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Dietary Habits of the Gafftopsail Catfish, *Bagre marinus*, in Tarpon Bay and Pine Island Sound, Florida

PAUL J. RUDERSHAUSEN AND JAMES V. LOCASCIO

A total of 507 gafftopsail catfish, *Bagre marinus*, were captured by hook and line in Tarpon Bay and neighboring Pine Island Sound, Florida from June 3, 1999 to May 6, 2000 in order to identify foods of this understudied species. A total of 86 (17.0%) specimens contained only unidentifiable food, and 187 (36.9%) specimens were found with empty stomachs. Based on the index of relative importance, the pink shrimp, *Farfantepenaeus duorarum*, was the most important food for specimens ≤ 200 mm fork length (FL), amphipods the most important food for specimens 201–300 mm FL, and unidentifiable fish the most important food for specimens ≥ 301 mm FL. Diet of *B. marinus* was also compared among four seasons: June through August; September through November; December through February, and March through May. Unidentifiable fish was the most important food for June through August and September through November. Clupeid fishes were the most important food for December through February. The amphipod *Ampelisca abdita* was the most important food for March through May. The wide variety of foods consumed by *B. marinus* indicates an opportunistic feeding strategy.

The gafftopsail catfish, *Bagre marinus*, is an understudied species that inhabits coastal waters of Florida. It is eurythermal and euryhaline, and its morphological, reproductive, feeding and migratory patterns are linked to the heterogeneity of habitats encountered in estuaries (Yanez-Arancibia and Lara-Dominguez, 1988). *B. marinus* ranges from Massachusetts to Panama and is reportedly common in bays and shallow areas of the northern Gulf of Mexico (Hoese and Moore, 1998). In Florida, *B. marinus* is considered to be unexploited (Armstrong et al., 1996), with no recreational size limits or bag limits imposed.

Literature suggests that *B. marinus* is an unselective feeder. Gudger (1910) found that the blue crab, *Callinectes sapidus*, is the staple food of *B. marinus* in North Carolina waters (quoted from Gunter, 1945) and also found *C. sapidus* in all five stomachs of *B. marinus* that he examined from Texas waters. Miles (1949) examined stomachs of 85 specimens from Texas and found 6 species of crabs, 11 species of fishes, and penaeid shrimp. Pew (1954) reported that, in Texas coastal waters, *B. marinus* usually fed near the bottom, consuming fishes, shrimps, and other small crustaceans. In Venezuela, Cervigon (1966) found that *B. marinus* fed on crabs, shrimp, and small fishes. Odum (1971) found in a sample of eight *B. marinus* (262–445 mm) taken from the North River, Florida, that three specimens had consumed *C. sapidus*, two had consumed unidentified fish, and three were empty. Yanez-Arancibia and

Lara-Dominguez (1988) found in waters of the southern Gulf of Mexico bordering the Yucatan Peninsula that the main food of *B. marinus* between 70 and 240 mm was unidentifiable organic matter, followed by fishes, penaeid shrimps and *Callinectes* sp.

The feeding habits of *B. marinus* in the lower Caloosahatchee River estuary have not been described. Additionally, no data are available that describe the impact of *B. marinus* feeding in the estuary. Knowledge of the diet composition of a fish species is useful in assessing its ecological function and impact, for the construction of ecosystem models, and to help define nutritional requirements (Froese and Pauly, 2000). Given the potential impact of *B. marinus* on economically important species such as *Farfantepenaeus duorarum*, we believe that this examination represents an important step in understanding ecological relationships in the study area. Specific objectives of this study were to identify foods of *B. marinus* captured in the lower Caloosahatchee River estuary, identify the most important foods of *B. marinus* by use of an index of relative importance, and delineate seasonal changes in foods of *B. marinus*.

