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The Archaeology of Aquatic Adaptations: Paradigms for a New Millennium

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Although aquatic resources are often seen as central to the development of post-Pleistocene cultural complexity, most models of human evolution have all but ignored the role of aquatic or maritime adaptations during the earlier stages of human history. When did aquatic resources, maritime adaptations, and seafaring first play a significant role in human evolution? I explore this fundamental question by (1) reviewing various theories on the subject; (2) discussing a variety of problems that prevent archaeologists from providing a clear answer; and (3) examining the archaeological record for evidence of early aquatic resource use or seafaring. I conclude that aquatic resources, wherever they were both abundant and relatively accessible, have probably always been used opportunistically by our ancestors. Evidence suggests, however, that aquatic and maritime adaptations (including seafaring) played a significantly greater role in the demographic and geographic expansion of anatomically modern humans after about 150,000 years ago. Another significant expansion occurred somewhat later in time, with the development of more sophisticated seafaring, fishing, and marine hunting technologies.

KEY WORDS: aquatic resources; human evolution; maritime societies; coastlines; boats.

INTRODUCTION

> The average molluscan flesh is certainly not very appealing in appearance and the earliest humans apparently existed for uncounted millennia before that anonymous hero ate the first oyster. In any event, shell middens of real antiquity are rare or absent in world archaeology (Meighan, 1969, p. 417).

Central to the success of our species—measured by our wide geographical range and astounding population growth—is the combination of human

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intelligence, adaptive flexibility, and technological sophistication. In a broad historical or evolutionary framework, humans are the ultimate in generalists and opportunists, omnivores who thrived in the widest range of earthly environments, both natural and cultural. On a planet whose surface is almost 75% water, where life itself is dependent on water to survive, and where our ancestors have successfully adapted for at least 2.5 million years, it has always seemed strange to me that modern anthropological theory has maintained that aquatic resources and habitats were not systematically used by humans until relatively recently (e.g., Binford, 1968; Cohen, 1977; Osborn, 1977a,b; Waselkov, 1987; Washburn and Lancaster, 1968; Yesner, 1987). As Bass (1972, p. 9) noted "even our land masses are crossed and broken by rivers and streams or dotted with lakes." Yet among the 10 major habitats listed by Gamble (1994, pp. 10–11, 1998) as significant to our early ancestors as they spread around the earth, coastlines, lakeshores, and other aquatic habitats are nowhere to be found.

As Washburn and Lancaster (1968, p. 294) argued more than 30 years ago, many archaeologists still seem to believe that

> During most of human history, water must have been a major physical and psychological barrier and the inability to cope with water is shown in the archaeological record by the absence of remains of fish, shellfish, or any object that required going deeply into water or using boats. There is no evidence that resources of river and sea were utilized until this late pre-agricultural period . . . for early man, water was a barrier and a danger, not a resource.

More recently, Yesner (1987, p. 285) stated categorically that the "historical fact that maritime resources were not exploited until relatively late in the prehistoric record has attracted a general consensus. . . . A real commitment to maritime lifeways did not precede late Upper Paleolithic times."

If such statements are accurate, how did hominids spread around the globe, colonizing much of Africa and Eurasia by at least a million years ago, without the aid of floats, boats, or the capability to cross sizable bodies of water? How did they survive in such a wide range of landscapes when aquatic habitats were such a physical and psychological impediment? Why would our omnivorous hominid ancestors—problem solvers and keen observers of the world around them—ignore aquatic resources when hundreds of highly visible nonhuman predators and omnivores do not? Why is there so little archaeological evidence for the use of marine resources until postglacial times, long after the well-documented maritime colonization of island Southeast Asia and greater Australia? Is it really possible that aquatic resources were virtually ignored for more than 99% of human history?

I believe the general perception that humans only began to seriously adapt to aquatic environments during the last 15,000 years or so has had a stultifying effect on the evolutionary study of aquatic adaptations and societies, maritime migrations, and the development of boats and other seafaring technologies. Such perceptions peripheralize the significance of aquatic habitats in human evolution, relegating them to an essentially incidental role in the broad-spectrum revolution leading to agricultural societies and civilizations. Thus maritime adaptations appear to play a marginal role in a relatively brief process during which the human developmental trajectory departed from its natural course as population growth forced humans into increasingly artificial modes of subsistence and production.

As Yesner (1987) noted, however, the picture of aquatic resources as marginal foods of "last resort" is out of step with historical and archaeological data that suggest that maritime or aquatic hunter-gatherers were generally more sedentary, populous, and culturally complex than their terrestrially based interior neighbors (Birdsell, 1953; McCartney, 1975; Palsson, 1988; Townsend, 1980). Indeed, some of the most complex and artistically acomplished hunter-gatherers of all time developed in rich marine environments, including many North Pacific peoples (the Tlingit, Haida, Aleut, Koniag, etc.) who lived adjacent to terrestrial environments relatively unproductive for human subsistence. Thus, while aquatic resources supported some of the most complex and populous hunter-gatherer cultures on earth, archaeological evidence for the antiquity of aquatic resource use was extremely limited. This results in a fundamental paradox, where supposedly marginal aquatic resources (although often both diverse and abundant) appear to provide the economic foundation for relatively complex societies characterized by high populations and elaborated material cultures. Despite some notable attempts to account for problematic aspects of such models (e.g., Osborn, 1977b; Yesner, 1987), this aquatic paradox has yet to be adequately explained or resolved.

In this paper, I discuss some of these questions and problems by examining the nature and antiquity of aquatic adaptations. In the process, I address some of the broader implications for our understanding of human migrations, the evolution of human subsistence and technology, and current models of optimal foraging theory, human economic intensification, and the broad spectrum revolution. I begin with a short summary of historical thought about the archaeology of aquatic adaptations, then discuss some epistemological, methodological, and taphonomic problems that currently prevent any real consensus from being reached about the antiquity of aquatic adaptations. I then review the archaeological data available on early aquatic resource use and maritime migrations before discussing the broader implications and some approaches I see as potentially fruitful for the study of maritime and aquatic adaptations as we embark on our voyage into the twenty-first century.

A BRIEF HISTORY OF THOUGHT

The study of coastal and other aquatic societies has a long history in anthropology and archaeology, one that closely reflects the general development of the two fields. Despite this long history, recent decades have seen a lively debate about the nature of aquatic environments, their economic productivity for human societies, and the role they have played in human evolution (e.g., Bailey, 1975, 1978; Binford, 1968; Claassen, 1991, 1998; Erlandson, 1988, 1994; Fischer, 1995a; Glassow and Wilcoxon, 1988; Isaac, 1971; Jones, 1991; Moseley, 1975; Osborn, 1977a; Parmalee and Klippel, 1974; Perlman, 1980; Price, 1995; Quilter and Stocker, 1983; Raymond, 1981; Sauer, 1962; Waselkov, 1987; Washburn and Lancaster, 1968; Wilson, 1981; Yesner, 1980, 1987). Prior to the development of the "New Archaeology" of the 1960s and 1970s, however, there was little or no coherent body of theory on the broader evolution of aquatic adaptations. The opinions expressed on such matters were generally linked to regional discussions and varied widely (see Clark, 1936, p. 140; Morgan, 1877; Uhle, 1907). Nonetheless, as Clark (1936) and many others documented the close association of abundant and widespread shell mounds with postglacial shorelines, the development of shell middens and relatively intensive aquatic economies gradually came to symbolize an important component of the post-Pleistocene broad spectrum revolution (see Bailey, 1978; Binford, 1968). As an emphasis on theory, method, and broad synthesis came into vogue in the 1960s and 1970s, moreover, considerable interest focused on more global approaches to the nature and antiquity of human adaptations to aquatic environments.

In 1994, largely for heuristic purposes, I characterized the more polarized viewpoints in this debate as "Garden of Eden" versus "Gates of Hell" models (Erlandson, 1994, p. 273). Garden of Eden theorists, I suggested, saw coastal or aquatic habitats as veritable cornucopia where a diverse array of foods—essentially inexhaustible and easily harvested—was available (e.g., Cutting, 1962; Fischer, 1995a; Hewes, 1968; Morgan, 1877, p. 21; Okladnikov, 1965, pp. 114–115; Sauer, 1962). On a global level, such assertions may best be illustrated by Sauer's description of the role of the sea in human evolution.

> . . . the path of our evolution turned aside from the common primate course by going to the sea. No other setting is as attractive for the beginnings of humanity. The sea, in particular the tidal shore, presented the best opportunity to eat, settle, increase, and learn. It afforded diversity and abundance of provisions, continuous and inexhaustible. It gave the congenial ecologic niche in which animal ethology could become human culture (Sauer, 1962, p. 45).

Similar statements linked to specific ethnographic accounts for some coastal groups or to regional archaeological sequences limited to the last 5,000 years were espoused by a number of authors. Such glowing assessments often ignored the fact, however, that archaeological records for the same regions showed little evidence for such aquatic largesse dating back more than a few millennia. On a global level, moreover, the accumulation of archaeological data and the development of chronometric dating techniques made such statements increasingly problematic. If aquatic resources were so productive, why was there relatively little evidence in the archaeological record for their exploitation until very late in human prehistory?

After the 1960s, following the lead of Uhle (1907) and others, a number of scholars explicitly asserted that aquatic habitats and resources, when compared to the hunting of large terrestrial game, were relatively unproductive for human exploitation (e.g., Bailey, 1978; Cohen, 1977; Gamble, 1986, pp. 35–36; Hogg *et al.*, 1971; Osborn, 1977a). These Gates of Hell models articulated nicely with the prevailing view of the time that, prior to the development of agriculture, male-dominated big-game hunting was the driving force in human physical, cultural, and technological evolution. Shellfish and other aquatic foods, generally viewed in such models as marginal or even starvation foods, were portrayed as small and costly to harvest or process, poor sources of nutrition, relatively unpredictable or unreliable, or requiring high technological investments (boats, etc.) to access. The fact that collecting shellfish and other small aquatic foods was primarily women's work in most ethnographic societies further marginalized their importance in human economies (Claassen, 1998, p. 175). Gates of Hell models proposed, therefore, that the archaeological record accurately reflected the low productivity of aquatic resources and the relatively low value placed on them by many foraging peoples. They argue that humans did not systematically or intensively harvest aquatic resources until the productivity of terrestrial hunting had been reduced by the intensive harvest pressure of growing human populations or by the postglacial extinction of the Pleistocene megafauna. Thus the use of aquatic resources was (and is) often assumed to be evidence for population pressure and environmental degradation. Osborn, the most ardent advocate of this position, argued that our ancestors "ignored" shellfish and other aquatic resources for 99% of human history (Osborn, 1977b, p. 301) and that the low productivity of marine resources was virtually universal.

> . . . marine resources are low-return subsistence resources due to a need for labor intensification, in the case of shellfish and small food package-sized organisms, and due to their low protein content. A number of factors combine to create an evolutionary threshold that is too costly for human populations to cross unless they are experiencing density-dependent selection. This subsistence-related threshold is so costly to cross, in fact, that, given the option, we should expect to see human groups shift away from the exploitation of the sea, at least in nonindustrial societies, whenever possible (Osborn, 1977a, p. 177).

In practice, relatively few published opinions can easily be categorized into such polarized schemes, and most scholars generally recognize that the situation is considerably more complex. Nonetheless, something closer to the Gates of Hell model has heavily influenced the work of some of the most influential scholars who have worked with or discussed coastal or other aquatic archaeological sequences (e.g., Bailey, 1975; Binford, 1968; Cohen, 1977; Fagan, 2001; Gamble, 1986; Hayden, 1981; Isaac, 1971; Kelly, 1996; Washburn and Lancaster, 1968).

To square such a dismal view of the prospects of aquatic peoples with the evidence that many coastal societies were characterized by relatively high population densities, sedentism, and cultural complexity—the coastal paradox—required further explanation. Osborn (1977b) argued that the population density of aquatic societies was exaggerated because their offshore territories were not included in density calculations, but he could not resolve the more important issues of sedentism and cultural complexity. Cohen (1981) argued that the complexity of

Northwest Coast societies was a result of their high population densities, but never adequately explained how they attained such high populations in supposedly marginal environments. Yesner (1987) developed the most explicit and sophisticated explanation for the coastal paradox, arguing that marine and other aquatic environments were relatively unproductive until the post-Pleistocene period, when a combination of megafaunal extinctions, climatic amelioration, sea level stabilization, and the development of mature coastal habitats allowed coastal populations to bloom. Thus, he argued, humans did not intensively utilize aquatic resources until relatively late in human history, but the growing productivity of postglacial aquatic habitats ultimately fostered the high populations, sedentism, and complexity typical of many Middle or Late Holocene coastal societies. Problems with this model include significant variation in the patterns and timing of megafaunal extinction or survival, the considerable evidence for aquatic adaptations prior to such widespread extinctions, and little evidence that marine and other aquatic resources were relatively unproductive prior to sea level stabilization.

As we shall see, none of these explanations adequately accounts for either the basic paradox of supposedly low aquatic productivity versus high human populations and cultural complexity, or for the emerging archaeological data that suggest that aquatic adaptations developed earlier and were more widespread than previously believed. Nor do they explain how archaeologists armed with essentially identical data sets can come to such radically different conclusions about the development of such basic aspects of human economies. To explore these problems, however, we must first review some of the different perspectives on the nature of aquatic resources, then examine some epistemological problems that inhibit a comprehensive understanding of the evolution of aquatic adaptations.

AQUATIC RESOURCES

Much has been said about the productivity of various classes of aquatic resources: shellfish, fish, sea mammals, waterfowl and seabirds, amphibians, plants, and others. I do not review these arguments in detail, for such a task could easily be the subject of an entire paper. It is important to my later arguments, however, to examine some of the divergent opinions expressed about the nature of various classes of aquatic resources. Also significant is the fact that aquatic resources are often collectively lumped as “small” resources, with the unwarranted assumptions that they are therefore less productive than terrestrial game animals for human subsistence and their presence in archaeological sites represents de facto evidence for resource stress or economic intensification. In this section, I examine some disparate viewpoints about the major classes of aquatic resources, recognizing that classes of aquatic organisms not discussed (amphibians, reptiles, insect larvae, plants, etc.) may also be significant resources in some areas.

Freshwater

Curiously, perhaps the single most important aquatic resource for humans, freshwater for drinking, is seldom discussed. This may be because our dependence on water is so fundamental and so crucial to survival that it is taken for granted. It is significant, however, because the almost daily need for drinking water tethered our ancestors to aquatic habitats for most of human history. More than any other resource, drinking water determined where they settled and where they went, especially in relatively arid regions. Maintaining this crucial lifeline to aquatic habitats, hominids would have spent a great deal of time observing the behavior of animals in such environments, including many terrestrial and amphibious predators or scavengers that fed on aquatic animals (see Erlandson and Moss, in press). Under these circumstances, it seems unlikely that hominid hydrophobia would have prevented similar opportunistic harvesting of shallow water fauna by some of our earliest ancestors living along the shores of African lakes. With general similarities between many of the animals (fish, shellfish, birds, etc.) that live in lakes, rivers, estuaries, and marine habitats, it also seems unlikely that a significant learning curve would have been required to transfer such skills between aquatic habitats. The intensity of such aquatic harvesting probably varied tremendously, of course, depending on the relative productivity of such activities compared to the other subsistence pursuits available to a group at various times.

As noted above, the notion of a long-standing inability of hominids to cope with aquatic habitats is also difficult to reconcile with the fact that our human ancestors now appear to have spread from Africa into southern Eurasia by about 1.7 million years ago. How did they accomplish such extensive and early migrations if they were afraid of the water and incapable of either swimming or constructing simple rafts, boats, or other flotation devices?

