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TROPHIC COMPARISON OF TWO SPECIES OF NEEDLEFISH (BELONIDAE) IN THE ALVARADO LAGOONAL SYSTEM, VERACRUZ, MEXICO

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ABSTRACT We compared the diets of Atlantic needlefish, *Strongylura marina*, and redfin needlefish, *Strongylura notata*, in the Alvarado lagoonal system, Veracruz, Mexico, and analyzed diet breadth and trophic overlap between the species. All fishes were collected monthly from June 2000 to July 2001 at twelve sampling stations. A total of 74 intestinal tracts from *S. marina* were analyzed. The diet of *S. marina* consisted of 25 prey types with fish being the dominate prey. In eighty-nine digestive tracts examined from *S. notata*, the diet consisted of 29 prey types with the dominant prey including fishes, penaeid shrimp, polychaetes, and hymenopteran insects. There was moderate diet overlap (α = 0.4903) between *S. marina* and *S. notata* in the rainy season, while there was little diet overlap between species during the "nortes" (α = 0.1037) or dry (α = 0.1675) season. There was reduced niche breadth in both *S. marina* and *S. notata* during the "nortes" (B_A = 0.175 and 0.105, respectively) and dry (B_A = 0.128 and 0.173, respectively) seasons, with niche breadth values being higher for both species during the rainy season (B_A = 0.254 and 0.296, respectively).

RESUMEN Se realizó una comparación de la dieta de los belonidos, *Strongylura marina* y *Strongylura notata*, en el sistema lagunar de Alvarado, Veracruz, México, analizando la amplitud de dieta y el solapamiento trófico de ambas especies. Los organismos se colectaron mensualmente en el período de junio de 2000 a julio de 2001 en 12 estaciones de muestreo. Se analizaron 74 tractos digestivos de *S. marina*. La dieta de *S. marina* consiste de 25 tipos de presa de los cuales los peces constituyeron la presa dominante. Para *S. notata* se analizaron 89 tractos digestivos, la dieta de esta especie comprendió 29 tipos de presas diferentes, siendo los peces, camarón, poliquetos e himenópteros las presas dominantes para esta especie. El solapamiento trófico entre *S. marina* y *S. notata* fue moderado (α = 0.4903) en la época de lluvias, disminuyendo en las épocas de nortes (α = 0.1037) y secas (α = 0.1675). La amplitud del nicho trófico para *S. marina* y *S. notata* fue baja en nortes (B_A = 0.175 y 0.105, respectivamente) y en secas (B_A = 0.128 y 0.173, respectivamente), siendo mayor para ambas especies en la época de lluvias (B_A = 0.254 y 0.296, respectivamente).

INTRODUCTION

The eastern coast of Mexico consists of a series of estuarine lagoons that have recently been studied in relation to their ichthyofauna. Most studies focus on specific habitat types like mangroves (Gonzales 1995) and seagrass beds (Latisnere and Moranchel 1983, Solano 1991, Benavides 1996, Chavez-López 1998), or on general aspects of fisheries ecology (Castillo 1995), including selected trophic studies (Yañez-Arancibia 1978, Salgado 1997). Nevertheless, little work has been done with needlefishes (family Belonidae) in Mexico despite the ecological importance of this family in coastal lagoons.

The Belonidae are represented globally by 32 species in 10 genera. Belonids are rarely exploited by man, although there is a recreational fishery in Mexico (Torres-Orozco 1991), with consumption restricted to local areas where the fishes reach large sizes (Zeckua and Martinez-Perez 1993). The genus *Strongylura* occurs in the coastal lagoons of Mexico and is also found in oceanic and nearshore waters worldwide (Goulding and Carvalho 1984). Zeckua and Martinez-Perez (1993) studied the ontogenetic development of *Strongylura marina* in the estuary of Tecolutla, Veracruz. However, trophic relationships are unknown in these coastal lagoons. Understanding belonid feeding habits is important in establishing the functional role of these species in the ecosystem. Adult and juvenile needlefish are known to be piscivorous (Reid 1954, Springer and Woodburn 1960, Carr and Adams 1973), but trophic overlap in *Strongylura* has not been examined. Thus, the objective of this work was 1) to compare the diets of the Atlantic needlefish, *S. marina* (Walbaum, 1792), and the redfin needlefish, *Strongylura notata* (Poey, 1860), in the Alvarado lagoonal system, Veracruz, Mexico and 2) to analyze their diet breadths and trophic overlaps.

