, and permits it to inhabit a higher intertidal range than most mollusc species (Frey, Basan, and Smith, 1987: 12).

Although *Geukensia demissa* shells commonly occur in shell middens of coastal Georgia, there is very little available ethnohistoric information regarding exploitation of this resource by southeastern Indian populations (Thomas, 2008: 101). As is the case with many estuarine shellfish species, this species exhibits annual changes in soft tissue weight, independent (uncoupled) from shell growth. This is most common in older individuals and is often correlated with onset of the spawning cycle (e.g., oysters). Borrero and Hilbish (1988) noted that, for *Geukensia demissa* in coastal South Carolina, this uncoupled growth is more pronounced than it is for that species in other locations at higher latitudes. They attributed this to an extended growing season in South Carolina, and this would likely apply as well to coastal Georgia. This aspect of growth in some exploitable shellfish species has obvious archaeological implications for interpretation of caloric

intake as recorded in shell middens, but appears to be largely attributable to seasonal change and not longer life spans. However, Franz (1993) noted that *Geukensia demissa*, at a site in Jamaica Bay National Wildlife Refuge, N.Y., exhibited a "decrease in both shell and biomass with increasing shore level," but "shell metrics (length, height, width, weight) did not differ between shore levels." Thus, these patterns of growth may or may not be significant for the analyses of midden material over extended temporal spans. *Geukensia demissa* also has a very thin aragonitic shell, and that likely would lead to a significant taphonomic overprinting affecting its recordable fidelity in shell middens. Shell dissolution in acidic marsh mud would therefore be more pronounced in this species than would be the case with calcitic-shelled mollusc species.

Littoraria irrorata (marsh periwinkle)

Marsh periwinkles are commonly found in Georgia Sea Island shell middens and there appears to be little doubt that they were a foraged dietary item in the southeastern U.S. Native American smorgasbord (see Thomas, 2008: 107, and references therein). *Littoraria irrorata* is a conspicuous inhabitant of marsh cordgrass (*Spartina*), where it voraciously grazes on fungi coating the wounds on stalks and leaves induced by its radular scraping (Silliman and Bertness, 2002). Periwinkles occupy both short and tall *Spartina,* and dense accumulations (about 1200 individuals per square meter) of *Littoraria irrorata* have been indicted as significant destroyers of marsh cordgrass canopy, especially the nitrogen-rich tall *Spartina* zones where they can totally destroy the cordgrass within eight months, converting it to a barren mudflat. Silliman and Bertness (2002) noted that *L. irrorata* density, in turn, is predator-controlled (largely terrapins, blue crabs, and mud crabs) and fluctuations in top-down predation leads through trophic cascading to observed patterns of growth and destruction of marsh cordgrass (for a contrasting interpretation, see Kiehn and Morris, 2009). Marsh periwinkles, in coastal Georgia, are most abundant in areas of high marsh, whereas recruitment occurs more commonly in relatively quiescent low marsh areas, in closer proximity to the edges of tidal creeks and presumably the source and a mechanism for dynamic delivery of periwinkle larva (Silliman and Bertness, 2002).

Fierstien and Rollins (1987) described the morphometric variation and demography of several high marsh populations of *L. irrorata* on St. Catherines Island, and compared these modern populations with one subrecent but undated (fossil) sample ($N = 89$) collected from relict marsh mud exposed on Middle Beach between McQueen and Seaside inlets. They noted that present-day average adult size was expressed by the fossil individuals in fewer whorls, indicating more rapid average growth in the fossil population. Thomas (2008: chap. 20) presented preliminary data from the St. Catherines Shell Ring (9Li231), a Late Archaic midden accumulation that contained a number of larger than average (compared with modern) specimens of *L. irrorata* (see also Sanger and Thomas, 2010). This, in combination with the demographics of the fossil population (Fierstien and Rollins, 1987), suggests a temporal change in growth dynamics of this species, perhaps connected with environmental modification or predation intensity.

Busycon carica, Busycotypus canaliculatus, and *Busycon contrarium* (whelks)

Whelks occur frequently in shell middens of the southeastern United States, and were exploited by Native Americans for food and as a toolstone source for construction of beads and implements (Thomas, 2008: 111; Blair, Pendleton, and Francis, 2009). They were also widely traded throughout the American Southeast and were particularly important in the Black Drink ritual practiced there (Hudson, 1979). Prezant et al. (2002), in their survey of the modern macroinvertebrate fauna of St. Catherines Island, listed several species of whelk: the knobbed whelk, *Busycon carica*, the channeled whelk, *Busycotypus canaliculatus*, the lightning whelk *Busycon contrarium*, and the diminutive Kiener's whelk *Busycon carica eliceans*. Knobbed and channeled whelks range from Cape Cod, Massachusetts to Cape Canaveral, Florida and, in 1978, a fishery harvesting these species was initiated by shrimpers along South Carolina barrier islands and it quickly became the largest subtidal fishery in the United States. Since 1980 a whelk fishery, harvesting these species, has existed in coastal Georgia. However, in both states production of whelks peaked in the 1980s and has since declined, following overfishing due to poor shrimping years (Eversole, Anderson, and Isely, 2008).