Shellfish

No class of aquatic resources has generated more debate among archaeologists than shellfish (e.g., Bailey, 1975, 1978; Buchanan, 1988; Claassen, 1991, 1998; Erlandson, 1988, 1991; Glassow and Wilcoxon, 1988; Jones and Richman, 1995; Meehan, 1977, 1982; Meighan, 1969; Moss, 1993; Noli and Avery, 1988; Osborn, 1977a; Parmalee and Klippel, 1974; Quilter and Stocker, 1983; Waselkov, 1987; Yesner, 1987). The generic term shellfish is usually used to refer to a variety of aquatic invertebrates, dominated by molluscs (bivalves and univalves), but also including crabs, sea urchins, barnacles, shrimp, and other relatively common organisms. Although the size of shellfish taxa utilized by humans varies considerably, from large octopi or giant clams to very small bivalves or gastropods, most shellfish are relatively small organisms. What they lack in size, however, many shellfish make up for in quantity and accessibility—many types are found in large and sessile aggregations. While most shellfish provide nutritious sources of complete animal proteins and some vitamins or minerals, most are relatively low in fat, carbohydrates, and calories (see Sidwell, 1981). Although shellfish beds have often been portrayed by anthropologists as relatively unproductive, biological studies indicate that mussel beds produce one of the highest rates of biomass production on earth (Jones and Richman, 1995).

Since at least the early 1900s, many archaeologists have depicted these diverse and seemingly innocuous creatures as marginal, secondary, or even starvation foods for humans.

> . . . procuring the essentials of life by collecting shells in itself indicates a low form of human existence. In all parts of the world, even today, people may be seen on the shore at low water gathering for food the shells uncovered by the retreating tide . . . these people always belong to the lower classes of society and lead in this manner a primitive as well as a simple life (Uhle, 1907, p. 31).

Some archaeologists bolstered such arguments with simple comparisons of the nutritional content of shellfish versus large land mammals. Bailey (1978, p. 39) calculated, for example, that 156,800 cockles were required to provide the caloric yield of one red deer. Some of these comparisons were inaccurate, and others ignored the fact that shellfish may sometimes have been used primarily as a protein source or that they were often a relatively predictable and readily available meat source that could be gathered by virtually all members of society, including women, children, and the elderly (see Erlandson, 1988; Glassow and Wilcoxon, 1988; Meehan, 1977). The fact that shellfish gathering was done primarily by women in most ethnographic societies (Claassen, 1998, p. 175; Moss, 1993, p. 632), in fact, suggests that such comparisons of shellfishing versus hunting yields may often be inappropriate.

Some scholars have also argued that the small size of shellfish, their relatively low caloric content, and their generally high ratio of shell to meat meant that they were relatively laborious to process (e.g., Osborn, 1977a; Waselkov, 1987). Others countered that they required little search time or technological investment and could provide highly reliable and relatively large meat yields that could buffer the high failure rates of hunting forays (e.g., Jones, 1991; Meehan, 1982). While some researchers extolled shellfish as an efficient protein source (Erlandson, 1988), others noted that a heavy reliance on lean shellfish meats could produce “protein poisoning” (Noli and Avery, 1988), and still others pointed out that a reliance on many land mammals (bison, rabbits, etc.) could produce the same problem (Buchanan, 1988). While some criticized shellfish as a resource highly susceptible to periodic El Nino, storm, or red tide events, others pointed out that such problems could sometimes be predicted and controlled for (Moss, 1993, pp. 640–641) and that agricultural products and other terrestrial resources were equally susceptible to floods, droughts, disease, and other problems (Quilter and Stocker, 1983).

Finally, though Osborn (1977a,b) and others have used ethnographic or historical accounts to support the notion that shellfish were marginal or starvation foods, Moss (1993) clearly exposed the complexities and potential androcentrism often inherent in such accounts. I was present during her interview of an elderly Tlingit friend, Richard Newton, who insisted shellfish were not a major food for his people. Responding to questions about the incredible abundance of shellfish remains in Tlingit village and camp sites, however, Mr. Newton eventually characterized their dietary role as similar to bread and butter—long a staple in western society (Moss, 1993, p. 643). When asked about this contradiction, he patiently explained that the ideal Tlingit man needed to work hard to succeed, that shellfish encouraged laziness because they were too easy to collect, that they were gathered primarily by women, but that they also were regularly gathered and consumed by Tlingit men (Moss, 1993). Certain types of shellfish were especially prized by Tlingit men, in fact, because they were said to enhance the libido.

All this debate has had little effect on the pervasive notion that shellfish and other small resources are lower ranked by human foragers (e.g., Broughton and O'Connell, 1999; Renfrew and Bahn, 1996, p. 282). Fagan (2001, p. 341) concluded, for instance, that "no one can believe that mollusks were the staple diet" of any ancient society. Following such assumptions, many archaeologists continue to view the appearance of shell middens in archaeological sequences as evidence for human demographic pressure, environmental degradation, and economic intensification (e.g., Cohen, 1977; Hayden, 1981; Waselkov, 1987). The postglacial florescence of shell middens adjacent to aquatic habitats around the world, therefore, has become essentially synonymous with the anthropological notion that human economies were transformed by a global and relatively recent broad-spectrum revolution.

Fish

Similar debates have taken place over the nature and productivity of fishing (e.g., Butler, 1996; Clark, 1948; Garson, 1980; Kelly, 1996; Limp and Reidhead, 1979; Lindstrom, 1996; Morgan, 1877; Osborn, 1977b; Rick and Erlandson, 2000). Literally thousands of different varieties of fish inhabit the wide range of aquatic habitats, from the deep abyssal floors of the oceans to high mountain lakes. Even as adults, these fish range in size from tiny gobies to the gigantic whale shark. Some are largely solitary and relatively rare, while others are incredibly abundant and swim in concentrated schools numbering in the millions. Some aquatic communities, moreover, are characterized by a diversity and abundance of fish; others contain only one or two species and even these are relatively rare. Still other communities have low species diversity but a relatively high piscine biomass.

The nutritional value of fish also varies considerably, especially the fat and calorie content of various species. Although generally low in carbohydrates, fish are a relatively nutritious source of protein, vitamins, and minerals (Sidwell, 1981; Watt and Merrill, 1975). Fish eggs, which can sometimes be harvested in large quantities, are also generally very high in protein and calories. Fish flesh and protein are also highly digestible and metabolized more efficiently by the human body than the meat of land mammals. High rates of fish consumption in modern human populations—especially certain fish oils—also seems to be generally correlated with lower rates of disease and greater longevity.

Opinions expressed about the economic productivity of fishing vary widely. Some accounts have portrayed fishing as an extremely productive activity, beginning with Morgan's idealized statement that "Fish were universal in distribution, unlimited in supply, and the only kind of food at all times attainable" (Morgan, 1877, p. 21). In contrast, in comparing fishing to more traditional hunting activities, Kelly (1996, p. 209) stated that

> . . . fish are different. Some species, especially surface feeders, will give away their presence, but not bottom feeders. And fish cannot be tracked—this is a particular problem in exploiting oceanic fish. The forager can only go to a likely place to find fish, then begin searching randomly. If there are no fish there, the forager could waste quite a bit of time before accepting this as likely.

Kelly's characterization, however, is at odds with many types of marine fishing, including the extremely productive and predictable fishing that can characterize halibut or cod banks, kelp beds, and some other nearshore habitats.

Others have argued that fishing requires relatively sophisticated knowledge and high technological investments. Experimental work by Limp and Reidhead (1979) suggested, however, that under the right circumstances riverine fishing could be extremely productive even without complex technologies. In some aquatic habitats, the seasonal drying of ponds or pools can strand fish in shallow water or on mud flats where they can be easily collected. In some lakes, periodic hypersaline or anoxic conditions can also lead to massive fish kills in which large windrows of dead fish are deposited on the beach (e.g., Butler, 1996, p. 701). Quilter and Stocker (1983, p. 549) described an apparently regular Peruvian phenomenon known as "anchovy beaching," in which hundreds of thousands of small fish strand themselves on the beach roughly four times a year. Spawning fish (salmon, herring, lamprey eels, grunion, and many others) also can be highly vulnerable to human predation, and such spawning runs are often highly predictable, facilitating the logistical planning required for mass harvesting and the processing of fish for storage.

Even when more sophisticated technologies are required to capture fish, these need not be especially elaborate or expensive to produce. Dip nets or small tidal weirs, for instance, can greatly facilitate the mass harvest of small fish in truly impressive yields. Before commercial overexploitation devastated many of California's marine fisheries, enormous schools of sardines and anchovies were available in nearshore and estuarine habitats. With the aid of boats and dip nets, huge quantities of these small fish could be captured quickly and easily dried for later consumption. Still, considering the lack of evidence for weaving techniques prior to the advent of the Upper Paleolithic, even relatively simple fishing technologies involving cordage, baskets, nets, or composite projectiles may have been beyond the capabilities of hominids prior to the appearance of anatomically modern humans. And some fishing activities—especially those requiring large nets, sophisticated boats, or elaborate weir structures—would have required considerable investment in materials, labor, and maintenance, as well as intellectual and communication skills that may have been beyond the capabilities of our archaic ancestors.

Despite such technological constraints, a number of cultural ecological studies have modeled the productivity of various fishing activities relative to alternative terrestrial subsistence pursuits (e.g., Osborn, 1977b; Perlman, 1980; Simms, 1987). Some of these estimates are based on incomplete data or the use of inappropriate technologies in potentially depleted modern environments, but they are still informative, suggesting that the productivity of fishing varies tremendously. The most sophisticated analysis of which I am aware is Lindstrom's study of the Truckee River fishery in the western Great Basin (Lindstrom, 1996), which suggests that fishing harvests using a number of different aboriginal techniques were higher than the return rates calculated by Simms (1987) for terrestrial hunting. Lindstrom's projected return rates varied considerably, however, and some methods of fishing produced yields that were considerably less productive than many terrestrial alternatives.

Aquatic Mammals

There has also been considerable debate about the nature, antiquity, and economic productivity of aquatic mammal use, especially marine mammals such as whales, seals, sea lions, sirenians (sea cow, manatees, etc.), and sea otters (e.g., Clark, 1946, 1947; Colten and Arnold, 1998; Erlandson *et al.*, 1998; Hildebrandt and Jones, 1992; Jones and Hildebrandt, 1995; Lyman, 1995; Osborn, 1977b; Workman and McCartney, 1998). Aquatic habitats also are home to a variety of freshwater animals (hippopotami, beavers, otters, etc.) of various sizes, which spend varying amounts of time in the water and, like some marine mammals, may sometimes be taken on land. Some aquatic mammals are also not easily categorized as clearly marine or freshwater: some seals or dolphins swim considerable distances up rivers; seals live permanently in Lake Baikal, the Caspian Sea, and other European lakes (Reeves *et al.*, 1992); some manatees are equally at home in salt- or freshwater habitats; and river otters and other typically freshwater mammals may also spend time in brackish or saltwater habitats.

Clearly most aquatic mammals are not small resources. They include many of the largest animals on earth, which until devastated by commercial whaling or hunting also were relatively abundant along many of the world's coastlines. Many marine mammals weigh well over 500 kg, with the largest whales weighing over 100,000 kg. Osborn (1977b) argued that most aquatic mammals occupy positions relatively high in the food chain, which limits their numbers relative to the primary productivity of the world's oceans. Such global modeling probably had little or no relevance, however, to maritime peoples such as the Koniag or Aleut, who lived in proximity to biannual migrations of hundreds of thousands of whales and pinnipeds (see Haggarty *et al.*, 1991).

Like virtually all mammals, the meat and organs of aquatic mammals are relatively rich sources of nutrients, high in protein, vitamins, and minerals (see Heller and Scott, 1967; Osborn, 1977b; Sidwell, 1981). Many aquatic (especially marine) mammals also have a thick layer of subcutaneous blubber that provides them with insulation and human hunters with a rich source of fat and calories. These fat deposits can also be rendered into oil that may be stored for later consumption or used in lamps as a source of heat and light. The skins, bones, teeth, ivory, and baleen of many aquatic animals also provide valuable raw materials used in a variety of technologies (houses, boats, clothing, tools, ornaments, etc.). Among many societies that actively pursue large aquatic mammals, successful hunters may also gain significant status, prestige, and possibly even reproductive advantages.

Such potentially lucrative economic payoffs must be measured against the costs and risks of procuring aquatic mammals. Sea mammal hunting can be a dangerous and seasonal pursuit, especially in offshore marine settings, and successful hunting forays are often relatively rare. Like fishing, some forms of aquatic hunting may also require relatively complex and expensive technology, including seaworthy boats and related hunting gear that represent a significant investment of energy to produce and maintain. This is particularly true for many types of sea hunting recorded among ethnographic marine hunters. Many of these peoples had high population densities and had hunted sea mammals for millennia, however, with negative effects on the distribution and density of local prey populations (Jones and Hildebrandt, 1995; Lyman, 1995). Prior to such impacts, many pinnipeds may have been taken relatively easily while hauled out in breeding or birthing colonies on islands or other isolated coastal locales. Where abundant, scavenging of cetacean and pinniped carcasses off the beach could also provide large (and potentially huge) subsistence dividends, with minimal technological or search costs (Smith and Kinahan, 1983). Finally, the costs of manufacturing and maintaining boats must be measured against the greater overall efficiency achieved in a variety of hunting, fishing, and transportation activities.

As with virtually all classes of aquatic and terrestrial resources, there is considerable variability in the characteristics of aquatic mammals and their economic potential. This includes aspects of their biology and behavior, their abundance and availability to humans, the methods used to procure them, and the relative productivity of various procurement strategies versus subsistence alternatives. Given this diversity, it should be no surprise that different researchers have reached quite different conclusions about the general role of aquatic mammals in human economies. In recent discussions, for instance, various researchers have viewed sea mammals as either central or peripheral to the development of maritime adaptations along the Pacific Coast of North America. Hildebrandt and Jones (1992; Jones and Hildebrandt, 1995) proposed that because of their large size and vulnerability to predation in rookeries, some seals and sea lions were the focus of early marine hunters, with later technological developments (boats, etc.) representing labor intensification as human impacts on pinniped populations increased and hunting strategies changed. Colten and Arnold (1998) and Erlandson *et al.* (1998) noted little evidence for an early focus on pinniped hunting in the area, however, and suggested that its general economic importance may have been overemphasized (see also Kent, 1989, p. 5; Workman and McCartney, 1998, p. 362). Central to resolving such debates are problems related to recovering and interpreting representative samples of sea mammal remains and estimating their dietary contribution within the larger economies of human societies.

PROBLEMS IN PARADIGMS

Underlying such debates, but often pushed well into the background, is the ambiguity of the archaeological record itself. In some cases, diverging opinions have been supported with data from different regions. In others, nearly opposite conclusions were drawn from virtually the same archaeological record. How is it possible for researchers to reach such different conclusions based on the analysis of the same body of data? The answer to that question lies in a variety of taphonomic, methodological, interpretive, and theoretical problems that make our reconstructions of the history of aquatic societies fraught with uncertainties. The divergence of opinions about the antiquity of aquatic adaptations can be attributed to a variety of problems with the archaeological record itself, to differences in the way individual archaeologists believe the record should be interpreted, and to differences in the preconceptions of various researchers.

Definitions

In part, different opinions can be attributed to the general lack of definition for what constitutes a dietary staple, systematic or intensive resource use, or terms such as coastal, aquatic, littoral, or maritime adaptations (Workman and McCartney, 1998). Definitions for coastal or maritime adaptations have varied, for instance, from those groups who procure some portion of their sustenance from the sea to those who go to sea in boats and rely on other specialized technologies. Recognizing the complexity and diversity inherent in northern cultures, Fitzhugh

(1975, p. 344) tried to bring some order to the classification of maritime societies by defining five broad adaptive types: modified interior, interior-maritime, modified marine, maritime, and riverine. In his work on the Oregon coast, Lyman (1991) differentiated littoral from maritime adaptations, the latter representing groups who went to sea to obtain much of their sustenance. Finally, in an attempt to operationalize the definition of maritime societies for anthropologists, Yesner (1980, p. 728) defined “fully maritime” peoples as those obtaining at least 50% of their calories or protein from marine sources. This definition is easily adapted to riverine or lacustrine peoples, but in practice it is difficult to accurately or precisely quantify the dietary contribution of aquatic versus terrestrial resources. Isotopic and trace element studies of human bone have improved our ability to quantify general aspects of ancient diets, but a variety of problems (diagenesis, varying photosynthetic pathways, etc.) continue to limit such studies.