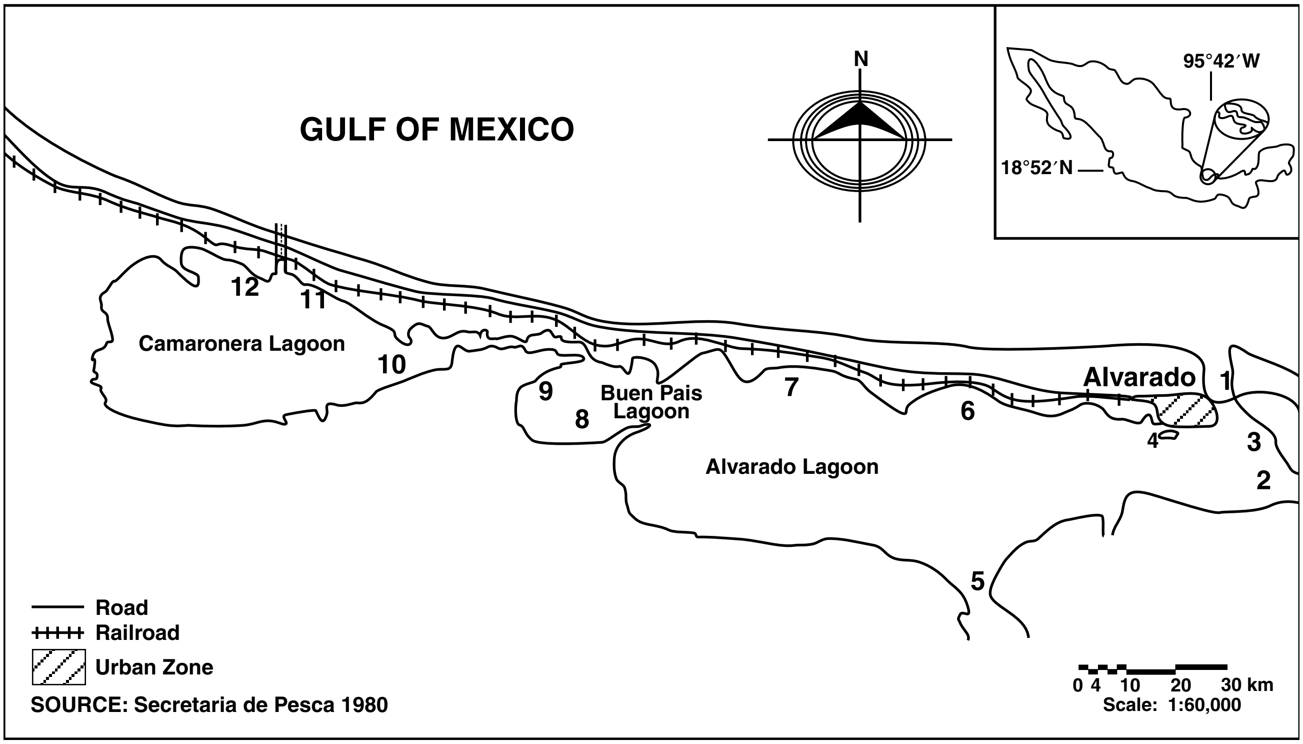

Figure 1. Collection stations in the Alvarado lagoonal system, Veracruz, Mexico.

