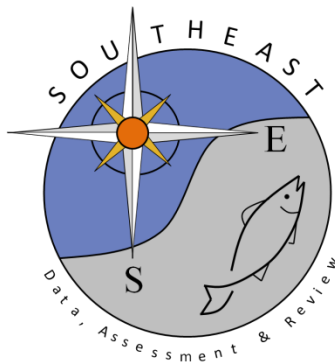# Spatial And Temporal Patterns Of Habitat Use By Fishes Associated With Sargassum Mats In The Northwestern Gulf Of Mexico

R. J. David Wells and Jay R. Rooker

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SPATIAL AND TEMPORAL PATTERNS OF HABITAT USE BY FISHES ASSOCIATED WITH *SARGASSUM* MATS IN THE NORTHWESTERN GULF OF MEXICO

R. J. David Wells and Jay R. Rooker

ABSTRACT

Distribution and abundance of fishes associated with *Sargassum* mats in the northwestern Gulf of Mexico were examined off northern (Galveston) and southern (Port Aransas) Texas from May–August, 2000. A total of 36 species (17 families) was identified from larval purse seine collections. Individuals from seven species composed over 97% of the catch: planehead filefish *Monacanthus hispidus* (Linnaeus, 1766), blue runner *Caranx crysos* (Mitchill, 1815), gray triggerfish *Balistes capriscus* (Gmelin, 1789), chain pipefish *Syngnathus louisianae* (Günther, 1870), sergeant major *Abudefduf saxatilis* (Linnaeus, 1758), sargassum fish *Histrio histrio* (Linnaeus, 1758), and greater amberjack *Seriola dumerili* (Risso, 1810). Sizes were variable throughout the sampling period; however, over 95% of the species collected were in the early life stages. Temporal patterns were observed for several taxa: *M. hispidus, S. louisianae,* and *H. histrio* were more abundant in May and June, while *C. crysos* and *A. saxatilis* were more common in July and August. Abundance of dominant taxa was higher in northern waters and both abundance and diversity increased as a function of distance from shore. Natural associations of ichthyofauna were observed across zones and region samples, and most of the variation was attributed to sample month. Results of this study suggest pelagic *Sargassum* serves as nursery habitat and may influence the recruitment success of several species.

Identification and conservation of essential fish habitat is a prerequisite to building healthy and sustainable fisheries (Rosenberg et al., 2000). To date, considerable work has focused upon characterizing habitats of demersal stocks (Lindeman et al., 2000), and these efforts have led to valuable information regarding the physical attributes and biological significance of these habitats. Unfortunately, information on habitat use of pelagic species is limited. The pelagic zone is typically characterized by its lack of physical structure and previous studies suggest that many pelagic organisms associate with structure, particularly during early life stages (Dooley, 1972; Rountree, 1990; Kingsford, 1992). Artificial structure, such as production platforms, flotsam, buoys, and fish aggregation devices (FADs), appears to function as pelagic habitat (Seaman et al., 1989; Rountree, 1990). Moreover, recent findings suggest that floating mats of brown algae (*Sargassum*) may be of critical importance, and the availability of these natural habitats may influence recruitment success of several species (SAFMC, 1998). Apart from qualitative surveys of pelagic *Sargassum* communities, the function of these mats as essential habitat has not been adequately addressed and warrants further consideration.

Floating pelagic *Sargassum* is a ubiquitous feature of surface waters in the Gulf of Mexico. Two species of brown algae (*Sargassum natans* and *Sargassum fluitans*) comprise nearly all the floating macro-algae in the pelagic zone (Parr, 1939). Both species originate in the Sargasso Sea within the North Atlantic Central Gyre, where physical factors such as currents, gyres, eddies, and winds influence their distribution (Dooley, 1972). *Sargassum* mats often accumulate in large windrows, thereby forming productive 'weedlines' in oligotrophic waters, and these algal mats may account for 60% of the total primary production in the upper

meter of water (Carpenter and Cox, 1974; Peres, 1982). In addition, epiphytic cyanobacteria contribute to overall production and nutrient recycling within the *Sargassum* complex (Phlips et al., 1986). A succession of bacteria, hydroids, and bryozoans initially colonize the algae (Conover and Sieburth, 1964; Ryland, 1974), and these early colonizers provide the base of a food web containing a variety of invertebrates, fishes, and sea turtles (Dooley, 1972; Bortone et al., 1977, Fedoryako, 1989).

Due to the physical complexity this habitat affords, *Sargassum* is of particular interest to scientists and fishery managers. Studies in the western Atlantic (Dooley, 1972; Settle, 1993), Japan (Edgar and Aoki, 1993), Australia (Kingsford and Choat, 1985), central Pacific (Gooding and Magnuson, 1967), and eastern Gulf of Mexico (Bortone et al., 1977) indicate that many fishes use *Sargassum*. The structural complexity of *Sargassum* acts to enhance growth by providing ample prey resources for juveniles (Hunter and Mitchell, 1967; Gorelova and Fedoryako, 1986; Edgar and Aoki, 1993), and may also enhance early life survival by reducing predation-mediated mortality (Kingsford, 1995). As a result, survivorship may increase and therefore recruitment success may be linked to *Sargassum* (Kingsford and Choat, 1985). The National Marine Fisheries Service (NMFS) has recently designated *Sargassum* as Essential Fish Habitat (EFH) for several coastal migratory species (NOAA, 1996). Nevertheless, studies assessing the value of *Sargassum* as habitat are limited, particularly in the northwestern Gulf of Mexico where large floating mats are predominant surface features on the continental shelf.

The aim of this study was to evaluate the role of *Sargassum* as nursery habitat of fishes in the northwestern Gulf of Mexico. Spatial and temporal patterns of habitat use were examined to determine the function and dynamics of the *Sargassum* complex. Specifically, patterns of abundance and assemblage diversity were assessed at two spatial scales. Inshore versus offshore comparisons were analyzed for small-scale spatial patterns, while northern and southern regions of the northwestern Gulf were investigated for large-scale differences. In addition, monthly changes in fish abundance and composition were examined to evaluate temporal stability and identify important periods of recruitment to the *Sargassum* complex.

