



A case study in the longevity of a regional estuarine fishing tradition: the central Georgia Bight (USA)

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Received: 14 December 2020 / Accepted: 13 April 2021 / Published online: 8 May 2021

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Abstract

Archaeofaunal remains from the central Georgia Bight (USA) are used in a case study for assessing coastal fisheries between 2760 BCE and 1500 CE, particularly from the perspective of sustainability. The longevity of this fishery is evaluated in terms of taxonomic attributions, richness, ubiquity, diversity, and mean trophic level (*TL*) of fish individuals (MNI) in assemblages from 22 coastal archaeological sites. The average pre-1500 *TL* ($TL = 3.1$) is below that of fish populations in a mid-twentieth-century ecological study ($TL = 3.3$). Although broad features of the regional fishery were sustained for millennia, practices at specific locations were influenced by environmental and cultural phenomena.

Keywords Fishing traditions · Estuaries · Archaeozoology · Diversity · Trophic levels · Georgia Bight

Introduction

The world's commercial fisheries are thought to be in decline, with overfishing one of the primary explanations. Pauly and his colleagues, for example, argue that a decline in the latter half of the twentieth century can be attributed, in part, to overfishing high-trophic-level fishes, resulting in widespread ecological stress (e.g. Pauly and Christensen 1995). Given the extent to which fish were used before the twentieth century, evidence for similar declines might have occurred in earlier coastal fisheries and may be recorded in the archaeological record.

The archaeological record of the central Georgia Bight (USA) of the western Atlantic Ocean offers a unique perspective on a coastal fishery prior to the twentieth century. In this case study, taxonomic attributions, richness, ubiquity, diversity, and mean trophic level (*TL*) in archaeofaunal assemblages from coastal sites associated with this region are evaluated for evidence of declines in, or persistence of, the fishery (Fig. 1). This record is noteworthy for the evidence it contains of a long-lived estuarine fishing tradition, one beginning ca. 2760 BCE and continuing at least until 1500 CE when

European-sponsored exploration and colonization began decimating Indigenous coastal communities (Reitz 2014). Fishing in the Georgia Bight's highly productive estuarine system was a major economic activity throughout the tidal reach. Although this regional fishing tradition was sustained for millennia, fishing traditions at specific locations probably were influenced by environmental and cultural changes.

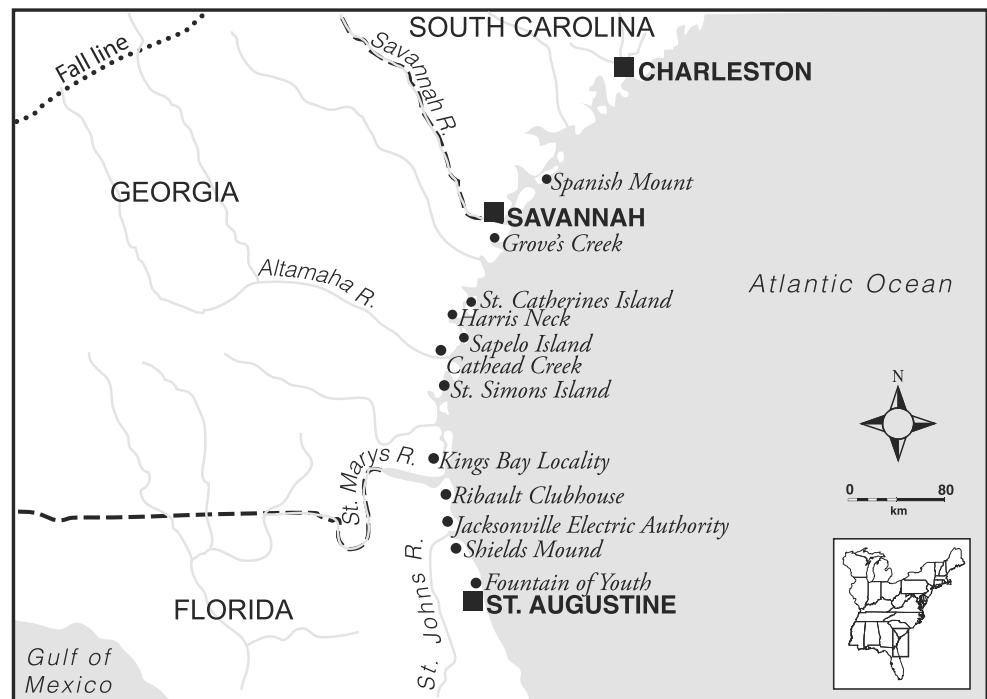
This study is interested particularly in *TL* over time. Trophic levels are functional energy relationships, hierarchical steps in a food chain defined by the trophic levels of foods consumed by a species, in this case, by fish (e.g. Odum and Barrett 2005:105–106). Pauly et al. (1998) report that the *TL* of the northwest and west central Atlantic fishery (FAO areas 21 and 31) peaked at $TL = 3.4$ around 1970 CE but declined to $TL = 2.9$ by 1994 CE. They attribute this decline, in part, to a trophic cascade associated with a focus by commercial fishing fleets on fish from high trophic levels. They argue that when it became difficult to catch large numbers of high-trophic-level consumers, such as mackerels and tunas (Scombridae), commercial fisheries increased their use of lower-trophic-level primary producers and consumers, particularly invertebrates such as molluscs, crustaceans, and echinoderms. This unsustainable practice adversely impacted entire ecosystems.

Trophic energy transfers are much more complex than this, of course (e.g. Odum and Barrett 2005:119–121); but here the question is whether a *TL* of 3.4 was truly unique and how *TL* relates to other aspects of a fishery. If *TL* exceeded 3.4, was this common? If fishing at high trophic levels, in and of itself,

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Fig. 1 Map of the study region



could not be sustained, were high *TL*s followed by lower *TL*s? Did fish richness and diversity also change? Archaeozoological assemblages offer historic proxies for exploring whether changes similar to those observed in the twentieth century also occurred before the twentieth century.

To begin characterizing the historical trajectory of the central Georgia Bight fishery, archaeozoological data from St. Augustine, Florida, were compared to the twentieth-century commercial records from St. Johns County, Florida (SJCF), near St. Augustine (Fig. 1) (Cato and Prochaska 1977; Florida Fish and Wildlife Conservation Commission 1978–2000; Reitz 2004). In this earlier study, the *TL* of archaeological fish biomass was compared to the *TL* of kilogrammes in the twentieth-century commercial fishery (Reitz 2004). St. Augustine archaeofaunal data do not include invertebrates because molluscs were a common construction material in that city. Deciding which molluscs were consumed and which were used for other purposes would be difficult, presuming such a distinction existed. In addition, some of the invertebrates dominating the twentieth-century catch, such as crustaceans, likely are under-represented archaeologically because of site formation processes and recovery methods. For these reasons, the 2004 study estimated the twentieth-century SJCF *TL* exclusively for vertebrates. The revised SJCF biomass *TL* (3.2) is lower than the 1500–1900 CE average biomass *TL* (3.4) for the central Georgia Bight (Reitz and Zierden 2021). This suggests the twentieth-century fishery was not historically high and that fishing at high *TL*s may not be the only explanation for the twentieth-century fishery collapse. The twentieth-century commercial fishery, however, was not

directly comparable to the pre-twentieth-century fishery because the commercial fishery used offshore species, continental shelf locations, and fossil-fuel-driven technologies not used before 1500 CE.

