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Lauren A. Yeager
Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Mexico

J. Ernesto Arias-Gonzalez
Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Mexico

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PRELIMINARY SURVEY OF FISH COMMUNITY COMPOSITION IN SEAGRASS HABITAT IN TWO BACK-REEF LAGOONS OF THE SOUTHERN MEXICAN CARIBBEAN

Lauren A. Yeager [1] and J. Ernesto Arias-Gonzalez

Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Unidad Mérida, Antigua Carretera a Progreso Km. 6, Mérida, Yucatán 97310, Mexico

[1]Current Address: Florida International University, Department of Biological Sciences, 11200 SW 8th Street, Miami, FL 33199, e-mail: l_yeager@hotmail.com

Abstract: Little is known about seagrass fish communities in the southern Mexican Caribbean. Diurnal and nocturnal fish community structure in seagrass habitat were compared between back-reef lagoons using a visual census technique in a natural protected area within a national park (Xcalak) and an unprotected area (Mahahual). Seagrass fish communities differed significantly between the two locations in the daytime and Xcalak supported greater total fish densities. Species richness did not differ statistically between locations. Observed nighttime fish communities were characterized by low species richness and low fish abundance when compared to diurnal communities. Heavy tourist use and coastal development may have degraded seagrass habitat at Mahahual causing lower fish abundance. Also, proximity of seagrass to mangrove habitat in Xcalak may have led to increased abundance and differences in species composition between locations. More extensive analysis and monitoring of the relative functioning of back-reef habitats in these two systems is needed as coastal development and fishing pressure continue to threaten the area.

Resumen: No se conoce mucho sobre la comunidad de peces en pastos marinos en el sur del Caribe mexicano. La estructura de las comunidades de peces nocturnas y diurnas en pastos marinos se obtuvo mediante censos visuales y se comparó entre la laguna arrecifial de un área protegida (Parque Nacional Arrecifes de Xcalak) y un área no-protegida (Mahahual). Las comunidades de peces fueron diferentes significantemente entre los dos sitios durante el día, Xcalak registró las mayores densidades de peces. No existe diferencia estadísticamente significativa con respecto a la riqueza de especies entre sitios. Las comunidades de peces nocturnas presentaron valores bajos de riqueza de especies y de abundancia con respecto a las comunidades diurnas. El desarrollo turístico y costero de Mahahual, podrían estar degradando el hábitat de pastos marinos, y como consecuencia el registro de bajas abundancia de peces. En contraste, en Xcalak, la proximidad del ecosistema de manglar adyacente a los pastos marinos podría estar influenciando con una mayor abundancia de peces y cambios en la composición de especies con respecto a Mahahual. Mientras en el área continué el desarrollo costero y la pesca en el área, es necesario un análisis más extensivo (escala temporal y espacial) del funcionamiento de ambas lagunas arrecifales.

Introduction

Seagrass beds are among the most productive aquatic ecosystems in the world (Duarte and Chiscano 1999) and support diverse communities of fishes and invertebrates. These habitats are an important component of the tropical marine environment, and are linked to mangrove and coral reef habitats through fluxes of nutrients and organisms (Parrish 1989, Adams et al. 2006).

Human use or alteration of back-reef biotopes may change their ecological functioning. Coastal development and tourist use of back-reef environments have the potential to degrade habitat through loss of structural complexity or decreased food quality. Globally, seagrass coverages have declined dramatically associated with human environmental degradation (Orth et al. 2006). Also, fishing that often targets larger piscivores may lead to shifts in trophic structure and subsequent community cascades in coastal systems (Chiappone et al. 2000, Graham et al. 2003, Mumby et al. 2006). Understanding the effects of anthropogenic impacts on habitat function becomes a high priority as humans continue to alter many habitats important to ecologically and economically valuable species.

