Gulf of Mexico Science

Volume 31
Number 1 *Number 1/2 (Combined Issue)*

Article 5

2013

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DOI: 10.18785/goms.3101.05

Gulf of Mexico Science, 2013(1–2), pp. 50–66

Distribution, Abundance, and Feeding Habits of Juvenile Kingfish (*Menticirrhus*) Species Found in the North-Central Gulf of Mexico

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Southern Kingfish (*Menticirrhus americanus*), Gulf Kingfish (*Menticirrhus littoralis*), and Northern Kingfish (*Menticirrhus saxatilis*) were collected by beam plankton trawl and seine along shoreline habitats in 2005 and 2006. Specific habitats included barrier island (surf zones and grass beds) and mainland (marsh edge and sandy shorelines) areas. Five hundred sixty-seven kingfish were collected during this study, with over 85% of the specimens collected in 2006. Densities of both *M. americanus* and *M. littoralis* peaked during summer, whereas densities of *M. saxatilis* peaked in spring. All three kingfish species co-occurred within surf zone and sandy shoreline habitats, but *M. americanus* was the dominant kingfish along protected sandy shorelines, and *M. littoralis* was the dominant kingfish along open surf zones. Several *M. littoralis*, which are known to be surf zone species, were also collected from mainland sandy shoreline. Only *M. americanus* was collected from marsh edges, and all three species were absent from grass beds. Stomachs of all three kingfish species at sizes < 15 mm standard length (SL) most often contained calanoid copepods. Larger *M. americanus* (16–60 mm SL) fed most frequently on mysids, larger *M. littoralis* (31–60 mm SL) fed most frequently on bivalves, and larger *M. saxatilis* (31–60 mm SL) fed most frequently on both mysids and amphipods. The diversity of prey items increased with size for all three *Menticirrhus* species. This research provides a useful descriptive report on the distribution, abundance, and feeding habits of juvenile *Menticirrhus* species found in the north-central Gulf of Mexico.

Introduction

Southern Kingfish (*Menticirrhus americanus*), Gulf Kingfish (*Menticirrhus littoralis*), and Northern Kingfish (*Menticirrhus saxatilis*) are members of the drum family (Sciaenidae) and co-occur in the north-central Gulf of Mexico (GOM). *Menticirrhus americanus* range from New York to Argentina, *M. littoralis* range from Delaware to Brazil, and *M. saxatilis* range from Maine to Progresso, Yucatan (Irwin, 1970; Johnson, 1978; Armstrong and Muller, 1996). *Menticirrhus americanus* and *M. littoralis* are common in the GOM and along the south Atlantic coast, whereas *M. saxatilis* are more common along the northeast Atlantic coast and not as common in the GOM (Irwin, 1970). Spawning of all three species occurs in the shallow GOM from spring to early fall (Miller, 1965; Irwin, 1970; Johnson, 1978; McMichael and Ross, 1987; Clardy et al., 2014).

Many studies have reported on the distribution and abundance of adult kingfish species, but few have focused on juvenile kingfish species. Juvenile *M. americanus* occur in surf zones, in coastal bays and rivers, and along marsh edges (Gunter, 1945; Springer and Woodburn, 1960; Johnson, 1978). Unlike the other kingfish, juvenile *M. littoralis* occur primarily in surf zones (Modde and Ross, 1981; Ross et al., 1987). Juvenile *M. saxatilis* also can occur in surf zones and have been reported to enter bays (Bearden, 1963; Schaefer, 1965) and tidal rivers (Peebles, 2002).

Several studies have been conducted on the diet of juvenile *Menticirrhus* species. Welsh and Breder (1923) and Springer and Woodburn (1960) provided information on the diet of juvenile *M. americanus* and *M. saxatilis.* Modde (1979) and Modde and Ross (1983) described the feeding habits of juvenile *M. littoralis,* and Chao and Musick (1977) studied the diet and mouth position of juvenile *M. saxatilis.* Bearden (1963), Irwin (1970), and McMichael and Ross (1987) described the diet of all three *Menticirrhus* species; however, none of these studies compared the diet of juvenile kingfish species from different habitats.

The purpose of this study was to first determine the spatial and temporal distribution and abundance of juvenile kingfish from the north-central GOM, and second, to describe the feeding habits of juvenile *Menticirrhus* species from different shoreline habitats within the region. Specific habitats include barrier island (surf zones and grass beds) and mainland (marsh edges and sandy shorelines) areas.

Materials and Methods

Sampling began in April and extended through November in 2005 and 2006. Four

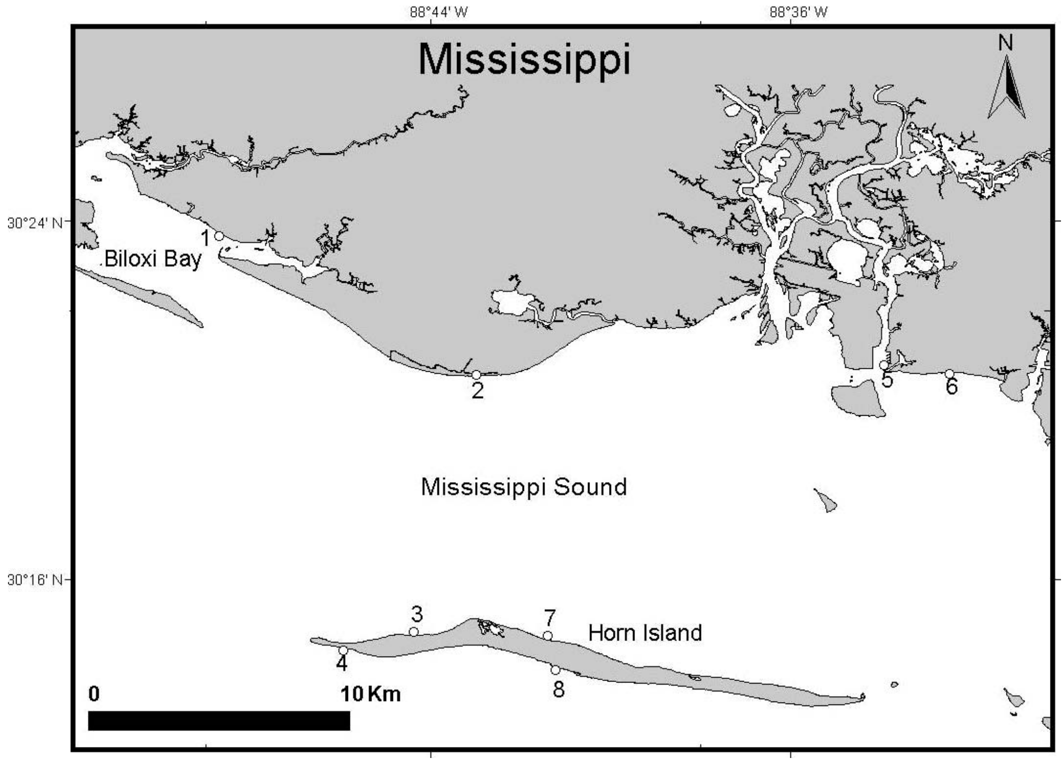

Fig. 1. Sampling sites along the Mississippi Gulf Coast included marsh edge (sites 1 and 5), sandy shoreline (sites 2 and 6), grass bed (sites 3 and 7), and surf zone habitats (sites 4 and 8). Numbers indicate sampling sites.

habitat types were sampled monthly, with each habitat type represented by two sites (eight total sites). Surf zone and grass bed sites were located along the south and north sides, respectively, of Horn Island, a barrier island 22 km long and about 1.2 km wide located about 10 km off the Mississippi coast (Fig. 1). Barrier island surf zone sites were located near the west tip and middle portion of the south side of the island (sites 4 and 8). Barrier island grass bed sites (sites 3 and 7) were located near the west tip and middle portion of the north side of the island; *Halodule wrightii* was the dominant submerged seagrass. Mainland marsh-edge sites (sites 1 and 5) were fringed by *Juncus roemerianus* and were located near the mouths of Davis Bayou, MS, and the east branch of the Pascagoula River. Mainland sandy shoreline sites (sites 2 and 6) were located at Bellefountaine and Pascagoula, MS, beaches. Offshore surf zone sites were also characterized by a sandy shoreline, but we use the designation sandy shoreline only for mainland sites with a sandy shoreline. Only sites 1–4 were sampled during the month of September 2005 because of damage caused from Hurricane Katrina.