Another way to assess the historic trajectory of the central Georgia Bight fishery is to compare archaeological data to the twentieth-century data collected from locations close to those used in the past with technologies more similar to those used before the twentieth century. Fortunately, a portion of the central Georgia Bight was the focus of an ecological study assessing annual cycles of species occurrences, abundance, and diversity in some of the same habitats likely used before the twentieth century, using capture methods more similar to those used in the past (Dahlberg and Odum 1970). Dahlberg and Odum (1970) enable the historic fishery of the central Georgia Bight to be compared to ecological data instead of commercial records. Details of the Dahlberg and Odum study are provided in the Methods section below.

To exclude European and African influences on the fishery, the focus here is on the period before European-sponsored exploration and colonization began in the sixteenth century. Little ethnohistoric and ethnographic information is available for fishing practices prior to 1500 CE because coastal populations were decimated rapidly by people with little interest in recording or sustaining indigenous practices. This precludes relying on descriptions of fisheries before the demographic and cultural consequences of colonization became widespread. Archaeological evidence for fishing gear also is rare. Thus, the archaeological record is one of the few sources of information about the Georgia Bight fishery before 1500 CE.

Fortunately, the region has a rich archaeological record to compare to present-day coastal fish populations. This comparison suggests fishing practices yielding assemblages with an average *TL* similar to that of the twentieth-century commercial fishery were sustained for millennia by coastal communities, though these communities also experienced environmental and cultural changes in climate, sea level, technologies, and cultural institutions.

The Central Georgia Bight

The central Georgia Bight is a ca. 346 km section of the Atlantic coast between St. Augustine, Florida, and Charleston, South Carolina (Fig. 1). It defines the eastern edge of the low, relatively flat southeastern Atlantic coastal plain. The coastal plain is drained by numerous streams and rivers carrying fresh water to the coast (Dahlberg 1975:4–11).

Coastal waters are divided into the offshore continental shelf and an inshore area. The inshore area includes barrier, or sea, islands, shallow backbarrier lagoons, locally known as estuaries, and that part of the mainland subject to tidal influence. The seaward sides of barrier islands consist of open sandy beaches and salt marshes. The landward sides of barrier islands face complex estuarine marshes and, at some distance, the tidewater mainland. Estuaries are ca. 8–11 km expanses of salt marshes, mud flats, oyster bars, and tidal creeks generally no more than 10 m deep (Schelske and Odum 1961). Small backbarrier islands are scattered throughout estuaries with larger marsh islands lining the tidewater mainland. Estuaries are subject to regular tidal exchange with the Atlantic through deep sounds between the barrier islands.

The central Georgia Bight estuarine system is one of the most productive and complex systems on the northwestern Atlantic coast, with about four times as much marsh per kilometre of coastline than elsewhere (Hayden and Dolan 1979:1063). The system has the highest tides and the greatest tidal range in the Georgia Bight (Hubbard et al. 1979). The twice-daily tidal range averages 2.4 m but can reach 3.4 m during spring high tides (Schelske and Odum 1961). Tidal influence is felt as much as 40 km inland (Frey and Howard 1986). Temperature, dissolved oxygen, salinity, turbidity, and related biogeochemical conditions vary widely due to large and frequent tides, interconnected networks of physical features, and freshwater drainage from the mainland and barrier islands (Dahlberg 1972, 1975:4–11). A complex marsh configuration means that tidal ebb and flow are not uniform throughout the system. Estuarine resources are spatially and temporally patchy and, in the case of fishes, highly mobile because of tidal and seasonal cycles and migrations of juvenile and adult fishes into and out of estuaries (Reitz et al. 2012). This could be viewed as a single large system because no major physical barriers prohibit movement within it.

The system is divided into low, middle, and upper reaches primarily by salinity (Dahlberg 1972, 1975). The highest salinity levels occur in the lower reaches, those along the seaward sides of barrier islands, and in sounds between the sea islands. Middle reaches lie between the lower and upper reaches. Upper reaches are adjacent to the mainland and have the lowest salinity levels. Upper reaches include mainland streams, which experience tidal influence as they approach the coast. Boundaries between each area are indistinct, shifting in response to tidal cycles and storms. Most of the archaeological sites used in this study are on barrier islands near what are today middle reaches. Some are located on the tidewater mainland near the upper reaches. Very few sites are near areas defined today as lower reaches.

In addition to its inherent, diachronic environmental complexity, the region has experienced numerous synchronic changes. Although details for specific locations are unclear, these changes include alterations in mainland elevations (largely due to subsidence), mean sea level, marsh and shoreline configurations, sedimentation, distance from fluvial sources, littoral drift, aeolian sand accumulation rates, and island evolution (e.g. Bishop et al. 2011; Linsley et al. 2008). Changes in coastal landscapes not only influenced estuarine resources, but some coincide with changes in human settlement patterns and cultural institutions (e.g. DePratter and Thompson 2013; Thompson and Turck 2009; Turck and Thompson 2016).

Climate is another important driver. Although also needing further study, complex oscillations in precipitation and temperature affected ecosystems all along the western Atlantic seaboard (e.g. Anderson et al. 1995; Cheung et al. 2013; Clifford and Booth 2015; Doney et al. 2012; Stahle and Cleaveland 1992, 1994; Stahle et al. 1988; Stinchcomb et al. 2011). The occurrence and impact of these phenomena are regionally asynchronous, and their dates vary widely depending on the proxies and methods used, the phenomenon evaluated (e.g. temperature or precipitation), and the region studied (e.g. Cronin et al. 2010). Temperature and precipitation cycles associated with the Medieval Warm Period or Medieval Climate Anomaly (ca. 950–1100 CE) and the Little Ice Age (ca. 1400–1850 CE) (Cronin et al. 2010) are particularly relevant to this study.

Although climate cycles are poorly studied for the central Georgia Bight, growth increments in bald cypress trees (*Taxodium distichum*) from the lower Altamaha River provide some evidence for precipitation after ca. 1000 CE. (The Blanton and Thomas 2008 study does not assess precipitation prior to that date.) These increments document several droughts after ca. 1000 CE with a prolonged cool, dry period between ca. 1176 and 1220 CE (Blanton and Thomas 2008). This was followed by additional droughts before and after 1500 CE. The Altamaha River is a major drainage system feeding fresh water into the central Georgia Bight. Droughts

reduce freshwater runoff into the estuarine system, change estuarine biogeochemical properties, and influence local fisheries. About this same time, the archaeological record shows changes in social organization and residential patterns and farming became widespread (Anderson et al. 1995).