METHODS

All sampling was conducted in southern Pine Island Sound and Tarpon Bay, J. N. "Ding" Darling National Wildlife Refuge, Sanibel, Florida. With exception of limited shoreline development, Tarpon Bay and Pine Island

Sound are fringed by red mangrove, *Rhizophora mangle*. Many shallow areas are covered with the seagrasses *Thalassia testudinum*, *Halodule wrightii*, and *Syringodium filiforme*. The study area is part of the Caloosahatchee River estuary. The flow of the Caloosahatchee River and freshwater input to the estuary is regulated by Franklin Lock and Dam (SR 79). Water quality in the estuary is widely believed to have degraded over the last decade (Wilzbach et al., 2000); however, it is not documented how the study area may have changed since the inception of Franklin Lock and Dam.

Sampling was conducted at irregular intervals between June 3, 1999 and May 6, 2000. Because of restrictions imposed on other forms of collection, we angled for *B. marinus* using a weighted single-hook jighead baited with a live pink shrimp, *F. duorarum*, fished at or near the bottom. The right side of the uropod of each *F. duorarum* used for angling was clipped, to distinguish them from naturally ingested *F. duorarum*. Fish were captured mostly over unvegetated bottom in water ~2 m deep. Collection of *B. marinus* occurred between 6:00 PM and midnight. Although not free of bias, hook-and-line bait fishing is an efficient means of capturing *B. marinus*.

Upon capture, fish were placed on ice to slow further digestion. Although it is understood that the digestive process is not completely halted by placing fishes on ice, this process was, for our sampling, the most practical method for inhibiting the digestive process and enabling a greater percentage of food items to be identified, compared with what might be expected without icing. No regurgitation was observed either during the capture of specimens or after they were placed on ice.

Fish were returned to the lab within 2 hr of capture and measured for fork length (FL) to the nearest mm and weighed to the nearest 0.1 g. Each stomach item was identified to the lowest practical taxon, weighed to the nearest 0.01 g, and measured for volume to the nearest 0.1 ml by water displacement in a graduated cylinder. *F. duorarum* that were used as bait were not counted as food items.

An index of relative importance (IRI; Pinkas et al., 1971) was used to measure the contribution of various taxa to the diet of *B. marinus*. The IRI is defined by the formula $IRI = F(N + V)$, where N is the numerical percentage, V is the volumetric percentage, and F is the percentage of frequency of occurrence of each food group, including empty stomachs. The inclusion of empty stomachs in the IRI calculations, used in other studies (e.g., Rudershausen and Loesch, 2000), underscored the abun-

dance of empty stomachs that were found in this study. In many specimens, substantial amounts of food could not be accurately separated into individual prey items. Although we calculated the volumetric percentage of unidentifiable stomach matter, the advanced decomposition of this food precluded us from calculating a complete IRI for this category. Thus, the volume of unidentifiable food was excluded from IRI calculations because we could not separate unidentifiable food into individual items.

IRI was computed for three size classes of *B. marinus*: ≤ 200 mm FL, 201–300 mm, and ≥ 301 mm FL. Because of the lack of life history information on this species, these size classes were arbitrarily selected. We believe that these groupings provided an adequate separation between sizes of *B. marinus* that may feed differently. A separate group was not created for *B. marinus* ≥ 401 mm because of the lack of specimens captured in this size category.

We also compared foods of *B. marinus* among seasons, defined as follows: June through August (summer), September through November (autumn), December through February (winter), and March through May (spring).

A gravimetric index of relative fullness (IRF), developed by Smyly (1952), was used to compute stomach fullness for comparison with future studies of daily ration. IRF is the quotient of wet weight of total stomach contents of a specimen divided by the wet weight of that specimen, multiplied by 100. Variation in the mean total weight of stomach contents relative to fish size was used to compare levels of feeding between size classes, between seasons, or to determine rhythms in feeding behavior. Empty stomachs were included in IRF comparisons. Average indices of relative fullness between size categories and between seasons, respectively, were statistically compared by use of the nonparametric Kruskal-Wallis test.

RESULTS AND DISCUSSION

A total of 507 *B. marinus* were captured, ranging from 97 to 492 mm (FL) and 11.0 to 1641.9 g, respectively. The majority of specimens (74.2%) were caught from June through September.

