Early Growth of Three Kingfish (*Menticirrhus*) Species Found in Coastal Waters of the Northern Gulf of Mexico

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EARLY GROWTH OF THREE KINGFISH (*MENTICIRRHUS*) SPECIES FOUND IN COASTAL WATERS OF THE NORTHERN GULF OF MEXICO

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ABSTRACT: Southern kingfish (*Menticirrhus americanus*), gulf kingfish (*M. littoralis*), and northern kingfish (*M. saxatilis*) are members of the drum family (Sciaenidae) that are widespread in coastal habitats of the western Atlantic, including in the Gulf of Mexico (GOM). Despite their economic and ecological importance, little is known about growth of young kingfish. Young kingfish were collected from four different Mississippi shoreline habitats in 2005 and 2006; two associated with barrier islands and two along the mainland. Barrier island habitats included surf zones on the south shore and grass beds on the north shore. Mainland habitats were located along marsh—edges and sandy shorelines. Kingfish growth comparisons were made using analysis of covariance (ANCOVA) on 194 aged fish (127 *M. americanus*, 54 *M. littoralis*, and 13 *M. saxatilis*). Growth rates for all three species were generally similar ranging from about 0.7mm/day at 4—6 mm standard length (SL) to 1.9mm/day at 55—60mm SL. In 2005, *M. americanus* from marsh—edges grew significantly faster than those from sandy shorelines. Size—at—age of *M. americanus* and *M. littoralis* was significantly smaller in the spring than in the summer and fall, while both growth rate and size—at—age were similar in the summer and fall.

KEY WORDS: *Menticirrhus americanus, Menticirrhus littoralis, Menticirrhus saxatilis,* growth rate, size—at—age

INTRODUCTION

Southern kingfish (*Menticirrhus americanus*), gulf kingfish (*M. littoralis*) and northern kingfish (*M. saxatilis*) co—occur in littoral habitats of the northern Gulf of Mexico (GOM) where they are important demersal members of the coastal ecosystem. In U.S. waters, *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 coast and not as common in the GOM (Irwin 1970). Young *M. americanus* occur in surf zones of barrier islands, in coastal bays and along marsh—edges. Unlike the other kingfish, young *M. littoralis* occur almost entirely in surf zones of barrier islands (Modde and Ross 1981, Ross et al. 1987). Young *M. saxatilis* also can occur in surf zones and have been reported to enter bays (Bearden 1963, Schaefer 1965). 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).

Much of what is known about kingfish growth is based on adult length—frequency data (Hildebrand and Cable 1934, Springer and Woodburn 1960, Bearden 1963, Fritzsche and Crowe 1981, Crowe 1984, Harding and Chittenden 1987), measurements of scale annuli (Schaefer 1965, Smith and Wenner 1985), and tag/return data (Miller et al. 2002). The current study is the first to use otoliths as a method for aging and comparing the growth of the three young kingfish species.

The purpose of this study was to determine growth patterns of young kingfish (4—60 mm standard length, SL) collected from barrier island surf zones and grass beds, and mainland marsh—edges and sandy shorelines in coastal Mississippi. Comparisons were made among the 3 species, in—ter—annually, seasonally, and among different habitats in an effort to better understand early growth histories of kingfish.

MATERIALS AND METHODS

Field sampling

Sampling began in April and extended through November in 2005 and 2006. Four habitat types were sampled monthly with each habitat type represented by 2 sites (8 stations). 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 (Figure 1). Barrier island surf zone sites were located near the west tip and middle portion of the south side of the island (stations 4 and 8). Barrier island grass bed 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 (1 and 5) were fringed with *Juncus roemerianus* and were located near the mouths of Davis Bayou, MS and the east branch of the Pascagoula River. Mainland sandy shoreline sites (2 and 6) were located at Bellefountaine, MS 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. 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. Surface water temperature was measured at each collection location with a YSI Model 55. Specimens were stored in labeled containers and placed on ice for transport to the laboratory. In the
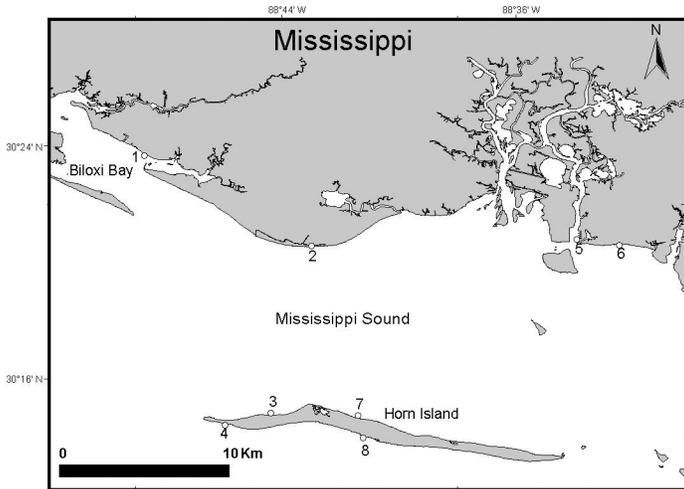
Figure 1. *Sample locations along the Mississippi Gulf Coast included marsh edge (sites 1 and 5), sandy shoreline (sites 2 and 6), grass bed (sites 3 and 7) and surf zone habitats (sites 4 and 8). Numbers indicate sampling sites.*