MATERIALS AND METHODS

SAMPLING DESIGN.—This study was conducted in coastal and offshore waters of the northwestern Gulf of Mexico (Fig. 1). All samples were obtained within the following boundaries: north (29° 07.82′N, 94° 43.31′W), south (27° 37.55′N, 96° 35.84′W), east (28° 58.52′N, 93° 55.19′W), and west (27° 46.81′N, 96° 45.05′W). Waters 15–70 nm off Galveston and Port Aransas, Texas were designated as the offshore north and offshore south regions, respectively. Regions are separated by approximately 200 mi and oceanographic differences between the two include currents, winds, bottom topography, and nutrient concentrations (Smith, 1980a; Sahl et al., 1993). In addition, an inshore north zone (< 15 nm) off Galveston, Texas was sampled and compared to the offshore north zone (same as the offshore north region). This inshore north zone is heavily influenced by physical and biological processes occurring within the Galveston Bay estuary, such as advection of riverine and bay discharges, while the offshore north zone is governed more by continental shelf processes, such as upwelling (Temple et al., 1977; Smith, 1980b).

Sargassum and associated fauna were sampled from May through August 2000, which was the duration *Sargassum* was present in the area. Replicate samples (3–5) were collected monthly from the offshore north region, offshore south region, and the inshore north zone. All mats were haphazardly chosen and samples were taken from 0800–1500 h using a larval purse seine (20-m long, 3.3-
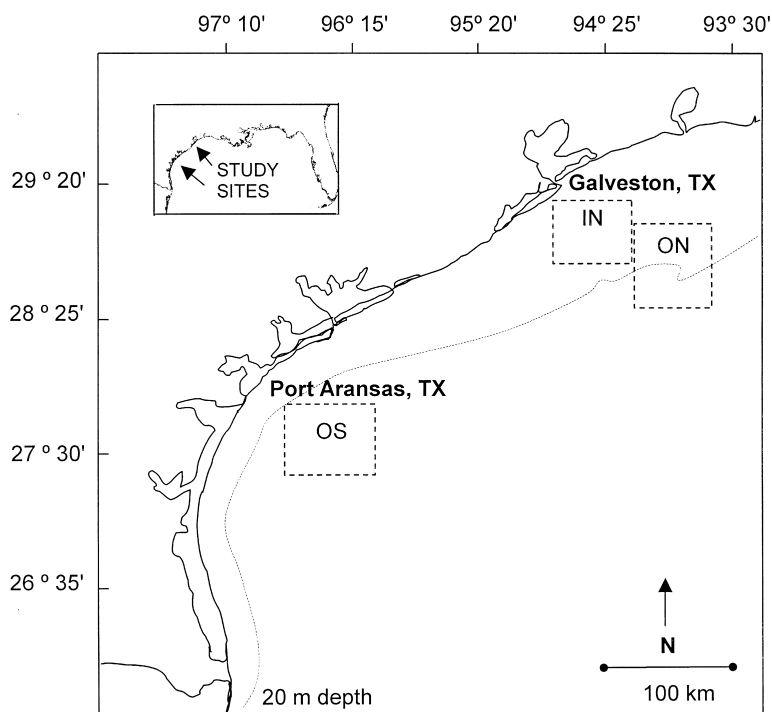
Figure 1. Map of sampling locations along the Texas Gulf coast. IN represents the inshore north zone, ON represents the offshore north zone and region, and OS represents the offshore south region.

m deep, 1000 μm mesh). The purse seine was deployed as the boat encircled the chosen mat, and once completely around the mat, the net was pursed. Next, *Sargassum* was removed (while the net remained in the water), and fishes were funneled into the cod end, collected, and frozen on dry ice. Mat volume (length × width × depth) and GPS locations were recorded at each sample location. Environmental parameters measured included depth, sea surface temperature, salinity, dissolved oxygen, and water clarity. Fishes were sorted and identified to species in the laboratory and standard length measurements were taken to the nearest 0.1 mm.

DATA ANALYSIS.—Relative abundance of fishes was expressed as catch per unit effort (CPUE), representing the number of fishes caught per larval purse seine sample. Seven species comprised 97% of the overall catch, and statistical analyses were limited to these taxa. Effects of location and date on CPUE estimates of each species were examined using a two-way analysis of variance (ANOVA). Two-way ANOVAs were also used to examine differences for several other dependent variables; these included environmental conditions, mat volume, sizes, and diversity estimates. Tukey's honestly significant difference (HSD) test was used to determine a posteriori differences ($\alpha = 0.05$) among means. The assumption of homogeneity of variances was examined using Levene's test and residual examination. Normality was examined using a probability plot of residuals versus expected values. CPUE data were log (× + 1) transformed to minimize heteroscedasticity. Regional August comparisons were not performed due to a lack of samples in the offshore south region (Port Aransas). In addition, sizes of all seven species were compared; however, sizes of only four species were statistically analyzed between the offshore north and offshore south regions due to a low number of individuals in the south region. Patterns of diversity using all species collected were investigated by Shannon diversity (H′) and evenness (J′) indices (Zar, 1984). The need to use a

rarefaction method was deemed inappropriate due to the similar number of samples among zones, regions and months. Diversity measures were estimated using the following equations:

$$H' = \frac{n \log n - \sum f_i \log f_i}{n}$$

where n is the total number of individuals and f_i is the number of individuals for each species.

$$J' = H'/\log S$$

where S (species richness) is the total number of species.

Factor scores from principal components analysis (PCA) were used to investigate natural fish assemblage structure (Hawkes et al., 1986). Percent composition estimates for the seven most abundant species were used as variables in the PCA model. Examination of eigenvalues in a scree plot determined the number of principal components to be used in the analysis (Tabachnick and Fidell, 1989; Tolimieri et al., 1998). Specifically, eigenvalues greater than 1.5 were selected. In addition, patterns of association between environmental factors and fish abundance data were examined using canonical correlation analysis (CCA). CPUE data of the seven abundant species were log ($\times$ + 1) transformed and temperature, salinity, and dissolved oxygen were used as environmental variables. Data analysis was carried out using SYSTAT 8.0 (SPSS Science, 1998) and CANOCO 4.0 (ter Braak and Smilauer, 1998).

RESULTS

ENVIRONMENTAL CONDITIONS.—Monthly variations in temperature, salinity, and dissolved oxygen were pronounced. Average temperature and salinity values were low during May and June, then significantly increased in July and August (Table 1). In contrast, average dissolved oxygen content was high throughout May and June, then significantly decreased in July and August (Table 1). Environmental differences also existed between the inshore and offshore zones of Galveston (inshore north and offshore north; Table 1). Significantly higher temperature, salinity, and depth were observed in the offshore zone, while the inshore zone exhibited significantly higher dissolved oxygen content. Visibility was also greater in the offshore zone, but no statistical comparison was performed due to several missing values. A significant zone × month interaction occurred for salinity, indicating the magnitude of differences was variable over time between the inshore and offshore zones. Further examination revealed large differences in May and August, and minimal differences in July. Regional environmental comparisons revealed similar trends (Table 1). Offshore south (Port Aransas) had significantly higher dissolved oxygen content, in addition to significantly lower temperatures than offshore north (Galveston). A significant region × month interaction occurred for dissolved oxygen due to the difference in magnitude during May. Additionally, both depth and visibility were greater in the offshore south region, but several missing values precluded statistical testing.

