Seasonal Distribution of Gobiids in Waters Adjacent to Estuarine Marsh-edge Habitats: Assessing the Effects of Habitat Alteration

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ABSTRACT

In order to assess the effects of habitat alteration on local fish populations, collections were taken by beam plankton trawl (BPL) in waters adjacent to marsh-edge habitats of the Mississippi Gulf Coast. Monthly samples were taken over two years along natural *Juncus/Spartina* marsh-edge, natural beach-edge, and altered marsh-edge habitats in Back Bay, Biloxi, and Davis Bayou, Ocean Springs. Altered habitats consisted of bulkheads or riprap. Gobies were the most abundant fishes found in these habitats, with *Gobiosoma bosc*, *Gobiosoma robustum*, *Gobionellus boleosoma*, *Gobionellus shufeldti*, *Microgobius gulosus*, *Microgobius thalassinus*, and *Evorthodus lyricus* being collected during the study. *Gobiosoma bosc* constituted the bulk of both the gobies (98.2%) and the fishes in general (47.0%) collected, with postflexion larvae occurring from May to October. Seasonally, larval abundance peaked in fall for all species except for *E. lyricus* (May) and *G. bosc*, which peaked twice in year one (May, October) and once in year two (June). Relative abundance of all gobies was highest along natural marsh-edge habitats (75.1%), followed by natural beach (19.5%), and then altered marsh-edge (5.4%), and larval *G. bosc* were significantly more abundant in natural marsh habitats than in altered marsh (Hendon et al., 2000). The relatively high abundance of larval gobies in natural habitats suggests that these are important spawning and/or nursery areas for gobiids. Alteration of these landscapes may thus adversely affect larval abundance and distribution, as was evident in the Back Bay/Davis Bayou estuary.

KEY WORDS: Gobiidae, habitat alteration, *Juncus/Spartina* marsh edge

INTRODUCTION

The importance of marsh-edge habitat, the ecotone between intertidal marsh grass and adjacent open water within three meters of the water/shore edge (Baltz et al. 1993, Peterson and Turner 1994), to estuarine fish populations has been well-documented over the past few years, particularly in relation to early life-history stages (Rakocinski et al. 1992, Baltz et al. 1993, Peterson and Turner 1994, Peterson et al. 2000). Marsh-edge habitat is a critical nursery area for both residents, such as gobiids, and transients, such as sciaenids and penaeids

(Peterson and Turner 1994). This is true primarily because of the refuge the marsh grass provides and the high productivity of both the phytoplankton community (diatoms associated with marsh grass) and the microbial community, which makes detrital energy available to animal consumers through the food web. The marsh-edge is, however, highly vulnerable to anthropogenic influences, i.e. development, which may reduce its suitability as a nursery area for young fishes (Hoss and Thayer 1993).

Members of the family Gobiidae are common benthic fishes found worldwide within a wide array of estuarine and marine habitats (Dawson 1969). This taxa includes the most abundant fish species in Mississippi marsh-edge habitat (Peterson et al. 2000) and two of the three most abundant fishes in Louisiana marshes (Rakocinski et al. 1992, Baltz et al. 1993). Spatial distribution of gobies is controlled mainly by habitat attributes (Wilkins and Myers, 1992), such as salinity (Gill and Potter 1993), depth (Baltz et al. 1993), density of vegetation (Humphries and Potter 1993), and size of oyster shell openings (Crabtree and Middaugh 1982). Community dynamics of marsh-edge habitats may be greatly affected by gobiid fishes, as they are abundant predators on polychaetes and small crustaceans (Fitzhugh and Fleeger 1985) and are themselves an important forage fish for many species, such as seatrout, croakers, striped bass, and drums (Pearson 1929, Dawson 1966, Wass and Wright 1969).

Because gobies are a ubiquitous resident fish and can tolerate a wide range of physical conditions (Dawson 1969), their relative abundance among habitats may be a good indicator of the effects of anthropogenic influence on habitat quality. For example, larval *G. bosc* taken from this study were found to be significantly more abundant along natural marsh habitat than along altered marsh during the first year of sampling (Hendon et al. 2000). The physical and chemical characteristics of these habitat types did not differ statistically, so it is likely that the alteration of the habitat landscape played a significant role in determining larval distribution. Since a statistical treatment of the habitat association of *G. bosc* larvae from this study has already been reported (Hendon et al. 2000) and because little has been published on the larval goby fauna of this area, the objective of this study was to describe the spatial and temporal distribution of gobiids within waters adjacent to Mississippi marsh-edge habitats, focusing primarily on the larval stage.