At times, we must even confront the issue of what constitutes an aquatic versus terrestrial resource. How do we classify a salmon or other anadromous fish that may be caught in the ocean one week, in a river or lake the next week, or scavenged from the shoreline the next? How do we classify the beaver, hippopotamus, crocodile, land otter, or many other animals that spend a good deal of time in aquatic habitats but may also be captured on land? Are seabirds (or their eggs) taken from terrestrial colonies aquatic or terrestrial resources? What about seals or sea lions taken from onshore rookeries? Finally, how do we classify a deer or elk captured—as they were sometimes taken along the Northwest Coast of North America—while swimming to or from islands (Tveskov, 2000, p. 131) or nearly paralyzed by the cold on the beach just after such a swim? It might be argued that such ambiguous cases are relatively unusual, but I suspect they are more common than many of us recognize, and they blur the arbitrary distinctions already drawn between aquatic and terrestrial resources or marine, estuarine, riverine, and lacustrine habitats. If such ambiguities can be recognized in modern habitats and behaviors, moreover, how can we hope to differentiate between such ambiguous cases in the archaeological record?

Changing Sea Levels, Coastal Erosion, and the Archaeological Record

Despite such ambiguities, the single greatest problem in evaluating the history of aquatic adaptations lies in the fact that sea and lake levels have varied tremendously over the past 2 million years, and erosion during high stands has repeatedly obliterated the archaeological record where evidence for early aquatic resource use is most likely to be found. Sea level today is among the highest of the Quaternary, exceeded only by Last Interglacial levels about 6 m higher than today. Many scholars are rightfully hesitant to assume that Pleistocene shell middens were once widespread along submerged shorelines. Geologically, however, there is ample reason to believe the archaeological record of coastal adaptations is seriously underrepresented (Kraft *et al.*, 1983). During the last glacial about 20,000 years ago, world sea levels stood between about 100 and 125 m below present, exposing broad coastal plains around the world that have virtually all been inundated as seas rose to their present levels. Similar cycles have occurred numerous times during the Plio-Pleistocene, causing enormous and highly variable changes in coastal geography around the world.

Worldwide, only Africa and Eurasia were occupied by hominids when sea levels were last comparable to today. Along such Old World coastlines, the Last Interglacial sea stand of 125,000–130,000 years ago cut erosional platforms that may have destroyed most evidence for earlier coastal occupations. In fact, each time global sea levels have risen significantly the record of hominid occupation associated with lower shorelines has either been inundated, destroyed by coastal erosion, or both. Even today, with sea level roughly 6 m below the Last Interglacial high, many important coastal sites (e.g., Klasies River Mouth caves, Gorham's Cave, Grotta dei Moscerini, Daisy Cave) occupied between about 125,000 and 10,000 years ago are being destroyed by marine erosion. Uplifted shorelines associated with earlier interglacials are present in some areas, but the periods of sea level maxima represent just a small fraction of the Pleistocene. It should be no surprise that associated occupation sites (e.g., Terra Amata) are rare. Much more common are localities such as those in North Africa and the Levant, where Lower Paleolithic artifacts (hand axes, etc.) have been found redeposited on raised marine terraces, testifying to the destruction of ancient sites located in coastal or pericoastal settings (e.g., Bar-Yosef, 1994; Howe, 1967).

Equally important for understanding the evolution of coastal and aquatic adaptations are the effects of sea level change on the paleogeography of coastal localities. As sea levels rise or fall, coastlines move laterally in response to such changes; the environmental setting of archaeological sites can change dramatically. Reconstructions at coastal sites with long occupational sequences have shown that the exploitation territories of many sites located on the modern coast were entirely terrestrial during earlier occupations (e.g., Parkington, 1981; Shackleton and van Andel, 1980). The maximum lateral movements of coastlines during the last 20,000 years, for instance, have varied from as much as 1000 km in some areas (e.g., northern Australia) to less than 1 km in others. Areas where shorelines have moved less than about 10 km are unusual and tend to be strongly correlated with relatively early evidence for coastal occupations (Erlandson, in press; see ahead). Reconstructing the paleogeography in the vicinity of coastal sites is crucial, because a cave or open site located on the coast today may have been 5, 10, 50 km, or more from the coast at various times during the last 25,000–125,000 years. Study of modern coastal hunter-gatherers suggests that they rarely travel more than about 5 or 10 km from a home base to gather foods (Bigalke, 1973, p. 161; Meehan, 1982). When they do hunt or forage further afield, the skeletal remains of shellfish, fish, or sea mammals are often not transported back to a residential base. In most situations, therefore, sites located more than about 5–10 km from an ancient shoreline are unlikely to contain substantial evidence for marine resource use. Distances of even 1 or 2 km can dramatically reduce the density of aquatic faunal remains (Wing, 1977). During periods of shoreline transgression or regression, the intensity of aquatic resource use at any given site should fluctuate depending on its proximity to coastal habitats. After the dramatic postglacial sea level rise of the last 17,000 years, coastal sites with long occupational sequences may show evidence for an intensification of marine resource use related primarily to changes in local environments rather than a regional diversification or intensification of human subsistence (see Bailey, 1983a; Parkington, 1981; Shackleton, 1988).

Some may argue that the loss of early coastal sites can be mitigated by examining the antiquity of the human use of lacustrine or riverine resources, but two problems inhibit such comparisons. First, it is not clear that the productivity and diversity of most freshwater habitats is comparable to marine or estuarine communities. Second, it is not clear if the archaeological record of riverine or lacustrine habitats is any more representative. Such freshwater environments are also highly dynamic, and climatic, glacial, and sea level changes have had profound effects on their structure and productivity. Fluctuating lake levels also are common, and shoreline erosion can produce geological features essentially identical to marine shorelines. In riverine systems, moreover, erosive cycles can rapidly destroy sites while depositional cycles can bury them under large quantities of sediment. Thus preservation and visibility problems may be just as significant in some freshwater systems as they are in marine environments.

Differential Preservation, Recovery, and Reporting

Another problem lies in the differential preservation, recovery, and reporting of organic remains. As we all know, the shell and bone remains that constitute the primary record of human use of aquatic resources are not preserved in many archaeological sites. Acidic soils, for instance, or the gradual action of humic acids in neutral soils, commonly lead to the deterioration of shells and bones in archaeological sites. In comparatively recent sites, especially those occupied by relatively sedentary peoples, the accumulation of substantial shell middens can mitigate the effects of soil acidity or other factors that lead to the destruction of shell or bone. For the Paleolithic or Paleoindian periods, however, when most scholars believe humans were relatively mobile, the shell in many low-density middens may have been insufficient to counteract soil acidity. The same may be true of pericoastal or other sites located some distance from aquatic habitats, where the density of aquatic food remains was limited by transportation costs. My experiments with shells and bones exposed to dilute acid solutions also showed that shells generally deteriorate faster than bones, probably due to their higher calcium carbonate and lower collagen or lipid content. At a number of archaeological sites, including Hidden Falls in southeast Alaska (Erlandson, 1989, p. 139) and Die Kelders in South Africa (Goldberg, 2000), moreover, researchers found bone still recoverable, while shells had either disintegrated or were too deteriorated to recover or identify. In the case of Die Kelders, despite the fact that calcareous rock was abundant in the site strata, decalcification completely destroyed the shellfish remains in portions of the site while bone fragments were still relatively well preserved.

Among animal bones alone, the denser and thicker bones of large land mammals are more likely to be preserved in most archaeological contexts (see Butler and Chatters, 1994). There has been relatively little experimentation on the comparative survivability of skeletal remains from terrestrial versus aquatic vertebrates, but differential bone density is a significant factor in preservation. The bones of aquatic vertebrates generally have lower densities and are probably more susceptible to chemical dissolution and mechanical breakdown. Except for the teeth of some taxa (sharks, etc.), fish bones are especially lightly built and often have very high surface area to volume or mass ratios, suggesting that they would be highly vulnerable to chemical deterioration. Some economically important fish (sharks, rays, sturgeon, lamprey eels, etc.) also have cartilaginous skeletons with very few bony parts, and small bony fish (i.e., sardines, anchovies) are often eaten whole. The bones of many aquatic mammals are also relatively porous and may be prone to differential deterioration from mechanical and chemical processes.

Numerous studies clearly show that the recovery techniques used by archaeologists dramatically affect the interpretations drawn from the recovered assemblages. Studies of faunal recovery, for instance, show that large proportions of the fish bone and shellfish remains in many sites are lost during screening of excavated sediments through coarser (0.25 in. or larger) mesh sizes (e.g., Erlandson, 1994; Garson, 1980; Koloseike, 1968; Moss, 1989). This is a crucial problem in evaluating the evidence for aquatic resource use in many early excavation reports, where researchers had limited interest in subsistence, faunal remains often were not systematically recovered, or fine-screen samples were not collected. Many investigators now routinely collect faunal and floral samples through fine screening and flotation, but others still rely on cheaper and less systematic recovery techniques.

Because the importance of hunting or scavenging large game animals has long been emphasized, there have sometimes been biases in the analysis or reporting of other faunal remains from archaeological sites. In many studies of Middle or Upper Paleolithic subsistence, in fact, the *only* subsistence remains reported on are large land mammals (e.g., Barker, 1974; Wolf, 1988), even in early coastal sites that produced a variety of faunal remains. Years ago, while visiting early sites in Gibraltar, I was surprised to find a number of bluefin tuna and mackeral vertebrae in the Gibraltar Museum, materials excavated from early Upper Paleolithic strata at Gorham's Cave. For some reason, these fish bones were never mentioned in any of the site publications, even though reports on mammals, tortoises, birds, and shellfish were all published (see Baden-Powell, 1964; Eastham, 1968; Waechter, 1951, 1964; Zeuner and Sutcliffe, 1964). A similar problem is encountered for the Middle and Upper Paleolithic levels at Mugharet el‘Aliya, located near Tangier in Morocco (Howe, 1967; Howe and Movius, 1947). One of the few Last Interglacial sites from the south coast of the Mediterranean, the Paleolithic cave deposits produced seal, fish, and “a series of” mollusk remains (Howe and Movius, 1947, p. 21). Although vertebrate remains were not quantified, they were at least identified (Arambourg, 1967). Description of the shellfish remains was limited to the statement that a “number of mollusks were found in Layers 5, 6, and 9 of the archaeological deposits in the Mugharet el‘Aliya, and were submitted to Dr. William J. Clench of the Museum of Comparative Zoology at Harvard. Nothing of value for our purposes came of this however” (Briggs, 1967, p. 187).

Such problems may have been due, in part, to the dearth of specialists who could identify and analyze the remains of aquatic fauna. They are symptomatic, however, of the lower priority archaeologists traditionally assigned to resources such as shellfish and fish that were considered economically marginal or unimportant. In Howe’s synthesis of the Mugharet el‘Aliya investigations (Howe, 1967), for instance, the description of stone tools is over 31 pages long, the vertebrate remains are relegated to 5 pages in an appendix, and the shellfish merit a single short and obscure paragraph.

The Hunting Hangover

Even if we can overcome such analytical hurdles, another serious problem still confronts us. This is the persistent effect of the ”Man the Hunter” paradigm on archaeology. The historical overemphasis on hunting as central to early human economies has been dealt with at length elsewhere (e.g., Slocum, 1975; Zihlman, 1997). The remnants of this outdated view are still with us, however, more than a decade after most scholars recognized that scavenging probably supplied much of the meat early hominids consumed and that gathering was much more important than recognized in earlier anthropological models. Comparative anatomy also tells us that human dentition is fundamentally adapted to omnivory and a relatively eclectic diet (Scott and Turner, 1997, p. 81). Evolutionary theory tells us that over the long haul species are rarely well served by excessive specialization. Modern medicine and nutritional studies show that dietary diversity is fundamental to human health, growth, and reproductive success. And common sense tells us that as our hominid ancestors spread around the globe, a fundamental part of their success was their ability to adapt to a variety of environments or situations and their relatively eclectic and opportunistic subsistence economies.

Nonetheless, many theoretical discussions of subsistence inappropriately compare the yields of shellfishing or fishing to those of large-game hunting. If many hominids relied heavily on scavenging rather than hunting, for instance, the relative productivity of gathering shellfish should be compared to scavenging yields in such cases and must have been higher than previously estimated. Many predictions based on optimal foraging principles also inappropriately treat early human societies as groups of generic individuals, ignoring the gender or age-based divisions of labor in hunting and gathering activities typical of most recent foraging cultures. Even for Holocene peoples, therefore, comparisons of shellfishing and hunting yields to predict dietary breadth and subsistence choices may be inappropriate, since large-game hunting was often a primarily male pursuit, and shellfish and some other aquatic resources were often collected mostly by women, children, and older individuals. There is little doubt, in fact, that the historical devaluation of shellfish gathering in human history is related to the fact that it was primarily the work of women or commoners, to an androcentric fascination with hunting, and to biases in historical and ethnographic accounts recorded primarily by men (Claassen, 1991, pp. 278–279; Moss, 1993).

Until anthropology transcends some pervasive misconceptions, the significance of aquatic adaptations will continue to be underemphasized in our reconstructions of human evolution. These misconceptions include (1) the notion that large land mammals were virtually always the most productive and highly ranked resources for our hominid ancestors; (2) that male-dominated hunting was always the central force that shaped human subsistence, settlement, and technological developments; (3) that the utilization of aquatic resources is automatically evidence for demographic pressure or resource stress; and (4) that the archaeological record preserves a representative picture of our past.

ARCHAEOLOGICAL EVIDENCE FOR THE ANTIQUITY OF AQUATIC RESOURCE USE

Given the nature and ubiquity of such problems, is it any wonder that we know so little about the history of aquatic resource use? To understand the development of aquatic adaptations we are burdened with several fundamentally flawed theoretical assumptions and blessed with a relatively small number of assemblages where faunal preservation is exceptional and the full range of faunal remains were systematically recovered and completely reported. At the same time, any current synthesis must rely on an archaeological record that comes almost exclusively from sites preserved above modern sea level even though virtually all coastlines dating between about 120,000 and 15,000 years ago now lie submerged and distant from the modern coast.

Despite such problems, numerous early sites with evidence for aquatic resource use have been listed over the years by Osborn (1977a,b), Perlman (1980), and Waselkov (1987) or mentioned by others (e.g., Claassen, 1998; Klein and Scott, 1986; Yesner, 1980). None of these lists were exhaustive when they first appeared, and additional data have continued to accumulate in subsequent years. In Tables I–III, I have compiled my own lists of early “aquatic” sites—those that

Table I. Some Early Old World Localities With Possible Evidence for Aquatic Resource Use

Locality/site	Description of aquatic fauna and associations	Age (yr)	Reference
Homo habilis			
Senga 5, Semliki River, Zaire	Possible use of freshwater fish, molluscs, and reptiles associated with Oldowan tools.	2.3–2.0M	Harris *et al.*, 1990; Meylan, 1990
Olduvai Gorge, Tanzania	Possible use of freshwater fish, crocodiles, turtles, amphibians, and molluscs.	1.8–1.1M	Leakey, 1971; Stewart, 1994
Homo erectus			
Olduvai Gorge, Tanzania	Possible use of freshwater fish, crocodiles, aquatic mammals (hippo), turtles, amphibians, molluscs, and possibly salt.	1.1–0.8M	Leakey, 1971, 1994; Roe, 1994, p. 304; Stewart, 1994
Kao Pah Nam, Thailand	Pile of freshwater oyster shells against cave wall, associated with hearth and land animal bones.	700K	Fagan, 1990, p. 120; Pope, 1989
Holon, Israel	Freshwater turtle (*Trionyx* sp.) shells and hippo bones in Middle Acheulian assemblage of mostly scavenged (?) land mammals.	500–400 K	Bar-Yosef, 1994, p. 246
Mas des caves, Lunel-Viel, France	Seal remains found in cave site now located ca. 10 km from Mediterranean coast.	ca. 400K	Cleyet-Merle and Madelaine, 1995, p. 306
Archaic *Homo sapiens*			
Hoxne, England	Remains of fish, otter, beaver, and waterfowl associated with Acheulian deposits; distributions similar to artifacts, suggesting a cultural origin.	∼350–300K	Singer *et al.*, 1993; Stuart *et al.*, 1993
Duinefontein 2, South Africa	Sea bird (penguin, cormorant) remains in Late Acheulian site dominated by land mammal bones.	∼400–200K	Klein *et al.*, 1999a
Terra Amata, France	Shellfish and possibly fish remains associated with multicomponent coastal campsite.	∼300–230K	de Lumley, 1969; Villa, 1983
Lazaret, France	Marine shellfish in late Acheulian context.	∼186–127K	Cleyet-Merle and Madelaine, 1995
Ramandils, France	Marine shellfish (>300 fragments) in Middle Paleolithic strata, probable food remains.	∼150 ± 50K?	Cleyet-Merle and Madelaine, 1995
Kebibat, Rabat, Morocco	Aterian shell midden on Atlantic coast, associated with Neandertal remains.	150 ± 50K	Souville, 1973, pp. 73–81
Presqu'ile du Canal, Berard, Algeria	Aterian site on coast near Berard, contains unspecified numbers of limpets.	∼130–40K	Roubet, 1969
Haua Fteah, Cyrenaica, Libya	Marine shellfish in Last Interglacial strata.	∼130–50K	McBurney, 1967

