Stable Isotopes as Natural Markers of Nursery Productivity for Juvenile Snappers Across Back-reef Habitats in Belize

Isótopos Estables como Marcadores Naturales de Productividad de Vivero para Pargos Juveniles Ocupan Hábitats de Arrecife Posterior de Belice

Isotopes Stables comme Marqueurs Naturels de la Productivité de la Pépinière pour Jeunes Vivaneaux Partout au dos des Récifs des Habitats au Belize

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EXTENDED ABSTRACT

In recent years, marine conservation efforts have focused increasingly on the preservation of productive nursery habitats for juvenile fishes (Beck et al. 2001), and characterizing nursery productivity is particularly critical in the tropics, where many important fisheries species require multiple back-reef nurseries during juvenile development (e.g. Adams et al. 2006). The dependence of these fishes on multiple habitat types makes them particularly vulnerable to environmental degradation and habitat loss, and studies have shown that the removal or modification of one or more required nursery habitats can adversely affect recruitment success and year class strength (Mumby 2006). Because of this, identifying productive back-reef nurseries and characterizing the sources of primary production (i.e. organic matter) that support consumers within these early life habitats is critical to the effective management of many tropical fisheries.

In the present study, we used $d^{13}C$ and $d^{15}N$ stable isotopes as dietary tracers to evaluate back-reef nursery productivity across the Belize coastal lagoon. The objectives of this study were to (a) identify the main sources of primary production supporting three species of juvenile snappers (family Lutjanidae), and (b) model the effects of seasonal runoff and water-shed impact (i.e. anthropogenic influence) on primary productivity within these nurseries. To accomplish this, four primary producers (phytoplankton, benthic diatoms, mangroves, and seagrass) as well as three species of juvenile snappers (dog snapper *Lutjanus jocu*, gray snapper *L. griseus*, and schoolmaster *L. apodus*) were collected from two latitudinal regions (i.e. North, South) in southern Belize (Figure 1). Samples were taken from an inner-shelf and an outer-shelf site within each region, and each site was sampled separately during the dry and the rainy season. For each site and season, estimates of organic matter contribution from the four primary producers were modeled using the *Isosource* program, based on isotopic $d^{13}C$ and $d^{15}N$ values of producers and juvenile snappers (Table 1).

Of our four producers, only phytoplankton showed a significant seasonal shift in isotopic signature, with more enriched $d^{15}N$ values (0.9 – 5.2 [dry season]; 2.0 – 4.6 [rainy season]) and more depleted $d^{13}C$ values (≈ -17-27 [dry]; ≈ -20-32 [rainy]) during the rainy season. Juvenile snappers at the north inner and south outer sites also showed significant seasonal differences in isotopic signature; however, these shifts occurred in the opposite direction from the observed shifts in phytoplankton, which indicates a seasonal shift in the source of primary production supporting juvenile snappers at these two sites, rather than a case of snapper signatures simply tracking seasonal changes in producers (Table 1). No significant differences in snapper isotopic signatures were observed at the north outer or south inner study sites, and this latter result was somewhat unexpected, given the strong riverine influence in our southern sampling region.

Isosource results for the two study sites with no seasonal differences in consumer signatures (i.e. north outer, south inner) indicated that seagrass and benthic diatoms were the largest contributors of organic matter supporting juvenile snappers during both sampling seasons (42-62% [dry]; 47-72% [rainy]). At the north outer site, estimated contribution from phytoplankton production was also significant (median 32% contribution [dry]; 28% [rainy]), reflecting the strong marine influence and regional upwelling along this area of the shelf edge. Meanwhile, *Isosource* results for the two sites where strong seasonal shifts in consumer signatures were observed (i.e. north inner, south outer) revealed that isotopic differences in juvenile snappers at both locations were driven primarily by a marked decrease in phytoplankton contribution from the dry to the rainy season, with mean estimated contribution at the north inner site decreasing from 25% to 12% in the rainy season, and median phytoplankton contribution at the south outer site decreasing from 40% in the dry season to 15% in the rainy season. Declines in contribution rates of phytoplankton during the rainy season were countered by increases in seagrass/benthic diatom contribution (21 – 43% [dry season] to 56 – 73% [rainy]). These results indicate that the main source of organic matter supporting upper-level consumers may change significantly between the dry and rainy seasons at certain back-reef nurseries.

