



Marine trophic levels targeted between AD 300 and 1500 on the Georgia coast, USA

Irvy R. Quitmyer^{a,*}, Elizabeth J. Reitz^b

^a Florida Museum of Natural History, University of Florida, Gainesville, FL 32611-7800, USA

^b Georgia Museum of Natural History, University of Georgia, Athens, GA 30602-1882, USA

Received 18 July 2005; received in revised form 5 October 2005; accepted 27 October 2005

Abstract

The marine trophic levels targeted during Swift Creek (AD 300–700) and Savannah (AD 1200–1500) occupations at the Cathead Creek site (9Mc360) and at two sites from the Kings Bay Locality (9CAM171a, 9CAM177), coastal Georgia, USA, differ in a consistent temporal and spatial pattern. Vertebrate and invertebrate remains from these three coastal sites contain similar suites of estuarine animals. However, Swift Creek peoples at these distinct hydrological settings obtained more biomass from fishes and less from molluscs compared to the subsequent Savannah occupants. The two Swift Creek faunal collections are less rich, more diverse, and more equitable than the two subsequent Savannah collections regardless of location. Furthermore, the mean trophic level is higher in the Swift Creek collections compared to the Savannah ones at both locations. These observations apply to both biomass and Minimum Number of Individuals. These differences likely are defining characteristics distinguishing the Swift Creek and the Savannah economies. More research is needed to determine the extent to which these temporal and spatial patterns are attributable to environmental and cultural variables.

© 2005 Elsevier Ltd. All rights reserved.

Keywords: Zooarchaeology; Marine resource use; Southeastern United States Atlantic coast; Trophic level; Mid-Holocene environmental change

1. Introduction

Marine resources played an important role in many economies in the past, just as they do today. Although generally it is assumed that pre-industrial fishing strategies had little impact on marine ecosystems, recent reviews of archaeological data indicate this assumption may be untrue [18,63]. The hypothesis that humans had little impact on marine ecosystems in the past rarely is tested objectively, in part because the zooarchaeological tool kit contains few methods by which to quantify fishing strategies and impact. Traditional zooarchaeological techniques have not been adequate to resolve distinctions between anthropogenic and non-anthropogenic changes in marine ecosystems, nor have they been helpful in integrating zooarchaeological with modern fisheries data.

All zooarchaeological methods have inherent biases; there is no single best way to quantify a faunal assemblage. Nonetheless, stronger arguments can be made if multiple lines of evidence are in agreement. The trophic level approach advocated by Pauly and his colleagues [15,34–36] offers a method that may assist in resolving this dilemma by augmenting other zooarchaeological approaches and by providing a common framework within which modern and zooarchaeological data can be compared [48].

Pauly and colleagues [35,36] argue that significant changes in the structure of the marine food web occurred during the last half of the twentieth century. They assign the marine animals that were part of the twentieth-century fishery to trophic levels that range between one and five based on the degree to which organisms feed directly on producers [15,34–36]. Primary producers and detritus are at the base of the food chain, a trophic level of one. Zooplankton, benthic herbivores, and detritivores occupy the second trophic level. Carnivores occupy trophic levels three to five.

* Corresponding author. Tel.: +1 352 392 1721x239; fax: +1 352 846 0287.

E-mail address: quitmyer@flmnh.ufl.edu (I.R. Quitmyer).

Based on their research Pauly and colleagues [35,36] argue that a recent shift in emphasis away from long-lived, piscivorous, high-trophic-level bottom fishes to short-lived, planktivorous, low-trophic-level invertebrates and small, pelagic fishes is a response to changes in relative abundance and body size of the preferred catch: high-trophic-level, piscivorous fishes. Such changes are primarily the result of poor fisheries management, over-fishing, and the degradation of aquatic habitats associated with fishing techniques. This downward spiral first led to larger catches and then to stagnant or declining ones. They term this decline “fishing down the food web.”

When Pauly and colleagues [35] examine trophic-level use in the region that includes the Georgia coast, USA, they find a peak in the 1970 mean trophic level followed by a sharp decline that they argue is part of the overall collapse in the global fishery. Mean trophic level (vertebrates and invertebrates) peaked at 3.4 in 1970 and declined to 2.9 in 1994. Among other consequences, people are competing with their own prey for food at the lower trophic levels, thereby impacting the entire marine ecosystem.

Are declines of this magnitude unprecedented or have they occurred previously, prior to industrialized, commercial fishing? Were resources from high trophic levels exploited prior to European-sponsored colonization of the Georgia coast and, if so, was high-trophic-level fishing followed by a similar decline in mean trophic level? If a similar decline occurred previously, is it evidence that ecosystems were stressed prior to the twentieth century by over-fishing or climate change, or does it suggest cultural change independent of environmental variables?

The study of trophic-level use by Swift Creek (AD 300–700) and Savannah (AD 1200–1500) people reported here was conducted with the knowledge that zooarchaeological remains deposited between 1450 BC and the twentieth century near St. Augustine, Florida, USA, suggest that “fishing down the food web” was not exclusively a phenomenon of the twentieth century (Figs. 1 and 2) [48]. The combination of archaeological and modern data from the St. Augustine area shows that use of high trophic levels was routine and that a decline in mean trophic level occurred at least once in the eighteenth century and perhaps in earlier centuries as well [48].

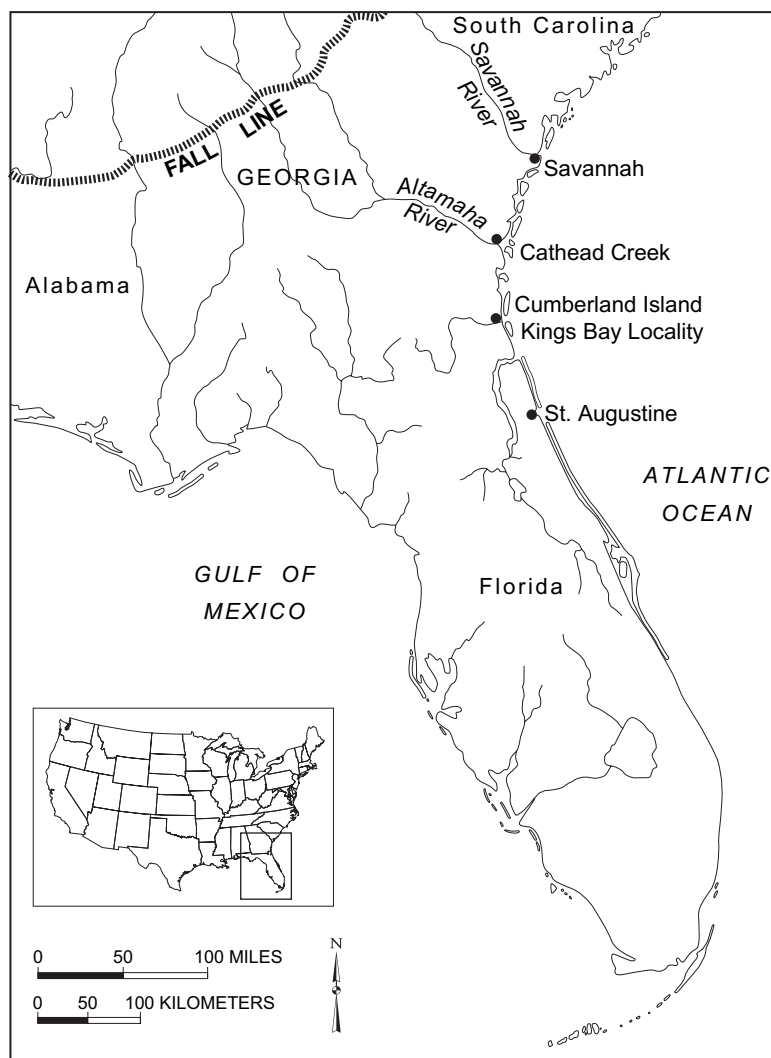


Fig. 1. Location of the study area.

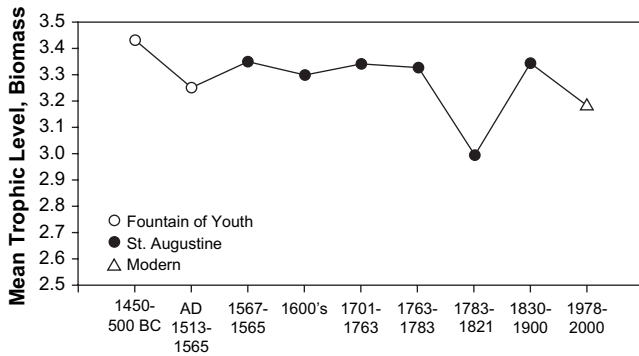


Fig. 2. Summary of mean trophic level derived from biomass from the St. Augustine area (modified from [48]). The Fountain of Youth Park site was occupied by Native Americans prior to Spanish colonial occupation at St. Augustine, Florida. Fountain of Youth is approximately 1 km north of the city of St. Augustine.

Zooarchaeological data from along the southeastern coast of the United States consistently demonstrate that estuaries were important sources of animal protein from the mid-Holocene onward [21,39,44–48,52,63]. As a consequence, fisheries data from coastal archaeological sites offer a local temporal sequence for the use of marine resources and ecosystem health covering much of the recent Holocene.

The purpose of the present article is to review zooarchaeological evidence from sites occupied before European fishing strategies were deployed along the Florida and Georgia coasts for evidence of “fishing down the food web” in order to fill in part of the temporal gap that exists in the St. Augustine sequence [48] as the next step toward developing a regional pattern. The research reported here focuses on the approximately 1200 years prior to the sixteenth-century European colonization of the Atlantic seaboard.

2. Swift Creek and Savannah occupations at Cathead Creek and the Kings Bay Locality, coastal Georgia

Vertebrate and invertebrate remains recovered from Swift Creek and Savannah components of the Cathead Creek site and two sites in the Kings Bay Locality, Georgia, USA, are reported here (Fig. 1). These sites are at the center of a large embayment, known as the Georgia Bight, which extends along the southeastern Atlantic coast of the United States. Thus, occupants of Cathead Creek, the Kings Bay Locality, and the St. Augustine area had access to similar estuarine resources, though differences in the local hydrology distinguish each of these watersheds. An important feature of this coast line is a series of sea, or barrier, islands separating the inshore waters of the continental shelf from the estuarine waters between the sea islands and the mainland [11,61]. Tidal creeks, sounds, salt marshes, and marsh islands lie between the sea islands and the mainland, forming extensive estuaries [19]. Estuarine waters are influenced by tidal forces with highly variable ranges in temperature, salinity, and turbidity. For example, the Cathead Creek site experiences limited tidal input because of its distance from the Atlantic Ocean. The Kings Bay

Locality and St. Augustine have greater tidal input, though Kings Bay lies behind a large barrier island and St. Augustine is more exposed to the Atlantic because its protecting island is much smaller. The entire system is a major nursery ground for a similar suite of fishes and shellfishes that ultimately support inshore and offshore fisheries. Due to lower salinity, estuaries are ecological barriers that protect developing fish and shellfish from a more diverse array of predators found in the inshore and offshore zones [61]. Modifications in drainage systems associated with rice cultivation in the eighteenth and nineteenth centuries and construction of the intra-coastal waterway in the twentieth century have altered the estuarine hydrology to an unknown extent throughout this region.

This area has a rich and complex human history. Swift Creek and Savannah sites are found in many parts of Georgia and northeast Florida [4,32, pp. 141–50, pp. 248–9, 65]. Archaeologists disagree about the identity and cultural classification of the people who lived on this coast. For example, some argue that the Savannah time frame also includes, or is distinct from, an Irene component that is found just prior to Spanish colonization of the area in the 1500s. Some argue that northern and southern communities on the Atlantic coast of northeast Florida and Georgia were culturally-distinct groups; others suggest that coastal communities should be termed simply “Mississippian;” and still others note that many classic Mississippian traits are absent from or poorly developed at coastal sites. Notably, this is not the subject of this paper and we defer, as we have in previous publications, to the nomenclatures and dates used by the principal investigators of the sites reported here [1,10,21,27,38,41,42,46,49]. The important point in the following presentation is that Swift Creek occupations clearly preceded Savannah ones by several centuries, that another cultural classification known as Deptford likely separated Swift Creek from Savannah occupations, and that many Savannah characteristics cease to be found in the archaeological record before or shortly after Spanish exploration and occupation began.

