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Utilization of carbon sources in a northern Brazilian mangrove ecosystem

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ABSTRACT

Carbon and nitrogen stable isotope ratios (^{13}C and ^{15}N) and trophic level (TL) estimates based on stomach content analysis and published data were used to assess the contribution of autotrophic sources to 55 consumers in an intertidal mangrove creek of the Curuçá estuary, northern Brazil. Primary producers showed δ^{13}C signatures ranging between −29.2 and −19.5‰ and δ^{15}N from 3.0 to 6.3‰. The wide range of the isotopic composition of carbon of consumers (−28.6 to −17.1‰) indicated that different autotrophic sources are important in the intertidal mangrove food webs. Food web segregation structures the ecosystem into three relatively distinct food webs: (i) mangrove food web, where vascular plants contribute directly or indirectly via POM to the most ^{13}C-depleted consumers (e.g. *Ucides cordatus* and zooplanktivorous food chains); (ii) algal food web, where benthic algae are eaten directly by consumers (e.g. *Uca maracoani*, mullets, polychaetes, several fishes); (iii) mixed food web where the consumers use the carbon from different primary sources (mainly benthivorous fishes). An IsoError mixing model was used to determine the contributions of primary sources to consumers, based on δ^{13}C values. Model outputs were very sensitive to the magnitude of trophic isotope fractionation and to the variability in ^{13}C data. Nevertheless, the simplification of the system by *a priori* aggregation of primary producers allowed interpretable results for several taxa, revealing the segregation into different food webs.

1. Introduction

The knowledge of the relative contribution of autotrophic sources to a given food web is fundamental for both theoretical and practical reasons. First, this information is essential for understanding the relationship between fauna and flora of different environments. Second, the identification of which autotrophic sources sustain the secondary production is often vital for the development of conservation priorities and effective management policies of ecosystems (e.g. Connolly et al., 2005).

Knowledge of food sources for consumers are particularly important in mangrove ecosystems, which have long been recognized as important nursery grounds for several fish and penaeid shrimp. Although food webs in mangroves have received considerable attention, they remain poorly understood.

While early investigations based on stomach content analysis (Odum and Heald, 1972) concluded that mangrove detrital material constitutes an important food source for many aquatic organisms, more recent stable isotope studies have questioned these results, showing that ingested mangrove material is not always assimilated efficiently by consumers and that other primary producers such as phytoplankton and microphytobenthos are important sources for consumers (e.g. Newell et al., 1995; Christensen et al., 2001; Bouillon et al., 2002). Less conspicuous primary producers (e.g. microalgae and small filamentous green algae) that have low biomass, but high turnover rates and palatability may be more important in the food web than evident large macrophytes (Wiedemeyer and Schwamborn, 1996; Bouillon et al., 2002; Alfaro et al., 2006). More specifically, stable isotope ratios are natural tracers that can be highly useful to assess the relative contributions of given primary sources in food webs, especially when detritus, microphagous food chains, or organisms that triturate their food (e.g. many crustaceans) are important (Fry, 2006).

Several previous studies have combined stable isotopes in the interpretation of stomach contents for selected species (Beaudoin et al., 1999; Schwamborn and Criales, 2000; Hadwen et al., 2007). Also, isotopic analyses of species aggregated into trophic guilds have been used in estuarine food web studies (Martinetto et al., 2006; Winemiller et al., 2007; Armitage and Fourqurean, 2009; Wilson et al., 2009). However, a combination of stomach content and stable isotope data into an ecosystem-wide food web model has not yet been attempted.

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The transfer of carbon and nitrogen through the food web results in a change in isotope ratios due to fractionation (*F*), with an alteration per trophic level (TL) ranging between −2.7 and 3.9‰ for δ^{13}C and between −2.4 and 7.8‰ for δ^{15}N (Post, 2002; Schwamborn et al., 2002; McCutchan et al., 2003; Sweeting et al., 2007; Caut et al., 2009; Travis et al., 2010). Estimates of *F* typically are based on paired isotopic measurements of diet and consumer, usually under artificial laboratory conditions (e.g. Buchheister and Latour, 2010; Elsdon et al., 2010). There is still no quantitative information on the possible existence of continuous isotope enrichment on a food web scale.

In contrast to many mangrove forests in the Indo-Pacific (e.g. Bouillon et al., 2004; Abrantes and Sheaves, 2010), Caribbean (e.g. Nagelkerken and van der Velde, 2004), and the semi-arid north-eastern Brazil (Schwamborn et al., 2002), the north Brazilian coast is covered by vast undisturbed mangrove forests without connection to other nearshore macrophytic habitats (e.g. seagrass beds, salt marshes or macroalgae beds). Brazil has one of the largest mangrove areas of the world (Aizpuru et al., 2000). There are still no data on stable isotope signatures of food webs in northern Brazilian mangrove forests, in spite of their huge biomass and extension, and their evident biogeochemical, ecological, and socio-economic importance.

The main objective of this study is to determine the contribution of autotrophic sources for a food web in an intertidal creek in the Curuçá mangrove estuary (Northern Brazil) through stable isotope analysis. Furthermore, this work evaluates the effect of *F* and TL on the potential source contributions to consumers estimated by Iso-Error mixing models (Phillips and Gregg, 2001).

