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Stable isotopes as tracers of residency for fish on inshore coral reefs

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ABSTRACT

Understanding the migratory movements of fish between habitats is an important priority for fisheries management. Carbon (C) and nitrogen (N) stable isotopes were used to evaluate the degree of movement and residency for five fish species collected from coral reefs in Queensland, Australia. Isotope values of fish were measured and compared between slow-turnover muscle tissue and fast-turnover liver tissue, with isotopic agreement between liver and muscle generally indicating resident animals, and relatively low C isotope values in muscle indicating migrants. Three fish species, rabbitfish (*Siganus fuscescens*), painted sweetlips (*Diagramma labiosum*) and Guenther's wrasse (*Pseudolabrus guentheri*) showed relatively consistent carbon isotope values between muscle and liver tissue as expected for resident populations. One quarter of bream (*Acanthopagrus australis*) individuals showed much lower $\delta^{13}C$ values in muscle than liver. These low values diverged from the −10 to −15‰ values of residents and were more similar to the −20‰ values of fish collected from coastal riverine habitats, the presumed migration source. Moses perch (*Lutjanus russelli*) also showed substantial differences between muscle and liver C isotopes for about a quarter of individuals, but the overall higher C values of these individuals indicated they may have switched diets within island habitats rather than migrating. Our results were consistent with previous studies of fish residency and indicate that measuring stable isotopes in multiple tissues provides a useful methodology for characterizing fish residency in inshore areas.

1. Introduction

Characterizing the movements of fish between coral reefs and other habitats has become a focus for improving our understanding of habitat connectivity and population dynamics in tropical seascapes (Green et al., 2014). Reef fish make movements at scales of a few hundred meters to kilometers for feeding and spawning, and when they transition between juvenile and adult habitats (Berkström et al., 2012). These movements are challenging to measure. Historically, fish movement was investigated using labor intensive tagging and recapture studies employing dyes, plastic tags, and data from acoustic transmitters which offer detailed and explicit evidence of movement patterns (Gillanders, 2009). Using artificial tags can be costly however, and can involve handling effects on behavior and mortality, and overall have low recapture efficiency (Gillanders, 2009). More recently, natural biochemical markers such as stable isotopes have proven useful for characterizing fish movement (Elsdon et al., 2008; McMahon et al., 2013) and because they are naturally present in all animals many of the difficulties associated with artificial tags are avoided.

Stable isotope values of carbon in animal tissues typically indicate diet, while isotopes of nitrogen reflect trophic level (Fry, 2006). The accuracy of stable isotopes as tracers of animal diet, however, depends on the assumed equilibrium between the tissue measured and the food sources consumed. Fish tissues have different turnover times depending on their rate of growth and metabolism (Hesslein et al., 1993; Perga and Gerdeaux, 2005; Carleton and Del Rio, 2010). Muscle tissue in fish has a slow turnover time and isotopic ratios of this tissue reflect long term diet for foods consumed during growth (approximately 100 days), while liver tissue has continuous protein turnover, and isotope ratios in liver reflect diet within the last 10–20 days (Perga and Gerdeaux, 2005; Logan et al., 2006; Buchheister and Latour, 2010). Consequently, fishes with dissimilar liver and muscle isotope values may be new arrivals to a habitat. In contrast, fishes with similar isotope values in these two tissues are more likely to be residents (Haas et al., 2009).

For stable isotopes to be effective indicators of fish residency, the habitats that fish move between must have foods diet sources

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with unique isotopic values. This makes estuarine habitats valuable study areas as they typically have well-characterized differences in isotope values between freshwater and marine food sources (Bouillon et al., 2011). Stable isotope ratios of C and N in multiple tissues, though rarely used, have successfully shown changes in residency of brown shrimp (Fry et al., 2003), riverine fish (Haas et al., 2009) and blue crabs (Gelpi et al., 2013) in estuarine habitats. Isotopes are therefore likely to provide useful natural tags for investigating fish movement in inshore reefal systems, and may help identify key nursery areas (Fry, 1981; Herzka, 2005).

The aim of this study was to investigate whether concurrent measurements of $\delta^{13}C$ and $\delta^{15}N$ in fish liver and muscle tissue could be used to characterize variability in residency among fishes common to inshore coral reefs in southeast Queensland. It was hypothesized that isotopic values of muscle and liver tissues would be consistent for fish that occupy small home ranges on reefs. For non-resident fish muscle tissue isotopes would diverge from those typical of reef values and instead reflect isotope values of fish frequenting coastal riverine habitats. These ideas were tested relative to the known isoscape distributions in the Moreton Bay area (Fig. 1).

1.1. Study area and fish movement across the Moreton Bay isoscape

Moreton Bay is a large (3400 km^2) subtropical embayment which supports extensive recreational and commercial fisheries. Habitats in the bay range from mangrove creek, salt marsh and seagrass habitats in the coastal riverine areas (referred to here as "coastal riverine habitats"), to seagrass, fringing coral reefs and fringing mangroves towards the ocean entrance (referred to here as "island habitats") (Fig. 1). The reefs consist of boulder corals (*Favia* spp.) and some branching corals (*Acropora* spp.) and are located within 1000 m of intertidal reef flats, fringing mangroves (*Avicennia marina*) and seagrass beds (*Zostera muelleri*).

