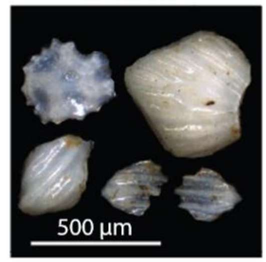
Understanding how life has responded to past global change events is paramount to predicting and mitigating anthropogenic impacts on the planet. My research uses a novel paleoceanographic and paleontological resource – microfossil fish teeth and shark scales (ichthyoliths) preserved in marine sediments – in conjunction with other paleo-proxies, ecological models, and evolutionary tools, to study how marine ecosystems have evolved in concert with climatic and biotic changes throughout Earth's history. This work lies at the intersection of oceanography, marine ecology, paleobiology, and paleoclimate, and is driven by two big-picture questions:


Fish Teeth

1. How have marine ecosystems evolved through Earth's history? How did past climate and biotic events impact the structure, function, and evolution of marine ecosystems, and what can that tell us about potential impacts of future global change?
2. How has the evolution of pelagic marine vertebrates, particularly fish and sharks, interacted with changes in the Earth system?



Shark Denticles

My dissertation work developed ichthyoliths as a paleoceanographic proxy, and applied the proxy to assess pelagic fish production and community structure across the Cretaceous-Paleogene (K/Pg) mass extinction and through the Cenozoic. A main focus of my postdoctoral work is to ascribe taxonomic and ecological meaning to individual ichthyoliths, by developing methods for quantifying tooth morphological disparity, creating a catalog of modern fish tooth, jaw, and skull diversity, relating this to known fish biology, and applying the taxonomic and ecological framework to assess changes in ichthyolith morphology and diversity through time. I was recently funded by NSF to expand this framework to denticles, which will be a main research focus over the next few years. I have also been collaborating with ecological modelers to develop data-model based frameworks to use the ichthyolith record to better understand ancient food-web dynamics, and using ichthyoliths to study the impact of humans on fisheries. My research synthesizes across biological oceanography and paleobiology, demonstrating that ichthyoliths can be used to diagnose paleoproductivity, paleoecology, and biodiversity of open-ocean fish through time – until now, a virtual blank in marine micropaleontology and a gap in our understanding of ancient food webs. This work lays the groundwork for a unique, interdisciplinary research program using ichthyoliths in conjunction with other paleoceanographic proxies, microfossils, and ecological and evolutionary modeling, to study the dynamics and evolution of marine ecosystems and their interaction with the earth system.

Ichthyolith Assemblages: Production and Community Structure

The abundance and type of fish in a marine ecosystem is dependent on many variables, including ocean circulation, nutrients, temperature, phytoplankton, food web structure, and ecosystem efficiency. I study how shifts in physical oceanographic conditions have affected fish and marine ecosystem productivity and community structure by assessing changes in ichthyolith accumulation rate (IAR) and assemblage size structure and relative dominance of different ichthyolith groups, across global change events. For example, IAR broadly correlates with export productivity proxies, across the Cretaceous-Paleogene mass extinction (*Sibert et al 2014* Nat. Geosci), however, the abundance of fish compared to sharks increased in the aftermath of the extinction all over the world (*Sibert and Norris 2015* PNAS) and initiated a massive radiation in open-ocean fish diversity (*Sibert et al 2018* Proc B*)*. The structure of pelagic vertebrate predator communities is stable for 10s of millions of years, despite major changes in IAR (*Sibert et al 2016* Proc B), and changes only once in the 65 million years following the Cretaceous-Paleogene extinction: abruptly around 19 million years ago, there was a major extinction in sharks that preceded radiations in modern open ocean predator lineages including whales, and disrupted the formerly stable vertebrate community (*Sibert and Rubin* 2021, Science). This extinction event is the focus of my second postdoctoral fellowship position, where I am collecting and analyzing paleoceanographic and paleontological records to study what may have caused the event. Through these projects, I have demonstrated that ichthyoliths record fish, shark, and marine ecosystem responses to climate change. To isolate the mechanisms behind these observed shifts in fish abundance and community structure, and their links to paleo-productivity and global climate, I collaborate with marine ecosystem modelers to develop size-structured ecosystem models for fish biomass production that can be integrated with the ichthyolith record, paleoclimate proxies, and models to simulate changes in fish biomass as a function of changing oceanographic conditions, which can provide insights into both past and future marine ecosystems (e.g. *Britten and Sibert* 2020, Nat Comms). I will continue to generate records of ichthyolith assemblages from more locations and time periods: the majority of my work thus far has focused on the open ocean during the Paleogene Period, however this is just the beginning of using this unique resource and toolkit to study fish, sharks, and marine ecosystem processes in deep time.

Individual Ichthyoliths: Evolutionary Dynamics and a Modern Ecological Framework
As ichthyoliths are abundant in nearly all marine and lacustrine sediments, they preserve highly resolved fossil evolutionary history of fish, allowing for precise dating of evolutionary events and community shifts, as well as direct comparison with local and global environmental changes recorded by other proxies. However, ichthyoliths have largely been overlooked for evolutionary studies due to their small size and relative rarity when compared to other microfossils. I developed methods for studying ichthyoliths as individual fossils, to quantify fish tooth morphology and study evolutionary dynamics at the precise temporal resolution afforded by the deep-sea microfossil record (*Sibert et al* 2018, Proc B). However, it is currently difficult to ascribe taxonomic or ecological affinity to ancient, isolated ichthyoliths. To this end, I have created a substantial database of modern fish tooth, skull, and jaw morphology using a combination of high-resolution digital imaging and microCT scanning, combining the ecological, taxonomic and morphological data to create a fish tooth ecological morphospace to match the ancient ichthyoliths with the fish that may have produced them. While still in progress, we are able to identify several clades of deep-sea fish in the fossil record, including Anglerfish and Lanternfish. I am in the process of publishing an R package, *ichthyoliths* (beta version is on GitHub), to provide a standardized tool for morphological analyses of the fossil group. My long-term goal is to build a system which will allow for high throughput classification of thousands of ichthyoliths. This will allow me to address more nuanced questions about the interactions between climate and biology, such as evaluating the susceptibility of specific taxonomic or ecological groups to different environmental or ecological stressors.

Beyond paleobiology: In addition to my work on deep-time and open oceans, I am applying these tools to human timescales and coastal environments. I helped develop and fund COD-REMAP, a large interdisciplinary project to study the impact of fishing and climate over the past 4000 years in the Scotia Shelf ecosystem off of Canada, which draws on historians, policy-makers, archaeologists, paleontologists, and paleoceanographers to give insights into fisheries management, a unique project which I hope to replicate in other marine and lacustrine ecosystems. Further, ichthyoliths are also carriers of several well-established isotope proxy systems (e.g. Neodymium), and I will continue to pursue collaborations to use these fossils for geochemical investigations as well. My aim is to create an interdisciplinary research group, with colleagues around the world, at the intersection of ecology, evolution, biological oceanography, and paleobiology, to investigate the interplay between fish, the ocean environment, marine ecosystems, and evolution.