The knobbed whelk is more abundant than the

other large whelk species in the coastal waters of the southeast United States; consequently more is known about its natural history (Walker, 1988). During spring and fall months both the knobbed whelk and (to a lesser degree) the channeled whelk can be readily collected alive along the lower intertidal shoreface and on oyster patches along salt marsh tidal creeks, as they prey on bivalves, wedging and breaking the shells of their prey using their outer apertural lips. During their "hunt," knobbed whelks often occur partially buried in sand, leaving a characteristic trace impression on the sand surface (Thomas, 2008: 113). Hunting is often carried out by "herds" of whelks, and they can easily be harvested by human foragers during these activities. Knobbed whelks are long-lived (average age of over 16 years) and sexually dimorphic, with adult females much larger than adult males (Power et al., 2002). Commercial hauls routinely display more females than males, contributing to the short life of this shellfishery along the South Carolina and Georgia coasts (Eversole, Anderson, and Isely, 2008). The vulnerability of this resource is pronounced today, and may have been also when it was manually foraged by Native American populations. Large numbers of living whelks have been observed lethargic and exposed on the intertidal shoreface during short-term anoxia events induced by natural or anthropogenic disruption of normal wave patterns and circulation. One such anoxia event was anecdotally noted along North Beach, St. Catherines Island, in October 1990 during an unusually large spring tide (range of 9.3 m; Prezant et al., 2002: 22). Therefore, as a manually foraged dietary marine resource, whelks would probably have been preferentially exploited by aboriginal populations during summer months while in predatory swarms and/or opportunistically during anoxia events.

The knobbed whelk and the lightning whelk exhibit very similar trophic positions and prey choices and are typically not found together, perhaps due to competitive exclusion. The channeled whelk is an occasional nocturnal feeder and unlike *B. carica* and *B. contrarium*, is commonly attracted to dead bait in crab traps (Walker, 1988; Edwards, 1988). Edwards and Harasewych (1988) noted that "busyconine species are distributed across most of their collective ranges in pairs, containing one *Busycon* species and one *Busycotypus* species." Such differences, although small-scale, might nevertheless affect resource distribution and be discernible in the shell midden record.

GEOMORPHOLOGICAL DIMENSIONS OF SHELLFISH RESOURCES

The aforementioned ecological constraints on shellfish distribution along coastal Georgia have been determined by time-static study of recent populations of these species. Although this transferred ecology approach provides invaluable insight into "deeper"-time paleoecology and archaeology, it inevitably suffers from a lack of input that might be provided by scenarios of change that were uniquely played out over the vast expanse of the Holocene. For St. Catherines Island these deep-time scenarios are the subjects of diverse and ongoing research, providing a rich, but continually evolving, hypothetical framework with myriad geomorphological dimensions. The following discussion represents a largely heuristic approach to exploration of these temporal geomorphological interactions and to retrodiction of their influences on marine shellfish habitats and resources.

Wave versus Tidal Dominance

The Georgia Sea Islands experience ebb-dominant tides with a mean amplitude of 2.4 m and ebb flow velocity that can approach 130 cm/second (Frey and Howard, 1988). This type of tide-dominated coast is quite unlike that to the north where wave dominance is the rule. Has ebb tidal dominance always characterized the St. Catherines Island shoreline? Chowns et al. (2008; see also Chowns, this volume, chap. 9) suggested that high sea level stands led to a tidal dominated coast whereas low stands resulted in wave dominance. Moreover, he postulates that during highstands of sea level some of the major inlets between the sea islands of Georgia straightened, effectively pirating former salt marsh estuarine river systems. The Ogeechee River, he suggests, switched from the Seaside/McQueen area to St. Catherines Sound, and later to Ossabaw Sound. The Newport River migrated from the present-day St. Catherines Island South Beach area southward to between Blackbeard Island and Sapelo Island, and then northward again to the modern Sapelo Sound.

Other sedimentary wrinkles accompany Chowns' model, and implications for the distri-

bution of shellfish resources could prove to be significant. On a regional scale along the southeastern United States and over extended time, the northern and southern interfaces between a wave-dominated coast and a tide-dominated coast may have changed with fluctuations in sea level (Chowns, 2008) and this might have correlated with major changes in the overall availability of shellfish to Native American populations—perhaps evidenced by noticeable shifts in dietary preferences. Chowns (2008) hints at such a correlation by suggesting that the 3 m regression between 4300 and 3600 cal B.P., noted by De-Pratter and Howard (1981), Gayes et al. (1992), Colquhoun, Brooks, and Stone (1995), and Scott, Gayes, and Collins (1995), may have led to a wave-dominated system and major ecosystem change. Chowns notes that "Archaeologists identify this still stand as a time of major change in the coastal ecosystem that apparently disrupted the St. Simons cultural phase (4350–3000) and led to replacement by the younger Deptford, Swift Creek, Wilmington, and Savannah phases (2400–450 B.P.)" (Chowns, 2008: 157).

A reasonable heuristic approach to analysis of the potential marine resource effects accompanying changes in wave and tidal dominance along the Georgia coast might involve examination of comparable low-gradient coastlines elsewhere. The microtidal, wave-dominated Gulf Coast along the Florida Panhandle has received intense geological scrutiny for decades, and provides some such insight (see later discussion of "Ecosystem Changes").