In the face of daily, monthly, seasonal, annual, and long-term variability, fish that thrive here are highly mobile animals with broad habitat tolerances and flexible habits (Dahlberg 1975; Dahlberg and Odum 1970; Reitz et al. 2012). Their population levels, age cohorts, feeding behaviours, and spatial distributions reflect this flexibility. The most common species are present someplace within this system during multiple seasons or throughout the year, though age cohorts, population structures, and community structures change seasonally. Changeable conditions form ecological barriers protecting young fish from many predators (Weinstein 1979). This nursery function means that many animals in estuaries are either young members of species more typically found offshore as adults or adults tolerant of frequent environmental fluctuations. Some species remain in the estuarine system throughout their lives, others leave estuaries when they reach sexual maturity, and only their young return to shelter in estuaries. Adults of other species return to estuaries after spawning, and others enter estuaries specifically to spawn.

Methods

“Fishing” and “fishery” refer to all aspects of access to and use of finfish and shellfish, including, but not limited to, the habits and habitats of the animals in that fishery, technologies deployed, locations used, schedules followed, labour management, and the role of the fishery in community life. Although the twentieth-century commercial fishery reports both vertebrates and invertebrates, this study focuses on cartilaginous (Chondrichthyes) and bony fishes (Actinopterygii). Invertebrates are not included in the Dahlberg and Odum twentieth-century comparative base and are inconsistently reported in the archaeological literature. Marrinan (2010), Quitmyer and Reitz (2006), Reitz and Quitmyer (1988), and Reitz et al. (2009) review invertebrates, primarily molluscs, commonly present in central Georgia Bight archaeozoological assemblages.

Site matrices consist largely of oyster valves (*Crassostrea virginica*). Oysters contribute to an alkaline environment that enhances vertebrate preservation at the expense of most plant remains. Although archaeobotanical studies are limited, cultivation of domestic plants probably began around 1000 CE (e.g. Anderson et al. 1995; Keene 2004; Scarry and Hollenbach 2012). The major cultigens were introduced through regional trade networks, including maize (*Zea mays*), beans (*Phaseolus vulgaris*), and squash (*Cucurbita pepo*),

plants commonly used in much of the North American Southeast by that time.

Fishery data are drawn from 22 archaeological sites from barrier islands and the tidal mainland (Fig. 1; Table 1). These archaeofaunal assemblages are used because quantified species lists are available for each and they were studied using comparative skeletal collections at the Florida Museum of Natural History or the Georgia Museum of Natural History using similar analytical methods. Seven assemblages are from the earliest sites known for the region, and the remaining assemblages are from the period 1450 BCE to 1500 CE. Occupations at Back Creek Village, AMNH 701, Meeting House Field (late), and Fountain of Youth (late) may extend into the sixteenth century when European-sponsored explorations and settlements began impacting indigenous life. This is particularly the case for the Fountain of Youth site, an indigenous community with the dubious honour of being occupied on September 8, 1565, by the first permanent Spanish colonists.

Archaeozoological data are compared to the twentieth-century species occurrence, richness, ubiquity, and diversity in Dahlberg and Odum (1970). Dahlberg and Odum collected samples from 14 inshore stations using a tugboat pulling a 6-m-wide otter trawl with a 32-mm mesh in St. Catherines and Sapelo sounds at 3-week intervals from January 1967 to February 1968. They report their results in terms of species collected and the number of fish individuals for each species; no weights are provided. For this reason, archaeozoological estimates of the minimum number of individuals (MNI) are used in this case study instead of weights or the number of identified specimens (NISP). To ensure the 1970 Dahlberg and Odum study is comparable to the archaeofaunal study, diversity is recalculated. The mean trophic level (*TL*) is estimated from the number of fish individuals for each species in the 1970 study. In a related publication, Dahlberg (1972) combines otter trawl data with results from samples collected with a 6.35-mm seine net. Although the 1972 publication quantifies species richness, it does not report the number of fish individuals or weights.

Using the Dahlberg and Odum study avoids one of the biases in the earlier St. Augustine study (Reitz 2004), which relied on commercial records of fish caught in an unspecified offshore area. Dahlberg and Odum’s tugboat and otter trawl were not invented until long after 1500 CE, but the seine nets used by Dahlberg (1972) likely were similar to those used in the past. Similarities between the fish collected in the 1960s and those in the archaeological record suggest the estuarine temperature and salinity gradients used by Dahlberg and Odum to define estuarine habitats and sampling stations are similar to those in the past, though probably not exactly in their present configurations and locations (e.g. Reitz et al. 2012). Several of the archaeological sites are near Dahlberg and Odum’s sampling stations, either on St. Catherines or

