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Comment on "An early Miocene extinction in pelagic sharks"

Gavin J. P. Naylor[1]*, Arthur de Lima[2], José I. Castro[3], Gordon Hubbell[4], Mario C. C. de Pinna[2]

[1]Florida Museum of Natural History, University of Florida, Gainesville, FL, USA. [2]Museu de Zoologia da Universidade de São Paulo, Sao Paulo, Brazil. [3]NOAA/SEFSC, St. Petersburg, FL, USA. [4]Jaws International, Gainesville, FL, USA.

*Corresponding author. Email: gnaylor@flmnh.ufl.edu

Sibert and Rubin (Reports, 4 June 2021, p. 1105) report an early Miocene extinction in pelagic sharks based on the loss of shark denticle diversity in two widely separated deep-sea sediment cores. We assert that the pattern observed is not a consequence of extinction but results from shifting species ranges induced by global current reorganization.

Sibert and Rubin (*1*) assert, based on a careful examination of shark denticles in two widely separated sediment cores from the Pacific Ocean, that the abrupt decrease in both the number and type of shark denticles at the 19-million-year mark in the Early Miocene reflects a previously undocumented extinction event. Their study is based on the premises that shark denticle diversity can serve as a proxy for shark species diversity and that the concomitant and abrupt loss in denticle diversity in the two widely separated locations in the Pacific is due to an oceanic extinction event. Although we commend Sibert and Rubin for their careful, stratigraphically controlled work, we disagree with their interpretation that the pattern observed is the consequence of an extinction event.

It is true that denticles from corresponding parts of the body often have shapes that are lineage-specific (*2*); however, denticle shape varies enormously by location on the body and through ontogeny. In Fig. 1 we reproduce Sibert and Rubin's figures S1 and S2 showing their 85 different denticle "morphotypes." In Fig. 2 we show denticle shape variation associated with a single specimen of the daggernose shark *Isogomphodon oxyrhynchus* studied by the second author. The denticle shape variation observed in *Isogomphodon* is comparable—indeed, it subsumes—the variation in morphology seen in Sibert and Rubin's linear denticle sample (left panel). The implication is that the diversity of denticles in Sibert and Rubin's sample is likely from just a handful of species. An exhaustive documentation of denticle variation from multiple parts of the body across the diversity of chondrichthyans has not yet been undertaken but would be a necessary prerequisite for the type of study carried out by Sibert and Rubin.

The weak association between denticle and species diversity notwithstanding, it is peculiar that sharks' teeth were conspicuously absent from Sibert and Rubin's sample. Sharks replace their teeth just as they replace their denticles, and tooth shape diversity has a closer correspondence with species diversity than does denticle diversity (although teeth, like denticles, also show extensive shape variation within individuals). The absence of sharks' teeth from samples that contain such a rich diversity of denticles (85 "morphotypes") suggests a biased depositional environment—one that evidently favors the preservation of bony fish teeth and shark denticles, but strangely, not sharks' teeth.

Interestingly, the fossil record of sharks' teeth shows no marked loss in diversity across this 19-million-year-old "extinction event." Indeed, all the major families of pelagic sharks that occur prior to 19 million years—such as the megatooth lamnids, sand tigers, threshers, makos, seven-gills, six-gills, tiger sharks, hammerheads, and requiem sharks—also occur in deposits at localities throughout the world, after the event. It is, of course, possible that the lineages with which we are familiar made it through, whereas an undocumented diversity of pelagic taxa (i.e., those represented by the denticles in the two cores explored by Sibert and Rubin) did not.

However, we contend that a more likely explanation is that the morphological diversity of denticles in Sibert and Rubin's samples could be accounted for by a more extensive exploration of denticle variation across different parts of the body in extant forms (*3*). We maintain that the abrupt change in denticle diversity documented by Sibert and Rubin is likely the consequence of a range shift by a few species of pelagic sharks that moved to different habitats at a time of global current reorganization induced by the opening of Drake's passage and the establishment of the Circumpolar Antarctic Current. Most extant pelagic sharks are known to traverse vast distances as a response to food availability and changing environmental conditions. The patterns observed by Sibert and Rubin are consistent with such a response.

Of course, we cannot rule out the extinction of several lineages of hitherto undocumented pelagic sharks as an explanation for the abrupt change, but we maintain that such a strong claim needs strong evidence to rule out alternative explanations for the patterns observed (*4*)—strong evidence that we consider to be lacking.