MATERIALS AND METHODS

Thirteen sites from Back Bay (Biloxi, MS) to Davis Bayou (Ocean Springs, MS) were sampled for fishes between October 6, 1995, and September 10, 1997 (Fig. 1). Sites were classified as waters adjacent to natural *Juncus/Spartina* marsh-edge ("natural marsh"; 7 sites), waters adjacent to natural beach-edge ("natural beach"; 3 sites), or waters adjacent to altered *Juncus/Spartina* marsh-edge ("altered marsh"; 3 sites). Altered marsh included one stretch of riprap (Site 5) and two bulkheads (Sites 9 and 12). Natural and altered marsh sediments were primarily fine-grained sand and mud, with natural marsh sediments having four times the total organic carbon (% TOC) than altered marsh (Peterson et al. 2000). Natural beach sediments were mainly medium- to coarse-grained sand with a high % TOC.

Collections were taken during daylight with a Renfro (1963) beam plankton trawl (BPL) fitted with 794 μm mesh outer netting and a 505 μm sleeve and cod end. The net was pulled by hand for 46 m along the marsh edge unless low water levels caused by atmospheric forcing required sampling further from the edge. Samples were fixed in 10% formalin and later stored in 70% ethanol.

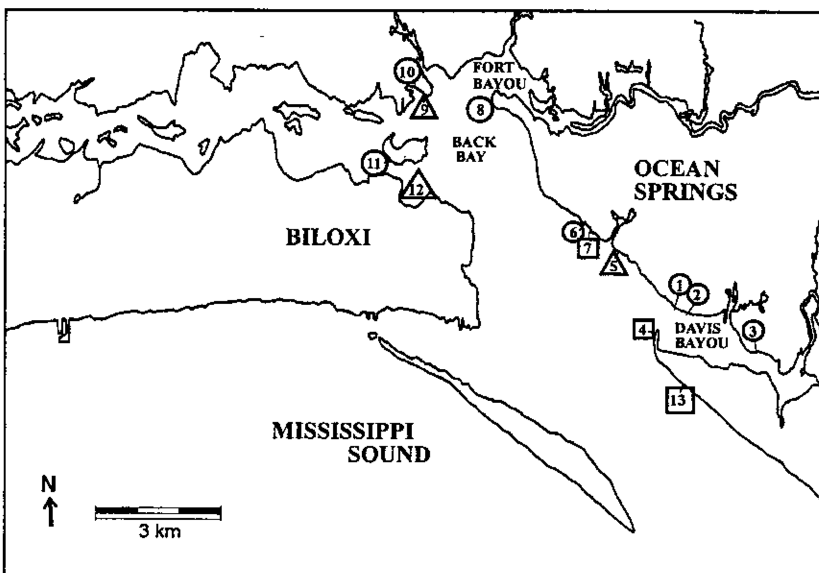

Figure 1. Sampling locations in Back Bay, Biloxi, and Davis Bayou, Ocean Springs. O= natural marsh; □= natural beach; Δ = altered marsh.

Physical parameters including water temperature (°C), salinity (°/₀₀), dissolved oxygen (D.O., mg/L), turbidity (NTU), and water depth (cm) were measured at each site on each date. Wind speed (mph, converted to m/sec) was also measured at each site with a hand-held anonometer. Rainfall (cm) was obtained from the NOAA National Climate Data Center, Asheville, North Carolina, and tide height (cm) above mean low water was obtained in thirty minute intervals for each sampling date using MicroNautics, Inc., Tide.1 Program for the Back Bay area. Physical/chemical data were compared with non-parametric analyses among habitats and seasons and between years (Hendon 1998).

