

“FISHING DOWN THE FOOD WEB”: A CASE STUDY FROM ST. AUGUSTINE, FLORIDA, USA

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Comparing zooarchaeological data for Native American, Spanish, and British occupations with modern fisheries data from St. Johns County, Florida (USA) shows differences in the use of marine resources from 1450 B.C. through A.D. 2000. Changes in biomass contribution, diversity, types of fishes used, and trophic levels of sharks, rays, and bony fishes suggest that the pattern described as “fishing down marine food webs” (Pauly et al. 1998) may have been present in the St. Johns County area as early as the eighteenth century. A change in the size and growth habits of Atlantic croaker (Sciaenidae: Micropogonias undulatus) occurred early in this sequence, indicating an impact on this specific fish. However, overharvesting of fishes is not the only explanation for these observations. Climate and cultural changes are additional explanations for the patterns observed that should receive closer attention. Exploring these alternative explanations is made possible by a zooarchaeological record that permits us to study fishing habits and fish behavior before large-scale industrial fishing began.

*Un análisis comparativo realizado con datos zooarqueológicos y recientes de pesquerías del condado de St. Johns (Florida, USA), ha detectado diferencias en el uso de los recursos marinos durante el periodo comprendido entre el 1450 A.C. y el 2000 D.C. Cambios tanto en los aportes de las biomásas, como de las especies de peces implicadas, su diversidad y niveles tróficos apuntan a que el modelo denominado “fishing down marine food webs” podría haber entrado en acción en las comunidades marinas del condado de St. Johns County a partir del siglo dieciocho. Cambios en el tamaño y en el patrón de crecimiento de la corvina *Micropogonias undulatus* (Pisces, Sciaenidae) se detectan en el inicio de la secuencia, lo cual indicaría un temprano impacto del esfuerzo pesquero sobre esta especie. A pesar de ello, la sobrepesca podría no ser la única explicación de tales patrones los cuales también pudieron haber sido debidos a fenómenos de tipo cultural o a cambios climáticos que deberían recibir más atención por parte de los investigadores en el futuro. Explorar tales alternativas resulta cada vez más factible gracias a que el registro zooarqueológico proporciona ahora información precisa acerca de los peces y de las pesquerías anteriores al inicio de la pesca industrial a gran escala.*

Archaeologists occasionally argue that overharvesting might be an explanation for changes in fishing strategies (e.g., Jackson et al. 2001). Theoretically, such changes could be stimulated by cultural dynamics unrelated to environmental change. It is difficult to demonstrate that a change in resource use was the result of environmental change and none of the other alternatives. It is even more challenging to verify that environmental change was caused exclusively or primarily by human behavior impacting fish populations and/or fish habitat. Distinguishing between the impacts of climate change and overharvesting on fish populations is complicated by the fact that both climate change and overharvesting may occur at the same time. Each of these aspects of fishing should be considered further, though this paper focuses on overharvesting.

Sharks and rays (Chondrichthyes) and bony fishes (Osteichthyes) play an important role in many economies today, as they did in the past. Fish biologists (e.g., Pauly et al. 1998, 2000) argue that recent changes in mean trophic levels exploited are associated with overfishing. Fisheries managers base such studies on recent fish catches (landings) and population statistics. The short time perspective limits their ability to assess the extent to which fisheries were impacted in earlier centuries. Archaeologists offer local records of marine resource composition and health for the entire Holocene, often from well-dated contexts (e.g., Amorosi et al. 1996; Jackson et al. 2001). Trophic-level analysis of archaeological fish remains could translate zooarchaeological data into a format that is similar to current management records. This would enable zooarchaeologists to explore fish use from another

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perspective and facilitate the use of archaeological data in efforts to restore marine ecosystems.

The Twentieth-Century Fish Declines

Pauly and his colleagues alert us to one aspect of the current decline in fish stocks. They argue that industrial fishing declined after 1950 in response to a change in marine ecosystems caused by overfishing (Pauly and Christensen 1995; Pauly et al. 1998, 2000). Using twentieth-century data reported by the United Nations Food and Agricultural Organization (FAO) and other sources, they demonstrate a decline in the mean trophic level of commercial fisheries throughout the world. Trophic levels are defined by the degree to which organisms feed directly on producers (Pauly et al. 2000). Producers are plants, including phytoplankton. Producers form the base of the food chain and occupy the first trophic level. Zooplankton and benthic herbivores and detritivores are in the second trophic level. Carnivores occupy trophic levels three to five.

Pauly et al. 1998 term this decline "fishing down the marine food webs." They report a shift away from long-lived, piscivorous, high-trophic-level bottom fishes, such as cod and haddock, to short-lived, planktivorous, low-trophic-level invertebrates (e.g., shrimps) and small, pelagic fish (e.g., herrings). This shift from high-trophic-level fishes to low-trophic-level invertebrates and fishes is a response to changes in the relative abundance of the preferred catch. Fishing down the food web to lower trophic levels initially led to larger catches and then to stagnant or declining ones. Among other consequences, we are competing with our own prey for food at the lower trophic levels, thereby impacting the entire ecosystem.

When Pauly et al. (1998) examined trophic-level use in the region that includes the Florida/Georgia coast of the United States, they found a 1970s peak in mean trophic level followed by a sharp decline. Trophic levels peaked at 3.4 in 1970 in the northwest and west-central Atlantic, followed by a subsequent decline to 2.9 in 1994. They argue this is part of the global fishery collapse (Pauly et al. 1998).

A similar pattern is apparent near St. Augustine, in St. Johns County, Florida, USA (Figure 1). The mean trophic level for finfishes in 1978 was 3.02 (Florida Fish and Wildlife Conservation Commis-

sion [FFWCC] 1978–2000). It peaked at 3.54 in 1988 and declined to 3.26 by 2000. This downward trend is expected to continue. The delayed peak in St. Johns County compared to the regional pattern may reflect a local variation on the regional theme, or it may be the result of different data used in analysis. The Pauly and Christensen (1995) study includes both invertebrates and vertebrates whereas the 1978–2000 data from St. Johns County used here include only sharks, rays, and bony fishes (see Methods).

The decline in trophic level in St. Johns County is accompanied by a decline in productivity. Records of fish catches (landings) between 1951 and 1973 for the Florida east coast, including St. Johns County, show that the highest landings were in 1952 (149.7 million pounds; Cato and Prochaska 1977:1). Landings for 1969–1973 were 55 percent of those between 1952 and 1956.

This decline raises questions about fishing patterns and their consequences. Were similar trophic levels used in the past and, if so, was high-trophic-level fishing followed by a similar decline in mean trophic level? If a similar trophic-level decline occurred before the twentieth century, ecosystems may have been stressed before the twentieth century. This stress might be caused by climate change or cultural behavior, including overfishing; but to assess causality in these terms we must first document changes in both the modern catch and the zooarchaeological record using the same method. Proposing a way to approach this question is the primary goal of this paper. A single approach will not demonstrate that shifts in mean trophic level are the result of changes in the intensity of fishing or in the abundance of fish but might eventually do so when combined with other techniques.

When the zooarchaeological record from St. Johns County is examined from a trophic-level perspective, it appears that the twentieth-century decline in trophic level is not unique. For most of the period reported here, the mean vertebrate trophic level used was much higher than it is today (FFWCC 1978–2000). Moreover, the percentage of biomass from both the lowest and the highest trophic levels declined from the 1600s until 1783. In the following pages, the method used to develop these observations and their implications are reviewed.

