COMMENTARY

Ancient aquaculture and the rise of social complexity

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The abilities of humans to produce and store food have been key components in theories that explain how and why societies flourished and developed complex socioeconomic systems over time. Archaeological evidence shows that the transition from hunting/gathering/foraging to the purposeful cultivation of plants and domestication of animals was an important turning point for humans on a global scale. These processes led to significant changes in how societies organized labor, managed resources, and affected environments. There has been increased recognition, however, that large population densities and the rise of social complexity would not have necessarily required agriculture, as Thompson et al. (1) demonstrate in their PNAS paper on the Calusa polity in southwest Florida. In some coastal areas here and elsewhere, peoples focused instead on mass harvesting and live storage of marine species to build surpluses and fuel economic specialization.

In the not-so-distant past, scholars argued that coastal regions were unattractive places for humans to live compared to interior regions with abundant floral and faunal resources (2). These were big game-centric models that privileged men as hunters, with the seacoast envisaged as being resource poor, patchy, and generally insufficient for larger human populations to live. Decades of archaeological research have now changed this perspective, with many acknowledging that marine foods were often more nutritious, plentiful, and easier to procure than once believed (3–6).

As part of living in these environments, peoples who settled islands and coastal regions around the world developed sophisticated technologies for fishing, hunting animals (e.g., whales, pinnipeds, birds), and storing foodstuffs. They were so successful, in fact, that populations grew considerably and expanded into some of the most remote places on Earth such as Hawaii, Easter Island, and New Zealand. Many of these and other maritime-oriented cultures developed in very complex ways (7, 8) with notable examples in the Americas, particularly the Chumash of the California Channel Islands (9) and indigenous cultures of the Pacific Northwest coast (10). However, it is a curious phenomenon when we see island and coastal peoples living in dense populations and following similar trajectories, but doing so without land-based, domesticated plants and animals as their primary food sources.

Marine Resource Use through Time

Human use of marine resources and occupation in and around coastal environments has been continually pushed back deeper in time. Pinnacle Point in South Africa contains solid evidence for shellfish harvesting at about 164,000 years ago (11), and there are a growing number of sites in the Americas that contain evidence for the exploitation of marine foods shortly after human arrival (2, 9). The incorporation of mollusks and fish into human diets was particularly pivotal, as it opened a new array of dependable foods that were highly nutritious and could be captured with relatively simple maritime technologies. Later, these technologies became increasingly sophisticated and included hook-and-line fishing, harpoons, poisons, kites, traps, and many other ingenious techniques. Some of the most widespread and elaborate forms of fish capture are seen in the Indo-Pacific in which artificially constructed stone ponds were situated along coastlines to take advantage of tidal flux that trapped fish behind impermeable structures (Fig. 1). They provided a consistent source of food that did not require preservation, which is a concern for peoples living in tropical environments, particularly when salt is not available. Like in Hawaii, however, these societies also had an arsenal of domesticates at their disposal on which they could rely—taro, sweet potato, chickens, and pigs, to name a few. That so few groups like the Calusa in Florida excluded cultivated plants (such as maize) from their diets when they were possibly (or probably) available, and instead exerted energy to craft a lifestyle focused instead on the capture and storage of marine resources, is remarkable.

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Fig. 1. Examples of fish-capturing structures used in the Pacific. (*A*–*C*) Nananu-I-Ra, Fiji. These structures are known as "moka" and are tidally dependent and opportunistic in the biota they catch. (*D*) Fishing weirs in Maeva, Huahine, French Polynesia, which are part of a community collective that serve to both catch fish and hold them. (*E*) He'eia, O'ahu, Hawai'i. A good example of the technological complexity of a large Hawaiian fishpond that focuses on its "makaha," or unique gating system. (*F*) The Apua fishpond located at Kualoa on O'ahu, Hawai'i. An example of a very simple Hawaiian style of pond known as a "Loko Wai." Image credit: Damion Sailors (University of Oregon, Eugene, OR).

