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# Emergence of Complex Societies After Sea Level Stabilized

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Sea level rose rapidly from the Last Glacial Maximum (LGM, ~18,000 years ago) until it stabilized about 7000 years ago. A millennium later, the rudiments of early civilizations appeared. However, the factors that might have spurred the first civilizations are a subject of debate, with proposals ranging across many possibilities from drought to the influence of individual rulers.

We hypothesize that sea level stabilization contributed significantly to the rapid advent of civilizations. Evidence from regions around the world shows that societies with class distinctions first emerged near coastal margins [e.g., *Day et al.*, 2004; *Kennett and Kennett*, 2006], but there is little understanding of this process on a global scale. We show that the stabilization of sea level and the consequent dramatic increase in coastal margin productivity (CMP)—which resulted in increased availability of the high-quality food necessary for the development of urban lifestyles—provide an explanation for the timing and location of emerging civilizations, and their varying regional characters. The coastal margin includes the continental shelf, nearshore upwelling zones, estuaries, and lower river floodplains affected by coastal water levels.

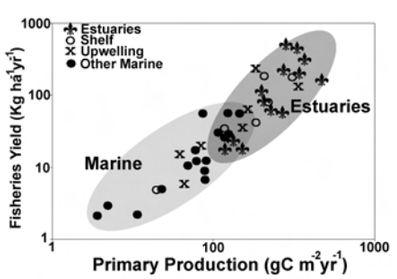


*Fig. 1. Relationship between aquatic primary productivity and fisheries for estuarine and marine systems (modified from Nixon [1982]). Primary production is related to fisheries yield with post–Last Glacial Maximum estuaries being 10 times more productive than open marine systems.*

## *Coastal Margin Productivity*

Since the end of the LGM, maximum sea level has risen about 120 meters in regions distant from the major ice sheets. Before sea level stabilized, coastlines moved rapidly across continental shelves. For a 100-kilometer-wide shelf, the shoreline advanced at a rate of about 1 kilometer per century, and depth increased at the rate of 1–2 meters per century, a rate that is too rapid for coastal margin habitats to mature. Shelf slope gradients generally range from 1:1000 to 1:20,000 (i.e., the Persian Gulf) compared with 1:200 for continental slopes. Thus, a typical estuarine depth change of 10 meters covers 2 kilometers on the slope versus 10–200 kilometers on the shelf. Observations [*Alley et al.*, 2005] and simulations [*Milne et al.*, 2005] indicate that a period of relative sea level stability began approximately 7000 years ago, after which time sea level changed only a few meters.

As more shelf regions became inundated by the encroaching ocean, more shallow water areas were created in the coastal margin. Further, global average temperature increased by 6°C in the 10,000 years after the LGM. Because biological activity increases nonlinearly with temperature, biological activity would have increased significantly. Light conditions in shallow coastal waters are favorable to aquatic primary production, and light decreases exponentially with depth, and thus expanded shallow-water coastal margin ecosystems would have resulted in enhanced aquatic productivity. Overall, CMP likely increased by an order of magnitude or more, probably changing from less than 300 grams dry weight per square meter per year to between 1000 and 2000 grams dry weight per square meter per year.

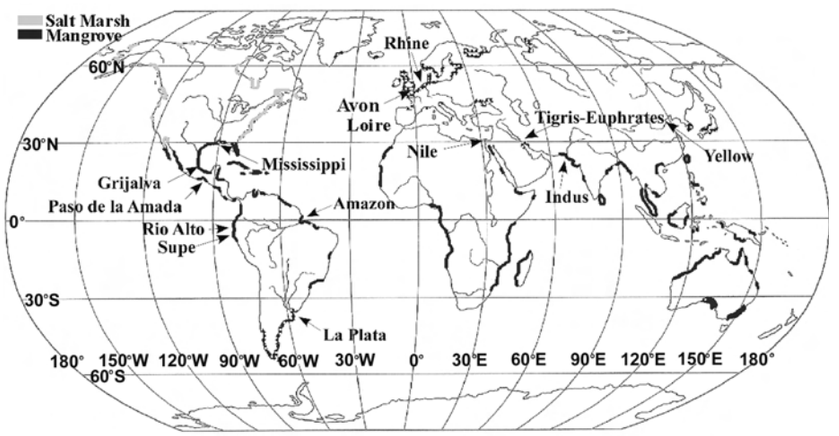


*Fig. 2. Distribution of early urban societies. The distribution of coastal mangroves and salt marshes is indicated by dark and light shades.*