During both occupations, populations living on the coast relied heavily upon estuarine resources for animal protein [23,46,49], occupied coastal sites throughout the year, and some cultivated plants. The use of estuarine resources will be discussed at greater length below. Although earlier work assumed that coastal faunal remains represented seasonal catches, growing bodies of evidence indicate that Swift Creek and Savannah people used Cathead Creek, the two Kings Bay Locality sites, and other coastal sites throughout the year, if not permanently [23,41,42, p. 835, 46,49]. This hypothesis should continue to be tested as new data become available. Cultigens are not common in Swift Creek contexts, though maize (*Zea mays*) pollen as well as squash (Cucurbitaceae) seeds and rinds are reported from the upper Savannah River for this time period [64, pp. 106, 394]. Savannah sites contain evidence for a greater role of cultivated plants [23,27, p. 139]. Compared to the number of Swift Creek sites, the number of Savannah sites on the Georgia coast is larger [62, p. 48], which may indicate a growing human population in the region during this later time period.

3. Materials and methods

The focus of the present study is on invertebrate and vertebrate remains from Cathead Creek (9Mc360), the Kings Bay site (9CAM171a), and Devils Walkingstick site (9CAM177) [1,10]. Both Cathead Creek and the Kings Bay Locality sites are mainland sites overlooking extensive estuarine systems. Cathead Creek is roughly 60 km north of the Kings Bay Locality. The Swift Creek occupations at both sites extended from AD 300 to 700 and the Savannah occupations were between AD 1200 and 1500 [1,10].

These dates are summaries of detailed occupational sequences for each site developed by the principal investigators based on their interpretations of stratigraphy, radiocarbon dates, and ceramics recovered from each context [1,10,49]. As stated earlier, our focus is on the broad temporal and geographical patterns rather than on smaller temporal differences within each site. More attention should be given to smaller variations in time and space if it is ever possible to do so using faunal remains. The choice of faunal samples for zooarchaeological analysis was made by the principal investigators of each site based on their interpretation of each context [1,10,49]. For more information about the chronological assignment of each deposit, the reader is referred to the primary sources for each site.

The Cathead Creek site (9Mc360) is on a bluff about 7 m high overlooking the upper reaches of the Altamaha Sound estuary at the mouth of the high-volume Altamaha River [10, pp. 5–16]. Today, the river is moderately fresh at this point. Cathead Creek is a shell midden about 1.6 m deep excavated by Water and Air Research, Inc. under the direction of Wayne [10]. The Cathead Creek animal remains are from a single 1 × 1 m excavation unit excavated in five zones defined by the amount of shell contained in each [10, pp. 5–45]. Due to the large volume of matrix recovered, a 10:1 sample of each zone was sieved through a nested series of screens with meshes measuring 1/2-inch (12.7 mm) and 1/4-inch (6.35 mm) and through a series of geological screens, the smallest of which was 0.5 mm. The upper 90 cm of the midden contained the Savannah component and the lower 70 cm contained the Swift Creek component [10]. Reitz and Quitmyer [49] published the Swift Creek faunal data from Cathead Creek elsewhere; the Savannah fauna are summarized below.

The Kings Bay Locality overlooks the lower reaches of the estuary behind Cumberland Island, Georgia [1, p. 1]. The data reported here are from excavations by the University of Florida under the direction of Adams. The Kings Bay site (9CAM171a) and the Devils Walkingstick site (9CAM177) consist of several small, discrete shell middens on high, well-drained soils overlooking the salt marshes. The Kings Bay and Devils Walkingstick sites are approximately 2 km apart in similar environmental settings. The Swift Creek fauna (AD 300–700) were excavated from Feature 6 (Artesian Well area), Feature 22 A/B (Poisonberry area), and Feature 23 (Bluff area) of the Kings Bay site and are reported in more detail elsewhere [49].

The Savannah faunal remains reported here are from three areas of the Devils Walkingstick site [38]. Materials from 11

50 × 50 × 10-cm column samples and two features were analyzed from the North Bunker area (Excavation Units 3, 4, and 5), the South Bunker area (Feature 34, Excavation Units 1, 2, 10, and 20), and the Marsh area (Feature 12, Excavation Units 13 and 15). The fauna was sieved through a nested series of 1/4-inch (6.35 mm), 1/8-inch (3.18 mm), and 1/16-inch (1.59 mm) mesh screens [38,40].

It would be naive to argue that all faunal materials are exclusively from the assigned time period. It is a hallmark of archaeology that materials are displaced throughout the stratigraphic sequence. It is particularly likely that smaller specimens could move either up or down in the midden. Anticipating for the moment our results, it is true that the number of identified specimens (NISP) of small-bodied fishes (*Clupeidae*, *Cyprinodontidae*, *Chloroscombrus chrysurus*, *Bairdiella chrysoura*, *Leiosotomus xanthurus*, *Stellifer lanceolatus*, and *Peprilus alepidotus*) are more abundant in terms of NISP in Swift Creek components at the Kings Bay Locality (28% of vertebrate NISP) compared to Savannah components (11% of vertebrate NISP); but equally small insectivores, mice, lizards, snakes, and amphibians, which would also be subject to sorting, are more common in Savannah contexts (1% of vertebrate NISP) than in Swift Creek contents (0.3% of vertebrate NISP). The same relationship is found at Cathead Creek, where small-bodied fishes constitute 19% of the NISP in the Swift Creek component and 17% in the Savannah one. Insectivore, mouse, lizard, snake, and amphibian specimens contribute 0.4% of the Swift Creek specimens and 1% of the Savannah ones at Cathead Creek. If sorting was a major factor in these deposits, it should have influenced all small-bodied organisms more equitably. We also note that sorting across the cultural boundary would be more likely at Cathead Creek because the materials are from a single stratified unit and yet Cathead Creek has less evidence for sorting than does the contextually more diverse Kings Bay Locality. Although we would not argue that this is evidence against sorting, it suggests that sorting is not solely responsible for the chronological pattern described below.

Vertebrate and invertebrate remains were examined using the reference collections at the Florida Museum of Natural History (Table 1). The number of identified specimens (NISP) and specimen weight were recorded and secondary data were derived. These methods are subject to many biases reviewed at length elsewhere [2,30,48,51]. Perhaps the most significant bias, and the most intractable at this point, is that the Cathead Creek data are from a single excavation unit and the Kings Bay Locality data are from a number of different contexts and two separate sites. Cathead Creek and the Kings Bay Locality sites were excavated in a similar manner by students or former students trained at the University of Florida, as was St. Augustine. This, in addition to internal consistencies within each faunal assemblage, encourages us to view these data as reliable.

Nonetheless, well-excavated zooarchaeological data from stratified sites are extremely rare. “Well-excavated” means that large samples were recovered from multiple contexts using a screen size appropriate to the recovery of the full range of fish

Table 1
Scientific and common names of taxa identified in the Savannah components from the Cathead Creek and Devils Walkingstick sites

Scientific name	Common name
Vertebrates	
Vertebrata	Unidentified vertebrates
Mammalia	Unidentified mammals
Large mammalia	Large mammals, e.g., white-tailed deer
Medium mammalia	Medium mammals, e.g., raccoon
Small mammalia	Small mammals, e.g., rat
<i>Blarina carolinensis</i>	Southern short-tail shrew
Rodentia	Rodents
<i>Neotoma floridana</i>	Eastern woodrat
<i>Oryzomys palustris</i>	Marsh rice rat
<i>Peromyscus</i> spp.	Mouse
<i>Sigmodon hispidus</i>	Hispid cotton rat
<i>Sciurus</i> spp.	Squirrel
<i>Sciurus carolinensis</i>	Gray squirrel
<i>Procyon lotor</i>	Raccoon
<i>Odocoileus virginianus</i>	White-tailed deer
Aves	Unidentified birds
Anatidae	Ducks
Reptilia	Unidentified reptiles
Testudines	Unidentified turtles
Kinosternidae	Musk and mud turtles
<i>Kinosternon</i> spp.	Mud turtle
Emyidae	Pond, marsh, and box turtles
<i>Malaclemys terrapin</i>	Diamondback turtle
<i>Terrapene carolina</i>	Eastern box turtle
Squamata	Unidentified snakes and lizards
Sauria	Unidentified lizards
Iguanidae	Iguanid lizards
<i>Anolis carolinensis</i>	Green anole
<i>Sceloporus</i> spp.	Spiny lizard
Serpentes	Unidentified snakes
Colubridae	Non-poisonous snakes
<i>Elaphe</i> spp.	Rat snake
<i>Heterodon</i> spp.	Hognose snake
<i>Thamnophis</i> spp.	Garter or ribbon snake
Viperidae	Pit vipers
<i>Sistrurus miliarius</i>	Pygmy rattlesnake
Amphibia	Unidentified amphibians
Caudata	Salamanders and newts
<i>Amphiuma</i> spp.	Amphiumas
<i>Siren</i> spp.	Siren
<i>Ambystoma</i> spp.	Salamander
<i>Notophthalmus viridescens</i>	Eastern newt
<i>Plethodon glutinosus</i>	Slimy salamander
Anura	Unidentified frogs and toads
<i>Scaphiopus holbrookii</i>	Eastern spadefoot toad
<i>Bufo</i> spp.	Toad
<i>Hyla</i> spp.	Tree frog
Chondrichthyes (TL = 3.6)	Unidentified cartilaginous fishes
Carcharhinidae (TL = 4.0)	Requiem sharks
Rajiformes (TL = 3.5)	Skates and rays
Dasyatidae (TL = 3.5)	Stingrays
<i>Dasyatus</i> spp. (TL = 3.5)	Stringray
Osteichthyes	Unidentified bony fishes
<i>Lepisosteus</i> spp.	Gar
<i>Amia calva</i>	Bowfin
Clupeidae (TL = 2.6)	Herrings and shads
<i>Brevoortia</i> spp. (TL = 2.8)	Menhaden
Siluriformes	Catfishes
<i>Ictalurus</i> spp. (TL = 2.6)	Bullhead catfish
Ariidae (TL = 3.2)	Sea catfishes
<i>Arius felis</i> (TL = 3.5)	Hardhead catfish
<i>Bagre marinus</i> (TL = 3.2)	Gafftopsail catfish

Table 1 (continued)

Scientific name	Common name
Cyprinodontidae	Killifishes
<i>Fundulus</i> spp.	Killifish
<i>Pomatomus saltatrix</i> (TL = 3.3)	Bluefish
Carangidae (TL = 3.3)	Jacks
<i>Chloroscrombrus chrysurus</i> (TL = 3.3)	Atlantic bumper
<i>Lobotes surinamensis</i>	Tripletail
<i>Archosargus probatocephalus</i> (TL = 3.4)	Sheepshead
Sciaenidae	Drums
<i>Bairdiella/Stellifer</i> spp. (TL = 3.3)	Silver perch or star drum
<i>Bairdiella chrysoura</i> (TL = 3.3)	Silver perch
<i>Cynoscion</i> spp. (TL = 3.4)	Seatrout
<i>Leiostomus xanthurus</i> (TL = 3.4)	Spot
<i>Menticirrhus</i> spp. (TL = 3.4)	Kingfish
<i>Micropogonias undulatus</i> (TL = 3.3)	Atlantic croaker
<i>Pogonias cromis</i> (TL = 3.4)	Black drum
<i>Sciaenops ocellatus</i> (TL = 3.4)	Red drum
<i>Stellifer lanceolatus</i> (TL = 3.3)	Star drum
<i>Mugil</i> spp. (TL = 2.1)	Mullet
<i>Peprilus alepidotus</i> (TL = 3.3)	Harvestfish
<i>Paralichthys</i> spp. (TL = 3.5)	Flounder
Invertebrates	
<i>Balanus</i> spp.	Barnacle
<i>Penaeus</i> spp. (TL = 2.3)	Brown or white shrimp
Brachyura	Crabs
<i>Callinectes sapidus</i> (TL = 2.6)	Blue crab
Mollusca	Unidentified bivalves and univalves
Pelecypoda	Unidentified bivalves
Mytilidae	Mussels
<i>Brachidontes exustus</i> (TL = 2.1)	Scorched mussel
<i>Geukensia demissa</i> (TL = 2.1)	Ribbed mussel
Arcidae (TL = 2.1)	Arks
<i>Anadara ovalis</i> (TL = 2.1)	Blood ark
<i>Crassostrea virginica</i> (TL = 2.1)	Eastern oyster
Unionidae (TL = 2.1)	Freshwater mussels
<i>Dinocardium robustum</i> (TL = 2.1)	Atlantic giant cockle
<i>Donax variabilis</i> (TL = 2.1)	Coquina
<i>Tagelus plebeius</i> (TL = 2.1)	Stout tagelus
<i>Polymesoda caroliniana</i> (TL = 2.1)	Carolina marsh clam
Veneridae (TL = 2.1)	Venus clams
<i>Gemma gemma</i> (TL = 2.1)	Amethyst gemclam
<i>Mercenaria</i> spp. (TL = 2.1)	Hard clam
<i>Mya arenaria</i> (TL = 2.1)	Softshell
Gastropoda (TL = 2.1)	Unidentified univalves
<i>Oligyra orbiculata</i>	Globular drop
<i>Campeloma</i> spp. (TL = 2.1)	Campeloma
<i>Littorina irrorata</i> (TL = 2.1)	Marsh periwinkle
<i>Crepidula</i> spp. (TL = 2.1)	Slippersnail
<i>Neverita duplicata</i> (TL = 2.1)	Shark eye
<i>Epitonium multistriatum</i> (TL = 2.1)	Many-ribbed wentletrap
cf. <i>Urosalpinx</i> spp. (TL = 2.1)	Possible oyster drill
<i>Busycon carica</i> (TL = 2.1)	Knobbed whelk
<i>Ilyanassa obsoleta</i> (TL = 2.1)	Eastern mudsnail
<i>Nassarius</i> spp. (TL = 2.1)	Nassa
cf. <i>Nassarius trivittatus</i> (TL = 2.1)	Threeline mudsnail
<i>Nassarius vibex</i> (TL = 2.1)	Bruised nassa
Columbellidae (TL = 2.1)	Dovesnails
<i>Mitrella</i> spp. (TL = 2.1)	Dovesnails
<i>Mitrella lunata</i> (TL = 2.1)	Lunar dove shells
<i>Olivella</i> spp.	Olive
<i>Olivella mutica</i>	Variable dwarf olive
Turridae	Turris shells

