SEASONALITY OF FISHES OCCUPYING A SURF ZONE HABITAT IN THE NORTHERN GULF OF MEXICO

TIMOTHY MODDE[1] AND STEPHEN T. ROSS[2]

ABSTRACT

The ichthyofauna occupying the surf zone habitat of Horn Island, Mississippi, between 1975 and 1977 was dominated by immature clupeiform fishes. The dusky anchovy, *Anchoa lyolepis*, and the scaled sardine, *Harengula jaguana*, together constituted 80.2% of the 154,469 fishes collected. The greatest number of fishes were collected in the late spring and summer, followed by a secondary peak in late winter. Occurrence of the fishes within the surf zone is divided into three categories according to seasonal utilization: spring and summer, summer only, and winter. Factors affecting numerical abundance within the surf zone differed among the most frequently appearing species. Differences in the numbers of clupeiform fishes—*A. lyolepis*; *A. hepsetus*, striped anchovy; and *H. jaguana*—were more closely associated with diel changes including tidal stage and time of day. The abundance of the Florida pompano, *Trachinotus carolinus*, and the gulf kingfish, *Menticirrhus littoralis*, were more dependent upon seasonal effects such as temperature.

Relatively few studies have investigated the role of exposed surf zone habitats in the early life history of fishes. While Springer and Woodburn (1960) described the surf zone region as an "extreme habitat offering little environmental diversity," this habitat does provide several benefits to fishes. Advantages suggested by Warfel and Merriman (1944) included the abundance of food (concentrated by incoming tides), increased metabolic efficiency via heat acquisition, and protection from predation.

Surf zone ichthyofaunas are numerically dominated by relatively few species. For instance, McFarland (1963) stated that 60-80% of the ichthyofauna occupying the surf regions along the south Atlantic and Texas coasts was comprised of only a few species. Gunter (1958) found high similarity in species composition between Mustang Island, Texas, and Atlantic coast surf zones and suggested that the surf zone region was dominated by a small group of species which remained relatively constant over wide geographical areas.

Much of the literature regarding shore zone fishes is restricted to either descriptions of species occurrence or seasonal characterizations, seldom exceeding one annual cycle. Reid (1955a, b), Schaefer (1967), and Hillman et al. (1977) have sampled the same habitats in successive seasons and have observed annual changes in species composition. Fewer studies have attempted to relate physical or biological parameters to the abundance of fishes within the shallow beach habitat. Gunter (1945) and Warfel and Merriman (1944) attributed the distinct seasonal fluctuations in fish abundance to temperature. Both Anderson et al. (1977) and de Sylva,[3] using multiple regression analyses and crosstabulation, respectively, also indicated that temperature was a significant factor in determining seasonal abundance of the most numerous fish species.

The present study describes seasonal and annual variations in fish species composition and the factors affecting fish occurrences within the surf zone of Horn Island, Miss., a barrier island in the northern Gulf of Mexico.

METHODS

The study area was located along the southern shore of Horn Island, Jackson County, Miss. Horn Island is in a chain of barrier islands lying parallel to the Mississippi-Alabama Gulf coast (Figure 1). The island lies approximately 14 km off the mainland and has a length of 19 km with a maximum width of 1.2 km. The beach is partially protected from oceanic wind-driven waves by a series of sand

[1]Department of Biology, University of Southern Mississippi, SS Box 5018, Hattiesburg, Miss.; present address: Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007.

[2]Department of Biology, University of Southern Mississippi, SS Box 5018, Hattiesburg, MS 39401.

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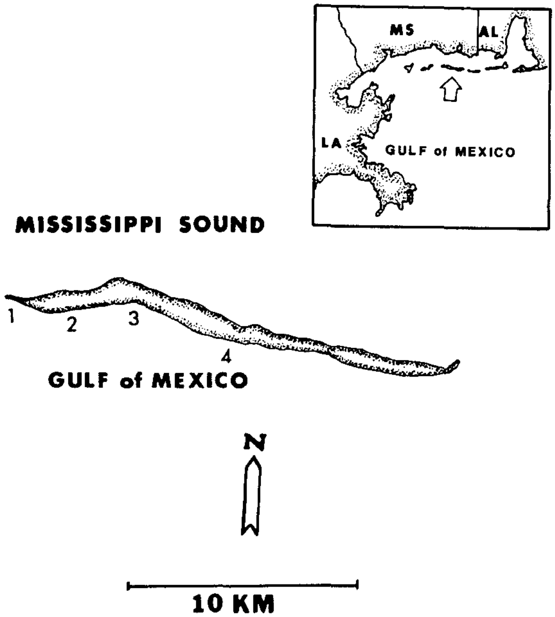

FIGURE 1.—Map of Horn Island, Jackson County, Miss., showing the four sampling areas. The southern side of the island represented the windward shore.

bars which extend the length of the island. The surf zone habitat is characterized by a sand substrate, the absence of any rooted vegetation, and sufficient wave activity to be categorized as a high energy beach (Odum and Copeland 1974).

