

# Diet and Trophic Ecology of Red Snapper, *Lutjanus campechanus*, on Natural and Artificial Reefs in the Northern Gulf of Mexico

## Ecología Trófica Dieta y Pargo, *Lutjanus campechanus*, en los Arrecifes Naturales y Artificiales en el Norte del Golfo de México

### Régime Alimentaire et l'écologie Trophique de Red Snapper, *Lutjanus campechanus*, Sur les Récifs Naturels et Artificiels dans le nord du Golfe du Mexique

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#### ABSTRACT

Red snapper, *Lutjanus campechanus*, were sampled in 2009-10 at northern Gulf of Mexico (GOM) natural (n = 10) and artificial (n = 9) reef sites to test for the effect of fish size and habitat type on diet and trophic position. Stomachs (n = 231) were sampled for diet analysis and white muscle tissue (n = 49) was sampled for stable isotope analysis ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$ ). Forty-four percent of stomachs (n = 104) had identifiable prey, with 56 of those fish sampled at natural reefs and 48 sampled at artificial reefs. Zooplankton (38%), fish (35%), and decapods (17%) constituted most of the observed diet. Habitat type did not affect diet (PERMANOVA,  $p = 0.087$ ), but fish size was significant (PERMANOVA,  $p = 0.023$ ). An ontogenetic shift was apparent among red snapper size classes in that smaller fish preyed most heavily on other fishes and decapods, while larger red snapper had a higher percentage of zooplankton in their diet. That finding was corroborated by significantly higher  $\delta^{15}\text{N}$  values for red snapper <400 mm total length (TL) relative to fish 400 - 500 mm or > 500 mm TL. Habitat type was not significant for  $\delta^{15}\text{N}$  (ANOVA,  $p = 0.777$ ), and neither fish size nor habitat were significant for  $\delta^{13}\text{C}$  or  $\delta^{34}\text{S}$  ( $p \geq 0.340$ ). Overall, data from this study indicate red snapper have a broad diet and are capable of feeding across multiple trophic levels, and that there is little evidence for differences in red snapper diet or feeding ecology between artificial and natural reefs. The occurrence of the Deepwater Horizon Oil Spill (DHOS) in summer 2010 greatly affected the original design of this study, but data collected provide an important pre-spill reference for red snapper diet and trophic ecology in the northern GOM.

KEY WORDS: Red snapper, artificial reefs, trophic ecology, stable isotopes

#### INTRODUCTION

Artificial reefs (ARs) have been deployed over vast areas of the northern Gulf of Mexico's (GOM) continental shelf with goals that include enhancing fishery resources, facilitating access and use of fishery resources, and minimizing user conflicts due to competition for resources (Bohnsack 1989, Baine 2001). However, it is unclear whether these ARs are more likely to enhance reef fish production or attract fish, thus increase catchability. Enhancement implies that reef fish grow faster or have lower mortality at ARs, or that AR creation increases the carrying capacity of the system for species of interest (Bohnsack 1989, Lindberg 1997). Enhanced growth, which is presumed to be a response of increased foraging success, would imply an increase in overall fitness leading to greater fecundity and stock biomass (Powers et al. 2003). Creation of AR habitat also has been demonstrated to decrease the foraging distance of predatory fish, thereby increasing net energy gain which can be utilized for growth and reproduction (Bohnsack 1989). However, the ability of ARs to mimic natural hard-bottom habitat depends on creating energetic links among reef-dependent organisms (Hueckel and Buckley 1987).

Clearly, understanding how ARs function ecologically requires comparisons with natural reef (NR) habitat (Carr and Hixon 1997). One aspect of examining the ecological function of natural reefs (NRs) versus ARs would be to examine differences in reef fish diet and trophic position between habitat types. In the current study, those parameters were examined for red snapper, *Lutjanus campechanus*, an important fishery species that is also a dominant species in the system with respect to both numbers of individuals and biomass (Dance et al. 2011). Two approaches were taken to examine red snapper diet and trophic ecology: stomach content analysis and stable isotope analysis of white muscle tissue. Stomach content analysis is the only method available to estimate the exact diet of a given species, but hundreds to thousands of stomach samples may be required to test factors that may affect the species' diet. Furthermore, physoclistous fishes such as red snapper often experience barotrauma effects, including everted stomachs, when brought from depth (Rummer 2007).