Oceanic primary productivity is currently approximately 125 grams dry weight per square meter per year, compared with about 500 for upwellings, 300 for shelves, 2000 for estuaries, and 1000 for floodplains. Coastal margin food chains are supported by several productive plant communities (e.g., wetlands, sea grasses, phytoplankton, algae, floodplain forests). Moreover, most oceanic planktonic primary productivity is consumed in the microbial food web, whereas much more production in estuaries is channeled into large organisms that are available for human exploitation, such as fish. Currently, estuarine fish production can reach 1000 kilograms per hectare per year, compared with 100–500 for shelves and less than 100 for open oceans (Figure 1). The relative abundance in coastal ecosystems of organisms available for human exploitation was significant for early urban societies. Among the advantages they offer, coastal margin habitats are often productive at different times of the year, especially in tropics and subtropics, providing a more constant food supply throughout the year. Also, coastal resources are easily accessible to humans, ensuring ample supplies of high-quality food year-round, including polyunsaturated omega-3 fatty acids, which are abundant in fish and essential for human fetal development and adult maintenance. Especially in arid and semiarid environments, the contrast in productivity between coastal ecosystems and nearby land ecosystems is profound. Thus, societies with nascent urban characteristics appeared soon after sea level stabilization and earlier among farming communities located near coastal margins than in those in continental interiors.

Rivers further enhance CMP by supplying soil, nutrients, and organic matter. As sea level stabilized, coastal habitats, such as deltas, wetlands, and reefs, developed to their fullest [*Stanley and Warne*, 1997] and freshwater residence time increased. Nitrogen retention in coastal systems is related to freshwater residence time, so more nitrogen was retained in the coastal margins [*Nixon et al.*, 1986]. Nitrogen generally puts limits on CMP, so increased residence time led to

***Societies*** cont. on page 170

## *Societies*

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higher CMP. Nutrients in coastal waters were also elevated by increased river discharge due to higher rainfall.

As a result of all these factors, large organisms were able to flourish in coastal margins, presenting emerging coastal communities a source of sustenance, and reason to congregate and organize.

### *Archaeological Analysis*

Given the relatively narrow time and location during which vast coastal margin food resources appeared, we analyzed locations in coastal margins to ascertain if there was a link to the origins of civilization (Figure 2). 'Civilization' broadly includes urban, state-governed societies beyond the scope of Neolithic agricultural villages. We also included complex social organizations that could mobilize large labor forces, such as the Olmec in Mexico and Poverty Point in the lower Mississippi valley of the United States. Urbanization was manifested as monumental architecture (e.g., pyramids, platforms, mounds, monoliths). Although regional archaeologists have not considered the worldwide scope of CMP increase and that the development of civilizations was a synchronized, worldwide phenomenon, they have understood for some time that the origin of more complex regional societies was often related to the availability of coastal margin resources, [e.g., *Kennett and Kennett*, 2006; *Stanley and Warne*, 1997].

Two conclusions arise from our study. First, the appearance of early civilizations, initially as villages with ranked societies, occurred near estuaries and lower floodplains of large rivers in tropical to temperate locales and within a relatively narrow time window postdating sea level stabilization. Second, following sea level stabilization, a typical trajectory led from coastal villages with nascent social classes to urban societies more distant from shore. For example, Zhengzhou, China, and Ur-by-the-Sea, Iraq, were originally class-based coastal societies. These societies were moved a millennium or two later to more strategically advantageous inland locations at Xi'an, China, and Uruk, Iraq. These urban populations appeared suddenly in a 'supernova-like' fashion representing a phase transition in human social organization [*Yoffee*, 2005].