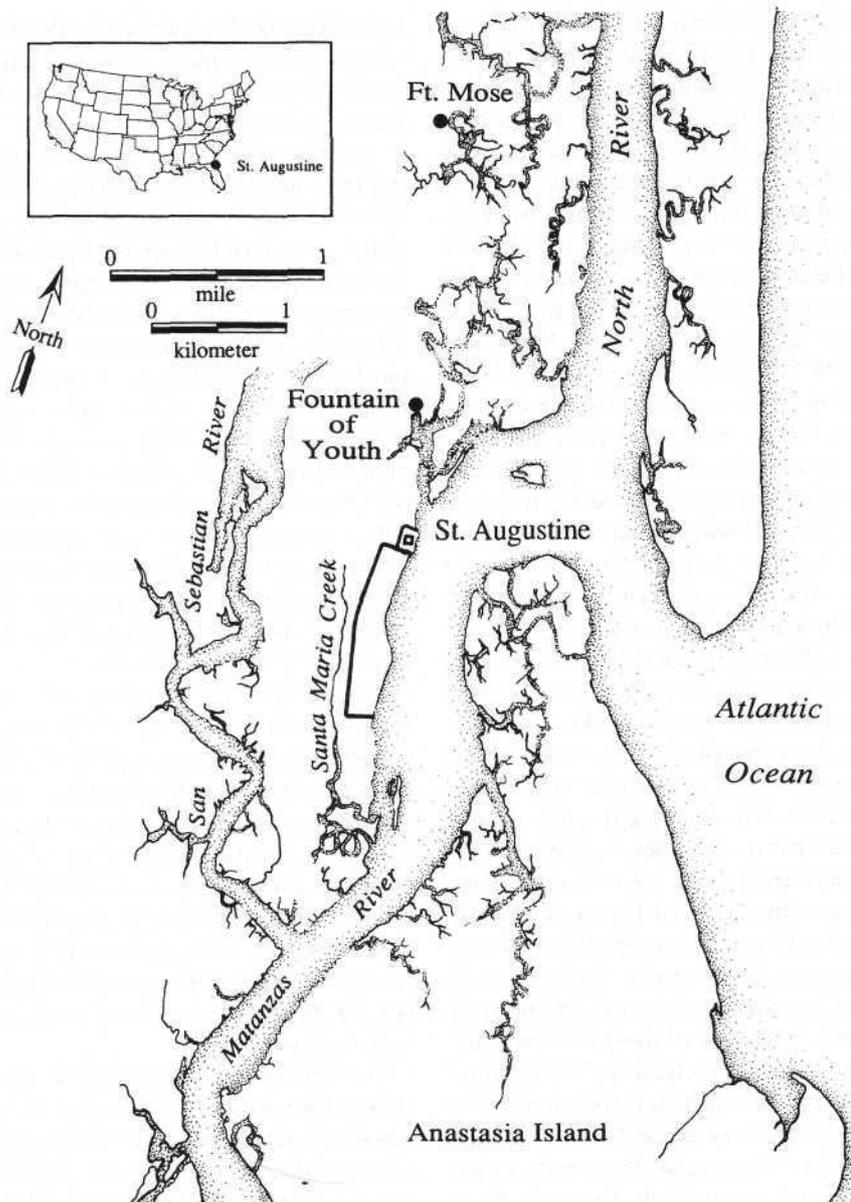


Figure 1. Map of study area.

Environmental and Cultural Change

Modifications in fishing strategies and in targeted trophic levels are the result of complex environmental and cultural interactions (e.g., Basgall 1999; Grayson 1981). Both fish and people may be creative in the face of environmental change, and cultural behavior may change in the absence of an environmental stimulus. It is not the purpose of this

brief contribution to review these interactions in detail. However, some aspects of this relationship are particularly relevant to the present study and are summarized below.

Alterations in fishing strategies may reflect environmental change for which humans had little or no responsibility. Resource availability reflects temperature and rainfall regimes that follow short-term as well as long-term patterns. Changes in relative sea

level and water circulation impact the distribution of plant and animal communities in coastal settings as well. A change in trophic-level use may reflect changes in these variables, producing alterations in the marine resource base for which humans were not responsible but to which they had to respond.

People also intentionally or unintentionally altered their environment in the past. The best known of these alterations is associated with fire but there are many other examples (e.g., Erickson 2000; Fowler 1996; Hong et al. 1994, 1996; Jackson et al. 2001; Nicholson and O'Connor 2000; Redman 1999; Renberg et al. 1994). Researchers using proxy data to study post-Pleistocene environmental phenomena should not presume that there was no human impact on marine resources prior to the 1850s. Essentially the entire Holocene history is a record of human interaction with the environment and it is likely that many aspects of today's environment reflect that history.

Moreover, the archaeological record is an imperfect mirror of former environments. Faunal remains reflect a "cultural filter" (Reed 1963), the cultural choices made by people as they select which resources to use or ignore; determine where to live and when; schedule resource use in terms of daily, seasonal, and annual cycles; develop the technologies to acquire and process resources; distribute resources; consume them; and dispose of the trash. Such behaviors form the fabric of cultural identity and are intrinsically interesting. However, they obscure the relationship between the original resource base, human use of those resources, and the recovered faunal collection. Taphonomic processes further confound the association among the original resource base and archaeological data.

It is important to appreciate that people are not and were not random scavengers. Few of the many fish species available in an ecosystem are represented in archaeological collections. People often use fish that are cosmopolitan and tend not to use fish with restricted habits and habitats (Cooke 1992; Wing and Reitz 1982). Further, the habitats and habits of some fish change as individuals mature. Thus, it is seldom possible to conclude that a fish 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. Because both humans and their preferred

prey often are characterized by flexibility, animal remains from archaeological sites are not necessarily the most sensitive indicators of environmental or cultural change.

The filtering aspect of culture is manifest in fishing strategies. 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. Distinguishing between changes in faunal assemblages related to cultural changes and those related to environmental changes must consider fishing techniques. Unfortunately, there is little ethnographic or archaeological evidence for basketry scoops, dip nets, seine nets, cast nets, weirs, hand lines, or other fishing devices for the St. Johns County area, leaving us to infer information from the faunal record itself (e.g., Reitz 1991; Reitz and Quitmyer 2003; Reitz and Scarry 1985:81–82).

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 archaeological fish assemblages strongly suggest modified human behavior in an altered environment. In a marine setting, that modification might be in response to climate changes over which preindustrial peoples had little or no influence, reflect a change in ethnic affiliation of the human population, or be a response to overexploitation of the resource base.

In addition to the problematic relationships between natural phenomena and archaeological deposits, data from both archaeological sites and modern fisheries have inherent problems that are compounded when they are combined. The primary requirement for studying long-term patterns of change or stability in a regional fishery is access to zooarchaeological data from temporally stratified archaeological sites and modern fisheries data from the same location. 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., Reitz and Wing 1999). 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 body sizes. 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 trends and routine behavior. 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 Minimum Number of Individuals (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 have their own biases (Pauly et al. 2000). The global FAO and other data used to assign fishes and invertebrates to a trophic level are complex and uneven in quality (Pauly et al. 1998, 2000). 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 underreported.

Some of the effects that Pauly et al. (1998) report are the product of recent fishery-management decisions. Both the FAO regional data and the St. Johns County data undoubtedly reflect changes in fishing regulations intended to protect sensitive ecosystems and commercial fish stocks. For example, the recent ban on net fishing over reefs probably explains some of the changes in the modern St. Johns County landing data because these regulations altered both the quantity and composition of

the catch. 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 overfishing.

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 his colleagues (2000) 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 this 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 defines patterns in the archaeological record that merit further consideration.

Materials and Methods

St. Johns County, Florida, is one of the locations where both modern and stratified zooarchaeological data are available in North America (Figure 1). Long-term research by Kathleen Deagan, Florida Museum of Natural History, in and around St. Augustine provides a rare opportunity to compare zooarchaeological data from 1450 B.C.–A.D. 1900 with twentieth-century industrial fisheries data collected between A.D. 1978 and 2000 (Table 1). The archaeological and zooarchaeological data are described in more detail elsewhere (Deagan 1983; Ewen 1984; Lyon 1976; McEwan 1980; Reitz 1985, 1991, 1992a, 1992b; Reitz and Brown 1984; Reitz and Cumbaa 1983; Reitz and Scarry 1985).

St. Augustine borders the southern end of a large embayment extending from North Carolina to just south of the city. Sea islands, such as Anastasia Island, are separated from the mainland by mud flats, oyster bars, tidal creeks, sounds, and salt marshes that form an inshore zone. The inshore zone includes the brackish-water estuaries behind Anastasia Island and low, sandy beaches bordering the seaward edges of Anastasia and North islands. Sea catfishes, drums, and mullets are typical inshore fishes.

The offshore habitat consists of the continental

Table 1. Time Period and Ethnic Affiliation of Archaeological Assemblages.

Site Name	Time Period	Affiliation
<i>Native American, Fountain of Youth Park:</i>		
Orange period	1450-500 B.C.	Native American
St. Johns IIc	A.D. 1513-1565	Native American
16th-century Mission period	A.D. 1565-1600	Native American
18th-century Mission period	A.D. 1701-1763	Native American
<i>St. Augustine, First Spanish Period:</i>		
16th-century town	A.D. 1567-1600	Largely Hispanic
17th-century town	A.D. 1600s	Largely Hispanic
18th-century town	A.D. 1701-1763	Largely Hispanic
<i>St. Augustine, British period</i>	A.D. 1763-1783	Diverse
<i>St. Augustine, Second Spanish period</i>	A.D. 1783-1821	Diverse
<i>St. Augustine, American Hotel period</i>		
Archaeological data	A.D. 1830-1900	Diverse
20th-century data	A.D. 1978-2000	Diverse

shelf that extends beyond Anastasia (Dahlberg 1975:4-11). The continental shelf is 110-130 km wide off St. Augustine with a gentle drop of about 30 cm per km. It is divided into two broad habitats. The coastal habitat extends from the beaches to 8-10 fathoms (14-18 m). The coastal habitat is turbid and productive, supporting both inshore and offshore fishes. The open-shelf habitat encompasses the continental shelf between 10 and 30 fathoms (18-55 m) and is relatively unproductive. The edge of the continental shelf lies between 30-100 fathoms (55-182 m). A diverse community of subtropical and tropical fishes such as groupers, snappers, and porgies may congregate where food is available along the upper and lower shelf habitat. The waters beyond the lower shelf edge have limited productivity.