(continued on next page)

Table 1 (continued)

Scientific name	Common name
<i>Boonea impressa</i>	Impressed odostome
<i>Melampus bidentatus</i>	Eastern melampus
Terrestrial gastropods	Terrestrial snails
Stylommatophora	Terrestrial snails
Sigmurethra	Terrestrial snails
Oleacinidae	Cannibal snails
<i>Euglandina rosea</i>	Elongate cannibal snail
Heterurethra	Terrestrial snails
Orthurethra	Terrestrial snails

Numbers in parentheses are the Trophic Level (TL) for that taxon used in the trophic level part of this study. Trophic level estimates are from FishBase 1998 [15].

body sizes [48]. The contexts studied must be more than a single column sample or a few features because such isolated deposits may represent short-lived phenomena or specialized activities rather than long-term patterns in routine behavior. The archaeological assemblages from Cathead Creek and the Kings Bay Locality come closer to meeting the criteria of “well-excavated” than do any other zooarchaeological samples from the Georgia coast, though there is always room for improvement.

The Minimum Number of Individuals (MNI) usually was estimated for each taxon using symmetry, size, and age [51, pp. 194–200]. In the case of herring (Clupeidae), Atlantic bumper (*Chloroscrombus chrysurus*), mullet (*Mugil* spp.), and harvestfish (*Peprilus alepidotus*), MNI was estimated by dividing the number of vertebrae in each archaeofaunal collection by the number of vertebrae in modern comparative specimens. MNI was estimated for each zone in the case of the Cathead Creek column sample and for each feature and column sample in the case of the two Kings Bay Locality sites.

Biomass was estimated from specimen weight using allometric formulae (Table 2) [49,50,51, pp. 221–31]. The biases associated with using the weight of the remains to estimate biomass are discussed elsewhere [48,50,51]. Biomass is used here because it is the closest zooarchaeological equivalent to the modern pounds landed values used by fisheries managers today [36] and because it does not rely upon MNI estimates [51, p. 229, Table 7.21d]. The constants used to estimate biomass for vertebrates include specimen as well as soft tissue weight. The allometric constants used to estimate meat weight for invertebrates were calculated without shell weight and the resulting estimate is of edible meat only.

MNI and biomass are not estimated for barnacles, boonea, or small terrestrial gastropods because it seems particularly unlikely these were dietary resources. Clutches of oysters support a microcosm of animals such as barnacles (*Balanus* spp.) and impressed boonea (*Boonea impressa*). These organisms probably found their way into the middens because they were attached to targeted species. Terrestrial gastropods (Stylommatophora, Oleacinidae, and *Euglandina rosea*) commonly live in and on coastal archaeological shell middens today. These organisms are retained in the species lists because of the environmental information they may provide other researchers and because our interpretation might change should evidence to the contrary be found.

Table 2

Allometric values used in study to derive biomass estimate

Faunal category	N	Y-Intercept (a)	Slope (b)	r ²
<i>Specimen weight (kg) to body weight (kg)</i>				
Mammal	97	1.12	0.90	0.94
Bird	307	1.04	0.91	0.97
Turtle	26	0.51	0.67	0.55
Snake	26	1.17	1.01	0.97
Chondrichthyes	17	1.68	0.86	0.85
Osteichthyes	393	0.90	0.81	0.80
Non-perciform fish	119	0.85	0.79	0.88
Siluriformes	36	1.15	0.95	0.87
Perciformes	274	0.93	0.83	0.76
Carangidae	17	1.23	0.88	0.86
Sparidae	22	0.96	0.92	0.98
Sciaenidae	99	0.81	0.74	0.73
Pleuronectiformes	21	1.09	0.89	0.95
<i>Shell weight (g) to meat weight (g)</i>				
<i>Penaeus</i> spp.	25	1.94	0.61	0.81
<i>Callinectes sapidus</i>	11	0.99	0.82	0.58
Pelecypoda	80	0.018	0.68	0.83
<i>Geukensia demissa</i>	100	−0.22	0.80	0.86
<i>Crassostrea virginica</i>	100	−0.77	0.97	0.97
<i>Tagelus plebeius</i>	46	0.29	0.99	0.95
<i>Polymesoda caroliniana</i>	40	0.01	0.83	0.85
Gastropoda	135	−0.16	0.92	0.89
<i>Littorina irrorata</i>	62	−0.34	0.94	0.97
<i>Neverita duplicata</i>	16	0.38	0.55	0.81
<i>Busycon carica</i>	16	−0.12	0.84	0.93
<i>Lynassa obsoleta</i>	50	−0.44	1.06	0.93

Key to abbreviations: Formula is $Y = aX^b$, where Y is estimated biomass, X is specimen weight, a is the Y-intercept, b is the slope of the line, and N is the number of observations [50,51, pp. 225–9].

The variety of exploited species and degree of subsistence specialization are assessed for each collection using richness, diversity, and equitability, measures which characterize resource specialization and the range of resources used [51, pp. 233–4]. Richness is defined as the number of taxa for which MNI or biomass is estimated and is derived by counting the number of taxa for which MNI was estimated in each species list. Diversity (H') and equitability (E) estimates are derived using the Shannon–Weaver and Sheldon formulae [51, pp. 233–4, 53,54]. The richness, diversity, and equitability of zooarchaeological assemblages differ as a function of human choice, natural resource characteristics, latitude, climate, and seasonal periodicity, among a host of other variables [49].

The mean trophic level of each collection is calculated using the method of Pauly and Christensen [34] and adapted by Reitz [48]. Mean trophic level (TL) is estimated by combining modern trophic level assignments with allometric estimates of biomass and MNI in the zooarchaeological assemblage for these same taxa. In estimating the mean trophic level for each component, Pauly's formula is applied:

$$TL_i = \sum (TL_{ij}) \cdot (Biomass_{ij}) / \left(\sum Biomass_i \right)$$

solving for the mean trophic level for the time period (TL_i). The trophic level (TL_{ij}) of each taxon (j) for the time period (i) is multiplied by the estimated Biomass of the taxon (j) for the time period (i). TL_{ij} is divided by the summed Biomass

for the time period (Biomass_{*t*}). This formula estimates the mean trophic level for each collection. MNI may be used instead of biomass in this same formula. This same formula can be used to estimate the relative contribution of each trophic level during each time period instead of the mean trophic level for the collection. The trophic levels were derived from FishBase 1998 [15,48]. When the identifications in the archaeological data, the modern fishery data, and/or FishBase 1998 are insufficiently precise, the trophic level for the closest taxonomic category is used. The trophic level assignments are noted in Table 1. If no *TL* notation is indicated, this means that the organism was not used in the trophic level study because it is not a marine organism, no trophic level assignment could be found in the literature, or the taxonomic level of the identification was too broad. A more complete review of the strengths and weakness of this approach is published elsewhere [48].

The study of long-term patterns of change or stability in a regional fishery requires access to zooarchaeological data from temporally stratified archaeological sites and modern fisheries data from the same location. Zooarchaeological and modern fisheries data have inherent problems that are compounded when they are combined. Primary among these is that few zooarchaeological data are available for the same locations for which good modern fisheries data are available and vice versa. Zooarchaeological data have many biases (e.g. [51]). Primary data for animal remains from archaeological sites are limited to taxonomic identifications, specimen counts, specimen weight, and morphological measurements. These primary data may be augmented by secondary data such as MNI, estimates of original body size and age at death, or derived measures such as biomass estimated allometrically. Other than studies of increments and stable isotopes, few zooarchaeological data have analogs in the modern fisheries literature.

Modern fisheries data also have their own biases [36]. Pauly et al. [35,36] report that global FAO and other data used to assign fishes and invertebrates to a trophic level are complex and uneven in quality. Fisheries data may be incorrectly recorded, incompletely reported, or presented in formats that are difficult to use. Assigning fish to trophic levels is also problematic. The feeding behaviors of most fishes are complex and may change as individuals mature, among other difficulties. Modern data also are collected using fishing techniques and locations that are very different from those used in earlier centuries. Fishing records are reported for commercial catches where they are landed and these ports may be some distance from where the fish were caught. Landing data usually are reported in terms of pounds or cash value, neither of which are comparable to archaeological data. Much of the modern fishery is based on invertebrates, such as squids, sea urchins, oysters, scallops, shrimps, crabs, and lobsters. Some of these organisms are rare in archaeological sites or under-reported [35,36,48].

Some of the effects that Pauly and his colleagues report are the product of recent fishery management decisions [35]. Modern fisheries data undoubtedly reflect changes in fishing regulations intended to protect sensitive ecosystems and commercial fish stocks. However, similar trophic-level changes are

found in several parts of the globe, suggesting that factors such as invasive species, pollution, and/or climate change are also involved in addition to ecosystem stress attributed to over-fishing. For these reasons, caution is appropriate when applying trophic-level concepts to interpret historical trends in fishing using archaeological and fisheries data. Nonetheless, Pauly and colleagues [15,34–36] argue that clear and consistent results in support of their hypothesis obtained from multiple lines of evidence justifies the use of trophic-level analysis. The relationship between human fishing strategies and the resource base is unlikely to be resolved by a single method. However, trophic-level analysis offers a way to link modern and zooarchaeological data that may foster comparative studies of human fishing strategies and facilitate long-term diachronic studies of marine resource use. Trophic-level analysis also quantifies patterns in the zooarchaeological record that merit consideration.

The data from the Swift Creek and Savannah collections are summarized in Figs. 3 and 4. The biomass estimate for a taxon is included in the calculations summarized in these figures only if MNI also is estimated for that taxon in order to maintain consistency in the sample universe; a step that is required because biomass is estimated for more taxa than is MNI [48,49]. Taxa are summarized by class with a few exceptions. Sharks and rays (Chondrichthyes) are combined with bony fishes (Osteichthyes) because the percentage of sharks and rays is very small. The term “fishes” refers to both Chondrichthyes and Osteichthyes.

Birds, amphibians, crustaceans, and marine gastropods are combined into a category labeled “other” because their role in the subsistence strategy was minimal, if it existed at all. Some of the animals included as “other,” such as shrew (*Blarina carolinensis*) and Eastern spadefoot toad (*Scaphiopus holbrookii*), are most likely commensal species. Nonetheless, MNI and biomass (for shrews only, no biomass formulae are available for amphibians) are estimated for these small, possibly commensal vertebrates. No reliable internal evidence is available to justify excluding them from this study and including them makes no difference in our interpretation. They are retained in the species lists in order to document their presence in the samples in the event that other studies require this verification. The best way to resolve this issue is to examine animal remains in paleofeces but the opportunity to do this has not presented itself for this area. We note with disapproval the tendency of some zooarchaeologists to edit their species lists to exclude what they interpret as non-food remains and urge our colleagues to always publish the full list. In particular, we urge them to be open-minded regarding the consumption of small rodents, lizards, snakes, and amphibians [56].