We found a total of 2,352 individual food items. Because of the advanced state of digestion of many foods, only 21 taxa were identified to the species level (Table 1). When all sizes of *B. marinus* were combined, amphipods were the most important food. *F. duorarum* was found in the highest percentage of specimens

TABLE 1. Species identified in stomachs of *B. marinus*. An "M" indicates that this species was placed in the miscellaneous category when computing IRIs.

Fishes

Anchoa mitchilli, bay anchovy
Bagre marinus, gafftopsail catfish
Ophichthus gomesi, shrimp eel

Crustaceans

Alpheus normanni, green snapping shrimp
Amakusanthura magnifica, isopod (M)
Ampelisca abdita, amphipod
Callinectes sapidus, blue crab
Farfantepenaeus duorarum, pink shrimp
Harrieta faxoni, isopod (M)
Libinia dubia, spider crab (M)
Limulus polyphemus, horseshoe crab (M)
Menippe mercenaria, stone crab
Rhithropanopeus harrisi, mud crab
Squilla mantis, mantis shrimp (M)

Echinoderm

Echinaster sentus, thorny starfish (M)

Molluscs

Bulla striata, striate bubble shell (M)
Lucina nassula, woven lucine (M)
Nassarius vibex, common eastern nassa (M)

Plants

Halodule wrightii, Cuban shoal grass (M)
Rhizophora mangle, red mangrove (M)
Thalassia testudinum, turtle grass (M)

(Table 2). Amphipods were the numerically dominant food, and unidentifiable fish were the volumetrically dominant food (Table 2). A total of 86 *B. marinus* (17.0%) contained only unidentifiable matter. Unidentifiable food constituted 39.1% of the total volume of all stomach contents, and 187 stomachs (36.9%) were empty. Numerical values for unidentifiable food items are not listed because it was not possible to determine the actual number of individual items comprising this category.

A total of 197 specimens ≤ 200 mm were captured. *F. duorarum* was the most important food within this size category, being numerically and volumetrically dominant and found in the highest percentage of specimens. Unidentifiable food in this size class constituted 37.5% of the volume of all stomach contents, and 74 stomachs (37.6%) were empty.

A total of 251 specimens 201–300 mm were captured. The amphipod *Ampelisca abdita* was the most important and numerically dominant food within this size category. Unidentifiable fish were the volumetrically dominant food

group for this size class. Unidentifiable food in this class constituted 41.5% of the volume of all stomach contents, and 99 stomachs (39.4%) were empty.

A total of 59 specimens > 300 mm were captured. Unidentifiable fish were the most important food within this category. Unidentifiable food in this size class constituted 36.6% of the volume of all stomach contents, and 14 stomachs (23.7%) were empty.

A total of 299 specimens were captured from June through August. Unidentifiable fish were the most important food during this time period. Unidentifiable food in this class constituted 66.0% of the volume of all stomach contents, and 106 stomachs (35.5%) were empty.

A total of 90 specimens were captured from September through November. Unidentifiable fish were the most important food during this time period. Unidentifiable food in this class constituted 67.4% of the volume of all stomach contents, and 34 stomachs (37.8%) were empty.

A total of 35 specimens were captured from December through February. Unidentifiable crabs were the most important food during this time period. Unidentifiable food in this class constituted 23.6% of the volume of all stomach contents, and 8 stomachs (22.9%) were empty.

A total of 83 specimens were captured from March through May. The amphipod *A. abdita* was the most important food during this time period. Unidentifiable food in this class constituted 16.0% of the volume of all stomach contents, and 39 stomachs (47.0%) were empty. Results of the seasonal analysis are summarized in Table 3.

The average IRF for all *B. marinus* was 0.909 ± 1.241 . The average IRF for *B. marinus* ≤ 200 mm was 0.971 ± 1.188 . The average IRF for *B. marinus* 201–300 mm was 0.829 ± 1.196 . The average IRF for *B. marinus* ≥ 301 mm was 1.046 ± 1.567 . The average IRF was not significantly different among these three size classes ($H = 2.52$; $P = 0.284$). Our results suggest that although dietary preferences (as measured by IRI) may change with size of *B. marinus*, rates of feeding (as measured by IRF) may not change significantly.

