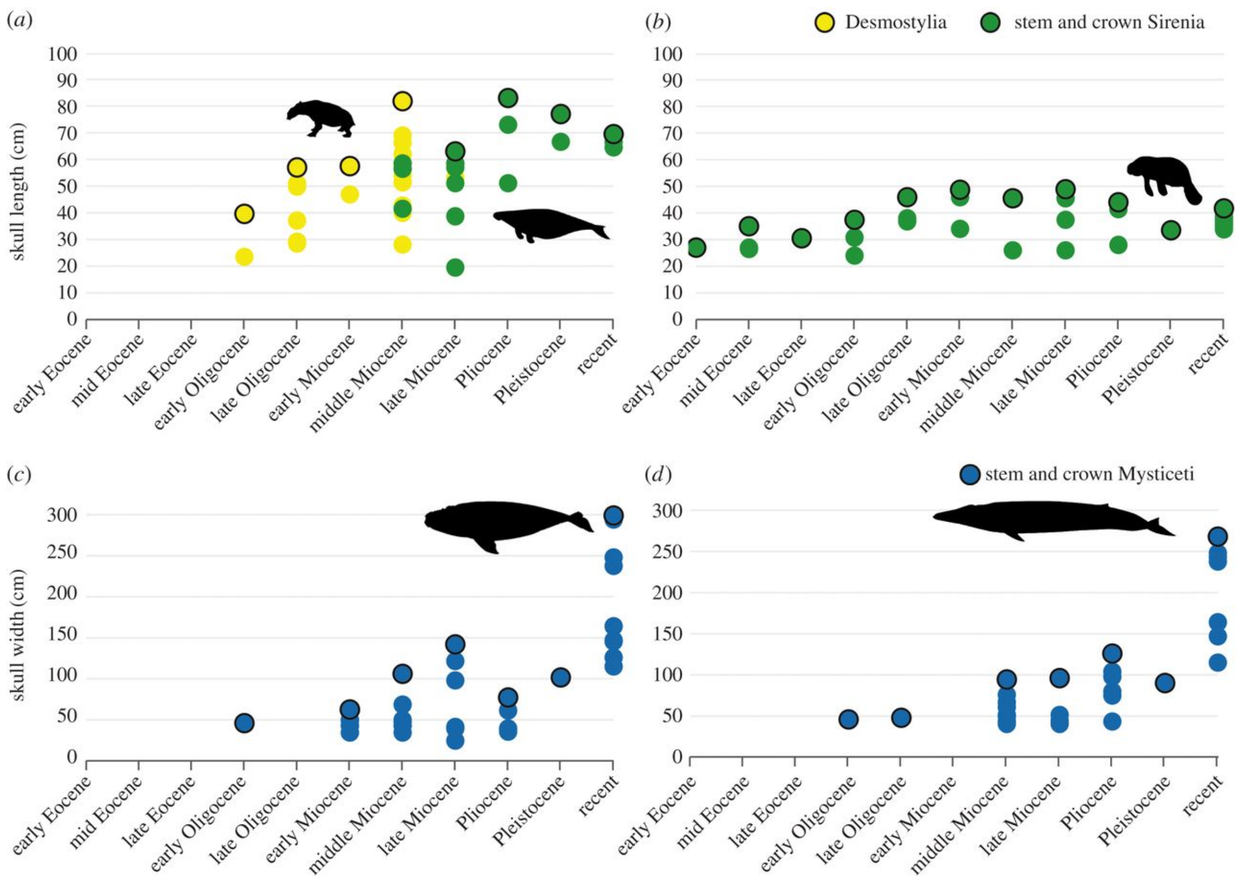
Size does matter: Using the size of fossil marine mammals to estimate primary productivity in ancient oceans

July 21 2016, by Sarah Gibson



(a,b) Maximal body size in North Pacific and North Atlantic marine mammal herbivores, and (c,d) similarly for mammalian filter-feeders, during the Cenozoic. PhyloPics of herbivores, except Hydrodamalis, by Steven Traver. From Pyenson and Vermeij (2016).