Stable isotope analysis of white muscle tissue complements stomach content analysis but provides different types of information about a fish's trophic ecology. In the case of carbon (C) and nitrogen (N), stable isotope ratios become enriched in heavier isotopes through assimilatory or metabolic fractionation in which molecules with lighter isotopes (e.g.,  $^{12}\text{C}$  and  $^{14}\text{N}$ ) are assimilated or catabolized more quickly than those with heavier isotopes (e.g.,  $^{13}\text{C}$  and  $^{15}\text{N}$ ; McCutchan et al. 2003, Fry 2006). Nitrogen stable isotope delta values ( $\delta^{15}\text{N}$ ) increase by approximately 3‰ for each trophic level increase in the marine food web, while C stable isotope delta values ( $\delta^{13}\text{C}$ ) increase approximately 1‰ for each trophic level. This more conservative nature of  $\delta^{13}\text{C}$ , combined with different  $\delta^{13}\text{C}$  values among different primary producers (e.g., phytoplankton, benthic microalgae, seagrasses, etc.), enables the estimation of the ultimate source of primary production. Unlike C and N,

sulfur (S) does not experience trophic fractionation. Differences in  $\delta^{34}\text{S}$  result from the source of primary S being either sulfate ( $\text{SO}_4^{2-}$ ) in the water column or hydrogen sulfide ( $\text{H}_2\text{S}$ ) in the sediments, and therefore can be used to estimate consumption of pelagic versus benthic production (McCutchan et al. 2003, Fry 2006).

### MATERIALS AND METHODS

Red snapper were sampled with hook and line from 2009 - 2010 at natural ( $n = 9$ ) and artificial ( $n = 10$ ) reef sites across the northern GOM continental shelf from  $86.6^\circ\text{W}$  to  $88.4^\circ\text{W}$ . Fish were measured to the nearest mm total length (TL) and then their stomachs were dissected and fixed in 10% formalin for at least 48 hours then preserved in 70% isopropyl alcohol. White muscle tissue samples (~50 g) were dissected and frozen for isotope ratio-mass spectrometry (IR-MS) analysis of C, N, and S stable isotopes, which were expressed using the standard delta notation ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$ ).

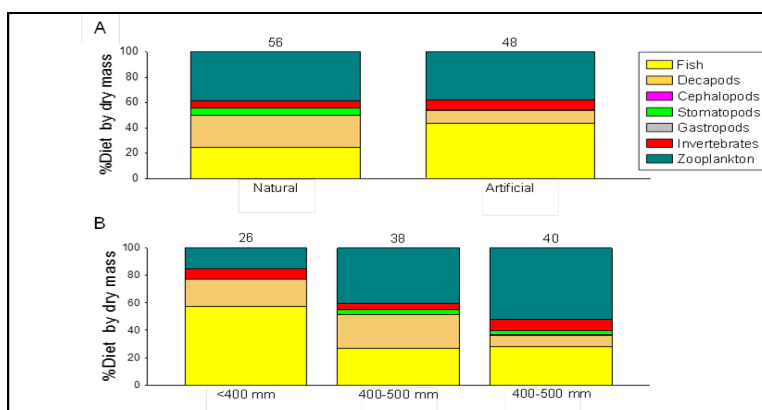
Diet analysis was performed by identifying stomach contents to the lowest taxonomic level possible before placing prey items in an oven to dry for 48 hours at  $60^\circ\text{C}$ . Dried prey were weighed and sorted into one of seven categories for statistical analysis: fish, decapods, cephalopods, stomatopods, gastropods, zooplankton, and other invertebrates. A permutational multivariate analysis of variance (PERMANOVA) was computed with the Primer statistical package (ver. 6, Anderson et al. 2008) to test for differences in red snapper diet between habitat types (natural versus artificial reefs) and among size classes (< 400 mm, 400 - 500 mm, > 500 mm TL). Muscle tissue samples were dried at  $60^\circ\text{C}$  for at least 24 hours, and then ground to a fine powder with a glass or agate mortar and pestle. Mortar and pestles were cleaned with 2% nitric acid and rinsed with ultrapure water between samples to prevent contamination. Ground samples were analyzed for  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$  with a Europa Scientific GSL/Geo 20-20 stable isotope ratio-mass spectrometer (SIR-MS). Two-way ANOVAs were computed to test the effects of habitat and fish size on red snapper muscle  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$ .

### RESULTS AND DISCUSSION

A total of 231 red snapper stomachs were sampled, with 104 samples coming from natural reefs and 127 samples from artificial reefs. Fish ranged in size from 251 to 730 mm TL, with a mean  $\pm$  standard error of  $459 \pm 6.7$  mm. Total length was significantly different between habitat types (ANOVA,  $p = 0.021$ ); however, TL was not significantly different between habitats (ANOVA,  $p = 0.380$ ) for the subsample ( $n = 49$ ) for which stable isotope analysis was performed.

Forty-four percent of red snapper stomachs ( $n = 104$ ) had identifiable prey, with 56 of those fish sampled at natural reefs and 48 sampled at artificial reefs. There were 53 prey taxa identified in snapper stomach samples, but only 9 taxa could be identified to species. Zooplankton (38%), fish (35%), and decapods (17%) constituted most of the observed diet. Within the zooplankton category, the most abundant prey taxon was a hyperiid amphipod, *Phrosina semiluna*, which was equally abundant in red snapper samples from natural and artificial reefs during spring months. Habitat type did not affect red snapper diet (PERMANOVA,  $p = 0.087$ ), but fish size (PERMANOVA,  $p = 0.023$ ) was significant. Fishes and decapods often were too decomposed to key to species, but some trends were apparent, such as more fish being consumed on NRs than ARs and greater amounts of decapods consumed on ARs than NR habitats (Figure 1A). An ontogenetic shift was apparent among red snapper size classes in that smaller fish preyed most heavily on other fishes and decapods, while larger red snapper had a higher percentage of zooplankton in their diet (Figure 1B).