REFERENCES

1. E. C. Sibert, L. D. Rubin, An early Miocene extinction in pelagic sharks. *Science* **372**, 1105–1107 (2021). doi:10.1126/science.aaz3549 Medline

2. J. I. Castro, *The Sharks of North America* (Oxford Univ. Press, 2011).

3. B. S. Rangel, A. F. Amorim, J. R. Kfoury Jr., R. E. G. Rici, Microstructural morphology of dermal and oral denticles of the sharpnose sevengill shark *Heptranchias perlo* (Elasmobranchii: Hexanchidae), a deep-water species. *Microsc. Res. Tech.* **82**, 1243–1248 (2019). doi:10.1002/jemt.23273 Medline

4. J. R. Platt, Strong Inference. *Science* **146**, 347–353 (1964). doi:10.1126/science.146.3642.347 Medline

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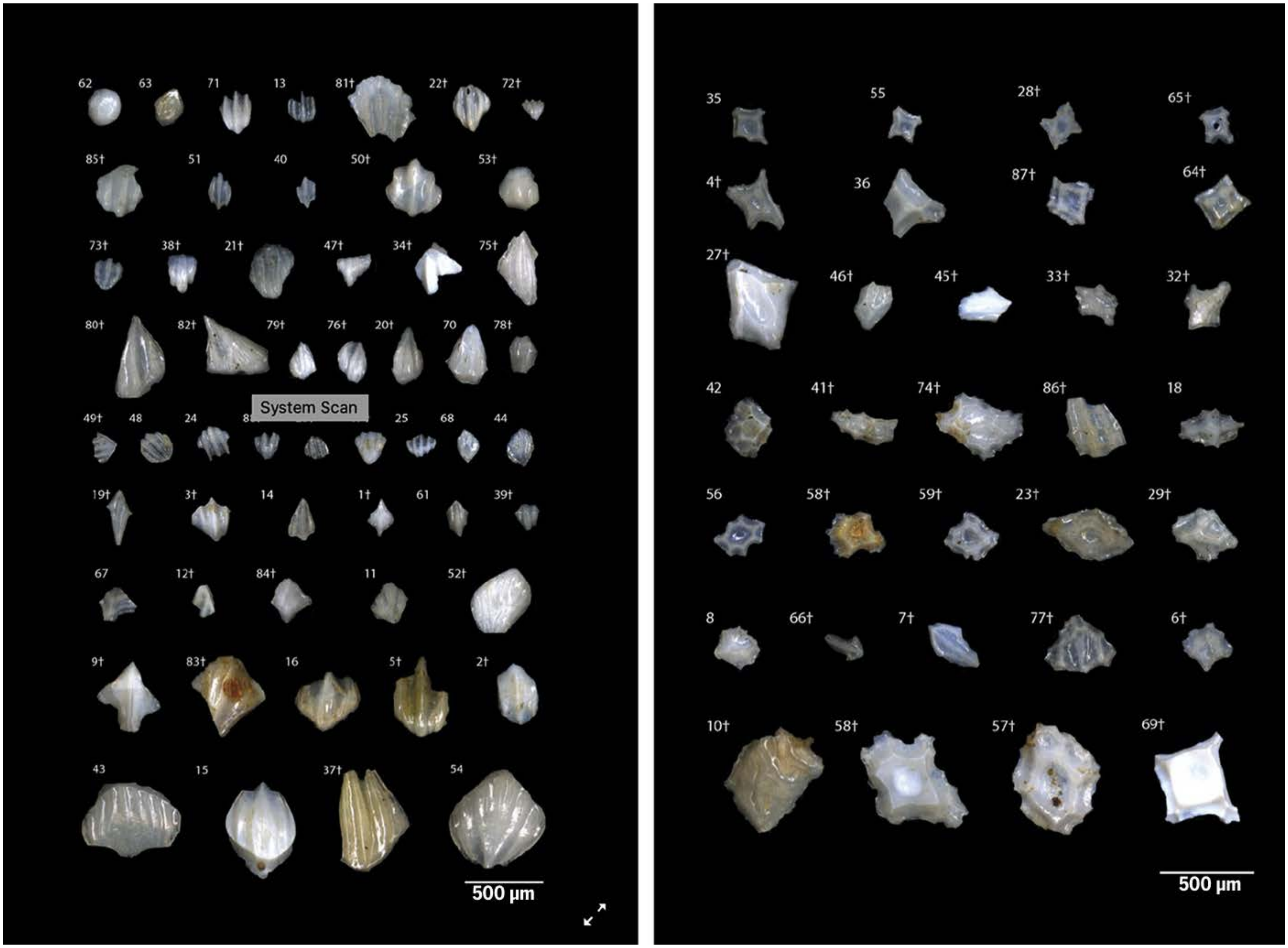
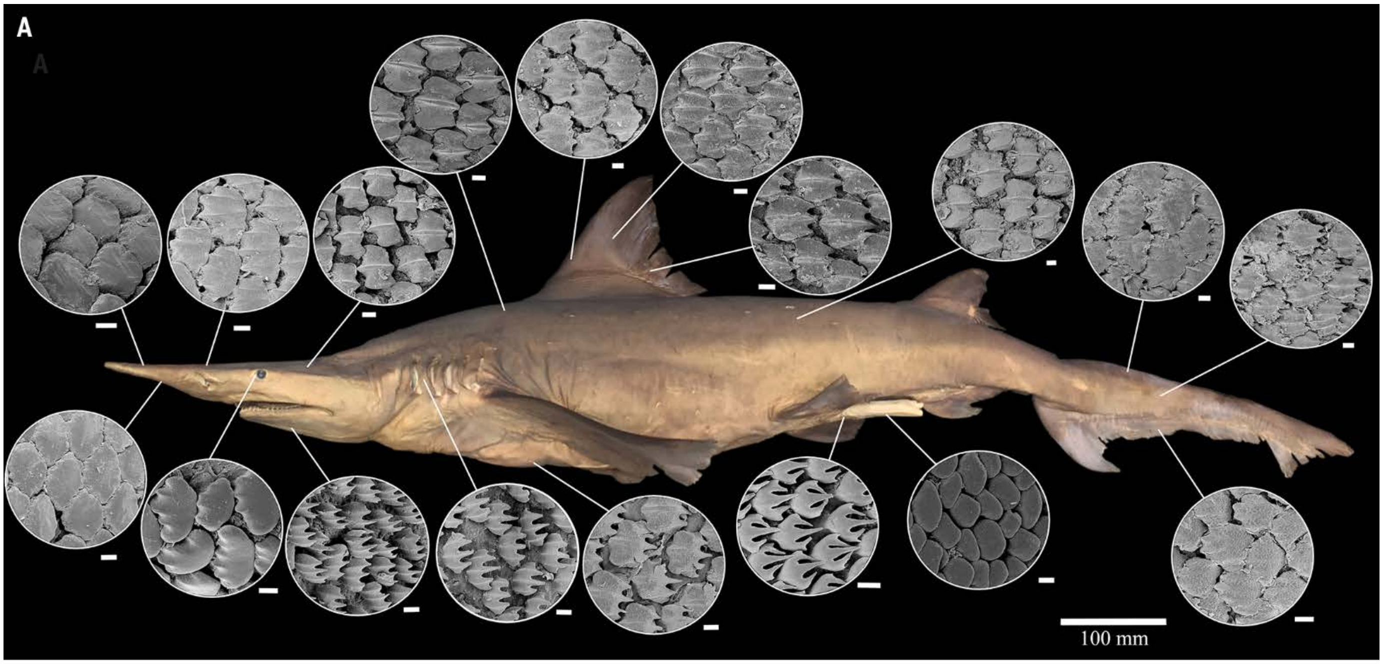


