Spatial variations in isotopic niches of two herbivorous fishes on Caribbean reefs

Variaciones espaciales de las firmas isotópicas de dos peces herbívoros en los arrecifes de coral del caribe

Variations spatiales des niches isotopiques de deux poissons herbivores sur les récifs caribéens

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ABSTRACT

Climate change, organic pollution and overfishing have led to major ecological disturbances in coral reefs, including the 'coral-algal phase-shift' phenomenon. Facing such ecological disturbance, ecological roles of herbivorous fish, which naturally regulate algal biomass, are becoming crucial for the future of the reefs. In the present study, we asked if the two species of herbivorous fishes commonly found in the Caribbean (*Sparisoma viride* and *Acanthurus coeruleus*) adapt their feeding patterns function to their habitat, and if spatial variations can be observed in their isotopic niche.

On four study sites located in Guadeloupe, 10 to 20 individuals per species were collected. Isotopic signatures (C and N) were measured in muscles to define the isotopic niche of each fish species using the model SIBER. The main results show that isotopic signatures of fish vary spatially, suggesting different isotopic ratios of the 'baseline' among sites. Moreover, on each site, ellipses representing the isotopic niche of each species never overlap, indicating that the two species display independent niche. To conclude, the absence of overlap between niches of *Sparisoma viride* et *Acanthurus coeruleus* indicate an ecological complementarity between the two fish species in term of resource use and, by consequence, algal regulation.

KEYWORDS**:** *Sparisoma viride – Acanthurus coeruleus* – Stable isotope - Ecological niche – Reef ecology

INTRODUCTION

On Caribbean reefs, herbivorous fishes, and particularly Scaridae and Acanthuridae, are major actors of the « coral-algal phase-sift » limitation, in regulating algal biomass and reducing algae cover in reefs. These two fish families display different feeding habits (Bellwood and Choat 1994, Dromard *et al*. 2015), and by consequence, play complementary ecological roles on the coral reef. In ecology, isotopic studies are particularly useful to determine the trophic niche of organisms or their trophic level in a trophic food-web. These studies are based on the measurement of carbon and nitrogen ratios (^{13}C:^{12}C and ^{15}N:^{14}N) with the assumption that the proportion of "heavy" isotopes (^{13}C and ^{15}N) increases from one trophic level to another. More recently, the concept of "isotopic niche", described as a bi-dimensional space ($\delta^{13}C$ *versus* $\delta^{15}N$), has been introduced by Newsome *et al.* in 2007, as a proxy of the ecological niche. Jackson *et al.* (2011) suggested several metrics to calculate ellipses areas (that clusters isotopic signature of all individuals in a population) with a model called "SIBER". This model and its associated metrics allow the calculation of niches areas and the possibility to compare these indices between species or between sites.

To date, few studies were done on herbivorous fishes in the Caribbean by using isotopic analysis (Lamb *et al.* 2012, Dromard *et al.*, 2015), but none used the model SIBER to compare isotopic niches of Scaridae or Acanthuridae.

Many questions, such as interspecific relation between herbivorous species, their feeding plasticity among species or sites, are not elucidated. The diversity of trophic niches of herbivorous fishes has been discussed in previous studies based on isotopic approach or different methodologies (e.g., McAfee and Morgan 1994, Burkepile and Hay 2011, Dromard *et al*. 2015), however, spatial variations of these isotopic niches have not been studied for the moment. By consequence, the main objective of this study is to describe and compare the isotopic niche of two herbivorous fish species *Sparisoma viride* and *Acanthurus coeruleus* on different sites of Guadeloupe, to study potential spatial variations in their niche at a scale of a Caribbean Island.