Many fishes move between inshore and offshore habitats in response to seasonal periodicity, tidal action, storms, feeding opportunities, and stages in their life cycles (Reitz and Scarry 1985:43-45). Estuarine fishes typically tolerate highly variable water conditions that change in oxygen, salinity, turbidity, and temperature within short periods of time in response to tidal cycles.

The earliest occupation in this study is from a site now operated as a tourist attraction under the name "Fountain of Youth Park" (8SJ31). The Fountain of Youth Park site was initially occupied between 1450 and 500 B.C. (Orange period). Marginal increments in otoliths of Atlantic croaker (*Sciaenidae: Micropogonias undulatus*) suggest that the Orange period occupation was multiseasonal and perhaps year-round (Hales and Reitz 1992; Reitz 1991). From A.D. 1513-1565, Timucuan

lived at the site and experienced intermittent, probably indirect, contact with European explorers (St. Johns period IIc). The Timucuan village was associated with the nearby Mission Nombre de Dios (8SJ34) from the late sixteenth century through the early eighteenth century. Mission period Native American data are divided into late sixteenth-century (ca. A.D. 1565-1600) and the late seventeenth/early eighteenth-century (A.D. 1701-1763) components. Native American residence at the mission was continuous due to the requirements of daily religious observances. During the Mission period, the Fountain of Youth Park site was occupied by Native Americans with diverse tribal affiliations, and some had little or no previous coastal experience (Reitz 1991).

The Spanish colony was established in 1565 by Pedro Menéndez de Avilés, thereby initiating the First Spanish period (Deagan 1983). When the Hispanic colony was first established, it was located briefly in the Timucuan village at Fountain of Youth. Spain established the town of St. Augustine at its present location in 1567 (Lyon 1976). The Hispanic St. Augustine data represent the period beginning with 1567 and continuing to 1763. The First Spanish period is divided into three different centuries, each of which is represented by data from two or more assemblages (Table 2; Reitz 1992a; Reitz and Cumbaa 1983; Reitz and Scarry 1985). During the First Spanish period, St. Augustine was a multiethnic community that included Spaniards from throughout the Spanish Empire, other Europeans, Africans, and Native Americans. The First Spanish period is referred to as Hispanic because of its political affiliation with Spain. The First Span-

Table 2. Relative Proportions of Fish in Archaeological Assemblages from Fountain of Youth Park and St. Augustine.

Site Name	Number of Assemblages	Number of Vertebrate Taxa	Number of Fish Taxa	Total MNI	Total Fish MNI	Fish as % of Vertebrates	
						MNI	Biomass
<i>Native American, Fountain of Youth Park:</i>							
1450–500 B.C. (Orange period)	1	16	11	29	23	79	78
A.D. 1513–1565 (St. Johns IIc)	1	36	27	218	204	94	93
A.D. 1565–1600 (16th-century Mission period)	1	31	20	129	115	89	56
A.D. 1701–1763 (18th-century Mission period)	1	40	25	322	283	88	83
<i>Euramerican St. Augustine:</i>							
A.D. 1567–1600 (First Spanish period)	9	100	36	1126	767	68	24
A.D. 1600s (First Spanish period)	2	41	15	166	105	63	36
A.D. 1701–1763 (First Spanish period)	6	96	32	722	429	59	6
A.D. 1763–1783 (British period)	4	48	22	191	124	65	7
A.D. 1783–1821 (Second Spanish period)	2	33	11	168	96	57	16
A.D. 1830–1900 (American Hotel period)	2	37	14	212	103	49	17

Note: MNI is the Minimum Number of Individuals. Biomass is estimated using allometric formulae (Reitz and Wing 1999:72). Fountain of Youth Park archaeological data are from Reitz (1985, 1991). St. Augustine archaeological data are from McEwan (1980), Reitz (1979, 1992a, 1992b), Reitz and Brown (1984), Reitz and Cumbaa (1983), and Reitz and Scarry (1985).

ish period ended in 1763 when control of Spanish Florida passed to England.

Additional Euramerican data are available from St. Augustine after the end of the First Spanish period. Most Spaniards and Catholic Indians evacuated the town when the brief British period began in 1763. Data from four British period collections are available (Reitz 1979; Reitz and Brown 1984). In 1783, the town reverted back to Spanish control during the Second Spanish period. The Second Spanish period data are from only two sites: St. Francis Barracks (SA42A; Reitz 1992b) and the Ximenez-Fatio house (SA34-2; Reitz and Brown 1984). Florida passed to American governance in 1821. The American data are from two collections from the Ximenez-Fatio house when it was used as a hotel (McEwan 1980; Reitz and Brown 1984). It is not possible at this time to determine if the Ximenez-Fatio data reflect the usual diet in the town or a special hotel menu.

Cartilaginous and bony fish remains for all of the archaeological collections were identified using the comparative skeletal reference collection at the Florida Museum of Natural History and the Georgia Museum of Natural History. The zooarchaeological species lists are available elsewhere (McEwan 1980; Reitz 1979, 1985, 1991, 1992a, 1992b; Reitz and Brown 1984; Reitz and Cumbaa 1983; Reitz and Scarry 1985). The Minimum Number of Individuals (MNI) is estimated for each taxon based on paired elements, size, and age. MNI for

cartilaginous sharks and rays (Chondrichthyes) is likely to be underestimated because these animals do not have paired elements that survive archaeologically. The MNI estimate of cartilaginous fishes represented by many vertebrae may be but one single individual depending upon how the samples are aggregated (e.g., Grayson 1984:31). Biomass is estimated from specimen weight using allometric formulae (Reitz et al. 1987). Biomass is the closest equivalent of modern pounds landed and preference is given in the following discussion to biomass for this reason. Diversity (H') and equitability (V') estimates are based on the Shannon-Weaver and Sheldon formulae (Reitz and Wing 1999:233–234; Shannon and Weaver 1949; Sheldon 1969). The reader is referred to Reitz and Wing (1999:194–200, 225–228) for further discussion of these methods.

Invertebrates are not included in this study for several reasons. Molluscs were used to make a building material known as tabby and for other architectural purposes. Tabby and mollusc remains are ubiquitous in St. Augustine. In only a few cases can molluscs used as food be separated from molluscs used as building material. Crustaceans (including shrimps) are underrepresented in archaeological sites because of preservation biases, though their role in the modern fishery is highly significant and probably was earlier as well. Because invertebrates are problematic in St. Augustine, they are not included in this study and

are also removed from the modern data. Excluding these low-trophic-level animals results in higher estimates of mean trophic levels than would be the case if invertebrates were included, a point that is important when the archaeological data are compared to Pauly's study in which invertebrates are prominent.

Modern fisheries data are from two sources. One of these sources is St. Johns County landing data reported in a Florida Cooperative Extension Service, Florida Sea Grant Program *Marine Advisory Bulletin* (Cato and Prochaska 1977). The *Bulletin* summarizes commercial fisheries landings for the Florida East Coast between 1952–1973. Cato and Prochaska (1977) also provide the average pounds for 16 major finfishes landed in St. Johns County between 1971 and 1973, lumping the other fishes into a single finfish category. More detailed commercial fisheries statistics for St. Johns County from 1978 to 2000 are provided by Steven T. Brown (FFWCC 1978–2000). Pounds are converted to kilograms for this paper and only fishes data are used to estimate mean trophic level. The term "fishes" refers to both cartilaginous (Chondrichthyes) and bony fishes (Osteichthyes) in the following discussion.

Zooarchaeological and modern data are assigned to trophic levels using data in FishBase 98 (Froese and Pauly 1998). It is necessary to use higher taxonomic levels when the identifications in the archaeological data, the modern fishery data, and/or FishBase are insufficiently precise. In cases where the zooarchaeological taxonomic identification is not in FishBase 98, the trophic level for the closest taxonomic category is used. The formula

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

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 $Biomass_{ij}$ of the taxon (j) for the time period (i). TL_{ij} is divided by the summed Biomass for the time period ($Biomass_i$). This formula estimates the mean trophic level for each assemblage. The results of this same calculation are used to estimate the relative contribution of each trophic level during each time period. MNI may be used instead of biomass in this formula.

Three Thousand Years of Fishing

A comparison of the zooarchaeological and modern data finds considerable variation in fishing during the archaeological time frame as well as between the fisheries represented archaeologically and the twentieth-century commercial fishery. Differences are found in the degree to which fish contributed to the diet, in the diversity and equitability of fish taxa, in the types of fishes used, and in the mean trophic level used. Each of these is reviewed in turn.

