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Stable nitrogen and carbon isotope ($\delta^{15}N$ and $\delta^{13}C$) variability in shallow tropical Pacific soft coral and black coral taxa and implications for paleoceanographic reconstructions

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Abstract

Soft corals and black corals are useful proxy tools for paleoceanographic reconstructions. However, most work has focused on deep-water taxa and few studies have used these corals as proxy organisms in shallow water (<200 m). To facilitate the use of stable nitrogen and carbon isotope ($\delta^{15}N$ and $\delta^{13}C$) records from shallow-water soft coral and black coral taxa for paleoceanographic reconstructions, quantification of the inherent variability in skeletal isotope values between sites, across depth, and among taxa is needed. Here, skeletal $\delta^{15}N$ and $\delta^{13}C$ values were measured in multiple colonies from eleven genera of soft corals and two genera of black corals from across a depth transect (5–105 m) at two sites in Palau located in the tropical western Pacific Ocean. Overall, no difference in skeletal $\delta^{15}N$ and $\delta^{13}C$ values between sites was present. Skeletal $\delta^{15}N$ values significantly increased and $\delta^{13}C$ values decreased with depth. This is consistent with changes in isotope values of suspended particulate organic matter (POM) across the photic zone, suggesting that the primary food source to these corals is suspended POM and that the stable isotopic composition of POM controls the skeletal isotopic composition of these corals. Thus, to compare the isotope records of corals collected across a depth range in the photic zone, first order depth corrections of $-0.013‰\ m^{-1}$ and $+0.023‰\ m^{-1}$ are recommended for $\delta^{15}N$ and $\delta^{13}C$, respectively. Average depth-corrected $\delta^{15}N$ values were similar between black corals and soft corals, indicating that corals in these orders feed at a similar trophic level. In contrast, average depth-corrected $\delta^{13}C$ values of black corals were significantly lower than that of soft corals, potentially resulting from metabolic processes associated with differing skeletal compositions among the orders (i.e., gorgonin vs. chitin based). Thus, a correction of +1.0‰ is recommended for black corals when comparing their $\delta^{13}C$-based proxy records to soft corals. After correcting for both the depth and order effects, variability in $\delta^{15}N$ values among corals within each genera was low (standard deviation (SD) of the mean $<\pm0.5‰$), with the exception of *Acanthorgorgia*. The calculated SD of $<\pm0.5‰$ provides a first order guideline for the amount of variability that could be expected in a $\delta^{15}N$ record, and suggests that these corals may be useful for $\delta^{15}N$-based paleoceanographic reconstructions. Variability in $\delta^{13}C$ values among corals within genera was also low (standard deviation of the mean $<\pm0.5‰$) with the exception of *Rhipidipathes* and *Villogorgia*. Similar to $\delta^{15}N$, records from the genera studied here with the exception of *Rhipidipathes* and *Villogorgia* may be useful for $\delta^{13}C$-based paleoceanographic reconstructions. Overall, using the recommendations developed here, stable isotope records from multiple sites, depths and taxa of these corals can be more rigorously compared.

1. INTRODUCTION

A vast array of proxy tools exist for reconstructing past ocean conditions. Yet few of these yield information at both high temporal resolution (i.e., sub-annual) and across a wide depth range. Soft corals and black corals, two

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separate orders within the class Anthozoa (Fabricius and Alderslade, 2001; Opresko and Sanchez, 2005), are a relatively new tool for paleoceanographic reconstruction. They have a global distribution, grow from the surface to several kilometers deep (Moore et al., 1956; Cimberg et al., 1981), and have a banded skeleton providing chronological control with the potential for sub-annual resolution (Risk et al., 2002; Sherwood et al., 2005a). While attention has mostly focused on deep-water taxa in mid-to-high latitudes, paleoceanographic reconstructions from shallow-water soft coral and black corals taxa in the tropics could prove essential to understanding past behavior of tropical oceanographic systems. Since large, and therefore old, colonies are rare, reconstructions from multiple soft coral and black coral taxa from a variety of sites and depths are inevitable. However, the natural variability that exists among specimens needs to be assessed so that corrections can be made when comparing records from multiple sites, depths, and/or taxa.