All fishes were sorted and archived, and gobiids were identified to the lowest possible taxonomic level, counted, and standard length (SL) was measured with dial calipers or an ocular micrometer. Small gobiids (<15 mm SL) were cleared and stained according to a revised protocol from Potthoff (1984). Identification to the species level was accomplished by counting dorsal and anal fin pterygiophores and comparing pigmentation patterns (Dawson, 1969). Specimens were then separated by life-history stage following the definitions in Leis and Rennis (1983). For unusually large collections, splits (3.9% of total samples) and subsamples (11.7%) were taken for enumeration and staging purposes, respectively. All splits and subsamples were adjusted accordingly before analysis. Because of low sample sizes for all species but *G. bosc*, abundance data given are general descriptive statistics ($\bar{x}\pm$ S.E. and ranges). A detailed statistical treatment of larval *G. bosc* distribution among habitat types is given in Hendon et al. (2000).

RESULTS

Habitat Characteristics

Habitats exhibited an overall significant difference in salinity [Kruskal-Wallis test (K-W); $\chi^2 = 10.20$; n =3 ; p = 0.006], turbidity (K-W test; $\chi^2 = 13.57$; n = 3; p = 0.001), wind speed (K-W test; $\chi^2 = 7.77$; n = 3; p = 0.021), and depth (K-W test; $\chi^2 = 87.46$; n = 3; p = 0.000), while water temperature, dissolved oxygen, tide height, and rainfall were not significantly different (p > 0.05). Natural beach was the most variable of the habitats sampled. Salinity ranks were statistically higher at natural beach habitats than at natural marsh [Mann-Whitney *U*-test (M-W); Z = -2.81; n = 2; p = 0.005] and at altered marsh (M-W test; Z = -2.84; n = 2; p = 0.005), but no difference existed between ranks for natural marsh and altered marsh (M-W test; Z = -0.73; n = 2; p = 0.466). Mean turbidity ranks were also significantly higher in natural beach habitats than in natural marsh (M-W test; Z = -3.11; n = 2; p = 0.002) and altered marsh (M-W test; Z = -3.38; n = 2; p = 0.001), yet ranks for natural marsh and altered marsh did not differ (M-W test; Z = -1.03; n = 2; p = 0.303). Further, wind speeds were highest at natural beach habitats ($\bar{x}$ = 2.20 m/s), followed by natural marsh ($\bar{x}$ = 1.65) and then altered marsh ($\bar{x}$ = 1.48), and natural beach waters were shallowest ($\bar{x}$ = 33.36 cm), with natural marsh being intermediate ($\bar{x}$ = 45.22) and altered marsh waters being deepest delineated by habitat type are given in Table 1.

All habitat parameters differed significantly among seasons ($p < 0.05$; Hendon 1998), and interannual differences existed between similar seasons for water temperature (higher in winter-1), salinity (higher in fall-1& summer-1), tide height (higher in winter-1 & spring-1), and rainfall (higher in summer-1 & spring-2).

Species Richness, Habitat Use, and Seasonality

During the two years of sampling, 26,348 gobies were collected with 24,213 (91.9%) developed enough to be identified to species. Only fish identified to species were included in these analyses. Seven gobiids were collected, with *G. bosc* constituting more than 98% of the goby abundance, and larvae comprising at least 50% of the abundance for each species (Table 2). At least 50% of the numbers of each species were collected in unaltered (natural) habitat.

Genus Gobiosoma — Two species in the genus *Gobiosoma* were collected over the two years: the naked goby, *G. bosc*, and the code goby, *G. robustum*. *Gobiosoma bosc* accounted for 23,780 (98.2%) of the specimens collected, with 23,667 (99.5%) of these being postflexion larvae. The naked goby occurred in 36.4% of the samples, with adults occurring throughout the year and juveniles present from August to December. Peaks in larval abundance occurred twice in year one, in May and in October, and only once in year two, in June, with larvae prevailing until October of both years (Figure 2). Mean abundance of *G. bosc* was highest in natural marsh habitat (165.35 ± 92.12; max = 9,808), followed natural beach ($\bar{x}$ = 127.45 ± 66.42; max = 2,511), and then altered marsh ($\bar{x}$ = 31.92 ± 14.45; max = 549), with larvae being significantly more abundant in natural marsh than altered marsh in year one (Hendon et al. 2000). Habitat measurements for *G. bosc* are given in Table 3.