Table I. (*Continued*)

Locality/site	Description of aquatic fauna and associations	Age (yr)	Reference
Mugharet el 'Aliya, Morocco	Marine shellfish, fish, and monk seal remains in Mousterian/Aterian strata.	∼125–40K	Arambourg, 1967; Howe, 1967
La Grotte Zouhrah, Rabat, Morocco	Aterian assemblage with marine shellfish (limpets, mussels, and crab), *Homo sapiens* remains.	∼125–140K	Débénath and Sbihi-Alaoui, 1979
Grotte des Contrebandiers, Morocco	Aterian shell midden on Atlantic Coast associated with *Homo sapiens* remains, abundant limpets.	∼127–40K	Roche and Texier, 1976; Souville, 1973, p. 112
Devil's Tower, Gibraltar	"Thick layers" of mussels over Mousterian hearths, and a "large heap" of marine shells.	∼125–50K	Garrod *et al.*, 1928
Gorham's Cave, Gibraltar	A variety of marine shellfish remains from several Mousterian occupation levels.	∼125–50K	Baden-Powell, 1964; Waechter, 1951, 1964
Grotta dei Moscerini, Latium, Italy	Diverse marine shell remains (3100 fragments), dominated by mussels and clams. High rates of burning suggest human predation; chipped shell tools.	∼115–65K	Stiner, 1994
Vanguard Cave, Gibraltar	Mousterian strata containing "clear evidence" for marine shellfish use by Neandertals; includes mussels, limpets, cockles, etc., some burned.	>45K	Barton *et al.*, 1999
Ras el-Kelb, Lebanon	Mousterian occupation of coastal or pericoastal cave site, with small numbers of marine shells recovered from various occupation levels.	>40K	Copeland and Moloney, 1998; Reese, 1998
Salzgitter-Lebenstedt, Germany	Freshwater fish and mollusk remains associated with Mousterian assemblage.	>40K	Butzer, 1971, p. 477; Cohen, 1977
Grotta Breuil, Latium, Italy	Small numbers of clam and limpet shells from Mousterian strata; probably not an "economically significant" resource.	>37K	Stiner, 1994, p.189
Gruta da Figueira Brava, Portugal	Marine shells (*Patella* sp.) in Mousterian levels; density, origin, and other constituents unknown.	31–30K	Straus *et al.*, 1993, p. 15
Anatomically Modern Humans (*Homo sapiens sapiens*)			
Klasies River Mouth, South Africa	Middle Stone Age use of shellfish, sea mammals, and flightless birds.	∼130–55K	Singer and Wymer, 1982
Boegoeberg II, South Africa	Middle Stone Age shell midden with numerous cormorant bones.	∼130–>40K	Klein, 1999, p. 455; Klein *et al.*, 1999b
Abdur, Eritrea	Middle Stone Age shell midden?	125K	Walter *et al.*, 2000
Herolds Bay Cave, South Africa	Early Middle Stone Age shell midden with mussels (*Perna perna*), other shellfish, and otter remains associated with hearths.	∼120–80K	Brink and Deacon, 1982

(*Continued*)

Table I. (*Continued*)

Locality/site	Description of aquatic fauna and associations	Age (yr)	Reference
Katanda 9 and 16, Semliki River, Zaire	Thousands of fish bones associated with MSA barbed bone harpoon points in riverine setting.	∼90–75K	Brooks *et al.*, 1995; Yellen *et al.*, 1995
Die Kelders 1, South Africa	Sea mammals, birds, and shellfish remains abundant in MSA cave deposits; shellfish remains are poorly preserved.	∼75–55K	Marean *et al.*, 2000; Tankard and Schweitzer, 1974
Hoodjies Punt, South Africa	Open air MSA site with evidence for shellfish, sea mammals, and fish.	∼70–60K	Volman, 1978
Sea Harvest, South Africa	Open air MSA site with evidence for the use of shellfish, sea mammals, and fish.	∼70–60K	Volman, 1978
Blombos Cave, South Africa	MSA shell midden strata, with variable densities of marine shell (mussels, limpets, etc.), fish remains, and formal bone tools.	∼60–50K or >100K	Henshilwood and Sealy, 1997; personal communication, 2000
Willandra Lakes, Australia	Abundant shellfish and fish remains from numerous lakeside camps, associated with terrestrial fauna and mixed economy.	∼50–15K	Johnston *et al.*, 1998
Ksar ‘Akil, Lebanon	Numerous freshwater and marine shellfish fragments in Early Upper Paleolithic strata; pelican, swan, goose(?), and duck also found.	43–22K	Altena, 1962; Ewing, 1947; Kersten, 1991
Mugharet el ‘Aliya, Morocco	Marine shellfish and fish remains in undated Upper Paleolithic strata.	∼40–15K	Arambourg, 1967; Howe, 1967
New Britain, Melanesia	Several early sites containing shell middens, fish bones, etc.; several substantial sea voyages required for colonization of archipelago.	36–15K	Allen *et al.*, 1989a,b
Riparo Mochi, Liguria, Italy	Early Aurignacian stratum produced almost 5000 pieces of marine food shell (MNI ca. 500), plus 240 shell ornaments made from 43 taxa.	35–32K	Kuhn and Stiner, 1998; Stiner, 1999
Castonet Shelter, France	Greenland seal (*Phoca hispida*) bones in early Aurignacian stratum.	∼35K	Cleyet-Merle and Madelaine, 1995
Mandu Mandu Rockshelter, Western Australia	Low density midden with shellfish, crab, and fish remains at pericoastal site ca. 5 km from coast during early occupation.	34–20K	Bowdler, 1990; Morse, 1988
Leang Burung, Sulawesi	Abundant freshwater shellfish remains in cave site.	31–19K	Glover, 1981
Gorham’s Cave, Gibraltar	Numerous marine shellfish remains in Early Upper Paleolithic levels; some sea bird, seal, and fish remains.	30–25K	Waechter, 1964; Zeuner and Sutcliffe, 1964
Kilu Rockshelter, Solomon Islands, Melanesia	Shell midden with fish bones and other fauna; colonization of island required several substantial voyages by maritime peoples.	29–20K	Wickler and Spriggs, 1988

Table I. (*Continued*)

Locality/site	Description of aquatic fauna and associations	Age (yr)	Reference
Shuwikhat-1, Upper Egypt	Catfish and large mammal remains at fishing and hunting station.	25K	Vermeersch and Van Peer, 1988
Ishango 11 and 14, Semliki River, Zaire	Abundant fish remains and some shellfish, crab remains with barbed bone points in early LSA assemblages in riverine and lacustrine setting.	25–16K	Brooks *et al.*, 1995; Yellen *et al.*, 1995
Site 1017 (Khor Musa), Egyptian Nubia	Khormusan campsite produced numerous catfish bones as part of mixed economy.	22.7K	Greenwood, 1968, p. 100
Ohalo II, Jordan Valley, Israel	Thousands of fish bones associated with house floor on south shore of Sea of Galilee.	21–18K	Nadel and Werker, 1999
La Riera, Asturias, Spain	Upper Paleolithic cave strata with shellfish, fish, and rare seal remains.	21–14K	Straus *et al.*, 1981
Ballana (Site 8859), Egyptian Nubia	Halfan campsite with large quantities of burned bone, mostly freshwater fish (catfish, etc.).	19–18K	Greenwood, 1968, p. 108; Wendorf, 1968, p. 797
Altamira Cave, Santander, Spain	Solutrean use of shellfish and seal within a predominantly terrestrial site economy.	∼18–17K	Straus, 1976–1977
Balmori Cave, Asturias, Spain	Upper Paleolithic conchero containing hundreds of marine shells, mostly limpets.	∼17K	Clark, 1974–1975
Coberizas Cave, Spain	Shellfish remains and occasional fish bones in Upper Paleolithic strata.	17–15K	Clark and Cartledge, 1973
Cueva Ambrosio, Almeria, Spain	Small numbers ($n = 44$) of salmon vertebrae and several hundred marine shell fragments—ornamental and nonornamental—in Solutrean levels of cave ca. 60 km from modern coast.	16.5K	López, 1988

Note. M = million years; K = thousand years.

have produced possible evidence for the use of aquatic foods, other resources, or maritime activities. These lists, too, are illustrative rather than comprehensive—I have compiled such data for years but still frequently encounter sites with apparent evidence for aquatic resource use that I was unaware of. Because of the proliferation of such sites, in fact, I have limited myself to Old World localities more than 15,000 years old and New World sites more than 8,000 years old. There is no question that aquatic resources were systematically used in these areas after these times, and the different thresholds for the Old and New Worlds also help compensate for the fact that the two areas were first colonized by humans at very different times. Even so, early aquatic sites are too numerous to discuss or list individually. Instead, I first discuss the evidence for the use of aquatic foods

Table II. Some Early New World Localities With Evidence for Aquatic Resource Use

Locality/site	Description of aquatic fauna and association	^{14}C age (Kyr)	References
Monte Verde, Chile	Pericoastal site with evidence for coastal contact (seaweeds, etc.).	12.5?	Dillehay, 1997
Broken Mammoth, Alaska	Abundant waterfowl remains, some fish, otter, and beaver in mixed economy.	11.6–9.6	Yesner, 1996
Tule Lake, California	Fish and waterfowl as a primary resource in basal layers of SIS-218 rockshelter.	11.4	Beaton, 1991
Lewisville, Texas	Several Clovis hearths associated with freshwater shellfish, turtles, and fish remains within diversified economy.	11	Storey *et al.*, 1990
Quebrada Jaguay, Peru	Faunal assemblage dominated by fish, shellfish, and seabird remains.	11.1–9.9	Sandweiss *et al.*, 1998
Pedra Pintada Cave, Brazil	Freshwater fish, shellfish remains in several Paleoindian occupation levels.	11.3–10	Roosevelt *et al.*, 1996
Marmes Rockshelter, Washington	Use of freshwater mussels and salmon along with terrestrial resources.	11–10	Caulk, 1988
Healy Lake, Alaska	Possible freshwater fish use.	10.9	Borden, 1979
Quebrada Tacahuay, Peru	Seabird, fish, and shellfish use.	10.8–10.5	Keefer *et al.*, 1998
Kanaka Rapids site, Idaho	Isotopic signature of Buhl woman skeleton suggests marine (salmon?) component in Paleoindian diet.	10.7	Carlson, 1998; Green *et al.*, 1998
Ring site, Peru	Basal levels of multicomponent shell dated to terminal Pleistocene.	10.5	Richardson, 1998; Sandweiss *et al.*, 1989
Rodgers Shelter, Missouri	Dalton Complex, fish as a primary meat source.	10.5–9.9	Goodyear, 1982
Daisy Cave, San Miguel Island, California	Abalones, mussels, turbans, and other shells in island Paleoindian site; Early Holocene component rich in shellfish, fish, and pinniped remains, with shell beads, fish gorges, etc.	10.4–7.8	Erlandson *et al.*, 1996; Rick *et al.*, in press
49-PET-408, southeast Alaska	Human skeletal remains with strongly marine dietary signature.	9.2	Dixon, 1999, pp. 180–181
Hidden Falls, southeast Alaska	Island occupation and probable maritime economy—faunal remains poorly preserved.	9–8	Davis, 1989
Cutler Ridge, Florida	Shell midden with tuna and shark remains, located adjacent to narrow continental shelf.	9.6	Dunbar, 1997
California coast	Numerous Early Holocene shell middens on islands and mainland with diversity of maritime adaptations.	9–8	Erlandson, 1994; Erlandson and Moss, 1996
Sabine River site, Texas	Submerged Gulf Coast shell midden with burned and unburned fish bone.	8.5	Dunbar, 1997
Chuck Lake II, southeast Alaska	Island shell midden with abundant fish remains	8.2	Ackerman *et al.*, 1985

Note. Kyr = thousand years.

Table III. Islands Colonized or Explored by Pleistocene Seafarers

Locality	Description of evidence	Date (Kyr)	References
Flores Southeast Asia	Possible evidence for *Homo erectus* crossing of initial water gap from Sunda to Flores.	800?	Morwood *et al.*, 1998; Sondaar *et al.*, 1994
New Guinea and Australia	Oldest sites in Sunda are the earliest evidence for planned maritime voyaging, involving several sea crossings up to 90 km long.	60–40	Clark, 1991; Groube *et al.*, 1986; Roberts *et al.*, 1990
Crete, Greece	*Homo sapiens sapiens* remains with poorly documented context; calcareous breccia in which bones were cemented dated by Pa/U to 51,000 ± 12,000 BP; colonization of Crete apparently required several short sea crossings.	∼50	Facchini and Giusberti, 1992
Bismarck Archipelago, Melanesia	Shell middens, fishing, and seafaring at several sites dated from 15–35 Kyr, with voyages up to 140 km long.	35	Allen *et al.*, 1989a,b; Wickler and Spriggs, 1988
Sicily, Italy	Aurignacian assemblage from Mediterranean Island involving short voyage.	30	Chilardi *et al.*, 1996
Ryukyu Islands, Japan	Human skeletal remains found in Yamashita-cho and other caves on Okinawa and other islands; involves voyages of ca. 75–150 km.	32–15	Matsu’ura, 1996
Kozushima Island, Japan	Upper Paleolithic peoples on Honshu crossing 50 km wide channel to obtain obsidian.	25–20	Oda, 1990, p. 64
Melos Island, Greece	Travel across ca. 24 km of open water to obtain obsidian for mainland trade.	13	Cherry, 1990
Admiralty Islands, Melanesia	Settlement of Manus Island required 200 km voyage.	12	Allen and Kershaw, 1996
Cyprus	Occupation of Aetokremnos site, Akrotiri Peninsula on southwest coast of Cyprus.	10.3	Cherry, 1990, p. 151
Channel Islands, California	Boat and marine resource use by coastal Paleoindian groups, with sea crossings of at least 10 km.	11–10	Erlandson *et al.*, 1996; Johnson *et al.*, 2000; Orr, 1968
Southeast Alaska and British Columbia	Presence on islands indicates a maritime lifestyle and seafaring capabilities.	10–9	Davis, 1989; Fedje and Christensen, 1999

Note. Kyr = thousand years.

during various stages of human evolution, examining several key sites along the way. After reviewing such “direct” evidence for aquatic subsistence, I show that questions often remain about the cultural origin of the aquatic (and other) faunal remains found in such sites. Finally, I discuss some other lines of evidence for early aquatic adaptations, including early seafaring and maritime adaptations, sites submerged on continental shelves around the world, and the significance of pericoastal sites that indicate some use of coastal or other aquatic habitats or resources.

Old World Localities

For the Lower Paleolithic, relatively little is known about hominid subsistence. Preservation problems are especially serious for sites of such antiquity, and taphonomic issues related to the origin of faunal remains and their association with evidence for hominid activity are paramount. The earliest evidence for the possible use of aquatic resources by hominids comes from East African Rift Valley localities where the remains of a variety of aquatic or amphibious fauna have been found with stone tools between about 2.5 and 1.7 million years old (e.g., Auffenberg, 1981; Greenwood and Todd, 1970; Harris *et al.*, 1990; Leakey, 1971, 1994; Meylan, 1990; Stewart, 1994). Probably left primarily by *Homo habilis*, the contents of these lacustrine sites record the scavenging and foraging activities of early hominids, as well as the background noise of natural accumulation processes. Most researchers today believe the remains of large land mammals found at such sites were accumulated primarily via scavenging of animals killed by more efficient predators or other natural causes. Fernandez-Jalvo *et al.* (1999) have suggested, however, that some of the small mammals represented at such sites may have been hunted by hominids. Several early Rift Valley sites have also produced the bones of aquatic or amphibious animals, including hippos, crocodiles, fish, frogs, shellfish, etc. (Leakey, 1971). Because many of these sites formed in dynamic lakeshore settings, however, any clear association of aquatic (and terrestrial) fauna with hominid activities is difficult to demonstrate. At some sites, the remains of fish appear to be closely associated with hominid artifacts, but in others fish bones are relatively abundant in both cultural and natural strata. Greenwood and Todd (1970, p. 240) and Stewart (1994) have argued, however, that fish (especially the catfish, *Clarias sp.*) would have been relatively easy to procure in some Rift Valley aquatic settings and are unlikely to have been ignored by early hominids. This seems logical, especially for hominids living in lakeshore settings with economies based on opportunistic scavenging and foraging.