The average IRF for *B. marinus* captured from June through August was as 0.974 ± 1.241 . The average IRF for *B. marinus* captured from September through November was 1.178 ± 1.441 . The average IRF for *B. marinus* captured from December through February was 0.934 ± 1.116 . The average IRF for *B. marinus* captured from March through May was 0.401

TABLE 2. Numerical percentage (*N*), volumetric percentage (*V*), percentage of frequency of occurrence (*F*), and IRI of major foods for three size classes of *B. marinus*.

Food group	No. <i>B. marinus</i>	No. eaten	Vol. (ml)	<i>F</i>	<i>N</i>	<i>V</i>	IRI
<i>B. marinus</i> ≤200 mm (<i>n</i> = 197)							
<i>F. duorarum</i>	28	29	22.2	14.3	25.9	39.0	928.1
Unidentified fish	17	19	9.9	8.7	17.0	17.4	299.3
Miscellaneous	16	17	5.4	8.2	15.2	9.5	202.5
<i>A. normanni</i>	15	15	3.2	7.7	13.4	5.6	146.3
Xanthidae	10	10	4.5	5.1	8.9	7.9	85.7
Clupeoidei	6	8	4.9	3.1	7.1	8.6	48.7
Unidentified crab	6	8	2.2	3.1	7.1	3.9	34.1
Fish, non-Clupeoidei	2	2	3.1	1.0	1.8	5.4	7.2
<i>C. sapidus</i>	2	4	1.6	1.0	3.6	2.8	6.4
Unidentifiable			34.3			37.5	
Empty	74			39.0			
<i>B. marinus</i> 201–300 mm (<i>n</i> = 251)							
<i>A. abdita</i>	15	2029	3.9	5.9	93.3	1.7	560.5
Miscellaneous	19	29	33.8	8.3	1.3	14.6	131.0
Unidentified fish	16	19	42.4	6.3	0.9	18.0	119.1
<i>F. duorarum</i>	16	16	30.5	6.3	0.8	12.9	86.3
Unidentified crab	14	17	26.7	5.5	0.8	11.3	66.6
<i>C. sapidus</i>	9	15	41.4	3.5	0.7	17.6	64.1
Xanthidae	15	17	15.9	5.9	0.8	6.7	44.3
Fish, non-Clupeoidei	11	13	17.2	4.3	0.6	7.3	34.0
Clupeoidei	9	14	14.9	3.5	0.7	6.3	24.5
<i>A. normanni</i>	5	6	5.3	2.0	0.3	2.3	5.2
Unidentifiable			164.3			41.5	
Empty	99			38.7			
<i>B. marinus</i> ≥301 mm (<i>n</i> = 59)							
Unidentified fish	12	14	58.6	22.2	21.5	30.2	1147.7
Unidentified crab	8	14	55.9	14.8	21.5	28.8	744.4
<i>C. sapidus</i>	5	12	39.5	9.3	18.5	20.4	361.8
<i>F. duorarum</i>	9	9	16.2	14.8	13.8	7.3	312.3
Fish, non-Clupeoidei	3	4	14.0	5.6	6.2	7.2	75.0
Clupeoidei	2	5	8.5	3.7	7.7	4.4	44.8
Miscellaneous	2	6	2.3	3.7	9.2	1.2	38.5
<i>A. normanni</i>	1	1	1.0	1.9	1.5	0.5	3.8
Unidentifiable			112.0			36.6	
Empty	14			22.0			
All <i>B. marinus</i> (<i>n</i> = 507)							
<i>A. abdita</i>	15	2029	3.9	3.0	86.3	0.8	261.3
Unidentified fish	45	52	110.9	8.9	2.2	23.0	224.3
<i>F. duorarum</i>	53	54	68.9	10.3	3.3	13.9	177.2
Unidentified crab	28	39	87.5	5.5	1.7	17.6	106.2
Miscellaneous	37	52	41.5	7.7	2.2	8.6	83.2
<i>C. sapidus</i>	16	31	82.5	3.2	1.3	17.1	58.9
Xanthidae	25	27	20.4	4.9	1.1	4.2	26.0
Fish, non-Clupeoidei	16	19	34.3	3.2	0.8	7.1	25.3
Clupeoidei	17	27	28.3	3.4	1.2	5.9	24.1
<i>A. normanni</i>	21	22	9.5	4.1	0.9	2.0	11.9
Unidentifiable			310.6				
Empty	187						

TABLE 3. *N*, *V*, *F*, and IRI of major foods for *B. marinus* captured during four different seasons.

