Déjà vu: When sharks nearly disappeared

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Each year, the discovery of yet more new shark species underscores how little we know about the biodiversity of the oceans (*1*). This knowledge shortfall is alarming not only because human pressures threaten sharks with extinction much more than any other marine lineage (*2*), but because their fossil record suggests that they were largely resilient to extinction in the past (*3*), with some extant species persisting for tens of million years (*4*). However, our view of the ancient oceans is constrained by the environments recorded in the rock record, which are often limited to shallow-water deposits that provide little insight into the ocean-wide history of pelagic faunas. The challenges for understanding marine organisms in the past are thus not dissimilar from our knowledge shortfalls for today's species: we might know a lot less about past oceans than we think.

On page xx of this issue, Sibert and Rubin (*5*) report a surprising finding from deep sea sediment cores: a wholesale extinction of shark lineages in the pelagic ocean, the largest ecosystem on Earth, about 19 million years ago. Their discovery suggests that some extinctions in the open sea of the past may have been cryptic. More puzzling is that this event in the Early

Miocene seems to have been hiding in an interval of geologic time that was previously unremarkable. How did they find it and what does it mean?

The study takes advantage of a system that Siebert largely pioneered (*6*) using ichthyoliths: tiny, hard bits of shark skin (and bony fish teeth) that fall from their bodies to the seafloor. Once retrieved and sorted from deep sea sediment drill cores, these microscopic fossils provide a rich record of ancient shark ecomorphotypes, abundance, and richness, all with strong stratigraphic control. Although this proxy record of diversity has weak phylogenetic control because the hard parts do not always correspond 1:1 with host lineages, its power derives from the high temporal resolution and broad geographic coverage that comes with sediment cores. By using cores from multiple regions, the diversity patterns from the microfossils of marine fauna can yield major insights into pelagic evolution that would be otherwise unknown.

Siebert and Rubin (*5*) quantify the magnitude of this extinction, reporting a 90% decline in abundance and >70% drop in morphological diversity. Critically, they make a compelling case for the secular nature of this event by adjusting their counts for sedimentation rate and preservation potential. This control of geologic factors, along with the finely resolved cores from two sites, hemispheres apart in the Pacific Ocean, point to a real global signal. There is also a strong ecological dimension to this faunal turnover: nearer-shore taxa appear to survive while migratory, ocean-going ones go extinct. The novelty of this study is that no one knew that shark ecology underwent a wholesale extinction that reorganized their communities, in an apparent global manner, in the Early Miocene.

Although the Early Miocene marine faunas were roughly similar to those of today, the body size distributions of major ocean predators were askew. While whales lacked extreme gigantism at this time (*7*), the 20 m shark “Megalodon” (*8*) first appeared (*9*), persisting as a top predator until

the Pliocene (*3, 10, 11*). Siebert and Rubin (*5*)'s findings suggest that there is still much for us to learn about the ecological roles for these marine predators that likely crossed the oceanic-neritic interface in the Early Miocene. Did they migrate seeking seasonal prey the way whales and sharks do today? What was the structure of their feeding ecology over the course of their life history?