METHODS

This study was conducted in Guadeloupe, Lesser Antilles. Between 10 and 34 individuals of *Acanthurus coeruleus* and *Sparisoma viride* were collected by spearfishing on five and four sites respectively, located around Guadeloupe: Grand- Cul-de-Sac-Marin barrier (GCSM), Pointe-à-Lézard (PL), Le Moule (Moule1 and Moule2) and Sainte-Anne (SA1 and SA2). Sampling campaigns were conducted between January 2019 and June 2020. Five sample of *Dictyota* sp. macroalgae were also collected in order to obtain an isotopic "baseline" for each site. A piece of muscle was collected from each individual, and isotopic ratios (^{13}C:^{12}C and ^{15}N:^{14}N) were measured with a spectrometer. These ratios were noted

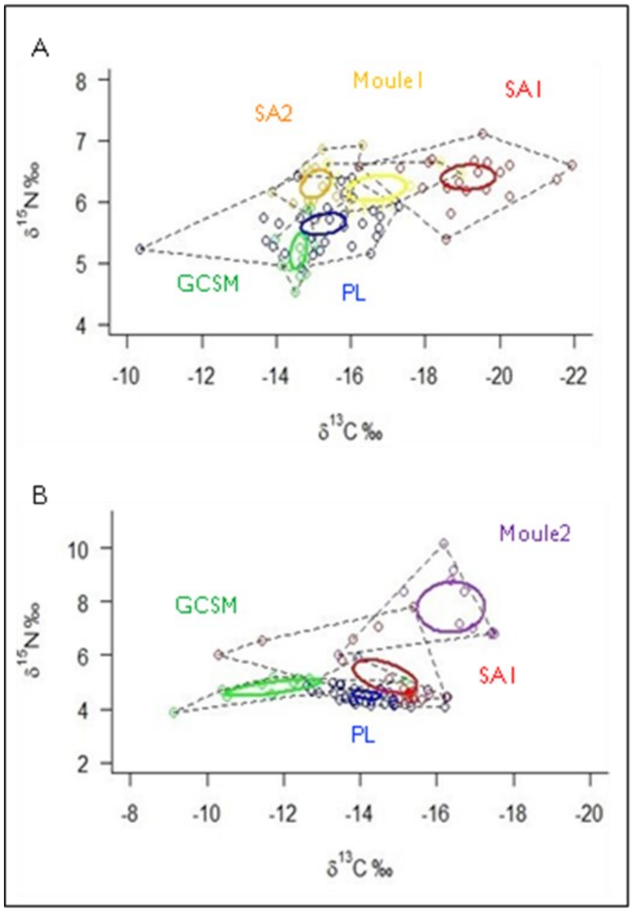

Figure 1. Total areas (TA, doted lines) and Corrected Standard Elllipses Areas (SEAc, full lines) expressing isotopic niches (δ 13C and δ15N in ‰) of *Acanthurus coeruleus* (A) and *Sparisoma viride* (B) according to sites. GCSM : Grand cul-de-sac Marin, PL: Pointe a Lezard, SA : Sainte Anne.

as isotopic signatures, noted "$\delta_{13}C$" and "$\delta_{15}N$" and expressed in ‰. Carbon and nitrogen isotopic signatures of fish were compared among sites using one-way Analyses of Variance (ANOVAs) while isotopic signatures of *Dictyota* were compared using Kruskal-Wallis tests. Isotopic signatures of fish were then entered into SIBER models, one for each species, to describe isotopic niches of each fish populations. All statistical tests were performed using the R statistical program.

RESULTS AND DISCUSSION

Carbon and nitrogen isotopic signatures of macroalgae *Dictyota* sp. were statistically different according to sites (Kruskal-Wallis, X_2=23.3, df=5, p-value<0.001 for carbon and for nitrogen). These differences are mostly explained by the enrichment in $_{13}C$ for *Dictyota* collected at PL and GCSM, and the carbon depletion observed at Moule1 and Moule

