

Abalone Shells as Oceanography Archives: Linking Paleoceanography and Conservation Amid Changing Ocean Condition

*Huang Zihan^{1,2}, Yusuke Yokoyama^{1,2,4}, Shoko Hirabayashi¹, Yosuke Miyairi¹, Kotaro Shirai¹, Shotaro Hirase³, Jun Hayakawa¹

1. Atmosphere and Ocean Research Institute, the University of Tokyo, 2. Graduate School of Arts and Sciences, the University of Tokyo, 3. Graduate School of Agricultural and Life Sciences, 4. Graduate School of Science, University of Tokyo

Abalones (*Haliotis spp.*) are widely distributed around the world and have a strong kinship with human societies for centuries. Of the 21 abalone species harvested commercially for human consumption, 15 are classified as threatened (Peters et al., 2024). In the past three years, abalone survival along the Sanriku Coast has become increasingly challenging. Beach cleaners have reported large amounts of abalone shells washing ashore, while the owners of an aquaculture facility in Iwate, Japan, have noted a rising mortality rate among their abalones since around three years ago. This decline may be linked to shifts in the Kuroshio and Oyashio currents, potentially driven by global warming. Understanding these environmental changes is crucial not only for conservation efforts but also for the sustainable management of abalone aquaculture.

Abalones form their shells from calcium carbonate. Their shells have the potential to serve as valuable climate archives, particularly in high-latitude regions where corals are absent. Similar to corals, abalone shells incorporate environmental signals during growth, preserving isotopic information that reflects past ocean conditions. However, while corals have been widely studied for reconstructing low-latitude ocean history, paleoceanographic research using abalone shells in high-latitude regions remains limited.

In this study, we investigated the potential of abalone shells as high-resolution marine environmental proxies by conducting a multiproxy analysis of radiocarbon concentration ($\Delta^{14}\text{C}$), stable oxygen isotope ratios ($\delta^{18}\text{O}$), and stable carbon isotope ratios ($\delta^{13}\text{C}$). The nuclear tests conducted during the 1950s and 1960s resulted in a doubling of atmospheric ^{14}C levels, producing anthropogenic radiocarbon known as “bomb- ^{14}C .” Through air-sea CO_2 exchange, “bomb- ^{14}C ” infiltrated the surface ocean and has since been widely used as a tracer for studying water mass mixing processes such as upwelling and advection (GEOSECS: Broecker et al., 1985; WOCE: Key, 1996; Lan et al., 2024). $\Delta^{14}\text{C}$ -based water mass mixing studies have primarily focused on low-latitude reef-building corals (Adkins et al., 2002; Hirabayashi et al., 2017; Hirabayashi et al., 2019), while high-latitude regions, where corals are absent, lack sufficient biological archives for paleoceanographic research (Kubota et al., 2018; Ota et al., 2019). The calcium carbonate shells of abalones, which inhabit high-latitude environments, are therefore promising candidates for paleoclimate reconstructions in these regions.

To evaluate the reliability of abalone shells as paleoceanographic proxies, we analyzed both natural and aquacultured *Haliotis discus hannai* as well as natural *Haliotis discus hannai* and *Haliotis madaka* to identify species-specific differences in isotopic signals. By comparing farmed and wild specimens, we also aim to assess the effects of controlled versus natural environmental conditions on isotopic incorporation.

Beyond its scientific contributions, this study seeks to apply isotopic analysis in collaboration with aquaculture facilities to improve environmental monitoring and sustainable abalone management. As climate change continues to alter oceanographic conditions, utilizing abalone shells as a natural record of

environmental fluctuations could provide valuable insights for both scientific research and practical conservation strategies.

Keywords: abalone, climate change, isotopic analysis, radiocarbon, ocean conservation