MAT CHARACTERISTICS.—A positive linear relationship between mat volume and CPUE values existed in both the inshore and offshore north zones (Fig. 2). A significant relationship was observed for the offshore north zone (P = 0.005). No significant location effects were detected among mat sizes between zones and regions (P = 0.114); however, a sig-

Table 1. Environmental conditions from May–August of 2000. Average (±1 SE) temperature (° C), salinity, dissolved oxygen (mg L^{-1}), depth (m), and visibility (m). * indicates P ≤ 0.05 and ^{ns} indicates P > 0.05. Months connected by vertical line are not significantly different from each other.

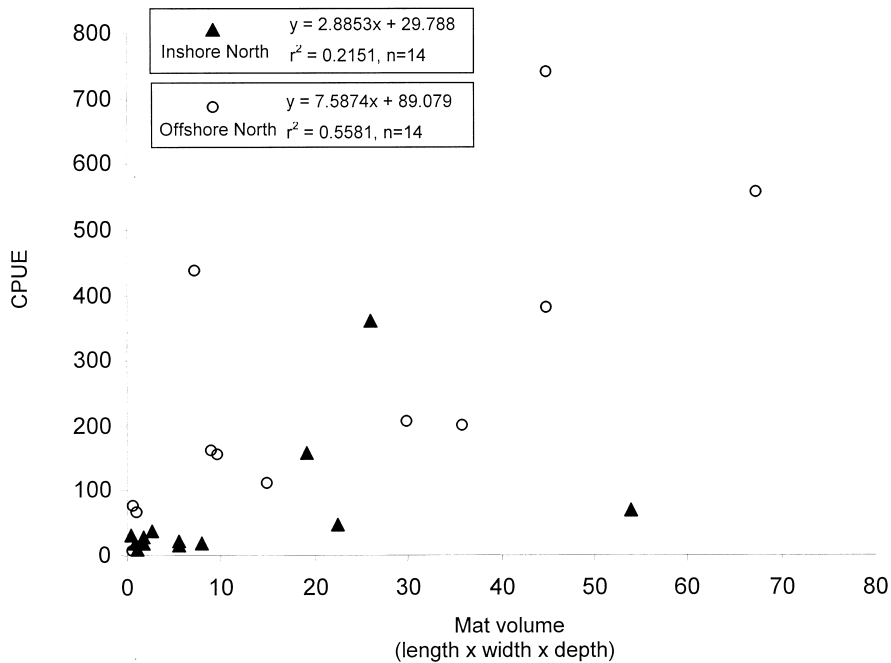|		Temperature	Salinity	Dissolved oxygen	Depth	Visibility
Season	May	27.8 (0.3)*	32.1 (1.0)*	7.6 (0.1)*		
	June	28.6 (0.2)	35.2 (0.7)	7.2 (0.1)		
	July	29.9 (0.2)	37.4 (0.2)	5.8 (0.2)		
	August	30.2 (0.1)	37.0 (1.0)	5.5 (0.1)		
Zone	Inshore	28.8 (0.2)	33.6 (0.9)	6.9 (0.3)*	17.1 (0.2)	5.3 (0.4)
	Offshore	29.9 (0.2)*	36.1 (0.5)*	6.0 (0.3)	24.9 (2.6)*	12.6 (1.4)
Region	North	29.9 (0.2)*	36.1 (0.5)	6.0 (0.3)	24.9 (2.6)	12.6 (1.4)
	South	28.5 (0.3)	37.4 (0.3)^{ns}	6.9 (0.1)*	36.7 (3.2)	19.8 (0.6)

Figure 2. Relationships between mat volume (length × width × depth) and CPUE of fishes associated with *Sargassum* mats within the inshore and offshore north zones. Two outliers were removed from the plot for visual purposes.

nificant temporal effect was observed (P = 0.029; Table 2). Mat volume was largest in May and smaller throughout the remaining months.

CATCH COMPOSITION.—A total of 10,518 individuals representing 36 fish species from 17 families was collected over the spring and summer sampling months (Table 3). Domi-

Table 2. Comparisons of *Sargassum* mat volume (length × width × depth) (±1 SE) among locations and seasons.

Location	Month	Mean mat volume	n
Inshore North	May	30.4 (8.0)	4
	June	1.8 (0.0)	3
	July	3.9 (1.1)	6
	August	0.4 (0.0)	1
Offshore North	May	117.5 (72.5)	3
	June	34.9 (17.6)	3
	July	4.2 (2.2)	5
	August	20.2 (8.1)	3
Offshore South	May	4.5 (0.0)	1
	June	15.9 (7.1)	5
	July	na	na
	August	na	na

nant taxa included monacanthids (filefishes), carangids (jacks), balistids (triggerfishes), and syngnathids (pipefishes). Individuals of seven species comprised 97.2% of the total catch: *Monacanthus hispidus* planehead filefish (44.0%), *Caranx crysos* blue runner (17.4%), *Balistes capriscus* gray triggerfish (15.3%), *Syngnathus louisianae* chain pipefish (10.4%), *Abudefduf saxatilis* sergeant major (5.3%), *Histrio histrio* sargassum fish (3.5%), and *Seriola dumerili* greater amberjack (1.5%).

Overall catch efficiency was highly variable ranging from 1–3201 individuals per seine, with an average CPUE of 276.6 (± 100.8). Relative abundance of the seven abundant species varied among months, and CPUE values peaked early. CPUE values ranged from 47–3191 fishes per purse seine in May, while averaging 632.0 (± 374.1). Average CPUE values greatly decreased in June to 130.4 (± 55.1), increased in July to 217.5 (± 158.3), and decreased to the lowest average CPUE values in August at 118.3 (± 34.6).

SIZE DISTRIBUTION.—Size distributions varied within *Sargassum* mats, with most species in the larval or juvenile stage (Fig. 3). The majority of *M. hispidus*, *A. saxatilis*, and *C. crysos* were < 25 mm: 75, 95, and 62%, respectively. *Histrio histrio* and *B. capriscus* were abundant at larger sizes, as 75% of *H. histrio* ranged between 20–50 mm and 95% of *B. capriscus* ranged between 35–65 mm. *Syngnathus louisianae* and *S. dumerili* were prominent over a wide size spectrum, ranging from 52–209 mm and 32–210 mm, respectively.

