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Article

Truly Long-Term Sustainability: An Archaeological Analysis of Oyster Shell

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Abstract: The simultaneous effects of today's population growth and climate change are endangering the world's vulnerable resources. Oyster reefs, which provide vital ecological services, have an estimated 85% loss from historical levels worldwide. This loss threatens the sustainability of current high-intensity industrial oyster harvesting practices. Fortunately, a deeper time perspective on oyster harvesting provides insight to policy options for sustaining the industry into the distant future. During the 19th century, Cedar Key, Florida was among the largest oyster exporters in the U.S. Two-thousand years earlier, the area was teeming with aboriginal communities that harvested oysters and collected the inedible remains in huge mounds and middens. One such site, Shell Mound, just north of Cedar Key, is a 7-m-tall, 200-m-wide shell ring that was erected in only a couple of centuries. This construction followed a period of another 2,000 years during which oysters were routinely collected and consumed in large quantities. With such large-scale harvesting over four millennia, native people employed a strategy of resiliency to sustain their maritime economies. With case material from parallel native experiences in the Chesapeake region, I illustrate how oyster harvesting was diversified to include wider catchments and less selectivity through time. While these data suggest that native shellfishers experienced downturns in local production, niche expansion and diversification enabled recovery of local oyster beds and supported, in the long-term, sustained settlement without disruption in occupation or economy. The methods employed in the Chesapeake study can be used to examine long-term oyster harvesting in the Cedar Key region, an area that is currently suffering decreasing yields due to climate change, diminished water quality, and underregulated harvesting. Although contemporary ecological studies provide short-term assessments of changes in oyster populations, an understanding of multicentury exploitation, such as what can be offered by archaeological data, is crucial for successfully creating a long-term future in sustainable oyster exploitation.

Keywords: overharvesting, oyster, archaeology, historical ecology, Chesapeake Bay

1. Introduction

Although it is too late to turn back time and undo the anthropogenic forces that have caused environmental degradation, we do have the ability to understand these forces using data from paleobiologists, historians, archaeologists, and practitioners of other disciplines. The data collected from their studies have the potential for reconstructing natural and anthropogenic causes of resource collapse over a multi-millennia time frame and will contribute to implementing new environmental policy that can take into consideration sustainability policies for the *truly* long term. In this effort, I contribute information regarding oysters from an archaeological shell midden in the Chesapeake area spanning from 500 B.C- A.D.1600, providing evidence of pre-Columbian peoples' impact on local oyster populations and their strategies for sustainability.

At present levels of exploitation, no Atlantic coastal fishery is sustainable. Policy directed at reconstructing oyster habitats is important not only for sustaining multimillion dollar commercial fishery to serve the world's growing population, but also in maintaining the balance of the aquatic ecosystem which rely on oysters to function as a keystone species, maintaining water quality, food webs, habitat creation, coastal land protection, and other essential economic, cultural, and ecological roles. Worldwide, there has been an 85 percent loss of oyster reefs, and in the Chesapeake historical ecological studies have documented as much as a 99 percent decline in oyster abundance since the early to mid-1800s [1, 2]. The co-occurrence of today's population growth and climate change exacerbate the loss of this vulnerable resource.

It is important to consider that natural environmental factors have been continuously affecting marine environments as well as the fact that humans have been affecting marine environments for over 150,000 years with the expansion of intellectually and technologically sophisticated anatomically modern humans. In North America, the Chesapeake Bay was once the largest and most productive estuary [3]. Overfishing has fundamentally altered this coastal marine ecosystem throughout history. The changes affected by overfishing contribute to larger human and environmental concerns that can be remedied by future policy. Jackson et al. [4] explain that overfishing is responsible for the majority of the 52-fold decline of oyster populations they studied in the Chesapeake Bay, with decline in water quality and disease as secondary contributing factors.

Jackson argues that by creating a historic reconstruction through paleoecological, archaeological, and historical evidence, we have the ability to know what is possible in coastal marine environments, and today's sustainability issues benefit from this deeper time perspective [3]. By limiting my data to an archaeological perspective from one site, I do not presume to imply a full understanding of all the forces at play in such a resource loss in the Chesapeake; I put forth my pilot study of archeological oyster analysis in hopes to highlight the importance of taking into account the long-term, pre-Columbian anthropogenic impact on oyster populations and glean insight into how our historic counterparts may have dealt with diminishing resources due to overharvesting.