We began sampling in April 1975 along the southwestern edge of the island (Station 1), and collections were made at about 7-wk intervals until November 1975. From May 1976 to November 1977 we sampled four stations along the windward shore of Horn Island (Figure 1) at about 5-wk intervals (Table 1). We also sampled sheltered beach areas adjacent to Stations 3 and 4 during the summer of 1976. All of the above collections were taken between 0900 and 1600 h c.s.t. (central standard time).

TABLE 1.—Sampling dates for fish taken from the surf zone habitat on the southern shore of Horn Island, Miss., between April 1975 and November 1977. Each collection represents a set of seine hauls at a specific location.

	1975		1976		1977	
Season	Date	No. of collections	Date	No. of collections	Date	No. of collections
Winter			13 Mar.	6	22 Jan.	4
					17 Mar.	5
Spring	12 Apr.	3	23 Apr.	4	28 Apr.	5
	21 June	2	28 May	7	27 May	8
Summer	12 Aug.	3	25 June	11	27 June	5
			23 July	8	23 July	5
			24 Aug.	5	17 Sept.	4
			2 Sept.	8		
Fall	18 Oct.	4	1 Oct.	6	23 Nov.	4
			4 Dec.	5		

Every month between March and September 1976 (excluding August) we sampled either Station 1, 3, or 4 over a 24-h period, taking samples at about 4-h intervals. The choice of station was based in part on the availability of a safe anchorage for our boat. In order to compare data throughout the study, collections made between 1600 and 0900 h were not included in seasonal or annual comparisons.

Fishes were collected with a 3.2 mm Ace[4] mesh bag seine measuring 9.1 × 1.8 m. Hauls were made perpendicular to the beach face beginning 16-18 m offshore. The area sampled extended from the swash zone to the midlongshore trough, and we made an effort to take regular samples only in areas directly exposed to surf. We continued seining at each location until no additional new species were collected; usually 5-9 hauls sufficed. Each collection at each location was thus comprised of a successive number of seine hauls. Fishes collected from all seine hauls at a single station were pooled for analysis. Catch-per-effort data from all stations were pooled to provide monthly means. The study included 613 seine hauls.

Species similarity by months was analyzed by the unpaired group arithmetic average clustering (UPGMA) method (Sneath and Sokal 1973). Only the 15 most abundant species, which were collected in at least 15% of the locations sampled, were analyzed. Pair similarity based on species presence or absence (Odum 1971) was determined by:

$$S = 2C/A + B$$

where C = number of species common to samples a and b,
A = number of species in sample a,
B = number of species in sample b.

We used stepwise multiple regression to define the dominant factors associated with the abundance (fish per seine haul) of the five most frequently occurring species. Environmental parameters selected as independent variables were

[4]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

temperature, salinity, tide level, wave height, beach slope, wind speed, and wind direction. The latter two parameters represented means of the 4-wk period preceding each collection. Wind direction and velocity data were recorded at Keesler Air Force Base on the adjacent mainland. Tide level data were entered as the difference from mean low water and were from tide tables. Because of the absence of data regarding several environmental parameters, collections made during 1975 were not included in the regression analysis.

RESULTS

Annual and Seasonal Occurrence

During the 32-mo study period, 154,469 fishes, representing 14 orders, 42 families, and 76 species, were collected (Table 2). These were primarily late larvae and early juveniles, and only 1.1% exceeded 50 mm SL. The major families represented in the surf zone, in both percent occurrence and numbers collected, were the Engraulidae, Clupeidae,

TABLE 2.—Total number of fishes collected from the surf zone of Horn Island, Miss., between April 1975 and November 1977, and percentage frequency of species occurrence in the collections.