Proximity to Hinterland: Foraging and the Degree of Resource Separation

The interface of marine and terrestrial resources was highlighted by Thomas (2008: esp. chaps. 10 and 11) in his discussion of optimal foraging on St. Catherines Island, particularly with respect to the central place foraging model describing various field processing and transport strategies. Thomas (and other researchers) has noted that the rise and fall of sea level could dramatically change the exploitation potentials of marine and terrestrial resources, and that these changes might be in evidence upon analyses of coastal archaeological sites (Bailey and Flemming, 2008). Even a moderately rapid 2 m drop in sea level along the Georgia Bight, under present conditions of a very low onshore/offshore bathymetric gradient, in addition to imposition of a wave-dominated

system (as discussed above) would likely expose a vast expanse of barren coastal margin, and it would probably be millennia, even under optimal climatic conditions, before mature forest cover and other aspects of hinterland diversity could be established. An elevated sea level would compress this interface, juxtaposing marine and older terrestrial resource bases, rendering both available to foraging.

If a Native American population existed close to the carrying capacity of the environment and exploited both marine and terrestrial resources, under conditions of sea level lowering along a broad shallow shelf, the degree of separation could be expected to more quickly become an impediment to joint exploitation of these resources than it might along a narrow, steep shelf. As the land/sea interface widens, during sea level lowering, the more inland archaeological sites might be expected to display evidence of dwindling marine resources. Perhaps there would be a gradual overall decrease of such evidence (as well as major change in harvested species due to habitat modifications), and examples of resource overexploitation culminating in sudden absence, when isolation (separation from marine resource base) reached a "tipping" point. Bailey and Craighead (2003) point out that it is generally assumed that a distance of 10 km represents a maximum for daily subsistence trips.

Thomas (2008: 265–271) constructed a case in support of the central place foraging model for the foraging populations on St. Catherines Island over the past five millennia. Central place foraging focuses upon exploitation of diverse resources engendered by long-term residential stability at optimal locations. Thomas points out that residential proximity to hinterland resources would be critical, even for populations exploiting predominantly marine resources. Under such conditions, shoreline position becomes exceedingly significant and even a relatively slight lowering of sea level played out over a century scale along the Georgia Bight might be reflected in the archaeological record by first a decrease and then absence of marine shell material.

Before the degree of separation became critical in this scenario, one might expect to see other nuances in the St. Catherines Island archaeological marine shellfish record. For example, marsh shellfish "targets" should be impacted early on as marshland becomes increasingly restricted (Reitz and Quitmyer, 1988; Reitz, Quitmyer, and

Marrinan, 2009). Shoreface resources, such as whelks, and nearshore resources, including fish, turtles, etc., might remain in the record after the disappearance of marsh species. This projected pattern would be quite unlike that expected in a steeper coastal intertidal setting, especially a rocky coast.

LATERAL VARIABILITY

Lateral, or along-shore, variability in the resource base would change with sea level rise and fall. St. Catherines Island currently displays not only diverse proximal marine and terrestrial resources, but habitats of resource species exhibit great lateral variation as a result of relative temporal stability and low rate of sea level change. The inherited stability of the Silver Bluff island core combined with a few millimeters per year of sea level rise permit simultaneous growth and development of marshland along portions of the island while marsh loss, erosion, and ebb delta and inlet modifications occur at other island sites. In other words, lateral habitat diversity correlates with relative sea level stability and contiguous presence of an "inherited" mature hinterland. Such would not have been the case during sea level lowering.

ONSHORE/OFFSHORE VARIABILITY

Onshore and offshore variability in the resource base would also radically change with sea level rise and fall. There would be not only, as mentioned previously, an increase in the degree of separation of hinterland and marine resources during a prograding shoreline, but one would also expect rapid habitat change in marine environment and overall decrease in marine resource diversity. On the other hand, a high local rate of relative sea level rise might have occurred along the Georgia Bight due to various combinations of tectonic activity, inlet switching and change of sediment supply, and episodic change in eustatic sea level. This rise would have had rather predictable effects on the transitional states of coastal vegetation (and their respective resources), such as coastal gradations between marsh and more landward shrub- and forest-dominated states. Under such conditions of more rapid sea level rise, physical loss of marshland occurs primarily along the seaward edges and marsh species (again, with attendant resources) migrate landward, replacing shrub and forest species (Brinson, Christian, and Blum, 1995; Shirley

and Battaglia, 2006; see figs. 16.1, 16.2).

The subtleties of ecosystem changes in coastal wetlands accompanying sea level rise have been, in general, little studied. However, Brinson, Christian, and Blum (1995) presented, for the Virginia Coast Reserve, detailed scenarios of change that might provide a theoretical base applicable to the Holocene geomorphic evolution of St. Catherines Island (fig. 16.2). Defining "state" changes as "transformations from one ecosystem class to another" they recognized four "patterns" that would likely accompany combinations of dynamic interactions both at the marsh-estuarine margin (prograding versus eroding) and at the terrestrial-marsh margin (migrating landward versus stalling). With only slight modification, each of their scenarios might apply to potential geomorphic change on St. Catherines Island under conditions of varying rate of sea level rise (episodic fast versus slow gradual), variation in slope gradient (low plain versus escarpment), variation in sediment supply ("jumping inlet" model of Chowns et al., 2008; see also Chowns, this volume, chap. 9), and tidal intensity (wave versus tidal dominance). The following geomorphic conceptualization, Brinson, Christian, and Blum (1995) noted, omits an important component of resource development—i.e., the more or less internal ecosystem dynamics, both biotic and abiotic, that take place at a fixed site as these transitional states interact. Moreover, add to all of this the variables associated with Native American foraging strategies and the situation becomes complex indeed (Thomas, 2008: esp. chap. 35).