The Mexican Caribbean supports the northern extent of the Mesoamerican Barrier Reef Tract. The Parque Nacional Arrecifes de Xcalak is located on the southern Caribbean coast of Mexico, and development and fishing are restricted within this reserve. However, moderate fishing pressure still exists within the park boundaries as much of the town of Xcalak relies on artesanal fishing. Mahahual is an unprotected location with increasing tourist use after the construction of a cruise ship pier in 2000. Fishing pressure has declined in Mahahual as tourism has taken over as the primary economic activity. This provides the opportunity to compare sites within the reserve with comparatively less coastal development to sites at an unprotected location where coastal development and use of the reef lagoon has dramatically increased. As development continues to threaten coastal ecosystems and

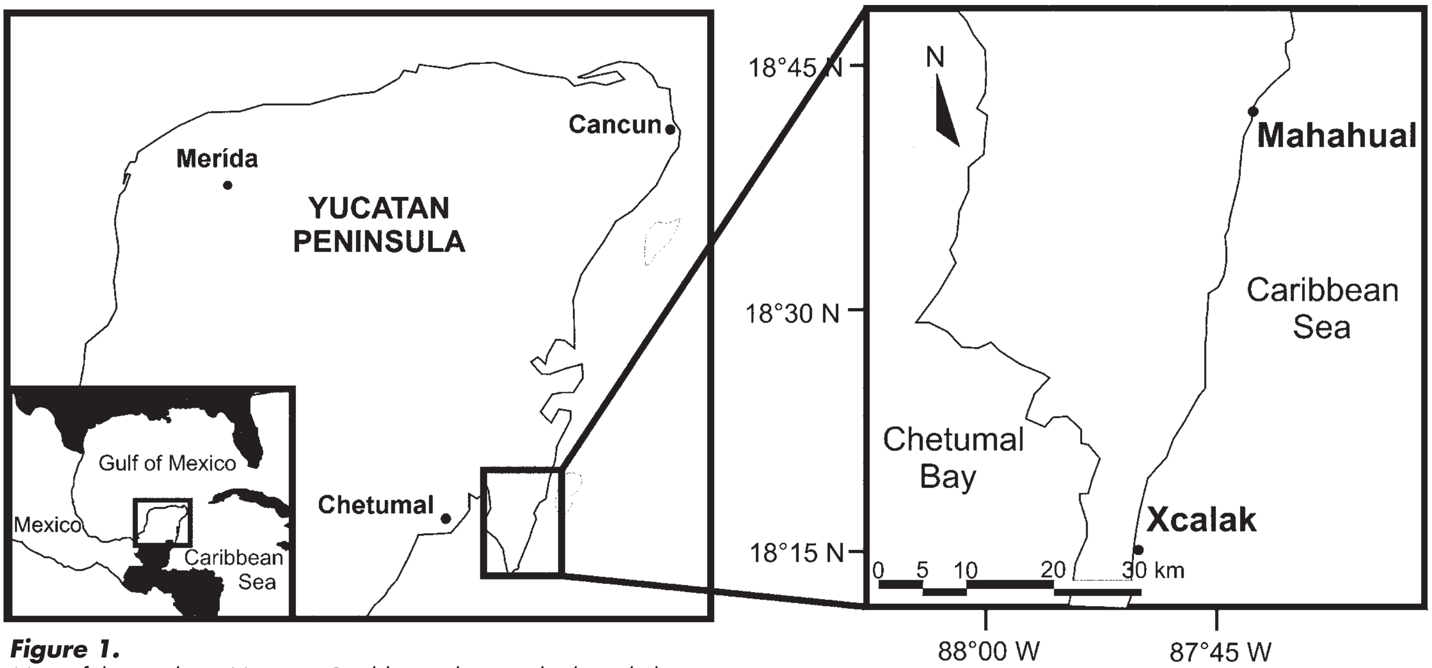

Figure 1.
Map of the southern Mexican Caribbean showing both study locations.

fishing pressure persists in this region, understanding the potential impacts on back-reef habitats becomes imperative.

Few studies have surveyed seagrass fish communities explicitly in the southern Mexican Caribbean. Chitarro et al. (2005) censused seagrass and mangrove habitats at Mahahual and found that juvenile reef fish densities in seagrass were lower than observed juvenile densities in mangroves. Núñez-Lara and Arias-Gonzalez (1998) surveyed lagoon fish communities at Mahahual; however they did not distinguish between lagoon habitat types (i.e. seagrass, sand, patch reefs) in their surveys. Castro-Perez (1998) censused back-reef fish communities at Mahahual, but grouped sand and seagrass habitat together. The authors are not aware of any studies which have surveyed seagrass fish communities in Xcalak. Therefore, overall, little is known about seagrass fish communities in this region.