2. Overfishing: A Truly Deep History

Kirby [5] studied the historical trajectory of the degradation and collapse of oyster fisheries by proxy of fishery records, revealing the geographically linear expansion and collapse of oyster fisheries along coastlines. Kirby hopes that the historical patterning shown in his study will provide insight to policy makers on where to concentrate their efforts to protect and revitalize vulnerable oyster reefs. Although this study reaches into a deeper history than is usually provided and contributes evidence of the impact of several centuries of destructive fishing practices, I argue that an even deeper historical perspective provided by archaeology is needed to fully grasp all of the effects of humans on oyster populations.

With oysters being a subsistence staple in the diets of coastal prehistoric people, an important food source today, and vital to the maintenance of marine ecosystems, it is critical to understand the deeply historical human-mollusk relationship and how humans have contributed to oyster reef collapse and responded to it. Recently, researchers have adopted an historical ecological approach to the issue of oyster collapse [3-5], but have dismissed the importance of pre-Columbian exploitation. Jackson [3]

argues that although there is a long history of extensive aboriginal exploitation, referencing shell middens that are one quarter of a million cubic meters in volume, the "great harvests were apparently sustainable." This statement is problematic, as it gives validity to the idea of "ecological Indians," the original conservationists, and takes for granted that pre-Columbian peoples somehow existed above the threshold of overexploitation, a historical myth that needs to be examined, not blindly accepted [6].

From pre-Columbian shell mound construction, to being one of the largest oyster exporters in the US in the 19th century, Cedar Key, Florida, has continually been subject to large-scale oyster harvesting. Early extensive exploitation began with native communities harvesting oysters and collecting the inedible remains in huge mounds and middens. Shell Mound, a 7-m-tall, 200-m-wide shell ring just north of Cedar Key, was erected in as little as a couple of centuries. After Shell Mound's construction, there followed a period of another 2,000 years during which oysters were routinely collected and consumed in large quantities [7]. It would be wrong to disregard the effects of such large-scale intensive oyster harvesting and consumption by native peoples on oyster populations. As is evidenced by the size of Shell Mound and time-frame for its construction, it is reasonable to conclude that pre-Columbian oyster exploitation was equal to or even greater than the scale of exploitation today at this site, as well as in places like the Chesapeake which I discuss below. Rather than solely focusing on the historic era, oyster collected from pre-Columbian archaeological sites provide data that transcend the particulars of century-scale time, allowing important patterns to be observed over a substantially longer period of time.

3. Archaeology and Sustainability

Primarily focusing on the world's marine resources, Erlandson and Rick [8] have lobbied for the existence of integrated approaches to historical ecology as the means to improve contemporary long-term conservation and sustainability practices. They critique the relatively "shallow" historical focus that has been the foundation for policy makers, arguing that this perspective is fundamentally flawed as it ignores the longer term forces at play including population growth and long-term intensive subsistence practices, beginning with pre-Columbian peoples, impacting aquatic resources. Jackson et al. [4] also strongly advocate the need for recognizing the importance of "retrospective records," arguing that there have been important changes to worldwide marine ecosystems for many centuries due to overfishing and the "framework for remediation and restoration is invisible without a historical perspective." Looking to the future, they argue the vulnerability and potential collapse of many more marine ecosystems that may ensue if long-term records of overfishing and ecological extinction are not consulted.

Insofar as archaeological data can provide, Erlandson and Rick [8] argue that there is archaeological evidence of varying foraging strategies employed by native coastal populations from niche expansion to diversification. It is accepted that heavy predation pressure on oysters will cause them to reduce the average size and age of local populations which can then affect their breeding capabilities: smaller and younger individuals tend to produce less offspring than larger, older individuals [8]. Also, smaller individuals yield less nutritional value. Erlandson and Rick [8] argue that the simplest way to gauge human predation pressure on oysters is to measure their average size changes through time. The simplicity in this measurement is also valuable because these measurements can be compared to wide swaths of data from various fields to construct a long and relatively continuous data set documenting change in marine ecosystems.