Although based on a limited sample, diet results reported here are consistent with the findings of McCawley and Cowan (2007) that red snapper are generalist predators that feed across multiple trophic levels. Similar to their work, we report that red snapper principally consumed prey associated with sand or mud substrates, and pelagic organisms. McCawley and Cowan (2007) were the first to report that adult red snapper subsidized their diet with

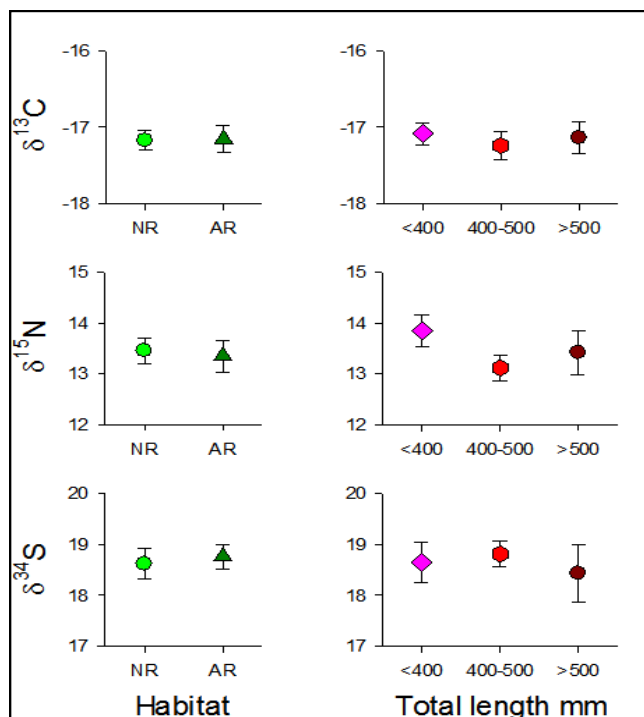


**Figure 1.** Percent diet composition for red snapper sampled at A) natural versus artificial reefs, and B) size classes < 400 mm, 400 - 500 mm, and > 500 mm total length. Sample size given above each bar.

pelagic zooplankton, which is counterintuitive given red snapper dentition and the fish's relatively short gut length. McCawley and Cowan (2007) concluded that red snapper on artificial reefs off Alabama consumed zooplankton because the fish had grazed down higher trophic level prey around artificial reefs, possibly due to reefs being too closely spaced. However, we report the same phenomenon for fish sampled on natural reefs. Therefore, red snapper appear to have a broad diet and are capable of foraging among a range of trophic positions regardless of the habitat in which they occur.

General conclusions based on limited gut content data are supported by results from stable isotope analysis. There was no significant difference in  $\delta^{13}\text{C}$  or  $\delta^{34}\text{S}$  among size classes or habitat types (ANOVA,  $p > 0.340$  for each). There was also no significant difference in  $\delta^{15}\text{N}$  between habitat types (ANOVA,  $p = 0.777$ ), but there was a significant difference in  $\delta^{15}\text{N}$  among size classes (ANOVA,  $p = 0.008$ ). The smallest size class (TL  $\leq 400$  mm) actually had the highest mean  $\delta^{15}\text{N}$  value, thus indicating smaller red snapper in the sample fed at a higher trophic position than the larger fish (Figure 2). This finding is consistent with the observation that larger fish had a higher percentage of zooplankton in their stomach samples, which is particularly important given that stomach content samples only convey what fish consumed in the hours to days prior to being sampled, while stable isotope values of white muscle tissue are integrated over weeks to months. Therefore, smaller red snapper in our sample fed at a higher trophic position than larger fish, and that difference existed for weeks to months prior to fishing being sampled. While that may seem surprising, McCawley and Cowan (2007) also reported that fish between 400 and 500 mm TL had the highest percentage of zooplankton in their diets. Perhaps fish in that size class of have higher energetic demands than smaller fish due being reproductively mature, yet are outcompeted by larger fish (red snapper max size = 1 m TL) for higher trophic position prey (Bailey et al. 2005).

Overall, data from this study indicate red snapper have a broad diet and are capable of feeding across multiple trophic levels, and that there is little evidence for differences in red snapper diet or feeding ecology between artificial and natural reefs. The original objective for this study was to collect  $> 1,000$  stomach samples over 2 years and multiple seasons to provide a comprehensive examination of red snapper diet and trophic ecology between natural and artificial reefs. However, the occurrence of the Deepwater Horizon Oil Spill (DHOS) in summer 2010 greatly affected the study plan. While data are somewhat limited to describe pre-DHOS differences in red snapper diet between artificial and natural reefs, they do provide important pre-spill information on red snapper diet between habitat types.



**Figure 2.** Mean ( $\pm$ SE) red snapper muscle  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$  values between habitat types and among fish size categories.

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