Food group	No. <i>B. marinus</i>	No. eaten	Vol. (ml)	<i>F</i>	<i>N</i>	<i>V</i>	IRI
<i>B. marinus</i> June–August (<i>n</i> = 299)							
Unidentified fish	33	40	106.1	11.0	19.3	29.8	540.1
<i>F. duorarum</i>	34	34	44.7	11.4	16.4	12.6	330.6
Miscellaneous	27	39	61.2	9.0	18.8	17.2	324.0
<i>C. sapidus</i>	13	25	79.4	4.3	12.1	22.3	147.9
<i>A. normanni</i>	19	22	8.7	6.4	10.6	2.4	83.2
Xanthidae	17	18	13.2	5.7	8.7	3.7	70.7
Unidentified crab	10	10	14.3	3.3	4.8	4.0	29.0
Clupeoidei	7	11	12.9	2.3	5.3	3.6	20.5
Fish, non-Clupeoidei	5	6	15.2	1.7	2.9	4.3	12.2
<i>A. abdita</i>	1	2	<0.1	0.3	1.0	0	0.3
Unidentifiable			234.65				
Empty	106						
<i>B. marinus</i> September–November (<i>n</i> = 90)							
Unidentified fish	11	11	19.9	12.2	22.9	37.1	732.0
<i>F. duorarum</i>	12	12	12.5	13.3	25.0	23.3	642.4
Clupeoidei	7	10	10.3	7.8	20.8	19.8	312.0
Miscellaneous	7	8	4.7	7.8	16.7	8.8	198.9
Fish, non-Clupeoidei	3	4	5.0	3.3	8.3	9.3	58.1
Xanthidae	2	2	1.2	2.2	4.2	2.2	14.1
Unidentified crab	1	1	0	1.1	2.1	0	2.3
Unidentifiable			36.1				
Empty	34						
<i>B. marinus</i> December–February (<i>n</i> = 35)							
Clupeoidei	8	11	7.6	22.9	21.5	35.5	1129.0
Unidentified crab	6	6	16.8	17.1	19.4	30.5	853.3
Miscellaneous	2	2	12.0	5.7	6.5	21.8	161.3
Unidentified fish	2	4	5.8	5.7	13.0	10.5	134.0
Xanthidae	3	3	2.3	8.6	9.7	4.2	119.6
<i>C. sapidus</i>	2	2	2.1	5.7	6.5	3.8	58.7
Fish, non-Clupeoidei	1	1	8.0	2.9	3.2	14.5	51.3
<i>F. duorarum</i>	2	2	0.5	5.7	6.5	0.9	42.2
Unidentifiable			13.0				
Empty	8						
<i>B. marinus</i> March–May (<i>n</i> = 83)							
<i>A. abdita</i>	14	1927	8.1	16.9	98.5	11.1	1852.2
Miscellaneous	5	5	13.7	6.0	0.3	18.9	115.0
Unidentified crab	8	9	14.2	9.6	0.5	19.5	191.6
Unidentified fish	3	3	20.0	3.6	0.2	27.5	99.5
<i>F. duorarum</i>	5	5	10.3	6.0	0.3	14.2	86.8
Xanthidae	4	5	4.2	4.8	0.3	5.8	29.1
<i>A. normanni</i>	2	2	1.2	2.4	0.1	1.7	4.3
<i>C. sapidus</i>	1	1	1.0	1.2	0.1	1.4	1.7
Unidentifiable			11.6				
Empty	39						

± 0.759 . The average IRF for specimens captured from March through May was significantly less ($P < 0.01$) than each of the three other seasons. Reduced food consumption is a factor associated with the deposition of annuli in otoliths of fishes (Casselman, 1987). Our investigation of otoliths removed from *B. marinus*

captured from the study area indicates a peak in the formation of a new annulus (100% of specimens, $n = 30$) in April, consistent with the significant reduction in feeding noted for this season.

