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Methods for inferring oyster mariculture on Florida's Gulf Coast

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ABSTRACT

Archaeologists and historians have demonstrated that marine resource management, or mariculture, has been practiced by coastal peoples worldwide for thousands of years. Typically evidence for these practices is in the form of ethnohistoric accounts or associated infrastructure (e.g. clam gardens). This paper presents methods for inferring oyster mariculture by using proxy evidence from attributes of the shell itself. The methods are applied to archaeological shell from a Woodland Period site on Florida's Gulf Coast, where it appears that two techniques of mariculture, shelling and culling, were practiced during a period of intensive large-scale and sustained harvesting.

1. Introduction

Recent archaeological literature on shellfish has addressed how past peoples actively managed marine resources, specifically at sites along the Northwest Coast of North America. Examples of ancient marine management of economically important shellfish include size and age selection of clams (Cannon and Burchell, 2009), selective harvesting of mussels (Whitaker, 2008), and the construction of clam gardens (Lepofsky et al., 2015). Archaeological evidence of traditional marine management systems in place on the Northwest Coast is supported by ethnohistoric accounts that describe a variety of maricultural traditions among indigenous coastal people of the recent past (Brown and Brown, 2009; Lepofsky and Caldwell, 2012). While the Northwest Coast has been the focus of this new research, there is evidence of ancient mariculture and aquaculture worldwide.

Evidence for ancient shellfish management becomes more elusive in areas lacking both infrastructure (e.g. intact clam gardens) and ethnohistoric accounts of shellfishing practices. In the absence of such evidence shellfish mariculture must be inferred from outcomes to archaeological shell, including attributes of the shell itself, as well as the context in which shell is deposited. I argue that methods for determining maricultural practices involving shellfish, especially in areas where ethnohistoric accounts of mariculture are absent, can include, but also go beyond, measurements of size, as uniform size in deposits may be an outcome of other phenomena such as spawning and growth patterns or preference for a particular size of shellfish.

Presented in this paper are methods for inferring the maricultural practice of culling from patterned variation in the condition of shell as it is affected by cluster growth and parasitic infection. Coupled with nonrandom variation in the ratio of left and right valves—a proxy for a maricultural practice known as "shelling"—oyster shells expressing evidence for culling covary positively with intensity of harvesting as expressed in rapid accumulations of archaeological shell. The methods presented here are informed by ecological and biological literature, personal experience with researchers and oystermen practicing mariculture, as well as modern and archaeological literature describing marine management practices (see Jenkins, 2016 for review of this literature). These methods are applied to oysters excavated from Shell Mound (8LV42), a Woodland period site on Florida's northern Gulf Coast, where as many as 1.2 billion oysters were deposited in about 150 years. The results of this study indicate that the inhabitants of Shell Mound were likely employing maricultural methods when the scale and intensity of oyster harvesting were at their peak.

2. Mariculture

Mariculture, as defined by National Oceanic and Atmospheric Administration (2016), is a branch of aquaculture in which marine organisms, often shellfish, are manipulated by humans to sustain or enhance production primarily for food. When applying the term mariculture to ancient populations, I argue that the

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definition should be expanded to acknowledge manipulating marine shellfish for purposes aside from simply subsistence to include any intensive use of shell, such as mound building or tool making, which would necessitate a reliable resource pool. Furthermore, I suggest that the term mariculture should be limited to purposeful and deliberate futures planning, as opposed to potentially opportunistic harvesting techniques that have the unintended consequence of sustained production.

Shellfish mariculture today in North America includes restoration projects, habitat enhancement, harvesting restrictions, and oyster farming. Along the Atlantic coast, maricultural endeavors range from multi-million dollar restoration efforts involving the collaboration of state and federal agencies and NGOs to community-based and volunteer projects (ASMFC, 2007). Examples include spawner sanctuaries for hard clams in New York and oyster reef restoration projects in North Carolina, Virginia, Florida, and Maryland (ASMFC, 2007). Similar techniques are being applied to shellfish along the Gulf Coast with oyster reef restoration through cultching, or returning dead shell to extant reefs, in Apalachicola Bay (Camp et al., 2015; Pine et al., 2015) and water leases for the cultivation of clams and oysters in Cedar Key (Colson and Sturmer, 2000). Other maricultural methods used today include the closure of shellfish beds and reefs, legal harvest-size laws and culling of oysters so that dead shell is returned to reefs as substrate and spat, or baby shellfish, are returned to the water to grow as singles.

Maricultural practices today have a long history behind them. People all over the world have been practicing different forms of shellfish mariculture and aquaculture for thousands of years. On the Northwest Coast "harvesting rules" were in place beginning at least 2000 years ago (Grier, 2014; Lepofsky and Caldwell, 2012) and clam gardens were constructed to enhance and protect clam populations (Lepofsky et al., 2015). At the same time, Romans depicted maricultural practices on vases, with drawings of hanging techniques used to grow oysters, a practice which is still used today on Italy's coast (Gunther, 1897). Also, researchers have evidence of management through pest control and size selection of oysters at northern Pacific coastal Neolithic and Early Iron Age sites (Rakov and Brodianski, 2007, 2010).

