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A COMPARISON OF FISH POPULATIONS IN SHALLOW COASTAL LAGOONS WITH CONTRASTING SHOALGRASS (*HALODULE WRIGHTII*) COVER IN THE NORTHCENTRAL GULF OF MEXICO

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INTRODUCTION

It is widely accepted that seagrass meadows provide abundant food and structure for a variety of organisms (see reviews by Hemminga and Duarte 2000, Williams and Heck 2001). The seagrasses themselves, epiphytes and macroalgae constitute a diverse array of food resources for first-order consumers, which in turn fuels a complex and rich food web in seagrass meadows (Williams and Heck 2001). Enhanced structure in seagrass meadows is mainly provided by the canopy of leaf blades and sheaths, drifting macroalgae and bulky epiphytes (Orth et al. 1984).

Large seagrass declines, mostly due to anthropogenic impacts, have been reported worldwide (i.e., Orth et al. 2006), and shoalgrass (*Halodule wrightii*), which is common in subtropical and tropical Atlantic waters (Den Hartog 1970), is no exception. For instance, Pulich and White (1991) documented that in lower Galveston Bay shoalgrass declined steadily since the 1950's and disappeared completely in the 1980's mainly due to urban development, wastewater discharges, chemical spills and dredging. Similarly, Quammen and Onuf (1993) estimated a >330 km^2 reduction in shoalgrass cover in lower Laguna Madre from 1965 to 1988 as a result of increased turbidity caused by dredging. Shoalgrass beds continue to decline in a number of locations in the Gulf of Mexico (GOM) (Hall et al. 1999).

A number of studies have examined the effects of reduced seagrass cover on local fish populations (e.g., Heck et al. 1989, Ferrell and Bell 1991, Hughes et al. 2002 and more), but few of those studies have focused on shoalgrass (e.g., Tolan et al. 1997, Rydene and Matheson 2003). We present a preliminary comparison of fish populations in three shallow coastal lagoons in the northcentral GOM that have varying levels of shoalgrass cover. Namely, we compare (1) abundances of individual species and the entire fish population, (2) fish population diversity, and (3) length-frequency distributions of the most abundant species.

MATERIALS AND METHODS

The study was done in three shallow (mean depth < 1m) coastal lagoons situated at the southern end of Perdido Bay

(FL, USA) in the northcentral GOM. Water-column temperature, salinity and dissolved oxygen concentrations were similar in the three lagoons. In contrast, shoalgrass cover differs notably among the lagoons. State Park is the most vegetated lagoon, Kee's Bayou has little shoalgrass, and Gongora has no shoalgrass. Other than shoalgrass, the bottom of the lagoons is characterized by open sediment consisting of sand and mud. A full description of the lagoons is provided by Stutes et al. (2007).

Fish were collected using a 6.0 m x 1.2 m bag seine with 3-mm mesh. Seining is an adequate method for the capture of the small fish, including juveniles of larger species, that typically predominate in shallow coastal embayments such as the three lagoons studied here (Connolly 1994, Rozas and Minello 1997). To examine the fish populations before and after the fall migration that many fish in these shallow embayments exhibit with the arrival of the first cold fronts (Stoner 1983, Middaugh and Hemmer 1987a), we sampled in late summer (i.e., pre-migration samples, September 12-18, 2000) and after several cold fronts had moved through the area and water temperature in the lagoons had decreased significantly (i.e., post-migration samples, October 23-25, 2000).

In each lagoon on each sampling date, we seined sixteen, 20 m transects. Transect selection was haphazard. We estimated the area covered by shoalgrass at 1m intervals along each transect. Each interval was considered to be covered by shoalgrass if cover was greater than 50%. The fraction of the entire transect covered with shoalgrass was the number of intervals with >50% cover divided by 20, and a grand average was calculated for all the transects in the lagoon. To reduce personal bias, two individuals (JC and GAM) did all the seining, and a third individual (JPS) made all estimates of shoalgrass cover.