Differences in the Degree to Which Fish Contributed to the Diet

Marine resources were a very important part of the diet at the Fountain of Youth Park site and at most sites in St. Augustine (Table 2). Fishes comprise half of the estimated vertebrate individuals (MNI) in all time periods. The trend is for the percentage of fish individuals to decline from the sixteenth through the nineteenth century in both Native American and Euramerican assemblages. Fishes contributed a quarter or more of the biomass consumed in this area until the Euramerican diet of the 1700s. After 1700, fish biomass increases at Fountain of Youth Park and declines in St. Augustine.

The lower percentages of fish biomass in St. Augustine assemblages compared to Native American ones may reflect an increase in European-introduced domestic animals in the town by the end of the First Spanish period (see Reitz 1991). Domestic animals are absent at Fountain of Youth Park, even during the Mission period. Alternatively, the decline in fish biomass at the beginning of the eighteenth century could signal that the Spanish fishing strategy was less productive because the resource base was altered by climate change or overfishing.

The Diversity and Equitability of Fish Taxa

The variety of fish taxa is expressed by estimates of richness (N), diversity (H'), and equitability (V') for fish biomass (Figure 2; Table 3). Both Native American and Euramerican assemblages are less rich, less diverse, and generally more equitable than the twentieth-century St. Johns County commercial fishery.

In the Native American collections from Fountain of Youth Park, fish biomass diversity peaks in the early 1500s before the First Spanish period. It

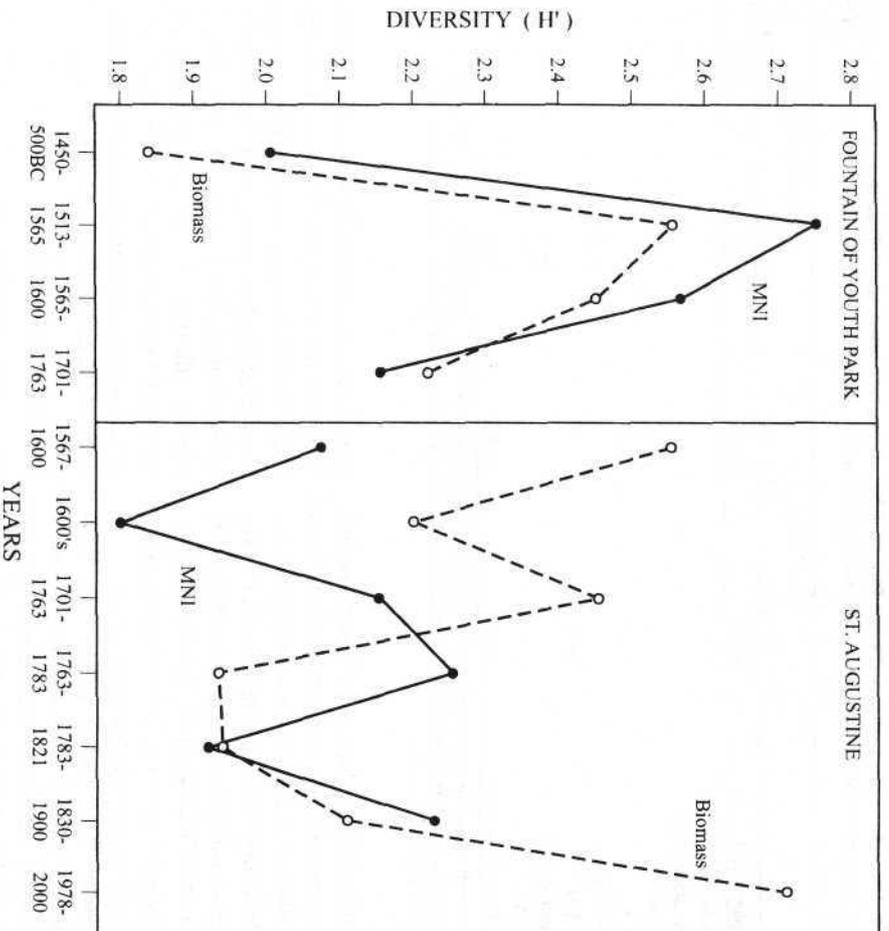


Figure 2. Relationship between MINI and Biomass Diversity.

Table 3. Biomass Diversity and Equitability for Fishes.

Site Name	Biomass, kg	N	H'	V	% Vertebrate Biomass
<i>Native American, Fountain of Youth Park</i>					
1450-500 B.C. (Orange period)	.606	11	1.834	.765	78
A.D. 1513-1565 (St. Johns IIc)	1.46	27	2.556	.776	93
A.D. 1565-1600 (16th-century Mission period)	.704	20	2.450	.818	56
A.D. 1701-1763 (18th-century Mission period)	11.37	25	2.222	.690	83
<i>Euremerican St. Augustine</i>					
A.D. 1567-1600 (First Spanish period)	30,459	35	2.545	.716	24
A.D. 1600s (First Spanish period)	4,964	15	2.203	.814	36
A.D. 1701-1763 (First Spanish period)	20,968	30	2.453	.721	6
A.D. 1763-1783 (British period)	7,788	22	1.922	.622	7
A.D. 1783-1821 (Second Spanish period)	9,828	11	1.933	.806	16
A.D. 1830-1900 (American Hotel period)	3,694	14	2.110	.799	17
<i>Twentieth Century</i>					
A.D. 1978-2000 St. Johns County	88,429,061	67	2.680	.637	
1978	87,638,924	55	2.657	.663	
1988	314,022	42	2.379	.636	
1998	279,836	42	2.670	.714	
2000	196,279	42	2.709	.725	

Note: Twentieth-century data are from FFWCC (1978-2000). *N* is the number of fish taxa in each assemblage contributing data to the calculations. Diversity (H') and equitability (V) are calculated using the Shannon-Weaver (1949) and Sheldon (1969) formulae.

Table 4. Native American Fountain of Youth Park: Fish Taxa Representing at Least 10 Percent of the Fish Biomass, Expressed as Percentage of Fish Biomass and Organized from Low Trophic Level (2.1) to High Trophic Level (4.0).

	Pre-Colonial		Mission Period	
	1450–500 B.C.	1513–1565	1565–1600	1701–1763
Mean Trophic Level:	3.438	3.255	3.315	3.411
Sea catfish family (3.2)				13.7
Gafftopsail catfish (3.2)				14.4
Bumper (3.3)		11.8		
Croaker (3.3)	28.9	25.1		17.2
Black drum (3.4)			13.2	
Eagle ray (3.5)	30.9			
Hardhead catfish (3.5)			19.5	15.0
Flounder (3.5)			11.2	
Chondrichthyes (3.6–4.0)	10.2	11.6	12.1	19.5

Note: Mean trophic level for each time period is noted across the top of the table and for the specific fish in parentheses. The highest trophic level represented by Chondrichthyes in the Fountain of Youth Park assemblage is 4.0, which is also the highest trophic level for the site.

subsequently declines during the Mission period. The Orange period collection is remarkable for its low diversity, which reflects the dominance of two taxa: eagle ray (*Myliobatidae*) and Atlantic croaker. These two taxa contribute 41 percent of the MNI and 60 percent of the biomass (Table 4). The dominance of these two taxa and the low diversity likely is related, in part, to the small sample size.

In the Euramerican assemblages, biomass diversity declines irregularly from a sixteenth-century high to lows in the British and Second Spanish periods, and then rises in the American Hotel period. The Hispanic fishing strategy during the First Spanish period was more diverse than the fishing strategy of subsequent archaeological periods. The higher diversity between 1701 and 1763 coincides with the period when fish contribute only 6 percent of the biomass. Although many different fishes were consumed at the end of the First Spanish period, the contribution of fish to the diet was low compared to previous centuries. It remained low in the 1763–1783 period. Diversity and the percentage of fish biomass increases after 1821, indicating that more types of fishes contributed more biomass than in the late 1700s. Equitability is relatively stable considering the variability in diversity. Even as overall fish diversity declines, three or four fishes dominate each time period, complemented by many less-common ones. Only a few species contribute most of the biomass in every assemblage.

These aspects of the fishery are similar to patterns found at the end of the twentieth century. Richness is far higher in the twentieth century com-

pared to the earlier centuries, but only a few taxa dominate the catch. The late twentieth-century catch tends to be more diverse but less equitable than the archaeological catches. Diversity and equitability both declined in 1988 when richness and catch size dropped dramatically. Diversity rose by 1998–2000 even though the catch size continued to decline. Both richness and equitability remained stable at the end of the twentieth century.