Aquaculture Construction and Management

As Thompson et al. (1) note, the Calusa were a vibrant and politically complex, but nonagricultural, society that flourished across a vast swath of southwest Florida at the time of European contact. Members of their ruling elite were centered at the Mound Key site, itself an artificially constructed island made from sequential deposits of shell and soil, from which they controlled a population estimated to be around 20,000. These elites were also responsible for overseeing the production and distribution of various resources. Given their propensity for exploiting marine environments and building shell mound features, but not growing maize (which was prevalent in the southeast United States at the time), the end result was the construction of canals and walled structures called "watercourts" that were used to capture fish and provide live storage. How were these built and managed by the Calusa, especially given the intricate nature of tidal processes, estuarine systems, and fish behavior?

Thompson et al. (1) used both passive and active archaeological investigations to help answer these questions. To determine the overall size and shape of the watercourts, Thompson et al. (1) used light detection and ranging, which can see through vegetation and map topography with extreme precision. The West Court enclosure was 50 × 75 m and an astounding 3,350 m^2 in area, while the East Court was 42 × 70 m and 2,670 m^2 in area. To put this in perspective, the total area of these two large watercourts (6,020 m^2) is roughly the size of 14 basketball courts and bigger than a football field. These were supplemented with smaller watercourts that may have been interconnected.

These walled enclosures were connected to the sea by canals. The "Grand Canal" that links the West and East Courts through openings on their northern sides measures 10 × 12 m in size, providing ample room for boats to maneuver and fish to survive until harvesting. Access was likely directed through the use of gates made from organic materials such as wood that have not preserved. A combination of ground-penetrating radar and coring of sediments in and around the watercourts revealed stratigraphic deposits showing that there was a shell midden prior to construction and that sequential deposits had built up over time.

Some of these appear to have been the result of erosion and maintenance through dredging and other activities, which would have been required to ensure that canoes could access the features. Darker, organic-rich mud show that water circulation was poor (and thus enclosed), thereby confirming that this area was not representative of natural deposits, but the result of artificial construction.

A series of excavation units also provide complementary evidence for how these structures and associated features were built over time. Preserved wood chips and cordage along with small post holes point to a number of activities taking place related to fish capture and subsistence, including canoe building, fish net manufacturing (perhaps one of the preferred means for collecting fish caught in the watercourts), and smoking or drying racks. Radiocarbon dates from this single, interconnected hydrologic system shows that the Grand Canal was constructed first between AD 885 and 1095, with midden deposits forming along the shoreline of Mound Key shortly thereafter, AD 1025 to 1155; the beginning of watercourt use came between circa AD 1000 and 1400.

Given the diversity of fish found along the southwest coast of Florida, what species were captured, and were any of these preferred? Analysis of vertebrate remains from cores in the West Court indicate a high propensity for mullet with minor contributions of others such as herring and pinfish, which are well known from nearby archaeological sites. The high density of fish remains here (in this case, scales), compared to almost none found in cores away from the site in the estuary, further support the notion that these watercourts were intended for fish capture and storage. This was also tested hydrologically (i.e., would these structures have been suitable reservoirs during different tidal regimes?). Estimates of water height at different tide levels demonstrate that these artificial basins would have been effective at not only holding sufficient amounts of water to maintain live fish, but that the Calusa likely built and continued to maintain them with daily and seasonal changes taken into account.

Aquaculture Taken to the Next Level

While marine resources were a fundamental part of subsistence for coastal peoples in the Americas, the use of mariculture is virtually unknown. Recently reported clam gardening by First Nations peoples at four locations along the coast of British Columbia (12) and watercourts reported here by Thompson et al. (1, 13) at the site of Mound Key in southwest Florida greatly add to our understanding of how coastally focused peoples in the past exploited and modified their environments to feed growing populations. The amount of labor and time required to construct these kinds of structures and maintain them was probably significant, as was monitoring their storage efficacy. This exemplary case of fish capture and storage—that may have also been used to house other kinds of animals such as shellfish—provided a much-needed way for the Calusa to ensure food security and maintain stability.

This interesting case of aquaculture—the scale of which is quite extraordinary—is even more so when one considers that agriculture was nowhere to be found. This places Mound Key and its fish-capturing strategies in a unique position among complex societies and challenges the perceived trajectories that human societies must take to achieve certain milestones. The complexity inherent within the Calusa—documented through multiple lines of archaeological and environmental evidence—clearly shows that scholars have continued to underestimate the adaptive abilities of coastal peoples worldwide. The engineering prowess and hydrological knowledge demonstrated by the Calusa show that there are multiple ways that complexity can be structured or defined and that large-scale plant cultivation is not necessarily a requirement.

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