Species	1975	1976	1977	Total	Frequency of occurrence
Carcharhinidae					
Carcharhinus limbatus, blacktip shark		1		1	0.9
Dasyatidae					
Dasyatis sayi, bluntnose stingray		1		1	.9
Megalopidae					
Megalops atlantica, tarpon	2	1		3	2.7
Elopidae					
Elops saurus, ladyfish	2		3	5	2.7
Albulidae					
Albula vulpes, bonefish			4	4	3.6
Ophichthidae					
Myrophis punctatus, speckled worm eel			2	2	1.8
Clupeidae					
Harengula jaguana, scaled sardine	1,941	45,790	12,001	59,732	64.3
Sardinella anchovia, spanish sardine	170	107	27	304	17.0
Opisthonema oglinum, Atlantic thread herring	87	88	1	176	8.9
Brevoortia patronus, gulf menhaden	1,069	1,046	6,733	8,848	17.9
Etrumeus teres, round herring			1	1	.9
Engraulidae					
Anchoa lyolepis, dusky anchovy	6,855	41,690	15,486	64,031	47.3
A. hepsetus, striped anchovy	74	2,656	1,021	3,751	44.6
A. mitchilli, bay anchovy	788	275	1,890	2,953	29.5
A. cubana, cuban anchovy	5	2		7	1.8
Anchoviella perfasciata, flat anchovy	507	514	234	1,255	21.4
Synodontidae					
Synodus foetens, inshore lizard fish	26	30	11	67	18.8
Ariidae					
Arius felis, sea catfish	8	16	6	30	13.4
Gobiesocidae					
Gobiesox strumosus, skilletfish		3	10	13	5.4
Gadidae					
Urophycis regius, spotted hake			1	1	.9
Polynemidae					
Polydactylus octonemus, Atlantic threadfin			2	2	.9
Pomatomidae					
Pomatomus saltatrix, bluefish		11	28	39	8.0
Rachycentridae					
Rachycentron canadum, cobia		4		4	1.8
Sphyraenidae					
Sphyraena borealis, northern sennet		24	106	130	12.5
S. guachancho, guaguanche		7		7	3.6
Scombridae					
Scomberomorus maculatus, spanish mackerel	7	52	4	63	12.5
Lutjanidae					
Lutjanus sp., snapper		1		1	.9
Mugilidae					
Mugil cephalus, striped mullet	4	323	493	820	24.1
M. curema, white mullet	3	73	420	496	24.1
Stromateidae					
Peprilus sp., butterfish		2	1	3	1.8
Gerreidae					
Eucinostomus sp., mojarra	142	553	180	875	36.6
Sparidae					
Archosargus probatocephalus, sheepshead		2		2	1.8
Lagodon rhomboides, pinfish	27	7	1,216	1,250	18.8
Uranoscopidae					
Astroscopus y-graecum, southern stargazer		11	8	19	9.8

TABLE 2.—*Continued.*

Species	1975	1976	1977	Total	Frequency of occurrence
Pomacentridae					
Abudefduf saxatilis, sergeant major			18	18	.9
Lobotidae					
Lobotes surinamensis, tripletail	1	236	5	242	21.4
Blenniidae					
Hypsoblennius sp., blenny		22	2	24	6.3
Gobiidae					
Gobionellus hastatus, sharptail goby		1		1	.9
Ophidiidae					
Lepophidium sp., cusk eel		1		1	.9
Exocoetidae					
Hemiramphus brasiliensis, ballyhoo		3		3	1.8
Hyporhamphus unifasciatus, halfbeak	1	3	24	28	6.3
Belonidae					
Strongylura marina, Atlantic needlefish		3	1	4	1.8
Cyprinodontidae					
Fundulus similis, longnose killifish		2	2	4	3.6
Atherinidae					
Menidia beryllina, tidewater silverside	29	35	109	173	24.1
Membras martinica, rough silverside	180	5	317	502	17.9
Syngnathidae					
Syngnathus louisianae, chain pipefish	2	133	35	170	28.6
S. floridae, dusky pipefish	7	3	7	17	6.3
S. scovelli, gulf pipefish	5		2	7	2.7
Hippocampus zosterae, dwarf seahorse		1		1	.9
Sciaenidae					
Bairdiella chrysoura, silver perch		1	2	3	2.7
Cynoscion arenarius, sand seatrout		7		7	.9
C. nebulosus, spotted seatrout	1		2	3	2.7
Leiostomus xanthurus, spot	6	795	1,415	2,216	18.8
Menticirrhus littoralis, gulf kingfish	269	431	694	1,394	67.0
M. americanus, southern kingfish	19	213	40	272	25.9
M. saxatilis, king whiting	10	52	54	116	34.8
Larimus fasciatus, banded croaker		13	5	18	4.5
Micropogonias undulatus, Atlantic croaker		3		3	1.8
Carangidae					
Chloroscombrus chrysurus, Atlantic bumper	3	9	13	25	8.9
Trachinotus carolinus, Florida pompano	154	528	2,586	3,268	56.3
T. falcatus, permit		1		1	.9
Oligoplites saurus, leatherjacket	4	4	2	10	6.3
Caranx hippos, crevalle jack	2	56	14	72	11.6
Seriola zonata, banded rudderfish		1		1	.9
Selene vomer, lookdown		1		1	.9
Dactyloscopidae					
Dactyloscopus tridigitatus, sand stargazer			2	2	.9
Triglidae					
Prionotus tribulus, bighead searobin			1	1	.9
Cynoglossidae					
Symphurus plagiusa, blackcheek tonguefish		1		1	.9
Bothidae					
Citharichthys macrops, spotted whiff	3	16	4	23	6.3
Etropus sp., flounder		627	2	629	13.4
Paralichthys albigutta, gulf flounder		19	2	21	4.5
P. lethostigma, southern flounder	2	9	6	17	3.6
Tetraodontidae					
Sphoeroides sp., puffer		196	35	231	18.8
Balistidae					
Monacanthus hispidus, planehead filefish		39		39	4.5
Aluterus schoepfi, orange filefish		3		3	.9
Diodontidae					
Chilomycterus schoepfi, striped burrfish			1	1	.9
Totals	12,415	96,763	45,291	154,469	

Carangidae, and Sciaenidae. The dusky anchovy, *Anchoa lyolepis*, and the scaled sardine, *Harengula jaguana*, were numerically most important making up 80.2% of the total number of fishes collected. These species were abundant in all 3 yr, although *A. lyolepis* was most numerous in 1975 and 1977 and *H. jaguana* in 1976. The families Sciaenidae and Carangidae were represented by nine and seven species, respectively. The gulf kingfish, *Menticirrhus littoralis*, although only eighth in number, exhibited the highest frequency of occurrence (67%) of any species. The Florida pompano, *Trachinotus carolinus*, was the only carangid regularly occurring in the surf zone.