Table 1 Summary of archaeological sites and vertebrate assemblages

Key	Site names and numbers	Location	Time period	Screen size, mm	NISP	MNI	No. vtaxa	No. fish taxa	Fish NISP	Fish MNI	Fish MNI diversity	Fish MNI TL	Source
1	Cannon's Point (Marsh) Ring, 9Gn57	St. Simons Island, GA	2760–2200 BCE	3.18	19,970	345	45	25	18,783	318	2.279	2.927	Marrinan 2010
2	St. Catherines Shell Ring, 9Li231	St. Catherines Island, GA	2580–1770 BCE	3.18	48,506	1216	69	31	41,432	1104	1.941	2.690	Colaninno 2010:122–124, 131–132, 138–140; Colaninno 2012
3	McQueen Shell Ring, 9Li1648	St. Catherines Island, GA	2460–1850 BCE	3.18	138,917	3430	79	46	135,333	3330	2.262	2.999	Colaninno 2019; Colaninno and Reitz 2015
4	West Ring, 9Gn76	St. Simons Island, GA	2320–1970 BCE	3.18	9453	250	30	16	8910	235	2.117	3.064	Marrinan 2010
5	Sapelo Shell Ring III, Units 4 & 9, 9Mc23	Sapelo Island, GA	2332–1740 BCE	1.59	20,951	515	39	26	20,381	497	1.524	3.400	Colaninno and Compton 2019
6	Spanish Mount, 38Ch62	Edisto Island, SC	2200–1800 BCE	Unknown	3251	219	42	18	1490	133	2.628	3.316	Reitz and Jung 2018
7	Ribault Clubhouse, 8Du76	Duval Co., FL	2000 BCE	3.18	2885	144	37	26	2498	126	2.706	3.194	Reitz et al. 2009
8	Fountain of Youth, Early, 8SJ31	St. Augustine, FL	1450–500 BCE	1.59	213	28	15	11	119	23	2.065	3.361	Reitz 1991
9	Cathhead Creek, Early, 9Mc360	Darien, GA	300–700 CE	0.5	1610	74	27	19	1566	64	2.520	3.152	Reitz and Quitmyer 1988
10	Kings Bay Locality, Early, 9Cam171a, 9Cam177	Camden Co., GA	300–700 CE	1.59	37,530	1704	46	27	37,310	1672	1.373	3.277	Reitz and Quitmyer 1988
11	Shields Mound, 8Du12	Duval Co., FL	900–1250 CE	6.35	39,885	718	85	37	34,545	555	2.660	3.105	Marrinan 2005
12	Meeting House Field, Early, 9Li229	St. Catherines Island, GA	910–1140 CE	Various	23,641	453	45	20	18,951	361	2.204	3.135	Bergh 2012b:122–123
13	Bourbon Field, Mississippian, 9Mc71	Sapelo Island, GA	1000–1500 CE	1.59	15,331	563	35	19	8206	398	2.000	3.141	Reitz 1982
14	Jacksonville Electric Authority, 8Du634 & 669	Duval Co., FL	1000–1500 CE	1.59	7380	179	30	16	7020	157	1.842	2.827	Reitz et al. 2009
15	Cathhead Creek, Late, 9Mc360	Darien, GA	1200–1500 CE	0.5	2248	84	34	16	2068	61	2.328	3.302	Quitmyer and Reitz 2006
16	Kings Bay Locality, Late, 9Cam171a, 9Cam177	Camden Co., GA	1200–1500 CE	1.59	36,667	903	57	26	36,110	853	1.501	3.246	Quitmyer and Reitz 2006
17	Grove's Creek, 9Ch71, midden unit	Skidaway Island, GA	1300–1450 CE	1.59	4931	43	23	12	3682	30	2.000	3.033	Keene 2002:208–209, 2004
18	Harris Neck, 9Mc141	McIntosh Co., GA	1330–1490 CE	3.18	6253	128	28	8	794	88	0.945	2.417	Braley et al. 1986:105–116
19	Back Creek Village, 9Li207	St. Catherines Island, GA	1300–1580 CE	3.18	14,881	449	51	26	5026	334	2.184	2.960	Bergh 2012a
20	AMNH 701 9Li1637	St. Catherines Island, GA	1300–1580 CE	3.18	11,145	239	36	22	10,672	218	2.202	2.992	Bergh 2012b:145–146
21	Meeting House Field, Late, 9Li21	St. Catherines Island, GA	1350–1580 CE	Various	23,958	414	50	20	21,603	272	1.756	3.000	Bergh 2012b:128–129

Table 1 (continued)

Key	Site names and numbers	Location	Time period	Screen size, mm	NISP	MNI	No. vtaxa	No. fish taxa	Fish NISP	Fish MNI	Fish MNI diversity	Fish MNI <i>TL</i>	Fish MNI Source
22	Fountain of Youth, Late, 8SJ31	St. Augustine, FL	1513–1565 CE	1.59	14,891	218	36	27	14,769	204	2,739	3,255	Reitz 1991
23	Dahlberg and Odum, 1967–1968						70				2,103	3,317	Dahlberg and Odum 1970

^a Key refers to the number for each assemblage in Figs. 2, 3, 4, 5, and 6. NISP refers to number of identified vertebrate specimens. MNI refers to the minimum number of vertebrate individuals; No. taxa refers to richness, the total number of vertebrate taxa each collection; and No. fish taxa is the number of fish taxa in each collection. Diversity and mean trophic level (*TL*) are described in the text. Sites are arranged in approximate chronological order. The Fountain of Youth, Cathed Creek, Kings Bay Locality, and Meeting House Field are the only stratified assemblages in the study. Frequently, a range of screen sizes was used during recovery to accommodate the challenges of excavating in deposits containing a large amount of shell. The smallest screen size is reported here. Site descriptions, excavation methods, dates, and the original archaeozoological studies are found in the above sources.

Sapelo islands or, in the case of Harris Neck, on the tidewater mainland.

MNI estimates used here are listed in Table 1. To standardize the study, only taxa with an MNI estimate are used, but all vertebrate taxa with an MNI estimate are included regardless of the taxonomic level of the attribution. MNI estimates rarely are available for species-level attributions, are commonly available only for family, order, or class. This decision impacts all subsequent quantification approaches. For information about how each analyst estimated MNI, readers are referred to the original studies (Table 1). Ubiquity refers to the number of assemblages in which a taxon is present and for which an MNI estimate is available. A fish taxon present in all 22 archaeological assemblages has a high ubiquity (100%), and a taxon present in only a few assemblages has a low ubiquity (see Reitz et al. 2012:72–75] for ubiquity data for all fish taxa in these assemblages). Richness is defined as the number of taxa for which MNI is estimated in each assemblage.

Diversity (H') permits fishing traditions to be assessed in terms of the variety or heterogeneity of fish in each assemblage. Dahlberg and Odum estimate MNI diversity using the Shannon–Weaver index, which is used here. The formula is

$$H' = -\sum(p_i) (\log_e p_i)$$

where p_i is the number of the i th species divided by MNI estimate for each archaeological assemblage (Shannon and Weaver 1949:14). Diversity ranges from a low of 0.1 to a high of 5.0. Biases associated with this index are discussed elsewhere (Reitz and Wing 2008:110–113, 245–246).

The mean trophic level (*TL*) is estimated using trophic levels reported in FishBase 98 (Froese and Pauly 1998) and the method of Pauly and Christensen (1995) adapted by Reitz (2004). The formula

$$TL_i = \sum(TL_{ij}) (MNI_{ij}) / \sum MNI_i$$

solves 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 MNI_{ij} of the taxon for the time period. TL_{ij} is divided by the summed MNI for the time period (MNI_i). This formula estimates *TL* for each archaeological assemblage and the Dahlberg and Odum study. Trophic-level assessments are updated regularly in FishBase (www.fishbase.org), but the FishBase 98 estimates are used to remain consistent with earlier publications using some of these same data (e.g. Quitmyer and Reitz 2006; Reitz 2004). When identifications in an archaeozoological species list, the Dahlberg and Odum study, and/or FishBase 1998 are insufficiently precise, the trophic level for the closest taxonomic category is used. Vertebrate trophic levels generally range from a low of 2.1 to a high of 5.0. Biases associated with this index are discussed in Reitz (2004).

The concept of trophic levels is more appropriate for communities than for species. Most species feed at several trophic levels, changing their feeding behaviour and ecological niche as food becomes available and as they mature. The concept is useful in assessing historic fisheries, however, because low-trophic-level fish are far more abundant in ecosystems than are high-trophic-level ones. Thus, vegetarian fish such as mullets (Mugilidae, *Mugil* spp.) generally are more abundant in an estuary than carnivorous fishes such as sharks and rays might be. Fishing communities may balance the costs of time, labour, and risk against the return for those costs by focusing on abundant fish with the potential to offer a greater yield for effort. These would be primarily lower-trophic-level fish. The higher the trophic level of a species, the less abundant it is in an ecosystem and the more human resources are needed to acquire it. Carnivorous fishes also may require individual capture methods such as leisters or handlines. On the other hand, costly resources may be more prestigious because they are more difficult to acquire.