Measurements of the stable nitrogen ($\delta^{15}N$) and stable carbon ($\delta^{13}C$) isotopic composition of the organic skeleton is a primary method of obtaining paleoceanographic information from the skeleton of these types of corals (see review in Sherwood and Risk, 2007). In deep-water taxa (i.e., commonly found greater than 200 m), $\delta^{15}N$ and $\delta^{13}C$ values reflect sinking particulate organic matter (POM) (Heikoop et al., 2002; Roark et al., 2005; Sherwood et al., 2005b; Williams et al., 2007a). Since $\delta^{15}N$ and $\delta^{13}C$ values of sinking POM undergo minimal alteration with depth (Altabet and Francois, 1994), the isotope values of sinking POM, and therefore coral colonies at depth, record surface processes or sources of nutrients influencing the isotopic composition of surface organic matter. However, such reconstructions utilizing multiple specimens do not always account for differences in diet or metabolic fractionation among species, across depth, or in geographically distant locations in the ocean. In fact, in deep-water temperate taxa, these factors may be important as $\delta^{15}N$ values may vary up to 2.5‰ among colonies from the same location and up to 1.5‰ from a single skeletal ring within a colony (Sherwood et al., 2005b; Williams et al., 2007a,b). Quantifying and understanding the variability in organic skeletal $\delta^{15}N$ and $\delta^{13}C$ among deep-water taxa and among specimens within these taxa was the first step in developing proxy-based paleoceanographic reconstructions with these organisms.

Less is known about the natural isotope variability and the source(s) of that variability in tropical shallow-water taxa (<200 m). Similar to deep-water taxa, differences in diet (e.g., Grigg, 1965; Lewis, 1978; Ribes et al., 1998), growth rates (e.g., Khalesi et al., 2007; Bo et al., 2009), or metabolic fractionation rates (e.g., Sorokin, 1991) among shallow-water taxa could influence their skeletal isotope signatures independent of oceanographic conditions, making their derived proxy records difficult to compare. In addition, variable skeletal composition among taxa may override any environmental signal recorded in these corals since inherently different isotope signatures may characterize unique skeletal compositions. This may be particularly evident among orders, as the soft corals with internal skeletons (groups Scleraxonia, Holaxonia and Calcaxonia, formerly in the order Gorgonacea) suitable for paleoceanographic reconstructions are composed of gorgonin (an organic proteinaceous substance), sometimes in combination with calcite (Grasshoff and Zibrowius, 1983; Lewis et al., 1992), whereas black corals form a skeleton predominately composed of chitin complexed with proteins (Goldberg, 1976; Ellis et al., 1980).

$\delta^{15}N$ and $\delta^{13}C$ values of tropical shallow-water black coral and soft coral taxa could differ between sites, across depth, among colonies within a taxa, or among taxa if (1) the source of nitrogen and carbon differed among these parameters, and/or (2) if biological fractionation of acquired nitrogen and carbon were taxa-specific. A detailed study is needed to quantify the baseline isotope variability among genera in soft corals and black corals to facilitate comparison of isotope-based paleoceanographic proxy reconstructions from multiple taxa. With this in mind, we examined the organic skeletal $\delta^{15}N$ and $\delta^{13}C$ values among multiple coral colonies from different sites, depths, and taxa in the western tropical Pacific Ocean, and identified strategies for comparing the proxy records of these corals in paleoceanographic studies.

2. METHODS

2.1. Study site

Soft coral and black coral colonies were collected from Short Drop Off (7°16N, 134°31E) and Ulong Rock (7°17N, 134°14E) offshore of Palau. Both sites are 300 m vertical reef walls located offshore of the island Koror and experience similar seasonal seawater temperature patterns in the top 85 m of the water column (Colin, 2001). The temperature of the mixed layer is greater than 28 °C and the average temperature below the mixed layer is 23 °C. The base of the mixed layer fluctuates in depth on seasonal and El Niño-Southern Oscillation timescales with an average depth of 55 m (Zhang et al., 2007).

2.2. Colony identification

Colonies from a wide range of taxonomic groups were collected along a vertical wall from 5, 15, 25, 35, 45, and 85 m by SCUBA in 2006 and from 105 m by submersible in 2008. Colonies were growing outward into the water column, perpendicular to the wall. Photos showing gross colony morphology and branching pattern were taken of each colony after collection. A basal section of the stem from each colony was removed from below the lowest branches, and transported to the laboratory for isotope analyses. Taxonomic identification was made in the laboratory based on photos and sclerites. Soft corals were identified to the genus level according to Fabricius and Alderslade (2001) and with the assistance of Gary Williams of the California Academy of Sciences. Black corals were identified to the genus level by Dennis Opresko of the Oak Ridge National Laboratory. Identification below genus was not feasible as many species have not been described for both soft corals and black corals.