Collections were taken at each site during each sampling event with a 7.5 m bag seine fitted with 3.2 mm mesh and a beam plankton trawl (BPL) with 1.6 mm mesh wings and a 750 μm cod-end. The seine was deployed in about 0.75 m of water, pulled 46 m parallel to the shoreline, and landed on the shoreline once at each site. At the surf zone sites, waves and currents prevented pulling the seine parallel to the shoreline, so the seine was deployed about 10 m from the shore and pulled toward shore three times along adjacent transects about 10 m apart (Murphy and Willis, 1996). Consequently, densities of fish were expressed as number collected per 30 m of seine-distance pulled. The BPL was pulled parallel to the shore a distance of 46 m in about 0.75 m of water at each site, and densities of fish were expressed as number collected per 46 m of BPL distance pulled.

Surface water temperature (°C), salinity, and dissolved oxygen (mg/L) were measured at each site with a YSI Model 55. Specimens were stored in labeled containers and placed on ice for transport to the laboratory. In the laboratory on the day of capture, kingfish were identified to species, counted, weighed, and measured to the nearest mm standard length (SL). Fresh-collected kingfish specimens were identified to species level using Table 1. It is noted that the

DOI: 10.18785/goms.3101.05

Table 1. Guide for identification of juvenile *Menticirrhus* species from the northern Gulf of Mexico. Meristics and morphological features for different size classes are presented for each species. Compiled from Hildebrand and Cable (1934), Gunter (1945), Viosca (1959), Irwin (1970), Johnson (1978), Darovec (1983) and personal experience. SL, standard length.

Meristics	*Menticirrhus americanus*	*Menticirrhus littoralis*	*Menticirrhus saxatilis*
Dorsal fin	X–XI (usually 11) spines, 24–25 rays	X–XI (usually 11) spines, 24–25 rays	X–XI (usually 11) spines, 24–25 rays
Anal fin	I spine, 7 rays	I spine, 7 rays	I spine, 8 rays
Pectoral fins	18–24 (usually 20 or more) rays	18–21 (usually less than 20) rays	Usually at least 20 rays
Size classes			
4–0 mm SL	Body moderately compressed and fairly deep, depth 3.0–3.8 in length to base of caudal fin; caudal fin nearly symmetrical, long and pointed; spinous dorsal often black; ventral fins colorless	Body somewhat compressed, rather broad and low, depth 3.2–4.0 in length to base of caudal fin; caudal fin asymmetrical, somewhat rounded, never sharply pointed, the longest rays in lower half of fin; fins all colorless	Body strongly compressed; depth 2.6–3.0 in length to base of caudal fin; caudal fin asymmetrical, somewhat rounded, never sharply pointed; spinous dorsal and ventral fins usually wholly black
11–20 mm SL	Body moderately deep; greatest depth 3.4–3.8 in length to base of caudal fin; caudal fin long and pointed, longest ray longer than head; spinous dorsal and ventrals with moderate pigment; barbel small without pigment	Body quite elongate, greatest depth 3.8–4.2 in length to base of caudal fin; caudal fin asymmetrically rounded; longest rays in lower half of fin, shorter than head; barbel large and bulbous without pigment	Body deeper, greatest depth 3.3–3.4 in length to base of caudal fin; caudal fin broadly pointed, the longest rays in lower half of fin, notably shorter than head; spinous dorsal and ventrals black; barbel medium size with pigment
21–40 mm SL	Body slender, greatest depth 3.8–4.0 in length to base of caudal fin; ventral fins small; sides with dark blotches, usually forming indefinite cross bars, not forming a V on the sides under the spinous dorsal; pupils perfectly round	Body slender, greatest depth 4.1–4.3 in length to base of caudal fin; caudal fin short, lower lobe longest, notably shorter than head; ventral fins large; sides with a few dark dots, no large blotches or bars, color mostly silvery; pupils vertically elliptical	Body deeper, greatest depth 3.5–3.7 in length to base of caudal fin; caudal fin not long and pointed, angulate, body with distinct dark oblique marks forming a V-shaped pattern on the sides and back; pupils vertically elliptical
41–75 mm SL	Body silver gray to coppery color and irregular dark patches; body elongate; gill cavity dusky; scales 86–90, vertical series above lateral line	Body elongate; gill cavity pale; scales 70–75, vertical series above lateral line; scales on chest much smaller than on sides; pectoral and dorsal fins short	Body elongate; second ray of spinous dorsal elongate; same V-shaped pattern on the sides and back; scales 91–96, vertical series above lateral line

identified specimens were fresh because Table 1 contains some morphological and pigmentation characters that can be affected by preservation. Specimens were then individually stored in labeled containers and preserved in 95% ethanol for feeding analysis. An incision was made in specimens > 30 mm SL to expose the gut cavity before preservation.

For each *Menticirrhus* species, up to two specimens from each of six size classes (0 to 60 mm SL, in 10 mm increments) were randomly selected from each of the four habitats for each month sampled in 2005 and 2006. These specimens were used for the diet analysis. All specimens were analyzed when a maximum of 16 individuals of a *Menticirrhus* species were collected from any one of the four habitats. The stomachs (the portion of the alimentary tract between the esophagus and the pylorus) were excised, and the contents were carefully removed. Stomach fullness was estimated for each stomach on a scale from 0 (empty) to 5 (full). The contents were sorted, counted, and identified to the lowest practical taxonomic level (LPTL; usually species)

Table 2. Total number of juvenile *Menticirrhus* species by site, habitat, and year from beam plankton trawl and seine collections. Samples were not collected at sites 5–8 during September 2005 (▫). BPL, beam plankton trawl; GB, grass bed; ME, marsh-edge; SS, sandy shoreline; SZ, surf zone.

					M. americanus		*M. littoralis*		*M. saxatilis*		
Site	Habitat	Year	No. of BPLs	No. of seines	BPL	Seine	BPL	Seine	BPL	Seine	Total
1	ME	2005	8	8	0	6	0	0	0	0	6
		2006	8	8	0	19	0	0	0	0	19
2	SS	2005	8	8	6	19	0	0	0	0	25
		2006	8	8	4	57	0	4	4	12	81
3	GB	2005	8	8	0	0	0	0	0	0	0
		2006	8	8	0	0	0	0	0	0	0
4	SZ	2005	8	8[a]	0	2	0	4	0	0	6
		2006	8	8[a]	1	0	31	70	153	8	263
5	ME	2005▫	7	7	0	0	0	0	0	0	0
		2006	8	8	0	0	0	0	0	0	0
6	SS	2005▫	7	7	1	5	0	1	0	0	7
		2006	8	8	0	38	0	3	0	2	43
7	GB	2005▫	7	7	0	0	0	0	0	0	0
		2006	8	8	0	0	0	0	0	0	0
8	SZ	2005▫	7	7[a]	2	0	2	20	0	3	27
		2006	8	8[a]	0	0	2	88	0	0	90
	Total		124	124	14	146	35	190	157	25	567

[a] Seines at the surf zone sites were pulled three times perpendicular to the beach for a total distance of 30 m, at each of the other sites the seine was pulled once parallel to the shoreline for a total distance of 46 m.

using available literature (Johnson, 1978; Johnson and Uebelacker, 1984; Abele and Kim, 1986; Johnson and Allen, 2005; Heard et al., 2007; LeCroy, 2004–2011). Diets were described by mean stomach fullness (MSF) and frequency of occurrence of food items by prey categories for each kingfish species by habitat, season, and size range (Hyslop, 1980). Seasons included spring (April–May), summer (June–September), and fall (October–November). Frequency of occurrence is the proportion of fish that contained one or more of a given food type. Size ranges were adjusted to sequential 15 mm SL intervals, since few specimens < 10 mm SL were collected. Supplemental BPL and seine collections were conducted periodically from 2004 through 2007 at each type of habitat to provide additional samples for dietary analysis. These specimens were not included in the abundance and distribution part of this paper because they were not collected during the 2005–2006 study period or area (sites 1–8).