Types of Fishes Used

Many of the taxa used in the past are not commercially valuable today and many of today's important commercial fishes are not present in zooarchaeological collections (Tables 4–6). Seven of the 16 finfish considered to be common in the modern St. Johns County fishery by Cato and Prochaska (1977:4–5) and 49 of the 70 bony fishes in the FFWCC commercial fisheries statistics (1978–2000) are not identified in the archaeological collections. Eleven of the 28 bony fishes in Native American collections and 10 of the 33 bony fishes in Euramerican assemblages are not reported by the FFWCC (1978–2000). (Sharks and rays are lumped into categories such as “shark, mixed” or “shark fin” and, therefore, are not readily compared with the more detailed archaeological species lists.) Mechanized industrial fishing in the twentieth century enabled fishermen to define a modern catchment basin extending far beyond that of earlier centuries (e.g., Myers and Worm 2003). The modern finfish stock is clearly from deeper waters whereas fishing prior to 1900 focused on the estuary and immediate inshore locations.

Table 5. Euramerican Contexts Beginning with the First Spanish Period through the end of the Twentieth Century: Fish Taxa Representing at Least 10 Percent of the Fish Biomass, Expressed as Percentage of Fish Biomass and Organized from Low Trophic Level (2.1) to High Trophic Level (4.5).

	1567-1600	1600s	1701-1763	1763-1783	1783-1821	1830-1900	1978-2000
Mean Trophic Level:	3.352	3.302	3.343	3.324	2.991	3.343	3.188
Mullet (2.1)	22.4	24.9	14.3		35.2	10.2	30.0
Menhaden (2.8)							15.8
Gafftopsail catfish (3.2)				14.0			
Sheepshead (3.4)						14.9	
Black drum (3.4)			14.8	12.4	12.6		
Red drum (3.4)	11.5		16.7	12.2		15.4	
Hardhead catfish (3.5)	18.6		16.7	39.6			
Flounder (3.5)					12.2		
Chondrichthyes (3.6-4.5)	24.1	49.0	26.3		15.2	30.2	

Note: Mean trophic level for each time period is noted across the top of the table and for the specific fish in parentheses.

The highest trophic level represented by Chondrichthyes in the St. Augustine assemblage is 4.5, though fishes from trophic levels 4.5-4.6 are present in the assemblage.

The most abundant fishes in the archaeological collections are sharks (Chondrichthyes), sea catfishes (Ariidae, hardhead catfish [*Arius felis*], gafftopsail [*Bagre marinus*]), black drum (*Pogonias cromis*), and flounders (*Paralichthys* spp.). These contribute more than 10 percent of the fish biomass in at least one time period in both Native American and Euramerican assemblages (Tables 4 and 5). With few exceptions, the dominant fishes in Native American collections are also dominant in Euramerican archaeological contexts. The 1450-500 B.C. use of eagle ray (Myliobatidae) is unique. The first archaeological evidence that continental-shelf fishes such as grouper (*Epinephelus*

sp.) and snapper (*Lutjanus* sp.) were used is found in the 1701-1763 period, though they play a very minor role. Neither grouper nor snapper is found in any other archaeological context, supporting the argument that fishing was predominately focused on inshore and estuarine locations prior to the twentieth century.

Most of the fishes in the modern fishery are not present in the archaeological record or at least were not subject to fishing in a way that left archaeological evidence (Table 6). In St. Johns County between 1971 and 1973 the most important fish species was king whiting. Other fishes contributing more than 5 percent of the weight landed are

Table 6. Important Commercial Finfish in St. Johns County, Florida, Based on Kilograms Landed Between 1971 and 1973 and Organized by Trophic Level.

Common Name (Trophic Level)	% kg Landed	Scientific Name
Striped mullet (2.1)	1.3	<i>Mugil cephalus</i>
Bluefish (3.3)	4.3	<i>Pomatomus saltatrix</i>
Pompano (3.3)	.6	<i>Trachinotus</i> spp.
Sheepshead (3.4)	.6	<i>Archosargus probatocephalus</i>
Spotted seatrout (3.4)	.5	<i>Cynoscion nothus</i>
Spot (3.4)	5.6	<i>Leiostomus xanthurus</i>
King whiting (3.4)	36.7	<i>Menticirrhus americanus</i>
Sea bass (3.5)	4.1	<i>Centropristis</i> spp.
Red porgy (3.5)	2.1	<i>Pagrus pagrus</i>
Flounder (3.5)	7.8	Pleuronectiformes
Grouper (3.8)	6.6	<i>Epinephelus</i> spp.
Spanish mackerel (3.9)	.8	<i>Scomberomorus maculatus</i>
Red snapper (4.0)	14.9	<i>Lutjanus campechanus</i>
King mackerel (4.0)	1.5	<i>Scomberomorus cavalla</i>
Gray snapper (4.6)	.4	<i>Lutjanus griseus</i>
Vermilion snapper (4.6)	3.2	<i>Rhomboplites aurorubens</i>
Other finfish	9.0	

Note: Data are from Cato and Prochaska (1977:46-47).

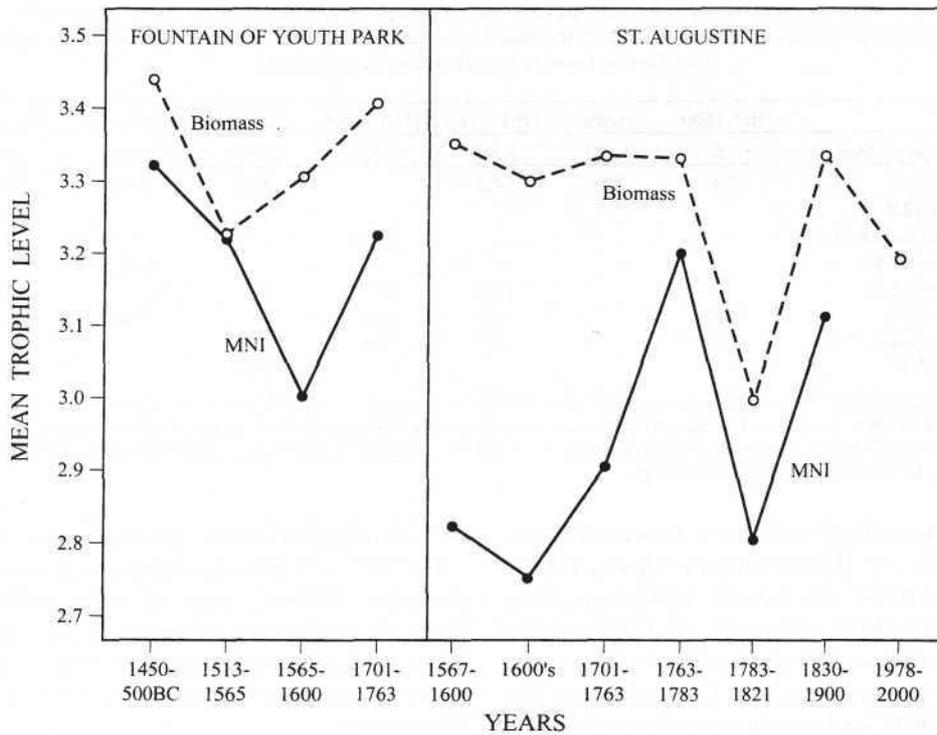


Figure 3. Relationship between MNI and Biomass Mean Trophic Levels.

red snapper (*Lutjanus campechanus*), flounder, grouper, and spot (*Leiostomus xanthurus*) (scientific names are not used by Cato and Prochaska and the common names "flounder" and "grouper" could refer to several different fishes). Of these, only flounder and spot are found in archaeological contexts and only flounder is ubiquitous.

More complete data for St. Johns County identify 71 cartilaginous and bony fish taxa among the fishes landed (FFWCC 1978–2000). However, 46 percent of the weight landed is contributed by just two of these: mullet (*Mugil cephalus*) and menhaden (*Brevoortia* spp.). Other fishes contributing more than 5 percent of the weight landed are sea basses (Serranidae) and mackerels (*Scomberomorus maculatus*, *S. cavalla*). Menhadens and mackerels are not present in the archaeological materials. The sea basses present archaeologically are members of the smaller-bodied genus *Centropristis* rather than the larger-bodied genus *Epinephelus*. *Centropristis* is more commonly found in the estuarine waters of St. Johns County than is *Epinephelus*.

Mullet is the only fish significant in twentieth-century St. Johns County that consistently con-

tributes more than 10 percent of the fish biomass in archaeological contexts (Cato and Prochaska 1977:46–47; FFWCC 1978–2000). Mullet are more prominent in the 1978–2000 catch landed in St. Johns County (30 percent; FFWCC 1978–2000) than in the Cato and Prochaska study of 1971–1973 (1 percent; Table 6). This could be part of the trend of fishing down the food chain highlighted by Pauly et al. (1998). The low levels of mullet use in Native American contexts is an unresolved mystery that is typical of Native American collections from the Florida and Georgia coasts (Reitz and Quitmyer 2003). This phenomenon is not entirely due to screen size (see Discussion). Menhaden, the second major fish in the FFWCC statistics, is not present in the archaeological samples.