Despite the body of literature on ancient marine management at sites where shellfish were heavily exploited, there has been no investigation into shellfish management along the Atlantic and Gulf coasts of North America, where massive oyster shell mounds and middens abound. Without intact infrastructure for mariculture or ethnohistoric accounts of maricultural practices, methods for determining oyster mariculture must rely on proxy evidence from the archaeological shell itself as well as the contexts from which shell is excavated.

3. Relevant aspects of oyster biology and ecology

The Eastern Oyster, *Crassostrea virginica*, from here on referred to simply as oysters, are sessile bivalves with an upper, flat valve and a lower, cupped valve (Kennedy, 1996). This species of oyster is found in estuarine environments along the Atlantic and Gulf Coasts of North America. While water temperature and salinity are instrumental to the success of oyster populations, the type and availability of suitable substrate and bottom conditions are also important factors. Oysters are gregarious, meaning that, while they are larvae, their settlement preference for attachment is their own species, creating aggregations of conspecifics in the form of oyster beds or reefs (Kennedy, 1996). Oyster reefs, composed of both live and dead oysters, tend to form in estuarine environments where oysters have already settled on muddy sand bottoms with a scattering of hard substrates, and where ecological conditions are favorable.

Oysters are often called resilient, as they can withstand a wide range of environmental conditions which influence shell morphology (Supan, 2002). The most important environmental conditions for oyster growth and reproductive success are temperature (Gunter, 1957; Shumway, 1996), salinity (Butler, 1949; Shumway, 1996), substrate (Camp et al., 2015; Kennedy, 1996), and location in the water column (subtidal versus intertidal) (Hopkins, 1957; Lawrence, 1988). These varying environmental conditions affect oysters' shells. For example, shell size and shape are influenced by the location in the water column, shell thickness changes based on salinity, and attachment scars replicate the substrate on which oysters attach and grow (Lawrence, 1988).

Subtidal oysters, those that consistently remain underwater, differ from intertidal oysters, those that are exposed at low tide, in both morphology and quality (Lawrence, 1988). Intertidal oysters grow in tight clumps or burrs, causing their shells to be relatively small, thin, and elongate. Intertidal oysters have refuge from many marine predators and parasites that can only withstand subtidal conditions, although they are typically considered to have poorer meat quality as the organism's energy is more rapidly expended as they are exposed at low tide. In contrast, subtidal oysters often have ovate to subovate shell outlines with thicker shells, and are larger with increased valve cupping. Subtidal oysters are subject to predation and parasitism from subtidal organisms, especially in high salinity waters (Shumway, 1996).

One of the most telling bioindicators of subtidal habitat is the presence of parasitic bore holes on oyster shell. The three most common types of boring predators or parasites that are visible on shell are from the boring sponge, *Cliona*, *Polydora* worms, and the boring clam, *Diplothyhra* (Camp et al., 2015; Kent, 1988). Of these three boring organisms, the presence of holes from the boring sponge relays the most useful information about the environmental conditions of the oyster.

Boring sponges are parasites which attach to and burrow into oyster shells, leaving cylindrical holes on the shell that are easily observed (Hopkins, 1957). Boring sponges can survive in only high-salinity (above 15 parts per thousand), subtidal conditions; therefore, any oyster shell with evidence of sponge parasitism can be assumed to have lived primarily in high-salinity, subtidal areas (deLaubenfels, 1947). Boring sponges do not actually eat the oyster, rather they use the oyster shell as an anchor, chemically etching out the shell, potentially as a means to protect themselves from fluctuating salinity in estuarine environments (deLaubenfels, 1947).

4. Methods: detecting mariculture using oyster shells

There are several attributes of archaeological shell that can serve as proxy data for determining anthropogenic influence on oyster populations. For example, archaeologists use oyster valve height, the longest measurement of the oyster shell, as a measure of overharvesting or resource depression (Erlandson et al., 2008; Kent, 1988; Lightfoot et al., 1993; Savarese et al., 2016). Also, resource niches where past people harvested oysters from, primarily subtidal or intertidal, can be determined by height, height-to-length ratio (HLR), and presence or absence of sponge parasitism (Lawrence, 1988). Similarly, proxies for oyster mariculture are drawn from metric and non-metric observations made of archaeological oyster shell. There is a range of maricultural practices that may have been practiced in the past, two of which, shelling and culling, I have archaeological evidence for and will be the focus of this study.

4.1. Shelling

Shelling, or cultching, is a form of mariculture where dead