Most studies of fish communities associated with seagrass habitat have been conducted during the day. However, previous studies of tropical seagrass habitats indicate that nocturnal fish communities may differ substantially from diurnal communities (Weinstein and Heck 1979, Robblee and Zieman 1984, Kopp et al. 2007). Fishes from surrounding habitats, such as coral reefs and mangroves, are known to migrate into seagrass habitat at night to feed (Ogden and Ehrlich 1977, Burke 1995).Therefore, in order to accurately assess the value of seagrass habitat, it is imperative to consider both diurnal and nocturnal communities of fishes that may associate with this critical habitat.

The primary objective of this study is to make a preliminary comparison of seagrass fish community structure, species richness and fish density between two back-reef lagoons with different levels of protection and human use. Additionally, a second objective is to investigate day-night shifts in seagrass fish communities at these sites.

Methods

Study Area

Both study locations are on the southern Caribbean coast of Quintana Roo, Mexico (Figure 1). Xcalak (18°15' N, 87°50' W) is located within Parque Nacional Arrecifes de Xcalak, a marine protected area managed by the Comisión Nacional de Áreas Naturales Protegidas (CONANP). The reserve encompasses 179.49 km^2 of terrestrial and marine habitats. Little coastal development exists within the park and tourist use is low. Fishing is allowed with permits within the reserve, and un-permitted fishing with nets is common. The study location was 2 km south of the town of Xcalak. Mahahual (18°42' N, 87°42' W) is located 50 km north of Xcalak and is unprotected by conservation management regulations. A cruise ship pier was built in Mahahual in 2000, which resulted in increased tourist traffic and development. Sites surveyed at Mahahual were located about 2 km south of most of the town's development.

All sites at both locations were in continuous seagrass habitat (dominated by *Thalassia testudinum*) with *Syringodium filiforme* and macroalgae (including *Laurencia* sp., *Halimeda* sp. *Penicillis capitatus*, *Dictyota* sp., *Padina* sp. *Amphiroa* sp. and *Caulerpa* sp.), and were characterized by sandy bottom. At Xcalak sites were 1.0 to 1.6 m in depth and located within the back-reef lagoon (about 1 km wide) adjacent to fringing mangroves. At Mahahual, all sites were located in seagrass habitat 1.0 to 2.0 m deep adjacent to sandy shore in a reef lagoon (lagoon width ranged from 0.25 to 0.45 km). Seagrass beds at Mahahual were patchier than those surveyed at Xcalak (L.A. Yeager, personal observation).

Visual Surveys

To determine the composition of the seagrass fish community, visual censuses were completed during the daytime and nighttime in November and December 2006. At Xcalak and Mahahual, 15 and 19 sites were surveyed during the day and 9 and 5 sites were surveyed at night, respectively. All diurnal censuses were completed between 1120 and 1520 h and nocturnal surveys between 1830 and 2020 h. A dive light was used to illuminate the transect during nighttime censuses. Visual surveys were conducted along 20 m belt transects of 2-m width (modified from Brock 1954). All surveys were performed by the first author while snorkeling as follows: the transect line was started from a haphazardly selected point in continuous seagrass habitat and laid out perpendicular to shore. All transect starting points were at least 20 m apart and no transects overlapped within time of day (some transects between day and night in the same locations may have overlapped). Fish species abundance and estimated total length (TL) in 5-cm size classes (e.g., 0-4.9 cm, 5-9.9 cm, 10-14.9 cm) were recorded on dive slates with 5-cm increments marked on the side to aid in estimation of fish size. Members of the species *Sparisoma radians*, *S. aurofrentatum*, and *Nicholsina usta* were grouped into a Scaridae complex due to difficulties distinguishing between juveniles.