Mean Trophic Level

The mean trophic level from which biomass is derived is relatively stable throughout the study period (Figure 3; Tables 7 and 8). Trophic level declines twice in the archaeological sequence; once in the 1513–1565 period and again in the 1783–1821 period. Both times fishes from trophic levels 2.1–3.3 comprise a high percentage of the

Table 7. Native American Fountain of Youth Park: Contribution of Fishes from Each Trophic Level Based on Percentage of Biomass Derived from Each Trophic Level for Each Time Period Organized from Low Trophic Level (2.1) to High Trophic Level (4.6).

	Pre-Colonial		Mission Period	
	1450–500 B.C.	1513–1565	1565–1600	1701–1763
Mean Trophic Level:	3.438	3.255	3.315	3.411
2.1	1.2	8.9	6.4	3.0
2.6–3.3	37.7	50.2	27.8	46.7
3.4–3.5	50.9	28.5	53.7	30.4
3.6–3.9		12.4	12.1	1.3
4.0	10.2			18.6
4.5–4.6				

Note: Mean trophic level for each time period is noted across the top of the table.

catch and fishes from trophic levels above 3.9 are not present. The relative stability in mean trophic level masks shifts through time in the emphasis placed on fishes from lower and higher trophic levels (Figure 4). Trophic levels between 4.5 and 4.6 were a source of biomass in the Euramerican fishing strategy as early as 1567 but were never part of the Native American strategy. The archaeological mean trophic levels is higher than the 1978–2000 mean trophic level (3.19) with only one exception (1783–1821).

About half of the biomass in both the Native American and the Euramerican fishery is from trophic level 3.4–3.5, with three exceptions. In the two Native American exceptions (1513–1565 and 1701–1763) lower trophic levels (2.6–3.3) are the primary source of biomass (Figure 4; Table 7). In the Euramerican exception (1600s), 49 percent of the biomass is from higher trophic levels (Figure 4; Table 8).

Euramericans generally took higher percentages of biomass from high trophic levels than did Native Americans. Until the middle of the eight-

teenth century, over a quarter of the biomass is from trophic levels above 3.5. Beginning with Spanish colonization, use of the trophic levels above 3.9 was routine. In spite of the similarity in mean trophic level, Native Americans made very little use of resources from trophic levels above 3.5, and there is little evidence that they used trophic levels above 4.0. This characterization applies to Native American data from elsewhere on the Florida and Georgia Atlantic coasts (Reitz and Quitmyer 2003).

Beginning with the first decades of the colony, Spanish fishermen fished at both ends of the trophic spectrum while competing with their preferred high-trophic-level prey for low-trophic-level food and persisted in doing so. In the 1600s, 49 percent of the biomass is from trophic levels above 3.5, combined with 25 percent of the biomass from trophic level 2.1, all of which is mullet. By 1701–1763, use of trophic levels above 3.5 declines and by 1763–1783 use of levels above 3.5 is rare. In the 1783–1821 period, a third of the biomass is from trophic level 2.1, with reduced use of trophic levels above 3.4 and very little use of trophic levels

Table 8. Euramerican Contexts Beginning with the First Spanish Period through the End of the Twentieth Century: Contribution of Finfishes from Each Trophic Level Based on Percentage of Biomass from Each Trophic Level in Each Time Period from Low Trophic Level (2.1) to High Trophic Level (4.6).

	1567–1600	1600s	1701–1763	1763–1783	1783–1821	1830–1900	1978–2000
Mean Trophic Level:	3.352	3.302	3.343	3.324	2.991	3.343	3.188
2.1	22.4	25.0	14.3	8.5	35.2	10.2	31.0
2.6–3.3	3.8	.8	2.5	15.7	2.2	2.3	28.8
3.4–3.5	49.7	25.1	56.6	70.3	47.4	57.3	14.6
3.6–3.9	17.6	24.9	13.7	3.8	15.2	28.5	12.4
4.0	4.2	18.9	11.4			1.7	9.4
4.5–4.6	2.3	5.2	1.4	1.6			3.9

Note: Mean trophic level for each time period is noted across the top of the table. Trophic Level 4.5–4.6 in the 1701–1763 collection includes the only animal from Trophic Level 4.6, a snapper (*Lutjanus* sp.).

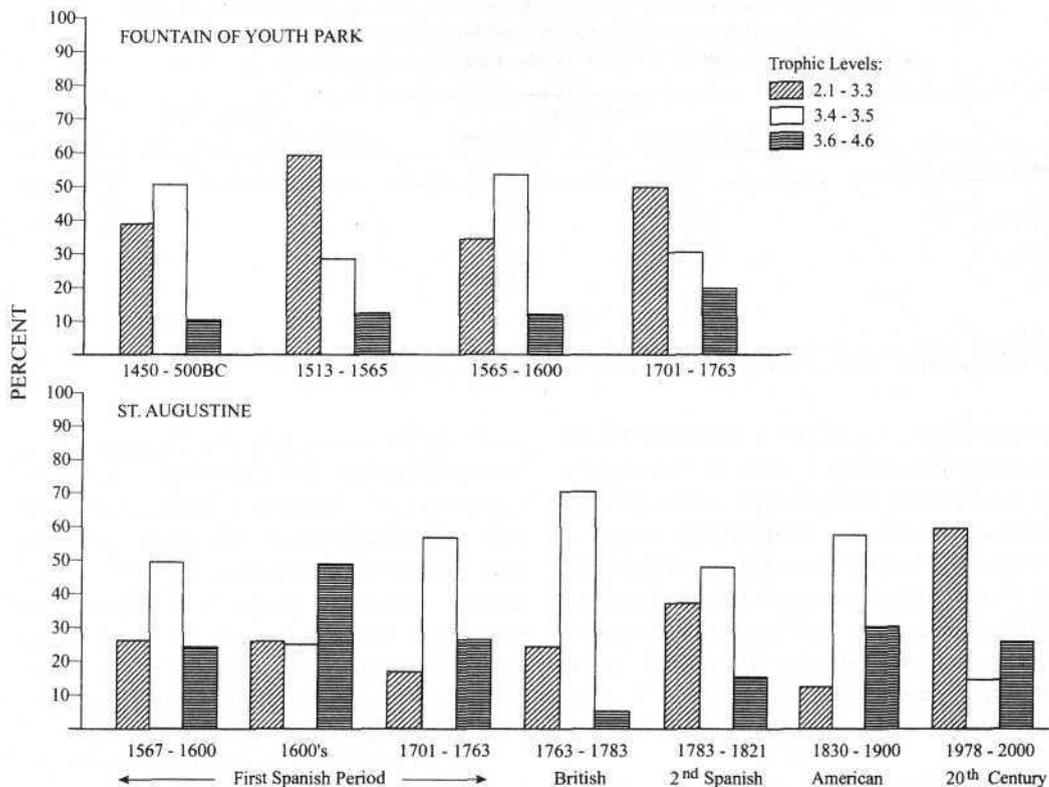


Figure 4. Comparison of Fishes from Each Trophic Level Based on Percentage of Biomass from Each Trophic Level.

above 3.6. By the end of the twentieth century, 60 percent of the biomass is from the trophic levels below 3.4.

MNI Comments

Although biomass is used as the primary basis for this study because it is most directly comparable to twentieth-century fisheries records, it is interesting to consider MNI briefly. The merits of using NISP, MNI, or meat estimates as analytical tools have been widely reviewed and the issues remain unresolved. Coastal zooarchaeological collections are particularly difficult to assess from a single perspective because turtles and fishes, with indeterminate growth and no single body size, are often the dominant vertebrates. Many of the fishes vary greatly in body size. The mullets from Fountain of Youth Park are primarily small individuals and those from St. Augustine are primarily large individuals. The same 10 individuals in two assemblages may have made a substantially different dietary contribution. Some taxa, such as cartilagi-

nous fishes, are underestimated by both NISP and MNI because they have few paired elements. They may also vary greatly in body size and, therefore, dietary contribution. None of this variation, however, may be captured by either MNI or NISP. For these reasons, it is possible to have taxa that contribute a high percentage of NISP or MNI but very little meat and vice versa.

This effect is apparent in these materials, where diversity estimates derived from MNI and biomass (Figure 2) and mean trophic level (Figure 3) generally track one another, but are not identical. Typically, MNI diversity is higher than biomass diversity. The higher MNI diversity in the Fountain of Youth assemblage compared to the biomass diversity can be attributed to a greater variation in MNI than in biomass. For example, in the 1513-1565 component at Fountain of Youth two taxa each contribute over 10 percent of the individuals (totaling 33 percent of the MNI), but three other taxa each contribute over 10 percent of the biomass (totaling 48 percent of biomass). Thus,

Table 9. Mean Trophic Level for Archaeological Data (Based on Biomass) Compared to Twentieth-Century Data.