laboratory, kingfish were identified to species, measured to the nearest mm SL and preserved in 95% ethanol. Supplemental seine collections were taken during the summers of 2005 and 2006 from each habitat type to provide additional samples for otolith analyses.

Otolith preparation and analysis

For otolith analyses, kingfish were divided into 10 mm size increments over a size range of up to 60 mm SL. A minimum of 2 specimens of each species was randomly selected from each of the 6 size increments. Specimens were taken from all habitats and months when available. When a species was not common from a habitat, all available specimens were analyzed from that habitat. Growth rates of young kingfish were based upon SL and the number of daily otolith growth increments. Daily periodicity of increment formation has not been validated for the 3 *Menticirrhus* species, but has been validated for early life stages of 4 other Gulf sciaenids including *Sciaenops ocellatus* (Comyns et al. 1989), *Cynoscion nebulosus* (Peebles and Tolley 1988), *Micropogonias undulatus* (Nixon and Jones 1997), and *Leiostomus xanthurus* (Siegfried and Weinstein 1989). Because the growth increment formation for the kingfish resembles that of other sciaenids, it was presumed increments were formed daily.

The left sagittal otolith was removed from each specimen, embedded in a resin block, and a thin cross–section containing the otolith primordium was prepared in the transverse plane following Secor et al. (1992). Otolith increments were counted using an Olympus compound microscope and a second blind reading was made at a later date. Otoliths having conflicting readings were read a third time by 2 readers, and if a consensus could not be reached, the otolith was excluded. Right sagittal otoliths were used if the left was damaged or unreadable. A comparison of left and right otolith diameters with a paired t–test (SPSS 15.0) for *M. americanus* showed no significant difference between di-

ameters of left and right sagittal otoliths (n = 18, p = 0.40).

To determine the best relationship for describing kingfish age–length relationships, age–length data were fitted with a power curve, an exponential curve, and a linear regression. A power curve described by the equation $SL= aA^b$ [where a= Y–intercept of the functional regression, A= age in days, and b = slope of the regression line (instantaneous growth rate)] provided the best fit. To meet assumptions of normality and homogeneity of variance the linearized form of the power curve was used: $\ln(SL) = \ln(a) + b * \ln(A)$. Linearized regressions were compared by species, seasons, years, and habitats when sufficient sample sizes were available using an analysis of covariance (ANCOVA, SPSS 15.0), with log–transfered age as the covariate. To analyze differences in growth, both growth rates (regression slopes) and size–at–ages (adjusted group means) were assessed as potentially separate influences on the early growth histories. First, growth rates were tested for significant difference, and if there was not a difference in growth rates, then size–at–ages were tested. The Bonferroni sequential procedure was used to control for type I errors when 3 pair–wise comparisons were made. Where heterogeneous slopes precluded conventional ANCOVA, slopes of linearized age–length relationships were compared using the GT2–method which generates 95% comparison intervals among a set of regression coefficients (Sokal and Rohlf 1995). In order to compare growth of kingfish species by seasons, kingfish were classified as being collected during spring (April–May), summer (June–September), or fall (October–November).

RESULTS

Kingfish growth comparisons were made on 194 aged fish (127 *M. americanus*, 54 *M. littoralis*, and 13 *M. saxatilis*) which showed increasing growth with increasing size and warmer water temperatures. Water temperature varied annually with mean station water temperature 1.4 to 3.3°C lower in 2005 than in 2006 (Figure 2).