MATERIALS AND METHODS

Study area

The Alvarado lagoonal system (Figure 1) is located in the southeast portion of Veracruz State in the Papaloapan basin, between 18°52'15"N, 95°57'32"W and 18°23'00"N, 95°42'20"W. Camaronera, Buen Pais, and Alvarado Lagoons are connected by channels and the system is about 26 km long and 5 km wide, with a total area of 6200 ha. The mean annual water temperature oscillates between 25.6 °C and 26.1 °C and the mean annual precipitation is 212.1 cm (Chavez-López 1998). Seasons are well defined, with the rainy season from June to September, the nortes season from October through February (occassionally extending until May), and the dry season from March through June (Contreras 1985). The lagoonal system is almost entirely surrounded by red mangrove (*Rhizophora mangle* L.) and is bordered by a landward zone of black mangrove (*Avicennia germinans* L.) and white mangrove (*Laguncularia racemosa* (L.) Gaertn. f.). Other emergent vegetation includes cordgrass (*Spartina* spp.) and cattail (*Typha* spp.) (Resendez 1973), with the shallow, muddy bottom containing large patches of Widgeon grass (*Ruppia maritima* L.). During the rainy season, the water hyacinth (*Eichomia crassipes* (Mart.) Solms.) enters the lagoon from the upstream watershed.

Field procedures

All fishes and physical-chemical variables were collected monthly from June 2000 to July 2001 at twelve sampling stations. These stations represented seagrass, mangrove, shell reef, and muddy bottom habitat types. Samples were taken with a beach seine (40 m long, 1.5 m high, 6.3 mm mesh), and digestive tracts were fixed in the field by injecting 39% formaldehyde into the coelomic cavity to stop the digestive process. Samples were then placed in plastic bags containing 4% formalin or 70% alcohol. At each station, salinity (psu) was measured with a YSI model 33 salinometer, dissolved oxygen (D.O., mg/L) was measured with an Otterbine Sentry III oxygen meter, and water temperature (°C) was obtained with a mercury thermometer.

Laboratory and statistical procedures

In the laboratory, fishes were rinsed with tap water, preserved in 70% alcohol, and identified (Alvarez del Villar 1970, Hoese and Moore 1977, Fischer 1978, Castro-Aguirre 1978, Castro-Aguirre et al. 1999). Preserved standard length (SL, cm) and wet mass (g) were taken, and the fishes were divided into 8 size classes (cm): I = 3.0–9.0, II = 9.1–15.0, III = 15.1–21.0, IV = 21.1–27.0, V = 27.1–33.0, VI = 33.1–39.0, VII = 39.1 45.0, and VIII = 45.1–51.0.

TABLE 1

Summary of seasonal minimum, maximum, and mean physico-chemical variables in the Alvarado lagoonal system from June 2000–July 2001. D.O. = dissolved oxygen.

	Rainy Season			Nortes Season			Dry Season		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature (°C)	22.0	32.0	30.0	21.0	32.0	25.0	27.0	30.0	27.0
Salinity (psu)	0.0	21.0	4.9	0.0	11.5	4.0	2.5	35.0	10.4
D.O. (mg/L)	2.4	14.4	10.8	8.0	12.3	9.8	8.0	12.2	9.5

The entire digestive tract from the esophagus immediately behind the branchial cavity to the anus was examined, and only digestive tracts containing identifiable prey types were used in the analysis. Prey was identified to the lowest possible taxonomic level and then grouped into fishes, crustaceans, insects, annelids, and others for analysis. Numeric (percentage of all prey types), gravimetric (percentage of the total mass of all prey items), and frequency of occurrence (percentage of digestive tracts in which one or more prey types were present) were documented. These measurements were incorporated into a percent Index of Relative Importance (%IRI; Cortez 1997) to determine the most important prey for these predator species. Schoener's index, α (Schoener 1970, Wallace 1981), was used to assess dietary overlap, where α approaches 0 when diets do not contain items in common, and α approaches 1 with high similarity between diets. Niche breadth was calculated using Levin's standardized index, B_A (Krebs 1989), where values of B range from 0 to 1 and low values indicate diet specialization because of the dominance by a few prey types.