OVERLAND MIGRATION AND MARSHLAND PROGRADATION: This is the classic condition of a prograding salt marsh estuary under abundant sediment supply, and one that has been applied to the evolutionary development of the expansive modern salt marsh estuaries along the Georgia coast (Frey and Basan, 1985). The combination of sediment abundance, enlarged tidal amplitude, and decreased wave intensity converts subtidal estuary into intertidal marshland. Degree and rate of overland migration of transitional marsh vegetation depends upon the gradient of the landward slope (fig. 16.2A). To the extent that it results in overall expansion of clam- and oyster-rich intertidal marsh, this scenario affords optimization of marsh resources.

OVERLAND MIGRATION AND MARSHLAND EROSION: Conditions of sediment starvation in the face of relatively fast-rising sea level leads to

seaward erosion of marshland and, depending on the rate of low-marsh flooding, this loss can occur over the marsh interior as well as at the seaward edge (fig. 16.2B). Sediment starvation can occur following changes in coastal riverine source, inlet switching, climate, or wave/tidal dynamics. As in the first condition (above), the degree of overland migration depends on the coastal gradient.

STATIONARY LANDWARD, PROGRADING MARSHLAND: Under conditions of a steep shoreward gradient, marshland encroachment might be abruptly halted. If there is adequate sediment supply and the rate of sea level rise is slow to moderate, the seaward marsh edge would prograde (fig. 16.2C). Some of the fringing marshes that abut the steeper Silver Bluff escarpments of St. Catherines Island fall into this category.

STATIONARY LANDWARD, ERODING MARSHLAND: The tug of war (fig. 16.2D) between marsh progradation and erosion is visible today in many of St. Catherines Island fringing marshes, especially along the eastern margin of the island (e.g., North Beach) where ebb tidal sediment supply is constantly changing.

ECOSYSTEM CHANGES

The four geomorphic categories of Brinson, Christian, and Blum (1995) were developed under the constraint of slow gradual sea level rise. They recognized that ecosystem dynamics (espe-

cially the biotic factors) complicate the resultant patterns of marsh development and distribution. Understanding the effects on shellfish resources demands the integration of biotic (organismal) and abiotic (geomorphic) influences. With slow sea level rise, ecosystem states would be expected to change over time from a forest to a subtidal benthic system (Brinson, Christian, and Blum, 1995). On St. Catherines Island, upland forested bluffs (live oak, longleaf pine, hickory) would change to organic-rich high marsh (shrubland, *Juncus*, *Salicornia*, *Distichlis*, etc.), then sequentially to a predominantly sediment-rich intertidal low marsh (*Spartina*) and mud flat, shallow subtidal autotrophic benthic system (benthic algae) and, finally, a deeper subtidal heterotrophic benthic system (embayment or lagoon; Coile and Jones, 1988; Howard and Frey, 1985).

Although quantitative zooarchaeological studies are ongoing, it seems clear that oysters are the shellfish resources most commonly exploited by Native American populations on St. Catherines Island; hard clams occur in most middens, although their relative frequencies vary considerably. These two taxa, as stressed earlier, were ecologically optimal in various intertidal low marsh and tidal creek habitats (herein termed the zone of optimal shellfish harvesting, or ZOOSH). The rate of sea level rise may control the developmental expression of the gradual transitions described above, and individual stages may be
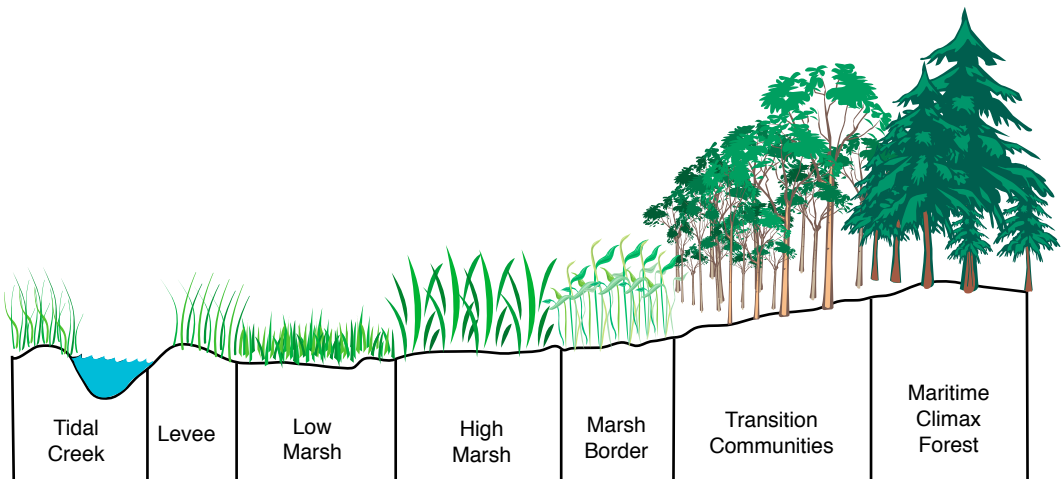

Fig. 16.1. Schematic illustration of transitional states from marsh to maritime forest.