Fig. 1. “Linear” (left) and “geometric” (right) denticles, reproduced from Sibert and Rubin’s figures S1 and S2. These represent Sibert and Rubin’s 85 denticle “morphotypes” whose variation they use as a proxy for shark species diversity. The geometric morphotypes in Sibert and Rubin’s figure S2 are consistent with some deep-water squaloid shark denticle morphologies (lantern sharks, dalatiids, and their allies) that have block-like denticle morphologies.



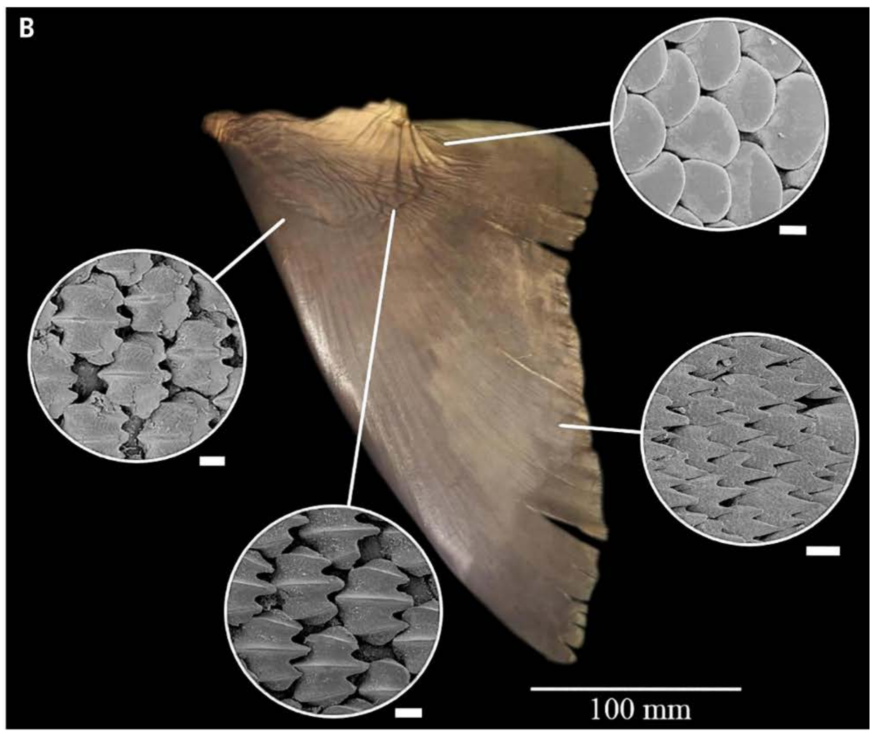


Fig. 2. Denticle diversity associated with a single specimen of the daggernose shark *Isogomphodon oxyrhynchus* taken from different parts of the body (top) and from the pectoral fin (right). Scale bars (10 μm) are shown separately for each micrograph. A large scale bar (100 mm) is shown for the photograph of the preserved specimen and the pectoral fin.

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