Five of the seven most abundant species (*C. crysos*, *B. capriscus*, *S. louisianae*, *H. histrio*, and *S. dumerili*) were small early in the sampling months, and significantly larger in May through June (Tukey HSD, $P < 0.05$). The smallest average size of *M. hispidus*, *C. crysos*, and *A. saxatilis* occurred in July, whereas average size of *B. capriscus*, *S. louisianae*, and *H. histrio* was smallest in August. Three of the seven most abundant species were significantly larger in the inshore zone: *M. hispidus* ($F_{1,4420} = 89.78$, $P < 0.001$), *C. crysos* ($F_{1,1553} = 372.65$, $P < 0.001$), and *A. saxatilis* ($F_{1,430} = 20.38$, $P < 0.001$; Table 4). Significant zone × month interactions occurred for all species, indicating the magnitude of differences in size between zones was variable over time. Of the four species statistically analyzed for regional differences, *M. hispidus* ($F_{1,1340} = 79.82$, $P < 0.001$), *C. crysos* ($F_{1,1604} = 52.81$, $P < 0.001$), and *A. saxatilis* ($F_{1,366} = 17.09$, $P < 0.001$) were significantly larger in the offshore south region. In contrast, *B. capriscus* ($F_{1,1438} = 13.81$, $P < 0.001$) was significantly larger in the offshore north region (Table 4). *Monacanthus hispidus* and *A. saxatilis*

Table 3. Number of fishes collected within *Sargassum* mats by family and species from May–August, 2000.

Family	Species	Total numbers
Antennariidae	*Histrio histrio*	368
Balistidae	*Balistes capriscus*	1,604
	Canthidermis maculata	3
Carangidae	*Caranx crysos*	1,827
	Seriola dumerili	154
	Decapterus punctatus	24
	Seriola rivoliana	17
	Caranx bartholomaei	11
	Seriola fasciata	5
	Elagatis bipinnulata	5
	Caranx hippos	1
Clupeidae	*Harengula jaguana*	23
	Sardinella aurita	1
Coryphaenidae	*Coryphaena hippurus*	1
Diodontidae	*Diodon holocanthus*	1
Engraulidae	*Anchoa hepsetus*	24
Haemulidae	*Conodon nobilis*	2
Kyphosidae	*Kyphosus sectatrix*	7
	Kyphosus incisor	7
Lobotidae	*Lobotes surinamensis*	16
Monacanthidae	*Monacanthus hispidus*	4,621
	Aluterus scriptus	35
	Aluterus heudeloti	21
	Cantherhines pullus	19
	Monacanthus setifer	16
	Aluterus monoceros	2
Mugilidae	*Mugil curema*	2
Nomeidae	*Psenes cyanophrys*	14
	Psenes pellucidus	1
Pomacentridae	*Abudefduf saxatilis*	555
Priacanthidae	*Pristigenys alta*	1
Syngnathidae	*Syngnathus louisianae*	1,096
	Syngnathus pelagicus	25
	Hippocampus erectus	1
	Syngnathus scovelli	1
Tetraodontidae	*Sphoeroides parvus*	7
TOTAL		10,518

had a significant region × month effect with a trend of both species having a pronounced size difference in July and a minimal difference in June.

Spatial and Temporal Patterns of Abundance.—*Zonal Comparison*.—CPUE of each of the seven most abundant species in the offshore north zone greatly exceeded those of the inshore north zone (Fig. 4). Average CPUE of the seven species in the offshore zone ranged from 2–87 times higher than the inshore zone. Significant zone effects were ob-
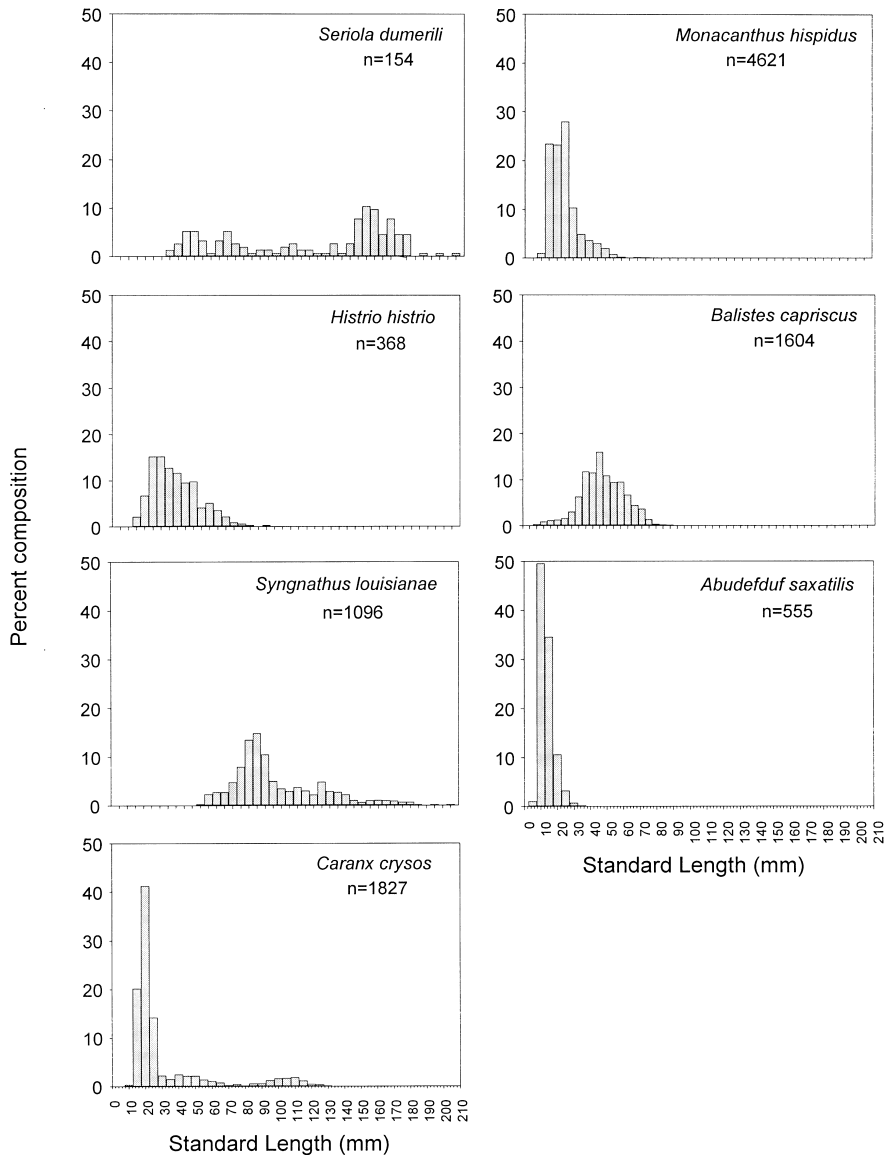
Figure 3. Length frequency distributions of the seven abundant fish species collected within *Sargassum* mats. Based upon the number of individuals per 5 mm size class.