Relationships within two genera, *Sardinella* (Clupeidae) and *Menidia* (Atherinidae), are currently uncertain for the Gulf of Mexico. We followed Houde and Fore (1973) and Hoese and Moore

(1977) in recognizing the low anal ray count (generally 16) specimens of *Sardinella* sp. as Spanish sardine, *S. anchovia*. Our specimens of *Menidia* generally had three or fewer anal fin rays anterior to the posterior extension of the swim bladder by which Johnson (1975) characterized *M. peninsulae* (Goode and Bean). However, we have followed Edwards et al. (1978) in retaining tidewater silverside, *M. beryllina*, for this form.

Although some variation occurred in the annual ranking of species abundance (Table 3), *A. lyolepis*; *H. jaguana*; and gulf menhaden, *Brevoortia patronus*, were among the four most abundant species in all 3 yr. Less numerous species showed more variability. For instance, the striped anchovy, *A. hepsetus*, was third in abundance in 1976 but eighth in abundance in 1977, while *T. carolinus* was sixth in abundance in 1976 and fourth in abundance in 1977.

TABLE 3.—Rank order of abundance of the 10 most numerous fish species collected from the Horn Island, Miss., surf zone by year.

Species	1975	1976	1977
Anchoa lyolepsis	1	2	1
Harengula jaguana	2	1	2
Brevoortia patronus	3	4	3
Anchoa mitchilli	4	—	5
Anchoviella perfasciata	5	9	—
Menticirrhus littoralis	6	10	9
Membras martinica	7	—	—
Sardinella anchovia	8	—	—
Trachinotus carolinus	9	8	4
Eucinostomus sp.	10	7	—
Leiostomus xanthurus	—	5	6
Etropus sp.	—	6	—
Lagodon rhomboides	—	—	7
Anchoa hepsetus	—	3	8
Mugil cephalus	—	—	10

The number of fishes collected from the surf zone habitat of Horn Island was characterized by distinct seasonal changes. Peaks in fish per seine haul (collected between 0900 and 1600 h) occurred during the warmer months between June and September 1976 and 1977 (Figure 2). In 1975 fishes were not collected in large numbers until the August collection. Large numbers of fishes were collected as early as June in 1976 although few fishes were collected in July of the same year. In 1977 fishes were not collected in abundance in June, but were in July.

The number of fishes collected dropped during the fall and winter months but rose again during late winter and early spring (Figure 2). This secondary peak, occurring in March 1976 and 1977, was composed of denatant migrants (sensu Cushing 1975) which had recently been spawned

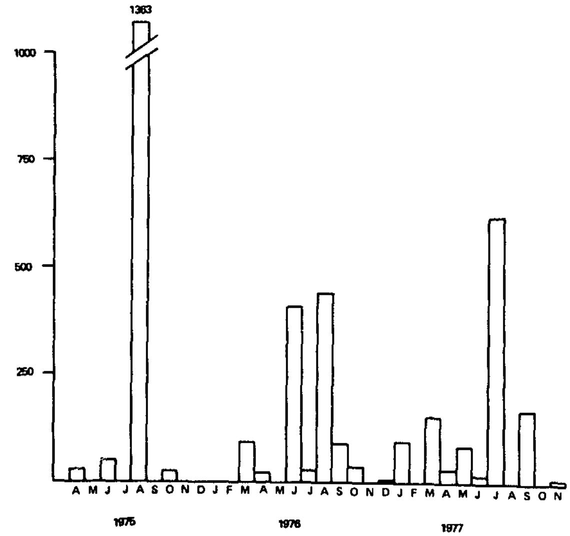

FIGURE 2.—Mean number of fishes collected per seine haul from Stations 1 through 4 on Horn Island, Miss., between April 1975 and November 1977. Data represents collections made between 0900 and 1600 h c.s.t.

offshore and were drifting into Mississippi Sound via the barrier island passes. Following the late winter (March) peak there was another period of low catch per effort between April and June in 1976 and 1977.

The numerically dominant species collected within the surf zone exhibited distinct seasonal occurrence patterns. Cluster analysis among these species indicated three modes of occurrence (Figure 3). Although data for the cluster analysis included only fishes collected between 0900 and 1600 h, there was no significant difference (χ^2, 5% level) in the monthly presence of fish species collected at this time period and those collected between 1600 and 0900 h. The most numerous species, *A. lyolepis* and *H. jaguana*, showed the highest similarity in seasonal occurrence and were most common during spring and summer. Other species also characteristic of spring and summer included *Eucinostomus* sp. and *T. carolinus*. *Anchoa hepsetus* and *Menticirrhus littoralis* had less seasonal affinity with the above species since they also occurred well into fall.

