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Reconstructing the environmental history of macroalgae by the use of dual carbon isotope tracers

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The Sanriku coastal region, one of the world's greatest fishing grounds, is largely influenced by Oyashio and Kuroshio. These waters with distinct properties seasonally enter into the bays along the coast, and exert large influences on ecosystem dynamics in this region. Prominent examples include the intrusion event of Oyashio water into the bays (replacement of Tsugaru warm water with cold Oyashio water) during winter. This event has been suggested to cause fundamental alterations in environmental conditions (e.g., water temperature and nutrient concentrations) in the bays, which in turn may elicit complex physiological responses of coastal biota. However, the link between physiological responses of organisms to this oceanographic event has yet to be clarified fully. In order to gain insights into the relationship between the Oyashio intrusion event and coastal ecosystem dynamics, the present study used carbon isotopic signatures of *Undaria Pinnatifida* (wakame), a widespread and commercially important macroalgae in the Sanriku region. The growth of *U. Pinattifida* occurs at the basal point of sporophyte where the meristem is located. Near this basal growing point, a pair of pinnate blades are formed to spread toward opposite directions from the central axis. Following the formation of new blades at the growing point, older blades are forced to move toward the apical end. Therefore, the blades near the apical end (upper blades) are older than those near the bottom (lower blades). Assuming that the radiocarbon isotopic signature (Δ^{14}C) of each pinnate blade reflects Δ^{14}C of dissolved inorganic carbon (DIC) at the time of its formation, we hypothesized that Δ^{14}C values of the upper (older) blades formed under the influence of the Tsugaru warm water (characterized by high Δ^{14}C-DIC value) are high, whereas those of lower (younger) blades formed after the intrusion of Oyashio water (characterized by low Δ^{14}C-DIC value) are low.

To test this hypothesis, we cultured *U. Pinattifida* sporophyte in Otsuchi Bay between November 2013 and April 2014 and examined variability in Δ^{14}C among different pinnate blades formed during different periods. Our results indicated that the lower blades formed after the Oyashio water intrusion, which appeared to occur in early March as indicated by a marked shift in salinity and temperature, had significantly lower Δ^{14}C values compared to the upper blades formed before the event. These results are consistent with our hypothesis and suggest a possibility that the blade-order-dependent Δ^{14}C variability in a sporophyte can be used as a new tool to reconstruct the timing of the Oyashio intrusion event in Sanriku bays. Our results also showed that the carbon stable isotopic signature (δ^{13}C) varied widely (range, 4.7 ‰) among the blades. Because this range in δ^{13}C among blades largely exceeded the difference in δ^{13}C-DIC between Tsugaru warm water and Oyashio water (0.22 ‰), it was considered that the variability in the δ^{13}C of blades primarily reflected the variability in the extent of isotope fractionation, which was presumably related to changes in physiological state (growth rate) of the sporophyte. Furthermore, our data showed that there was a significant negative correlation between δ^{13}C and Δ^{14}C of the blades, suggesting that the growth rate of the sporophyte increased after the intrusion of Oyashio water. Dual carbon isotopic signatures of the blades of sporophyte could be potentially useful to reconstruct the timing of the Oyashio intrusion event and to examine physiological responses of macroalgae to this oceanographic event.

Keywords: microalgae, radiocarbon, carbon stable isotope, Sanriku region, Oyashio, Tsugaru warm current