Using biogeochemical tracers and sclerochronologies derived from fish otoliths to detect environmental change

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Abstract

Biogeochemical tracers and sclerochronologies are used to answer many ecological questions that require linking organisms with the environment. Calcified hard parts of organisms that remain chemically inert after formation are particularly advantageous for extracting information (e.g. otoliths, shells, coral) on both the organism and the environment. These structures have growth increments enabling time-resolved information to be extracted on a range of time-scales (sub-daily to centennial). For my research, otoliths (fish earstones) were chosen as an environmental proxy, as they contain both biogeochemical (i.e. radiocarbon and trace elements) and sclerochronological (i.e. growth) signals that reflect environmental change in marine systems. My overarching aim is to use otolith-based proxy records to provide new data describing environmental change in marine systems of southern Australia and New Zealand. More specifically, I employ biogeochemical tracers and sclerochronologies to: (1) detect changes in radiocarbon transport through time in marine waters; (2) establish a radiocarbon record for upwelled waters in the southeastern Indian Ocean; (3) examine local and regional effects of climate forcing on fish growth, and (4) determine the physiological controls acting upon trace element assimilation into otoliths and the differences in chemical constituents of an upwelled water mass. Otoliths of deep water fish – ocean perch from the genus *Helicolenus* – are used in all applications and originate from areas along southern Australia and New Zealand. Thus, the biogeochemical and sclerochronological data derived from these fish describe changes occurring in the marine environments of the southwest Pacific and southeastern Indian Oceans.

Radiocarbon records from the otoliths of *H. barathri,* combined with published records of other fish species in the southwest Pacific Ocean, show transport of the bomb radiocarbon signal from marine surface waters to depths approaching 1000 m. Transports lags ranging from 5 to 20 years are documented, and radiocarbon reservoir ages are calculated for water masses associated with the Tasman Sea.

Radiocarbon measurements from *H. percoides,* in an upwelling area along the southern coast of Australian (southeastern Indian Ocean), are the very first radiocarbon time series

documented for the region and reflect the lower radiocarbon values expected for seasonally upwelled water.

Long term growth responses resulting from sclerochronologies from a *Helicolenus* species complex from southern Australia to New Zealand are compared across regions and species with broad- and local-scale climatic/oceanographic variables using univariate mixed effects models. These data demonstrate how broad scale climate patterns and weather can have additive or synergistic effects on the local environment, which are reflected in the growth of the fish.

Biogeochemical tracers (Na, Sr, Mg, Ba, Li) and sclerochronologies (growth) are also extracted from otoliths of the same fish in this upwelling region. These data are used simultaneously in combination with univariate and multivariate mixed effects modelling to describe physiological and environmental controls on otolith chemistry. Temporal signals within these data are correlated with seasonal upwelling events. Ba:Ca and Li:Ca are more influenced by the environment, while Sr:Ca and Na:Ca are controlled by physiological processes. Ba:Ca negatively tracks upwelling events, suggesting an upwelled water mass not enriched in Ba. Li:Ca correlates positively with chlorophyll-a, indicating a possible proxy for marine productivity.

Thus, the overarching aim of this research has been achieved: biogeochemical tracers and sclerochronologies derived from *Helicolenus* otoliths have provided new data describing environmental change in marine systems of southern Australia and New Zealand.

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