Data Analysis

For comparisons of overall community structure, diurnal fish community data were square-root transformed to increase contribution of less abundant species (Clarke and Green 1988). The Bray-Curtis index was used to create a similarity matrix of species-specific abundance data (Clarke 1993). A multi-dimensional scaling (MDS) plot

TABLE 1. *List of observed taxa with mean density (# of individuals/40m² ± standard error) and percent community composition by location and time of day. n = number of transects per time of day and location.*

		XCALAK				MAHAHAUL			
		Day (n = 15)		Night (n = 9)		Day (n = 19)		Night (n = 5)	
Taxa	Common Name	$\bar{x}$ Density	Percent	$\bar{x}$ Density	Percent	$\bar{x}$ Density	Percent	$\bar{x}$ Density	Percent
Muraenidae									
Gymnothorax vicinus	Purplemouth moray	0	0	0	0	0	0	0.20 ± 0.20	20.0
Ophichthidae									
Myrichthys breviceps	Sharptail eel	0	0	0	0	0.11 ± 0.07	1.2	0	0
Synodontidae									
Synodus intermedius	Sand diver	0.07 ± 0.07	0.4	0	0	0	0	0	0
Carangidae									
Carangoides ruber	Bar jack	0.33 ± 0.33	2.2	0	0	0.74 ± 0.49	8.3	0	0
Caranx crysos	Blue runner	0	0	0	0	0.11 ± 0.11	1.2	0	0
Lutjanidae									
Lutjanus griseus	Gray snapper	0.20 ± 0.14	1.3	0	0	0	0	0	0
Lutjanus synagris	Lane snapper	0.40 ± 0.13	2.6	0	0	0.26 ± 0.13	3.0	0	0
Ocyurus chrysurus	Yellowtail snapper	1.60 ± 0.85	10.3	0	0	0.63 ± 0.22	7.1	0	0
Gerridae									
Eucinostomus sp.	Mojarra	0	0	0	0	0.16 ± 0.16	1.8	0	0
Gerres cinereus	Yellowfin mojarra	0	0	0	0	0.32 ± 0.22	3.6	0	0
Haemulidae									
Haemulon plumieri	White grunt	0.13 ± 0.13	0.9	0.22 ± 0.15	20.0	0.05 ± 0.05	0.6	0	0
Haemulon scirus	Blue-stripped grunt	0	0	0	0	1.47 ± 1.26	16.6	0.20 ± 0.20	20.0
Mullidae									
Pseudupeneus maculatus	Yellowtail goatfish	0.8 ± 0.3	2.2	0	0	0.16 ± 0.12	1.8	0	0
Chaetodontidae									
Chaetodon capristratus	Foureye butterflyfish	0	0	0	0	0	0	0.20 ± 0.20	20.0
Chaetodon ocellatus	Spotfin butterflyfish	0	0	0	0	0.05 ± 0.05	0.6	0	0
Pomecentridae									
Abudefduf saxatilis	Sergeant major	0	0	0	0	0.05 ± 0.05	0.6	0	0
Labridae									
Halichoeres bivittatus	Slippery dick	9.60 ± 1.26	62.1	0	0	1.42 ± 0.45	16.0	0	0
Halichoeres poeyi	Blackear wrasse	0.07 ± 0.07	0.4	0	0	0.79 ± 0.28	8.9	0	0
Scaridae									
Scaridae complex	Parrotfish	2.40 ± 0.63	15.5	0	0	2.21 ± 0.60	24.9	0.20 ± 0.20	20.0
Scarus iserti	Striped parrotfish	0.07 ± 0.07	0.4	0	0	0	0	0	0
Scarus taeniopterus	Princess parrotfish	0.27 ± 0.18	1.7	0	0	0	0	0	0
Sparisoma rubripinne	Redfin parrotfish	0	0	0	0	0.26 ± 0.17	3.0	0	0
Acanthuridae									
Acanthurus coeruleus	Blue tang	0	0	0	0	0.05 ± 0.05	0.6	0	0
Sphyraenidae									
Sphryaena barracuda	Great Barracuda	0	0	0.11 ± 0.11	10.0	0	0	0	0
Tetradontidae									
Sphoeroides spengleri	Bandtail puffer	0	0	0	0	0.05 ± 0.05	0.6	0	0
Diodontidae									
Diodon holocanthus	Long-spine porcupinefish	0	0	0.78 ± 0.32	70.0	0	0	0.20 ± 0.20	20.0
Total		**15.47 ± 2.13**		**1.11 ± 0.42**		**8.89 ± 1.70**		**1.00 ± 0.50**	