Site Name	Mean Trophic Level
<i>Native American Fountain of Youth Park Archaeological Data:</i>	
1450–500 B.C. (Orange period)	3.44
A.D. 1513–1565 (St. Johns IIc)	3.25
A.D. 1565–1600 (16th-century Mission period)	3.31
A.D. 1701–1763 (18th-century Mission period)	3.41
<i>Euramerican St. Augustine Archaeological Data:</i>	
A.D. 1567–1600 (First Spanish period)	3.35
A.D. 1600s (First Spanish period)	3.30
A.D. 1701–1763 (First Spanish period)	3.34
A.D. 1763–1783 (British period)	3.32
A.D. 1783–1821 (Second Spanish period)	2.99
A.D. 1830–1900 (American Hotel period)	3.34
<i>Twentieth-Century St. Johns County Landing Records:</i>	
A.D. 1978–2000 St. Johns County	3.19
1978	3.02
1988	3.54
1998	3.49
2000	3.26

Note: Native American archaeological data are from the Fountain of Youth Park Site and Euramerican archaeological data are from St. Augustine. St. Johns County Landing Records are from FFWCC (1978–2000).

MNI diversity is higher than biomass diversity. The observation that MNI diversity for the First Spanish period is lower than biomass diversity for this same time period is due to the overwhelming dominance of a single source of MNI throughout the First Spanish period (mullet) whereas three or four taxa individually contribute over 10 percent of the biomass and mullet is only one meat source among many.

The role of mullet is also the primary explanation for the differences between trophic-level estimates based on biomass and MNI. Mullet is a low-trophic-level fish (2.1) so that large numbers of mullet individuals would tend to reduce mean trophic level. Mean MNI trophic level at Fountain of Youth Park declines in the 1565–1600 component because this is the only time in which mullets contribute substantially to the MNI (15 percent), though they never contribute more than 9 percent of the biomass. The period when mullet contribute 9 percent of the biomass is 1513–1565 when the biomass mean trophic level declines. The two times when the estimated Euramerican MNI trophic level rises are the two times when mullets contribute less than 40 percent of the individuals (1763–1783 and 1830–1900). Other low-trophic-level fishes, such as gafftopsail catfishes and Atlantic croaker, also play roles in this variation but the relative rank of mullet is the most consistent variable.

“Fishing Down The Food Web”

During the 1950s, fishing in the northwest Atlantic was dominated by small, pelagic, low-trophic-level fishes (Pauly et al. 1998). As the century advanced, productivity of low-trophic-level fishes declined and higher-trophic-level fishes became a larger portion of the catch. In the 1970s, catches from high trophic levels also declined. According to Pauly, high-trophic-level fishes could sustain human predation only as long as their own low-trophic-level food base was stable. When it became unstable entire fisheries collapsed.

The historical perspective provided by the archaeological data suggests several modifications to this interpretation. First, the tradition of fishing large quantities of small, pelagic, low-trophic-level fishes such as menhaden was a twentieth-century innovation in this area. There is no archaeological precedent for it. Second, many of the bony fishes from trophic levels 3.4 and above in the twentieth-century continental-shelf fishery were not fished prior to the twentieth century. Third, though the mean trophic level generally does not change markedly during the archaeological period, use of high trophic levels was a major part of the fishing strategy as early as the sixteenth century. In fact, the 1978–2000 mean trophic level (3.19, Table 9) is low compared to the historical pattern established

by the archaeological evidence. Fourth, different species and different localities were used in the past compared to the twentieth century. Fifth, to the extent that archaeological data reflect changes in the resource base, some of those changes occurred in the eighteenth century if not before.

Virtually all of the fishes in trophic levels 3.6–4.6 are sharks (Chondrichthyes). Although sharks were used by Native Americans, shark use was higher under Spanish influence than it was before Spanish colonization began. Sharks contribute almost half of the fish biomass in the 1600s and roughly a quarter of the biomass in the other Euramerican assemblages, except for the 1763–1821 period. Sharks from trophic levels above 4.5 are found only in Euramerican contexts. Sharks constitute less than 1 percent of the kilograms landed in St. Johns County (FFWCC 1978–2000). The present decline in shark populations is an important conservation concern often attributed to overharvesting (e.g., Baum et al. 2003).

Many different sharks are present in these samples. Most frequent are the nurse sharks (*Ginglymostoma cirratum*), requiem sharks (*Carcharhinus leucas*, *C. plumbeus*, *Galeocerdo cuvieri*), and hammerhead sharks (*Sphyrna mokarran*, *S. tiburo*, *S. zygaena*). The habitats of these sharks are diverse, but they are all found in shallow coastal and estuarine waters (Castro 1983). Their food preferences are also diverse, but common foods include molluscs, crustaceans, and bony fishes (Castro 1983). Some may also eat rays and other sharks. Although we do not know how Native Americans or Euramericans caught sharks, sharks today are taken with nets, weirs, and hand lines. It is difficult to characterize the size of the sharks in the archaeological materials, but most were at the smaller end of the size range of each species.

The only fishes in trophic level 2.1 are mullets. The high use of mullets is the primary reason the Euramerican mean trophic level is between 3.3 and 3.5 and not as high as the use of sharks would otherwise indicate it should be. Mulletts are present in all Native American contexts but in minor quantities. Today mulletts are usually caught within the estuary using mass-capture techniques such as cast nets, though probably Native Americans caught them using scoops and seine nets before Spaniards introduced cast nets (Reitz and Scarry 1985:81). Mulletts in Native American contexts are typically

smaller than those recovered from Euramerican ones, perhaps because they were captured using scoops or nets in shallow, near-shore waters frequented by the small mullet.

The difference in the percentage of mulletts recovered from Native American contexts and those from St. Augustine is unlikely to be due to archaeological recovery technique. Although a ¼-inch mesh screen was used during excavation of the eighteenth-century Mission period materials from the Fountain of Youth Park site, a ¼-inch mesh suspended over a ⅛-inch mesh was used to recover the Orange period, St. Johns IIc, and sixteenth-century Mission materials. This fine-screen recovery technique would have recovered remains of small mulletts if they had been used by Native Americans instead of the large individuals preferred in the town.

Mullet use is notably high twice: in 1783–1821 and in 1978–2000 (Table 8). Euramerican fishing focused on a low-trophic-level, vegetarian resource and decreased use of higher trophic levels, fishing down the food web at least once prior to the twentieth century. Characteristics associated with fishing down the food web also may be present in the changes seen between the 1600s collection and that from 1701–1763: the percentage of fish biomass from trophic level 3.4–3.5 doubled, and biomass from levels above 3.6 declined by half. This is a less-dramatic case of fishing down the food web, but nonetheless could be a consequence of overfishing mulletts and sharks in the 1600s. The 1783–1821 peak in mullet use is preceded by 180 years during which the use of both mulletts and sharks declines. This may be an archaeological example of a situation where a predator (sharks) confronts a new competitor (humans) for part of its food base (mulletts) while also experiencing predation at historically high levels (at least from the sharks' perspective). By using high percentages of sharks and mulletts, the Spanish strategy may have stressed the entire estuary.

The diversity of fish and their role in the Euramerican diet may provide additional support for a fisheries collapse in the 1701–1763 period (Figure 2; Table 3). Use of fishes from both the high and the low ends of the trophic spectrum declines, the percentage of fish biomass in the diet declines, and fish diversity rises. It could be that by the end of the First Spanish period the fishery was so

stressed that it could not sustain previous fishing levels. Subsequently, diversity itself declines (1763–1821). After 1821, diversity rises, the percentage of fish biomass increases, and sharks eventually contribute a third of the fish biomass. It is possible that the return to shark fishing in the 1830–1900 period eventually contributed to the further increase in diversity, increase in use of low-trophic-level fishes, and decline in mean trophic level reported for the twentieth century.

Another component of “fishing down the food web” is a recent increase in low-trophic-level fishes that accompanies the decline in high-trophic-level animals. Although Native Americans did use trophic levels 2.6–3.3, fishes from this level became prominent in the Euramerican fishing strategy only in the twentieth century. In the past, the 2.6–3.3 fishes were primarily gafftopsail catfishes and a few other fishes. Today, herring and sardines are the major fishes from this trophic level.

Additional evidence of stress is found in Atlantic croaker. Croaker is a dominant fish in the Fountain of Youth Park collections as well as at the nearby sites of Mission Nombre de Dios (Orr 2001) and the free-African site of Gracia Real Santa Teresa de Mose (8SJ40; Reitz 1994; Figure 1). Analysis of croaker otoliths from Fountain of Youth and pre-colonial contexts at Mose indicates that either overfishing or climate change impacted this fish species (Hales and Reitz 1992). Croaker is a very common bottom-dwelling fish throughout the Atlantic coast (Barbieri et al. 1993). Analysis of croaker otoliths from Fountain of Youth Park and the prehispanic contexts at Mose shows that Native Americans captured croakers that averaged less than four years of age and less than 25 cm in total length. After Spanish colonization, Native Americans at Fountain of Youth Park site and Africans at what was by that time Fort Mose captured older and larger croaker. Some of the croaker recovered from these sites are among the largest and oldest croaker known. Today most croaker are less than two years of age and achieve a total length of less than 25 cm. The growth pattern of croaker has changed dramatically since the eighteenth century following a pattern that is consistent with a species whose rate of exploitation has increased. We cannot lay blame for this solely on Spanish colonists. During the First Spanish period, the fishermen at Fountain of Youth were Native Americans and the fishermen of Fort Mose

were African. Non-European fishermen may have been responding, however, to Spanish requirements, preferences, or examples for their choices of fishing techniques.