Bretton Kent [9] lays out some possible methodological devices, arguing that oysters respond to their environment with "subtle complexities" that can be measured and quantified. He uses oyster shell analyses techniques to discover which habitats oysters were being harvested from, the intensity of harvesting, the season of harvesting, and the methods used for harvesting and opening oysters. By employing some of Kent's methods on oyster shells from an archaeological midden and assessing the models of niche expansion and diet breadth, it is possible to gauge the influence of human predation pressure on oyster populations through time and how the local populations dealt with issues of resource depletion and overharvesting.

Rick and Lockwood [1] have coined the term conservation *archeobiology* to describe the analysis of biological remains from archaeological sites in an effort to advance conservation biology and restoration. Archaeological evidence shows that oyster was used in daily human activity including subsistence, mound construction, and tool making. The archaeological analysis of oyster shell can shed light on intricate aspects of past ecological and cultural life that has the potential to inform present day practices.

4. Case Study

4.1. History of Kiskiak

I present a case study with results of oyster shell analysis from the archaeological site, Kiskiak, in the Chesapeake. The Chesapeake region was particularly attractive for sustained settlement of pre-Columbian people as well as the seventeenth-century colonists because of the plethora of exploitable marine resources. Notable among those resources with economic value to humans is the Eastern Oyster (*Crassostrea virginica)*. This region has been home to large oyster reefs, sustaining inhabitants and allowing sedentism for centuries. Kiskiak, located on the James-York peninsula, stretched around the bluffs along the lower embayed portion of Indian Field Creek. It was home Algonquian speakers and shows up in the historical records as an important "district" in the Powhatan Chiefdom by 1607. It was also the site of many interactions, violent and non-violent, with the seventeenth-century British colonists from James Fort [10].

A. B.

Figure 1. (a) John Smith's A Map of Virginia 1608: With a Description of the Countrey, the Commodities, People, Government and Religion. Jamestown circled in red and Kiskiak circled in blue. **(b)** Close up view of the village of Kiskiak from John Smith's map of Virginia.