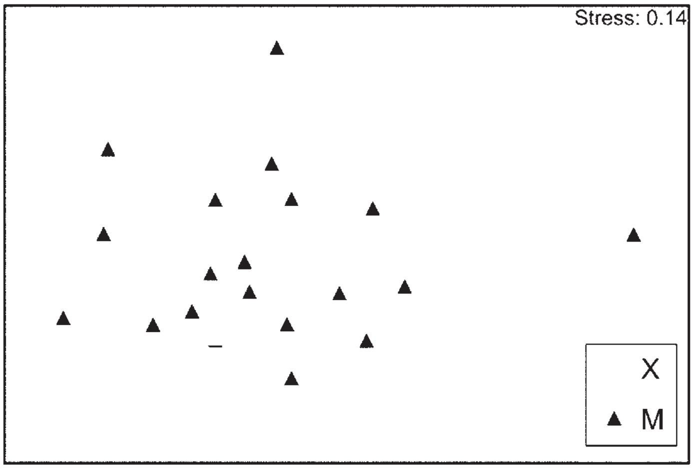

Figure 2.
MDS plot comparing community structure between study locations based on Bray-Curtis similarity matrix of diurnal fish community data (per species density in fish/40m²). Two overlapping points in the center of the cluster of gray triangles both represent transects at Xcalak. M=Mahahual and X=Xcalak.

was employed based on the similarity matrix to graphically explore differences in seagrass fish communities. An Analysis of Similarity (ANOSIM) was performed to test for statistical differences in fish communities between locations. Importance of individual taxa in contributing to differences between locations was determined with a Similarity-Percentages (SIMPER) analysis of square-root transformed abundance data (Clarke 1993, Primer© 5).

Non parametric statistics were used for all comparisons of fish abundance, species richness and length frequency because variables were not normally distributed despite numerous transformations (Kolmogorov-Smirnov normality test, $p < 0.05$ in all cases). Mean total fish abundance and species richness per transect were each compared between locations for diurnal communities with a Kruskal-Wallis ANOVA. For diel comparisons, data were grouped between locations by time of day. We feel this grouping of data was justified because of the lower number of nocturnal surveys and great differences between nocturnal and diurnal communities. Total fish abundance and species richness per transect between night and day were compared with a Kruskal-Wallis ANOVA.

Results

A total of 417 individuals representing 28 taxa from 16 families were observed in seagrass habitats at the two study locations during diurnal and nocturnal censuses (Table 1). The most abundant families included parrotfishes (Scaridae), wrasses (Labridae), snappers (Lutjanidae), grunts (Haemulidae), and jacks (Carangidae).

Daytime fish communities differed among locations (ANOSIM, Global $R = 0.21$, $p = 0.002$, Figure 2). Sites within Xcalak had greater similarity (57%) than sites within Mahahual (25%). Sites at Xcalak were characterized by two primary taxa (*Halichoeres bivitattus* and Scaridae complex, 77.6% of all fishes observed) while sites at Mahahual were dominated by Scaridae complex, *H. bivittatus*, *H. poeyi*, *Ocyurus chrysurus*, and *Carangoides ruber*, with these taxa making up 90% of all fishes observed (SIMPER). Sites at Xcalak were differentiated from those at Mahahual by the increased relative importance of *H. bivitattus*, Scaridae complex, *O. chrysurus* and *Lutjanus synagris* and decreased relative importance of *H. poeyi* and *C. ruber* (SIMPER). Even though *O. chrysurus* was not one of the two most abundant species making up 90% of the fish community at Xcalak, it still was more abundant at this location than at Mahahual (Table 1). Daytime fish abundance at Xcalak ($\bar{x} = 15.5 \pm 2.1$ fish/40m²) was greater than that at Mahahual ($\bar{x} = 8.9 \pm 1.7$ fish/40m², Kruskal-Wallis, $H = 6.806$, $p = 0.009$, Table 1). However, species richness did not differ between regions in the daytime ($\bar{x}_{xcalak} = 3.2 \pm 0.4$ fish species/transect, $\bar{x}_{mahahual} = 3.7 \pm 0.5$ fish species/transect, Kruskal-Wallis, $H = 0.150$, $p = 0.698$).