overstepped by rapid rates of sea level rise. Examples of such rapid rates of sea level rise along modern coasts are generally found in areas experiencing strong anthropogenic alteration and land loss due to subsidence, such as coastal Louisiana. Shirley and Battaglia (2006: 1058) noted that relative sea level rise (RSLR) "far exceeds accretion in the Mississippi Delta" whereas, "conversely, the Coastal Plain has a positive net accretion in selected sites along the Gulf Coast," and that "in the Delta, we expect migration to be unable to keep pace with RSLR, causing vegetation to be replaced by open water." The RSLR necessary for overstepping is largely unknown, and likely to vary from one coastal situation to another. For the southeastern United States, where sediment loading is rather high, it has been suggested that a RSLR of 1.2 cm/yr would provide the limiting threshold whereby *Spartina* growth could not keep apace with sea level rise (Morris et al., 2002). It is difficult to accurately assess whether Holocene RSLRs ever approached this threshold. The published temporal resolutions of sea level change can typically only be averaged over centuries to millennia and tell us little of marsh response to decadal to centuries variation that might

accompany, for example, local cessation of accretion due to tidal inlet switching and/or inherited antecedent topography, and how this might have affected the availability of shellfish resources in specific marshes on a barrier island such as St. Catherines. Some of the temporally averaged Holocene rates appear sufficient for overstepping, if viewed in concert with other factors of sediment loading and inherited topography. Anderson et al. (2008), in a study of Gulf Coast estuaries, reported landward shifts of bayhead deltas from flooding events in the early Holocene at RSLRs averaging 40 cm/100 yr. They noted that even the decreased rates of RSLR during late Holocene flooding events reached 15 cm/100 yr.

This may be a moot question in terms of late Holocene shellfish resources exploitable by St. Catherines Island foragers as the long-term Holocene RSLR rates would mostly bear upon the question of whether or not intertidal marshland facies would have marched landward as integral transgressive facies tracts during the early to mid-Holocene. Once "docking" of the Holocene barrier (Guale Island) against the Silver Bluff escarpment occurred, the waxing and waning of intertidal marsh resources would appear to be
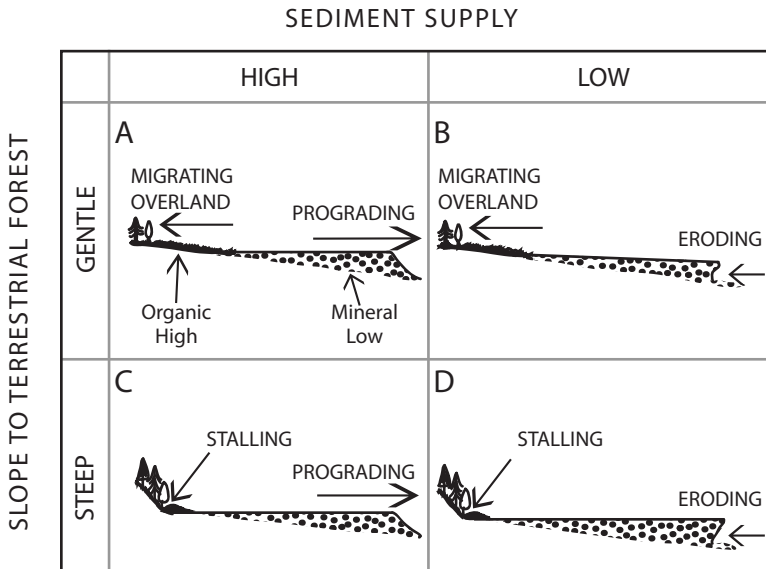

Fig. 16.2. Transitional states at Virginia Coastal Reserve (after Brinson, Christian, and Blum, 1995). The scenarios depicted in A–D are discussed in the text.

mostly controlled by local variation in sediment supply, inherited topography, and (possibly) climate change, and not by RSLR (unless late Holocene to recent episodic flooding events can be documented along coastal Georgia).

There is evidence for episodic flooding events rather than gradual eustatic early Holocene sea level rise but there is growing consensus that mid- to late Holocene eustatic sea level "overshoots" (i.e., higher than present levels), described in the northern Gulf Coast region (Morton, Paine, and Blum, 2000; Blum et al., 2001; Stapor and Stone, 2004) are not real but rather explainable in terms of local variation in antecedent topography and sediment supply (Otvos, 2005; Wright et al., 2005; Anderson et al., 2008; Milliken, Anderson, and Rodriguez, 2008; Rodriguez et al., 2008). Goodbred, Wright, and Hine (1998) described an 1800 ^{14}C yr B.P. flooding event that affected the Waccasassa Bay area of west Florida and ascribed it to a small sea level fluctuation of 10–20 cm over an interval of perhaps as little as 100 years. For some 2000 years prior to this incursion, relative stability had prevailed under conditions of slow sea level rise, permitting the extensive development of oyster reefs that "arguably required a considerable time to grow (hundreds of years)" (Goodbred, Wright, and Hine, 1998: 250). These large reefs were abandoned under conditions of shoreline retreat estimated at 10–20 m/yr, an order of magnitude greater than the retreat rate both before and after the flooding event. Whether this flooding event is attributable to regional sea level rise or to local shoreline dynamics is irrelevant for our purposes, for it does apparently demonstrate a late Holocene situation leading to a large-scale reduction of oyster resources (albeit subtidal oyster reefs) by transgressive overstepping—which could easily have played out in coastal Georgia, given similar conditions. However, in a study of early Holocene barrier-lagoon systems in the Adriatic shelf, Storms et al. (2008) suggested that the probability of barrier island overstepping may be inversely proportional to the tidal amplitude. The enlarged mesotidal ZOOSH of the Georgia coast may be more insulated from major habitat transgressive overstepping than the microtidal coast of the Adriatic, or Florida (for that matter); but, of course, these suggestions must be tested against the zooarchaeological record from Native American sites of the Georgia Bight.