The code goby, *G. robustum*, occurred in 5.1% of the samples taken, accounting for 246 of the gobies collected (Table 2). Only five adult *G. robustum* were collected, and juveniles (n = 37) were present only in October of year one. However, larvae were collected in relatively high numbers, occurring from May to October in year one, with peak abundance observed in August (Figure 2). Mean abundance was highest for this species in natural marsh (11.60 ± 3.38; max = 12), with altered marsh yielding the lowest mean abundance (1.60 ± 0.40). This species was collected only once along natural beach habitat (n = 6). The code goby occurred at the highest mean temperature of all species collected (Table 3).

Table 1. Habitat measurements for waters adjacent to natural marsh-edge, natural beach-edge, and altered marsh-edge. Data are given as mean ± standard error followed parenthetically by the range. Measurements for rainfall are not included in these statistics, as this was a regional phenomena that did not differ among habitats.

Variable	Natural Marsh-Edge	Natural Beach-Edge	Altered Marsh-Edge
Temperature (°C)	23.00±0.44 (09.7 - 32.3)	23.17±0.67 (10.7 - 32.0)	22.69±0.67 (11.1 - 32.3)
Salinity (°/oo)	11.22±0.51 (0.5 - 24.0)	13.96±0.79 (1.5 - 24.5)	10.62±0.79 (0.5 - 24.9)
D.O. (mg/L)	8.04±0.17 (2.8 - 13.0)	8.67±0.21 (4.5 - 12.0)	8.15±0.24 (4.0 - 12.4)
Turbidity (NTU)	15.73±1.11 (2.5 - 101.5)	30.66±4.33 (3.4 - 230.0)	14.24±1.61 (2.1 - 86.5)
Depth (cm)	45.22±1.20 (10.0 - 90.0)	33.36±1.44 (10.0 - 75.0)	64.65±2.56 (1.0 - 105.0)
Wind Speed (m/sec)	1.65±0.11 (0.00 - 5.81)	2.20±0.21 (0.00 - 8.94)	1.48±0.16 (0.00 - 5.81)
Tide Height (cm)	32.12±1.52 (1.25 - 67.91)	32.58±2.44 (1.09 - 68.13)	32.21±2.44 (2.69 - 67.59)

Table 2. Descriptive statistics for the seven gobiid species collected within waters adjacent to the three marsh-edge habitat types over two years. Total number of gobiids identified to the species level = 24,213. NM = natural marsh habitat and NB = natural beach habitat. (No species was predominantly abundant in altered marsh habitat.)

Species	Total No.	% Number	% Larvae	Habitat Occurrence ($\bar{x}$ %)	Larvae Present
Gobiosoma bosc	23,780	98.21	99.5	NM (50.9%)	May - Oct
Gobiosoma robustum	246	1.02	82.9	NM (60.0%)	May Aug - Oct
Gobionellus boleosoma	79	0.33	63.3	NM (50.0%)	Mar Aug - Dec
Gobionellus shufeldti	4	< 0.01	50.0	NM (100%)	Sep, Oct
Microgobius gulosus	40	0.18	100.0	NM (50.0%)	Jun - Oct
Microgobius thalassinus	60	0.25	98.3	NB (60.0%)	May Sep - Oct
Evorthodus lyricus	4	< 0.01	100.0	NB (100%)	May