Results

Distribution and abundance.—Five hundred sixty-seven kingfish (160 *M. americanus*, 225 *M. littoralis*, and 182 *M. saxatilis*) were collected during the study period (Table 2). Most of the specimens (87%) were collected in 2006. *Menticirrhus americanus* comprised 83.4% of the kingfish collected from sandy shorelines, whereas *M. saxatilis* and *M. littoralis* made up the remaining 11.5% and 5.1%, respectively. *Menticirrhus littoralis* represented 56.2% and *M. saxatilis* represented 42.5% of the kingfish collected from surf zones, with *M. americanus* only accounting for 1.3%. Mean site water temperature was 1.4°C to 3.3°C lower in 2005 than in 2006, and mean site salinities were 4.3 to 6.7 lower in 2005 than in 2006 for each site (Table 3). Water temperature and salinity varied more annually than spatially. Since numerous zero catches and small sample sizes were common, no statistics were used in this study. Thus, graphs and tables were developed to interpret the data.

Small *M. americanus* (< 20 mm SL) were collected with the BPL from April through October of 2005, with highest densities found during July (Fig. 2). The mean size of *M. americanus* in BPL collections was largest in October (17 mm SL). Densities of *M. americanus* declined slightly in 2006, with fish only occurring during July and August within BPL samples. Most *M. americanus* were collected from the low-energy sandy shorelines along the mainland, with a few smaller fish (< 8 mm SL) collected from surf zones in August of 2005 and 2006. None of the three *Menticirrhus* species were collected from grass beds or marsh edges with the BPL during the study period. Only two *M. littoralis* were collected with the BPL in 2005, and both were captured in August at surf zone site 8 (Fig. 2). In 2006, *M. littoralis* densities increased, and

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DOI: 10.18785/goms.3101.05

TABLE 3. Water temperature, salinity, and dissolved oxygen ranges and means from April through November of 2005 and 2006 by site, location, and habitat. ME, marsh edge; SS, sandy shoreline; GB, grass bed; SZ, surf zone.

Site	Location	Habitat	Year	Water temperature (°C) (mean)	Salinity (mean)	Dissolved oxygen (mg/L) (mean)
1	Davis Bayou	ME	2005	17.1–31.8 (25.8)	5.0–25.0 (16.5)	3.5–9.8 (6.2)
			2006	13.9–31.6 (27.5)	17.0–27.0 (21.6)	4.6–13.3 (6.6)
2	Bellefountaine	SS	2005	14.6–31.1 (24.6)	8.0–28.0 (18.4)	5.8–9.6 (7.4)
			2006	16.1–29.6 (26.0)	19.0–28.0 (23.4)	5.4–13.3 (7.1)
3	Horn Island	GB	2005	11.5–31.0 (24.1)	18.0–33.0 (23.4)	6.3–10.3 (8.0)
			2006	14.7–31.2 (26.4)	27.0–33.0 (30.1)	4.2–12.0 (7.0)
4	Horn Island	SZ	2005	12.4–30.2 (24.1)	18.0–33.0 (25.8)	6.0–8.5 (6.9)
			2006	16.2–30.7 (26.4)	27.0–35.0 (32.1)	4.5–10.1 (6.5)
5	Pascagoula	ME	2005	17.4–29.4 (23.6)	8.0–28.0 (17.4)	5.6–9.9 (6.8)
	River		2006	15.4–30.8 (26.9)	15.0–27.0 (22.1)	4.5–11.8 (6.2)
6	Pascagoula	SS	2005	17.4–30.4 (24.6)	8.0–32.0 (21.5)	4.1–9.3 (7.2)
	Beach		2006	16.4–30.2 (27.2)	18.0–30.0 (25.8)	5.4–13.8 (7.0)
7	Horn Island	GB	2005	11.8–31.7 (24.3)	17.0–33.0 (23.9)	6.7–10.0 (8.3)
			2006	15.1–31.8 (26.6)	27.0–33.0 (30.1)	4.3–12.4 (7.7)
8	Horn Island	SZ	2005	13.1–29.8 (23.4)	18.0–33.0 (26.2)	6.0–8.2 (7.0)
			2006	16.3–30.6 (25.1)	27.0–34.0 (31.9)	4.4–9.7 (6.3)

specimens were found in BPL collections during April, July, and September, with highest catches during April and July. The mean size of fish gradually increased from April (9 mm SL) to September (13 mm SL). *Menticirrhus littoralis* was only found in BPL collections from surf zones with highest catches at site 4; however, *M. saxatilis* was only collected in 2006 with the BPL (Fig. 2). In April, 152 *M. saxatilis* ($\bar{x} = 9$ mm SL) were collected from surf zone site 4. *Menticirrhus saxatilis* were also collected with the BPL in October from sandy shoreline site 2, with a mean size of 6 mm SL, and again in November from surf zone site 4, with a mean size of 12 mm SL.

Kingfish were generally larger and more abundant in the seine collections. *Menticirrhus americanus* was seined from May through November in 2005, with highest densities during July (Fig. 3). Monthly increases in mean size of fish, possibly attributed to 1 mo of growth, occurred from May (28 mm SL) to June (58 mm SL) and from July (19 mm SL) to August (45 mm SL) at sandy shoreline site 2. Most *M. americanus* collected with the seine in 2005 occurred at sandy shorelines. A few fish were collected from surf zone site 4 and marsh-edge site 1. No kingfish species were collected from grass beds or marsh-edge site 5 during the entire study period with the seine.

Densities of *M. americanus* in seines increased considerably in 2006 (Fig. 3). Fishes were collected from May through October, with highest densities during September. The monthly mean size of fish was quite variable, probably reflecting the protracted spawning season. As in 2005, most *M. americanus* collected with the seine in 2006 were found at sandy shorelines. Several fish were collected from marsh-edge site 1, but this species was absent from surf zone collections. *Menticirrhus americanus* were the only kingfish species collected with the seine from marsh-edge habitat during the study period.

Menticirrhus littoralis were collected with the seine from April through November in 2005, with densities highest during July (Fig. 3). All were collected from surf zones, except for one fish collected from sandy shoreline site 6 during June. As with *M. americanus*, densities of *M. littoralis* increased considerably in 2006. Fish were collected in every month, with highest densities during September. Most *M. littoralis* were collected from surf zones, but a few were collected at both sandy shoreline sites on the mainland in 2006.

The only *M. saxatilis* collected with the seine in 2005 occurred at surf zone site 8 during June (Fig. 3). *Menticirrhus saxatilis* were collected with the seine from April through June in 2006, with highest densities occurring in April and May. Similar densities of *M. saxatilis* were collected at sandy shorelines and surf zones. Eleven juvenile *M. saxatilis* (30–50 mm SL), unusually large for spring, were collected in April of 2006 from sandy shoreline site 2.

Menticirrhus americanus were collected in waters ranging in salinity from 5 to 32 and water temperatures from 17.6 to 31.1°C. Most specimens were collected from waters with a temperature $>$ 25.0°C and salinity > 20. *Menticirrhus littoralis* and *M. saxatilis* were not found in habitats with low salinity, being collected in waters that ranged in salinity from 18 to 35 and 19 to 32,