served for *M. hispidus* ($F_{1,20}$ = 11.32, P = 0.003), *C. crysos* ($F_{1,20}$ = 5.70, P = 0.027), *B. capriscus* ($F_{1,20}$ = 19.44, P < 0.001), and *S. louisianae* ($F_{1,20}$ = 13.46, P = 0.002). In addition, *M. hispidus*, *S. louisianae*, *H. histrio*, and *S. dumerili* showed a significant monthly effect with higher abundances in May and June (Tukey HSD, P < 0.05; Fig. 5). A significant zone × month interaction was observed for *S. louisianae*; however, trends were consistent over time.

Table 4. Size comparison (standard length) of the seven abundant species (±1 SE). * denotes significant difference in size between respective zones or regions.

| Species	Min.	Max.	Mean Size	Inshore zone	Offshore zone	North region	South region
Monacanthus hispidus (n = 4,621)	7.8	71.8	21.9 (0.1)	32.5 (0.4)*	20.5 (0.1)	20.4 (65.6)	29.1 (0.8)*
Caranx crysos (n = 1,827)	12.3	134.5	34.1 (0.6)	93.5 (6.3)*	32.5 (0.6)	29.7 (0.6)	48.4 (3.3)*
Balistes capriscus (n = 1,604)	13.2	105.8	59.8 (0.4)	65.2 (2.2)	60.1 (0.5)	61.5 (0.5)*	58.6 (0.7)
Syngnathus louisianae (n = 1,096)	52.2	209.0	99.7 (0.8)	75.9 (1.7)	103.2 (0.9)	103.3 (0.9)	135.0 (74.0)
Abudefduf saxatilis (n = 555)	9.5	38.0	15.8 (0.2)	20.1 (0.8)*	14.9 (0.2)	13.8 (0.2)	17.6 (0.5)*
Histrio histrio (n = 368)	12.0	91.8	36.5 (0.8)	41.4 (1.7)	34.8 (0.8)	35.0 (0.8)	30.5 (4.8)
Seriola dumerili (n = 154)	32.4	210.3	120.2 (4.0)	106.3 (5.3)	123.1 (4.7)*	123.4 (4.7)	115.1 (50.0)
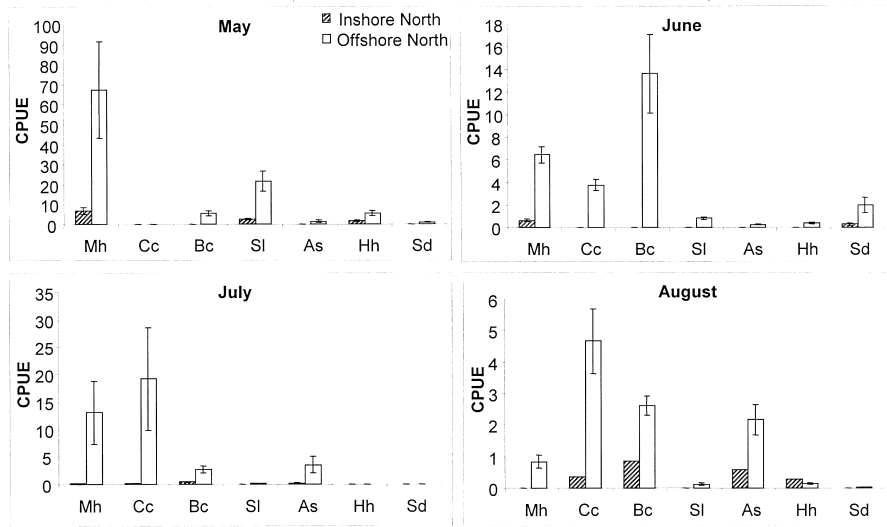
Figure 4. CPUE (# per purse seine) comparisons (±1 SE) of the seven abundant fish species associated with *Sargassum*, between inshore north and offshore north zones by month. Species codes: Mh = *Monacanthus hispidus*, Cc = *Caranx crysos*, Bc = *Balistes capriscus*, Sl = *Syngnathus louisianae*, As = *Abudefduf saxatilis*, Hh = *Histrio histrio*, Sd = *Seriola dumerili*.

Regional Comparison.—Similar trends were observed regionally; CPUE of six of the seven most abundant species was higher in the offshore north region than the offshore south region. Average CPUE's (except for *B. capriscus*) were 1.5–300 times higher in the north region (Fig. 6). Significant regional effects occurred for *M. hispidus* ($F_{1,15} = 10.10$, $P = 0.006$), *S. louisianae* ($F_{1,15} = 44.35$, $P < 0.001$), *H. histrio* ($F_{1,15} = 13.65$, $P = 0.002$), and *S. dumerili* ($F_{1,15} = 6.63$, $P = 0.021$). Additionally, a significant monthly effect was observed for *S. louisianae* and *H. histrio*; both were significantly more abundant in May (Tukey HSD, $P < 0.05$; Fig. 5).

Community Structure.—Species richness (S), diversity (H′), and evenness (J′) were variable among months and locations. Monthly comparisons showed that later months (July and August) exhibited significantly higher H′ and J′ than those of earlier months (May and June; Tukey HSD, $P < 0.05$; Table 5). Despite the change in composition, S remained relatively constant throughout the months sampled. Zonal comparisons indicated S and H′ were higher in the offshore north zone, whereas J′ was higher in the inshore north zone (Table 5). A two-way ANOVA showed that S ($F_{1,20} = 33.33$, $P < 0.001$) and J' ($F_{1,20} = 7.06$, $P = 0.015$) were significantly different between zones. Regional comparisons indicated significantly higher S ($F_{1,15} = 5.55$, $P = 0.033$) and H' ($F_{1,15} = 4.95$, $P = 0.042$) in the offshore north region (Table 5).