A second seasonal group included flat anchovy, *Anchoviella perfasciata*; *S. anchovia*; and white mullet, *Mugil curema*, which were representatives of the summer fauna (Figure 3). These species were never collected at water temperatures below 24.5° C.

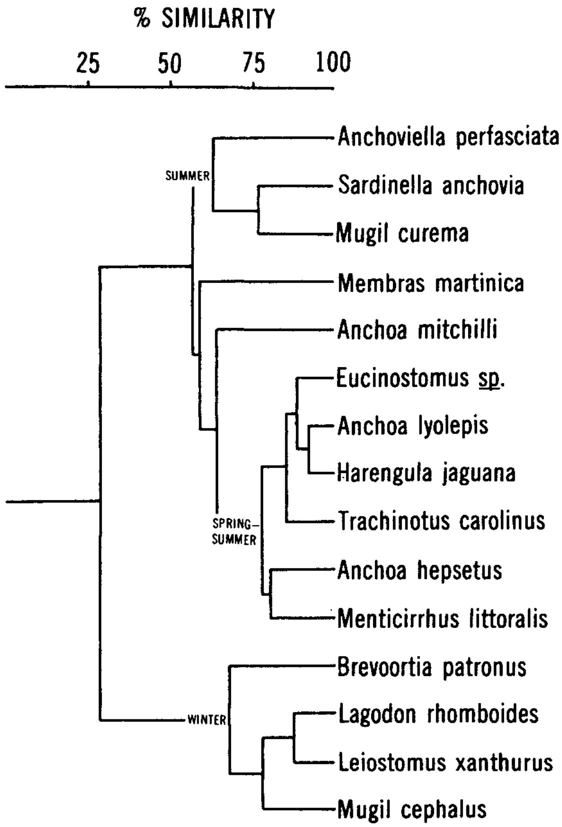

FIGURE 3.—Similarity dendrogram for species by month, based on presence or absence data, for fishes collected from the surf zone of Horn Island, Miss.

The third seasonal species group, *B. patronus*; pinfish, *Lagodon rhomboides*; spot, *Leiostomus xanthurus*; and striped mullet, *Mugil cephalus*, was prevalent during winter or early spring, generally in water temperatures below 24.5° C, with the first three occurring at temperatures as low as 11.5° C. Together these four species composed the secondary abundance peak of March 1976 and 1977 (cf. Figure 2).

Rough silverside, *Membras martinica*, and bay anchovy, *Anchoa mitchilli*, did not fit within the three seasonal categories. *Anchoa mitchilli* was collected in greatest abundance during the spring and in the fall, while *M. martinica* was most common in the spring, but only during 1975 and 1977. *Membras martinica* was infrequent in 1976.

Multiple regression analysis explained little of the variation associated with fish abundance (i.e., fish per seine haul). However, while tentative, the analysis may indicate the relative importance of these variables in controlling fish occurrence (Table 4). The dominant factor affecting the clupeiform fishes was tide level. Tide contributed only 5.1% and 8.9% in the regression equations for *H. jaguana* and *A. hepsetus*, and accounted for 19.2% of the model for *A. lyolepis* ($P<0.05$). The remaining variables contributed little to the predictive ability of the regression equations, although salinity composed 5.6% of the variance model for *A. hepsetus* ($P<0.05$). Temperature was the dominant parameter in the model for *T. carolinus* (not significant) and *Menticirrhus littoralis* ($P<0.05$).

While not apparent from Table 4, our observations indicate that catch per effort (cf. Figure 2) may coincide with wind direction. Wind patterns in the study area undergo annual cycles in which direction is primarily from the north during the winter and from the south during the summer. Fishes were collected in greatest numbers during the summer when southerly winds predominated.

Daily Activity Patterns

The greatest number of fishes were present within the surf zone during the early morning

TABLE 4.—Stepwise multiple regression of the five major environmental parameters contributing to the average number of fish collected per seine haul in the surf zone of Horn Island, Miss.