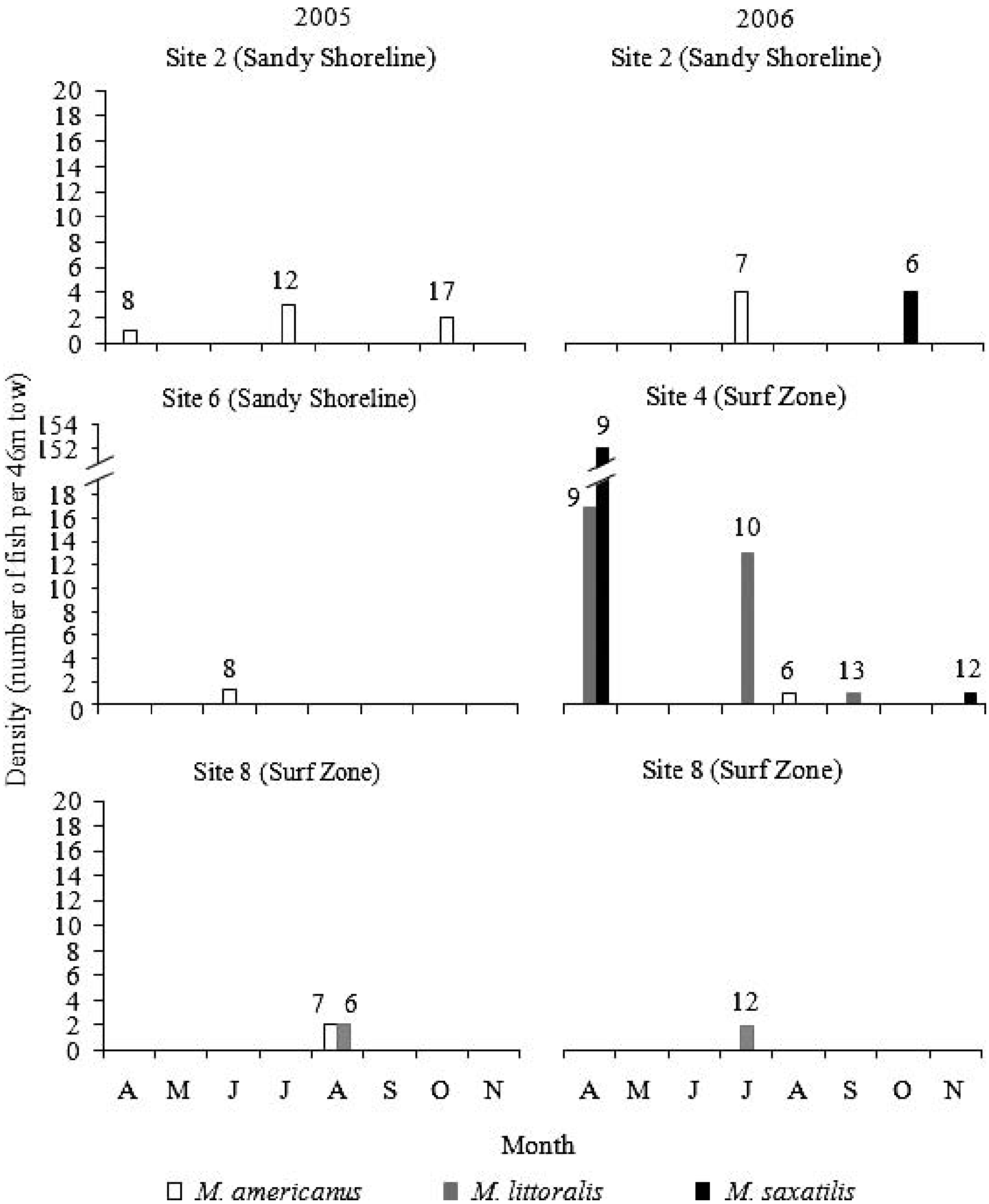

Fig. 2. Densities of *Menticirrhus americanus, M. littoralis,* and *M. saxatilis* collected monthly with a beam plankton trawl (46 m tow). Mean standard length (SL) of fish is shown above histogram bars. Sites 5–8 were not sampled during September 2005.

respectively. Both *M. littoralis* and *M. saxatilis* were collected in cooler water temperatures than *M. americanus*, with ranges of 13.2°C to 30.7°C and 12.9°C to 30°C, respectively. However, most *M. littoralis* and *M. saxatilis* were collected in water > 25.0°C. Most *M. saxatilis* were collected from waters with salinity > 20, whereas most *M. littoralis* were collected in high salinity waters > 30.

Feeding habits.—The majority of the stomachs examined were from kingfish collected in 2006. *Menticirrhus americanus* had the lowest mean MSF (2.7), although only 4 of the 79 stomachs

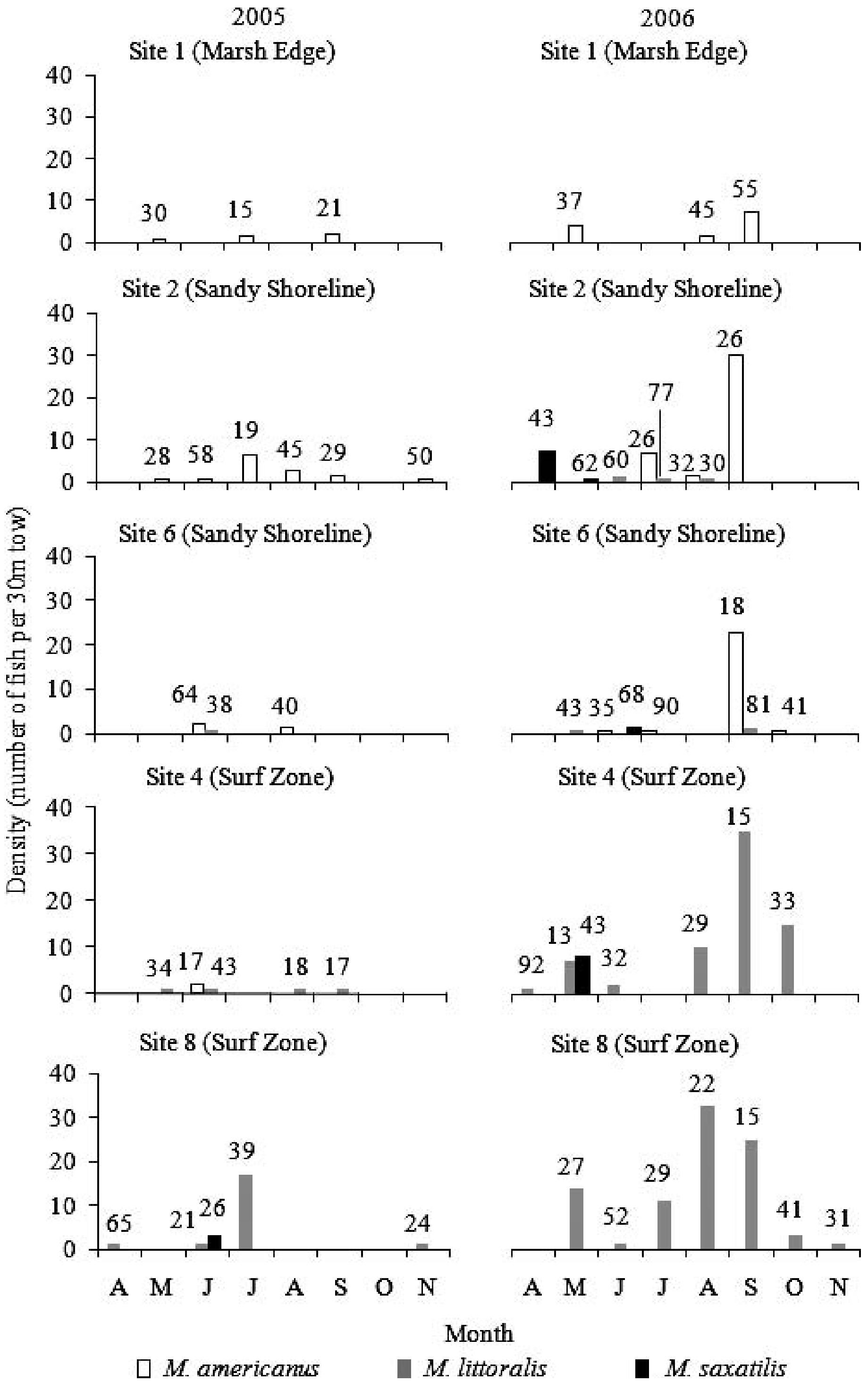

Fig. 3. Densities of *Menticirrhus americanus, M. littoralis,* and *M. saxatilis* collected monthly with a seine (30 m tow). Mean standard length (SL) of fish is shown above histograms. Sites 5–8 were not sampled during September 2005.

examined were empty (Table 4). *Menticirrhus saxatilis* (n = 33) had the highest mean MSF (3.3), and no fish were found with empty stomachs. Only three *M. littoralis* (n = 49) were found with empty stomachs, and these juveniles had a mean MSF of 3.2.