All fish were taken to the lab, where they were counted and identified. Diversity was calculated using the reciprocal of the Simpson index (1/D) after pooling all the seines on each sampling date at each lagoon to increase the robust-
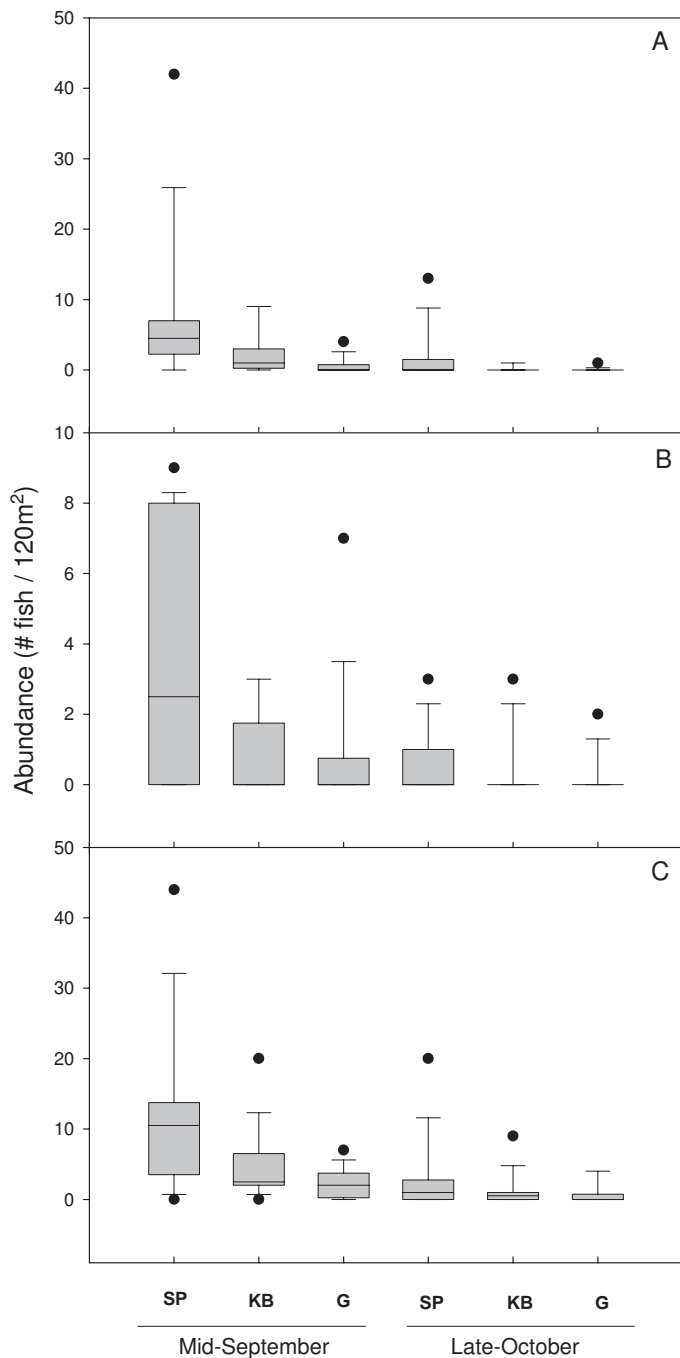
Figure 1. Box plots of abundance of (A) tidewater silversides, (B) juvenile pinfish, and (C) the fish population in State Park (SP), Kee's Bayou (KB) and Gongora (G) in mid September and late October. Boxes encompass the 25% and 75% quartiles, and the central line represents the median, for the sixteen seines in each lagoon on each date. Bars encompass the range of values between (1) the 25% quartile minus 1.5 times the difference between the quartiles 75% and 25% and (2) the 75% quartile plus 1.5 times the difference between the quartiles 75% and 25%. Circles represent values outside these limits.

ness of the diversity values. We chose D over other metrics of diversity because we found large differences in total fish abundance across the lagoons, and D is known to be robust against those differences (Magurran 2004). We also measured the standard length (SL, mm) of all tidewater sil-

versides (*Menidia peninsulae*) and juvenile pinfish (*Lagodon rhomboides*). We did not capture enough individuals of other species to make comparisons of fish length among lagoons.

Differences in abundances of individual species and of the entire fish population across the three lagoons and between the two sampling dates were analyzed with the Scheirer-Ray-Hare extension of Kruskal-Wallis, a non-parametric test in lieu of two-way ANOVA, due to the non-compliance of the data with the assumptions of ANOVA (Sokal and Rohlf 1995). Post-hoc comparisons between lagoons were done with the non-parametric Q test (Zar 1998). Differences in fish diversity across lagoons were analyzed with one-way ANOVA for each sampling date, and post-hoc comparisons were conducted with Tukey tests (Magurran 2004) after calculating the variance of D as explained in Lande (1996). Differences in the SL of tidewater silversides and juvenile pinfish among lagoons were analyzed only in mid September, because too few individuals of those species were captured in Kee's Bayou and Gongora in late October. Differences in fish SL were analyzed with the non parametric Kruskal Wallis and post-hoc Q tests due to the non compliance of the data with the assumptions of ANOVA. All tests were performed using SigmaStat 8 and considered significant if $p < 0.05$, marginally significant if $0.05 \leq p < 0.10$, and non-significant if $p \geq 0.10$.