For *Homo erectus*, a series of East African sites has produced similar associations of artifacts and aquatic or amphibious fauna. At Olduvai, Leakey (1994) reported that the bones of catfish and hippos are ubiquitous in artifact-bearing sediments dated between about 1.1 and 0.4 million years ago, and the remains of crocodiles, aquatic turtles, and shellfish also are found in some sites. As was the case with much of the Olduvai fauna, Leakey (1994, p. 142) recognized the difficulty in determining whether these aquatic taxa were deposited by hominids, but she argued that a cultural origin for the catfish was most likely given their fragmentary condition and close association with artifacts (see also Auffenberg, 1981; Roe, 1994; Stewart, 1994). In Bed III at Olduvai, dated between about 1.1

and 0.8 million years ago, Leakey (1994; see also Roe, 1994) also found a series of distinctive pits and furrows possibly associated with the evaporative production of salt by *Homo erectus.*

Along the coastlines of Africa and the Middle East, there is also relatively widespread evidence for Lower Paleolithic occupation (e.g., Bar-Yosef, 1994, p. 214; Howe, 1967; Wulsin, 1941). Most of these localities are poorly dated, however, and contain choppers, hand axes, and other stone tools found in raised interglacial beach deposits. Although many of these clearly document the occupation of coastal plains, the precise age and environmental context (coastal, pericoastal, inland?) of such occupations is not clear.

What appears to be relatively unambiguous use of aquatic resources by *Homo erectus* in Southeast Asia comes from the site of Kao Pah Nam, a limestone cave in northern Thailand occupied about 700,000 years ago (Pope, 1989). According to Fagan (1990, p. 120), “considerable numbers” of freshwater oyster shells were found piled against the cave wall. In the same level, stone tools, a cobble-ringed hearth, and the remains of hippo, ox, deer, porcupine, and rat were found.

Evidence for aquatic resource use increases somewhat with the appearance of archaic *Homo sapiens* after about 400,000 years ago. It is not clear, however, whether this increase represents real behavioral or environmental shifts or the better preservation and greater visibility of more recent occupations. At the Lower Paleolithic site of Hoxne in England, Clactonian artifacts and faunal remains have been found in what have been interpreted as lakeshore and alluvial deposits (Singer *et al.*, 1993). Although the dating of the Hoxne occupations is still somewhat tentative, much of the Clactonian occupation appears to have occurred during an interglacial period between about 350,000 and 300,000 years ago. The associated fauna are dominated by large land mammals (especially horse and deer), but include numerous specimens of freshwater fish (pike, roach, stickleback, etc.) and beaver, and smaller numbers of otter and waterfowl (Stuart *et al.*, 1993). The cultural origin of the aquatic and other faunal remains, like those from the Olduvai sites, has not been firmly established, but Stuart *et al.* (1993, p. 198) noted

> that the distributions of all of the beaver *Castor fiber* and extinct beaver *Trogontherium cuvieri* material . . . and most of the fish material . . . follow the same broad distribution pattern as the larger bones, stones, and artifacts. This suggests that the remains of these taxa also might be food remains accumulated by man. . . .

Also in England, excavations at the Lower Paleolithic site of Clacton-on-Sea produced fish and freshwater mussel remains (Singer *et al.*, 1973), although the dating of the site (ca. 425,000 years (Singer *et al.*, 1993, p. 219) or ca. 250,000 (Gamble, 1986, p. 140)) and the cultural origin of the aquatic fauna remain uncertain.

About 300,000 years ago, archaic *Homo sapiens* also occupied Terra Amata along the Mediterranean coast of France (de Lumley, 1969; Villa, 1983). Mussels and other marine shells were found at Terra Amata, but their context and quantity are poorly documented. Other early Old World evidence for shellfish use comes from several North African Middle Paleolithic or Aterian sites like Haua Fteah in Libya (Klein and Scott, 1986; McBurney, 1967), Mugharet el'Aliya in Morocco (Howe, 1967), and several sites in Morocco and Algeria (Débéneth and Sbihi-Alaoui, 1979; Roche and Texier, 1976; Roubet, 1969; Souville, 1973). In southern Europe, Mousterian use of shellfish is suggested by assemblages from Monte Circeo (Stiner, 1994) and Grimaldi caves (Stiner, 1999) in Italy, Ramandils in France (Cleyet-Merle and Madelaine, 1995), and Devil's Tower Rockshelter (Garrod *et al.*, 1928), Gorham's Cave (Waechter, 1964), and Vanguard Cave (Barton *et al.*, 1999) in Gibraltar. At the Italian cave of Grotta Moscerini, marine shells with flaked edges suggest that shell tools were used by Neandertals between about 60,000 and 80,000 years ago (Stiner, 1994, pp. 187–188). For Neandertals and other archaic *Homo sapiens* living in coastal areas, there is little evidence for the exploitation of fish (but see Cleyet-Merle, 1990; Cleyet-Merle and Madelaine, 1995), and the exceptional cases may represent scavenging from the beach. Pinniped bones also are rare in Middle Paleolithic sites and may represent scavenging of stranded animals or carcasses. Nonetheless, there is little doubt that archaic *Homo sapiens* occupying the Mediterranean littoral actively foraged for shellfish and other intertidal resources (Stiner, 1994, p. 216).

With the appearance of anatomically modern humans (*Homo sapiens sapiens* or AMH), beginning about 125,000 years ago, Old World evidence for the use of aquatic resources increases dramatically. This disparity is even more pronounced if the Aterian sites of northwest Africa are considered to be associated with early or nearly modern *Homo sapiens sapiens* groups (see Klein, 1999). The earliest evidence for such associations may come from a recently reported locality near Abdur in Eritrea along the Red Sea coast, where what are described as Middle Stone Age (MSA) stone tools were found with the remains of marine shells and other aquatic fauna in strata dated to about 125,000 year ago (Stringer, 2000; Walter *et al.*, 2000). With the information currently available, however, it is not clear whether the stone artifacts were left by anatomically modern humans or if the faunal remains represent the food refuse of hominids. More secure and better-documented associations and evidence come from a series of MSA coastal sites in South Africa dating between about 120,000 and 50,000 years ago, including Klasies River Mouth caves (Deacon and Deacon, 1999, pp. 102–106; Singer and Wymer, 1982), Die Kelders cave (Marean *et al.*, 2000; Tankard and Schweitzer, 1974), the Sea Harvest and Hoodjies Punt sites near Saldanha Bay (Volman, 1978), Herolds Bay Cave (Brink and Deacon, 1982), the Boegoeberg 2 rockshelter (Klein, *et al.*, 1999b), and Blombos Cave (Henshilwood and Sealy, 1997). At these sites, the earliest evidence for relatively diversified coastal (or mixed) economies is found, including the relatively intensive use of shellfish, pinnipeds and cetaceans, and flightless seabirds (i.e., penguins). Fish remains are virtually absent from these coastal MSA localities (Klein and Cruz-Uribe, 2000), except for Blombos Cave where a significant number of large fish bones have been found in MSA shell midden strata associated with bone and stone projectile points (Henshilwood and Sealy, 1997). Initially estimated to be between about 50,000 and 60,000 years old, sediments capping the MSA levels at Blombos Cave have now been dated via thermoluminescence (TL) to approximately 100,000 years ago (Vogel *et al.*, 1999). The dearth of fish in most South African sites led Klein (1995, 1998) and Klein and Cruz-Uribe (2000) to suggest that fishing may have been beyond the intellectual or technological capabilities of early anatomically modern humans. It is possible, however, that the higher technological costs of marine fishing generally discouraged such activities, just as fishing seems to have been limited at most sites along the California coast during the early Holocene (Erlandson, 1994, but see Rick *et al.*, in press). Along with the Blombos Cave fish remains, support for this latter idea comes from the carefully made barbed bone harpoon points found with the remains of numerous large freshwater fish at two MSA sites at Katanda on the Semliki River in Zaire (Brooks *et al.*, 1995; Yellen, 1998; Yellen *et al.*, 1995). Dated to about 80,000 years ago, the Katanda harpoons represent the earliest evidence for complex composite fishing technologies in the world and add to the evidence for a significant expansion of aquatic resource use among anatomically modern humans.

Similar barbed bone points also have been found associated with numerous fish bones at the Late Stone Age site of Ishango 14 on Lake Rutingaze (Edward) in Zaire, in strata dated to about 20,000 radiocarbon years before present (RYBP) (Yellen, 1998). Fish bone is relatively abundant at some other Late Pleistocene African sites, including the White Paintings rockshelter in Botswana (Stewart, 1994; Yellen, 1998) where the lower levels are tentatively dated to ca. 20,000 years ago, and a series of Nile River sites dated between about 40,000 and 15,000 RYBP. In coastal areas, little is known about aquatic resource use during this time period because sea levels were deeply depressed during the Last Glacial and most African coastlines were far removed from sites now located along the modern shore (see van Andel, 1989).

This same interval in southwest Asia and Europe also is problematic due to lowering sea levels and extensive glaciation. Numerous Upper Paleolithic sites in southern and southwest Europe have produced evidence for shellfish collection and consumption. Shellfish densities increase in many of these sites near the end of the Pleistocene (e.g., Straus, 1990; Straus *et al.*, 1980, 1981), but it is not clear if this represents an intensification of shellfishing in response to population growth, increased sedentism, changes in marine or estuarine environments, or a combination of such processes (see Bailey, 1983a,b; Clark and Straus, 1983; Straus and Clark, 1983). Numerous interior or pericoastal Upper Paleolithic sites in Europe and southwest Asia also have produced beads or other ornaments made from marine shells or artistic depictions of aquatic animals (Cleyet-Merle and Madelaine, 1995; Clottes and Courtin, 1996; White, 1993). The presence of sizable numbers of marine shell ornaments, in some sites obtained from both Atlantic and Mediterranean coastlines more than 100 km distant, suggests that interior people traveled to the coast seasonally or actively traded with peoples living along these coasts.

In southern Asia, there is only limited evidence for aquatic resource use from this time period. In Indonesia, a freshwater shell midden known as Leang Burung attests to the systematic exploitation of shellfish as much as 31,000 RYBP (Glover, 1981). At Longrien, a long Upper Paleolithic sequence contains very limited evidence for aquatic resource use, but produced a few bivalves from a layer dated to about 30,000 RYBP. Despite the current dearth of evidence, there can be little doubt that maritime or other aquatic peoples lived in Southeast Asia since at least 50,000 years ago.

The peopling of Australia and New Guinea testifies to this, since migrating from Southeast Asia to Sahul would have required several substantial sea crossings even during periods of much lower sea level (Clark, 1991). Not surprisingly, early evidence for the use of freshwater fish and shellfish comes from Australia, which now appears to have been settled by maritime peoples between about 50,000 (Roberts *et al.*, 1990) and 60,000 years ago (Thorne *et al.*, 1999). Numerous freshwater shell middens from the Willandra Lakes area of southeast Australia have been radiocarbon dated between 38,000 and 15,000 RYBP; Thorne *et al.* (1999) recently argued that some of these lacustrine occupations may date to as much as 60,000 years ago. Although evidence for intensive marine resource use in late Pleistocene Australia is lacking, several sites from western Australia have produced limited amounts of marine shell from strata dated between about 20,000 and 36,000 RYBP (e.g., Bowdler, 1990; Morse, 1988; O'Connor, 1989; Veth, 1993). At Mandu Mandu Creek rockshelter, located only about 4–5 km from the coast just prior to the Last Glacial, a low-density midden deposit includes the remains of shellfish, crab, fish, and terrestrial fauna (Bowdler, 1990; Morse, 1988). These sites could be interpreted as evidence for limited Pleistocene use of marine resources, but sea level and shoreline reconstructions show a strong correlation between the presence and density of marine resources and the variable distance of each site from the sea. The apparent abandonment of most of the sites during the height of the last glacial, and the fact that they were reoccupied when sea levels again approached modern levels, can be interpreted as evidence that the lateral migration of coastal habitats strongly influenced local settlement and subsistence patterns. Several saltwater shell middens located on the Melanesian islands of New Ireland, New Britain, and the Solomons—islands that required additional sea voyages of 80–100 km to reach—have been dated between about 35,000 and 15,000 RYBP (Allen *et al.*, 1989a,b; Wickler and Spriggs, 1988). The aquatic focus of these early Melanesian occupations is attested to not just by the seafaring required to settle the islands, but also by the abundance of marine shellfish and fish remains found in the site deposits. The presence of such sites in western Melanesia, in contrast to Australia and New Guinea, is due to the steep local geography, where the bathymetry plunges rapidly into deep water and changes in sea level have had relatively limited effects on the local shorelines and the coastal archaeological record.

New World Localities

In the New World, most early evidence for human use of marine resources comes from the Pacific Coast, where relatively steep bathymetry also has limited the lateral displacement of postglacial shorelines (Erlandson, in press; Richardson, 1998). The earliest sites currently come from South America. In Chile, the controversial pericoastal site of Monte Verde has been dated to ca. 12,500 RYBP and reportedly contains evidence for coastal foraging, including four types of seaweed (Dillehay, 1997). At the coastal site of Querero, which has produced a suite of dates between about 11,600 and 10,900 RYBP, marine shellfish, sea lion, and whale remains were all found associated with those of mastodon, deer, and other land mammals (Nuñez *et al.*, 1994). At Quebrada de las Conchas on Chile's north coast, Llagostera (1979) also documented the existence of a diversified maritime economy including the use of a variety of shellfish and fish between about 9700 and 9400 RYBP.

Along the south coast of Peru, Sandweiss *et al.* (1998) reported an early component from Quebrada Jaguay, where shellfish, fish, and sea bird remains have been found in strata dated between about 11,100 and 9,900 RYBP. The faunal remains at Quebrada Jaguay suggest an almost exclusive reliance on marine animals, but the presence of obsidian from a distant interior source suggests that the site may be just one aspect of a seasonal round that included interior sites as well (see Richardson, 1998). Also located on the southern Peruvian coast, and nearly as old (10,800–10,500 RYBP), is Quebrada Tacahuay, where the faunal remains from the earliest occupation are dominated by sea bird (cormorant, booby, and pelican) and fish (anchoveta, anchovy) bones, with a few shellfish (clam, mussel) remains (Keefer *et al.*, 1998). Of the 3,775 faunal elements recovered from the basal stratum at Quebrada Tacahuay, only eight (0.2%) were from terrestrial taxa. A third site on the south coast, the Ring site, contains a shell midden that first may have been occupied as early as 10,600 RYBP (Sandweiss *et al.*, 1989). Along the north coast of Peru, Richardson (1998) has described several ephemeral camps of the Amotape complex, where unifacial tools have been found associated with the remains of mangrove shellfish (*Anadara tuberculosa*) dated to about 11,200, 10,000, 9200, and 9000 RYBP (see also Llagostera, 1992). In Ecuador, coastal shell middens of the Las Vegas complex are now dated as early as 10,800–10,100 RYBP (Richardson, 1998; Stothert, 1985).

The meticulous work of Roosevelt *et al.* (1996) on Paleoindian components at Pedra Pintada cave in Brazil dated to ca. 11,000 RYBP also shows that freshwater fish were an important component of an early Amazonian economy that was relatively eclectic and focused on smaller plant and animal resources.