Natural associations of *Sargassum* fish fauna were investigated using both PCA and CCA. PCA results indicated principal components one and two accounted for 44.8% and 14.4% of the variability, respectively. PCA factor scores within respective zones and regions tended to group fairly near one another; however, samples within the same months tended to cluster more tightly, suggesting most of the variation was attributed to the month sampled (Fig. 7). The first two CCA axes explained 99.4% of the cumulative variance of the species with respect to the environmental variables (Fig. 8). Fishes abundant in May
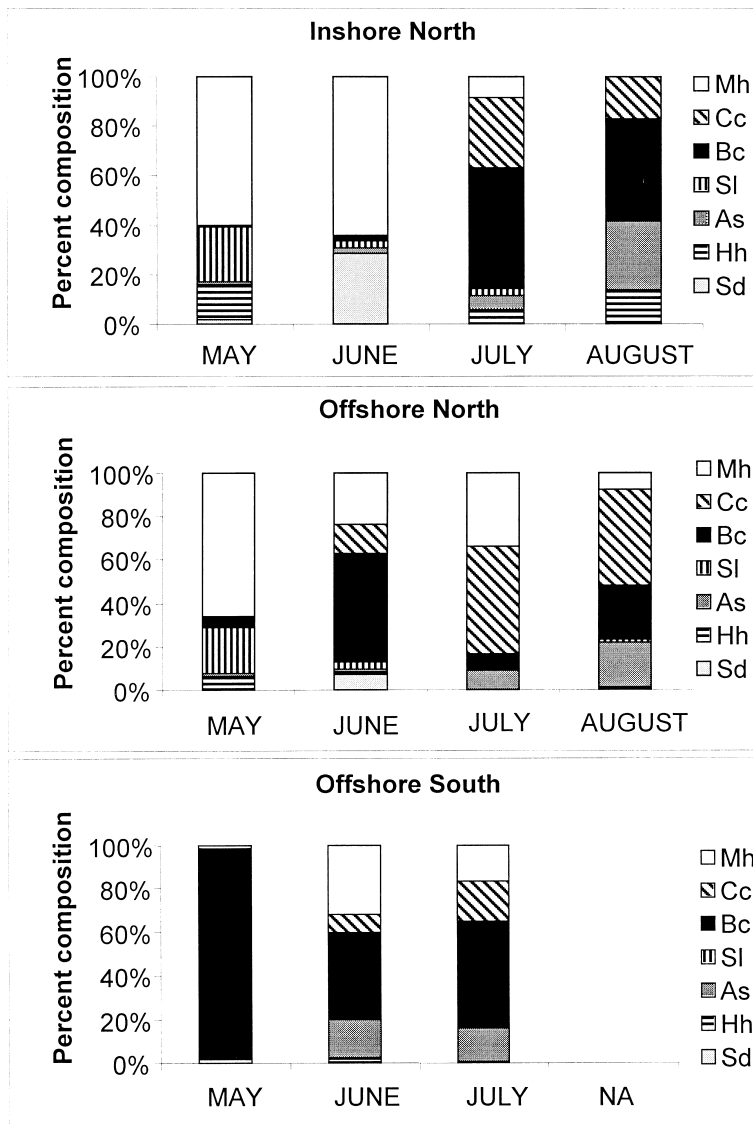
Figure 5. Seasonal comparison of the seven abundant fish associated species with *Sargassum* by month, based upon percent composition of these taxa. Species codes: Mh = *Monacanthus hispidus*, Cc = *Caranx crysos*, Bc = *Balistes capriscus*, Sl = *Syngnathus louisianae*, As = *Abudefduf saxatilis*, Hh = *Histrio histrio*, Sd = *Seriola dumerili*.

and June (*M. hispidus, S. louisianae, H. histrio,* and *S. dumerili*) tended to group together on the first CCA axis. In contrast, *C. crysos*, *A. saxatilis*, and *B. capriscus* grouped together on the opposite side of the axis. Dissolved oxygen was high in May and June, thereby grouping with species more abundant in earlier months. Conversely, temperature and salinity were high in July and August, hence grouping with the species more abundant in later months.
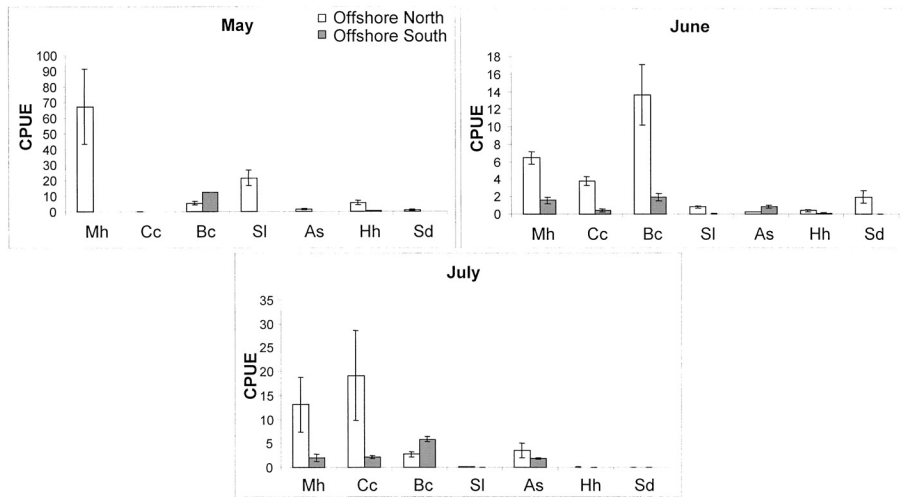
Figure 6. CPUE (# per purse seine) comparisons (±1 SE) of the seven abundant fish species associated with *Sargassum*, between offshore north and offshore south regions by month. Species codes: Mh = *Monacanthus hispidus*, Cc = *Caranx crysos*, Bc = *Balistes capriscus*, Sl = *Syngnathus louisianae*, As = *Abudefduf saxatilis*, Hh = *Histrio histrio*, Sd = *Seriola dumerili*.

DISCUSSION

The assemblage of fishes associated with *Sargassum* in the northwestern Gulf of Mexico was similar to other regions of the Atlantic Ocean (Settle, 1993). In the present study, carangids, balistids, monacanthids, and antennariids accounted for 87% of the total catch. Similarly, these four families represented approximately 90% of the total catch in studies conducted in the western Atlantic (Dooley, 1972) and 97% in the eastern Gulf of Mexico (Bortone et al., 1977). Moreover, one species, *M. hispidus*, dominated our catches in the northwestern Gulf (44% of total catch). Similar levels of numerical dominance by *M.*

Table 5. Average species richness (S), Shannon diversity (H′) and evenness (J′) indices for all samples. August was removed from regional comparison due to a lack of samples in the south region. * indicates P < 0.05 and ns indicates P > 0.05. Months connected by vertical line are not significantly different from each other.