Preliminary studies of sea catfishes (Ariidae) and drums (Sciaenidae) in St. Augustine area archaeological samples find a similar decline in body size in other fishes over the centuries. Recent fishing restrictions in marine sanctuaries south of St. Augustine have resulted in modern increases in body size in three of the fishes whose body size is thought to have declined in the archaeological record: spotted sea trout (*Cynoscion nebulosus*), black drum (*Pogonias cromis*), and red drum (*Sciaenops ocellatus*). Modern observations suggest that smaller body size, slower growth, and early maturation are related to human predation (Conover and Munch 2002; Roberts et al. 2001), as it appears to have been in Atlantic croaker. This aspect of fishing in the St. Augustine area should be studied in more detail.

Thus in the 1700s the two ingredients characteristic of fishing down the food web are present: use of high-trophic-level fishes (sharks) and a low-trophic-level fish (mullet), followed by a decline in mean trophic level.

Discussion

The zooarchaeological evidence clearly indicates that fishing was an important part of both Native American and Euramerican economies in the sixteenth through the nineteenth centuries and that there may have been an early impact on the fishery from some cause or causes. The mean trophic level was 3.3 before the middle of the eighteenth century and fluctuated between lower and higher levels thereafter. Further, the Euramerican fishery included fishes at both ends of the trophic-level spectrum, mullets and sharks, a combination that was not part of the Native American fishing strategy. We also see alterations in the body size and mean age of one of the major prehispanic resources, Atlantic croaker. The early twentieth-century resource base may not be the stable, pristine one assumed by many resource managers. Three factors may be responsible for the variability: cultural change, climate change, and overfishing.

We know that cultural change occurred several times in this sequence, an explanation considered extensively elsewhere (Reitz 1985, 1991, 1992a,

1992b; Reitz and Brown 1984; Reitz and Cumbaa 1983; Reitz and Scarry 1985). One of the most dramatic was in 1567, when Spanish colonization began. Another important cultural change accompanied the 1763 transition to British governance. Most of the Spanish-affiliated Europeans and Native Americans abandoned the territory during the British period. Although Spain resumed nominal control of Florida in 1783, the territory was rapidly colonized by Americans. The wide variation in mean trophic level and diversity after 1763 could be attributed to the century of political and economic instability that followed the First Spanish period. In particular, modifications in fishing technology and location in response to new economic demands need to be tracked in more detail.

Climate changes throughout the last 500 years may have influenced fishing productivity more than we understand at present (e.g., Attrill and Power 2002). The St. Johns Ic and First Spanish periods coincide with what is known as the Little Ice Age. The wide variations found in fishing strategies reported here may be evidence of a cultural response to alterations in the resource base that began before Spanish colonization and continued until the area became an American territory. This possibility needs to be more closely correlated with local evidence for the so-called Medieval Warm (ca. A.D. 800–1200), Little Ice Age (ca. A.D. 1350–1860), and Maunder Minimum (mid 1600s–early 1700s) (dates from Broecker [2001] and Shindell et al. [2001]). The regional impact and exact timing of these events is hotly debated (e.g., Bond et al. 2001; Kerr 1999; Stahle and Cleaveland 1994). Although it is extremely unlikely that preindustrial humans played any role in causing such large-scale climatic changes, predators and prey throughout the food chain would have been impacted by them.

Sea-surface temperatures historically vary on a 20–30-year cycle and were rising as fish stocks declined in the late twentieth century (Greene 2002). Changes in water temperature and related marine conditions are associated with shifts in the composition of fish stocks as well as with other impacts on fishes (e.g., Attrill and Power 2002; Chavez et al. 2003). Archaeological sites undoubtedly contain some of the clues needed to resolve the ongoing debate over the timing and extent of temperature changes in near-shore marine settings.

Future research should focus on applications of geochemical techniques (e.g., Thorrold, Campana, Jones, and Swart 1997; Thorrold, Jones, and Campana 1997) to establish a chronological sequence of temperature regimes that can be correlated with trophic level, diversity, and other aspects of fishing. Such data would improve studies of the relationships among climate, ecosystems, and culture.

This paper focuses on overfishing because the method used here was proposed by Pauly and Christiansen (1995) to argue that fishes are overharvested today. Following their method and arguments, these archaeological data may be evidence of overharvesting before the twentieth century. The mean trophic level rose from 3.25 in the early sixteenth century prior to Spanish colonization to 3.31–3.41 during the First Spanish period; dropped to 2.99 during the Second Spanish period; and then rose to 3.34 at the end of the 1800s (Table 9). There were undoubtedly variations in trophic-level use during this period on shorter cycles. Some of these shifts are larger than the recent rate of .1 per decade that concerned Pauly et al. (1998). In combination with the impact we see on the size, mean age, and growth habits of Atlantic croaker and in the types of fish caught, this could signal an early impact on the estuarine-based fishery that now extends to the continental shelf.

Pauly et al. (1998) report a shift away from long-lived, high-trophic-level bottom fishes to short-lived, low-trophic-level invertebrates and planktivorous pelagic fish in response to changes in relative abundance. By using zooarchaeological data, we can expand Pauly's hypothesis to suggest that before trophic levels rise to include groupers, snappers, and mackerel, other high-trophic-level fishes, specifically sharks and mid-trophic-level fishes such as sea catfish and drums, were the primary targets of the fishery. Only when this fishery could not sustain an industrially productive rate of return was fishing effort directed toward the long-lived, high-trophic-level bottom fishes reported by Pauly. This fishery, too, may be unsustainable.

Archaeological evidence for human predation in terms of trophic levels and other variables has wide ecological significance even though the relationship is not easily demonstrated. However, the importance of this evidence requires that we try to overcome the limitations of such studies in order to contribute to the ongoing review of human

impact on marine resources. Such data need to be considered in their cultural as well as environmental context using a diverse array of approaches. In this study, species information is combined with estimates of MNI, biomass, diversity, equitability, trophic levels, and fish body size. Other combinations may also be productive. It would be unwise to adopt a single measure to characterize a complex relationship, and clearly the trophic-level approach cannot address all of the questions raised by this research.

Conclusion

Several conclusions may be drawn from these data. One of these is that fishing strategies have changed over the centuries. Fish managers should not assume that fishing prior to the twentieth century was inflexible, stable, or unchangeable. It is difficult to isolate the causes for these changes because (1) people change their technology, fish in different places at different times, and target preferred resources which may lead to overfishing; and 2) there may be changes in the marine environment independent of human activity. More work needs to be done to isolate the causes of these changes.

The twentieth-century decline in trophic level reported by Pauly et al. (1998) is not unique. For most of the time reported here, the mean vertebrate trophic level used was higher than the twentieth-century level. In the Euramerican collections, use of high-trophic-level fishes was combined with use of low-trophic-level fishes. This strategy may have led to low fish use (6–7 percent) and a sharp decline in mean trophic level similar to what occurred after 1978. This description may mean that a collapse in the estuarine and inshore fishery began in the early 1700s and that the fishery was recovering at the end of the archaeological sequence. It is more likely that fishing was being transformed into a commercial industry in deeper waters, which has now collapsed as well.

Several factors may be responsible for these changes in trophic-level use. Although the archaeological record provides no artifacts to support the assumption, it is likely that some of these changes reflect modifications in fishing technology and location perhaps in response to changes in the political environment, subsequent cultural instability,

and new economic demands. In the twentieth century, pollution, habitat alterations, and the sheer volume of fish harvested must also be considered. Another aspect that should be evaluated is the impact of climate change on the growth and maturation of fishes in the 1700s and subsequently. These alternatives are not mutually exclusive; all could result in altered ecosystems, and all should be explored further.

What the data in this paper do enable us to conclude is that today's fishery is a new subsistence strategy that is more than simply a change in technology and location. Twentieth-century fishing strategies took larger quantities of new species of fishes from new locations using new technologies. It is not possible to draw this conclusion using the modern fisheries data alone. Studies such as Pauly et al.'s (1998) are extremely important but fisheries managers need the historic depth that only archaeologists can provide (Lyman 1996). If the zooarchaeological record from the St. Augustine area is accurate, the recent decline in the world's industrial fishery has its roots in changes that began several centuries ago. It is unlikely that the trend will be reversed simply by managing current harvest quantities and schedules of marine resources.

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