Along the Pacific Coast of North America, the earliest and best-documented maritime sites currently come primarily from California. On San Miguel Island off the California coast, Daisy Cave contains a thin dark soil containing a few chipped stone artifacts and a low-density shell midden containing abalone, mussel, turban, and other shellfish remains dated to about 10,400 RYBP (Erlandson *et al.*, 1996). That humans were on California's Channel Islands by the end of the Pleistocene has long been suggested by Orr's ^{14}C dating of the Arlington "Man" (probably a woman) skeleton to ca. 10,000 RYBP (Orr, 1968). Recent redating of this skeleton suggests that Arlington Woman actually may have died closer to 11,000 RYBP (Johnson *et al.*, 2000), but a precise date has yet to be established. Since the Channel Islands have been separated from the California mainland throughout the Pleistocene, these two sites demonstrate that Paleoindian peoples had seaworthy boats during the terminal Pleistocene and leave little doubt about their maritime capabilities. Along the California coast, there are also dozens of shell middens dated between about 9,700 and 8,000 RYBP (Erlandson, 1994; Erlandson and Moss, 1996; Jones, 1991). One of the best examples comes from Daisy Cave, where stratified shell midden deposits dated between about 9,700 and 7,800 RYBP contain abundant shellfish and fish remains, smaller numbers of pinniped and sea bird remains, numerous bone fishing gorges and shell beads, and woven artifacts made from sea grass (Connolly *et al.*, 1995; Erlandson *et al.*, 1996).

Along the coastlines of northern California, Oregon, and Washington, there are only two shell middens reliably dated to about 8,000 RYBP, Duncan's Landing Rockshelter on the northern California coast and the Indian Sands site on the Oregon coast (Erlandson, 1994; Erlandson and Moss, 1996; Lightfoot, 1993; Moss and Erlandson, 1995). The dearth of early sites in this intermediate area of the Pacific Coast now appears to be related to a long history of occasional massive subsidence earthquakes along the Cascadia Subduction Zone, tectonic events commonly associated with tsunamis and severe marine erosion (Erlandson *et al.*, 1998; Minor and Grant, 1996). In British Columbia and southern Alaska, a number of early coastal sites dated between about 8,000 and 10,000 RYBP have been documented (Carlson, 1998; Erlandson and Moss, 1996; Fedje and Christensen, 1999; Moss, 1998), including portions of a human skeleton found in a cave known as 49-PET-408 (On-Your-Knees Cave) on Prince of Wales Island dated to approximately 9,200 RYBP (Dixon, 1999, p. 118). The isotopic composition of this skeleton is consistent with a diet comprised almost entirely of marine foods. A bone tool manufactured from a land mammal rib found in another part of the same cave has been dated to about 10,300 RYBP (Dixon, 1999, p. 181), suggesting that the site may have been occupied even earlier. This terminal Pleistocene date is similar to the estimated age of a basalt flake recovered from the surface of a paleodelta deposit located on the continental shelf off the Queen Charlotte Islands of British Columbia (Fedje and Christensen, 1999), although these early dates should be regarded as very preliminary.

Adjacent to the generally broader and shallower continental shelves of the Gulf of Mexico and Atlantic coasts, early coastal archaeological sites are much less common. On the Louisiana coast, where shorelines of the Mississippi delta have been prograding for millennia, Gagliano (1970) reported estuarine shell associated with an 11,000-year-old archaeological site at Avery Island. Off the Gulf Coast, near the intersection of a creek and the submerged channel of the Sabine River by the Louisiana and Texas border, Dunbar (1997) noted the presence of a submerged shell midden dated to about 8,500 RYBP that contains both burned and unburned fish bone.

Along the Atlantic Coast of North America, shell middens dating earlier than about 8,000 years are extremely rare. Along most of the Florida coast, for instance, the Clovis-age shoreline is believed to have been between about 50 and 150 km offshore (see Dunbar *et al.*, 1992, p. 125). Consequently, postglacial shoreline changes have been dramatic in most areas, Florida coast shell middens more than about 5,000 years old are highly unusual, and a number of submerged shell middens have been found. One exception to this pattern is the Cutler Ridge site, located adjacent to a narrow stretch of continental shelf near Miami, where lateral shoreline changes associated with postglacial sea level rise have been minimal. This important site, dated to as much as 9,600 RYBP but largely unpublished, reportedly has produced the remains of a variety of marine fish (tuna, shark, etc.) and shellfish (Dunbar, 1997).

Although interior Paleoindian groups are often portrayed as relatively specialized big-game hunters, there is evidence for the use of aquatic resources at a number of early sites. These include the Broken Mammoth site in south-central Alaska, where two well-stratified terminal Pleistocene components have been identified, one dating between about 11,800 and 11,000 RYBP and another between about 10,300 and 9,600 RYBP (Yesner, 1996). Faunal remains are well preserved in these early components. Identifiable elements from the older component are dominated (>60%) by aquatic birds (swan, geese, and ducks), but also include some large and small land mammals (wapiti, bison, etc.). The younger of these components is dominated by the remains of large ungulates, but also contains about 30% small mammals, 10% waterfowl, and smaller numbers of salmonid, beaver, and otter remains. Another Paleoindian component containing the remains of aquatic fauna is the Lewisville Clovis site located along the Trinity River in north-central Texas, where archaeological deposits associated with numerous hearths yielded a diverse array of plant and animal remains. Of the 16 hearths excavated, 9 contained the remains of freshwater mussel and snail shells—many of them burned. Also recovered were the remains of box turtle, fish, amphibians, prairie dog, rabbit, tortoise, egg shells, raccoon, snake, etc. (Story *et al.*, 1990). At the Horn Shelter 2 site located along the Brazos River, Clovis-age deposits also yielded the remains of land turtles and a few fish remains. A younger component at the site, dated between about 10,000 and 9,500 RYBP, also produced a diverse faunal assemblage, including the remains of many freshwater mussels and fish such as drum, gar, and catfish, along with a double human burial associated with numerous beads made from the marine shells *Oliva sayana* and *Neritina reclivita* (Story *et al.*, 1990, pp. 203–204). Another early North American site is a small rockshelter (CA-SIS-218) located on the shore of Tule Lake in northern California, where Beaton (1991) identified a hearth dated to 11,450 ± 340 RYBP associated with charcoal, ash, and fish, waterfowl, and mammal bones. At Marmes Rockshelter in Washington, freshwater mussels and salmon bones are reported from deposits dated between about 10,000 and 11,000 RYBP.

Shellfish Feeders and Carrion Eaters

Globally, the growing number of early sites known to contain the remains of shellfish, fish, sea birds, sea mammals, and other aquatic fauna may indicate that aquatic resources were used relatively early in human history, by *Homo habilis*, *H. erectus*, and *H. sapiens*. Due to a variety of questions about the context, taphonomy, recovery, and interpretation of many ancient faunal assemblages, however, it is difficult to evaluate how significant aquatic resources were in early hominid economies. Moreover, lists like those presented here suffer from another problem that must be addressed before we can conclude that even incidental use of aquatic resources was both early and widespread. This problem is the possible role various animals and other noncultural processes may have played in the accumulation of aquatic animal remains in early sites (see Butler, 1993; Erlandson and Moss, in press). Although recent taphonomic studies show that a wide range of scavengers and predators transport bones into caves and other sites, few have considered the possibility that animals and not humans may have transported marine shells, fish bones, or sea mammal remains into early coastal sites.

After visiting several Paleolithic cave sites in Gibraltar in the mid-1980s, I did not initially question whether the remains of marine shellfish and fish found in the site deposits (other than a clearly defined Last Interglacial beach) could have been deposited by anything other than humans. In her detailed taphonomic analysis of faunal remains from the Monte Circeo caves in Italy, Stiner (1994) considered a host of possible sources for animal bones but considered only cultural mechanisms for the accumulation of shellfish remains. Recent research has shown, however, that a wide range of predators and scavengers—bears, hyenas, coyotes, badgers, cats, and a variety of birds—transport the remains of aquatic vertebrates (seals, fish, birds, etc.) and invertebrates (shellfish, etc.) to terrestrial landforms (e.g., Erlandson and Moss, in press; Jones and Allen, 1978; Klein *et al.*, 1999b). Caves and rockshelters, in particular, provide shelter for a wide variety of mammals and birds that hunt or scavenge in aquatic habitats and may deposit carcasses or skeletal remains at site locations where they can be mixed with faunal remains left by hominids. Archaeologists, therefore, must carefully evaluate the nature of terrestrial and aquatic faunal remains found in both cave and open sites to determine whether the activity of nonhuman predators or scavengers has contributed significantly to the faunal remains present at a site.

Unfortunately, such careful evaluations have rarely been done, and it is either difficult or impossible to evaluate the cultural origin of the aquatic fauna in many of the sites listed in Tables I and II. With a more critical eye toward the origin of aquatic remains in early sites, the evidence for early aquatic resource use at some key localities may need to be reassessed. Gorham's Cave produced hundreds of marine shells, for instance, but my observations suggest that these were widely scattered in the cave deposits. Gorham's Cave also produced the remains of a wide variety of birds, including seagulls and others known to feed on and transport shellfish (Erlandson and Moss, in press). Without further evidence to link these aquatic fauna to cultural activities, we cannot be certain how significant aquatic foods were to the Neandertal and Upper Paleolithic cave occupants (but see Barton *et al.*, 1999). At present, similar questions can be raised about virtually all of the Lower Paleolithic sites listed above, as well as the Mugharet el'Aliya in Morocco where monk seal, fish, and shellfish remains were found in Paleolithic layers (Arambourg, 1967; Howe, 1967). In the New World, similar questions have been raised about some Pleistocene or Early Holocene "shell middens" located on California's northern Channel Islands (e.g., Erlandson, 1994, pp. 183, 196; Erlandson and Morris, 1992; Erlandson and Moss, in press).

For other sites, the Middle Stone Age middens of South Africa prominent among them (but see Klein *et al.*, 1999a,b), the evidence linking hominids with aquatic resource use seems much more secure. In the Mousterian levels at Devil's Tower, for instance, Garrod *et al.* (1928, p. 42) described "thick layers" and a "large heap" of shells associated with hearths. At Grotta Moscerini in Italy, Stiner (1994, pp. 181–184) found that a significant percentage of the marine shells was burned, suggesting that they too were deliberately collected by Neandertals. Other Old World examples include many of the freshwater shell middens of Willandra Lakes in Australia and the Pleistocene middens of Melanesia (Allen *et al.*, 1989a,b; Wickler and Spriggs, 1988). In the New World, there seems to be little question about the predominantly cultural origin of the aquatic fauna found at most of the open air middens along the Pacific Coast. Early components at Daisy Cave, Broken Mammoth, and Lewisville also seem relatively secure.

The Distribution of Early Coastal Localities

Even allowing for such uncertainties about the origin of aquatic faunal remains—often even more serious for the remains of terrestrial fauna found at early sites—a significant number of Paleolithic localities with secure evidence for systematic early aquatic resource use are now relatively well documented. The spatial and temporal distribution of these early sites, particularly the coastal examples, is of special interest. Yesner (1987, 1998, p. 205) suggested, for instance, that such sites are exceptional and are located in areas of upwelling and unusually high marine productivity. Thus such early coastal sites are often viewed as rare examples of relatively intensive aquatic resource use in a Pleistocene world otherwise dominated by terrestrial economies.

This association holds for some early coastal localities, but it does not explain the evidence for early marine resource use at several early Mediterranean sites in Italy, Lebanon, Libya, and Algeria (see Klein and Scott, 1986; McBurney, 1967; Stiner, 1994), where marine productivity is comparatively low by global standards. My own comparison of the distribution of early coastal sites leads to a different conclusion. While a number of early sites are found in areas of intense upwelling (Peru, California, Gibraltar, etc.), many others are not. Comparing the distribution of coastal sites to various physical and biological characteristics in an atlas of the world's oceans (Couper, 1989), I found no clear correlation with intensive marine upwelling, exceptional primary (phytoplankton) or secondary (zooplankton) productivity, sea temperature, salinity, latitude, tidal range, tectonics or vulcanism, marine habitat, or terrestrial habitat. In fact, relatively early sites are found in areas of coral reefs, temperate seas, and even arctic or subarctic coasts (by 8,000–10,000 years ago). They are found adjacent to tundra environments, boreal forests, savanna, chaparral, and hyperarid landscapes, including some where contemporary interior sites contain relatively abundant remains of large terrestrial game.

I found only one trait that seems to link the early coastal localities: steep bathymetry. From California to Florida and from Melanesia to the Mediterranean, all the early sites are located along relatively steep shorelines where the offshore topography drops off rapidly. The opposite also holds true, with areas of broad and shallow continental shelves generally producing only relatively recent evidence for marine resource use, regardless of the intensity of marine upwelling. This is due to the simple fact, clearly demonstrated by several elegant studies (e.g., Parkington, 1981; Shackleton *et al.*, 1984), that most localities situated along modern coastlines were far removed from coastal habitats during most of the last 250,000 years and more. Studies of historical foragers in coastal habitats have shown that the skeletal remains of edible aquatic animals are rarely transported to residential sites more than about 10 km from the coast (Bigalke, 1973; Meehan, 1982), except for those that have ornamental or other utilitarian value. Where shorelines are steep, however, sites still preserved above sea level may sometimes be found within the foraging radius of ancient coastal habitats. The occupants of sites located along shallow continental shelves, on the other hand, may only have had access to marine resources for the last 5,000–8,000 years, as local sea levels and shorelines approached the modern condition.

This general bathymetric correlation (which I call Richardson's Rule)—in which steep shorelines are associated with relatively early evidence for marine resource use, while shallow shelves yield relatively recent evidence—is a much stronger predictor of the location of early coastal sites than upwelling or any of the other aquatic or terrestrial traits I examined. Furthermore, Richardson's Rule helps explain some puzzling anomalies. It explains, for instance, why early coastal sites are much more common along the generally steep Pacific Coast versus the relatively shallow Atlantic Coast of the United States. It explains why along the Peruvian coast, all of which is characterized by upwelling and high marine productivity, the earliest coastal sites are differentially distributed in areas of relatively steep bathymetry (Richardson, 1998). Finally, it helps explain why along most of the Florida coast, where beaches were as much as 100 km offshore about 14,000 years ago, the modern shoreline has produced evidence for maritime adaptations no more than about 5,000 years old, except for the steeply plunging shorelines near Miami where the Cutler Ridge site contains evidence for marine fishing and other coastal foraging dated to about 9,600 RYBP.

The correlation between steep bathymetry and the location of early coastal sites also seems to contradict two tenets of traditional theories about maritime adaptations, (1) that steep bathymetry, which generally limits the extent of intertidal and nearshore habitats, reduces the productivity of such marine environments and renders them relatively unattractive to humans; and (2) widespread maritime adaptations only developed in the Holocene after sea level stabilization led to the development of relatively broad, shallow, and productive nearshore habitats. My analysis of the distribution of early coastal localities suggests that many coastal habitats are more productive than previously envisioned, that Pleistocene maritime adaptations were more widespread than previously thought, and that the archaeological record for the antiquity of coastal adaptations is fundamentally biased in most parts of the world.

The Antiquity of Seafaring

Further support for this viewpoint comes from recent evidence for a relatively early development of seafaring in several parts of the world, including evidence for Pleistocene maritime voyaging in areas where the oldest coastal shell middens date to the Holocene. For decades, the idea that our Pleistocene ancestors may have made substantial migrations by boat suffered from the same theories that marginalized maritime adaptations in general and argued that our ancestors were relatively unsophisticated technologically. There is little question that hominids must have crossed rivers and other short water barriers in spreading out of Africa and through Eurasia. Prior to 1980, however, there was virtual unanimity that boats were a very recent addition to human technologies (e.g., Bass, 1972; Greenhill, 1976; Johnstone, 1980, p. xv). Due to preservation problems, evidence for the earliest use of boats—as opposed to simple logs or floats that allowed hominids to cross small water barriers while partly submerged—remains lost in obscurity, depending primarily on indirect evidence for the colonization of island groups (Table III). Except for the long-distance voyaging evident among Austronesian and other peoples in the last 5,000 years or so, such evidence requires the presence of not-too-distant islands that have been separated from continental land masses in recent geological times, criteria many regions of the world cannot meet.