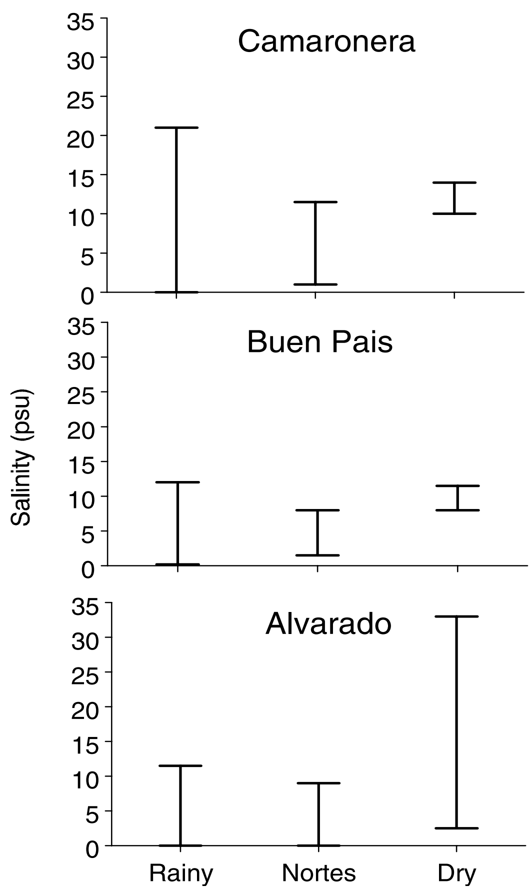

Figure 2. Minimum and maximum salinity values by lagoon and season within the Alvarado lagoonal system, Veracruz, Mexico.

RESULTS

Field collections

In the Alvarado lagoon system, the highest temperature and D.O. concentration occurred during the rainy season, with the lowest temperature and salinity noted during the “nortes” season. The highest salinity and the greatest salinity range were observed during the dry season (Table 1). The 3 lagoons also differed seasonally in relation to salinity. Camaronera generally had higher salinity, followed by Buen Pais, with Alvarado fluctuating between near 0 to 35 psu during the dry season (Figure 2).

The family Belonidae was represented by 3 species in the lagoon; *S. marina*, *S. notata*, and *Strongylura timucu* (Walbaum, 1792). Of 195 belonids captured, *S. notata* represented 53% of the total and *S. marina* represented 46%. *Strongylura timucu* accounted for only 1% of the total. Peak abundance of *S. notata* occurred in the low salinity “nortes” season; in contrast, *S. marina* was found predominantly in the high salinity dry season.

Size and seasonal abundance

All sizes of *S. marina* except class IV (21.1–27.0 cm) were collected in the rainy season, with size class II and III (9.0–21.0 cm) being most abundant. During the "nortes" season, size classes I, II, III, V and VII were taken in equal abundance. Dry season collections had all size classes, with small individuals (3–15 cm, classes I and II) being most abundant (Figure 3). In contrast, all size classes of *S. notata* except VIII were collected during the rainy season, with individuals in classes II and III dominating the catch.

TABLE 2

Seasonal %IRI of each prey item in the diet of *S. marina* and *S. notata* collected from June 2000–July 2001.

	S. marina			*S. notata*		
Taxa	**Rainy**	**Nortes**	**Dry**	**Rainy**	**Nortes**	**Dry**
Pisces						
Unidentified Fishes	61.12	82.28	82.74	60.40	11.93	52.73
Engraulidae	3.32	10.98	3.18			
Mugilidae			< 1			
Mugil curema					< 1	
Cichlidae				< 1		
Syngnathidae		< 1			< 1	
Belonidae						2.46
Hemiramphidae		< 1				
Larval fish		< 1		< 1	1.61	
Crustaceans						
Unidentified crustaceans	2.63	< 1			1.63	< 1
Penaeidae	15.56			6.49	53.98	
Litopenaeus setiferus			7.55			
Farfantepenaeus aztecus					2.79	
Palaemonetes pugio					< 1	
Macrobrachium spp.				1.62	< 1	14.10
Callinectes spp.			< 1		< 1	
Portunidae	1.27					
Amphipoda	< 1	< 1	< 1		< 1	3.87
Anomura (Albunea)					< 1	
Brachiura					< 1	
Caridea						< 1
Insects						
Unidentified Insects	< 1		< 1	3.94	1.44	
Hymenoptera parts			< 1		3.19	1.59
Hymenoptera (wasps)	13.41		1.70	20.31	< 1	< 1
Hymenoptera (bees)			< 1			
Formicidae	< 1	1.29	< 1	< 1	10.67	6.79
Diptera			< 1	< 1	7.69	1.42
Coleoptera	< 1	2.48	1.07	< 1		< 1
Coleoptera (Curculionidae)				< 1	< 1	< 1
Odonata				< 1	< 1	
Libellullidae			< 1			
Hemiptera	< 1		< 1		1.05	
Phasmidae				< 1		
Isoptera			< 1			
Homoptera					< 1	
Annelida						
Unidentified polychaetes	< 1	< 1	< 1	4.74	< 1	14.79
Others						
Chelicerata		< 1				
Seagrass	< 1					
Unidentified organic matter				< 1	< 1	