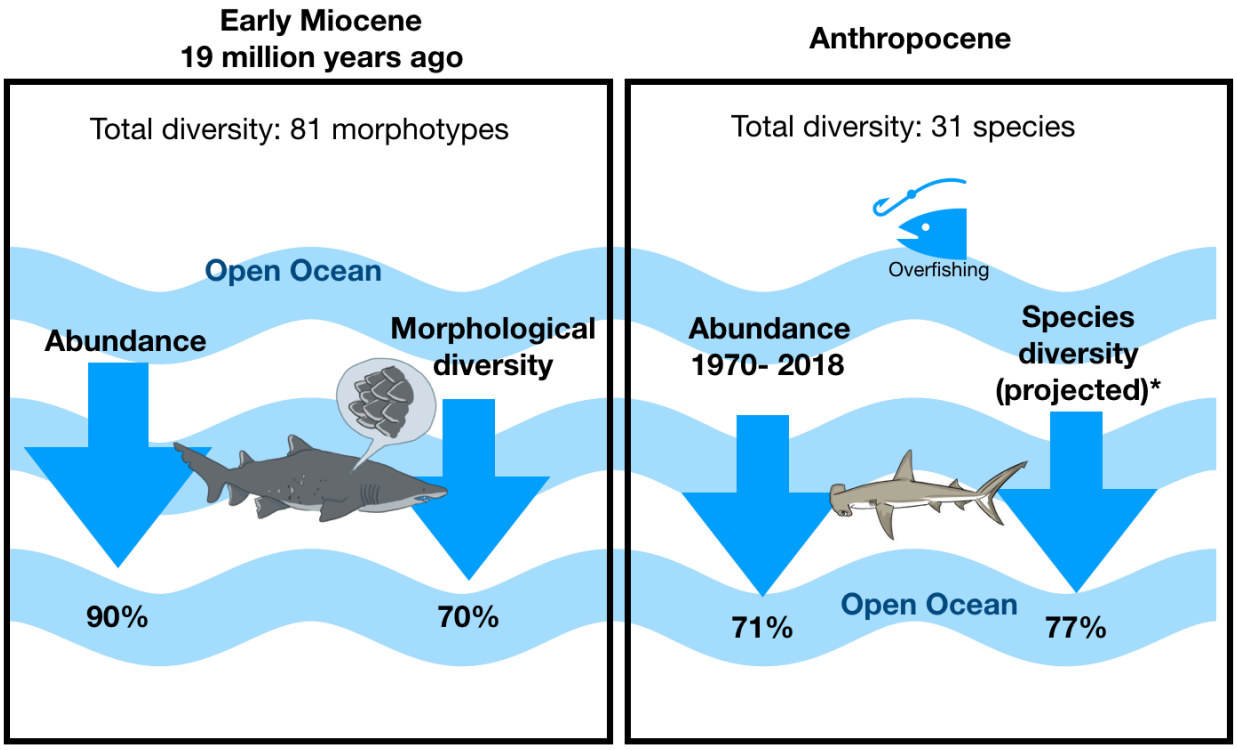
Still more mysteries remain. Siebert and Rubin (*5*) narrowed the disappearance of pelagic sharks to a window of time under 100,000 years around 19 million years ago, but the causes of this event remain obscure. Because the Early Miocene does not stand out as a period of major climatic change, Siebert and Rubin (*5*) do not attribute environmental factors as an extinction driver. Mechanism aside, this extinction resulted in a permanent suppression of pelagic sharks that has left a signal in the ecological composition of shark communities to the present day.

Despite the fact that sharks today are mostly distributed in the continental shelf (*2, 12*), in less than half a century, the global abundance of oceanic sharks (i.e., those living in the open ocean) has declined by over 70% (*13, 14*). This current loss of shark diversity is directly linked to overfishing (*12, 13*), even as the undisputable effects of global heating in the oceans continue to complicate this crisis. The parallels between this ongoing crisis and the extinction of pelagic sharks over 19 million years ago thus feels like *déjà vu*, except that this time we know that the decline for sharks is happening faster than at any other rate in the history of the planet (Fig. 1).

The loss of sharks from our oceans has profound, complex, and irreversible ecological consequences because they are semaphores for the stability of marine ecosystems (*15*). Yet, one quarter of their global diversity is currently threatened with extinction (*2*), with a substantial risk status increase for all 31 extant oceanic shark species (*13*). Despite recent improvements in conservation actions, few countries impose restrictions targeting oceanic sharks (*13*). Pelagic

shark communities never recovered from a mysterious extinction event 19 million years ago; the ecological fate of what remains is now in our hands.

Figure 1. Pelagic shark communities never recovered from the Early Miocene extinction event discovered by Siebert & Rubin (5). The parallels between that event and today's crisis driven by human pressures (i.e., overfishing) are striking.



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