To explore fish movement on inshore coral reefs in Moreton Bay a geographic isotope seascape or "isoscape" was developed. There is a gradient for $\delta^{13}C$ and $\delta^{15}N$ values of fishes and invertebrates in estuarine coastal areas of eastern Australia relating to local rivers (Connolly et al., 2009). Due to the increased availability of terrestrial sources and organic matter from mangroves and associated flora in coastal riverine areas, lower $\delta^{13}C$ values of −17 to −21‰ and higher $\delta^{15}N$ values (16‰ ^{15}N) should be found in muscle tissue of fish which have spent time feeding in coastal riverine habitats in Moreton Bay (Connolly, 2003). Fish that are long-term residents of island habitats nearer to the open ocean should have $\delta^{13}C$ isotope values in the −9 to −16‰ range usually seen for coral reef residents (Wyatt et al., 2012; Davis et al., 2014) and lower $\delta^{15}N$ values (approximately 14‰) (Fig. 1). Although mangroves are found in both coastal riverine and island habitats, those on the mainland are riverine mangroves with high levels of sediment input where fish are known to feed (Laegdsgaard and Johnson, 2001). Island habitats have dry sandy fringing mangroves that do not offer many ^{13}C-depleted foods to reef fish (Davis et al., 2014).

The criteria for resident fish in the coral reef islands of Moreton Bay were that (1) they have relatively similar liver and muscle isotope values reflecting a consistent long-term diet, and that muscle values of $\delta^{13}C$ were in the range usually seen for coral reef residents. Two other feeding strategies could also reflect residency; (2) inconsistent $\delta^{13}C$ values in liver and muscle tissue, but with values in the range consistent with island habitat foods, suggesting diet switching within the island habitat and (3) equilibrium for foods depleted in ^{13}C. This last strategy is highly unlikely given the typical range of isotope values in island habitats.

Lower $\delta^{13}C$ values and a strong difference in muscle vs. liver values are expected for animals migrating from coastal riverine areas. Foods very depleted in ^{13}C are not typically observed in the diet of fish collected from island habitats (Davis et al., 2014), ruling

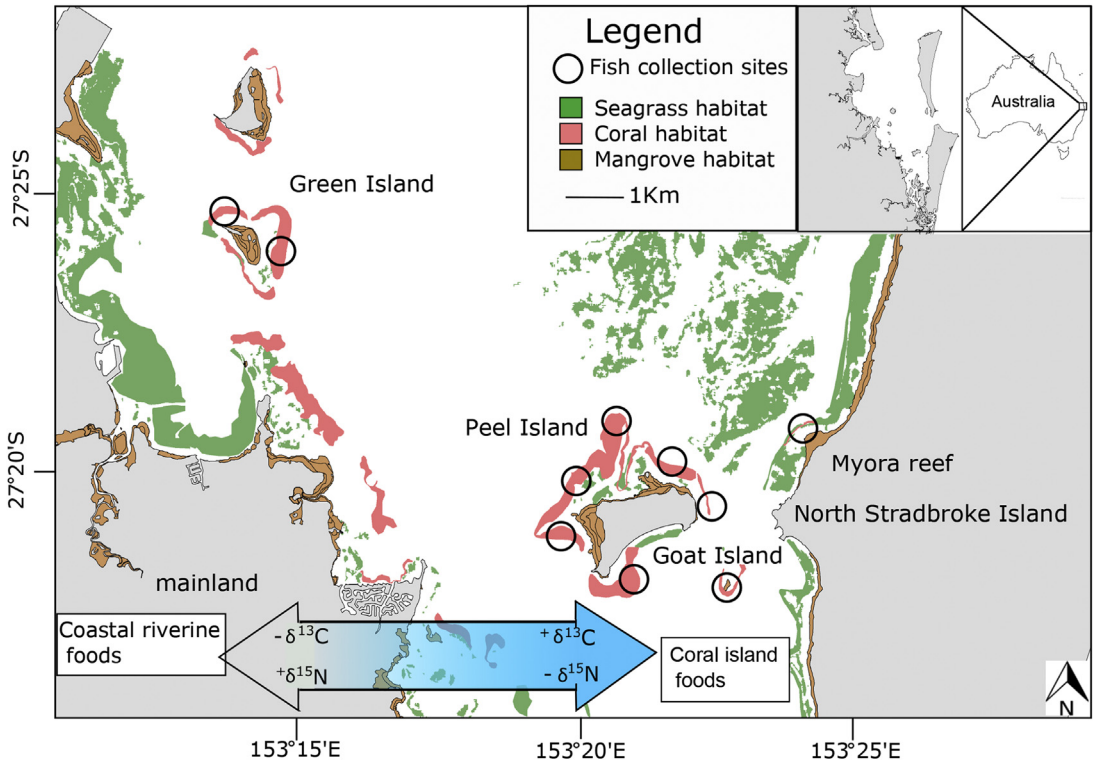

Fig. 1. Location of sampling sites in Moreton Bay, Queensland, Australia, and predicted trends in carbon stable isotope values (blue arrow). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)