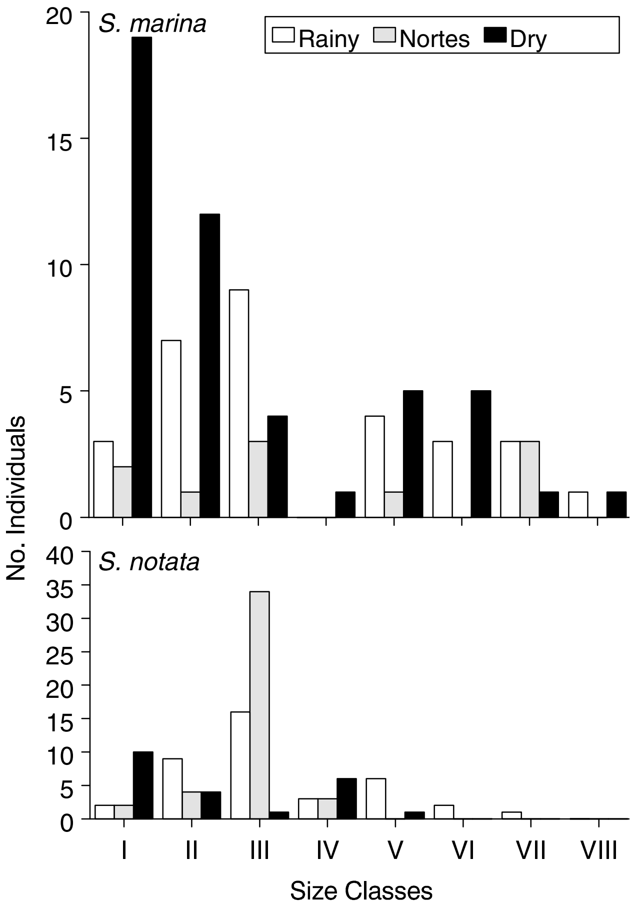

Figure 3. Abundance of S. marina and S. notata by size class in the Alvarado lagoon system, Veracruz, Mexico.

Only fish in classes I to IV were captured during the "nortes" season, although most were in the 15.1–21.0 cm range (class III). During the dry season, fish in classes I to V were captured, but the smallest fish (3–9 cm, class I) were most abundant (Figure 3).

General feeding habits

A total of 74 intestinal tracts from *S. marina* were analyzed with 24 from the rainy season, 7 from the "nortes" season, and 43 from the dry season. The diet of *S. marina* consisted of 25 prey types (Table 2). Fishes dominated the diet in all seasons (61–82.7 %IRI; Table 2) with penaeid shrimp (15.6 %IRI) and wasps (13.4 %IRI) also being important in the rainy season, engraulids (10.9 %IRI) being important in the "nortes" season, and the white shrimp, *Litopenaeus setiferus* (7.5 %IRI), being important in the dry season. There did not appear to be an ontogenetic shift in prey types, as fish > 5 cm SL included insects, crustaceans, and polychaetes within their diet.

Eightly-nine intestinal tracts from *S. notata* were examined with 28 from the rainy season, 41 from the "nortes" season, and 20 from the dry season. The diet of *S. notata* contained 29 prey types with the dominant prey including fishes, penaeid shrimp, polychaetes, and wasps (Table 2). Fishes dominated the diet in the rainy and dry season (52.7–60.4 %IRI; Table 2) with penaeid shrimp being most important (53.9 %IRI) in the "nortes" season. In the rainy season, wasps (20.3 %IRI) and penaeid shrimp (6.49 %IRI) were also important, whereas in the "nortes" season several orders of insects (Formicidae 10.7 %IRI, Diptera 7.7 %IRI) and fishes (11.9 %IRI) were important. Finally, polychaetes (14.8 %IRI), *Macrobrachium* spp. (14.1 %IRI) and Formicidae (6.8 %IRI) were also important prey items in the dry season. As with *S. marina*, there did not appear to be an ontogenetic shift in prey categories, with fish of all size classes equally likely to consume all prey types.