Families observed during nocturnal censuses included porcupinefishes (Diodontidae), grunts, parrotfishes, barracudas (Sphyraenidae), butterflyfishes (Chaetodontidae), and moray eels (Muraenidae). Nighttime fish communities exhibited much lower abundance (for both locations combined: $\bar{x} = 1.1 \pm 0.3$ fish/40m², Kruskal-Wallis, $H = 26.625$, $p < 0.001$) and lower species richness ($\bar{x} = 0.9 \pm 0.3$ fish species/transect, Kruskal-Wallis, $H = 19.798$, $p < 0.001$) when compared to daytime communities in this study.

Discussion

Diurnal communities of seagrass fishes differed between two back-reef lagoons with physical differences that included different levels of protection. The anthropogenic influences at both sites may partially explain the observed differences in fish communities. Greater environmental degradation, reflected in patchy seagrass habitat, at Mahahual may have led to lower abundance of fishes within this back-reef lagoon. Mahahual village has been recently urbanized for receiving thousands of tourists brought in by cruise ships. The beach was increased with dredged sand from the reef lagoon, the reef lagoon channel was deepened for boat and personal water craft transit, seagrass beds were removed, and the seascape was transformed with construction of a pier, small restaurants, shops and cabins. Following construction of the cruise ship pier, coral cover has decreased and algal cover has increased on coral reefs in Mahahual (Arias-Gonzalez et al., unpublished data), a sign of habitat degradation. However, no historical data related to seagrass fish communities or seagrass coverage at Mahahual are available for comparison to assess possible declines in abundance or shifts in community structure.

The greater fish density at Xcalak was mainly attributed to the greater abundance of *H. bivittatus*. Although this species is typically considered to be a habitat generalist (Gratwicke et al. 2006), the more extensive, less-disturbed seagrass habitat at Xcalak may have been preferable to this species.

Differences in contiguous habitats at the study locations may also account for differences in fish communities. Proximity to surrounding habitats affects the distributions of various fish species in back-reef environments (Drew 2006). Previous studies of seagrass fishes have found that proximity to mangroves and/or coral reef habitats may affect community structure or fish abundances (Robblee and Zieman 1984, Baelde 1990, Kopp et al. 2007). Mumby et al. (2004) found that coral reef sites adjacent to mangroves supported much greater biomass of fishes compared to those without mangroves nearby. Similarly, Kopp et al. (2007) observed greater fish density and biomass in seagrass habitat located adjacent to mangroves when compared to seagrass habitat near a coral reef. However, Baelde (1990) reported greater catch and greater species richness in a seagrass beds located in close proximity to mangrove and coral reef habitat compared to seagrass habitat only associated with mangroves. Seagrass beds at Xcalak are bordered by mangroves which may have contributed to the higher abundance of fishes found at this site. Also, the presence of *L. griseus* at Xcalak is likely due to the presence of mangroves at this location as this species is known for its association with mangrove habitats (e.g., Nagelkerken et al. 2000a, Gratwicke et al. 2006).

In contrast, the close proximity of reef habitat to Mahahual seagrass beds may have influenced community composition towards reef-associated species. The lagoon is narrower at Mahahual than at Xcalak, which may lead to increased connectivity between the reef and seagrass habitat at Mahahual. For example, *C. ruber*, a species that travels between reef and lagoon habitats, was more abundant and a more important component of the fish community at Mahahual.