As if we need another reason to justify paleontology as an important field of science, here's a good one: information regarding the history of this planet and its ecosystems is crucial in order to understand the health of our planet today, particularly with regard to sensitive but important topics like climate change. Oceans play a large role in the health of this planet, and the rate at which marine primary producers are able to participate in the carbon cycle depends on patterns of ocean circulation, climate and ecosystem structure, and other variable factors. But, how does one measure marine primary productivity in the the geologic record? It is difficult to do directly, but one indirect way is to look at metrics regarding the organisms that are primary consumers, those that rely directly on consuming plankton, marine algae, kelp, and other important primary producers in the oceanic realm. One can infer that a high abundance of filter-feeding, primary consumer organisms would suggest a high amount of primary producers to support that food web. For example, look at the sheer abundance of what are called forage fishes, with familiar examples such as herrings, shads, sardines, anchovies, smelt, etc. These are small fishes that filter feed on plankton in large groups, and when threatened by predators often create mesmerizing bait balls (for a beautiful example, watch this video on Youtube).

Large primary consumers, such as baleen whales or whale sharks, are the inverse of that. Though they have a smaller abundance of individuals in any given ecosystem relative to other groups, such as the forage fishes, they make up for it in their size alone; one blue whale is worth thousands upon thousands of herrings alone in terms of plankton consumption.'

So if what you are looking for in the history of Earth is the rise of primary production in the world's oceans over a long period of time, but you don't have any way to directly quantify that, fossils are your best bet. A paper recently did just that, by observing the evolution of large body size in several groups of marine mammals in both the North Atlantic and

North Pacific oceans, as a proxy for determining the available primary productivity in the pelagic zone of the Cenozoic.

The paper, published in *Biology Letters* by Nicholas D. Pyenson, curator of Fossil Mammals at the Smithsonian National Museum of Natural History, and Geerat Vermeij, Distinguished Professor at the University of California Davis, investigated the maximum body size of Cenozoic marine mammals within two feeding guilds, the first being large marine herbivorous mammals, comprising Sirenia and Desmostylia. Sirenia first evolved in the Eocene, and includes the modern dugong and manatees, as well as the more recently extinct Stellar's Sea Cow. Desmostylia, however, are a completely extinct group of marine mammals, which existed from the Late Oligocene to the Late Miocene. Unlike sirenids, which are fully aquatic, demostylians retained some degree of terrestrial locomotion, though most accept that they were predominantly an aquatic organism, and most likely fed solely in the aquatic realm. Both of these groups are primarily herbivorous.

The second group they examined are the larger filter feeding whales of the parvorder Mysticeti, which includes the largest members of the mammalian filter-feeding guild, including notable examples such as modern-day baleen whales, blue whales, etc., and a fossil record also extending into the Early Oligocene. The study did not include toothed stem-mycetes, but rather focused on baleen-type whales whose diets were primarily restricted to filter-feeding primary producers in the open ocean.

The study did note some distinct patterns regarding large body size evolution. Sirenians and desmostylians never achieved the sheer body size of mysticene whales, and for the most part, the evolution of body size is relatively stable for the herbivourous mammal guild. Geographically, however, herbivorous marine mammals are larger in the North Pacific than in the North Atlantic, but those in the North Pacific also span a larger latitudinal range, from temperate to sub-polar ranges, whereas those in the North Atlantic are more restricted to tropical and sub-tropical ranges, notably the Caribbean area. The North Pacific is also the origin for kelps during the same time period, and this study notes that the coincident rise of large, fast growing kelps and larger body size in marine herbivorous mammals is a pattern of mutual escalation. The Atlantic sirenians feed primarily on seagrasses that do not grow as large or as quickly as the Pacific kelps that sustain the herbivorous mammals there.

With regard to the mysticene cetaceans, this study notes that they maintain narrow body size range that remains relatively stable from their origin until the Plio-Pleistocene, at which point the size of these whales skyrockets, leading to modern lineages that awe us with what they've been able to obtain in terms of size.

Overall, this study was able to conclude, based on the evidence they observed in size patterns among marine mammals, that there was a marked increase in primary productivity in the Neogene. This result correlates with other studies that examined patterns of body size in marine invertebrates in nearshore and coastal habitats, and found the same pattern of increased primary productivity coinciding with growth of the organisms. These patterns also fit with what is occurring geologically, as these periods in the Neogene underwent massive tectonic shifts, which resulted in erosion and runoff into the ocean, bolstering primary production by providing large amounts of nutrients.

More information: Nicholas D. Pyenson et al. The rise of ocean giants: maximum body size in Cenozoic marine mammals as an indicator for productivity in the Pacific and Atlantic Oceans, *Biology Letters* (2016). DOI: 10.1098/rsbl.2016.0186

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