It is interesting to speculate about controls upon the vertical amplitude of the ZOOSH. For example, Chowns et al. (2008) and Oertel (1975a) have discussed the dynamics that have led to tide- versus wave-dominated sedimentary systems along the Georgia coast. Chowns (2008: 157) noted that "marine transgression tends to favor the tidal system," increasing sediment accommodation space by increasing the volume and velocity of tidally entrained water in the back-barrier area. This enhances back-barrier sediment entrapment and tends to destabilize the inlets between barriers, encouraging straightening. Given this relationship, the amplitude of the ZOOSH should be maximized by rapid sea level transgression, especially episodic flooding events, leading to an expansion of shellfish resources. Very rapid transgression might lead to (at least short-term) subtidal expansion of the ZOOSH as flooding of marshland transitions to lagoonal embayment. Filling of back-barrier accommodation space under stability or low RSLR would constrict the ZOOSH. Regression, to the extent that it might engender wave dominance, would likely further restrict the ZOOSH by greatly reducing the tidal prism that nourishes the salt marsh ecosystem.

The relevance of the central place foraging model to St. Catherines Island archaeology is conditioned, in large measure, by the relative modest size of the island, permitting diverse resources to be exploited with minimal foraging distance over shorter intervals of time (Thomas, 2008: esp. chaps. 10 and 11). The short-term (microscale, i.e., few centuries or less) stochasticity of intertidal marine shellfish resources becomes, under this model, relatively insignificant, as depletion of one shellfish source might be easily supplanted by exploitation of another—as long as the optimal intertidal shellfish zone is maintained along significant portions of the island by slow gradual sea level change and/or the vagaries of lateral sedimentary dynamics (see previous discussion). Furthermore, even over broader (mesoscale, i.e., few centuries to a millennium) time spans during which purported episodic flooding events might occur, the existence of the Silver Bluff escarpment might virtually ensure that these conditions would indeed persist along portions of the island by reducing the likelihood of shoreline retreat or transgressive overstepping of the optimal zone of intertidal shellfish productivity. On a macroscale time span (millennium or more) only evidence of a Holocene sea level highstand in excess of present-day

level would, it seems, lead to a major habitat disruption of intertidal marine resources.

The microscale stochasticity of the ZOOSH resources deserves further discussion. Coastal Georgia, South Carolina, Louisiana, and many areas in New England have experienced, in recent years, events involving what has been termed acute salt marsh "dieback." Dieback affects both *Spartina* and *Juncus* and is characterized by vegetational thinning and browning, leading eventually to bare mud and rhizomal stubble. In situations of dieback, plant death occurs within months—distinguishing it from the state changes discussed previously that typically play out over decades (Alber et al., 2008). Causes of marsh dieback remain speculative, ranging from overfishing to change in freshwater flow to airborne dust to ecosystem disruption catalyzed by trophic cascades (Silliman and Bertness, 2002). Although it may not be appropriately termed "dieback," even decadal-scale marsh destruction can be considered as microscale impact on the ZOOSH. In this regard the relationship between submergence and reducing conditions is especially germane to salt marsh viability. As little as a 20 cm change in marsh surface elevation can spell the difference between marsh life and death. Increased submergence time leads to reducing conditions, high sulfide concentrations, and death of marsh grasses, especially in the low-lying interior portions of a marsh. Such changes can readily occur locally with tidal creek meanders and cutoffs, and shifts of tidal deltas and inlets.

Climatic perturbations cannot be ruled out as microscale causation of marsh dieback events. Alber et al. (2008: 6) note that, in coastal Georgia, the years 1999 to 2001 were the "driest 3-year period on record." Moreover, climate can affect the ZOOSH in more indirect ways. Oyster production, for example, is apparently quite sensitive to salinity variation that might accompany the change in the freshwater budget. Buzan et al. (2009) analyzed over 20 years of eastern oyster production in Galveston Bay, Texas, noting that increased freshwater inflow and decreased salinity correlated with increased abundance of market-sized oysters. Apparently, oyster production simply benefits from avoidance of predation pressure, disease, and parasites that accompany normal marine salinity. On the other hand, another study conducted in Galveston Bay (Turner, 2004) indicated that oysters suffer mass mortality under conditions of excessive freshwater inflow

and extended periods of low salinity.

In addition, climate change can affect the frequency, intensity, and distributional pattern of hurricanes and tropical storms, although details of coupling of these processes remain somewhat elusive. Hurricanes are known to modify community structure and function, however, and "may be the most environmentally significant force in coastal tropical and subtropical ecosystems" (Michener et al., 1997: 775). Temporal changes in hurricane frequency might have impacted the ZOOSH of St. Catherines Island in several ways, including modification of salinity regimes and freshwater supply (e.g., local recharging of water table, freshwater flooding, low-elevational soil saturation, dramatic increase in surface sediment and nutrient supply to the marsh). Increased nutrient supply could have facilitated estuarine and bay anoxia events (storm-induced litterfall that occurs prior to normal litterfall is much richer in nitrogen [Blood et al., 1991]). Storm surges from hurricanes transport saltwater sediment inland, elevating salinity of freshwater marshes and soils, and possibly triggering long-term changes in successional gradients within marsh and hinterland (Hook, Buford, and Williams, 1991). Increased overwash activity from hurricane-induced storm surges salinizes lower elevations, leading to replacement of terrestrial forest species by high marsh vegetation. Increases in sediment supply from storm surges may enhance overall marsh growth and certain ZOOSH resources. Extended climate-induced intervals of increased frequency and intensity of hurricanes might have disproportionately affected the mesotidal ZOOSH of coastal Georgia where, as discussed previously, some resource species are more highly adapted to conditions of abiotic stress and the opportunism of the hydrodynamic regime than to the biotic interactions associated with competition, predation, etc. Might extended intervals of increased hurricane activity have led, in the past, to increased stochasticity of shellfish resources and, perhaps, a culling of species less adapted to abiotic stress? Would quahogs fare better than oysters under such conditions, and might this be discernible in the midden record? In this context of possible selective winnowing of more stenotopic taxa under abiotic stress, and also perhaps relevant to the broader spectrum of St. Catherines Island resources, Hurricane Hugo destroyed about 25% of the unhatched logger-