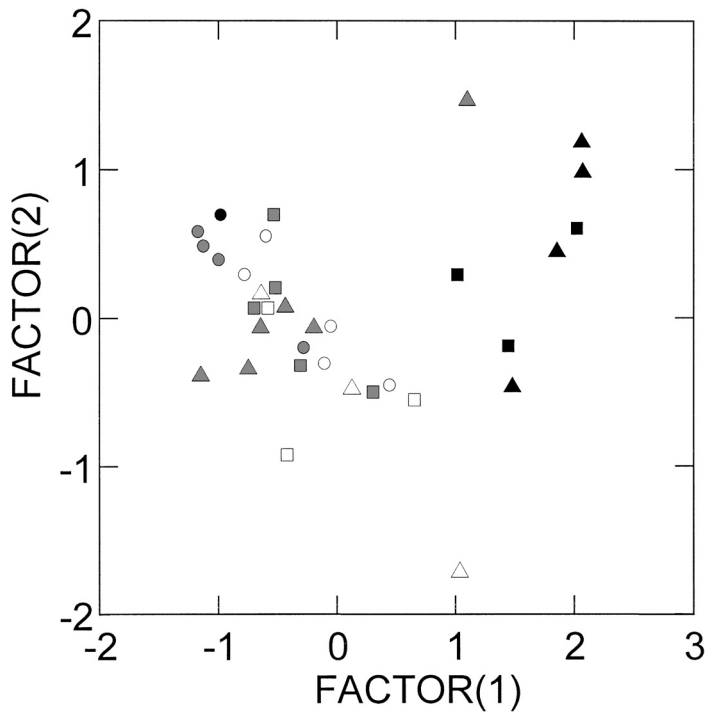|		S	H′	J′	Total # of species	Total # of individuals
Season	May	7.5[ns]	0.442*	0.520*	19	5,091
	June	7.6	0.447	0.551	26	1,529
	July	7.8	0.603	0.716	35	3,393
	August	8.8	0.599	0.654	14	505
Zone	Inshore	5.4	0.523	0.729*	20	862
	Offshore	10.5*	0.574[ns]	0.586	37	8,756
Region	North	10.7*	0.572*	0.584[ns]	36	8,291
	South	7.2	0.457	0.515	21	900

Figure 7. Factor scores plot of principal component analysis based upon the seven abundant fish species associated with *Sargassum*. August was removed from the analysis due to the limited number of samples. Solid figures (▲■●) = May, open (△□○) = June, and shaded (▲■●) = July. Triangles = inshore north zone, squares = offshore north zone and region, and circles = offshore south region.

hispidus were observed in other studies throughout the Gulf and western Atlantic (47–85% of total catch; Dooley, 1972; Bortone et al., 1977; Settle, 1993), indicating that patterns of faunal composition are widespread. Despite faunal similarities, diversity indices in this study were two to three-fold less than studies in the eastern Gulf and western Atlantic (Dooley, 1972; Bortone et al., 1977). In addition, four species collected in this study have not been reported as members of the pelagic *Sargassum* community (*Anchoa hepsetus* striped anchovy, *Conodon nobilis* barred grunt, *Harengula jaguana* scaled sardine, and *Sphoeroides parvus* least puffer). While such differences may be due to gear effects and the timing of our study, geographic location appears to play a role in fish community structure of *Sargassum* assemblages.

Abundance of juvenile fishes collected in association with *Sargassum* suggests that these mats serve as nursery habitat for pelagic fauna. Based upon size-at-collection and species-specific life history profiles, over 95% of the fishes were in their early life stage; 72% were under 50 mm (SL) and the average size of all fishes combined was 40 mm. These results are consistent with other studies investigating the fauna associated with pelagic algae (Fine, 1970; Kingsford and Choat, 1985). Bortone et al. (1977) found the average size of fishes associated with *Sargassum* in the eastern Gulf was < 25 mm, while Kingsford (1992) observed an average size < 20 mm in northeastern New Zealand. The association of these small fishes with pelagic *Sargassum* is likely attributed to the struc-
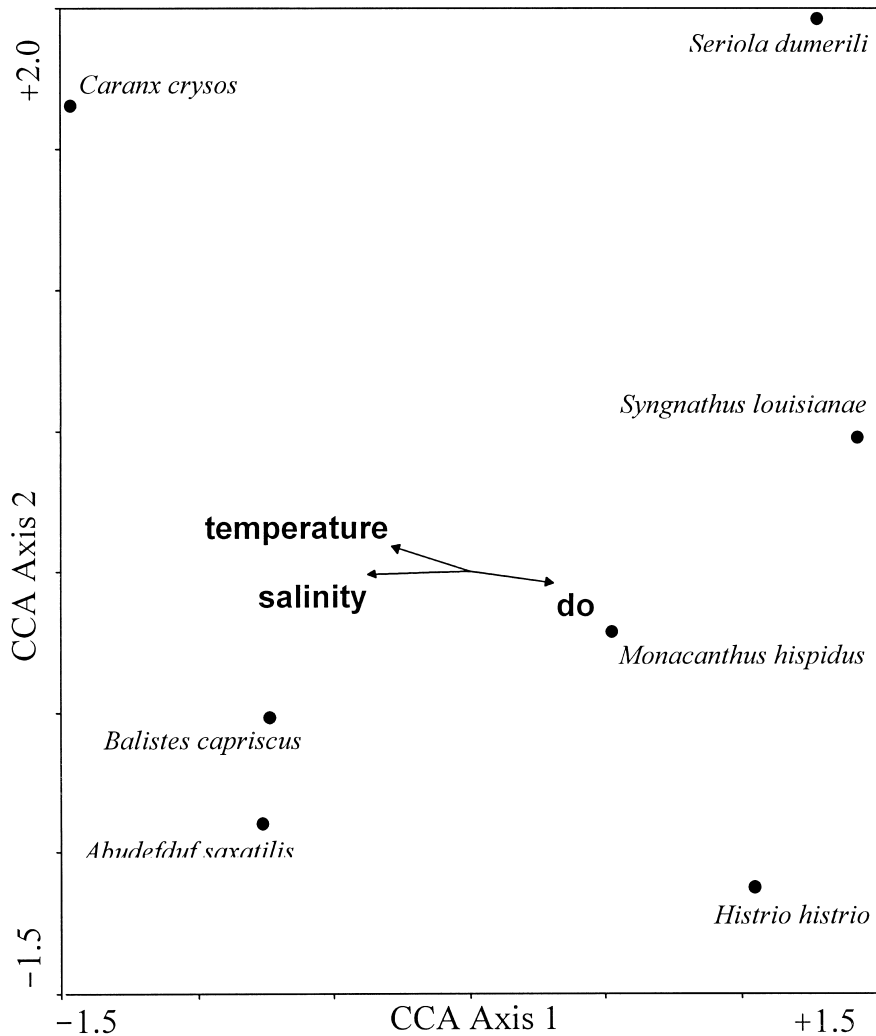
Figure 8. Bi-plot of CPUE and environmental variables in CCA axis 1 vs. axis 2, for *Sargassum* samples.

ture and food supply this habitat affords. Druce and Kingsford (1995) found that drift objects (i.e., algae and FADs) influenced the distribution of larval and juvenile fishes in surface waters when compared to open water habitats. Additionally, detached macrophytes have been suggested to serve as nursery areas for juvenile fishes as they provide prey resources and protection from predators (Lenanton et al., 1982; Lenanton and Caputi, 1989). Again, gear selectivity may influence the size range collected in this study; nevertheless, the abundance of juveniles associated with *Sargassum* suggests this habitat may be important for early life survival.