All growth slopes were homogeneous (p>0.05) except comparison of marsh and shoreline habitats (see below). Interspecific comparisons of growth rates did not reveal
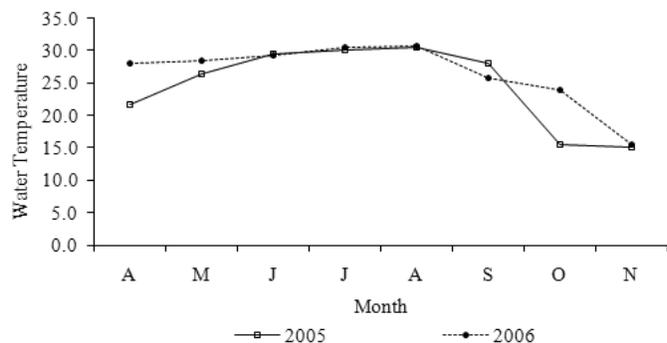

Figure 2. *Mean monthly water temperature (°C) from stations during the study period (April–November) in 2005 and 2006.*

TABLE 1. *An analysis of covariance (ANCOVA) of log–transformed kingfish standard length (SL) and log–transformed age as the covariate was used in comparisons of kingfish growth among species, year, season, and habitat. A. Regressions, sample size (n), slopes, and standard error (SE). B. ANCOVA regression comparison(s) and significance values for slopes and adjusted group means.*

A. Regressions	n	Slope	SE	B. ANCOVA Regression Comparison(s)	Slope Sig.	Adjusted Group Means Sig.
Species (2005)				1, 2	0.790	0.116
1 M. americanus	63	1.736	0.069			
2 M. littoralis	15	1.699	0.075			
Species (2006)				3, 4 ,5	0.644	0.062
3 M. americanus	64	1.686	0.040			
3 M. littoralis	39	1.617	0.068			
5 M. saxatilis	13	1.707	0.041			
Year (M. americanus)				6, 7	0.154	0.327
6 2005	29	1.591	0.070			
7 2006	45	1.709	0.041			
Year (M. littoralis)				8, 9	0.237	0.010
8 2005	12	1.723	0.079			
9 2006	17	1.589	0.076			
Season (M. americanus)				10, 11, 12	0.370	<0.001
10 Spring 2005	13	1.688	0.173	10, 11		<0.001
11 Summer 2005	33	1.607	0.087	10, 12		<0.001
12 Fall 2005	17	1.412	0.114	11, 12		0.087
Season (M. littoralis)				13, 14, 15	0.323	<0.001
13 Spring 2006	11	1.711	0.095	13, 14		<0.001
14 Summer 2006	20	1.562	0.060	13, 15		<0.001
15 Fall 2006	8	1.470	0.117	14, 15		0.240
Habitat (M. americanus)				16, 17	*	
16 Marsh–edge 2005	24	2.041	0.128			
17 Sandy shoreline 2005	39	1.585	0.073			
Habitat (M. americanus)				18, 19	0.360	0.050
18 Marsh–edge 2006	30	1.741	0.053			
19 Sandy shoreline 2006	34	1.669	0.075			

* Slopes were heterogeneous so the age–length relationships were compared using the GT2–method which generates 95% comparison intervals among a set of regression coefficients (Sokal and Rohlf 1995).

any significant differences between species. In 2005, only *M. americanus* and *M. littoralis* were collected in sufficient numbers for an interspecific comparison of growth. Growth of the 2 species was similar, with no significant difference in growth rate or size–at–age (ANCOVA, p = 0.116, Table 1). Similarly, no significant differences in growth rates or size–at–age relationships (ANCOVA, p = 0.062, Table 1) were found in kingfish collected in 2006. Mean growth rates of all 3 species were similar and ranged from about 0.7 mm/ day at 4–6 mm SL to 1.9 mm/day at 55–60 mm SL.

Interannual comparisons of growth rates were made for *M. americanus* and *M. littoralis* collected during the summers of 2005 and 2006. *Menticirrhus americanus* growth rates and size–at–age in 2005 and 2006 were not significantly different (ANCOVA, p = 0.327, Table 1). However, size–at–age of *M. littoralis* was greater in 2006 than in 2005, as evidenced

by a significant difference in the adjusted group means (ANCOVA, p = 0.010, Figure 3, Table 1).