A. B.

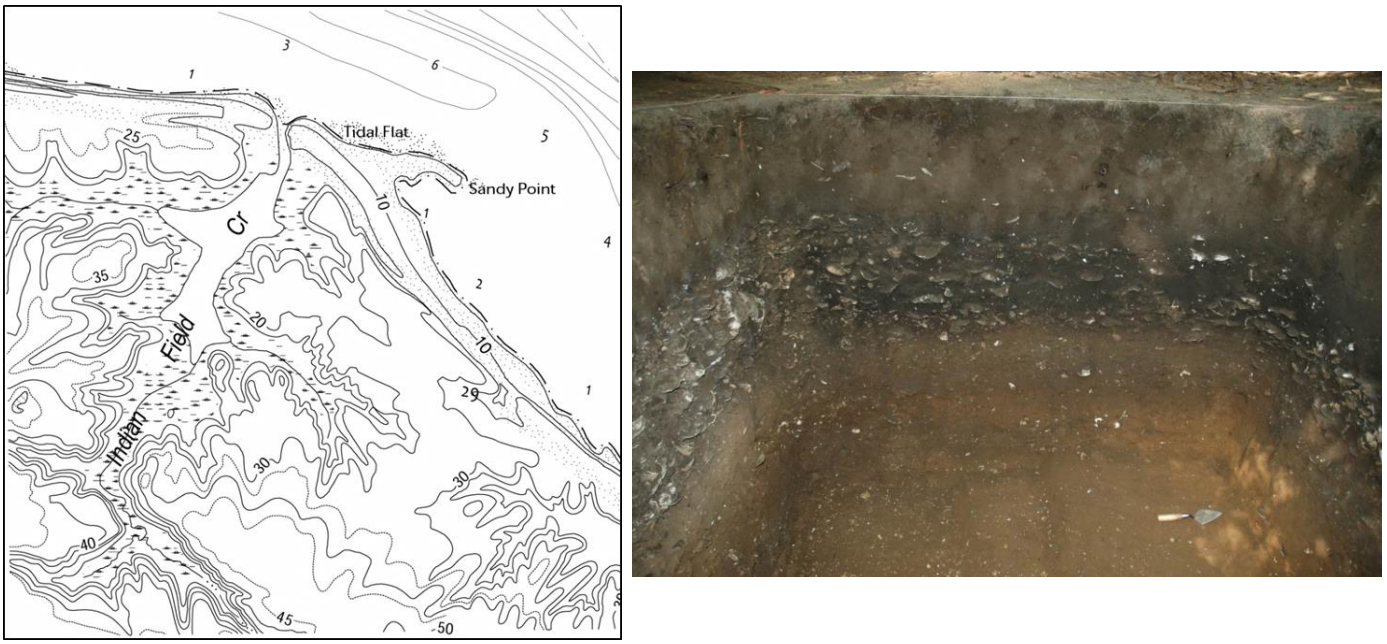

Figure 2. (a) Topographic map of Indian Field Creek with Kiskiak being located on the bluffs surrounding the lower embayed area of the creek. **(b)** View of excavated midden test unit from which the oyster shells for this study were collected (photo courtesy of Martin Gallivan).

The archaeological site is generally well preserved and contains intact midden deposits, house patterns, and ditch enclosures. Midden deposits associated with 3,000 years of settlement extend more than two meters below the surface. The oyster shell recovered for this study is from a two-by-two meter test unit in a deeply stratified midden on the east bank of Indian Field Creek near its mouth. The midden, which extends 50 by 25 meters in plan, contained a charcoal-rich, black, sandy-silt layer with terrestrial faunal remains, Native artifacts, and in certain levels, more oyster and clam shell than dirt [10].

The temporal periods examined in this study include the Middle Woodland (500 B.C.-A.D. 900), Late Woodland I (A.D. 900-1200), and Late Woodland II (A.D. 1200-1500). This time sequence is punctuated by two important events: the introduction of maize-beans-squash horticulture circa A.D. 1000 [11] and the rise of Kiskiak as a regional political center After A.D. 1200 [10]. Both of these events facilitated increased sedentism with the establishment of permanent base camps, and as population increased, the settlement of villages and towns at Kiskiak within broad social networks [10].

4.2 Methods

The results of this pilot study based on methods devised by Kent [9] show strong patterning over the long-term occupation of the site, possibly indicating a shift away from oyster harvesting with the incorporation of horticultural practices during the Late Woodland period. I evaluated a total of 1,552 intact, left oyster shells from level the upper 10-cm level of each strata in a midden test unit. This analysis includes two components: shellfish harvesting intensity and the type of oyster being harvested.

A.

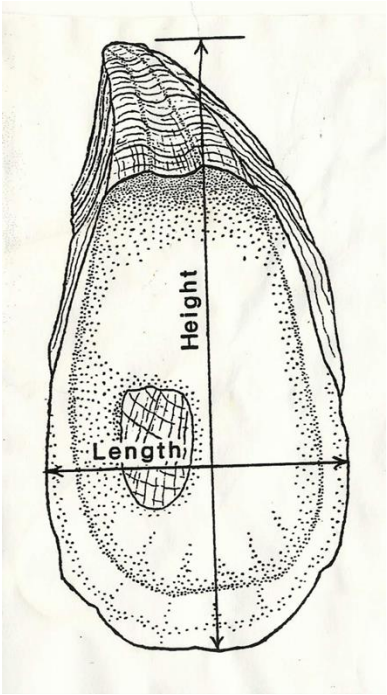

Figure 3. (a) Shellfish harvesting intensity: To determine the impact of human predation pressure, I evaluated the intensity of oyster harvesting by recording the shell height (the distance from the dorsal edge to the ventral edge). If the mean height of the oysters in a sample decreases significantly, then it is fair to assume that the intensity of the harvesting has increased, as intensive harvesting decreases the average size and age of individuals [9].

A.

	Sand	Bed	Channel	Reef
HLR	1.3mm	1.3-2mm	>2mm	>2mm
Other Attributes	-well developed radial ribs -firmly packed coarse sand in intertidal or shallow water	-mixed muddy sand -found singly or in loose clusters	-large -found in deeper waters in soft mud	-found in densely clustered reefs -usually have radial ribs

Table 1. (a) Type of oyster being harvested. The height-to-length ratio (HLR) indicates what type of oyster is being harvested: sand, bed, channel, or reef. To determine the HLR, I divided the height of the oyster by its width (the distance from the anterior edge to the posterior edge).