Even though fish densities are often reported to be lower in seagrass habitat than in surrounding coral dominated areas, total habitat area must be taken into account (Nagelkerken et al. 2000b, Mateo and Tobias 2004). Seagrass habitat is often quite extensive in back-reef lagoons when compared to the coverage of other habitat types (e.g., patch reefs). Therefore, even though fish densities are lower, the total contribution of seagrass beds as habitat may be greater (Nagelkerken et al. 2000b). Also, juveniles of ecologically and commercially important species (e.g., *O. chrysurus*, *L. griseus*, *L. synagris*) were observed in seagrass habitat, suggesting this habitat may serve as a nursery area for these species. Lesser abundance of predators may make seagrass meadows the preferred feeding/sheltering habitat for a number of fishes (Shulman 1985). Additionally, habitat use only provides one measure of the value of a habitat. The function of seagrass habitat in Mahahual and Xcalak in terms of providing refuge from predation, food sources, or connectivity to other habitats is unknown. More extensive surveys of daytime and nighttime fish communities, as well as investigation of other aspects of ecosystem functions of these habitats, are needed to fully understand the importance of seagrass habitat in these back-reef systems.

Diurnal seagrass fish communities of the southern Mexican Caribbean observed in this study were similar to assemblages in other regions of the Caribbean, being dominated by wrasses, parrotfishes, snappers and grunts (Weinstein and Heck 1979, Nagelkerken et al. 2000b, Mateo and Tobias 2004). However, most studies only survey daytime fish communities due to logistical difficulties associated with nocturnal sampling. The preliminary surveys in this study suggest that seagrass habitat may not be as important during the nighttime in terms of total fish density or species richness. Kopp et al. (2007) also observed low abundance of nocturnal fishes in seagrass habitat near mangroves when compared to seagrass near coral reefs or to diurnal abundance. Likewise, Nagelkerken et al. (2000c) found lower fish density and species richness during nighttime in seagrass habitat in Spanish Water Bay, Curaçao than during the day, but suggested that seagrass was an important nighttime feeding habitat for snappers and grunts. Weinstein and Heck (1979) reported increased abundance of adult grunts and snappers in seagrass habitat at night and found similar or greater abundance of fishes at night than during the daytime. In this study, grunts were observed at night and snappers were observed outside of the transects at night. However, members of both of these families are highly mobile, and true patterns of their habitat use may not have been detected with the lower number of nocturnal surveys in this study. Members of other diurnally dominant fauna (e.g., wrasses) were not observed during the nighttime in this study. Similarly, Robblee and Zieman (1984) found that diurnal fish communities in seagrass habitat in Tague Bay, St. Croix were dominated by small permanent residents of the seagrass bed, whereas nocturnal fish communities were dominated by predatory reef species. There appears to be a shift in fish communities between night and day, emphasizing the importance of considering diel changes in habitat use to gain a more complete understanding of the functioning of seagrass beds at these two locations.

Underwater visual census is a widely used technique for surveying shallow-water fish communities. The authors acknowledge that some biases associated with this technique do exist (e.g., observer effect, Samways and Hatton 2001), but efforts to minimize effects of the observer and transect line were made. However, abundance of more cryptic species that hide within the seagrass canopy may be underestimated. In this study system the relatively clear water and short seagrass canopy should have reduced this potential bias. Also, the relative efficacy of underwater visual census in quantifying fish abundance in seagrass habitat between day and night is not known. Some species may avoid the dive lights necessary for nocturnal surveys. However, a previous study using visual census to quantify diurnal and nocturnal fish communities in a variety of back-reef habitats including seagrass suggested dive lights did not seem to modify the behavior of most nocturnal species (Nagelkerken et al. 2000c).

Detailed conclusions about nocturnal community structure at these sites are difficult to reach when considering the confounding factors of lower numbers of nocturnal surveys and decreased nocturnal fish abundance. While these potential biases must be considered, qualitative differences in fish community composition at a family level as well as differences in fish abundance and species richness between night and day were so great that the overall patterns are believed to be real.

A limitation of this study is the fact that both anthropogenic influences and habitat characteristics varied between locations, so it is difficult to attribute differences in fish communities to any one factor. While the results presented in this paper are preliminary, and based on data collected during only one season, they do suggest both anthropogenic pressures and habitat differences between locations are affecting the fish communities. Additionally, this study provides an initial survey of seagrass fish communities in a little studied area that will likely continue to undergo change with increasing anthropogenic pressures. As coastal development and tourism continue to increase at both locations, monitoring of fish communities and bentho is recommended to better evaluate potential threats and changes in seagrass ecosystems.

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