Menticirrhus americanus had the most diverse diet of the three kingfish species. *Menticirrhus americanus* and *M. saxatilis* stomachs most frequently contained mysids, copepods, and amphipods, whereas *M. littoralis* stomachs most frequently contained bivalves (*Donax* spp.), copepods, and mysids (Table 4). Most (> 98%) of the copepods contained in each of the three kingfish species stomachs were calanoid copepods. Fishes were not found in the *M. littoralis* diet but were found in 10.7% and 3.0% of stomachs of *M. americanus* and *M. saxatilis*, respectively. Unidentified parasitic nematodes were not included as a food item or prey category but occurred in all three species, mostly in *M. littoralis* (6.5%) and *M. saxatilis* (15.2%) collected from surf zones during the spring.

Habitat influenced prey items used by all three kingfish species and was most noticeable for *M. littoralis* and *M. saxatilis* (Table 4). *Menticirrhus littoralis* collected from surf zones (n = 43) fed most often on bivalves (60.0%), copepods (42.5%), and mysids (30.0%). In contrast, amphipods (83.3%), bivalves (50.0%), and mysids (50.0%) occurred most frequently in *M. littoralis* collected from sandy shorelines (n = 6). Brachyurans were also important food items for *M. littoralis* collected from sandy shorelines, whereas anomurans were an important prey item for *M. littoralis* collected from surf zones. Polychaetes (16.7%) were also an important diet component for *M. littoralis* collected from sandy shorelines. The MSF and mean SL were both higher for *M. littoralis* collected from sandy shorelines than for those collected from surf zones (Table 4). None of the stomachs from *M. littoralis* collected from sandy shorelines were empty (n = 6), but three stomachs were empty from *M. littoralis* collected from surf zones (n = 43).

Menticirrhus saxatilis collected from surf zones (n = 16) fed most often on mysids (68.6%), with copepods (37.5%) and isopods (31.3%) also being important food items (Table 4). As with *M. littoralis*, *M. saxatilis* collected from sandy shorelines (n = 15) fed mostly on amphipods (73.3%), but copepods (53.3%) and polychaetes (26.7%) were also a common prey item. The only *M. saxatilis* collected from marsh-edge and grass bed habitats were part of the supplemental collections, were < 30 mm SL, and only consumed copepods. *Menticirrhus saxatilis* collected from surf zones fed on eight prey categories compared with only four for those collected from sandy shorelines (Table 4). The stomach of the only *M. saxatilis* collected from the marsh edge contained 130 calanoid copepods, which resulted in the highest MSF (4.0) by habitat. *Menticirrhus saxatilis* collected from sandy shorelines had a higher MSF than those collected from surf zones (Table 4).

Mysids (mostly *Americamysis alleni*) were the most important prey of *M. americanus* collected from marsh edges (67.7%) and sandy shorelines (73.5%). Copepods (38.7%) and amphipods (25.8%) were also consumed frequently by *M. americanus* collected from marsh edges (Table 4). *Menticirrhus americanus* collected from sandy shorelines fed more frequently on amphipods (29.4%) than copepods (26.5%). Fishes (16.1%) and polychaetes (16.1%) were also important food items along marsh edges, and sergestids (17.6%) were important food items at sandy shorelines (Table 4). Although stomachs of *M. americanus* collected from sandy shorelines contained more prey categories, including sergestids (*Acetes americanus carolinae*) and isopods, than those from marsh edges, the MSF was higher for specimens collected from marsh edges than from sandy shorelines (Table 4). *Menticirrhus americanus* collected from grass beds, which were also part of the supplemental collections, and surf zones contained only copepods and mysids. None of the stomachs from *M. americanus* collected from grass beds or marsh edges were empty, and only two were empty from those collected from both the sandy shorelines and surf zones.

Seasonal comparison of diets showed more diversity of prey categories during the summer for *M. americanus* and *M. littoralis*, and more diversity during the spring for *M. saxatilis* (Table 5). The MSF was highest for *M. saxatilis* in the spring, for *M. littoralis* in the summer, and for *M. americanus* in the fall. Mysids were the most common prey item during each season for *M. americanus*, but in the fall polychaetes and amphipods were also commonly consumed. Bivalves occurred most frequently in stomachs of *M. littoralis* from the spring and fall; however, during the summer, mysids were the most common prey item. *Menticirrhus littoralis* also fed frequently on anomurans in the fall (Table 5). Stomachs of *M. saxatilis* most often contained amphipods in the spring and mysids in the summer. The few specimens collected in the fall were < 15 mm SL and fed only on copepods.

Diversity of prey categories and the MSF increased with size for each kingfish species

Table 4. Frequency of occurrence of food items by prey category for juvenile *Menticirrhus* species collected from various habitats (2004–2007). Standard error variance is given for mean standard length and mean stomach fullness. *Menticirrhus* specimens from the grass beds were from supplemental collections used only for the diet analysis. All, all habitats combined; GB, grass bed; ME, marsh edge; SS, sandy shoreline; SZ, surf zone.

	M. americanus					*M. littoralis*			*M. saxatilis*				
Habitat	All	ME	SS	GB	SZ	All	SS	SZ	All	ME	SS	GB	SZ
Number of fish examined	79	31	36	6	6	49	6	43	33	1	15	1	16
Number of fish with food	75	31	34	6	4	46	6	40	33	1	15	1	16
Mean standard length (mm)	30.2 ± 1.86	34.3 ± 2.82	31.3 ± 2.71	16.3 ± 1.63	10.8 ± 4.42	29.6 ± 2.33	47.5 ± 4.74	26.9 ± 2.31	29.8 ± 3.07	26.0 ± 0.00	33.7 ± 4.71	7.0 ± 0.00	27.8 ± 4.34
Mean stomach fullness (1–5)	2.66 ± 0.15	3.00 ± 0.22	2.56 ± 0.22	2.17 ± 0.48	1.50 ± 0.29	3.17 ± 0.20	3.83 ± 0.60	3.08 ± 0.21	3.27 ± 0.21	4.00 ± 0.00	3.53 ± 0.34	2.00 ± 0.00	3.06 ± 0.30
Food item	Frequency of occurrence												
Cnidarians	0.0	0.0	0.0	0.0	0.0	2.2	0.0	2.5	0.0	0.0	0.0	0.0	0.0
Copepods	34.7	38.7	26.5	17.0	50.0	37.0	0.0	42.5	48.5	100.0	53.3	100.0	37.5
Mysids	65.3	67.7	73.5	33.0	25.0	32.6	50.0	30.0	42.4	0.0	20.0	0.0	68.6
Amphipods	24.0	25.8	29.4	0.0	0.0	26.1	83.3	10.0	34.1	0.0	73.3	0.0	12.5
Isopods	4.0	0.0	8.8	0.0	0.0	2.2	0.0	2.5	15.2	0.0	0.0	0.0	31.3
Tanaidaceans	4.0	6.5	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cumaceans	2.7	0.0	5.9	0.0	0.0	6.5	16.7	5.0	0.0	0.0	0.0	0.0	0.0
Sergestids	8.0	0.0	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anomurans	1.3	3.2	0.0	0.0	0.0	15.2	0.0	17.5	3.0	0.0	0.0	0.0	6.3
Brachyurans	5.3	9.7	8.8	0.0	0.0	8.7	33.3	5.0	12.1	0.0	0.0	0.0	25.0
Polychaetes	9.3	16.1	5.9	0.0	0.0	10.9	16.7	10.0	12.1	0.0	26.7	0.0	0.0
Oligochaetes	2.7	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bivalves	2.7	0.0	5.9	0.0	0.0	58.7	50.0	60.0	0.0	0.0	0.0	0.0	0.0
Fishes	10.7	16.1	8.8	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	6.3
Tunicates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	6.3
Arthropod remains	8.0	19.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crustacean remains	9.3	9.7	2.9	33.0	25.0	2.2	16.7	2.5	6.1	0.0	0.0	0.0	12.5
Unidentifiable animal remains	13.3	12.9	8.8	17.0	50.0	6.5	16.7	5.0	9.1	0.0	13.3	0.0	6.3
Unidentifiable plant remains	20.0	29.0	14.7	17.0	0.0	21.7	16.7	22.5	18.2	0.0	20.0	0.0	18.8

TABLE 5. Frequency of occurrence of food items by prey category for juvenile *Menticirrhus* species collected in the spring, summer, fall, and winter (2004–2007). Standard error variance is given for mean standard length and mean stomach fullness.