2. Material and methods

2.1. Study area

This study was carried out in an intertidal mangrove creek located in the inner part of the Curuçá estuary, approximately 160 km from Belém, northern Brazil (0°10′S, 47°50′W) (Fig. 1). The Curuçá estuary is surrounded by extensive mangrove forests (116 km^2) divided by a complex network of branching intertidal creeks. The mangroves are flooded by semidiurnal tides with an amplitude of up to 5 m. At neap tide, the sampled creek floods and drains a mangrove surface of approximately 20,000 m^2, dominated by *Rhizophora mangle* and *Avicennia germinans*. There are no freshwater inputs to this creek other than direct rainfall, i.e. there is no measurable input from local rivers or from the Amazon (Giarrizzo and Krumme, 2009). Due to the macrotides, high rainfall (mean annual rainfall is 2526 mm), and high turbidity (Secchi depth usually less than 60 cm), there are no seagrass beds, macroalgal beds, or coral reefs in this region (Giarrizzo and Krumme, 2008). Therefore, mangroves, benthic and planktonic microalgae, and mangrove macroalgae are the only relevant primary producers in this system.

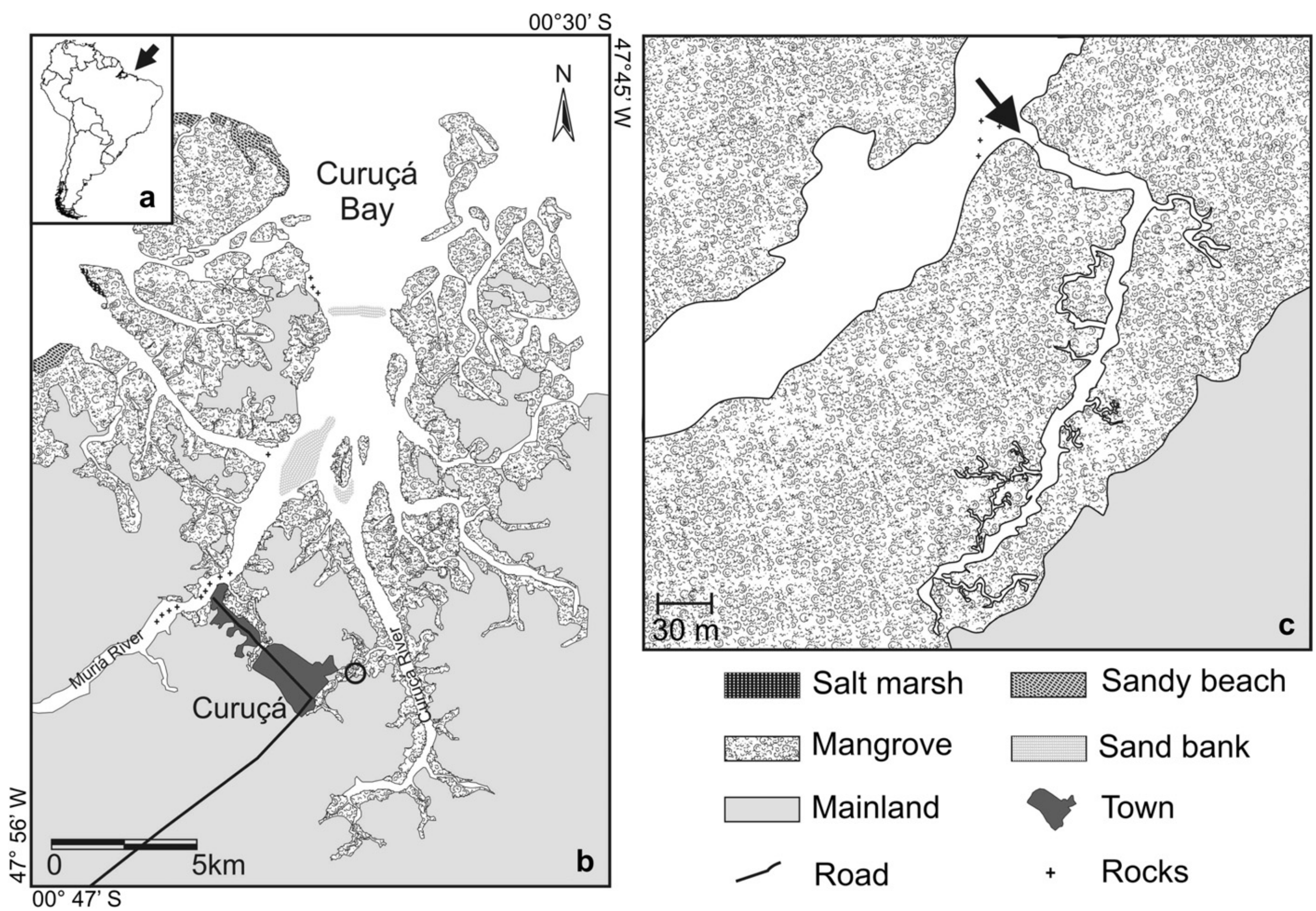

Fig. 1. Map of the Curuçá estuary, northern Brazil. a: Location of the Curuçá estuary at the mouth of the Amazon. b: Position of the macrotidal creek within the Curuçá estuary. c: Map of the macrotidal creek, indicating the sampling site.