Archaeologists have long argued inconclusively both for and against the idea that *Homo erectus* was capable of making the relatively short crossing (<20 km) of the Straits of Gibraltar from Morocco to the Iberian Peninsula (see Cachel and Harris, 1998; Rolland, 1998). As evidence accumulates for a relatively long isolation of Neandertals in western Europe (e.g., Krings *et al.*, 1997), however, it seems increasingly unlikely that archaic *Homo sapiens* had the capability to routinely cross the potentially hazardous Straits of Gibraltar. Elsewhere in the Mediterranean, there is limited but more convincing evidence for occasional island exploration by Neandertals (Cherry, 1990). For Southeast Asia, recent evidence may indicate that *Homo erectus* reached the Indonesian island of Flores as much as 700,000–800,000 years ago (Morwood *et al.*, 1998, 1999; Sondaar *et al.*, 1994), and Bednarik (1998) and Bednarik *et al.* (1999) proposed that relatively sophisticated seafaring and maritime adaptations date back a million years or more. So far, however, there is little evidence for any systematic use of seaworthy watercraft by *Homo erectus* or archaic *Homo sapiens*, and their voyaging capabilities appear more likely to have been relatively rudimentary.

Evidence for Pleistocene seafaring by anatomically modern humans is much more compelling and more widespread, involving the dispersal of hominids across a number of unequivocal and substantial water barriers (Clark, 1991; Erlandson, in press; Irwin, 1992). Evidence for systematic and sophisticated Pleistocene voyaging comes primarily from eastern Asia, Australia, and Melanesia, where voyages in excess of 20–200 km have now been widely documented between at least 50,000 and 15,000 years ago. The proof that seafaring extended well back into the Pleistocene requires a fundamental paradigm shift, not yet fully realized, since maritime voyaging was once thought to be strictly a Holocene phenomenon. By the 1970s, terminal Pleistocene seafaring had been documented by the presence of obsidian from the Mediterranean island of Melos in strata at Franchthi Cave in mainland Greece dated to as early as 13,000 RYBP (Cherry, 1990). The antiquity of seafaring was extended with the discovery that humans had reached Australia by 20,000 years ago (Lampert, 1971), a date rapidly pushed back to 33,000 years ago (Bowler *et al.*, 1970), 40,000 years ago (Groube *et al.*, 1986), and now as much as 50,000–60,000 years ago (Roberts *et al.*, 1990; Thorne *et al.*, 1999). Regardless of the route chosen, colonization of New Guinea and Australia required several separate sea crossings, including voyages of at least 80 km (Clark, 1991; Irwin, 1992). As a result, the colonization of Australia is now widely viewed as the earliest evidence for planned maritime voyaging in human history and possibly some of the earliest evidence for anatomically modern human behavior anywhere in the world (Davidson and Noble, 1992).

For a time, two puzzling facts allowed some scholars to believe the Pleistocene colonization of Australia may have been accomplished by accident. First, in historic times Australian Aborigines reportedly had no sophisticated watercraft capable of making substantial sea crossings (Flood, 1990, p. 36), which raised questions about their ability to travel through island Southeast Asia by boat. Like much of the rest of the world, Australia also had no true coastal shell middens or other direct evidence for maritime adaptations dating to the Pleistocene. In fact, the vast majority of such sites were less than about 5,000–6,000 years old.

With the discovery in the late 1980s of several Pleistocene shell middens in the Bismarck Archipelago and the Solomon Islands in western Melanesia (see Allen *et al.*, 1989a,b; Wickler and Spriggs, 1988), any doubts about the role of deliberate maritime voyaging in the peopling of Australia essentially vanished. Settlement of these islands, now dated to at least 35,000 RYBP (Allen and Kershaw, 1996, p. 185), added several significant maritime crossings to those already required to reach Australia and New Guinea. More importantly, these islands contain relatively impoverished terrestrial flora and fauna, and the sites themselves contained the marine shellfish, fish, and other remains expected of a maritime people. The Melanesian evidence also suggests that maritime voyaging capabilities improved significantly between about 35,000 and 15,000 years ago. While the initial settlement of New Guinea, New Britain, and New Ireland required voyages of up to 100 km, colonization of Buka in the Solomon Islands at least 28,000 years ago required a minimum sea voyage of 140 km and possibly 175 km (Irwin, 1992, p. 20). By 15,000 years ago, moreover, Melanesian seafarers had reached Manus Island in the Admiralty group, which required an uninterrupted voyage of 200–220 km, 60–90 km of which would have been completely out of sight of land (Irwin, 1992, p. 21).

Further evidence for Pleistocene seafaring comes from the islands of Japan. Japan itself was connected to the Asian mainland during periods of very low sea level, so its settlement did not necessarily require boats. Fagan (1990, p. 191) argued, however, that new blade and edge-grinding technologies introduced about 30,000 years ago when Japan was separated from the mainland probably involved maritime contacts. This idea may be supported by the discovery of human bones beneath a charcoal-rich stratum in Yamashita-cho Cave on Okinawa dated to about 32,100 RYBP (Matsu'ura, 1996, p. 186). Human remains dated between about 15,000 and 26,000 RYBP also have been found in several other limestone caves on Okinawa and the smaller islands of the Ryukyu chain (Matsu'ura, 1996), which stretches southward from Japan nearly to Taiwan. At Pinza-abu Cave on Miyako Island, human remains found below a calcareous flowstone were associated with charcoal dated to about 26,000 RYBP (Matsu'ura, 1996, p. 187). Given the bathymetry of the Ryukyu Islands, several sea voyages would have been required to reach Okinawa from Japan, including a crossing about 75 km long. Reaching Miyako Island, from either Japan or Taiwan, would have required even longer voyages of up to 150 km. In Japan itself, archaeological evidence suggests that by about 21,000 RYBP, maritime peoples from Honshu were using boats to obtain obsidian from Kozushima Island approximately 50 km offshore (Oda, 1990). Similar to Australia, despite considerable evidence for Pleistocene seafaring, the oldest shell middens in Japan date to the Holocene (Aikens and Akazawa, 1996, p. 224; see also Aikens and Higuchi, 1982). It seems likely, therefore, that earlier coastal sites have been submerged by rising sea levels.

The evidence for Pleistocene seafaring in Japan is also significant because it places competent mariners in the cool waters and boreal climates of the North Pacific at a date early enough to have contributed to the initial colonization of the Americas (Engelbrecht and Seyfert, 1995; Erlandson, 1994, in press). From Japan, the Kurile Islands stretch to the northeast like stepping stones to the Kamchatka Peninsula and the southern shores of Beringia. With the now well-documented Pleistocene seafaring capabilities of *Homo sapiens sapiens,* the presence of Pleistocene seafarers in Japan, and the geography of the North Pacific, maritime peoples appear to have had the capabilities to follow a coastal pathway to the Americas. Whether they made such a journey is still unknown, and the evidence that could resolve the issue—like so many questions related to the evolution of maritime adaptations—lies largely unstudied and submerged on the continental shelves of the North Pacific.

Other Evidence for Early Aquatic Adaptations

Two other sources of data need to be considered in any comprehensive evaluation of the antiquity of aquatic adaptations: the archaeological record from submerged or “drowned” terrestrial sites, and the nature of pericoastal sites that show limited evidence for marine or estuarine resource use. Although a detailed examination of either topic is beyond the scope of this paper, it would be a mistake not to consider such evidence at all.

Submerged Terrestrial Sites

Scholars have long known that human occupation sites lie submerged on continental shelves around the world (see Negris, 1904; Smyth, 1854) and that these may fundamentally bias our understanding of the development of aquatic adaptations (e.g., Emery and Edwards, 1966; Flemming, 1998, p. 130; Kraft *et al.*, 1983; Richardson, 1981; Shepard, 1964). What to do with such knowledge, however, raises fundamental problems. We must be governed by some rules of evidence, after all, and simply assuming that ancient shell middens lie submerged off coastlines around the world and that coastal adaptations have always been a part of the human story leaves many scholars with a very uncomfortable feeling. On the other hand, assuming that the archaeological record is representative in the face of clear evidence to the contrary is equally problematic. The obvious solution is to examine submerged coastal landscapes for the presence or absence of submerged shell middens or other evidence for early aquatic resource use.

Unfortunately, this is not as easy as it sounds, and such programs have been limited so far. During marine transgressions, the submergence of most terrestrial sites would have been accompanied by their essential destruction. Just as it is destroying countless coastal sites around the world today, wave erosion would have redeposited most older sites into the intertidal zone, leaving only lag deposits on wave-cut platforms such as the Lower Paleolithic localities documented on Old World marine terraces. Along the predominantly erosional outer coasts around the world, intact submerged sites would be preserved only in special situations where local landforms are protected by offshore islands, archaeological deposits are cemented or sealed under erosion-resistant strata, or earthquakes caused a rapid subsidence of sites into the intertidal or subtidal zone. In estuarine or lacustrine settings, where wave energy and shoreline erosion are generally less severe, the potential for the preservation of submerged sites is considerably better (Flemming, 1983, 1998). Even in these settings, however, relatively little archaeological work has been accomplished on submerged terrestrial sites (but see Fischer, 1995b; Masters and Flemming, 1983). Due to technological and financial constraints, moreover, the work that has been done has been limited primarily to sites found comparatively close to shore and in relatively shallow water. Because sea levels have risen up to 150 m in the past 17,000 years, these limitations have so far prevented effective undersea reconnaissance along shorelines more than about 10,000–12,000 years old.

Nonetheless, impressive numbers of submerged coastal sites have been found, and the number of sites is rapidly growing (see Fischer, 1995b; Flemming, 1998). In a recent summary, Flemming (1998, p. 129) noted that roughly 550 submerged human occupation sites (SHOS) have been located in coastal settings around the world, about 100 of which are older than 3,000 years. These include Acheulian hand axes found in sediments underlying a historical shipwreck 8 m below sea level off the South African coast and thousands of Mousterian artifacts eroding from a creek bank submerged 18 m below sea level near Cherbourg on the Atlantic coast of France (Flemming, 1998, pp. 135–136). Elsewhere, numerous submerged sites dating to the middle and early Holocene are now known, and artifacts of Pleistocene age also have been recovered from the sea floor (e.g., Dunbar *et al.*, 1992; Faught *et al.*, 1992; Fedje and Christenson, 1999; Flemming, 1983, 1998; Sanger, 1995; Stright, 1990). In a number of protected coastal areas, submerged sites that contain evidence for aquatic adaptations have been found. Some of these submerged sites feature remarkable preservation, as shown by the intact structural remains, human burials, canoes, canoe paddles, hearths, and other materials recovered from early Holocene sites such as Tybrind Vig in Denmark (Andersen, 1985, 1987) and Newe Yam off the coast of Israel (Raban, 1983; Wreschner, 1983).

One of the earliest submerged sites, and surely one of the most remarkable, is the Upper Paleolithic Cosquer Cave discovered in 1991 on the Mediterranean coast of France (Clottes *et al.*, 1992; Clottes and Courtin, 1996). Cosquer Cave is a partly submerged limestone cavern, the small mouth of which lies 37 m below sea level. A narrow and gradually rising shaft extends for approximately 140 m before opening into a large cavern, only parts of which remain above sea level. Over 250 engraved or painted motifs have been documented in the unflooded remnants of the cavern, and radiocarbon dates indicate that these were executed primarily during two periods about 27,000 and 18,500 RYBP (Clottes and Courtin, 1996). Upper Paleolithic artistic representations of marine animals are rare in Europe, but at Cosquer they make up about 12% of the animal images and include depictions of seals, the great auk (*Pinguinus impennis*), and possibly fish and jellyfish. Although the cave appears to have been located more than 10 km from the sea during the height of the Last Glacial, these images testify to the significance of marine animals to the artists. As Clottes and Courtin (1996, pp. 44–45) noted, several Upper Paleolithic skeletons excavated in the late 1800s from the Grimaldi Caves about 150 km to the east were associated with hundreds of marine shell ornaments, also testifying to the symbolic importance of the sea among Upper Paleolithic people of the area.

Clearly, submerged terrestrial sites do exist and may be preserved under the right conditions. The questions that remain are whether such submerged coastal sites represent the proverbial tip of the iceberg or isolated cases, whether even earlier coastal sites lie offshore in deeper water, and whether such sites can be found and sampled to help unravel some of the mysteries that remain about the role of the sea in human history.

Pericoastal Sites

Like Cosquer Cave and the Grimaldi Caves, there are scores of Pleistocene sites around the world that are located in pericoastal or even interior settings that lack dense accumulations of aquatic food remains, but nonetheless testify to linkages to aquatic habitats. These include numerous coastal sites listed in Table I, which at various times in their occupational histories appear to have been located some distance from the coast. In a number of well-dated sites with detailed paleogeographic reconstructions, these periods seem to correlate with reduced densities of marine food remains, the presence of strictly ornamental or utilitarian objects (shell beads, baler shells, etc.), a complete reliance on terrestrial foods, or site abandonment. For a number of other sites, less well documented or located further from aquatic habitats, such relationships are not as clear. Sites that contain small amounts of aquatic food remains can be viewed as evidence that aquatic resources were relatively unimportant, as part of a seasonal round that included residential periods on the coast, of exchange with more maritime people living closer to the coast, or some combination of such inferences. A similar range of arguments has been made for interior sites in Upper Paleolithic Europe where marine shell ornaments are found far from the coast. Such sites clearly indicate some economic or ritualized use of aquatic resources, but their significance can be argued depending on the theoretical stance of individual investigators.

In this regard, I find the Australian case particularly compelling, where several pericoastal sites (Mandu Mandu, Shark Bay, etc.) more than 30,000 years old contain small numbers of shells, often ornamental or utilitarian types traded between interior and coastal groups ethnographically. It is currently impossible to know for certain whether these shells are evidence that early terrestrially adapted Australians occasionally visited the coast, that coastal people occasionally visited the interior, or that they represent the exchange of goods between discrete groups residing separately in coastal and interior areas. How can a continent like Australia, which we now know was colonized by boat at least 50,000 years ago, have so few early coastal sites? Did maritime peoples reach Australia then abandon its coastlines in favor of more productive terrestrial habitats and resources for tens of thousands of years? If so, how do we account for the evidence for the systematic use of shellfish and fish in the Willandra Lakes area at least 40,000 years ago? Why do we see further evidence for maritime voyaging into western Melanesia by 35,000–40,000 years ago? To me, it seems most likely that the early pericoastal sites in Australia are the remnants of inland settlement and subsistence by coastally adapted Pleistocene peoples whose main settlements were submerged or destroyed by rising postglacial seas.

DISCUSSION

To some, none of the individual lines of evidence I have examined may provide a compelling argument for the early development of aquatic adaptations. When the theoretical and methodological issues I have raised are combined with current knowledge about world sea levels and coastal paleogeography, as well as a variety of lines of archaeological evidence, I believe there are compelling reasons to doubt the veracity of the current consensus model. Comparatively speaking, it is still true that there is only limited evidence for the intensive use of aquatic resources prior to the end of the Pleistocene. This is not surprising in the New World, which appears to have been colonized near the end of the Pleistocene when sea levels were much lower than they are today. Even on a global scale, however, it is not clear that this pattern accurately reflects changes in human subsistence through time. To understand the history of aquatic adaptations, globally or in any particular region, we must first determine if the patterns evident in the archaeological record result from actual changes in human behavior, patterns imposed by geological or taphonomic forces, or the recovery and analytical methods of archaeologists themselves. Unfortunately, except for areas first occupied by humans relatively recently (i.e., Polynesia), such evaluations are fraught with difficulty and have rarely been done in a manner that inspires confidence in the results.

A New World Test Case

It is possible, however, to return to some of the fundamental tenets of recent theory about aquatic adaptations and examine them in light of current archaeological data from the New World. If shellfish and other aquatic foods are generally smaller and less productive than terrestrial alternatives—and their systematic use reflects demographic pressure, resource stress, or economic intensification—then the antiquity of coastal adaptations in the Americas should provide an excellent test case. Traditional theory, including many recent applications of diet breadth-prey ranking models, suggests that until population growth produced sufficient demographic pressure to reduce the productivity of "high-ranked" terrestrial game, aquatic resources would not be systematically used. Thus the relatively recent peopling of two vast continents with highly diverse and productive terrestrial landscapes, especially by small hunter-gatherer groups generally thought to have migrated through an interior route into the heart of North America, should show little evidence for marine resource use or even coastal settlement until quite recently. If aquatic resources are not necessarily marginal, then we should find relatively early evidence for their use, at least in areas where the economics of aquatic resource use compare favorably to those available in adjacent terrestrial habitats.