   Patterns of habitat use also appeared related to the timing and location of spawning. Variability in size frequencies throughout the sampling period suggests that protracted

spring and summer spawning events occurred for several species. *Monacanthus hispidus*, *C. crysos*, and *A. saxatilis* were significantly smaller in offshore waters, which may be related to their proximity to spawning grounds. These findings are consistent with the season and location of reproduction for *M. hispidus* (Berry and Vogele, 1961), *C. crysos* (Leak, 1981; Shaw and Drullinger, 1990), and *A. saxatilis* (Shaw, 1955), which exhibit extended spring and summer spawning events in offshore areas. Conversely, *S. louisianae* is known to spawn inshore, often in close proximity to seagrass beds (Diaz-Ruiz et al., 2000).

Spatial patterns indicated that the abundance of fishes associated with pelagic *Sargassum* varies as a function of distance from shore. The seven abundant species associated with *Sargassum* in the offshore zone was much greater than in the inshore zone. Bortone et al. (1977) found similar trends in fish abundance for several species, including *M. hispidus*, *B. capriscus*, and *S. dumerili*, as distance increased from shore. Since physiochemical conditions differed between zones, physiological tolerances may contribute to the observed patterns. Average salinity differed between zones by 2.5, and differences in both temperature and dissolved oxygen content differed between zones by as much as 2.2°C and 2.5 mg L^{-1}, respectively, in certain months. Boehlert and Mundy (1994) found temperature and salinity were likely factors responsible for onshore-offshore distribution patterns of pelagic fish larvae. Additionally, Raynie and Shaw (1994) suggested that ichthyoplankton assemblages from offshore to estuarine areas were attributed to different life-history strategies and temperature regimes. The combination of environmental conditions and life history patterns likely influence observed spatial differences; however, other factors such as season and differential resource exploitation also may be important.

On a larger scale, patterns of habitat use were observed between the offshore north and south regions along the Texas Gulf coast. Six of the seven abundant species in this study were far more abundant in the north region. Qualitative measurements of *Sargassum* abundance indicated less *Sargassum* was present in the north region throughout our sampling. Therefore, species may have been concentrated beneath the limited available habitat in the north region and dispersed in the south region, where much more *Sargassum* was present. Physiochemical factors may contribute to this pattern; Sahl et al. (1993) found that temperature, salinity, oxygen, and nutrients (nitrate, phosphate, silicate) differed markedly between offshore areas of Galveston and Port Aransas. Results from our study indicated that the north region experienced significantly higher temperatures and lower salinity and dissolved oxygen content. In addition, the abundance of different species varied over the spring and summer sampling periods and corresponded to environmental conditions. The difference in shelf currents, freshwater discharges, and upwelling at the shelf edge may further contribute to both physical and biological differences between the two regions (Smith, 1980b; Cochrane and Kelly, 1986). Previous studies have shown that the distribution and abundance of pelagic fish assemblages are influenced by environmental and hydrological conditions (Rey, 1996; White, 1997). Consequently, the numerical dominance in the north region may result from an unknown combination of biological, physical, and chemical conditions.

Species that dominated the *Sargassum* complex in this study appear to rely upon the pelagic habitat for a portion of their early life, but to different extents. Several fishes have unique relationships with pelagic *Sargassum*, ranging from obligatory to facultative associations. *Histrio histrio* and *Syngnathus pelagicus* have developed specific adaptations

for pelagic *Sargassum* and are endemic to this habitat (Bohlke and Chaplin, 1968; Pietsch, 1992; Cho et al., 2001). These species live within the *Sargassum* complex and appear to depend upon its resources during early life and adult stages (Dooley, 1972). In contrast, more mobile species, such as *C. crysos*, *B. capriscus*, *A. saxatilis*, and *S. dumerili* have developed a facultative association utilizing the pelagic habitat for a portion of their early life. These species live beneath the mats, where it is suggested pelagic *Sargassum* provides both prey and protection from predators (Gooding and Magnuson, 1967; Hunter and Mitchell, 1968; Dooley, 1972). Moser et al. (1998) suggested larger juvenile and adult species, such as the jacks and triggerfish, do not show a high degree of association with the *Sargassum* and thus may not require this habitat during early life. Therefore, the value of *Sargassum* differs among species with respect to its role as essential fish habitat.

Abundance of several estuarine associated species within the *Sargassum* complex indicates this habitat is used by both estuarine and pelagic species. Eight of the 36 species collected in this study are common in estuaries, including *H. jaguana*, *Sardinella aurita, A. hepsetus*, *Mugil curema*, *S. louisianae*, *Syngnathus scovelli*, *Hippocampus erectus*, and *S. parvus*. Of the four species (*A. hepsetus*, *C. nobilis*, *H. jaguana*, and *S. parvus*) never before documented with pelagic *Sargassum*, three are estuarine species (Shipp and Yerger, 1969; Modde and Ross, 1981; Garcia-Abad et al., 1999). Several of the estuarine associated fishes collected throughout the study are known to spawn offshore, including *H. jaguana*, *S. aurita*, and *M. curema* (Finucane et al., 1979; Houde et al. 1979; Ditty, 1986; Ditty and Shaw, 1996). Consequently, this pelagic habitat may serve as an important means of transport, thereby enhancing the survivorship of larval and juvenile species as they move from offshore waters into bays and estuaries.

In summary, juvenile fishes associated with pelagic *Sargassum* exhibited a variety of spatial and temporal patterns of habitat use. Discrimination between respective zones and regions based upon faunal composition was negligible, and monthly influences (i.e., environmental conditions) appear to play an important role in *Sargassum* fish assemblages in the northwestern Gulf of Mexico. Results of this study suggest *Sargassum* mats serve as nursery habitat for some species and may influence the recruitment success of fishes using this habitat.

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