Rainy season

In Alvarado Lagoon, *S. marina* of size classes I and VIII fed exclusively on fishes. In contrast, individuals in size classes II and III fed on crustaceans and insects, whereas those in size class VI fed principally on crustaceans. Feeding was quite different in Camaronera Lagoon, with fish < 20 cm having a varied diet of fishes, wasps, and crustaceans, while larger fish (size class VII) consumed polychaetes exclusively.

Strongylura notata were collected from all 3 lagoons during the rainy season. In Alvarado Lagoon, size classes I and II fed mainly on fishes, whereas slightly larger individuals (size class III) ate mostly fishes and *Macrobrachium*. Size class VII ate exclusively insects. In Buen Pais Lagoon, size class I fed on fishes (65 %IRI) and wasps, size class II individuals consumed insects (principally odonatids and dipterans), and size classes III and IV fed exclusively on insects, primarily wasps. In Camaronera Lagoon, size class I ate predominately wasps and penaeid shrimp, whereas fish dominated the diet of individuals in size classes III–V, and wasps were the principal prey type of size class VI.

Nortes season

Strongylura marina was found in Alvarado Lagoon only during the "nortes" season. Size class I individuals fed on fishes and crustaceans, size class II individuals ate fishes, Formicidae and coleopteran insects, while size class VII fed on engraulids. During the "nortes" season, *S. notata* was captured only in Camaronera Lagoon, and the smallest individuals (size classes I and II) were primarily piscivorous. Larger individuals added penaeid shrimp (size class III) and dipterans (size class IV) to their diet.

Dry season

In Alvarado Lagoon, a wide variety of predator sizes and prey items were found. Size classes I and II *S. marina* fed principally on fishes. As they increased in size (size classes III–IV), the diet became more varied, including crustaceans and insects (primarily hymenopterans). Fish in size class V consumed predominantly engraulids (38.4%) along with other fishes, whereas the largest predators (size class VIII) ate fishes and insects. In Buen Pais Lagoon, size class I fed on amphipods, individuals in size class V ate polychaetes, those in size class VI fed on polychaetes and wasps, and the largest (size class VII) were piscivorous. In Camaronera Lagoon, the principal prey items in size classes II and VI were engraulids, whereas polychaetes were the predominate prey in size class V.

Strongylura notata were collected from all 3 lagoons during the dry season. In Alvarado Lagoon, size class I ate hymenopteran insects exclusively, whereas individuals in size class II ate fishes and Formicidae. The largest predators (size class IV) had a more varied diet, consisting of fishes, *Macrobrachium*, amphipods and dipterans. In Buen Pais Lagoon, only the smallest size class was collected, and they fed principally on fishes. A wide range of size classes was collected in Camaronera Lagoon. The smallest ate amphipods (60 %IRI), fishes (19 %IRI) and *Palaemonetes pugi*o Holthuis, 1949 (20 %IRI). Predators in size class II had a diet of < 90 %IRI polychaetes, whereas size class III exclusively ate insects from the coleopteran family. Larger individuals (size class IV) had a diet consisting of fishes (including belonids) and *Macrobrachium*, while the largest (V) fed primarily on polychaetes with a small component of fishes and formacid insects.

Diet overlap and niche breadth

There was a moderate diet overlap ($\alpha = 0.4903$) between *S. marina* and *S. notata* in the rainy season. In contrast, there was little diet overlap between species during the "nortes" ($\alpha = 0.1037$) or dry ($\alpha = 0.1675$) season. There was reduced niche breadth in both *S. marina* and *S. notata* during the "nortes" ($B_A = 0.175$ and 0.105, respectively) and dry ($B_A = 0.128$ and 0.173, respectively) seasons, suggesting specialization due to the presence of few prey types. In contrast, niche breadth values were twice as high for both species during the rainy season ($B_A = 0.254$ and 0.296, respectively), suggesting a more generalist approach to feeding.