Species and parameter	Cumulative R	R^2	Cumulative R^2	F	df
Anchoa lyolepis					
Tide	0.438	0.192	0.192	15.72*	6, 75
Wave height	.452	.012	.205	.16	
Wind direction	.457	.005	.209	.23	
Temperature	.461	.003	.212	.22	
Wind speed	.462	.001	.213	.06	
Harengula jaguana					
Tide	.227	.051	.051	3.96*	5, 76
Temperature	.255	.014	.065	.82	
Wind direction	.274	.010	.075	.69	
Salinity	.278	.002	.077	.20	
Wave height	.279	.001	.078	.06	
Anchoa hepsetus					
Tide	.297	.089	.089	8.96*	6, 76
Salinity	.380	.056	.144	5.00*	
Temperature	.398	.014	.158	.90	
Wind direction	.411	.011	.169	1.00	
Slope	.415	.003	.172	.32	
Trachinotus carolinus					
Temperature	.199	.040	.040	2.14	7, 74
Salinity	.241	.018	.058	1.02	
Wind speed	.254	.007	.065	.93	
Tide	.262	.004	.068	.68	
Wind direction	.268	.004	.072	.60	
Menticirrhus littoralis					
Temperature	.309	.095	.095	8.62*	6, 75
Tide	.329	.013	.108	.77	
Salinity	.333	.002	.111	.21	
Wave height	.334	.001	.112	.52	
Slope	.338	.002	.113	.38	

*Significant ($P<0.05$).

(0300-0900) for all six 24-h samples made in 1976 (Figure 4). From May to September, excluding August when diel collections were not taken, fishes exhibited a distinct rise in abundance between 0300 and 0600 h c.s.t. with peak occurrences just after sunrise. The number of fishes collected during this time period far exceeded those captured during the later daylight hours; in June no collection was made during this time period.

The daily pattern of catch per effort reflected the numerical dominance of *H. jaguana* and *A. lyolepis*. The greatest number of fish for both species was collected during the early morning with a subsequent decline throughout the day (Figure 5). Peak capture rates for *H. jaguana* and *A. lyolepis* were 1,712 and 2,339 fish/seine haul, whereas the lowest mean rates were 6 and 0.1 fish/seine haul during the 1200-1500 h period for *H. jaguana* and the 1800-2100 h period for *A. lyolepis*. A secondary peak in abundance occurred between 1500 and

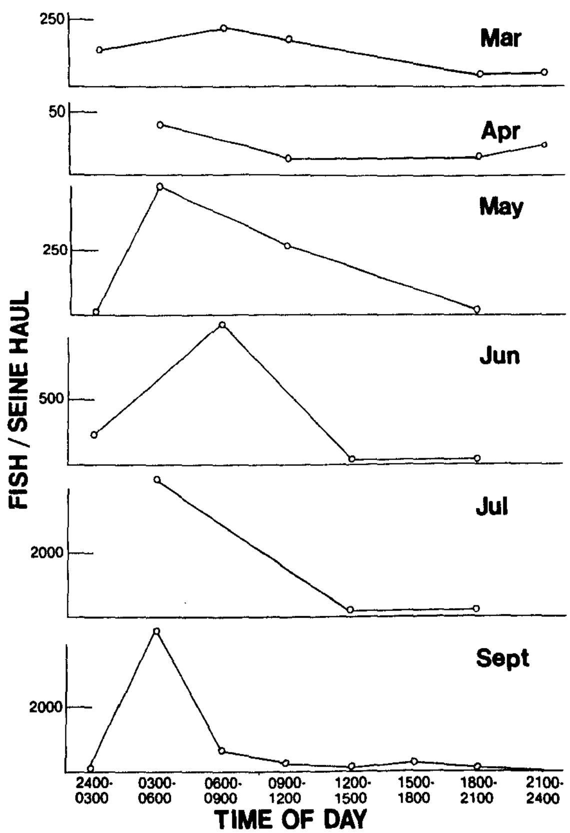

FIGURE 4.—Monthly mean number of fish per seine haul collected during the designated time intervals from the surf zone of Horn Island, Miss., between March and September 1976, excluding August.

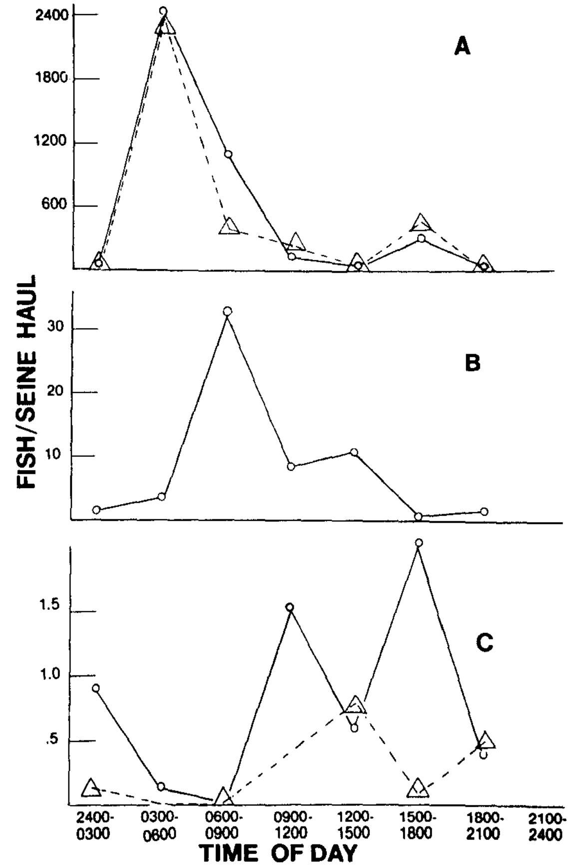

FIGURE 5.—Daily changes of mean number of fish per seine haul for the Horn Island, Miss., surf zone (April 1976-September 1976). Data are for the numerically most important species. A = *Anchoa lyolepis* (broken line) and *Harengula jaguana* (solid line). B = *Anchoa hepsetus*. C = *Trachinotus carolinus* (broken line) and *Menticirrhus littoralis* (solid line).