Trophic productivity of back-reef nurseries across the Belize coastal lagoon may be strongly related to land use and management policies within adjacent watersheds. The two study sites (i.e. north inner, south outer) where we observed seasonal shifts in juvenile snapper signatures are both impacted by watersheds with extensive aquaculture and agricultural development. Decreased water quality due to anthropogenic runoff during the rainy season may have influenced the consistent seasonal decreases in phytoplankton contribution supporting nursery food webs at these sites. In comparison, despite similarly strong riverine input during the rainy season, no significant seasonal effects on primary production were observed at the south inner site, where the majority of land within the watershed is managed under the Maya Mountain Marine Corridor and coastal development is strictly regulated. Land-sea connectivity is well established in Belize (Heyman and Kjerfve 1999), and our results appear to indicate that terrestrial runoff from areas of extensive aquaculture and agriculture may negatively impact the productivity of adjacent coastal nurseries for upper-level consumers (i.e. juvenile snappers). Thus, preservation of ecological functioning within back-reef nurseries in Belize may require consideration of regional watershed influence, in addition to local habitat conservation.

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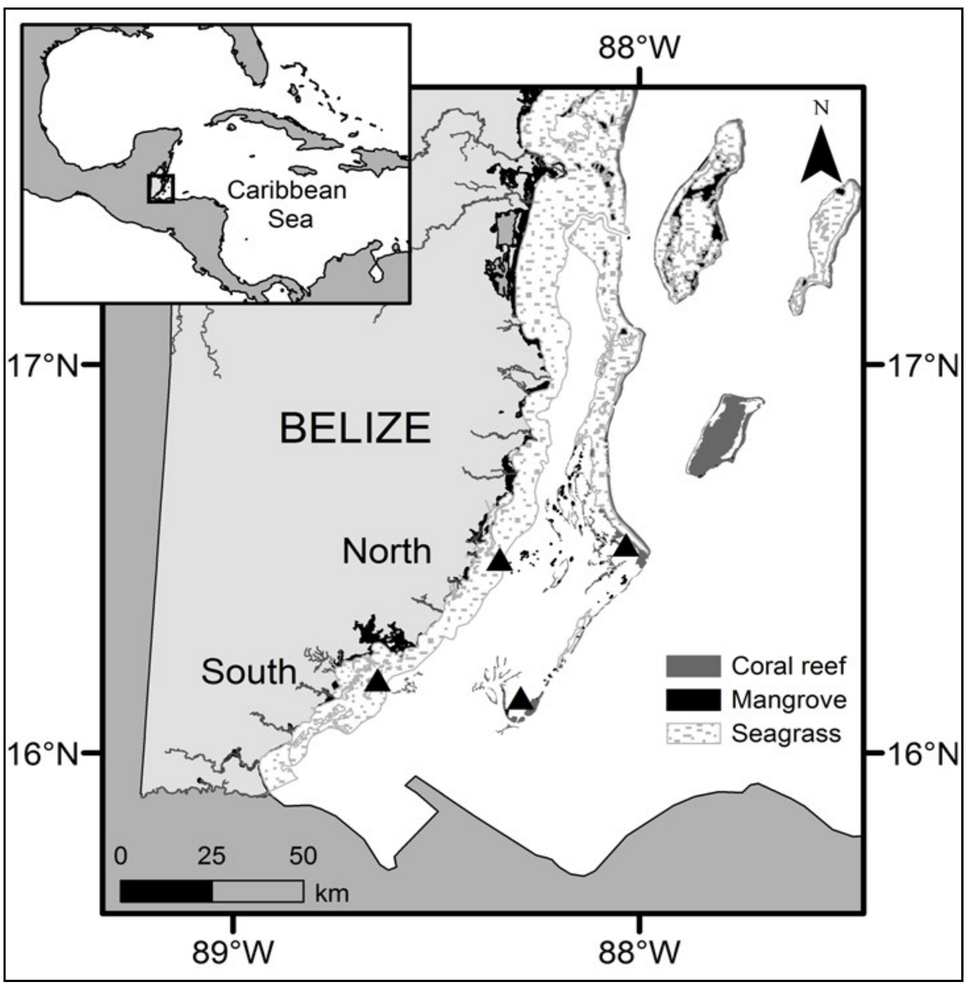

Figure 1. Regional context of study sites in southern Belize. Northern and southern sampling regions are labeled, and black triangles indicated the location of the inner-shelf and outer-shelf study site within each region. Shaded areas denote habitat distribution within the coastal lagoon.