In terms of the archaeological data, the number of fish taxa and fish MNI reflects fish NISP, though fish diversity (H') and fish TL appear less influenced by fish NISP and fish MNI (Fig. 2; Table 1). Higher fish MNI diversity and TL are found in several assemblages with fewer fish specimens than in the very large McQueen Shell Ring assemblage.

Results

The potential richness of this fishery is suggested by the Dahlberg and Odum study. They collected 31,637 fish individuals from 38 families and 70 species during their 14-month sampling period. A direct comparison of the fish they collected with the archaeozoological record is problematic due to the difficulty of matching the precise attributions that can be achieved with a live fish in hand with fragmentary archaeological specimens. For example, distinguishing between estuarine anchovy species (e.g. Engraulidae, *Anchoa hepsetus* and *A. mitchilli*) may be relatively easy for an intact live fish but exceedingly difficult for vertebrae. The most abundant fish reported by Dahlberg and Odum are seatrouts (Sciaenidae, *Cynoscion* spp., 8% of the individuals) and stardrums (Sciaenidae, *Stellifer lanceolatus*, 48% of the individuals).

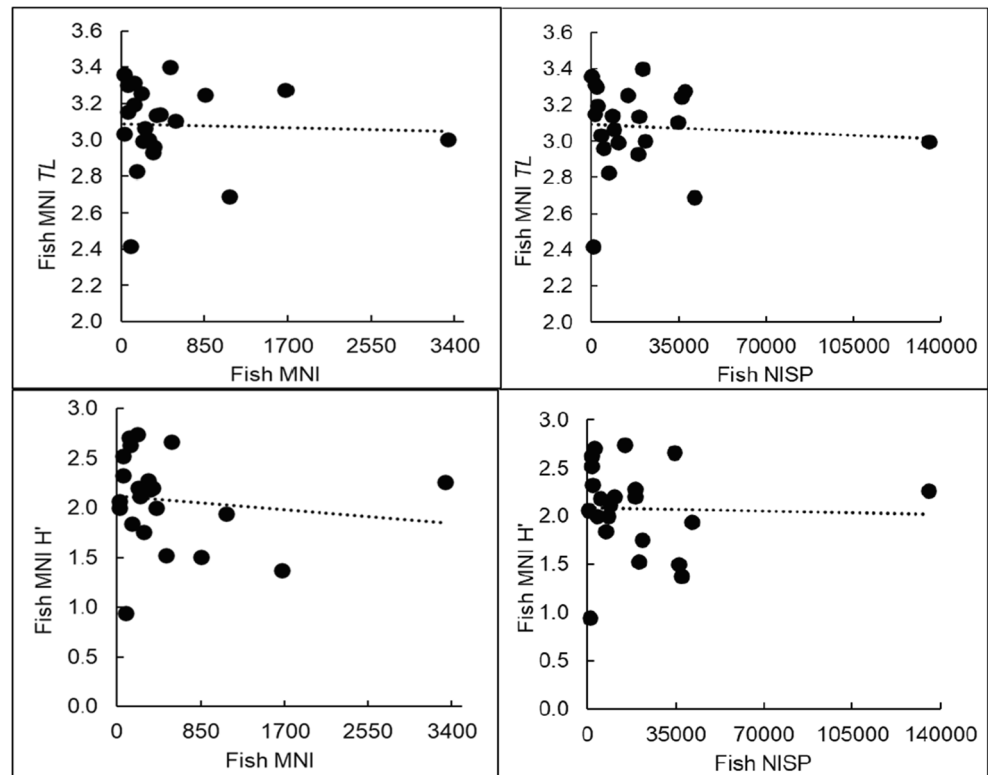
Prior to 1500 CE, people relied heavily upon many of the same estuarine fish collected by Dahlberg and Odum. Members of 26 families and 38 genera collected by Dahlberg and Odum also are present in at least one archaeozoological assemblage, suggesting the ecosystem's richness extended into the past and is reflected in the archaeofaunal fishery record. Fish average 22 taxa, 54% of the vertebrate taxa, and 83% of the vertebrate MNI in these archaeofaunal assemblages (Figs. 3 and 4). The two most abundant fish in the Dahlberg and Odum study have

archaeological ubiquities of 100% (*Cynoscion* spp.) and 77% (*S. lanceolatus*). Stardrums are small fish (< 152 mm) and may be under-represented in the archaeological record because of recovery methods.¹ The archaeozoological record includes animals with a wide variety of body sizes, feeding habits, reproductive strategies, and habitat preferences representing both the diverse biogeochemical conditions of the central Georgia Bight estuarine system and its nursery role. Markedly seasonal anadromous and catadromous species such as sturgeons (Acipenseridae, *Acipenser* spp.), eels (Anguillidae, *Anguilla rostrata*), and shads (Clupeidae, *Alosa sapidissima*) are rare in the archaeofaunal record.

Five of the 86 fish taxa in the archaeozoological record are characterized by high ubiquity. Sea catfishes (Ariidae, *Ariopsis felis*, *Bagre marinus*), mullets (Mugilidae, *Mugil* spp.), and seatrouts (Sciaenidae, *Cynoscion* spp.) are present in all 22 of the archaeofaunal assemblages (ubiquity = 100%). Atlantic croakers (Sciaenidae, *Micropogonias undulatus*) are present in 21 of the assemblages (ubiquity = 95%). Members of this core fish group are wide-ranging, flexible, resilient animals and dominate fishing records into the nineteenth century (Reitz and Zierden 2021). Hardhead catfishes (*A. felis*) are more abundant than gafftopsail catfishes (*B. marinus*) in the Dahlberg and Odum study, and when archaeozoologists can distinguish between the two sea catfish species, hardhead individuals usually are much more abundant than gafftopsail individuals. Both catfish species are found in lower, middle, and upper reaches, and adults are rare in cold weather (Dahlberg 1972). The two species of mullets also are difficult to separate in archaeological materials. Grey mullets (*M. cephalus*) tolerate a broader temperature range than do white mullets (*M. curema*) and are present in all habitats except freshwater creeks (Dahlberg 1972). Although it is difficult to distinguish among the three species of seatrouts using archaeological specimens, spotted seatrouts (*C. nebulosus*) are among the important estuarine fishes today, widespread in the estuarine system, and present throughout the year (Dahlberg 1972), though weakfishes (*C. regalis*) are far more abundant in the Dahlberg and Odum survey. Members of the core fish group are not necessarily abundant in an assemblage; ubiquity merely denotes presence in one or more assemblages. On the other hand, 44% of the 11,033 fish individuals in this study are members of the core fish group.