2. These results indicate that isotopic "baseline" of the five studied sites is not homogeneous on the different coast of Guadeloupe, especially between PL-GCSM and Moule1-Moule2. This tendency was reflected in isotopic signatures of fish, that exhibited enriched $\delta_{13}C$ at GCSM for both species and depleted carbon signatures for *Sparisoma viride* at Moule2. For *Acanthurus coeruleus*, isotopic signatures of muscles were significantly different according to sites (ANOVA, $F_{(4,83)}$=48.8, p<0.001 for carbon and $F_{(4,83)}$=29.2, p<0.001 for nitrogen). Post-hoc multiple comparisons tests (Tukey HSD) indicate that the five *A. coeruleus* populations exhibit different isotopic signatures, even between sites SA1 and SA2 that presented close isotopic baselines (moy ± SD: -16.3 ± 0.5‰ at SA1 and -15.5 ± 0.9‰ at SA2). Ellipses corresponding to Total Area (TA) (which is the area clustering all individual of a population) and SEAc (Areas corrected by the sample size) were minimum in GCSM (0.83 and 0.44 ‰$_2$ respectively) and maximal in PL (6.16 and 1.64‰$_2$) (Figure 1A).

For *Sparisoma viride*, isotopic signatures of muscles were significantly different according to sites (ANOVA, $F_{(3,70)}$=26.1, p<0.001 for carbon and $F_{(3,70)}$=49.0, p<0.001 for nitrogen). Post-hoc multiple comparisons tests (Tukey HSD) indicate that the four *S. viride* populations exhibit different isotopic signatures. Lowest TA values were also found in GCSM (2.72‰$_2$) while lowest SEAc was found in PL (0.94‰$_2$). Fish population from SA1 exhibited the highest TA (11.2‰^{2}) while those of Moule2 showed the largest SEAc (5.3‰^{2}). These results attest the need to consider sample size in the measurement of isotopic niche.

For both fish species, the smallest ellipses were found at GCSM indicating restricted isotopic niches and a limited feeding plasticity on this site. This site, located close to the marine park, in a shallow site with a high density, suggesting higher potential competitive interactions between herbivorous fish species and a higher partitioning of the food resources between species.

For each species, overlaps between ellipses were very low or absent, indicating clear spatial variations of the isotopic niches between the different fish population. These variations can be explained by different isotopic baselines, that can be reflected in the whole trophic food-web of each site or different feeding patterns adopted by fish population among the different sites in response to resources availability or palatability or feeding plasticity to avoid competitive interactions with other species or other individuals.

LITERATURE CITED

Bellwood D. R. et Choat H. 1990. A functional analysis of grazing in parrotfishes (family Scaridae): the ecological implications. *Environmental Biology of Fishes* **28**: 189-214

Burkepile D. E. et Hay M. E. 2011. Feeding complementarity *versus* redundancy among herbivorous fishes on a Caribbean reef. *Coral Reefs* **30**: 351-362

Dromard, C. R., Bouchon-Navaro Y., Harmelin-Vivien M., et Bouchon C. 2015. Diversity of trophic niches among herbivorous fishes on a Caribbean reef (Guadeloupe, Lesser Antilles), evidenced by stable isotope and gut content analyses. *Journal of sea research* **95**: 124-131.

Jackson A. L., Inger R., Parnell A. C., et Bearhop S. 2011. Comparing isotopic niche widths among and within communities: SIBER–Stable Isotope Bayesian Ellipses in R. *Journal of Animal Ecology* **80**(3): 595-602.

Lamb, K.L., Swart, P.K., Atlabet, M.A., 2012. Nitrogen and carbon isotopic systematics of the Florida reef tract. *Bulletin of Marine Science* **88**: 1-28.

Layman C.A., Arrington D.A., Montana C.G. et Post D.M. 2007. Can stable isotope ratios provide for community-wide measures of trophic structure? *Ecology* **88**(1): 42-48.

McAfee, S.T., Morgan, S.G. 1996. Resource use by five sympatric parrotfishes in the San Blas Archipelago, Panama. *Marine Biology* **125**: 427–437.

Newsome S. D., Martinez del Rio C., Bearhop S., et Phillips D. L. 2007. A niche for isotopic ecology. *Frontiers in Ecology and the Environment* **5**(8): 429-436 .