Recognizing sea level stabilization as a factor in the origin of civilization divides the post-LGM period into two broad epochs (Figure 3). During the Neolithic (~12,000 to 7000 years ago), atmospheric moisture increased and important segments of the world's human population abandoned mobile hunting and gathering for village lives tending plants and animals. Burials normally lacked goods that can indicate social classes. Settlements generally focused in foothills and mountains. Within 500 years of sea level stabilization, however, Neolithic populations refocused on coastal margins [*Stanley and Warne*, 1997]. The Neolithic way of life does not seem to have supported urban aggregates except for trade centers such as Jericho, a city currently in the disputed West Bank on the Jordan River.

The 'Urbanic' epoch, which began about 7000 years ago, marks the transition to city life. Our study shows that, generally, urban communities (>2500 persons) emerged about 1100 years following sea level stabilization, allowing sufficient time for coastal margin resources to become fully established. As human settlement shifted to the coasts, the initial signs of 'urban transition' were a threefold to fourfold increase in village populations [e.g., *Possehl*, 1998], followed by indications of social classes in burials. The urban transition lasted approximately 1600 years, culminating in urban governments whose signature undertakings included monumental architecture, which indicated that societies had developed social skills to mobilize large labor forces. The increase in the size of the Neolithic population and the later appearance of monumental architecture bookended the hundreds-of-years-long transition to the Urbanic epoch. We suggest that the great increase in CMP following sea level stabilization underwrote the considerable social costs of creating these class societies, thus establishing the key element of urban lifestyles.

Data show that high-quality food from the coasts was an important part of diets in both early and late stages of urban transitions, significantly augmenting agricultural crops. Near La Venta, an Olmec capital, early farmers inhabited newly established barrier islands consuming estuarine and freshwater shellfish, fishes, turtles, and manatees. In addition, they were raising the earliest detected corn in the world by 7100 years ago. At Caral, Peru, in the Supe River valley, clams, mussels, anchovies, and sardines were being eaten by 5000 years ago. In the lower Mississippi valley, bone assemblages consist of 50–90% fish, again around 5000 year ago. As these new coastal societies extended their reach inland, they continued to rely on estuarine resources. Mesopotamian documents report the transportation of 13,000 fish inland from Lagash near the sea to Nippur 200 kilometers inland [*Trigger*, 2003].

In interior habitats, other food sources comparable in scale to that of estuaries were developed to support the new urban societies, including fish farming and intensifying the cultivation of Neolithic agricultural species. Public works such as irrigation canals raised agricultural productivity of the interior toward that of the coastal margins. Sea level stabilization and enhanced CMP opened the gates to civilization. Human ingenuity provided a range of social designs to address these needs. Some failed; others continue to this day.

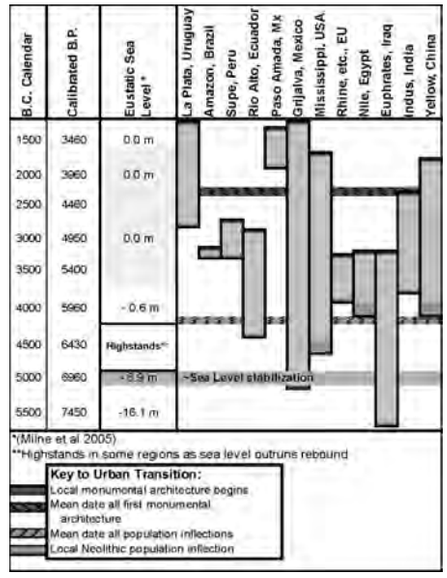


*Fig. 3. The urban transition period was bounded by the Neolithic population inflection approximately 1100 years after sea level stabilization and construction of monumental architecture, which followed approximately 1600 years later. Local initiation times and overall means are shown for both.*

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