¹ *Stellifer lanceolatus* is present in 77% of the assemblages reviewed here and could not be considered rare in the archaeofaunal record. A standardized, consistent screen size was used to recover specimens in 19 of the 22 assemblages reviewed here. *Stellifer* specimens are present in 8 of the 19 cases recovered using a screen size larger than 1.59 mm and absent in two cases where a screen size smaller than 1.59 mm was used. *S. lanceolatus* TL is 3.3, which is above the average TL for archaeological assemblages in this study (3.1), but in line with the Dahlberg and Odum TL (3.3), likely because this fish is abundant in the Dahlberg and Odum study. If the number of *Stellifer* individuals in archaeological assemblages was increased, this probably would raise the archaeological average TL .

Fig. 2 Number of fish specimens (NISP) and fish individuals (MNI) plotted against fish mean trophic level (TL) and fish diversity (H'). Dotted lines represent trend lines



People took advantage of estuarine richness by expanding the fishery far beyond the core fish group. The average archaeological MNI diversity is $H' = 2.1$ (Fig. 5; Table 1), as is the ecological MNI diversity reported by Dahlberg and Odum ($H' = 2.1$). Dahlberg and Odum report seasonal changes in diversity, from a fall low of $H' = 1.4$ to a spring high of $H' = 2.8$, reflecting the influence of seasonal changes in temperature, salinity, and spawning cycles, among other variables. Richness (the number of taxa) is a component of diversity, though in this case seven assemblages with fewer fish taxa are more diverse than the large assemblage from McQueen Shell Ring, which has the highest number of taxa. Screen sizes

used for the seven assemblages range from 0.5 to 3.18 mm (Table 1). Fish NISP and fish MNI do not appear to bias this relationship (Fig. 2).

When archaeological MNI diversity is low, it is because the assemblage is dominated by a single widespread, abundant estuarine fish. The lowest diversity value is from the tidewater mainland Harris Neck site: 76% of the fish MNI are mullets in an assemblage containing only eight fish taxa. A similar dominance of a single species characterizes the Sapelo Island Shell Ring assemblage (hardhead catfishes = 62% of the fish MNI) and the tidewater mainland Kings Bay (early) assemblage (stardrums = 70% of fish MNI). Dahlberg (1972) found these

Fig. 3 Fish taxa as a percentage of all vertebrate taxa, 2760 BCE to 1500 CE. Sites are arranged in chronological order. See Table 1 for key. The dotted line represents the trend line

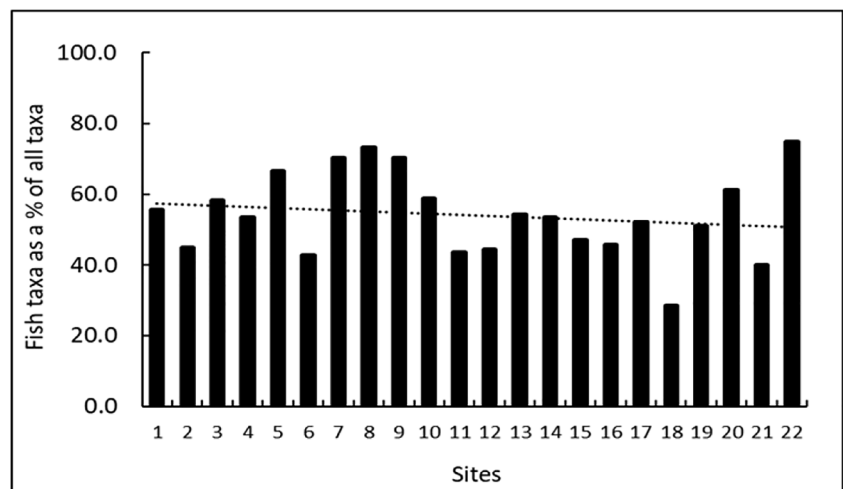
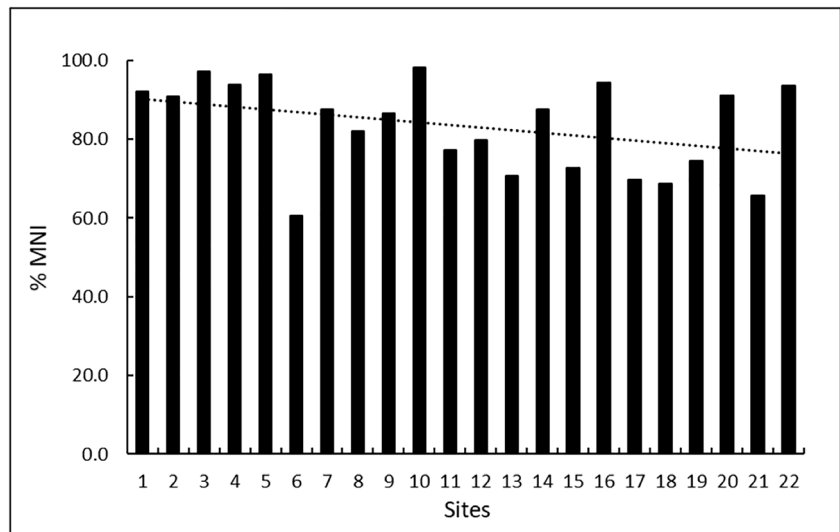


Fig. 4 Percentages of the minimum number of fish individuals (MNI) in archaeological assemblages, 2760 BCE to 1500 CE. Sites are arranged in chronological order. See Table 1 for key. The dotted line represents the trend line



three species to be widespread and present in the estuarine system throughout the year though rare during their spawning seasons. They also are sensitive to cold temperatures and unfavourable salinities. Perhaps people at these three sites practised specialty fishing strategies taking advantage of unique fishing opportunities available at each location during late summer and fall peaks in these populations.

As a general rule, the fishing strategy was slightly below the ecological *TL* (Fig. 6; Table 1). The average archaeological *TL* ($TL = 3.1$) is lower than that of the Dahlberg and Odum assemblage ($TL = 3.3$). Only two archaeological assemblages exceed the Dahlberg and Odum *TL* level and one matches it. These three assemblages are from the early part of the sequence; thereafter, the fishery appears to be consistently below the ecological *TL* with 19 assemblages registering a *TL* between 3.0 and 3.3 regardless of the number of individuals. Fish NISP and fish MNI do not appear to bias this relationship (Fig. 2; Table 1). The seven assemblages with the highest *TL*

values have fish MNI estimates between 23 and 1672 individuals. These seven assemblages also have low percentages of mullet individuals (0.5–8%). This would strongly influence *TL* because mullets are vegetarian feeders occupying a low 2.1 trophic level.