RESULTS

The areas swept with the seine had mean (± se) shoalgrass covers of 17.0 (± 0.9), 2.0 (± 0.3) and 0 % in State Park, Kee's Bayou and Gongora, respectively, which reflects well the differences in total shoalgrass cover (i.e., cover for the entire lagoon) among the three lagoons (Stutes et al. 2007).

We captured twenty fish species (Table 1). The two most abundant species in all three lagoons in mid September were tidewater silversides and juvenile pinfish. In late October, these species continued to be the most abundant in State Park, they co-dominated along with bay anchovy (*Anchoa mitchilli*) and spot (*Leiostomus xanthurus*) in Kee's Bayou, and spotfin mojarra (*Eucinostomus argenteus*) and juvenile pinfish were the dominant species in Gongora.

Abundances of tidewater silversides and juvenile pinfish were higher in mid September than in late October (Figures 1A and B; Scheirer-Ray-Hare test for each species, $p < 0.05$). Abundances of these two species were also higher in State Park than in Gongora (Q test between the two lagoons for each species, $p < 0.05$), and those differences persisted on both sampling dates as indicated by the lack of a significant interaction between lagoon and time (Scheirer-Ray-Hare test for each species, $p \geq 0.10$). Comparisons of total fish abundance yielded similar results due to the dominance or co-dominance by tidewater silversides and juvenile pinfish in the lagoons studied (Figure 1C). Total fish abundance was higher in mid September than in late October, and it was higher in State Park than in Gongora regardless of sam-

TABLE 1. *Fish captured in three lagoons in the north-central Gulf of Mexico. Numbers with no parentheses are the total number of individuals of each species captured in sixteen seine hauls per lagoon per sampling period, and numbers in parentheses indicate the percentage of the total number of fish captured per lagoon per sampling period.*

	State Park		Kee's Bayou		Gongora	
	Mid-September	Late-October	Mid-September	Late-October	Mid-September	Late-October
Anchoa mitchilli (bay anchovy)			1 (1.4)	6 (30.0)	1 (2.9)	
Dorosoma petenense (threadfin shad)						1 (9.1)
Harengula jaguana (scaled sardine)	4 (2.2)				4 (11.4)	
Anguilla rostrata (American eel)					1 (2.9)	
Ariopsis felis (hardhead catfish)			1 (1.4)			
Mugil cephalus (striped mullet)			5 (6.9)	2 (10.0)	5 (14.3)	
Menidia peninsulae (tidewater silverside)	117 (63.2)	24 (54.5)	39 (54.2)	3 (15)	9 (25.7)	1 (9.1)
Adinia xenica (diamond killfish)		4 (9.1)			1 (2.9)	
Fundulus grandis (Gulf killifish)		1 (2.3)				
Poecilia latipinna (sailfin molly)		2 (4.5)			1 (2.9)	
Syngnathus scovelli (Gulf pipefish)		1 (2.3)				
Chloroscombrus chrysurus (Atlantic bumper)	3 (1.6)					
Oligoplites saurus (leatherjack)			6 (8.3)			
Eucinostomus argenteus (spotfin mojarra)			5 (6.9)	1 (5.0)	2 (5.7)	4 (36.4)
Eucinostomus gula (silver jenny)	1 (0.5)		2 (2.8)			
Archosargus probatocephalus (sheepshead)		1 (2.3)				
Lagodon rhomboides (pinfish)	59 (31.9)	9 (20.5)	11 (15.3)	5 (25.0)	11 (31.4)	4 (36.4)
Bairdiella chrysoura (silver perch)						1 (9.1)
Leiostomus xanthurus (spot)			2 (2.8)	3 (15.0)		
Achirus lineatus (lined sole)	1 (0.5)	2 (4.5)				
Total	**185**	**44**	**72**	**20**	**35**	**11**

pling period.

Contrary to abundance, diversity increased from State Park (1/D = 2) to Kee's Bayou (1/D = 3.1) to Gongora (1/D = 5.5) in mid September (all three Tukey tests, $p < 0.05$). Diversity was lower in State Park (1/D = 3) than in Kee's Bayou (1/D = 5.9) in late October (Tukey test, $p < 0.05$).

In mid September tidewater silverside were larger (mean SL ± se) in Gongora (53.6 ± 0.7 mm) than in Kee's Bayou (51.0 ± 0.5 mm) (Q test, $p < 0.05$), and marginally larger in Gongora than in State Park (51.6 ± 0.3 mm) (Q test, $p = 0.07$). Juvenile pinfish were larger in Gongora (68.9 ± 1.6 mm) than in State Park (54.6 ± 1.7 mm) (Q test, $p < 0.05$).