4. Savannah animal use at Cathead Creek and Devils Walkingstick

Fishes and marine bivalves contribute 85% of the estimated biomass in the Savannah collection from Cathead Creek and 96% of the estimated MNI (Table 3; Fig. 3). Catfishes (*Ictalurus* spp., *Arius felis*, *Bagre marinus*) and killifishes

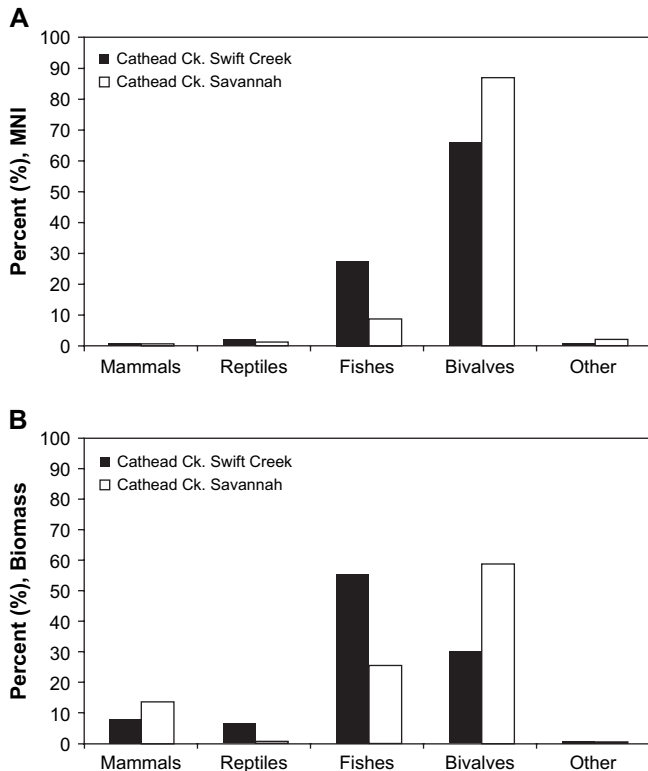


Fig. 3. Cathead Creek summary, Swift Creek and Savannah data: (A) MNI and (B) biomass. Biomass estimate for each taxon is included in these figures only if MNI also is estimated for that taxon in order to keep the sample universe identical. See Tables 3 and 4 and [49] for MNI and biomass values in these groups.

(*Fundulus* spp.) comprise 14% of the Cathead Creek biomass and 5% of the MNI. Small numbers of shrimp (*Penaeus* sp.) are present, but this crustacean may be under-represented because of its fragile exoskeleton. Bivalves provide the greatest percentage of biomass (59%) and MNI (87%). Bivalves are primarily Eastern oyster (*Crassostrea virginica*; 54% of the biomass; 80% of the MNI). All of these animals are abundant in Georgia's shallow, near-shore estuarine waters today.

Fishes and marine bivalves contribute 95% of the estimated biomass in the Savannah collection from Devils Walkingstick and 96% of the estimated MNI (Table 4, Fig. 4). Catfishes and killifishes contribute only 5% of the biomass and less than 1% of the MNI. Instead, eight members of the drum family (Sciaenidae; 5% of biomass and 3% of MNI) comprise the largest vertebrate group. The small star drum (*Stellifer lanceolatus*) contributes 4% of the biomass and 3% of the MNI. Bivalves provide the greatest amount of biomass (83%) and MNI (92%). Oyster is the dominant source of biomass (69%) and MNI (83%). As with the Cathead Creek collection, all of these animals are common to abundant in local estuarine waters today.

5. Comparison of the Swift Creek and Savannah components at Cathead Creek

During the Swift Creek and Savannah occupations at Cathead Creek, most of the biomass (85%) and MNI (95%—

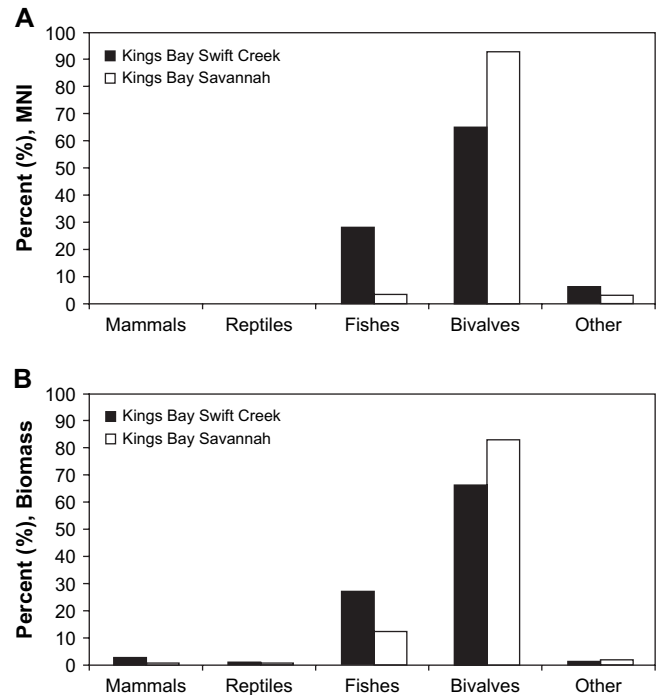


Fig. 4. Kings Bay Locality summary, Swift Creek and Savannah data: (A) MNI and (B) biomass. Biomass estimate for each taxon is included in these figures only if MNI also is estimated for that taxon in order to keep the sample universe identical. See Tables 3 and 4 and [49] for MNI and biomass values in these groups.

96%) are from fishes and bivalves (Fig. 3; see Tables 3 and 4 and [49] for MNI and biomass estimates in these groups). In this respect, both the Swift Creek and Savannah components are similar. As we will discuss later, this characteristic is also present in the Kings Bay Locality data.

Nonetheless, important differences are present in the two Cathead Creek collections. For example, fishes contribute 55% of the biomass estimated for the Swift Creek occupation and 26% in the Savannah one (Fig. 3). Although the percentage of oyster increases substantially in the Savannah collection compared to the Swift Creek one, the abundance of some of the other prominent Swift Creek vertebrates declines; for example, the reduction of gafftopsail catfish (*Bagre marinus*) biomass from 20% of the Swift Creek biomass to 11% of the Savannah biomass and of rays (Rajiformes) from 14% to 3% of the biomass. As the percentage of biomass from fishes declines, the percentage of bivalve biomass increases from 30% to 59%. The same decrease in fishes and increase in bivalves also characterizes the MNI data (e.g., 28% to 9% for fishes).

The difference in the types of organisms that dominant these temporally-stratified collections also is reflected in richness, diversity, and equitability (Tables 3 and 4, Fig. 5) [49]. Although richness increases, diversity and equitability decline for both biomass and MNI. The resource base expanded considerably, fewer of the taxa present in each collection actually contribute most of the biomass or MNI. This is primarily because the contribution made by oysters increases from 27% to

Table 3
Savannah faunal remains from Cathead Creek, Georgia

	NISP		MNI		Weight (g)	Biomass (g)
	(#)	(#)	(%)	(%)		
Vertebrata	—	—	—	—	58.50	—
Mammalia	34	—	—	—	9.60	215.9
Rodentia	3	—	—	—	0.10	3.3
<i>Neotoma floridana</i>	1	1	0.1	—	0.01	0.4
<i>Sigmodon hispidus</i>	1	1	0.1	—	0.05	1.8
<i>Procyon lotor</i>	2	2	0.3	—	0.60	17.4
<i>Odocoileus virginianus</i>	4	2	0.3	—	22.00	428.4
Aves	1	1	0.1	—	0.20	4.7
Testudines	104	—	—	—	9.20	165.3
Kinosternidae	1	1	0.1	—	0.20	10.8
Emydidae	2	—	—	—	1.30	37.7
<i>Malaclemys terrapin</i>	3	1	0.1	—	0.27	13.2
Sauria	2	—	—	—	0.10	—
<i>Anolis carolinensis</i>	7	4	0.6	—	0.62	—
<i>Sceloporus</i> sp.	1	1	0.1	—	0.01	—
<i>Heterodon</i> sp.	1	1	0.1	—	0.001	0.01
Amphibia	1	—	—	—	0.001	—
Caudata	2	1	0.1	—	0.02	—
<i>Amphiuma</i> sp.	1	1	0.1	—	0.01	—
<i>Siren</i> sp.	1	1	0.1	—	0.01	—
<i>Ambystoma</i> sp.	1	1	0.1	—	0.01	—
cf. <i>Notophthalmus viridescens</i>	1	1	0.1	—	0.10	—
<i>Plethodon glutinosus</i>	1	1	0.1	—	0.05	—
Anura	4	1	0.1	—	0.35	—
<i>Hyla</i> sp.	1	1	0.1	—	0.05	—
Rajiformes	25	1	0.1	—	0.62	87.2
Dasyatidae	3	—	—	—	0.05	9.7
<i>Dasyatis</i> sp.	1	1	0.1	—	0.05	9.6
Osteichthyes	720	—	—	—	35.60	541.3
<i>Lepisosteus</i> spp.	207	6	0.8	—	5.05	123.8
<i>Amia calva</i>	7	2	0.3	—	0.21	8.8
Clupeidae	13	1	0.1	—	0.25	10.1
Siluriformes	118	—	—	—	4.75	89.1
<i>Ictalurus</i> spp.	47	11	1.5	—	1.55	31.2
Ariidae	93	—	—	—	3.95	74.1
<i>Arius felis</i>	26	1	0.1	—	2.15	41.3
<i>Bagre marinus</i>	349	7	1.0	—	20.85	361.5
cf. Cyprinodontidae	78	—	—	—	0.45	16.1
Cyprinodontidae	61	—	—	—	0.50	18.9
<i>Fundulus</i> spp.	221	14	2.0	—	1.05	33.9
<i>Bairdiella/Stellifer</i> spp.	7	—	—	—	0.20	11.8
<i>Bairdiella chrysoura</i>	5	3	0.4	—	0.16	10.0
<i>Cynoscion</i> sp.	1	1	0.1	—	0.50	23.3
<i>Leiostomus xanthurus</i>	1	1	0.1	—	0.35	17.9
<i>Micropogonias undulatus</i>	14	7	1.0	—	0.70	32.5
<i>Pogonias cromis</i>	4	2	0.3	—	0.70	29.9
cf. <i>Stellifer lanceolatus</i>	1	—	—	—	—	—
<i>Stellifer lanceolatus</i>	1	1	0.1	—	0.15	9.6
<i>Mugil</i> spp.	65	2	0.3	—	0.55	18.6
<i>Balanus</i> spp.	—	—	—	—	2.00	—
<i>Penaeus</i> sp.	1	1	0.1	—	0.02	8.01
Brachyura	3	1	0.1	—	0.05	0.84
Mollusca	1	—	—	—	0.50	—
Mytilidae	—	—	—	—	73.15	21.35
<i>Brachidontes exustus</i>	16	9	1.3	—	0.55	0.37
<i>Geukensia demissa</i>	169	6	0.8	—	63.35	19.12
<i>Micostrea virginica</i>	1096	567	79.9	—	13620.00	1768.02
Unionidae	1	1	0.1	—	0.80	0.76
cf. <i>Tagalus plebeius</i>	24	—	—	—	0.80	1.56
<i>Tagalus plebeius</i>	37	22	3.1	—	59.05	110.96
cf. <i>Polymesoda caroliniana</i>	11	—	—	—	45.30	24.82
<i>Polymesoda caroliniana</i>	61	13	1.8	—	74.50	36.64
Veneridae	9	1	0.1	—	1.00	1.04

Table 3 (continued)

	NISP		MNI		Weight (g)	Biomass (g)
	(#)	(#)	(%)	(%)		
Gastropoda	1	—	—	—	0.01	0.01
<i>Oligyra orbiculata</i>	1	—	—	—	0.10	—
<i>Campeloma</i> sp.	1	1	0.1	—	0.35	0.26
<i>Littorina irrorata</i>	3	3	0.4	—	1.90	0.84
<i>Ilyanassa obsoleta</i>	1	1	0.1	—	0.40	0.14
<i>Olivella</i> sp.	1	—	—	—	0.10	—
<i>Boonea impressa</i>	230	—	—	—	1.46	—
Terrestrial Gastropods	1	—	—	—	0.05	—
Stylommatophora	1	—	—	—	5.40	—
Sigmurethra	4664	—	—	—	12.90	—
cf. <i>Euglandina rosea</i>	—	—	—	—	0.15	—
<i>Euglandina rosea</i>	4	—	—	—	0.20	—
Heterurethra	1	—	—	—	0.20	—
Orthurethra	2268	—	—	—	1.85	—
Total	10854	710	—	—	14149.892	4503.85

54% of the biomass and from 64% to 80% of the MNI despite the richer suite of Savannah resources.