DISCUSSION

Salinity varied seasonally in the Alvarado lagoonal system. In the rainy season, low salinity conditions were present as a consequence of increased river discharge from the Blanco, Acula, and Papaloapan rivers. During the "nortes" season, salinity was low (approaching 0 psu) due to strong wind-driven circulation. In contrast, the salinity in the system increased during the dry season, as river discharge slowed and salt water entered the lagoon from the inlets.

The diets of *S. marina* and *S. notata* were dominated by fishes, crustaceans, polychaetes, and insects. *Strongylura marina* fed principally on fishes from the families Engraulidae, Mugilidae, Hemiramphidae, and Syngnathidae. Previously, *S. marina* has been reported to be voracious, principally consuming small pelagic fishes such as anchovies and sardines (Castro-Aguirre et al. 1999). Crustaceans were of secondary importance to *S. marina* and included such prey items as penaeid and caridean shrimp, amphipods, and portunid crabs (predominantly *Callinectes*). Insects (primarily hymenopterans) also occupied an important place in their diet. Franke and Acero (1992) reported wasps in the stomach contents of belonids, along with other insects such as coleopterans, odonterans, dipterans, hemipterans, and isopterans. The insect component of the diet was most important during the rainy season, when the salinity of the lagoonal system was low and there was high discharge from the rivers into the lagoon. This probably contributes to the increased availability of insects. During both the "nortes" and dry seasons, fishes were most important in the diets. *Strongulura marina* juveniles have been found to feed on small crustaceans, specifically amphipods, mysids and smaller shrimp, with an abrupt transition to a diet almost exclusively of fishes at about 5.0 cm TL (Carr and Adams 1973). However, in the present study *S. marina* > 5.0 cm had a more varied diet. Although occasionally the diet was piscivorous, consuming principally engraulids, the larger individuals at times ingested only insects or included crustaceans, polychaetes, and insects in their diet. The suite of prey in the diet of *S. marina* appeared to vary among the 3 basins within a given season. This may be related to the salinity differences among basins due to differing levels of freshwater input.

Fishes from the families Belonidae, Syngnathidae, Mugilidae, and Cichlidae were the major components in the diet of *S. notata*. This species also fed on different types of crustaceans such as *Macrobrachium* spp., *Callinectes* spp., *P. pugio*, penaeid shrimp, *Farfantepenaeus aztecus* Ives, 1891, amphipods, brachyurans, and anomurans. Other items that formed a part of the diet included polychaetes and insects such as hymenopterans, dipterans, phasmids, odonatids, and coleopterans. Our findings agree with previous reports that fishes and insects dominate the diet of *S. notata* (Ley et al. 1994). Insects were important during the rainy and the dry seasons, whereas crustaceans dominated the diet during the "nortes" season. Similarly, Chavez-López (1998) mentioned that *S. notata* complemented its fish diet with crustaceans during the "nortes" season, whereas complementary prey during the rainy and dry seasons were the hymenopterans and dipterans. In the present study, there was no diet transition observed in *S. notata* associated with body size. Indeed, the lack of specific prey types as related to size was more evident in *S. notata* than in *S. marina*, as the former species actively fed in the water column.

The variety in the diets of the *Strongylura* species may also be related to their feeding behavior. Belonids have been observed to capture prey in different ways, such as attacking benthic prey, catching fishes swimming at the surface, or jumping out of the water to capture insects in mangroves (Ley et al. 1994). Both *S. marina* and *S. notata* feed throughout the water column, as demonstrated by both the demersal and pelagic components of the diet.

Clearly, the diet of these 2 predators is variable spatially and temporally, which can be due to variation in prey availability and/or the level of prey identification in the diet. Prey availability varies, in part, due to different environmental conditions within the lagoon system which are driven by seasonal weather patterns and landscape factors. These seasonal weather patterns characterize the environment of the Alvarado lagoonal system. As both species appear to be opportunistic predators with only little to moderate diet overlap and a low niche breadth during the dry and "nortes" seasons, it follows that their diets will change spatially and temporally as river discharge, tidal flushing, rainfall, and salinity change.

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