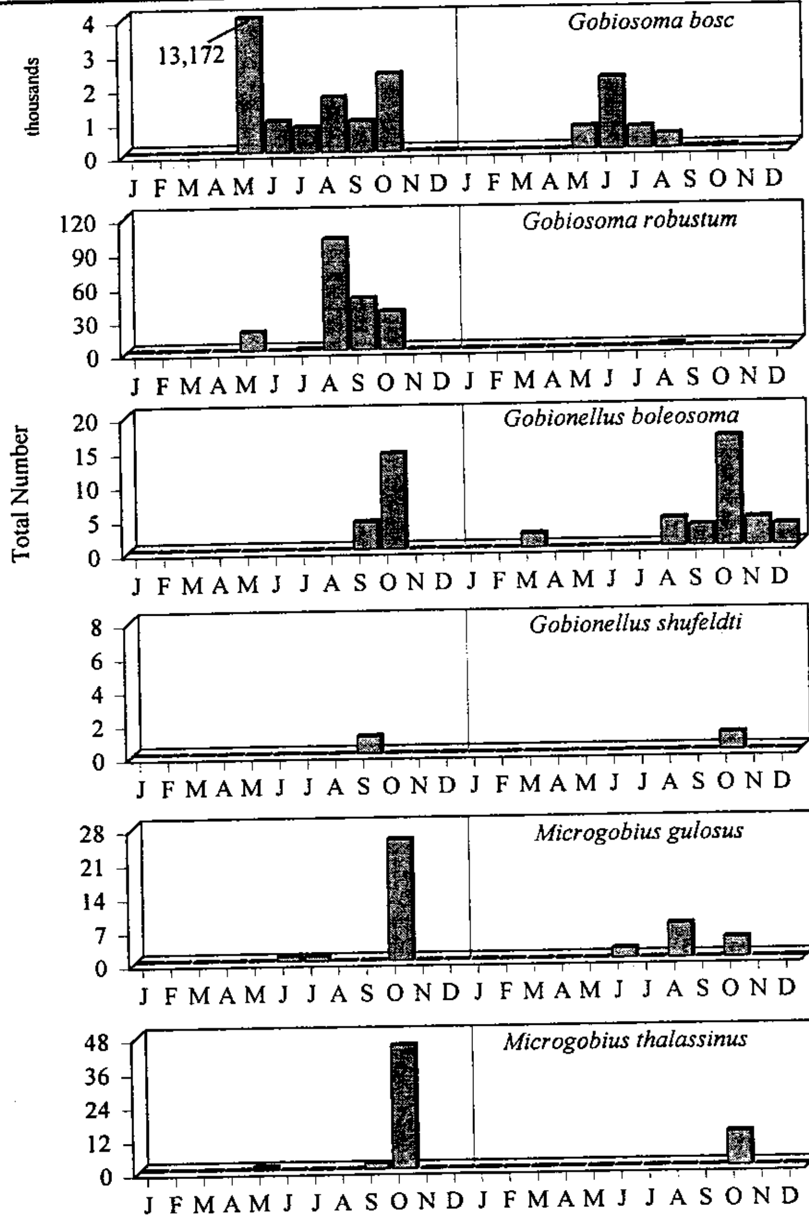

Figure 2. Total monthly abundance of postflexion larvae collected along Mississippi marsh-edge habitats over two years (habitats combined). Note that y-axis scale differs among graphs.

Table 3. Habitat measurements (mean ± S. E. followed parenthetically by the range) for each gobiid species collected (habitats combined). Habitat measurements for *E. lyricus* are given in the text.