DISCUSSION

Our results are only based on two sampling dates. In addition, despite encompassing a gradient in shoalgrass cover (Stutes et al. 2007), we only sampled three lagoons. Finally our seine was rather short and some fast-swimming fish could have escaped from it. Thus, our results can only be viewed as preliminary. At any rate, our findings reveal a number of significant differences among the lagoons and suggest important effects of contrasting shoalgrass cover on the fish populations.

Abundance of tidewater silversides and juvenile pinfish decreased across lagoons as the shoalgrass cover in the lagoon decreased. This may be due to selection of seagrass beds over bare sediment as nursery habitat, most likely due to enhanced physical structure (which in turn provides more protection against predators and wave energy) and food availability (Stoner 1983, Jordan et al. 1996, Tolan et al. 1997). Adult tidewater silversides spawn preferentially on seagrass leaves and attached macroalgae upon their return to shallow embayments in late winter/early spring (Middaugh and Hemmer 1987b). The young-of-the-year grow fast and most of them reach adult size (60-70 mm SL) by the end of the summer (Lucas 1982, Middaugh and Hemmer 1987b). Pinfish spawn offshore and juveniles recruit preferentially to seagrass beds in late winter/early spring, where they grow fast to reach 90-100 mm by the end of the summer (Hoss 1974, Spitzer et al. 2000, Nelson 2002). Measurements of abundance of the main prey for juvenile pinfish (i.e., amphipods, isopods and shrimp; Stoner 1982) in the three lagoons on September 5, 2000 indicate that food availability

for juvenile pinfish decreases across the lagoons as shoalgrass covers decreases. This may also be the case for tidewater silversides, since most of their prey (i.e., suspended organic matter, their own larvae -for adults only-, and some benthic prey such as amphipods; McMullen and Middaugh 1985) is more abundant within the canopy of seagrass beds than in open water (Tolan et al. 1997, Gacia et al. 2002).

Abundance of tidewater silversides and juvenile pinfish also decreased from mid September to late October, which was likely due to migration offshore. In the fall, as water temperature starts decreasing, most tidewater silversides and juvenile pinfish migrate from shallow embayments to deeper coastal waters, although a few overwinter in shallow embayments (Hoss 1974, Lucas 1982, Middaugh and Hemmer 1987a). Interestingly, the differences in abundance across the three lagoons persisted in late October, suggesting that a larger population of tidewater silversides and juvenile pinfish overwinter in the lagoon with the most shoalgrass.

Our finding that the mean size of tidewater silversides and juvenile pinfish increases as shoalgrass cover in the lagoon decreases suggests that shoalgrass beds offer effective protection against predators for small individuals of these two species. In accordance with these results, other comparisons have found that tidewater silversides sampled in seagrass-vegetated sites tended to be smaller than those sampled in areas of bare sediment (Tolan et al. 1997).

Because tidewater silversides and juvenile pinfish dominated or co-dominated the fish populations studied, differences in total fish abundance among the lagoons and between the two sampling dates mimicked those in the abundances of the two species. Total fish abundance was lower in late October than in mid September, and it decreased across lagoons as shoalgrass cover in the lagoon decreased regardless of the date considered. Interestingly, diversity showed an opposite tendency, with diversity increasing across the lagoons as shoalgrass cover in the lagoon decreased. This result emerges from a parallel reduction in the extent of dominance by tidewater silversides and juvenile pinfish as shoalgrass cover in the lagoon decreases, which renders the distribution of species relative abundance more even and leads to higher diversity as measured with the Simpon index. Indeed, tidewater silversides and juvenile pinfish accounted for 95, 69 and 57% of all the fish captured in State Park, Kee's Bayou and Gongora in mid September, and for 75, 40 and 45% in late Octoter.

Our results are consistent with previous reports that seagrass declines are deleterious for fish species that select seagrass beds as preferred habitat, and that the effect on the total local fish population will depend on how numerous seagrass-associated species are in relation to the other species in the population (e.g., Heck et al. 1989, Hughes et al. 2002, Vanderklift and Jacoby 2003). These results also suggest that losses of shoalgrass cover in shallow coastal lagoons may result in lower abundance of tidewater silversides and juvenile pinfish, which could entail reduced prey availability for the many predators than feed on these species as they migrate to deeper waters in the fall (Lucas 1982, Jordan et al. 1996). At any rate, our results are based on limited effort and sample size. Furthermore, the seine employed was rather short, which could lead to underestimating the abundance of some species. As such, our results can only be regarded as preliminary. For instance, previous comparisons have also found reduced tidewater silverside abundance in sites with less seagrass (Tolan et al. 1997), but other comparisons have only found a weak association between the abundance of tidewater silversides and seagrass cover (Rydene and Matheson 2003). Clearly, our findings need to be confirmed with longer, more complete studies.

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