head turtle nests in South Carolina and also greatly reduced white-tailed deer and squirrel populations in selected areas (Cely, 1991; Michener et al., 1997; see also Thomas, this volume, chap. 1).

Any of these factors, as well as anthropogenic ones, may have influenced the accessibility of the ZOOSH resources for late Holocene foragers and farmers on St. Catherines Island. One might suspect that central place foraging (and farming) may have imposed some peripheral impact on the ZOOSH. For example, if grid-ditching (ditches dug to channel water) or impoundment were employed in agricultural practice it may have influenced the ZOOSH by changing salinity, sediment supply, and/or submergence. Artificial impoundments in coastal Georgia have led to depositional rates of 1 cm/month (Edwards and Frey, 1977; Kennish, 2001), especially in the streamside-levee marshes, thus choking off the residence time of tidal flooding (and sediment delivery for vertical accretion) of the shellfish-productive lower marsh habitats. Inhibition of marsh accretion could lead to marsh death by submergence. Similarly, the possibility of oyster farming (see Thomas, 2008: 82–85), perhaps undertaken to stabilize the stochasticity of marine resources on the island, may have affected the natural ZOOSH. Ironically, as far as marine resources of the ZOOSH are concerned, what might not have worked for Native Americans would have been any activity that interfered with the natural stochasticity of the Georgia salt marsh system and demanded harvesting of a specific intertidal site.

RISING VERSUS FALLING SEA LEVEL: RESOURCE ASYMMETRY?

There appears to be a paucity of research on the ecological effects of sea level fall, perhaps because we live in a time of rising, not falling, sea level in most parts of the world. There is empirical justification for not viewing the effects of rise and fall as mirror images. In terms of applying central place foraging models to the archaeological record of St. Catherines Island, it seems clear that the degree of isolation of food resource patches should increase, over longer spans of time, with lowered sea level as the ZOOSH becomes more separated from the higher elevation forested hinterland by an intervening low-gradient coastal plain. If Chowns' mod-

el of sedimentary dynamics is correct, we could also expect that the very nature of the ZOOSH would change as a more wave-dominated coastline led to destruction of back-barrier marshland and greater focus on eastern shoreface intertidal and subtidal resources.

However, over micro- to mesoscale intervals of time, more subtle differences exist in resource pattern change during sea level rise and fall. As Brinson, Christian, and Blum (1995: 657) noted, "resistance to change in state is an important property that regulates the pace of landward migration." On barrier islands such as St. Catherines, during sea level rise, transitions from forest to high marsh (e.g., as seen along edges of the Silver Bluff escarpment) are influenced by shore-parallel (longitudinal, sensu Thomas, 2008) nuances, such as the inherited gradient of the landward surface, presence of forest canopies (preventing marsh invasion into shaded areas—some dominant high marsh grasses possess C-4 photosynthetic pathways hindering competition in the shade; Brinson, Christian, and Blum, 1995), the amount of freshwater runoff and groundwater discharge (retards transition to high marsh by flushing out saltwater intrusion and precipitation of potentially toxic sulfide minerals—often evidenced by iron-rich "beach rock" along marsh margins), and the frequency of fire or a variety of human activities, such as agriculture or cattle grazing (all of which may destroy forested areas). High marsh may either prograde by organic accretion or erode and be replaced by intertidal marsh. These patterns can coexist along shore under sea level rise. Aggressive colonization by intertidal plant species, such as *S. alterniflora*, *Salicornia* sp., and *Distichlis spicula*, occurs in areas where high marsh plants, such as *Juncus* sp. and *S. patens*, die or are smothered by blankets of wrack. All of these transitional patterns can be currently observed along the eastern North Beach margin of St. Catherines Island between Yellow Bank Scarp (Picnic Point) and Seaside Inlet.

Many of the aforementioned nuances would be lacking under conditions of sea level fall. For example, the progradational "push" of an accreting marsh in a Georgia mesotidal salt marsh estuarine setting is unique to a stable or slowly rising sea level and would not exist during lowering when a low gradient with surplus sediment prevails, leading perhaps to a microtidal wave-dominant coast, reduction of marshland, migration of inlets, and extension of spits by avulsion

and longshore transport of sediment previously trapped in the tidal prism (Chowns et al., 2008).

CONCLUSIONS

It may be instructive to consider the aforementioned nuances in the context of the putative late Holocene -2 m regressive event that occurred along coastal South Carolina and Georgia, and to hypothesize how the ZOOSH resources might have been affected along the eastern margin of St. Catherines Island. The following scenario relies heavily upon geomorphic and archaeological data and syntheses taken from Chowns et al. (2008), Thomas (2008), Bishop et al. (2007), Linsley (1993), Gayes et al. (1992), and DePratter and Howard (1981); see also chapter 1, this volume.[2] The presentation follows the format of Thomas (2008: chap. 4).