Growth rates of *M. americanus* in 2005 and *M. littoralis* in 2006 were not significantly different between seasons. However, size–at–age of *M. americanus* collected in the spring of 2005 was smaller than that for specimens collected in the summer and fall, as indicated by the significant difference in the adjusted group means (ANCOVA, p < 0.001, Figure 4A, Table 1). A significant difference in the adjusted group means (ANCOVA, p < 0.001, Figure 4B, Table 1) for *M. littoralis* collected during the 3 seasons in 2006 suggested that size–at–age in the spring was smaller than that for specimens collected in the summer and fall. For both seasonal comparisons, growth during summer and fall was similar, as shown by similar adjusted means (ANCOVA, p> 0.05). It should be noted that the sample size for *M. littoralis* col-
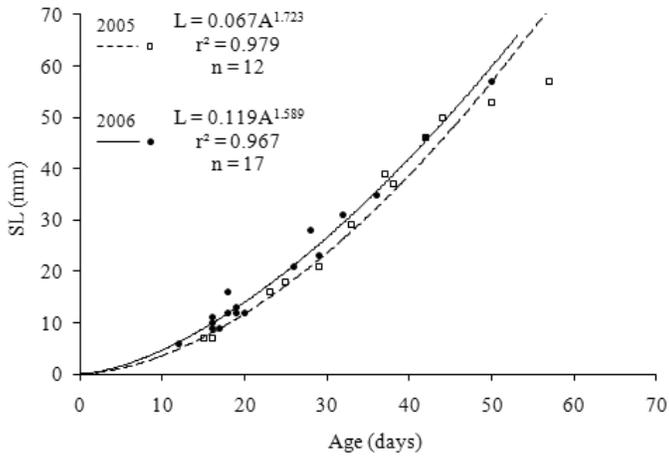
Figure 3. *Relationships between age and standard length (SL) for* Menticirrhus littoralis *collected in 2005 and 2006 as represented by fitted power curves.*

lected in the fall was small with only 8 otoliths available.

Menticirrhus americanus collected from mainland marsh edges grew significantly faster than *M. americanus* collected from mainland sandy shorelines in 2005 (Figures 5, Tables 1 and 2; GT2—Method comparison of slopes, p < 0.05). Comparison of growth for *M. americanus* collected from mainland locations and offshore surf zone habitats could not be made because relatively few *M. americanus* were collected from surf zones. In 2006 there was no significant difference in the growth rates (regression slope) of *M. americanus* collected from mainland marsh edges and sandy shorelines (Table 1). There was, however, a significant difference in adjusted group means (ANCOVA, p = 0.05) between *M. americanus* collected from these two mainland habitats, indicating that specimens collected in 2006 from marsh edges were of a larger size—at—age than specimens collected from sandy shorelines.

DISCUSSION

Otolith age—length relationships of kingfish indicated increased rate of growth with increasing size and warmer water temperatures. Growth rates of all 3 kingfish species were similar, ranging from about 0.7 mm/day at 4—6 mm SL to 1.9 mm/day at 55—60 mm SL. These growth rates are similar to values reported by Miller et al. (2002). Their tagging study of *M. saxatilis* found growth varied from 0.7—2.8 mm/day (among specimens 34—194 mm SL). Specimens used in this study were smaller (< 61 mm SL), which probably explains the slower maximum growth rates (< 1.9 mm/day). *Menticirrhus americanus* had similar growth in 2005 and 2006; however, size—at—age of *M. littoralis* was greater in 2006 than 2005. Water temperatures were higher in 2006 than in 2005, which may have contributed to the increased growth. Comyns et al. (1989) also reported a positive relationship between water temperature and growth for another sciaenid, *S. ocellatus*.

Growth of *M. americanus* and *M. littoralis* collected during the spring was slower than growth of fishes collected during the summer and fall. The few *M. saxatilis* that were collected during summer also grew noticeably faster than those collected in the spring. Nixon and Jones (1997) reported faster growth of young Atlantic croaker, *M. undulatus*, collected from estuarine waters of Virginia during the summer versus those collected in the fall. They concluded warmer water temperatures and higher food availability in the summer accounted for the more rapid growth. During the current study, water temperatures were similar during the spring and fall and warmest during the summer. Larger juvenile kingfish collected in the early fall may be relatively large for their age because they grew rapidly as larvae during the late summer when water temperatures were warm. In contrast, larger juvenile kingfish collected in the early spring may be small for their age because they grew slowly as larvae during the late winter when water temperatures were cooler.