The mean marine trophic level declines between the Swift Creek and Savannah occupations at Cathead Creek in terms of both biomass and MNI (Fig. 6). The dominant trophic level for both time periods and for both biomass and MNI is TL 2.1 (Fig. 7). TL 2.1 is dominated by molluscs; mullet is the only vertebrate taken from this trophic level (Table 1). TL 3.2, from which only sea catfishes (Ariidae) and gafftopsail catfishes were taken, contributes 30% of the Swift Creek biomass but only 14% of the Savannah biomass. TL 3.5 contributed 19% of the Swift Creek biomass and 5% of the Savannah biomass. This is consistent with the decline in diversity and equitability; reflecting a focus on a single, low, trophic level during the Savannah occupation supplemented by a broader range of resources compared to the Swift Creek strategy.

6. Comparison of the Swift Creek and Savannah components from the Kings Bay Locality

As in the two Cathead Creek temporal components, most of the biomass (93–95%) and MNI (93–96%) are from fishes and bivalves in the Kings Bay Locality collections (Fig. 4). Fishes contribute 27% of the biomass estimated for the Swift Creek occupation and 13% in the Savannah one. Among the reasons for this decline in fishes is that star drums decline from 10% of the biomass to 4% and from 20% of the MNI to 3%. As the percentage of fish biomass declines, the percentage of biomass from bivalves increases from 66% to 83%. The same decrease in fishes and increase in bivalves is observed in the MNI data (e.g., a decline from 28% to 4% for fishes). As in the Cathead Creek collections, the percentage of biomass contributed by fishes decreases and the percentage from bivalves increases.

Although biomass and MNI richness increases, diversity and equitability decline for the two temporal components at the Kings Bay Locality (Fig. 5). Despite the richer suite of resources and expanded resource base, few of the taxa used during the Savannah occupation contribute much biomass or

Table 4
Savannah faunal remains from the Devils Walkingstick, Kings Bay Locality, Georgia

	NISP		MNI		Weight (g)	Biomass (g)
	(#)	(#)	(%)	(%)		
Vertebrata	—	—	—	—	27.6	—
Mammalia	6	—	—	—	4.7	105.90
Large mammalia	5	1	0.005	—	11.0	227.64
Medium mammalia	5	—	—	—	0.3	9.49
Small mammalia	18	1	0.005	—	0.5	16.56
<i>Blarina carolinensis</i>	10	3	0.014	—	0.1	3.31
Rodentia	7	—	—	—	0.4	13.00
<i>Oryzomys palustris</i>	3	1	0.005	—	0.1	3.31
<i>Peromyscus</i> sp.	1	1	0.005	—	0.1	3.31
<i>Sigmodon hispidus</i>	5	3	0.014	—	0.3	9.93
<i>Sciurus</i> spp.	4	1	0.005	—	0.5	14.10
<i>Sciurus carolinensis</i>	1	1	0.005	—	0.2	6.18
<i>Procyon lotor</i>	4	1	0.005	—	0.6	16.61
<i>Odocoileus virginianus</i>	1	1	0.005	—	1.3	33.31
Aves	6	3	0.014	—	1.4	29.93
Anatidae	1	1	0.005	—	0.5	10.87
Reptilia	6	—	—	—	0.3	4.00
Testudines	55	3	0.014	—	4.0	119.06
Kinosternidae	2	—	—	—	0.2	10.76
<i>Kinosternon</i> spp.	3	2	0.009	—	0.4	21.51
Emydidae	6	—	—	—	1.0	31.62
<i>Terrapene carolina</i>	6	1	0.005	—	0.9	29.47
Squamata	9	—	—	—	0.4	—
Iguanidae	4	1	0.005	—	0.2	—
<i>Anolis carolinensis</i>	5	4	0.019	—	0.4	—
Serpentes	74	—	—	—	1.1	15.06
Colubridae	13	1	0.005	—	2.6	36.05
cf. <i>Elaphe</i> sp.	1	1	0.005	—	0.1	1.35
<i>Elaphe</i> spp.	6	1	0.005	—	0.7	1.35
<i>Thamnophis</i> sp.	1	1	0.005	—	0.1	1.35
Viperidae	1	1	0.005	—	0.1	1.35
cf. <i>Sistrurus miliarius</i>	1	1	0.005	—	0.1	1.35
Caudata	188	3	0.014	—	0.4	—
cf. <i>Plethodon glutinosus</i>	3	2	0.009	—	0.2	—
<i>Plethodon glutinosus</i>	65	3	0.014	—	0.2	—
Anura	27	3	0.014	—	0.5	—
cf. <i>Scaphiopus holbrooki</i>	1	1	0.005	—	0.1	—
<i>Scaphiopus holbrooki</i>	1	1	0.005	—	0.2	—
<i>Bufo</i> sp.	1	1	0.005	—	0.1	—
<i>Hyla</i> sp.	1	1	0.005	—	0.1	—
Chondrichthyes	7	—	—	—	0.5	69.36
Carcharhinidae	4	1	0.005	—	0.3	44.70
Rajiformes	18	2	0.009	—	0.2	34.76
Osteichthyes	29341	—	—	—	213.9	2768.00
<i>Lepisosteus</i> spp.	11	5	0.023	—	0.7	31.63
Clupeidae	307	6	0.028	—	2.7	75.00
<i>Brevoortia</i> spp.	3	1	0.005	—	0.2	9.80
Siluriformes	905	—	—	—	22.0	403.59
<i>Ictalurus</i> spp.	16	4	0.019	—	1.0	20.64
Ariidae	490	45	0.209	—	29.2	525.04
<i>Arius felis</i>	261	29	0.135	—	30.3	545.68
<i>Bagre marinus</i>	32	9	0.042	—	2.0	40.88
cf. <i>Fundulus</i> spp.	17	—	—	—	0.1	—
<i>Fundulus</i> spp.	266	37	0.172	—	1.6	51.85
cf. <i>Pomatomus saltatrix</i>	1	—	—	—	0.1	—
<i>Pomatomus saltatrix</i>	3	1	0.005	—	0.1	4.07
Carangidae	1	1	0.005	—	0.1	5.13
<i>Chloroscrombrus chrysurus</i>	4	1	0.005	—	0.1	5.13
<i>Lobotes surinamensis</i>	11	3	0.014	—	7.3	143.40
<i>Archosargus probatocephalus</i>	10	4	0.019	—	1.0	17.10
Sciaenidae	202	—	—	—	0.4	25.98
<i>Bairdiella/Stellifer</i> spp.	564	—	—	—	2.7	90.80

Table 4 (continued)

	NISP		MNI		Weight (g)	Biomass (g)
	(#)	(#)	(%)	(%)		
<i>Bairdiella chrysoura</i>	65	25	0.116	—	1.5	70.07
<i>Cynoscion</i> spp.	20	9	0.042	—	2.2	81.75
<i>Leiostomus xanthurus</i>	7	6	0.028	—	0.2	14.16
<i>Menticirrhus</i> spp.	2	2	0.009	—	0.2	14.16
<i>Micropogonias undulatus</i>	39	23	0.107	—	3.4	106.16
<i>Pogonias cromis</i>	3	2	0.009	—	1.7	68.78
<i>Sciaenops ocellatus</i>	2	1	0.005	—	0.1	7.08
<i>Stellifer lanceolatus</i>	2735	566	2.635	—	59.6	836.06
<i>Mugil</i> spp.	528	49	0.228	—	20.1	397.64
<i>Peprilus alepidotus</i>	213	18	0.084	—	0.5	15.49
<i>Paralichthys</i> spp.	22	3	0.014	—	0.6	18.41
<i>Balanus</i> spp.	—	—	—	—	246.4	—
Brachyura	293	7	0.033	—	8.3	64.80
<i>Callinectes sapidus</i>	4	1	0.005	—	0.6	6.43
Pelecypoda	—	—	—	—	58737.0	6147.20
Mytilidae	1	—	—	—	0.3	1.15
cf. <i>Brachidontes exustus</i>	1	1	0.005	—	1.5	0.89
<i>Brachidontes exustus</i>	22	13	0.061	—	1.1	0.65
<i>Geukensia demissa</i>	2458	1263	5.879	—	7770.7	1006.64
Arcidae	3	3	0.014	—	3.2	2.24
<i>Anadara ovalis</i>	1	1	0.005	—	5.8	0.79
<i>Crassostrea virginica</i>	30910	17725	82.507	—	168326.0	17071.70
<i>Dinocardium robustum</i>	1	1	0.005	—	47.0	10.55
<i>Donax variabilis</i>	1	1	0.005	—	0.4	0.15
<i>Tagelus plebeius</i>	1514	776	3.612	—	1133.6	2066.17
<i>Polymesoda caroliniana</i>	20	11	0.051	—	46.6	42.62
<i>Gemma gemma</i>	21	13	0.061	—	0.3	—
<i>Mercenaria</i> spp.	66	36	0.168	—	1468.9	308.56
<i>Mya arenaria</i>	1	1	0.005	—	0.2	0.40
Gastropoda	9	8	0.037	—	0.6	—
<i>Littorina irrorata</i>	268	268	1.247	—	206.0	71.19
<i>Crepidula</i> sp.	1	1	0.005	—	0.1	—
<i>Neverita duplicata</i>	1	1	0.005	—	2.0	3.51
<i>Epitonium multistriatum</i>	1	1	0.005	—	0.1	—
cf. <i>Urosalpinx</i> sp.	1	1	0.005	—	0.1	—
<i>Busycon carica</i>	13	13	0.061	—	1241.0	341.70
<i>Ilyanassa obsoleta</i>	390	390	1.815	—	158.5	72.68
cf. <i>Nassarius</i> sp.	1	—	—	—	0.1	0.03
<i>Nassarius</i> spp.	8	8	0.037	—	0.2	0.66
cf. <i>Nassarius trivittatus</i>	1	1	0.005	—	0.1	0.03
<i>Nassarius vibex</i>	3	3	0.014	—	0.8	0.27
Columbellidae	1	—	—	—	0.1	—
<i>Mitrella</i> spp.	7	7	0.033	—	0.3	—
<i>Mitrella lunata</i>	25	25	0.116	—	0.5	—
<i>Olivella mutica</i>	1	—	—	—	0.2	—
Turridae	1	—	—	—	0.1	—
<i>Boonea impressa</i>	16093	—	—	—	105.5	—
<i>Melampus bidentatus</i>	6	—	—	—	0.5	—
Sigmurethra	6855	—	—	—	101.1	—
Oleacinidae	1	—	—	—	—	—
<i>Euglandina rosea</i>	8	—	—	—	0.9	—
Heterurethra	33	—	—	—	0.5	—
Orthurethra	185	—	—	—	0.6	—
Total	95897	21483			240088.4	34541.04

many individuals. This is primarily because oyster use increases from 27% to 69% of the biomass; and from 42% to 82% of the MNI.

The mean marine trophic level also declines between the Swift Creek and Savannah occupations at the Kings Bay Locality (Fig. 6). The dominant trophic level for both time periods and for both biomass and MNI is TL 2.1 (Fig. 7). This

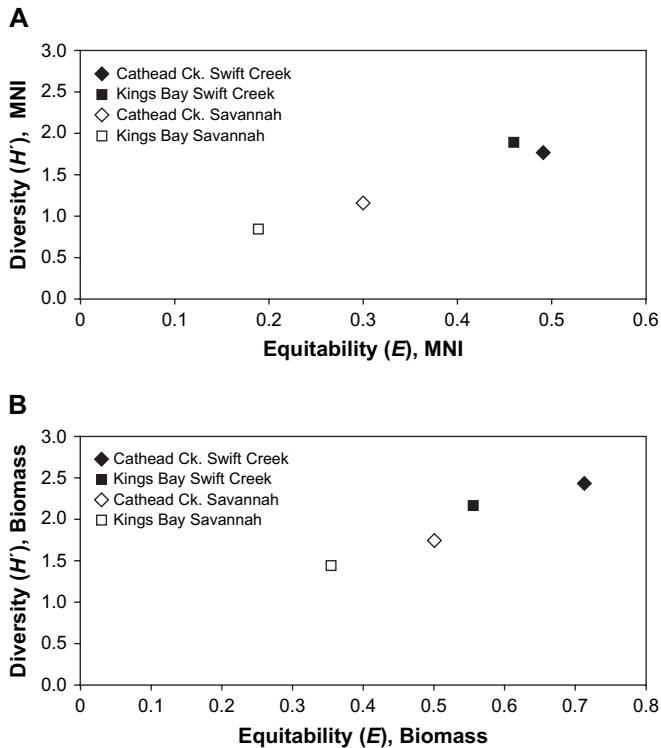


Fig. 5. Cathead Creek and Kings Bay Locality, diversity and equitability, Swift Creek and Savannah data: (A) MNI and (B) biomass. Biomass estimate for each taxon is included in these figures only if MNI also is estimated for that taxon in order to keep the sample universe identical.

trophic level is dominated by molluscs; mullet is the only vertebrate used from this trophic level. TL 3.3 contributes 15% of the Swift Creek biomass and 24% of the Swift Creek MNI but very little of either during the Savannah occupation. This, too, is consistent with the decline in diversity and equitability; combined with a focus on resources from the lowest trophic level during the Savannah occupation (Fig. 5).