	M. americanus			*M. littoralis*			*M. saxatilis*		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Number of fish examined	4	65	10	13	25	11	20	7	5
Number of fish with food	4	61	10	12	23	11	20	7	5
Mean standard length (mm)	31.0 ± 8.38	29.0 ± 2.08	37.8 ± 4.42	24.2 ± 3.97	28.3 ± 3.54	38.3 ± 3.78	37.6 ± 3.39	25.0 ± 5.77	9.8± 4.05
Mean stomach fullness (1–5)	2.75 ± 0.48	2.59 ± 0.17	3.00 ± 0.33	2.67 ± 0.45	3.43 ± 0.27	3.18 ± 0.35	3.55 ± 0.26	3.29 ± 0.52	2.40 ± 0.51
Food item	Frequency of occurrence								
Cnidarians	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0
Copepods	50.0	34.4	30.0	66.6	39.1	0.0	40.0	28.6	100.0
Mysids	50.0	63.9	80.0	0.0	52.4	36.4	40.0	85.7	0.0
Amphipods	0.0	19.7	60.0	0.0	26.1	27.3	60.0	14.3	0.0
Isopods	0.0	4.9	0.0	0.0	4.3	0.0	10.0	42.9	0.0
Tanaidaceans	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0
Cumaceans	0.0	3.3	0.0	0.0	4.3	18.2	0.0	0.0	0.0
Sergestids	0.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anomurans	0.0	1.6	0.0	0.0	8.7	45.5	5.0	0.0	0.0
Brachyurans	0.0	8.2	10.0	0.0	4.3	27.3	5.0	42.9	0.0
Polychaetes	0.0	4.9	40.0	8.3	17.4	0.0	20.0	0.0	0.0
Oligochaetes	0.0	1.6	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Bivalves	0.0	3.3	0.0	75.0	30.4	100.0	0.0	0.0	0.0
Fishes	50.0	6.6	20.0	0.0	0.0	0.0	0.0	14.3	0.0
Tunicates	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
Arthropod remains	25.0	4.9	20.0	0.0	0.0	0.0	0.0	0.0	0.0
Crustacean remains	25.0	9.8	0.0	8.3	0.0	0.0	5.0	14.3	0.0
Unidentifiable animal remains	0.0	14.8	10.0	0.0	4.3	18.2	15.0	0.0	0.0
Unidentifiable plant remains	25.0	18.0	30.0	33.0	13.0	27.3	30.0	0.0	0.0

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DOI: 10.18785/goms.3101.05

TABLE 6. Frequency of occurrence of food items by prey category for juvenile *Menticirrhus* species in 15 mm SL size increments (2004–2007). Standard error variance is given for mean stomach fullness.

	M. americanus				*M. littoralis*				*M. saxatilis*			
Standard length (mm)	< 15	16–30	31–45	46–60	< 15	16–30	31–45	46–60	< 15	16–30	31–45	46–60
Number of fish examined	20	19	22	18	14	14	11	10	11	4	11	7
Number of fish with food	18	18	21	18	12	13	11	10	11	4	11	7
Mean stomach fullness (1–5)	1.72 ± 0.18	2.78 ± 0.22	2.48 ± 0.26	3.67 ± 0.30	2.58 ± 0.36	2.62 ± 0.38	3.45 ± 0.37	4.30 ± 0.26	2.45 ± 0.28	3.25 ± 0.75	3.64 ± 0.36	4.00 ± 0.38
Food item	Frequency of occurrence											
Cnidarians	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0
Copepods	50.0	22.2	52.3	11.1	66.7	46.2	9.1	20.0	90.9	25.0	36.4	14.3
Mysids	27.8	83.3	85.7	61.1	50.0	15.4	27.3	40.0	18.2	50.0	36.4	85.7
Amphipods	5.6	27.8	19.0	44.4	8.3	15.4	18.2	40.0	9.1	0.0	72.7	57.1
Isopods	0.0	5.6	0.0	11.1	8.3	0.0	0.0	0.0	0.0	50.0	18.2	14.3
Tanaidaceans	0.0	0.0	4.8	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cumaceans	0.0	0.0	4.8	5.6	0.0	0.0	18.2	10.0	0.0	0.0	0.0	0.0
Sergestids	0.0	0.0	9.5	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anomurans	0.0	0.0	0.0	5.6	0.0	7.7	27.3	30.0	0.0	0.0	0.0	14.3
Brachyurans	0.0	5.6	9.5	16.7	0.0	7.7	9.1	20.0	9.1	0.0	9.1	28.6
Polychaetes	0.0	0.0	19.0	16.7	0.0	23.1	0.0	20.0	0.0	0.0	36.4	0.0
Oligochaetes	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bivalves	5.6	0.0	0.0	5.6	16.7	53.8	100.0	70.0	0.0	0.0	0.0	0.0
Fishes	0.0	0.0	9.5	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Tunicates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0
Arthropod remains	0.0	16.7	9.5	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crustacean remains	16.7	0.0	14.3	5.6	0.0	0.0	9.1	0.0	9.1	25.0	0.0	0.0
Unidentifiable animal remains	16.7	5.6	9.5	22.2	8.3	0.0	9.1	10.0	9.1	0.0	18.2	0.0
Unidentifiable plant remains	11.1	22.2	23.8	22.2	0.0	15.4	45.5	30.0	0.0	0.0	27.3	42.9

(Table 6). All three kingfish fed most frequently on copepods at sizes < 15 mm SL. At sizes from 16 to 60 mm SL, the most important prey item for *M. americanus* was mysids and for *M. littoralis* was bivalves. *Menticirrhus saxatilis* fed most often on mysids and isopods at sizes from 16 to 30 mm SL, on amphipods at sizes from 31 to 45 mm SL, and on mysids at sizes from 46 to 60 mm SL (Table 6). Copepods occurred in the diet of all three kingfish through all size ranges, but the percentage occurrence decreased with increasing fish size. Fishes (*Anchoa mitchilli* and *Eucinostomus* spp.) were found in stomachs of *M. americanus* at sizes > 30 mm SL and for *M. saxatilis* at sizes > 45 mm SL. Plant material increased in frequency of occurrence with size for all three species.

The interannual comparison of feeding for *M. americanus* showed few differences in feeding between specimens collected from marsh edges and sandy shorelines from 2005 to 2006 (Table 7). Copepods did occur more frequently in specimens collected from marsh edges in 2005 than 2006. Mysids occurred frequently during both years, but fishes were more frequently consumed in 2006. Plants occurred more frequently in stomachs from *M. americanus* collected from marsh edges in both years than those collected from sandy shorelines. The MSF was higher for specimens collected from marsh edges than for those collected from sandy shorelines during both years, especially during 2005.

Discussion

Abundances of the three *Menticirrhus* species varied annually in the north-central GOM and were greater in 2006 than in 2005. Collection effort was similar during both years, but 87% of the kingfish were collected in 2006. Modde and Ross (1981) also found interannual variability in abundance of kingfishes collected along a Mississippi barrier island. In their study, abundances of all three species were higher in 1976 and 1977 than in 1975. This variability in annual abundance of kingfish was likely influenced by abiotic factors. During this study, water temperatures were much warmer in the spring and fall of 2006 than in 2005. Mean monthly water temperatures were > 6°C warmer in April of 2006 than 2005 and > 8°C warmer in October of 2006 than in 2005.

The interannual variability in kingfish abundance was also associated with differences in salinity between 2005 and 2006. *Menticirrhus littoralis* and *M. saxatilis* were more abundant in 2006 when the salinity was highest and were not collected in salinities < 18. Springer and Woodburn (1960) reported higher abundances of *M. littoralis* when the salinity was > 30 and *M. saxatilis* when the salinity was > 25. *Menticirrhus americanus* have been found over a much broader range of salinities than *M. littoralis* and *M. saxatilis* (Gunter, 1945; Bearden, 1963; Dahlberg, 1972). Chapman (1966) reported higher fish harvest of estuarine-dependant species along the Texas coast during wet years but did not hypothesize why the lower salinities were correlated with increased catches.