Menticirrhus americanus collected in 2005 from mainland marsh edges had higher growth rates than *M. americanus* collected along mainland sandy shorelines. *Menticirrhus americanus* may have grown faster along marsh edges because pre-
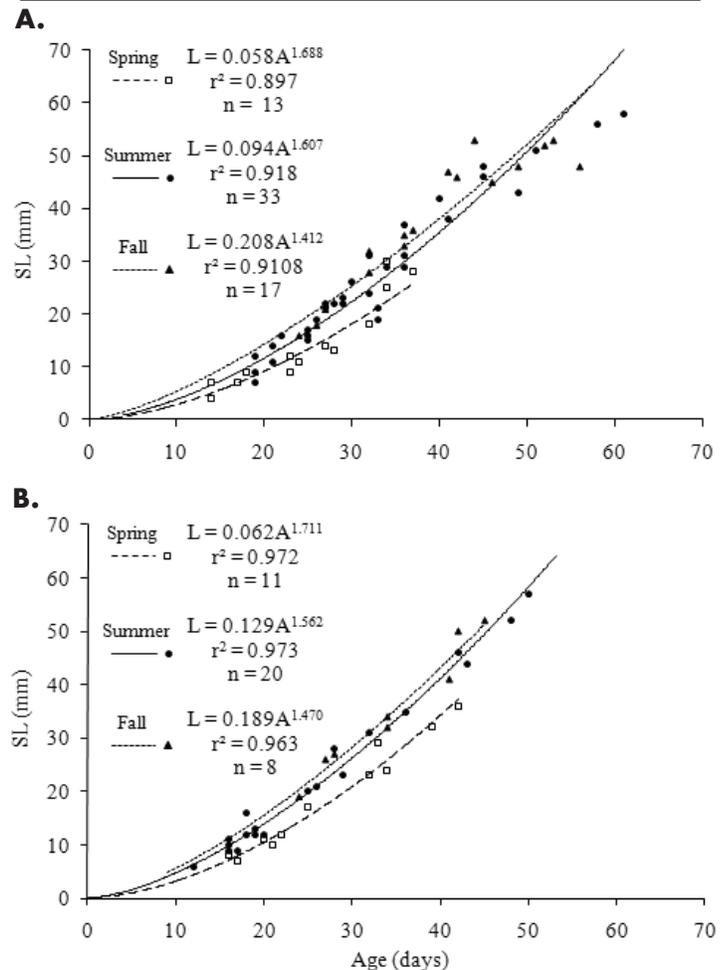

Figure 4. *Relationships between age and standard length (SL) for* Menticirrhus americanus *collected during spring, summer, and fall as represented by fitted power curves.* **A.** *Year 2005.* **B.** *Year 2006.*
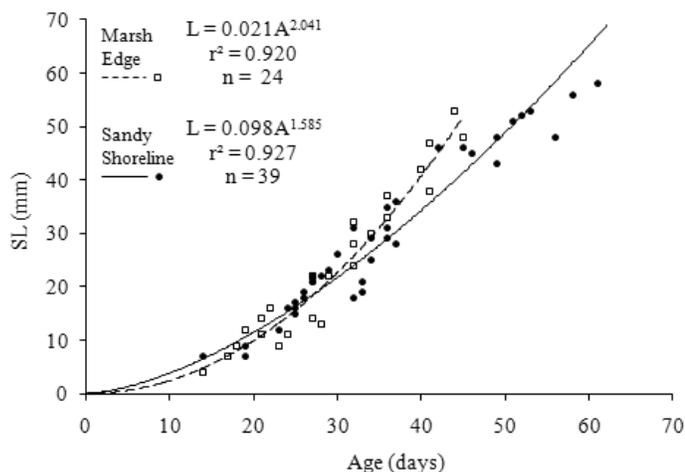
Figure 5. *Relationships between age and standard length (SL) for Menticirrhus americanus collected from the mainland marsh–edges and sandy shorelines in 2005 as represented by fitted power curves.*