7. Comparison of results from the Cathead Creek site and the Kings Bay Locality

One of the objectives of this research is to fill the temporal gap afflicting the previously published St. Augustine sequence [48], which cannot be done with presently available data from the St. Augustine area itself. For this reason, as well as to initiate the development of a regional pattern, it is necessary to consider the geographical component of this study. It is worth mentioning again that the two sites are part of hydrologically different estuaries. The Altamaha is a high-volume river while Kings Bay is more tidally controlled. The similarity in the temporal trends documented in the faunal assemblages from the two sites argues against a purely geographical explanation for the data and strengthens the conclusions. In other words, the approach overrides local variation while testing the spatial component of the data.

For each of the two time periods, the northern component has a lower percentage of biomass from fishes and bivalves

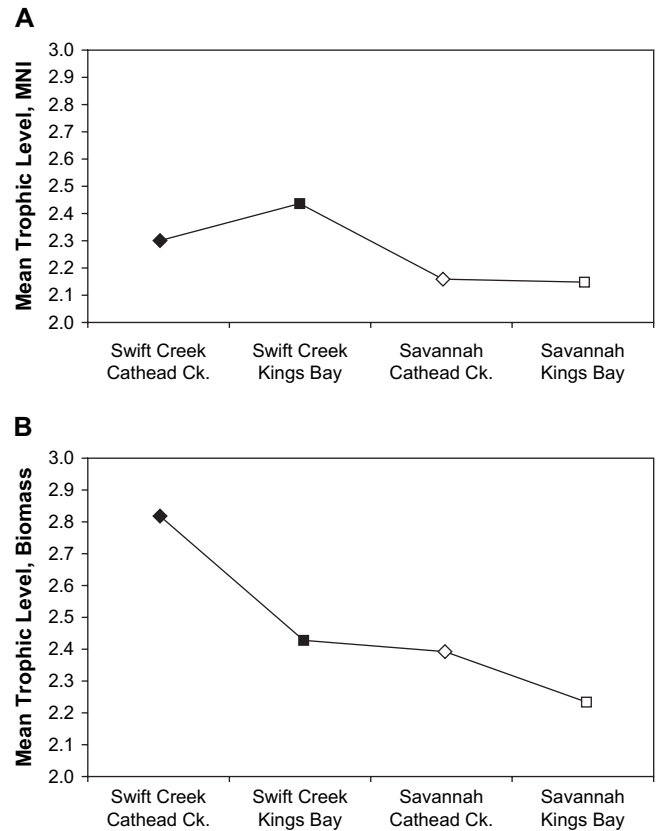


Fig. 6. Cathead Creek and Kings Bay Locality, mean trophic level, Swift Creek and Savannah data: (A) MNI and (B) biomass. Biomass estimate for each taxon is included in these figures only if MNI also is estimated for that taxon in order to keep the sample universe identical.

than does the southern component (Figs. 3 and 4). The percentage of biomass contributed by fishes and bivalves in both time periods at the northern Cathead Creek is 85%; but in the collections from the southern Kings Bay Locality, the percentage of fishes and bivalves is between 93% and 95%. The distinction in terms of MNI is less dramatic because over 93% of the individuals are fishes and bivalves in all four temporal and spatial components. Although use of bivalves increases compared to fishes at both locations, the percentage of marine biomass in the Kings Bay collections is always higher than it is in the Cathead Creek collections.

The Swift Creek residents generally were less specialized than were the Savannah occupants at the same location and people at the northern location used fewer resources more equitably than did contemporaneous peoples living to the south (Table 5, Fig. 5). The Swift Creek sources of biomass and MNI are less rich, more diverse, and more equitable than the Savannah components at each location. The lower Savannah diversity and equitability reflects increased reliance on shellfish during the Savannah occupations at both locations within an overall strategy in which the number of different resources used expanded. Each collection from the northern Cathead Creek site is generally less rich, more diverse, and more equitable than is the contemporaneous collection from the southern Kings Bay Locality. The only exception is in MNI; the Swift

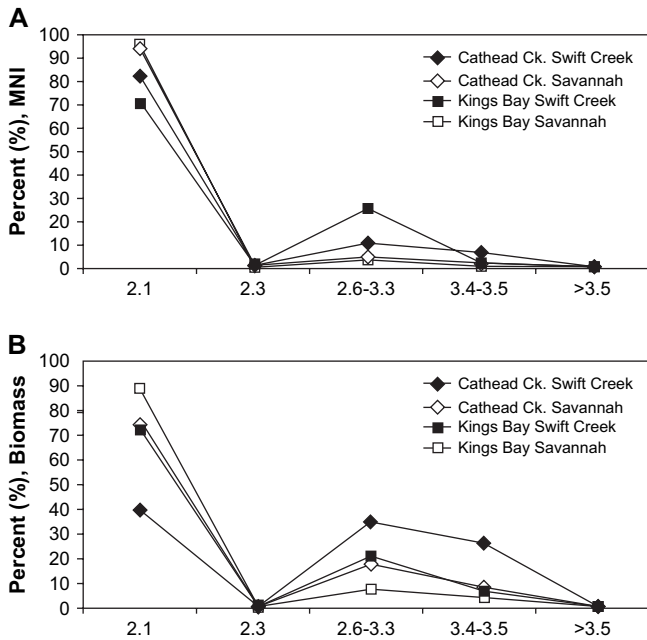


Fig. 7. Cathead Creek and Kings Bay Locality, Swift Creek and Savannah data: distribution of MNI (A) and biomass (B) among trophic levels. No taxa from trophic levels 2.2, 2.4, and 2.5 are present in these collections.

Creek component from Cathead Creek is slightly less diverse than the Swift Creek component at Kings Bay.

A similar temporal and spatial relationship characterizes the mean trophic level from which resources at each site were obtained (Fig. 6). The earlier Swift Creek collections are characterized by higher mean trophic levels than are the later Savannah ones. Within each time period, the northern Cathead Creek collection reflects a fishing strategy that took resources from a higher mean trophic level than is reflected in the southern Kings Bay collection. Swift Creek MNI mean trophic level is the only exception, which is attributable to the prominent role of star drum ($TL = 3.3$) in the Swift Creek collection from the Kings Bay site. Although the geographical variation can be attributed to changes in many aspects of the marine strategy, in part it reflects the degree to which oysters were used. Oysters comprise 27% of the Swift Creek biomass and between 54% and 69% of the Savannah biomass at both sites. The Savannah collection from the southerly Kings Bay Locality has the highest percentage of oyster biomass of the four collections.

The distribution of effort among the major trophic levels also conforms to this temporal and spatial pattern. Fig. 7 summarizes the distribution of effort assessed in terms of the percentage of biomass or of MNI derived from five trophic-level clusters. The lowest trophic level is $TL 2.1$, which is composed of shellfish and mullets. $TL 2.3$ contains only shrimps, which are probably under-represented. $TLs 2.6$ through 3.5 are composed of sea catfishes (Ariidae), drums (Sciaenidae), and other estuarine fishes. Resources in the high trophic levels, between $TLs 3.6$ and 4.1 were rarely exploited during either time period or at either location.

Low trophic levels were used predominately during both time periods and at both locations (Fig. 7). In terms of

Table 5
Diversity, equitability, richness, sample size, and mean trophic level for the Cathead Creek and Kings Bay Locality, Georgia collections

	Cathead Creek	Kings Bay	Cathead Creek	Kings Bay
	Swift Creek	Swift Creek	Savannah	Savannah
MNI diversity	1.7479	1.8769	1.1466	0.8367
MNI equitability	0.4916	0.4603	0.2995	0.1883
MNI richness	35	59	46	85
Total MNI	230	5892	710	21483
MNI TL	2.301	2.432	2.155	2.142
MNI vertebrate TL	2.960	3.267	3.031	3.224
Biomass diversity	2.4587	2.1844	1.7813	1.4755
Biomass equitability	0.7094	0.5502	0.4971	0.3497
Biomass richness	32	53	36	68
Total biomass, g	1835.78	14169.30	3272.91	24845.10
Biomass TL	2.822	2.427	2.392	2.230
Biomass vertebrate TL	3.249	3.290	3.223	3.153

MNI and Biomass richness are not the same because MNI was estimated for more taxa than Biomass; biomass formulae are not available for some taxa. Biomass estimates are included in this table only if MNI was also estimated for that same taxon in Tables 3 and 4 and in Ref. [49]. Vertebrate TL is the mean trophic level for each collection with invertebrates excluded. Richness is derived by counting the number of taxa for which both MNI and Biomass is estimated in each of the species lists.

biomass, Swift Creek peoples at Cathead Creek made less use of invertebrates in the lowest trophic level, $TL 2.1$, and greater use of fishes in higher trophic levels, between $TLs 2.6$ and 3.5 , compared to people at the Kings Bay Locality. During the subsequent Savannah occupations, people at both locations fished further down the food web by increasing their use of resources in $TL 2.1$. At the same time the use of resources from $TLs 2.6$ – 3.5 (primarily fishes) declined. This change is more pronounced at Cathead Creek than it is at the Kings Bay Locality. In both time periods, the northern Cathead Creek peoples used more resources from higher trophic levels than did their contemporaries to the south. With the exception related to the high percentages of star drums in the Swift Creek occupation of the Kings Bay site, this description also characterizes the MNI pattern.

8. Discussion

One of the motivations for initiating this research was to begin developing a regional database, building upon the temporal sequence published for the St. Augustine area [48]. Based on the discussion above, the Kings Bay Locality data are considered more suitable for use in the St. Augustine sequence because of the geographical component found in the comparison of data from Cathead Creek and the Kings Bay Locality. In order to insert the Kings Bay Swift Creek and Savannah data into the St. Augustine sequence, invertebrates must be removed from the Kings Bay Locality data. Invertebrate data are not included in the St. Augustine study because molluscs were used to make “tabby,” a building material, as was a local aggregate rock known as coquina. It is rare that tabby and coquina can be separated from food debris in St.

Augustine materials. Thus, the modern fisheries, Swift Creek, and Savannah data must be recalculated to include only vertebrates in order to compare them to the St. Augustine pattern (Fig. 8). Excluding the low-trophic-level invertebrates produces higher trophic level estimates than would be the case if invertebrates were included, a point which is important when the zooarchaeological data are compared to modern evidence for fishing down the food web. We use only biomass to develop the mean trophic level temporal series because modern fisheries data do not include the MNI of the catch. Table 5 summarizes the mean trophic levels for Cathead Creek and Kings Bay Locality with the invertebrates omitted (MNI vertebrate *TL* and biomass vertebrate *TL*), though only the Kings Bay Locality data are summarized in Fig. 8, having demonstrated that some differences between Cathead Creek and Kings Bay are geographically sensitive.

Modern mean trophic level for vertebrates peaked in the St. Augustine area at approximately *TL* 3.2 for vertebrates [48]; somewhat below the mean trophic level of the historic high reported by Pauly for both vertebrates and invertebrates (*TL* = 3.4) [35]. It is clear in Fig. 8 that fishing at similar, historically-high mean trophic levels for vertebrates, around *TL* 3.2, is not simply a consequence of twentieth-century industrial fishing or even of European fishing strategies after the sixteenth century. In fact, fishing above *TL* 3.2 appears to have been the norm. A decline in mean vertebrate trophic level, however, seems to have occurred at three different times. The first decline occurred between AD 1200–1500, during the Savannah occupation reported here; a second decline occurred between 1783 and 1821 [48]; and we appear to be experiencing a third decline at the present time [34–36,48].

When we see trends such as these we wonder to what extent they represent cultural evolution independent of environmental forces and to what extent they represent cultural adaptations to environmental changes that occurred independent of human impact or because of it. Are these three declines in mean trophic level evidence of non-anthropogenic environmental change; evidence of anthropogenic resource depletion such as that encapsulated in the phrase “fishing down the food web”; or evidence of changes in cultural preferences

independent of environmental parameters? We cannot answer this question at this point, but this is clearly an important distinction that would not have been so clearly defined without the use of the trophic level approach. The following discussion focuses on the Cathead Creek and Kings Bay Locality data to avoid complicating the matter further with the commercial enterprise introduced in the 1500s by Spanish colonization.