Densities of both *M. americanus* and *M. littoralis* peaked during early summer of 2005 and late summer of 2006, whereas densities of *M. saxatilis* peaked during the spring of 2006; the few *M. saxatilis* collected in 2005 were collected in June. Although the reported timing of peak abundances of larval and juvenile *Menticirrhus* species is variable in most northern GOM studies, larval and juvenile *M. americanus* and *M. littoralis* are reported to be most abundant from June to August, and larval and juvenile *M. saxatilis* are most abundant in May and June (Gunter, 1945; McFarland, 1963; Modde and Ross, 1981; McMichael and Ross, 1987; Ross et al., 1987). During the present study, *M. saxatilis* was most abundant in April 2006, which could possibly be attributed to warmer water temperatures in the early spring of 2006. The difference in temporal distribution of *M. saxatilis* when compared with *M. americanus* and *M. littoralis* is likely due to the influence of water temperature on spawning.

All three kingfish species co-occurred in surf zone and sandy shoreline habitats along the mainland, but *M. americanus* was the dominant kingfish along the sandy shorelines, and *M. littoralis* was the dominant kingfish in barrier island surf zones. Several studies found *M. americanus* (< 50 mm SL) were common in barrier island surf zones of the northeast GOM (Fritzsche and Crowe, 1981; Modde and Ross, 1981; McMichael and Ross, 1987). In contrast, only five *M. americanus* were collected from barrier island surf zones during this study. The salinity during this 2-yr study period was high, especially during 2006, when compared with other studies conducted in the northeast GOM. Historical data show the mean annual salinity from site 3 (barrier island grass bed) was 24.2 in 2005 and 29.6 in 2006 (personal observation). In contrast, the mean annual salinity using long-term Fisheries Assessment and Monitoring data at the same site during the study by Modde and Ross (1981) was 18.9 in 1975, 22.7 in 1976, and 21.7 in 1977, and during the study by McMichael and Ross (1987) 22.5 in 1978 and 16.5 in 1979 (Unpublished

https://aquila.usm.edu/goms/vol31/iss1/5
DOI: 10.18785/goms.3101.05

TABLE 7. Frequency of occurrence of food items by prey category for juvenile *M. americanus* from marsh edge (ME) and sandy shoreline (SS) habitats for 2005 and 2006. Standard error variance is given for mean standard length and mean stomach fullness.

	2005		2006	
Habitat	ME	SS	ME	SS
Number of fish examined	24	37	31	36
Number of fish with food	24	36	31	34
Mean standard length (mm)	24.0 ± 2.96	29.4 ± 2.45	34.3 ± 2.82	31.3 ± 2.71
Mean stomach fullness (1–5)	3.33 ± 0.21	2.58 ± 0.16	3.00 ± 0.22	2.56 ± 0.22
Food item	Frequency of occurrence			
Copepods	91.7	38.9	38.7	26.5
Argulidae	0.0	2.8	0.0	0.0
Mysids	50.0	47.2	67.7	73.5
Amphipods	8.3	16.7	25.8	29.4
Isopods	0.0	8.3	0.0	8.8
Tanaidaceans	8.3	0.0	6.5	2.9
Cumaceans	4.2	0.0	0.0	5.9
Sergestids	0.0	2.8	0.0	17.6
Carideans	0.0	2.8	0.0	0.0
Anomurans	0.0	0.0	3.2	0.0
Brachyurans	12.5	0.0	9.7	8.8
Polychaetes	8.3	36.1	16.1	5.9
Oligochaetes	4.2	2.8	6.5	0.0
Bivalves	4.2	16.7	0.0	5.9
Fishes	0.0	5.6	16.1	8.8
Arthropod remains	0.0	0.0	19.4	0.0
Crustacean remains	4.2	8.3	9.7	2.9
Unidentifiable animal remains	8.3	5.6	12.9	8.8
Unidentifiable plant remains	33.3	25.0	29.0	14.7

data, 1973–present).[1] *Menticirrhus americanus* was most abundant inshore, where salinities were < 25% during this study.

Hildebrand and Cable (1934) and Armstrong and Muller (1996) reported that *M. littoralis* was confined almost entirely to surf zones and just offshore, but during the present study seven specimens were collected in 2006 and one in 2005 from low-energy sandy shorelines along the mainland. These *M. littoralis* were 38 to > 60 mm SL and were collected during the summer, suggesting that some *M. littoralis* in this size range use low-energy sandy shoreline habitat. *Menticirrhus saxatilis* was surprisingly slightly more abundant from mainland sandy shorelines than surf zones in the seine hauls in 2006. These results differ from Bearden (1963) in South Carolina and Schaefer (1965) in New York, who reported highest abundances of *M. saxatilis* from surf zones and few specimens collected inshore. Juvenile *M. littoralis* and *M. saxatilis* may venture inshore during drought years when the salinity reaches preferable levels, as in 2006. *Menticirrhus* species were not collected from grass beds during the study period, although other sciaenids (*Cynoscion nebulosus* and *Bairdiella chrysoura*) were frequently collected from grass beds (Anderson, 2009). *Menticirrhus americanus* was the only kingfish collected from marsh edges during the study period. The spatial distribution for *M. littoralis* and *M. saxatilis* was limited to surf zones and sandy shorelines, whereas *M. americanus* was most common at sandy shorelines and marsh edges but was also collected from surf zones.

Monthly densities indicated *M. americanus* and *M. littoralis* likely spawned between April and October, which corroborates other kingfish research (Irwin, 1970; Darovec, 1983; and McMichael and Ross, 1987; Clardy et al., 2014). In 2006, juvenile *M. saxatilis* was collected from the spring through early summer and again in the fall. Additionally, 11 *M. saxatilis* specimens (30–50 mm SL) were collected in April, indicating Northern Kingfish may begin spawning earlier than Gulf and Southern Kingfish. Jannke (1971) reported possible fall through spring spawning for this species in the Everglades National Park, Florida. While most of the

[1] Unpublished data, Fisheries Assessment and Monitoring of Mississippi's Interjurisdictional Marine Resources. Gulf Coast Research Laboratory, University of Southern Mississippi, October 1973–present. Ocean Springs, MS.

literature reports spring through early fall spawning in the GOM (Irwin, 1970; Johnson, 1978; McMichael and Ross, 1987), Northern Kingfish from the United States Atlantic coast spawn in April and May (Hildebrand and Cable, 1934; Dahlberg, 1972) or just in summer (Welsh and Breder, 1923).

In previous studies of juvenile *M. americanus* (< 60 mm SL), common prey items have included mysids, crabs, copepods, amphipods, and polychaetes as important prey items (Welsh and Breder, 1923; Springer and Woodburn, 1960; Bearden, 1963; Irwin, 1970; McMichael and Ross, 1987). Accounts of the diet of juvenile *M. littoralis* tend to vary among previous studies. Juvenile *M. littoralis* (< 60 mm SL) from surf zones at Horn Island have been reported to feed on small crustaceans, polychaetes, and bivalves (Modde, 1979; Modde and Ross, 1983; McMichael and Ross, 1987). Irwin (1970) reported juvenile *M. littoralis* (< 60 mm SL) collected from surf zones at Ship Island, MS, also fed on small crustaceans and polychaetes but not on bivalves, while Bearden (1963) reported that juveniles (25–80 mm SL) from a surf zone in South Carolina fed almost entirely on beach fleas (*Orchestia* spp.). Studies of juvenile *M. saxatilis* (< 74 mm SL) showed copepods, mysids, amphipods, crabs, and polychaetes as major food items (Welsh and Breder, 1923; Springer and Woodburn, 1960; Irwin, 1970; Chao and Musick, 1977; McMichael and Ross, 1987). McMichael and Ross (1987) reported bivalves and cumaceans were also important prey of *M. americanus* and *M. saxatilis* from surf zones of Horn Island. However, in the present study, stomachs from *M. saxatilis* did not contain any cumaceans or bivalves, and < 3% of *M. americanus* stomachs contained cumaceans or bivalves. Both *M. americanus* and *M. saxatilis* fed most frequently on mysids and calanoid copepods. Bivalves were the primary prey of *M. littoralis,* occurring in almost 60% of the stomachs analyzed. Several studies (Modde, 1979; Modde and Ross, 1983; McMichael and Ross, 1987) reported that bivalve siphon tips, not the entire bivalve, were the primary prey of juvenile *M. littoralis* at Horn Island. However, the majority of bivalves found in stomachs of juvenile *M. littoralis* during this study included the entire organism. This could be because *M. littoralis* from this study fed on smaller bivalves than did specimens collected during the other studies from Horn Island surf zones.