Variable	*G. bosc*	*G. robustum*	*G. boleosoma*	*G. shufeldti*	*M. gulosus*	*M. thalassinus*
Temperature (°C)	25.97 ± 0.34 (13.0-32.3)	27.14 ± 0.85 (16.2-32.3)	22.71 ± 0.85 (10.2-31.0)	24.28 ± 1.52 (21.5-28.6)	26.64 ± 0.69 (22.5-32.3)	25.60 ± 0.71 (20.4-29.7)
Salinity (°/oo)	12.09 ± 0.47 (0.5-24.5)	13.33 ± 1.18 (0.8-21.0)	17.11 ± 0.97 (0.5-24.5)	18.23 ± 1.74 (15.1-22.2)	14.46 ± 1.70 (3.0-24.5)	16.19 ± 1.42 (3.6-24.4)
D.O. (mg/L)	7.40 ± 0.14 (2.8-11.5)	7.74 ± 0.42 (2.8-13.0)	7.64 ± 0.29 (2.9-11.7)	7.40 ± 0.31 (7.0-8.3)	7.70 ± 0.48 (4.3-10.6)	8.39 ± 0.40 (6.7-11.0)
Turbidity (NTU)	18.42 ± 1.24 (3.6-83.8)	17.52 ± 3.05 (4.3-64.6)	10.21 ± 0.91 (2.5-24.7)	9.68 ± 1.64 (6.8-13.0)	13.15 ± 1.98 (5.2-42.1)	17.47 ± 3.69 (5.2-47.8)
Depth (cm)	52.19 ± 1.43 (1.0-105.0)	56.38 ± 3.76 (20.0-90.0)	49.72 ± 2.89 (10.0-100.0)	45.00 ± 8.90 (30.0-65.0)	57.71 ± 5.24 (30.0-97.0)	60.62 ± 6.56 (30.0-97.0)
Wind Speed (m/s)	1.67 ± 0.10 (0.00-5.81)	1.86 ± 0.234 (0.00-4.47)	1.38 ± 0.23 (0.00-4.92)	2.01 ± 0.47 (0.89-3.13)	1.82 ± 0.35 (0.00-4.02)	2.13 ± 0.30 (0.45-3.58)
Tide Height (cm)	40.72 ± 1.33 (8.69-68.13)	40.96 ± 3.00 (13.83-65.63)	24.60 ± 2.57 (1.25-51.29)	22.90 ± 2.85 (15.44-28.54)	45.89 ± 2.94 (20.16-65.63)	38.07 ± 3.40 (15.07-59.71)
Rainfall (cm)	0.22 ± 0.04 (0.00-1.57)	0.50 ± 0.13 (0.00-1.57)	0.27 ± 0.07 (0.00-1.14)	0.25 ± 0.25 (0.00-0.99)	0.01 ± 0.01 (0.00-0.13)	0.16 ± 0.10 (0.00-0.99)

Genus Gobionellus — Two species in the genus *Gobionellus* were collected during this study: the darter goby, *G. boleosoma*, and the freshwater goby, *G. shufeldti*. The darter goby occurred in 7.5% of the samples taken and accounted for 79 of the gobies collected. Larvae dominated collections of this species, with abundance peaking in October of both years (Figure 2). Adults were sporadically collected throughout the year. Mean abundance of *G. boleosoma* was highest in natural marsh ($\bar{x}$ = 2.3 ± 0.54; max = 14), with collections in natural beach ($\bar{x}$ = 1.00 ± 0.001; max = 1) and altered marsh ($\bar{x}$ = 1.17 ± 0.17; max = 2) being uncommon. Habitat measurements for this species are given in Table 3.

Gobionellus shufeldti was less abundant than its congener, as one postflexion larva was collected in September of year one and one in October of year two (Figure 2). Two juveniles were collected in October of year two. This species was the only gobiid collected solely in natural marsh habitat. Contrary to its name, the freshwater goby occurred at the highest mean salinity of all gobiids (Table 3).

Genus Microgobius — The clown goby, *M. gulosus*, was present in 3.4% of the samples, accounting for 40 of the gobies collected (Table 2). All *M. gulosus* collected were larvae taken from June to October, with peak abundance occurring in fall of both years (Figure 2). Mean abundance was highest in natural marsh habitat (3.13 ± 1.33; max = 12) followed by natural beach (¿=2.20±0.58; max=4) and altered marsh ($\bar{x}$ = 1.00 ± 0.00; max = 1). This species generally occurred in October when tide heights were high (Table 3).

The green goby, *M. thalassinus*, occurred in 2.8% of the collections with 60 individuals collected (Table 2). Only one adult was collected during the study (December-1), and no juveniles were obtained. Larvae were present from May through October, with numbers peaking in October of both years (Figure 2). Abundance of the green goby was higher at natural beach ($\bar{x}$ = 8.50 ± 3.50; max = 12) than natural marsh ($\bar{x}$ = 4.33 ± 1.44; max = 11) or altered marsh ($\bar{x}$ = 2.00 ± 1.00; max = 3), and this species occurred mainly during the seasonally deep waters of October (Table 3).

Evorthodus lyricus — The lyre goby was collected only once during the study, in May of 1996 in natural beach habitat. The four larvae were collected at a depth of 75 cm in turbid (70.90 NTU), low-salinity (4.5 $^o/_{oo}$) waters 57.42 cm above mean low tide. Water temperature for this collection measured 27.9°C, and D.O. was 7.3 mg/L.