To adequately evaluate the evidence, of course, we need to know when humans first settled the Americas and whether the archaeological record is representative of the full range of early adaptations, especially in coastal zones. At present, we cannot answer either question with any certainty. In 1977, Osborn used a regional analysis of the Peruvian archaeological record to argue that marine resources were inferior in the arid western slopes of the Andes. When Osborn (1977a) evaluated the Peruvian evidence, he believed there was a lag between the earliest interior versus coastal occupation equal to more than half of the total cultural sequence for the region, well over 12,000 years. This apparent gap was explained by proposing that the earliest occupants of the region did not systematically use marine resources until their population densities had effectively reached the carrying capacity of the terrestrial environment. Thus the Andean coast—one of the richest marine environments on earth—was characterized as an environment marginal for human occupation.

In retrospect, we now know Osborn's analysis had significant problems (see Erlandson, 1988; Perlman, 1980; Quilter and Stocker, 1983; Yesner, 1980). First, he assumed the Andean archaeological record was representative, based on the now disproved claim that tectonic uplift of the Peruvian landscape had outpaced sea level rise since the last glacial. Second, he assumed that the regional demographic clock began with initial human occupation of the Andean uplands at least 23,000 years ago, based on claims by MacNeish (1971) for the presence of "artifacts" (made from the same rock as the cave walls) in the lower levels of Pikimachay (Flea) Cave. Even today, with the "Clovis barrier" seemingly broken, few scholars accept the dubious evidence for pre-Clovis occupation at Flea Cave (e.g., Dixon, 1999, pp. 100–101).

Today, the earliest widely accepted (there are still doubters) Andean archaeological site is Monte Verde (Dillehay, 1997), which appears to date to about 12,500 RYBP. Monte Verde is located in a valley roughly 30 km from the coast of Chile. While there is evidence that big game was hunted from the site, there is also evidence for a relatively eclectic economy in which plants and smaller resources played a significant role. The presence of seaweed also suggests that the site occupants had links to the coast. Recent research also has pushed back the earliest occupation of the Andean coast to approximately 11,200–10,500 RYBP (Keefer *et al.*, 1998; Richardson, 1998; Sandweiss *et al.*, 1998), and the earliest site, Quebrada Jaguay, shows interior links (Sandweiss *et al.*, 1998) that may represent the opposite end of a seasonal subsistence round represented at Monte Verde. If we accept that Monte Verde is one of the earliest sites in the Andes (which seems likely) and assume that its occupants had no coastal neighbors and used few aquatic resources themselves (which seems less likely), the age differential between the earliest coastal versus interior settlements has withered to less than 2,000 years. This might be enough time for terrestrial foragers to shift to a partly littoral or maritime focus, but it seems highly unlikely that a shift to marine resources about 11,000 years ago was due to demographic pressure on the vast Andean landscape.

In North America, the situation is very similar, with increasing evidence for early coastal settlement and use of marine and other aquatic resources. The presence of people on California's Channel Islands 10,500–11,000 years ago (Erlandson *et al.*, 1996; Johnson *et al.*, 2000; Orr, 1968), for instance, is extremely difficult to account for as a response to human pressure on the highly productive and diverse terrestrial resources of the adjacent mainland. The earliest people of the Channel Islands, moreover, seem to have subsisted primarily on shellfish, small fish, plant foods, and occasional seals or sea lions. There is currently no evidence that they were big-game hunters drawn to the islands by pygmy mammoths or massive elephant seals. Rather, they seem to have been eclectic foragers who relied on a variety of resources, including abalones, mussels, small turban snails, and a variety of small fish. The very presence of such people on the islands at this early date suggests that shellfish, fish, and other marine resources were highly ranked, highly regarded, and highly relied on. Along the Atlantic and Gulf coasts of North America, the evidence for early coastal adaptations is neither as early nor as widespread, but in these areas the presence of submerged sites and Paleoindian artifacts on the continental shelves indicates that we are missing early components of the coastal archaeological record.

To me, the available data suggest that marine and other aquatic resources were an integral part of many early New World economies, that their significance has been underemphasized in previous models, and that their presence in archaeological sites does not necessarily indicate the existence of environmental deterioration, population pressure, resource stress, or economic intensification. I am not suggesting—as many have done for large land mammals and other terrestrial resources—that aquatic resources were universally productive. Nor am I arguing that the use of aquatic resources was not, at times, associated with resource stress and economic intensification. What I am suggesting is that, in the New World and the Old World, the factors that govern human decisions about what resources will be used, when, and by whom are highly complex and situational. Recognizing this complexity, the diversity of environments (terrestrial and aquatic) encountered by our ancestors, and the flexibility and opportunism of hunter-gatherers, I believe global or universal statements about the productivity of aquatic resources do not do justice to the diversity and complexity that we should expect of the archaeological record.

SUMMARY AND CONCLUSIONS

I began this paper by suggesting that general conceptions of the history and nature of aquatic adaptations have marginalized the study of coastal, riverine, and lacustrine societies, relegating them to the last 1% of human history. The view that aquatic resources are marginal and that aquatic adaptations developed relatively recently renders their study essentially peripheral to many of the most compelling issues addressed by archaeologists: human evolution, early hominid migrations, the appearance of anatomically modern humans, peopling of the Americas, the development of agriculture, the rise of civilization, and others. I also argued that a variety of taphonomic processes, epistemological issues, methodological problems, and data gaps raise serious questions about assertions that widespread and systematic aquatic adaptations developed only since the end of the last glacial. Specifically, I suggested that

1. postglacial sea level rise has submerged most of the shorelines older than about 10,000 years along which the evidence for earlier coastal occupations would logically be found;
2. differential preservation, recovery, or reporting of site constituents has selectively underemphasized the importance of aquatic resource use in archaeological sites around the world;
3. traditional models of hunter-gatherer behavior have overemphasized the role of hunting in general, and large land mammal hunting in particular, in many ancient societies;
4. normative cultural ecological reconstructions have too often treated human societies as aggregations of generic individuals rather than groups of diverse people (men, women, and children; young and old, rich and poor, etc.) who often were engaged in different activities;
5. prior to the development of relatively effective hunting technologies, hominids relied to a significant extent on scavenging behavior that would have increased the relative productivity of and reliance on aquatic resources that required no specialized technologies to obtain or process;
6. our hominid ancestors have always, with rare exceptions dictated by unusual environmental conditions, been highly opportunistic and relatively eclectic omnivores, an economic orientation fundamental to our extraordinary success in colonizing virtually every habitable land and seascape on earth.

With these issues in mind, I reviewed the evidence for early aquatic resource use in archaeological sites around the world, focusing on Old World sites dating earlier than about 15,000 years ago and New World sites more than 8,000 years old. I concluded that a variety of unresolved problems continue to prevent us from determining when aquatic adaptations developed, how widespread they were, and how important they were in the broad scheme of human evolution. Some of the earliest archaeological localities associated with *Homo habilis* and *Homo erectus* in Africa contain the remains of aquatic or amphibious animals such as fish, crocodiles, molluscs, and hippos, as do some early European sites associated with late *Homo erectus* or early archaic *Homo sapiens* populations. Although the distribution of fish and other aquatic remains in some of these early sites coincides closely with artifacts and other faunal remains, the cultural origin of the faunal remains (aquatic and terrestrial) and their nature (scavenged or hunted) are difficult to prove. Less equivocal evidence for the use of shellfish by *Homo erectus* and archaic *Homo sapiens* also is found at several Old World sites. There is no doubt that these hominids occupied coastal and other aquatic habitats and little reason to doubt that aquatic resources were used by them at least occasionally. At present, the intensity of such use remains unknown, just as the overall nature of Lower Paleolithic subsistence remains largely obscure.

Hominids clearly crossed aquatic hurdles in spreading out of Africa and through much of Eurasia, indicating that rivers and even some straits were not necessarily the physical or psychological barriers sometimes imagined. Prior to the appearance of anatomically modern humans, however, the use of aquatic resources may have been limited largely to shellfish and occasional "low-tech" uses of fish, birds, mammals, and other resources that could be collected without specialized technologies. Only with the appearance of anatomically modern humans do we find the evidence for a more intensive use of shellfish and a wider range of marine or aquatic resources. Not surprisingly, this economic diversification coincides with the first evidence for the development of a number of "modern" or transitional technologies, including the earliest relatively intensive use of chipped stone blade and geometric or microlithic industries, the first formal bone tools, the earliest widespread evidence for the use of red ochre, and probably the first use of relatively sophisticated boats. In the context of such transitional Middle Stone Age technologies at Klasies River Mouth caves, Die Kelders, and other Last Interglacial localities in South Africa, for instance, AMH appear to have regularly eaten a variety of shellfish, marine mammals, and flightless birds (Klein and Cruz-Uribe, 2000), although some or all of the larger vertebrates may have been scavenged rather than hunted (Binford, 1984). From the Semliki River area in Zaire comes the earliest evidence for complex aquatic hunting gear, ~80,000-year-old barbed harpoons from Katanda associated with numerous large fish remains (Yellen *et al.*, 1995). From Blombos Cave in South Africa comes evidence for Middle Stone Age marine fishing, probably dating to over 60,000 years (Henshilwood and Sealy, 1997). And from the Boegeberg 2 shell midden comes possible evidence for the relatively intensive MSA use of cormorants (Klein, 1999, p. 456).

Dated to about 90,000 years ago are the earliest skeletal remains of *Homo sapiens sapiens* found outside of Africa—the Qafzeh and Skhul skeletons from coastal Israel—suggesting that early modern populations had begun to move out of Africa by this time. Although anatomically modern humans do not appear to have moved into most of Europe for another 50,000 years (Klein, 1998), current evidence suggests that they spread into southern Asia at least 60,000 years ago. From there, within just a few millennia, they probably made the multiple maritime voyages through island Southeast Asia required to settle Australia and New Guinea. By about 30,000–35,000 years ago, seafaring AMH peoples also had colonized western Melanesia and the Ryukyu Islands south of Japan.

Although the current state of our knowledge remains somewhat fluid, the earliest subsistence strategies that included relatively eclectic and intensive use of marine or other aquatic resources may be associated with the appearance of anatomically modern humans. When such aquatic adaptations were combined with the exploitation of a range of terrestrial plants and animals, a more diversified and stable resource base would have resulted. Such economies may have contributed significantly to the development of greater sedentism (see Kelly, 1995, p. 125), to the reproductive success of *Homo sapiens sapiens*, and to our apparently dramatic demographic and geographic expansion over the last 150,000 years. In this regard, it is worth noting that current (“Out of Africa”) models for the rapid spread of anatomically modern humans allow only about 10% of the time available in multiregional models for this demographic and geographic expansion (Erlandson, in press). Wherever anatomically modern humans first appear, they seem to have carried with them a penchant for art and symbolism, technological innovation, and complex problem-solving and communication skills (see Davidson and Noble, 1992; Klein, 1998; Mellars, 1998). Aquatic adaptations and Pleistocene seafaring played a more significant role than previously supposed in the demographic expansion, the geographic spread, and the phenomenal success of our species.

The available archaeological evidence contradicts aspects of both Gates of Hell and Garden of Eden models, with the most likely scenario falling—like Aristotle’s “golden mean”—somewhere in between. Despite a number of categorical statements to the contrary, we simply do not know when aquatic resources were first widely used by our hominid ancestors or how important they were in human evolution. However, it makes no sense that hominids would have completely ignored aquatic resources for more than 2 million years. As long as scavenging was a significant hominid pursuit, in fact, it seems likely that aquatic resources found in shallow water or on the shore would have been utilized when reasonably abundant and available without complex technologies. There undoubtedly has been some intensification of aquatic resource use during human history, but it also seems likely that our ancestors used such resources opportunistically and situationally whenever and wherever it made economic sense to do so. If aquatic resources sometimes compare favorably to terrestrial subsistence alternatives, it raises significant questions about the emblematic role shell middens have played as anthropological indicators of the broad spectrum revolution and postglacial economies (see Bailey, 1978). If shell middens are not diagnostic of postglacial economies, is the broad spectrum revolution still a revolution?

We cannot afford to ignore the fact, however, that the efficient or intensive exploitation of many types of marine and other aquatic (and terrestrial) resources requires relatively complex technologies (e.g., sophisticated boats, nets, harpoons, hook-and-line) that currently appear to have been beyond the capabilities of hominids other than anatomically modern humans. We should also recognize that aquatic habitats are extremely variable, that they are juxtaposed with equally varied terrestrial habitats, and that together these offer such a diverse range of environments that they defy broad generalization (Erlandson, 1994, p. 278; Perlman, 1980). Given the nearly endless diversity in the relative productivity and accessibility of aquatic versus terrestrial habitats around the world, it seems likely that the antiquity and intensity of aquatic adaptations varied widely through both space and time. Today, rather than searching for general rules of human behavior in aquatic settings, we should be working to overcome the taphonomic problems that currently inhibit our interpretations so we can more effectively document the diversity of aquatic adaptations. More interesting questions should take the place of dichotomized debates about whether the world's aquatic habitats were Gardens of Eden or Gates of Hell. Once we recognize the diversity of aquatic habitats through space and time, as well as the almost limitless combinations of mosaic environments that result from juxtaposing such aquatic habitats with equally diverse terrestrial habitats, we can focus on the complexity of human responses to aquatic environments that took place as our ancestors developed increasingly sophisticated subsistence strategies on both land and in the water. Given this diversity and the innumerable adaptive responses possible under various intellectual, technological, demographic, and sociopolitical circumstances, a search for a global model or universal laws of aquatic adaptations is almost certainly fruitless.

As we move into the twenty-first century, I hope we can transcend the simple models and polarized arguments that have often characterized scholarly debates about the evolution of aquatic adaptations. Surely, as Claassen (1991, p. 275) has suggested, "it is time to put to rest the generic clam," as well as the generic fish, sea mammal, or coastal forager. In the last century or so, archaeologists have made great strides in understanding the development of maritime and other aquatic adaptations in human history. As our studies continue in the next century, there are numerous issues yet to be resolved and numerous productive avenues of inquiry to be studied. To truly understand the role of the sea (and aquatic habitats) in human history, however, a number of issues need to be resolved.

Perhaps the most pressing are questions related to the antiquity of seafaring and the search for ancient sites located along Pleistocene shorelines beneath the sea. It is time to extend the search for submerged terrestrial sites to a wider range of shorelines around the world and into deeper waters to look for coastal sites dating to the crucial period between about 60,000 and 10,000 years ago. Utilizing new technologies, offshore archaeological survey might be particularly productive along steeply dipping shorelines of the Mediterranean, where sites like Cosquer Cave and submerged caves off Gibraltar (Waechter and Flemming, 1962) have been identified in limestone bedrock where dripstone formations may have helped to preserve evidence for early coastal adaptations despite the problems of rising sea levels and coastal erosion (Flemming, 1998). Underwater reconnaissance and excavation work might also be particularly fruitful off some of the more protected shorelines of the Japanese archipelago, where evidence for the Upper Paleolithic antecedents of the Jomon peoples may lie submerged. We need to know not only where such sites are located and when they were occupied but also whether aquatic resources played a significant role in the lives of the occupants and how widespread such adaptations were.

Critical to evaluating the idea that anatomically modern humans may have moved rapidly out of Africa along the coastlines of southern Asia into Australia and beyond is a search for early shell middens or other sites on land, in areas associated with Last Interglacial shorelines of East Africa, southern Asia, and the islands of Southeast Asia. Considering the spatial distribution of early coastal sites elsewhere in the world, such efforts are most likely to succeed if they are focused along coastal stretches characterized by relatively steep bathymetry, where lateral shoreline movements associated with sea level fluctuations have been minimized.

Also needed are renewed excavations at early sites that have already produced the remains of aquatic resources, with more sophisticated excavation and analytical techniques, including fine screen recovery, flotation, and more critical evaluation of the origin of aquatic and other faunal remains. We need more taphonomic and actualistic studies to help distinguish between aquatic animal remains of cultural versus natural origin, work that will complement the extensive studies that have been done for terrestrial fauna in interior areas.

Ultimately, we need more data from “aquatic” sites of all ages and in all regions to better document the variability in aquatic adaptations through space and time. In the twenty-first century, the study of maritime peoples and aquatic adaptations should focus on documenting the remarkably diverse role that aquatic resources played in human history as hominids and humans spread around the world, from sea to shining sea.

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