1800 h with 252 and 545 fish collected per seine haul for *H. jaguana* and *A. lyolepis*. High numbers of *A. hepsetus* also occurred during the morning; however, peak catch per effort occurred between 0600 and 0900 h. This species was less abundant than *H. jaguana* and *A. lyolepis*, with only 33 fish collected per seine haul. *Anchoa hepsetus* remained within the beach area through 1200-1500 h, but no fish were captured between 1500 and 1800 h.

Menticirrhus littoralis and *T. carolinus* did not exhibit distinct daily activity patterns, but tended to be more abundant during midafternoon or evening. The greatest number of *M. littoralis* collected was only 2.0 fish/seine haul between 1800 and 2100 h while the greatest number of

T. carolinus per seine haul was 0.8 fish between 1500 and 1800 h.

DISCUSSION

Species Composition

The ichthyofauna of the Horn Island surf zone resembles that of other surf zone habitats within the Gulf of Mexico. Using similar collecting gear, Gunter (1958) reported that over a 3-yr period *T. carolinus* and *H. pensacolae* (= *H. jaguana*) were the numerical dominants from the surf zone of Mustang Island, Texas. McFarland (1963), using a much larger seine (193 m long with 1.9 cm mesh), found that *Mugil cephalus* and Atlantic threadfin, *Polydactylus octonemus*, were dominant by weight and number, respectively, of the same area. While fishes collected by McFarland were generally >100 mm, many of the same species were collected by Gunter (1958) and in our study as larvae and juveniles.

Springer and Woodburn (1960) described a faunal assemblage for the surf habitat (exposed beach) near Tampa Bay, Fla., which was very similar to that of Horn Island. *Harengula jaguana* was the numerically dominant species collected during the warmer months, followed numerically by *Lagodon rhomboides* and *Menticirrhus littoralis*.

Although a numerically dominant species in the present study, *Anchoa lyolepis* has never been reported as common within a Gulf of Mexico coastal surf habitat. Gunter (1958) reported that *A. lyolepis* was taken only occasionally in the surf zone of Mustang Island, and Naughton and Saloman (1978) found it to be rare in a western Florida surf area. Springer and Woodburn (1960) collected only *A. hepsetus* and *A. mitchilli* from exposed beaches near Tampa Bay. Daly (1970) found *A. nasuta* (synonymized with *A. lyolepis* by Whitehead 1973) to be uncommon on the western tip of south Florida, although it ranges from Cape Hatteras, N.C., into the Gulf of Mexico through the West Indies to the Gulf of Venezuela (Daly 1970). In Mississippi Sound, Christmas and Waller (1973) occasionally collected *A. nasuta* of 36-59 mm SL in higher salinity water (20.0-35.5‰). Their data, based on several years of observation, indicated that *A. nasuta* occurred only in the summer and fall and was never abundant.

In comparing latitudinal variation of surf zone ichthyofaunas Gunter (1958) suggested that the major species occupying the Texas beach were the same or cognates to species observed in North Carolina which were cognates to those reported from New England beaches. Springer and Woodburn (1960) acknowledged that certain similarities existed within broad geographical ranges; however, they pointed out that many dissimilarities existed between temperate and tropical faunas within the eastern United States.

Between-study comparisons are made difficult due to differences in sizes of collecting gear and sampling designs. For instance, McFarland (1963) stated that the small clupeids, particularly the scaled sardine and engraulids, were undersampled because his collecting gear generally eliminated fishes <40 mm SL. However, for the warm-temperate to tropical regions of the Atlantic and Gulf of Mexico there seems to be a very characteristic species assemblage utilizing surf zone areas. Species listed as numerically important in both warm-temperate to tropical Gulf of Mexico and western Atlantic studies (Table 5) were *A. mitchilli*, *A. lyolepis* (= *A. nasuta*), *T. carolinus*, *M. littoralis*, and *H. jaguana* (= *H. pensacolae*). In addition, Atlantic silverside, *Menidia menidia*, and Atlantic menhaden, *B. tyrannus*, in the Atlantic and *M. beryllina* and *B. patronus* in the Gulf were numerically important. *Harengula jaguana* was most frequently reported as numerically dominant along Gulf of Mexico beaches; only Gilmore (1977) found it to have high abundance in the Atlantic surf zone off the Indian River area of Florida. However, the northern limit of this species is in the area of Cape Kennedy on the Florida Atlantic coast (Rivas 1963). Gilmore (1977) also found *A. nasuta* to be abundant in the surf zone along the eastern Florida coast. While *Menticirrhus littoralis* was not among the five most abundant species in some Gulf of Mexico studies (including ours), its high frequency of occurrence in our study indicates that it is an important surf zone species. Based on Table 5, atherinids, primarily of the genus *Menidia*, were more often among the five most abundant species collected in the Atlantic (seven out of nine studies) than Gulf of Mexico surf zones (two out of six studies).