dation pressure was less within the emergent vegetation or because the probability of foraging success was higher. Several studies have compared growth rates of juvenile fish collected from vegetated and nonvegetated habitats. Sogard et al. (1992) held juveniles of 3 species (*Pseudopleuronectes americanus, Tautoga onitis,* and *Gobiosoma bosc*) in cages in areas with submerged vegetation and in nonvegetated areas and found that only *T. onitis* showed faster growth with the presence of vegetation. *Tautoga onitis* showed a clear preference for vegetated habitats, as none were collected from throw trap samples from nonvegetated habitats. *Pseudopleuronectes americanus* and G. *bosc* were abundant in both types of habitats, but faster growth rates occurred within the nonvegetated habitats. Levin et al. (1997) reported that *Lagodon rhomboides* from artificial grass bottoms grew significantly faster than those from nonvegetated sand bottoms. They concluded that *L. rhomboides* may select vegetated habitats because high growth rates could lead to lower mortality. Using enclosures, Stunz et al. (2002) determined that growth rates of juvenile *S. ocellatus* were higher in salt marsh and seagrass vegetation than over nonvegetated bottoms and oyster reefs. Using otoliths, they also showed that free–living *S. ocellatus* collected from salt marsh, seagrass, and nonvegetated bottoms had similar growth rates, which they attributed to movement among habitats. Another study by Zapfe and Rakocinski (2008) compared growth of young *L. xanthurus* (20–60 mm SL) during marsh access and marsh restriction in coastal Mississippi. In contrast to this study, they found growth of *L. xanthurus* decreased with access to emergent shoreline vegetation (ESV) and increased with less access to ESV. This is may be due to differences in prey selection considering juvenile *L. xanthurus* feed mostly on polychaetes by

sifting through the bottom sediment (Zapfe and Rakocinski 2008), whereas kingfish collected from the marsh edge fed preferentially on mysids (Anderson 2009).

Other studies from freshwater systems have compared growth rates of juvenile fish, and documented the effects of habitat structural complexity and other interactions on fish growth. Crowder and Cooper (1982) compared the diets of *Lepomis macrochirus,* collected from experimental ponds with varying vegetation and reported that fish grew better in ponds with intermediate vegetation densities than in those with low and high vegetation densities. They concluded that several variables including food, habitat structure, temperature and predators influenced fish growth along with behavioral changes of both prey and predator. Werner and Hall (1988) reported that *L. macrochirus* ontogenetically shifted habitats in response to feeding rate and predation risk. They also determined that if predator densities increased, *L. macrochirus* delayed shifting habitats to avoid predation. *Menticirrhus americanus*, which were most abundant from mainland sandy shoreline, were also numerous along marsh edges (Anderson 2009). Movement of M. *americanus* between these habitats was unlikely, as growth of similar–sized M. *americanus* from marsh edge was faster than growth of fish from sandy shorelines. Shervette and Gelwick (2007) used enclosures to determine relative growth rates of juvenile *L. rhomboides* in marsh edge, oyster, and nonvegetated habitats. They found highest growth rates from the marsh edge habitat and lowest growth rates from the nonvegetated habitat.

This research shows that both abiotic and biotic factors can affect the growth of young kingfish. Increased growth was associated with specimens collected from warmer water temperatures (during the summer and fall) and also those from marsh edge habitat. Many studies have documented that a combination of factors influence the growth of young fish. Rakocinski et al. (2006) showed that fluctuations in growth of juvenile *L. xanthurus* were tied to short term changes in water temperature and salinity. Baltz et al. (1998) determined that water temperature, salinity, and dissolved oxygen contributed more to growth of juvenile C. *nebulosus* and S. *ocellatus* than diet or grass stem density. Although they did not compare growth of fish from different habitats, they did show that a combination of abiotic and biotic factors contributed to fish growth. Growth comparison studies of young fish from different habitats aid in understanding the early

TABLE 2. *Comparison intervals (95%) of regression coefficients of the growth rate (slope) for Menticirrhus americanus collected from marsh–edge and sandy shoreline habitats. Comparison intervals were computed via the GT2–method (Sokal and Rohlf 1995). Sample sizes are presented along with the confidence interval ranges.*

Species	Habitat	Sample size	Slope	Comparison interval range
M. americanus	Marsh edge	24	2.041	(1.864 – 2.220)
M. americanus	Sandy shoreline	39	1.585	(1.454 – 1.719)

life history of estuarine—dependant fish. Also, research that documents the importance of marsh edge habitat is particularly relevant in the northcentral GOM because this region has seen tremendous population growth and development during the past decade, and shoreline habitats continue to be degraded by anthropogenic influences.

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