4.3 Results and Interpretation

The transition from Middle to Late Woodland I periods (AD 500-900) show a marked increase in artifact frequency in the midden, including the largest number of flaked stone and fire-cracked rock and the greatest density of ceramics [10]. A comparison the mean height of oyster shells from Kiskiak during this transition, shows an increase in height during the Late Woodland I period (Middle Woodland=61.22mm, Late Woodland I=67.14mm). The smaller size of oysters in the Middle Woodland period reduces the economic value of the oyster, ushering in the need for supplementary reliable food sources, and thus the need for agriculture. The transition from the Middle Woodland period to the Late Woodland I period marks the increase in average size of oysters, indicating less reliance on them as the main food source, allowing more time for growth and maturation which coincides with the introduction of maize-bean-squash horticulture.

The transition from the Middle to Late Woodland I period also shows an increase in the use of channel oysters from representing 1.49 percent of the total type of oyster being harvested in the Middle Woodland period to 3.81percent in the Late Woodland I period. Although these numbers are both relatively low compared to sand (Middle Woodland=32.84 percent, Late Woodland I=20.24 percent, Late Woodland II=20 percent) and bed oysters (Middle Woodland=65.67 percent, Late Woodland I=75.95 percent, Late Woodland II=78.75 percent), which remained the dominant type of oyster being exploited in all three periods, it speaks to increased niche width during a time of diminished resources to include oysters that are more challenging to gather. Bed and sand oysters are relatively easy to collect as they both are found in shallow waters, whereas channel can be obtained only by diving into deeper waters [9]. The spike during the Late Woodland I period shows that the people at Kiskiak were expending more energy or traveling further to gather channel oysters during this period. Instead of relocating due to diminishing resources, the people at Kiskiak employed a strategy of resilience to sustain their needs by diversifying their diet, adopting maize-beans-squash horticulture, reducing the reliance on oysters as a main food source, and expanding niche width to include channel oysters when their first-choice was producing less economic value.

Between the Late Woodland I and Late Woodland II periods there is a 17.8 percent (11.95mm) decrease in the average size of oysters (Late Woodland I=67.14mm, Late Woodland II=55.19mm), further demonstrating the anthropogenic forces on oyster populations. The beginning of the Late Woodland II period marks the emergence of Kiskiak as a regional political center and important site in the Powhatan chiefdom. The decrease in average oyster size speaks to higher rates of exploitation as Kiskiak's population increased.

5. Conclusion and Future Research

This oyster shell analysis can be used in a comparative way across time and space to be able to show the impact of humans on marine environments as early as 500 BC. The general patterning in this study shows how Kiskiak's residents' oyster exploitation practices shifted with changes in subsistence and demography. Furthermore, these pre-Columbian peoples' exploitation had a more than negligible effect on local oyster populations. This analysis of the exploitation of oysters as a food resource will also add a critical chapter in the history of Kiskiak by providing evidence concerning how hunter-gatherers at Kiskiak were resilient in their subsistence strategies over time to sustain their oyster consumption practices. From this study we can see how less reliance on oyster allows time for the reefs to revitalize. This idea can inform policy in so much as implementing restrictions around harvesting practices before completely collapsing the reefs, sustaining the availability of the resource.

Rick and Lockwood [1] have also used the eastern oyster fishery of the Chesapeake Bay as a case study in evaluating the utility of historical ecological data in future conservation and sustainable policies. Although their results were fruitful, they acknowledged the limitation of current data for understanding long-term changes and the lack of a methodologically transferable interdisciplinary approach. The pilot study offered here produces interpretable results considering anthropogenic effects on oyster populations, but also suffers from the same limitations, providing a strictly anthropological and archaeological perspective. To fully understand the complexity of human-mollusk relations, a

deeper ecological understanding is necessary of the specific processes of the oyster itself as well as environmental factors such as sea-level rise and climate change, potentially contributing to changes in oyster biology over time. In the future I endeavor to take on such a challenge at Shell Mound near Cedar Key, Florida which is discussed above. In this study I intend to inform sustainable policy options in the area using oyster data from the archaeological site as well as incorporating data from across disciplines to more completely understand the truly long term anthropogenic and environmental forces at play.

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Conflict of Interest

The author declares no conflict of interest.

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