Faunal remains reflect a “cultural filter” [43, p. 210] consisting of choices people make individually and as a group. People were not random scavengers. The filtering aspect of cultural choices is manifest in fishing techniques. Fishing technologies, locations, and schedules take advantage of the habits, habitats, shape, size, and other aspects of prey species. Fishing techniques balance the time and energy required to capture resources against risks and the goal of achieving an acceptable return for effort. These behaviors are the fabric of cultural identity but they obscure changes in the resource base itself. Site formation processes and excavation techniques further confound the association between the original resource base and the archaeofaunal samples studied. Because both humans and their preferred prey often are characterized by flexibility, it is seldom possible to conclude that an animal in an archaeological collection is characteristic of a single habitat, can be taken at only one time and place with a specific technology, has a single feeding strategy, or is restricted to a specific trophic level. All of these factors obscure the relationship between the original resource base, human use of such resources, and the recovered animal remains.

On the other hand, patterns of animal use do reflect the environment in which they occur and continuity is more characteristic of human subsistence than is change. Modifications in established subsistence patterns strongly suggest modified human behavior in an altered environment. Thus, it is likely that the trend described here is the result of both environmental and cultural factors. Some of the explanations that are likely follow.

(i) The changes observed here might be evidence of a cultural response to climate changes that impacted the resource base. Although the regional impact and timing of various global climatic events are hotly debated (e.g., Hypsithermal, Medieval Warm, and the Little Ice Age), there is ample evidence for climate change coincident with the Swift Creek and Savannah occupations. The Savannah occupation coincides with the early part (AD 1200–1500) of the Little Ice Age, between approximately AD 1350 and 1860 (dates from [7,9,55]). Relative to the Little Ice Age, the Swift Creek occupation (AD 300–AD 700) occurs during a warmer climate period that ultimately leads into the Medieval Warm, between AD 800 and 1200 [5–7,9,24–26,29,55–59]. More research is needed to correlate these archaeofaunal data with evidence for the timing of global climatic events and the local consequences. Local evidence is necessary because climate change may be asynchronous [28,31,33].

Fisheries research shows that temperature changes of only a few degrees can fundamentally alter a marine ecosystem in a variety of ways [3,13,37]. Changes in sea surface temperatures would alter the productivity of estuaries, the reproductive and growth habits of both predator and prey members of

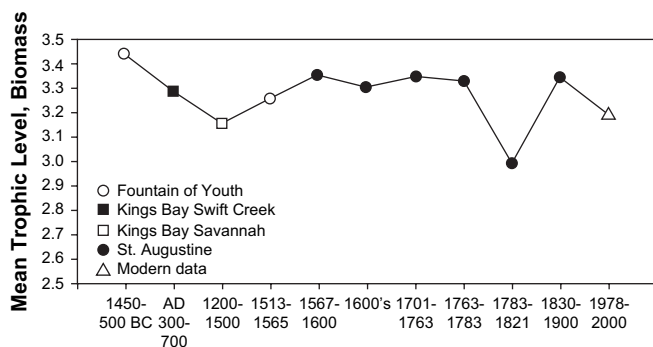


Fig. 8. Trophic level time sequence from 1450 and 500 BC through the twentieth century using biomass data from the Kings Bay Locality and St. Augustine area. Archaeological data from Fountain of Youth and St. Augustine, as well as modern data, are published elsewhere [48].

the estuarine system, and the distribution of these animals. In any given estuary, warmer waters are more productive through the annual and climatic cycle than are cooler ones. Thus, warmer Swift Creek estuaries may have been more productive than cooler Savannah estuaries in the same location. The decline in diversity between the Swift Creek and Savannah components at both locations may be evidence of a decline in productivity related to cooler water conditions along the coast of Georgia. The growth rates of some fish species may slow if the water temperature is outside that species' optimal growth temperature. Such an event would increase the length of time during which developing juvenile fishes were exposed to predation. In other words, they remain at a smaller, more vulnerable size for a longer time. Warmer waters enhance fish egg development in some species, which may increase survival and productivity [17]. Due to the dominance of protein, fat, and fat-soluble vitamins from fishes and bivalves in the subsistence strategy, any of these changes would profoundly influence human behavior in a number of ways.

(ii) The pre-Hispanic data may be evidence that the estuarine environment was stressed by pre-industrial fishing techniques, as reported elsewhere [18]. Such human-induced resource depletion would require fishing at such a level that the age classes, size classes, reproductive capacity, population density, and or recruitment of fishes and shellfishes was impacted. One of the mechanisms by which people deplete a resource is through their fishing technology, with the ultimate questions being how many people were supported by what type of technology for how long with what degree of effort? We do not wish to get embroiled in the question of how many people lived on the Georgia coast or how long each site was occupied by how many people; but we do know human populations lived, and fished, in both the Kings Bay Locality and within the Altamaha estuary for several thousand years. There is also evidence that human population density increased with the passage of time [62].

Fishing technology is more amenable to zooarchaeological consideration than are these other ingredients of fishing effort and human impact. Unfortunately, little direct archaeological evidence exists for fishing tools on the Georgia coast. The most useful evidence is offered by net-marked ceramics in Savannah ($N = 4$), Deptford ($N = 1$), and Deptford/Swift Creek ($N = 2$) deposits at the Kings Bay Locality [12, p. 306]. The gauge of the net mesh ranges from 2.5 mm to 6.8 mm and probably represents a very important, successful adaptation to the estuarine environment. Nets with such a small gauge are ideally suited to catching the small, schooling fishes that are so ubiquitous in fine-screened (1/16-inch mesh screens) faunal assemblages from the Georgia coast [11,27,40,44,46,48,49,61]. The dominance of shellfish and small schooling fishes suggests the use of digging devices, weirs, fine-mesh nets, and scoops at both locations. Hooks and leisters also may have been part of the tool kit.

Estuaries are the foundation of the fisheries resources of the southeastern United States because they are nursery grounds. Mass-capture fishing techniques targeting small individuals that would also capture the larger reproductive adults, are

particularly effective and destructive in such nursery environments. Given the small size and schooling behaviors of many of the fishes in these faunal collections, along with the occasional large individual, it is probable that the nursery component of near-shore, estuarine waters was targeted with mass-capture technologies. Perhaps the Swift Creek fishing strategy at a higher trophic level at both locations was unsustainable so that subsequently people expanded their resource base and also intensified use of lower trophic levels in response to declining resources induced by over-fishing; just as appears to be happening today.

At first glance this resource depletion seems improbable because it is difficult to envision that the human population density, fishing effort, and fishing technology would be able to over-fish Georgia's large, complex estuarine system. However, a focus on low trophic levels by people may be sufficient to impact resources needed by other predators and prey with whom they share each system. The effects of altering part of an ecosystem, such as targeting members of a specific trophic level, can cascade throughout the ecosystem, whether that impact is due to altered production rates (bottom-up processes) or predator-prey interactions (top-down processes) [8,14,60]. Thus, it may not require a major fishing effort for people to impact an estuary if they are particularly successful in capturing a specific taxon or members of a specific trophic level, whatever that trophic level may be. Targeting specific members of a wild estuarine population may not be possible without eventually causing harmful consequences even if that use is on a relatively small scale.

(iii) A change in the pattern of marine resource use may be related to domestic crops. Increasing the amount of plant cultivation after the Swift Creek occupation would have required alterations in the management of time, labor, and use of other resources throughout the cultural systems at both locations. This may have impacted the way estuarine resources were used. The decline in diversity and equitability may be evidence of an intensification of the protein-based component of the subsistence effort. On the other hand, a decline in the productivity of the estuarine resource base may have encouraged people to increase their use of domestic crops whether they wished to do so or not. If an increase in the amount of time and energy spent on plant cultivation is related to these changes, it is noteworthy that people at both locations made very similar choices with regards to their estuarine resource base.

These three hypotheses are not mutually exclusive; in fact, they are closely related. They require further research to clarify their role in the subsistence strategies summarized here. To test whether estuarine characteristics changed during the temporal sequence described here, data from stable isotopes and other aspects of incremental growth structures as well as morphometric data for the fishes and shellfishes involved need to be obtained. With this information, age at maturity, size at maturity, and growth rate of invertebrates and vertebrates can be correlated with proxy paleo-temperatures [16,20–22]. This work should be combined with vastly improved botanical studies as well as more attention to direct evidence for subsistence technologies and additional zooarchaeological studies. Eventually it should be possible to distinguish between human-induced

resource depletion and climate change as causal factors in the patterns described here; discounting for sake of argument the possibility that humans altered their subsistence strategy to include domestic crops without a motivation to do so.

These data may indicate that the definition of coastal Swift Creek and Savannah life should include differences in the strategies by which marine resources were used. In part, these differences may reflect scheduling needs arising from the cultivation of crops. In part, however, these changes probably reflect an environmental change that affected the entire coast. The spatial trend suggests this change is not simply a local shift in strategy reflecting a cultural choice, but represents a force with a regional impact. This environmental component may have been climatic initially, which, when compounded by the human response, resulted in resource depletion. At the moment, however, these data at the very least may be interpreted as evidence of a strong environmental component associated with a multi-faceted cultural response.

9. Conclusion

Multiple lines of evidence that reinforce one another give more confidence in interpreting zooarchaeological data. The trophic level approach demonstrated here is another tool that will enable zooarchaeologists to explore fish use from an ecological perspective. The technique also has the added value of allowing the researcher to link modern and archaeological data. The clear and consistent results from multiple lines of evidence of the vertebrate and invertebrate data reviewed above suggest that a change in the use of marine resources occurred between AD 300–700 and AD 1200–1500 throughout the study area. That this change is found at two different estuarine systems, three including the St. Augustine area, within the same biogeographical province suggests a broadly based phenomenon impacted the Georgia and northeast Florida coast. This geographical scope suggests this is not simply a local, cultural shift in strategy but is a response to a larger stimulus felt throughout the entire coastal region.

Identifying the causes requires further study on many fronts; but new research using modern best practices in archaeobotany, stable isotope geochemistry, and zooarchaeology would undoubtedly resolve some of the questions raised by the data reviewed here. This study highlights the merits of examining data from a variety of perspectives and from several sites rather than applying single techniques to small samples from one site and extrapolating from that single study to a broader area. As more data become available, it is likely that finer-grained temporal and geographical resolution will be achieved. The present study is the first step toward building a regional sequence; but further development will only be possible if improvements are made in the way coastal archaeological sites are excavated.

Fisheries managers base their decisions on recent fish catches (landings) and population statistics. The short time perspective within which they operate limits their ability to assess the extent to which present aspects of local fisheries represent long-term characteristics or short-lived phenomena. Archaeologists offer biological resource managers local

records of marine resource composition and health for the entire Holocene, often from well-dated contexts. Trophic-level analysis of archaeological fish remains offers a method by which zooarchaeological data can be translated into a format that is similar to current management records; thereby making this historical record available to present efforts to develop management plans for marine resources and to restore marine ecosystems. The present decline in the world's marine resource base, whatever the cause, requires a joint effort to resolve.

Acknowledgments

We wish to thank the numerous people who supported this study. Thanks are due to Martin Dickinson and Lucy Wayne who facilitated the research by agreeing to take what was in essence a very large column sample and transporting it back to their lab. This was done under a sub-contract with Water and Air Research, Inc. and funded by the Environmental Protection Agency and the Farmers Home Administration through McCrary Engineering. The Kings Bay identifications were done under contract number N00025-79-C-0013 from the Department of the Navy to the University of Florida and directed by William H. Adams. Karla Bosworth, George Burgess, Steve Hale, Minh Ngo, Carolyn Rock, Michael Russo, Helen D. Shapiro, Sylvia Scudder, and Erika Simons assisted in this effort. We acknowledge the role Lewis Larson played in encouraging the study of animal remains from the Georgia coast at these sites. We are especially grateful for the advice and assistance provided by Douglas S. Jones, Elizabeth S. Wing, and Kitty F. Emery of the Florida Museum of Natural History. We express our gratitude as well to the reviewers of the manuscript for their thorough and thought-provoking comments. An earlier version of this paper was presented at the 60th annual meeting of the Southeastern Archaeological Conference, Charlotte, North Carolina.