DISCUSSION

Gobies were an abundant resident taxa of the marsh-edge habitats of this estuary, particularly along natural marsh habitat. Although abundance was dominated by larval *G. bosc*, the collection of seven species in this family illustrates the diversity of these fishes in marsh-edge habitats. In a larger marsh-edge community study from which these data came (Peterson et al. 2000), gobiids accounted for 50.6% of all fishes collected. Several studies have examined the fish community within similar marsh habitats, but only a quarter of the studies reviewed showed gobiids constituting >13% of the total fish abundance, a feature probably due to sampling gear bias (Hendon 1998). Consequently, gobies are likely a more important component to marsh-edge community dynamics than several studies have exemplified, as the adults are both a resident predator and prey, and the larvae are an abundant seasonal source of food (Pearson 1929, Fitzhugh and Fleeger 1985). Three of the seven goby species were commonly collected, with the larvae of *G. bosc*, *G. robustum*, and *G. boleosoma* occurring in enough collections to suggest that natural marsh-edge serves as an important nursery habitat for the young of these species. Low and infrequent numbers of larval *G. shufeldti*, *M. gulosus*, *M. thalassinus*, and *E. lyricus* suggest that these species are relatively uncommon or may use other habitats during early developmental stages. The juvenile and adult stages of the gobiids collected are benthic and may likely be under-represented in this study, because the BPL would only effectively sample the pelagic environment. However, gobiid larvae are pelagic until about 15 mm SL (Shenker et al. 1983) and would consequently be fully vulnerable to our sampling gear.

The greatest numbers of larval *G. bosc* were collected in May and June of each year. By relating the mean SL of this stage of *G. bosc* ($\bar{x}$ = 6.63 mm) with published growth rates of 5 to 6 mm per month for this species (Nero 1976, Conn and Bechler 1996), it may be ascertained that these fish are approximately one month old and that peak spawning occurred during April and May, respectively. A second, smaller peak in abundance of larval *G. bosc* occurred in October of year one, and consequently spawning of *G. bosc* lasted from April to September in this year. The same appears to be true for *G. robustum*. *Gobiosoma bosc* employed a bimodal spawning strategy in year one as in Conn and Bechler (1996), while only a single peak in larval abundance was evident in year two. These larvae were also much more abundant in year one than two. It is likely that the reproductive strategies of these two species were affected by the lower water temperatures of spring-2 (Dahlberg and Conyers 1973), and consequently year two abundances were lower. Assuming growth rates similar to *G. bosc*, the spawning season for each gobiid collected coincides with the available literature on goby reproduction (Dawson 1966, Fritzsche 1978, Allen and Barker 1990), except for *G. boleosoma* which spawned in the fall of this study but were reported to spawn in spring by Fritzsche (1978).

All gobiids collected were more abundant at unaltered habitats (namely natural marsh) than altered shorelines, and no larvae occurred in relatively high numbers at altered marsh habitats. It is therefore likely that natural *Juncus/Spartina* marsh-edge is a significant nursery habitat for gobiids in this estuary. The occurrence of *G. bosc*, *G. robustum*, *G. boleosoma*, *G. shufeldti*, and *M. gulosus* along natural marsh-edge habitats coincides with much of the current literature on these species (Peterson and Ross 1991, Rakocinski et al. 1992, Baltz et al. 1993, Peterson and Turner 1994). However, Peterson and Ross (1991) found juvenile and adult *G. boleosoma* to be the dominant gobiid along a Mississippi riverine-estuarine gradient, whereas larval *G. bosc* were numerically dominant in the present study.

In conclusion, gobies appear to be a much more important component to marsh-edge communities than previously thought, based on both their high abundance and their reported significance to the estuarine food web. The high abundance of these fishes along natural marsh relative to altered marsh suggests that unaltered *Juncus/Spartina* marsh is fundamental to the reproduction and/or recruitment of gobies, and thus these habitats may be viewed as source areas. Further, because gobies are eurytolerant and are abundantly distributed throughout the Gulf and Caribbean, yet appear to be adversely affected by the modification of natural marsh habitats, it is likely that alteration may be equally if not more detrimental to the reproductive success of less tolerant fishes, including several recreational and commercial species.

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