Table 1. $d^{13}C$ and $d^{15}N$ signatures (mean ± SD) of primary producers (phytoplankton [PMA], benthic microalgae [BMA], mangrove [MG], and seagrass [SG]) and juvenile fishes (dog snapper [DS], gray snapper [GS], and schoolmaster [SM]) collected at each region (North, South) and shelf position (Inner, Outer) during the Dry and Rainy sampling seasons in 2009. MG leaves were sampled from each region during each sampling season, but were pooled across shelf positions.

Region	Site	Sample Type	$d^{13}C$		$d^{15}N$	
			DRY	RAINY	DRY	RAINY
Producers						
North	**Inner**	PMA	-27.1 ± 4.7	-30.2 ± 4.1	1.5 ± 0.8	4.6 ± 0.6
		BMA	-15.5 ± 2.9	-15.2 ± 5.7	1.3 ± 0.7	2.1 ± 0.3
		MG	-28.4 ± 1.0	-28.5 ± 0.5	0.8 ± 2.0	-0.1 ± 2.5
		SG	-7.5	-11.7	2.4	0.9
	Outer	PMA	-23.8 ± 3.3	-23.8 ± 5.6	0.9 ± 0.7	1.9 ± 1.2
		BMA	-8.7 ± 3.5	-11.6 ± 7.7	2.4 ± 0.5	2.4 ± 0.2
		MG	-28.4 ± 1.0	-28.5 ± 0.5	0.8 ± 2.0	-0.1 ± 2.5
		SG	-8.3	-8.3	3.3	1.4
South	**Inner**	PMA	-18.3 ± 1.7	-31.3 ± 2.1	5.2 ± 0.2	4.4 ± 0.8
		BMA	-12.2 ± 7.0	-11.2 ± 5.3	2.3 ± 0.2	1.5 ± 1.9
		MG	-29.6 ± 1.3	-28.5 ± 0.5	2.1 ± 0.5	0.8 ± 0.7
		SG	-6.8	-7.6	2.3	3.0
	Outer	PMA	-17.9 ± 3.8	-20.1 ± 7.9	1.0 ± 0.9	2.0 ± 2.1
		BMA	-4.5 ± 0.6	-8.8 ± 2.3	0.8 ± 0.6	1.8 ± 1.7
		MG	-29.6 ± 1.3	-28.5 ± 0.5	2.1 ± 0.5	0.8 ± 0.7
		SG	-8.1	-8.3	1.3	2.4
Juvenile Snappers						
North	**Inner**	DS	-16.5 ± 1.3	-15.9 ± 2.6	11.1 ± 0.6	10.0 ± 0.4
		GS	-16.8 ± 2.6	-15.1 ± 1.0	10.9 ± 1.8	10.2 ± 0.4
		SM	-14.4 ± 2.0	-14.9 ± 2.3	10.9 ± 0.8	10.3 ± 0.9
	Outer	DS	-14.5 ± 0.9	-14.4 ± 1.4	9.6 ± 0.4	10.6 ± 1.1
		GS	-15.1 ± 1.0	-15.0 ± 0.8	9.8 ± 0.5	10.0 ± 0.2
		SM	-14.3 ± 1.3	-14.9 ± 1.0	9.4 ± 0.5	9.8 ± 0.5
South	**Inner**	DS	-16.8 ± 1.4	-16.8 ± 0.7	11.7 ± 0.4	10.8 ± 0.6
		GS	-14.8 ± 2.0	-15.3 ± 1.6	11.2 ± 0.2	10.2 ± 0.4
		SM	-15.1 ± 2.0	-14.9 ± 1.3	10.9 ± 0.4	10.4 ± 0.4
	Outer	DS	-16.4 ± 0.1	-13.7 ± 1.7	11.0 ± 0.2	9.5 ± 1.0
		GS	-16.5 ± 1.1	-11.4 ± 0.9	10.9 ± 0.5	10.0 ± 0.1
		SM	-14.6 ± 0.7	-13.3 ± 1.7	10.4 ± 0.7	9.3 ± 0.4