Future studies of gastric evacuation rate would be necessary to determine whether fish

size has an effect on the rate of digestion and feeding for this species under different environmental conditions and diet. Estimates of food consumed by fish in the field are influenced by many factors, including size of fish, amount of food eaten in a meal, number of meals in a day, rate of gastric clearing, water temperature, activity of fish, type of food eaten, and prior feeding history (Windell, 1978).

The data indicate that *B. marinus* consumes prey that varies widely in size and habitat. Food items ranged from benthic infauna and epifauna such as *Lucina nassula* and *Rhithropanopeus harrisi*, respectively, to pelagic species such as *Anchoa mitchilli*. Sizes of foods in stomachs ranged from 0.004 ml for individual benthic amphipods, *A. abdita*, to 35.0 ml for half of a horseshoe crab, *Limulus polyphemus*, found in the stomach of a 400-mm specimen.

A substantial portion of *B. marinus* stomachs were empty or contained unidentifiable food, which may suggest that this species has a rapid rate of digestion. Our catch rate (as high as eight specimens per hour) clearly shows that *B. marinus* is an active night feeder. However, because sampling was not conducted at regular intervals over a 24-hr period, we are unable to define diurnal feeding patterns of this species. Despite large differences in sample sizes and locations, the only other study we found that examined foods of *B. marinus* in Florida was Odum's (1971) survey of *B. marinus* ($n = 8$) from North River, Everglades, which found similar percentages of specimens containing unidentifiable food (25%) and empty stomachs (37.5%).

Although we did not record catch per unit effort, we did observe that *B. marinus* was less available for capture during winter months. Adult hardhead catfish (*Arius felis*) and adult *B. marinus* will move out of estuarine waters to nearshore coastal waters to avoid temperatures $<25^{\circ}\text{C}$ (Armstrong et al., 1996). This seasonal movement, as well as potential seasonal changes in the abundance of prey, may shift the diet of *B. marinus*. Although our sample size in winter was the smallest ($n = 35$) of any season, the data do indicate a seasonal shift from the consumption of *F. duorarum* and *A. abdita* to crabs (Table 3).

Florida-wide exploitation of *B. marinus* is low, and data indicate that the population contains a wide range of ages, indicative of low mortality (Armstrong et al., 1996). Given that *B. marinus* is eurythermal and euryhaline (Yanez-Arancibia and Lara-Dominguez, 1988), it may be more adaptable than other marine fishes to variable quality and quantity of artificial fresh-

water releases entering the Caloosahatchee River estuary. The versatility of a species' foraging behavior may aid it in exploiting physiologically severe, variable, unproductive, and (or) species-poor environments (Paszkowski, 1984).

No current information exists that demonstrates the role of *B. marinus* as a potential competitor and predator of recreationally and commercially important fishes that inhabit the study area. This topic warrants investigation. We collected 42 spotted seatrout, *Cynoscion nebulosus*, and found that the two most important food items were *F. duorarum* and unidentifiable fish, foods we found in abundance in *B. marinus*. The dietary habits of *C. nebulosus* in marine waters of southwest Florida has been verified by Hettler (1989), who found that *F. duorarum* was the most numerous prey in stomachs of *C. nebulosus* captured from western Florida Bay. Although not verified by our study, it is possible that juvenile *C. nebulosus* constitute part of the diet of *B. marinus*.

The dietary habits of *B. marinus* that inhabit Florida waters is a largely unexamined area of research. Little quantitative information exists on how species composition and abundance may be altered because of freshwater releases into the study area. We suggest that future research attempt to characterize changes in the food web in the study area due to the manipulation of freshwater delivery to the study area. We recommend that future studies on the diet of *B. marinus* be conducted to measure dietary overlap with other fishes. Quantitative estimates of daily ration based on IRI results of this species should be investigated, to better understand its ecological impact and trophic importance in the study area.

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