5300–4300 CAL B.P.

Following the Holocene transgression, Guale Island formed off St. Catherines Island, adjacent to the eastern margin of the Pleistocene Silver Bluff shoreline. Jones, Quitmyer, and Andrus (2004, 2005) report isotopic evidence of 3.5°C higher seawater temperature from northeastern Florida during this time period. Guale Island was separated from St. Catherines Island first by short-lived lagoonal embayment and then by an extensive interisland marsh (Guale Marsh) that developed as the rate of sea level rise slowed, about 1 m below the present level. Although Guale Island has been lost to erosion, remnants of such Sea Island doublets can still be seen along the coast (e.g., Sapelo-Blackbeard). As the mesotidal prism was sandwiched against the Silver Bluff escarpment, saltmarsh progradation filled in the lagoonal embayment (transitional state change) and the precursor of the modern Ogeechee River coursed through Guale Marsh, debouching in the vicinity of present-day Seaside Inlet. Over an interval of a few centuries to a few millennia the ZOOSH changed from a predominantly shoreface context to one of open lagoon, and then to intertidal marsh with bountiful oyster and clam resources (exploited by Native American foragers from marsh habitats on both the eastern and western margins of St. Catherines Island). The ZOOSH changed accordingly from less bountiful albeit more predictable lagoonal marine target areas to the very abundant, but unpredictable (stochastic), resources afforded by the hydrodynamism of the mesotidal regime. The relict marshland preserved along North Beach from Yellow Bank Scarp to Middle Beach preserves abundant evidence of the formerly expansive Guale Marsh tidal creeks and resources (Rollins, West, and Busch, 1990; West, Rollins, and Busch, 1990). Perhaps the most relevant modern analog for Guale Marsh is provided by the Letzsch and Frey's (1980b) two-year study of Blackbeard Creek, similarly sandwiched between a Pleistocene core island (Sapelo) and its Holocene doublet island (Blackbeard). They established six monitoring stations along Blackbeard Creek and its tributaries and noted very active erosion (as much as 7.2 m/yr with a mean of 1.9 m/yr) due to slumping of unstable tidal creek banks and intense bioerosion by decapods. Such a high rate of lateral erosion demonstrates the downward control on the ZOOSH of such compressed marsh environments. The geographic compression of maritime forest and marsh resources (then and now) enabled operation of the central place foraging strategy (Thomas, 2008: chaps. 34–35), even under conditions of an unpredictable ZOOSH. Thomas (2008: 1084) estimates that, overall, "more than 80 percent of the maritime forest edge on St. Catherines Island fronts directly on the margin of a significant salt marsh—effectively doubling the number of optimally positioned central places." Shoreline-parallel (i.e., longitudinal, sensu Thomas, 2008) habitats are many and closely spaced, offering a maximum array of marine and terrestrial resources within a short foraging radius of centrally placed residential settlement loci, e.g., both the St. Catherines Shell Ring (9Li231) and the McQueen Shell Ring (9Li1648), the two oldest-known sites on the island (Thomas, 2008: chap. 20; Sanger and Thomas, 2010).

4300–3600 CAL B.P.

A relatively rapid 2 m drop in sea level occurs (about 3 m below present MSL). Marshland to the west and east of St. Catherines Island is destroyed as the tidal exchange disappears, wave-dominance supplants tidal dominance, the Ogeechee River incises, and a surplus of sediment avulses to be transported by longshore currents and deposited by spit building as St. Catherines Island becomes elongated southward of the Zapala Scarp (Chowns, 2008). Guale Island is reduced by erosion. The rich marshland ZOOSH is significantly degraded or disappears, and the remaining shoreface ZOOSH becomes so isolat-

ed from human settlements that the central place foraging strategy is no longer operational. The ZOOSH collapses first along the island's western margin, extending soon thereafter to the eastern area of Guale Marsh. Major centrally placed St. Simons period sites (including both shell rings) are abandoned (Thomas, 2008: chap. 30; Sanger and Thomas, 2010). Greater emphasis is placed upon terrestrial resources, both freshwater and forest, and the midden record is conspicuously depleted in estuarine resources in general. Increasing numbers of Late Archaic settlements are sited along the island's eastern margin and around interior ponds and swamps (Thomas, 2008: chaps. 20 and 30).

3600 cal b.p. to Recent

Sea level slowly rises to present-day level. Transgression proceeds over a low gradient, oversteps the remnant of Guale Island, and embays the Ogeechee. The tidal prism is reestablished; Ogeechee Inlet is straightened and dis-

placed northward to the present-day St. Catherines Sound and later moves more northerly to Ossabaw Sound (Chowns, 2008). Stripped of active tidal estuarine activity and less protected due to a diminished presence of Guale Island, the inherited former Guale Marsh surface becomes partially reactivated but is quickly threatened by increased overwashing of abundant sand now made available by the displaced inlet. The Guale Marsh ZOOSH never achieves its former stature and does not play a prominent role as a source of marine resources in post–St. Simon cultures.

NOTES

1. We gratefully acknowledge the assistance of Irvy Quitmyer, who provided extraordinarily useful feedback on an earlier draft of this paper.

2. We do note the significant lack of zooarchaeological data in this scenario, and we are presently trying to generate relevant empirical evidence on the shellfish proportions found in the archaeological record.