Discussion

This work was designed to explore whether a *TL* of 3.4 was truly unique, if fishing at high trophic levels, in and of itself, could not be sustained and if high *TL*s in the central Georgia Bight fishery were followed by lower *TL*s. The central Georgia Bight fishery appears to represent a long-lived, persistent regional estuarine fishing tradition consistently just below the 3.4 threshold. Although three assemblages approach this level, most do not. Most of the fish species in these archaeological assemblages feed at trophic levels between 3.0

Fig. 5 Archaeological fish diversity (*H'*) for the minimum number of fish individuals (MNI), 2760 BCE to 1500 CE, compared to Dahlberg and Odum (1970), #23 on this graph. Sites are arranged in chronological order. See Table 1 for key. The dotted line represents the trend line

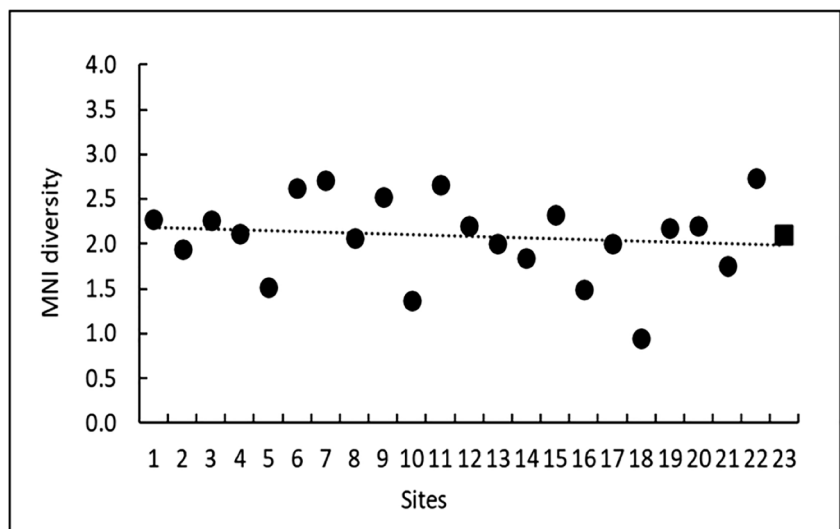
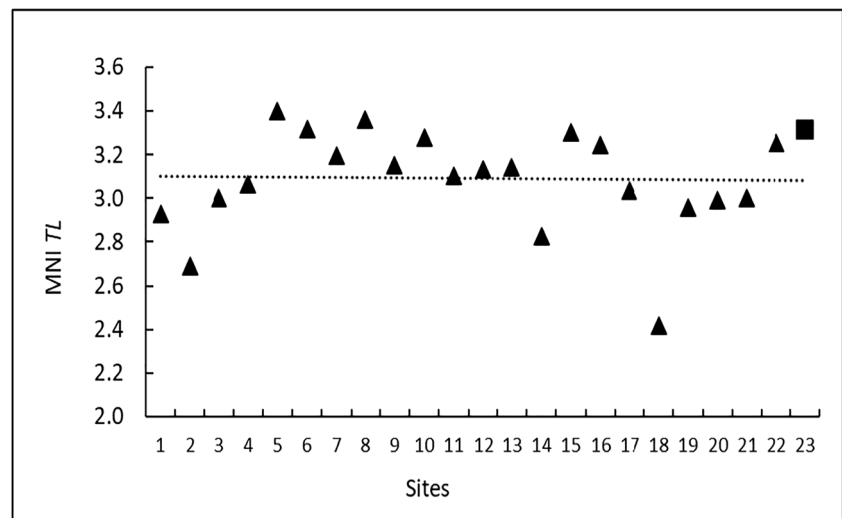


Fig. 6 Fish mean trophic level (TL) based on the minimum number of fish individuals (MNI), 2760 BCE to 1500 CE, compared to Dahlberg and Odum (1970), #23 on this graph. Sites are arranged in chronological order. See Table 1 for key. The dotted line represents the trend line



and 3.5; but the feeding behaviour of the core fish group strongly influences the *TL* of each assemblage. Hardhead catfishes and seatrouts generally feed at relatively high trophic levels (ca. 3.4–3.5); but this was balanced against low-trophic-level mullets (2.1). These three fish alone yield an estimated average *TL* of 3.0. Although 19% of the archaeological fish individuals in this study are mullets, less than 8% of the fish individuals in the seven assemblages with the highest *TL* estimates are mullets.

It is difficult to assess whether fishing at high trophic levels is followed by lower *TL*s at a specific location because only four sites provide stratified assemblages. *TL* decreases from the early components to the later components in three of these: Fountain of Youth, Kings Bay Locality, and Meeting House Field. Only in the Fountain of Youth assemblage could the early *TL* (3.4) be considered high. The late component in the fourth stratified site (Cathead Creek) returns a higher *TL* than the early one. If we view the central Georgia Bight fishery as a regional fishery, however, the trend changes little over time though with variations (*TL* range 2.4–3.4; Fig. 6).

Although the high ubiquity of the core fishery persisted throughout the temporal sequence, the percentages of fish taxa and MNI, as well as fish diversity and *TL*, are generally lower after ca. 1000 CE (Figs. 3, 4, 5, 6). The explanations for this decline are unclear at this point, but likely reflect environmental and cultural changes influencing where, how, and when fishing occurred. Among the environmental changes, droughts such as the one ca. 1176 CE recorded by Blanton and Thomas (2008) would alter estuarine attributes by reducing freshwater input. Within this same time frame, farming activities are thought to have become more widespread along the coast. Farming requires rethinking labour allocations and work schedules which might conflict with a fishing tradition habituated to tidal cycles. Although fishing continued to be an important economic activity after 1000 CE, relationships among coastal landforms, hydrology,

temperature, rainfall, fishing traditions, and farming need further study (Anderson et al. 1995; DePratter and Thompson 2013).

The regional fishing tradition undoubtedly experienced cycles of crisis and recovery but was sufficiently diverse and flexible to endure most environmental and cultural changes. At some point, however, sites were abandoned in favour of other locations. Changes in settlement patterns likely were responses to cultural changes in sociopolitical institutions and technologies but may also reflect phenomena causing long-lasting changes in coastal landforms, seascapes, and hydrology. Such environmental changes might have serious consequences for resources preferred by a community, especially the availability and abundance of specific fish species at customary fishing grounds and their susceptibility to traditional fishing methods. Although the vertebrate component of the fishery focused on a mobile resource, the “best” places to deploy specific devices to capture specific species are limited, and some, such as weirs, are costly to build and maintain. If fish behaviour changes in responses to estuarine biogeography and the return for effort would be better someplace else, this might encourage people to follow the fish to newly advantageous locations, which might mean relocating both weirs and villages. If biological, chemical, or geological changes impacted the efficacy of preferred fishing methods or the core fish group moved, this response might give the appearance of a stable fishery over millennia even though the locations of villages and fishing grounds changed.

Although this study refers to a fishing tradition, in reality multiple fishing traditions prevailed, each defined by a specific community’s perception of the resource base at a given time and place. Each tradition emphasized widespread, ubiquitous fish in a dynamic estuarine landscape. The widespread use of the core fish group supplemented by many other fish species indicates a shared perception of the region’s potential, but differences among the assemblages suggest this regional

tradition was filtered through local temporal, spatial, technological, and social choices. The most abundant fishes in each assemblage are sensitive to tidal cycles, which may have been more influential than season in a community's decision about who fished when, where, and how. The richness and diversity of this tradition may have protected the core group from over-use and buffered communities from temporary shortages in the preferred catch following storms, unseasonable weather, or other disruptions.