References

- [1] W.H. Adams (Ed.), *Aboriginal Subsistence and Settlement Archaeology of the Kings Bay Locality*, vol. I, University of Florida Department of Anthropology Reports of Investigations No. 1, Gainesville, 1985.
- [2] T. Amorosi, J. Woollett, S. Perdikaris, T. McGovern, *Regional zooarchaeology and global change: problems and potentials*, *World Archaeology* 28 (1996) 126–157.
- [3] M.J. Attrill, M. Power, *Climate influence on a marine fish assemblage*, *Nature* 417 (2002) 275–278.
- [4] J.A. Bense, *Archaeology of the Southeastern United States: Paleoindian to World War II*, Academic Press, San Diego, 1994.
- [5] G. Bond, B. Kromer, J. Beer, R. Muscheler, M.N. Evans, W. Showers, S. Hoffmann, R. Lotti-Bond, I. Hajdas, G. Bonani, *Persistent solar influence on North Atlantic climate during the Holocene*, *Science* 294 (2001) 2130–2136.
- [6] R.S. Bradley, M.K. Hughes, H.F. Diaz, *Climate in Medieval time*, *Science* 302 (2003) 404–405.
- [7] W.S. Broecker, *Was the Medieval Warm Period global?* *Science* 291 (2001) 1497–1499.
- [8] D.O. Conover, S.B. Munch, *Sustaining fisheries yields over evolutionary time scales*, *Science* 297 (2002) 94–96.

- [9] P. deMenocal, J. Ortiz, T. Guilderson, M. Sarnthein, Coherent high- and low-latitude climate variability during the Holocene Warm Period, *Science* 288 (2000) 2198–2202.
- [10] M.F. Dickinson, L.B. Wayne, M.J. Melendez, Cultural Resource Impact Mitigation for the Darien, Georgia, Sewer System Project, Report prepared by Water and Air Research, Inc., for McCrary Engineering, Inc., Georgia, Atlanta, 1986.
- [11] M.E. Dahlberg, Guide to coastal fishes of Georgia and nearby states, University of Georgia Press, Athens, 1975.
- [12] C. Espenshade, Aboriginal subsistence activities in the Kings Bay Locality, in: W.H. Adams (Ed.), *Aboriginal Subsistence and Settlement Archaeology of the Kings Bay Locality*, vol. 1, University of Florida Department of Anthropology Reports of Investigations No. 2, Gainesville, 1985, pp. 73–91.
- [13] B.P. Finney, K. Gregory-Eaves, J. Sweetman, M.S.V. Douglas, J.P. Smol, Impacts of climate change and fishing on Pacific salmon abundance over the past 300 years, *Science* 290 (2000) 795–799.
- [14] K.T. Frank, B. Petrie, J.S. Choi, W.C. Leggett, Trophic cascades in a formerly cod-dominated ecosystem, *Science* 308 (2005) 1621–1623.
- [15] R. Froese, D. Pauly, FishBase 98: Concepts, Design and Data Sources, The International Center for Living Resources Management, Kakati City, Philippines, 1998.
- [16] L.S. Hales Jr., E.J. Reitz, Historical changes in age and growth of Atlantic Croaker, *Micropogonias undulatus* (Perciformes: Sciaenidae), *Journal of Archaeological Science* 19 (1992) 73–99.
- [17] E.G. Haynes, S.E. Ignell, Effect of temperature on rate of embryonic development of walleye pollock (*Theragra chalcogramma*), *Fisheries Bulletin* 81 (1983) 890–894.
- [18] J.B.C. Jackson, M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlanson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, R.R. Warner, Historical overfishing and the recent collapse of coastal ecosystems, *Science* 293 (2001) 629–638.
- [19] A.S. Johnson, H.O. Hillestad, S.F. Shanholtzer, G.F. Shanholtzer, An Ecological Survey of the Coastal Region of Georgia, National Park Service Scientific Monograph Series 3, Washington, DC, 1974.
- [20] D.S. Jones, I.R. Quitmyer, Marking time with bivalve shells: Oxygen isotopes and season of annual increment formation, *Palaos* 11 (1996) 340–346.
- [21] D.S. Jones, I.R. Quitmyer, C.F.T. Andrus, Seasonal shell growth and longevity in *Donax variabilis* from Northeastern Florida: Evidence from oxygen isotopes, *Journal of Shellfish Research* 23 (2004) 707–714.
- [22] D.S. Jones, I.R. Quitmyer, C.F.T. Andrus, Oxygen isotopic evidence for greater seasonality in Holocene shells of *Donax variabilis* from Florida, *Palaos*, in press.
- [23] D.A. Keene, Reevaluating Late Prehistoric coastal subsistence and settlement strategies: New data from Grove's Creek Site, Skidaway Island, Georgia, *American Antiquity* 69 (2004) 671–689.
- [24] R.A. Kerr, The Little Ice Age—Only the latest big chill, *Science* 284 (1999) 2069.
- [25] R.A. Kerr, Big chill from sun and volcano, *Science* 296 (2002) 1963.
- [26] R.A. Kerr, Millennium's hottest decade retains its title, for now, *Science* 307 (2005) 823–829.
- [27] C.H. Lee, I.R. Quitmyer, C.T. Espenshade, R.E. Johnson, Estuarine Adaptations During the Late Prehistoric Period: Archaeology of Two Shell Midden Sites on the St. Johns River, University of West Florida Office of Cultural and Archaeological Research Report of Investigations No. 5, Pensacola, 1984.
- [28] K.J. Little, Late Holocene climate fluctuations and cultural change in Southeastern North America, *Southeastern Archaeology* 22 (1) (2003) 9–32.
- [29] J. Luterbacher, D. Dietrich, E. Xoplaki, M. Grosjean, J. Wanner, European seasonal and annual temperature variability, trends, and extremes since 1500, *Science* 303 (2004) 1499–1503.
- [30] R.L. Lyman, Applied zooarchaeology: The relevance of faunal analysis to wildlife management, *World Archaeology* 28 (1996) 110–125.
- [31] J. Lynch-Stieglitz, Hemisphere asynchrony of abrupt climate change, *Science* 304 (2004) 1919–1920.
- [32] J.T. Milanich, *Archaeology of Precolumbian Florida*, University Press of Florida, Gainesville, 1994.
- [33] T. Nakagawa, H. Kitagawa, Y. Yasuda, P.E. Tarasov, K. Nishida, K. Gotanda, Y. Sawai, Yangtze River Civilization Program Members, Asynchronous climate changes in the North Atlantic and Japan during the Last Termination, *Science* 299 (2003) 688–691.
- [34] D. Pauly, V. Christensen, Primary production required to sustain global fisheries, *Nature* 374 (1995) 255–257.
- [35] D. Pauly, V. Christensen, J. Dalsgaard, R. Froese, F. Torres Jr., Fishing down marine food webs, *Science* 279 (1998) 860–863.
- [36] D. Pauly, V. Christensen, R. Froese, M.L. Palomares, Fishing down aquatic food webs, *American Scientist* 88 (2000) 46–51.
- [37] A.L. Perry, P.J. Low, J.R. Ellis, J.D. Reynolds, Climate change and distribution shifts in marine fishes, *Science* 308 (2005) 1912–1915.
- [38] I.R. Quitmyer, Aboriginal subsistence activities in the Kings Bay Locality, in: W.H. Adams (Ed.), *Aboriginal Subsistence and Settlement Archaeology of the Kings Bay Locality*, vol. 2, University of Florida Department of Anthropology Reports of Investigations No. 2, Gainesville, 1985, pp. 73–91.
- [39] I.R. Quitmyer, Zooarchaeology of Cinnamon Bay, St. John, U.S. Virgin Islands: PreColumbian overexploitation of animal resources, in: F.W. King, C. Porter (Eds.), *Papers in Honor of Elizabeth S. Wing*, *Bulletin of the Florida Museum of Natural History* 44(1) Florida Museum of History, University of Florida, Gainesville, 2003, pp. 131–158.
- [40] I.R. Quitmyer, What kind of data are in the back dirt? An experiment on the influence of screen size on optimal data recovery, in: K.F. Emery, W.G. Teeter (Eds.), *Archaeofauna*, 13, Special Issue: Tropical Zooarchaeology, 2004, pp. 109–129.
- [41] I.R. Quitmyer, H.S. Hale, D.S. Jones, Paleoseasonality determination based on incremental shell growth in the hard clam, *Mercenaria mercenaria*, and its implications for the analysis of three southeast Georgia coastal shell middens, *Southeastern Archaeology* 4 (1985) 27–40.
- [42] I.R. Quitmyer, D.S. Jones, W.S. Arnold, The sclerochronology of hard clams, *Mercenaria* spp., from the southeastern U.S.: A method of elucidating the zooarchaeological records of seasonal resource procurement and seasonality in prehistoric shell middens, *Journal of Archaeological Science* 24 (1997) 825–840.
- [43] C.A. Reed, *Osteoarchaeology*, in: D. Brothwell, S. Higgs (Eds.), *Science in Archaeology*, first ed., Basic Books, New York, 1963, pp. 204–216.
- [44] E.J. Reitz, Vertebrate fauna from four coastal Mississippian sites, *Journal of Ethnobiology* 2 (1982) 39–61.
- [45] E.J. Reitz, A comparison of Spanish and Aboriginal subsistence on the Atlantic Coastal Plain, *Southeastern Archaeology* 4 (1985) 41–50.
- [46] E.J. Reitz, Evidence for coastal adaptations in Georgia and South Carolina, *Archaeology of Eastern North America* 16 (1988) 137–158.
- [47] E.J. Reitz, Animal use and culture change in Spanish Florida, in: P.J. Crabtree, K. Ryan (Eds.), *Animal Use and Culture Change*, University of Pennsylvania Museum of Archaeology and Anthropology MASCA 8, Supplement, Philadelphia, 1991, pp. 62–77.
- [48] E.J. Reitz, "Fishing down the food web": A case study from St. Augustine, Florida, USA, *American Antiquity* 69 (2004) 63–83.
- [49] E.J. Reitz, I.R. Quitmyer, Faunal remains from two coastal Georgia Swift Creek sites, *Southeastern Archaeology* 7 (1988) 95–108.
- [50] E.J. Reitz, I.R. Quitmyer, H.S. Hale, S.J. Scudder, E.S. Wing, Application of allometry to zooarchaeology, *American Antiquity* 52 (1987) 304–317.
- [51] E.J. Reitz, E.S. Wing, *Zooarchaeology*, Cambridge University Press, Cambridge, 1999.
- [52] M. Russo, Southeastern mid-Holocene coastal settlements, in: K.E. Sassaman, D.G. Anderson (Eds.), *Archaeology of the Mid-Holocene Southeast*, University Press of Florida, Gainesville, 1996, pp. 177–199.
- [53] C.E. Shannon, W. Weaver, *The Mathematical Theory of Communication*, University of Illinois Press, Urbana, 1949.
- [54] A.L. Sheldon, Equitability indices: Dependence on the species count, *Ecology* 50 (1969) 466–467.
- [55] D.T. Shindell, G.A. Schmidt, M.E. Mann, D. Rind, A. Waple, Solar forcing of regional climate change during the Maunder Minimum, *Science* 294 (2001) 2149–2152.
- [56] K.D. Sobolik, Nutritional constraints and mobility patterns of hunter-gatherers in the northern Chihuahuan Desert, in: E.J. Reitz,

- L.A. Newsom, S.J. Scudder (Eds.), *Case Studies in Environmental Archaeology*, Plenum Press, New York, 1996, pp. 195–214.
- [57] D.W. Stahle, M.K. Cleaveland, Tree-ring reconstructed rainfall over the southeastern U.S.A. during the Medieval Warm Period and Little Ice Age, *Climatic Change* 26 (1994) 199–212.
- [58] D.W. Stahle, E.R. Cook, M.K. Cleaveland, M.D. Therrel, D.M. Meko, H.D. Grissino-Mayer, E. Watson, B.H. Luckman, Tree-ring data document 16th century megadrought over North America, *Eos* 18 (12) (2000) 121–132.
- [59] E.J. Steig, Mid-Holocene climate change, *Science* 286 (1999) 1485–1487.
- [60] D.M. Ware, R.E. Thomson, Bottom-up ecosystem trophic dynamics determine fish production in the northeast Pacific, *Science* 308 (2005) 1280–1284.
- [61] M.P. Weinstein, Shallow marsh habitats as primary nurseries for fishes and shellfishes, Cape Fear River, North Carolina, *Fishery Bulletin* 77 (2) (1979) 339–357.
- [62] M. Williams, Archaeological site distributions in Georgia: 1994, *Early Georgia* 22 (1994) 35–76.
- [63] E.S. Wing, The sustainability of resource use by Native Americans on four Caribbean islands, *International Journal of Osteoarchaeology* 11 (2001) 112–126.
- [64] W.P. Wood, D.T. Elliott, T.P. Rudolph, D.B. Blanton, *Prehistory in the Richard B. Russell Reservoir: The Archaic and Woodland Periods of the Upper Savannah River*, Russell Papers, National Park Service, Atlanta, GA, 1986.
- [65] J.E. Worth, *Timucuan Chiefdoms of Spanish Florida: Assimilation*, vol. 1, University Press of Florida, Gainesville, FL, 1998.