Menticirrhus americanus fed on a greater variety of food items than *M. littoralis* or *M. saxatilis.* However, we examined more stomachs from *M. americanus* (79) than from *M. littoralis* (49) or *M. saxatilis* (33). Furthermore, most *M. americanus* specimens were collected from inshore habitats, where species richness from seine collections was higher than at surf zones (Anderson, 2009). McMichael and Ross (1987) also reported *M. americanus* had a more diverse diet than the other kingfish species. Fishes were consumed by *M. americanus* (10.7%) and *M. saxatilis* (3%) but not by *M. littoralis* during this study. McMichael and Ross (1987) reported fishes occurring in *M. americanus* (7.5%), *M. littoralis* (0.7%), and *M. saxatilis* (17.8%). The higher percentage of piscivory in *M. saxatilis* than in *M. americanus* in their study could be associated with the size ranges of specimens examined: < 100 mm SL for *M. saxatilis* and < 80 mm SL for *M. americanus.*

Seasonal effects on the feeding habits of three *Menticirrhus* species varied among species. The diets of *M. americanus* and *M. littoralis* were most diverse during the summer, whereas *M. saxatilis* fed on a greater variety of prey items during the spring. The MSF was highest for *M. saxatilis* in the spring, for *M. littoralis* in the summer, and for *M. americanus* in the fall. Mysids were most common during each season in *M. americanus,* and bivalves occurred most frequently in *M. littoralis* from the spring and fall, although during the summer mysids occurred most frequently. Stomachs of *M. saxatilis* most often contained amphipods in the spring and mysids in the summer. The few small specimens collected in the fall fed only on calanoid copepods. Currently, this is the only study that compares diets of *Menticirrhus* species < 100 mm SL seasonally.

Interannual comparisons of the feeding habits of *M. americanus* showed that copepods occurred more frequently in specimens collected from marsh edges in 2005 than 2006, and fishes were more frequently consumed in 2006. Also, the MSF was higher for specimens collected from marsh edges than sandy shorelines during both years, especially during 2005. Anderson et al. (2012) found that *M. americanus* collected in 2005 from marsh edges grew significantly faster than *M. americanus* collected along sandy shorelines. Foraging success was likely higher for *M. americanus* at marsh edges in 2005.

Diets were most similar between species at sizes < 15 mm SL when all three kingfish fed most frequently on calanoid copepods. Calanoid copepods occurred in the diet of all three kingfish through all size ranges, but the percentage occurrence decreased with increasing fish size. McMichael and Ross (1987) reported the presence of copepods in the diet of *M. americanus* (< 60 mm SL) and *M. littoralis* (< 60 mm SL), but not at all in the diet of *M. saxatilis.* For

DOI: 10.18785/goms.3101.05

the next larger size class (16–30 mm SL), the most important prey item switched from copepods to mysids (mostly *Americamysis* spp.) for *M. americanus*, to bivalves for *M. littoralis*, and to both mysids (mostly *Chlamydopleon dissimilis*) and isopods for *M. saxatilis*.

The diversity of prey items increased with increasing size for all three *Menticirrhus* species. Adults of all three kingfish species are reported to be demersal feeders (Trewavas, 1964; Chao and Musick, 1977; Sikora and Sikora, 1982), and a shift from planktonic to demersal prey with increasing size was found for all three kingfish species, as other studies have reported (Modde, 1979; Modde and Ross, 1983; McMichael and Ross, 1987). McMichael and Ross (1987) reported that these ontogenic shifts in diet could be associated with swim bladder development. Small *M. americanus* and *M. saxatilis* have swim bladders, facilitating movement in the water column (Bearden, 1963; Irwin, 1970; McMichael and Ross, 1987). The swim bladder becomes less functional with increasing size as both species begin feeding near the bottom. In contrast, the swim bladder is completely missing in *M. littoralis*, even as juveniles (Irwin, 1970; McMichael and Ross, 1987). Several *M. littoralis* (< 10 mm SL) during this study consumed bivalves, but most *M. americanus* and *M. saxatilis* of the same size only fed on planktonic calanoid copepods.

Habitat influenced the prey consumed by all three kingfish, most noticeably for *M. littoralis* and *M. saxatilis*. *Menticirrhus littoralis* from surf zones fed most often on bivalves, calanoid copepods, and mysids, whereas amphipods, bivalves, and mysids were the dominant food groups of *M. littoralis* from sandy shorelines. This could be associated with a size difference between *M. littoralis* collected from the sandy shoreline, which were larger than those collected from the surf zone. Although *M. littoralis* from sandy shorelines fed most often on amphipods, bivalves remained an important dietary component. *Menticirrhus littoralis* switched from consuming common barrier island bivalves (*Donax* spp.) at surf zones to common inshore bivalves (*Mulinia lateralis*) at sandy shorelines. *Menticirrhus saxatilis* from surf zones fed most often on mysids, calanoid copepods, and isopods, and *M. saxatilis* from sandy shorelines most frequently fed on amphipods, calanoid copepods, and polychaetes.

Diets of *M. littoralis* and *M. saxatilis* from sandy shorelines were similar. Both *Menticirrhus* species fed most frequently on two species of amphipods, although the fishes were collected at different times of the year. In surf zones, *M. littoralis* fed mostly on bivalves, and *M. saxatilis* fed mostly on mysids. The MSF was higher for *M. littoralis* and *M. saxatilis* collected from sandy shorelines than from those collected from surf zones, suggesting food availability for both species was greater at sandy shorelines than at surf zones. *Menticirrhus littoralis* and *M. saxatilis* also may have been able to feed more easily at sandy shorelines without the intense wave action that normally occurs at surf zones.

Mysids were the dominant food group of *M. americanus* at both marsh edge and sandy shoreline habitats. *Menticirrhus americanus* fed more frequently on *A. alleni* than on other mysid species. Calanoid copepods and amphipods were also consumed frequently by *M. americanus* from the inshore habitats. *Menticirrhus americanus* consumed fish more often at marsh edges (16%) than along sandy shorelines (9%). Although the diet was more diverse for *M. americanus* from sandy shorelines, the MSF was higher for specimens collected from marsh edges than from sandy shorelines. Otolith analysis (Anderson, 2009; Anderson et al., 2012) revealed *M. americanus* grew faster at marsh edges than at sandy shorelines. Although food availability and growth may have been higher at marsh edges, *M. americanus* was most abundant at sandy shorelines. *Menticirrhus americanus* collected from grass beds (supplemental collections) and surf zones contained only calanoid copepods and mysids, probably because the few specimens available were small.

The abundance and early development of the three kingfish species in the north-central GOM appears to be mostly influenced by abiotic variables including water temperature and salinity. Highest abundances for all three *Menticirrhus* species occurred in 2006, when salinity and water temperature were higher than in 2005. Other abiotic factors, such as river discharge and habitat interactions, may also influence abundance and development of juvenile kingfish. In estuarine systems, increased river flow increases phytoplankton production, remineralization, and suspended sediment transport (Day et al., 1989). The spatial and temporal variability in kingfish abundance in the north-central GOM is likely caused by a combination of abiotic factors influencing biotic factors such as prey availability, predator abundance, and habitat accessibility. Long-term data on the three *Menticirrhus* species is needed to better understand the influence of abiotic and biotic factors and the interaction of factors on the abundance, distribution, and vital rates of larvae and juveniles.

Acknowledgments

This paper represents research completed by EJA in fulfillment of the M.S. degree from the University of Southern Mississippi. We thank M. Peterson, J. Lyczkowski-Shultz, H. Perry, and C. Rakocinski for their guidance. We also thank G. Sanchez, P. Grammer, R. Hendon, and D. Graham for their help with sampling and research. This research was conducted concurrently with Mississippi's Interjurisdictional Fisheries Assessment and Monitoring Program (Grant No. NA07NMF4070032) at the Gulf Coast Research Laboratory.

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