Many of the fish form schools or large aggregations, making them susceptible to mass capture, especially when linked to the tidal cycle. Although direct evidence of fishing gear is rare, the fish themselves offer indirect evidence of the most common technologies. For example, when Dahlberg and Odum used a tug boat and a large-gauge seine net in their 1976–1968 study, they collected only two mullet individuals. Mulletts, however, were “widespread and abundant” in a subsequent study which used a net with a smaller gauge in shallower waters (Dahlberg 1972). The high richness and generalist behaviours of the core fish group suggest that mass-capture facilities such as weirs and nets were used. These could capture large numbers of fish of different species, ages, feeding behaviours, and size. Capture devices designed to capture individuals, such as leisters, gorges, and hooks, likely also were used, either alone or in conjunction with weirs and similar impoundments. The possibility that fishing communities modified estuarine conditions to encourage preferred resources is intriguing (e.g. Lulewicz et al. 2017; Thompson et al. 2020) as is the scope of intra-estuarine transport of resources (e.g. Andrus and Thompson 2012; Thompson and Andrus 2011).

Sustained fishing traditions such as these probably relied on social and ritual mechanisms to control who fished when and where, to safeguard fishing grounds, to protect facilities such as weirs, and to organize work parties, particularly those needed to maintain weirs. Both sacred and mundane activities reinforced the rights and responsibilities of individuals and communities to specific locations and brought social pressure to bear on those who violated behavioural norms, especially if the violation was a threat to fishing success and the community's survival.

The importance of the fishery to these communities is highlighted by a suite of animals emblematic of fishing skills and index objects for people who relied on the coast's bounty (Reitz et al. 2020; Zedeño 2009). These skilled fishers include alligators (*Alligator mississippiensis*), sea turtles (Cheloniidae), herons and egrets (Ardeidae), bald eagles (*Haliaeetus leucocephalus*), beavers (*Castor canadensis*), small cetaceans (Cetacea), river otters (*Lontra canadensis*), and minks (*Mustela vison*). Most assemblages contain at least one specimen from one of these animals. The first use of these symbols is found in the earliest coastal assemblages and persisted into the European era. This suggests people identified with these fishers and used this association to protect themselves while sustaining and

managing their fishery. It is probable that lineages owned the rights to specific fishing grounds, the facilities constructed at each, and to the fishing rituals and regalia represented by these symbols. By these means, the fishers were managed even if the fish themselves were not.

To return to the original question, it appears that fishing at ecologically high trophic levels was sustained by this tradition but rarely exceeded the Dahlberg and Odum ecological level ($TL = 3.3$). This does not mean fishing was consistently at a low trophic level. The central Georgia Bight fishing tradition exceeded $TL = 3.1$ in 55% of the assemblages considered here and exceeded $TL = 3.3$ in six assemblages (Fig. 6; Table 1). This would appear to be a sustainable strategy that endured in its broad configuration for over 4000 years. Nonetheless, the percentages of fish individuals (Fig. 4) decline over time as does diversity (Fig. 5). This likely is associated with a change in the region's fishery's focus, perhaps because of overfishing, changes in the estuarine environment, fish preferences, fishing technologies, and increased farming. This should be explored further, especially in terms of changes in estuarine conditions related to droughts and other environmental variables and changes in cultural choices associated with farming. Compound-specific stable isotope analyses may be a fruitful avenue for future research.

This study raises the possibility that trophic cascades may not be the only explanation for the collapse of the twentieth-century fishery. Commercial fishing deploys novel technologies, taking large numbers of previously under-utilized animals from previously unexploited locations. The impact of this is exacerbated by deforestation, urbanization, drainage projects, harbour management, beach enhancements, and similar landscape modifications. At the same time, estuarine systems are subject to climate-driven changes in sea level, estuarine configurations, and biogeochemistry. All of these phenomena would adversely impact estuarine functions, especially those related to nurseries. The present-day combination of taking large numbers of reproductive adults offshore and hampering juvenile recruitment within estuarine systems may impact fisheries in ways that are poorly understood. Establishing archaeological baselines for early fisheries that were sustained over millennia before offshore and inshore fish populations and estuarine communities experienced commercial fishing and degraded habitats could contribute substantially to our knowledge of the broad consequences of human impacts on coastal ecosystems in the twentieth and twenty-first centuries, thereby enhancing our ability to manage fishery resources (e.g. Ackermann et al. 2020; DiFranco et al. 2016; Hambrecht et al. 2020; McKechnie and Moss 2016).

Conclusion

The estuarine system of the central Georgia Bight once supported a dynamic fishery. Broad features of a regional estuarine

fishery persisted for millennia, though specific local fishing traditions were influenced by tidal cycles, climate, sea level, technologies, the habits and habitats of the targeted fish, and cultural objectives. People emphasized a core group of fish but also used a rich array of other fish. Fishing practices, particularly the use of mass-capture methods, yielded diversity levels similar to the region's present-day ecological capacity and *TL* values slightly below that capacity. This long-term strategy reminds us that fishing traditions were designed by skillful and prudent people who used technologies and cultural institutions to manage and monitor their use of resources upon which they relied.

Acknowledgements A special thanks to the following colleagues who contributed to the data used here: Sarah G. Bergh, Chad O. Braley, Carol E. Colaninno, J. Matthew Compton, Morgan Ray Crook, Kathleen A. Deagan, Martin F. Dickinson, Joel A. Dukes, Taesoo E. Jung, Deborah A. Keene, Clark Spencer Larsen, Maran E. Little, Rochelle A. Marrinan, Irvy R. Quitmyer, Rebecca Saunders, Matthew C. Sanger, Anna Semon, Karen Y. Smith, David Hurst Thomas, Victor D. Thompson, Lucy B. Wayne, Daniel C. Weinand, and Elizabeth S. Wing. I am grateful to Kenneth Ritchie, Harry K. Robson, and the reviewers for their helpful comments and to Susan Duser, who drafted Fig. 1. Previous versions of this paper were presented at the Warfare, Environment, Social Inequality, and Pro-Sociability (WESIPS) Biennial Conference, May, 2019, Seville, Spain, and the twentieth Meeting of the International Council of Archaeozoology Fish Remains Working Group, August, 2019, Portland, Oregon.

Funding Support was provided in part by the National Science Foundation Doctoral Dissertation Improvement Grant BCES0912176; the Edward John Noble Foundation; the St. Catherines Island Foundation; the South Carolina Department of Parks, Recreation, and Tourism; the South Carolina Archaeological Research Trust; the Charleston Museum; and the Florida Museum of Natural History. Additional funding details are available in the sources listed in Table 1. These institutions had no role in the design, data collection, analysis, decision to publish, or preparation of this manuscript.

Availability of data and material Data are available from sources cited in Table 1, as is information about the last known location of the materials.

Declarations

Conflict of interest The author declares no competing interests.

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