Seasonal and Annual Variations

Temporal changes in both abundance and composition were primary characteristics of the ichthyofauna utilizing surf zone habitats of Horn Island. Fishes collected in our study were most

TABLE 5.—List of the first five numerically abundant fish species collected from the surf zone habitat of marine sandy beaches of the Gulf of Mexico and temperate Atlantic coast states.

Region	Major species	Total no. of species	Reference
Gulf coast:			
Mustang Island, Texas	*Trachinotus carolinus, Harengula jaguana, Mugil curema, Anchoa mitchilli, Micropogonias undulatus*	44	Gunter (1958)
Mustang Island, Texas	*Polydactylus octonemus, Menidia beryllina, Mugil cephalus, Menticirrhus littoralis, Chloroscombrus chrysurus*	48	McFarland (1963)
Gilchrist, Texas	*Brevoortia patronus,*[1] *Anchoa mitchilli, Polydactylus octonemus, Arius felis, Chloroscombrus chrysurus, Trachinotus carolinus*	25	Reid (1955b)
Horn Island, Miss.	*Anchoa lyolepis, Harengula jaguana, Brevoortia patronus, Anchoa hepsetus Trachinotus carolinus*	76	Present study
Panama City, Fla.	*Harengula jaguana, Menidia beryllina, Lagodon rhomboides, Trachinotus carolinus, Mugil curema*	44	Naughton and Saloman (1978)
Tampa Bay, Fla.	*Harengula jaguana, Lagodon rhomboides, Menticirrhus littoralis, Leiostomus xanthurus, Trachinotus carolinus*	47	Springer and Woodburn (1960)
East coast:			
Indian River, Fla.	*Harengula jaguana, Ophisthonema oglinum, Sardinella anchovia, Anchoa hepsetus, A. mitchilli, A. nasuta*[2]	78	Gilmore (1977)
Statewide, South Carolina	*Menidia menidia, Anchoa mitchilli, Trachinotus carolinus, Menticirrhus littoralis, Anchoa hepsetus*	39	Cupka (1972)
Folly Island, S.C.	*Menidia menidia, Anchoa hepsetus, Menticirrhus littoralis, Trachinotus carolinus, Mugil curema*	43	Anderson et al. (1977)
Beaufort, N.C.	*Menidia menidia, Anchoa mitchilli, Trachinotus carolinus, Menticirrhus* sp., *Fundulus majalis*	8	Pearse et al. (1942)
Beaufort, N.C.	*Brevoortia tyrannus, Anchoa hepsetus, Membras martinica, Lagodon rhomboides, Menticirrhus littoralis*	40	Tagatz and Dudley (1961)
Fire Island, N.Y.	*Sphoeroides maculatus, Alosa aestivalis, Poronotus triacanthus, Morone saxatilis, A. mediocris*	71	Schaefer (1967)
Long Island, Conn.	*Menidia menidia, Fundulus majalis, Menidia* sp. (immature), *Brevoortia tyrannus, Fundulus heteroclitus*	35	Hillman et al. (1977)
Pine Orchard, Conn.	*Menidia menidia, Sphoeroides maculatus, Brevoortia tyrannus, Pseudopleuronectes americanus, Syngnathus peckianus*	13	Merriman (1947)
Morris Cove, Conn.	*Menidia menidia, Brevoortia tyrannus, Syngnathus fuscus, Clupea harengus, Pseudopleuronectes americanus*	32	Warfel and Merriman (1944)

[1]Abundance of *Brevoortia patronus* was considered distorted due to the coincidence of a large school of adults moving inshore during the sampling effort.
[2]Equal numbers of *Anchoa mitchilli* and *A. nasuta* collected.

abundant during the summer, although the onset of high fish density varied somewhat between years. High numbers of fishes first appeared in June in 1976, but not until August in 1975 and July in 1977. Annual variability in the time of peak catch may be due, in part, to short-term variation in local water conditions. The low numbers of fishes collected in July 1976 may have been due to unusually calm and clear water which increased net avoidance. Large numbers of fishes were collected during the predawn hours of July 1976, indicating that fishes were abundant along the beach during this period.

Similar changes in the abundance of surf zone fishes have been observed in other studies. Gunter (1958) reported that fishes occupying the exposed beach of Mustang Island underwent seasonal succession during which fish abundance was greatest during the summer and least in the winter. Seasonal changes in abundance were also reported by Springer and Woodburn (1960), McFarland (1963), Schaefer (1967), and Anderson et al. (1977). McFarland (1963) proposed four categories of seasonal occurrence for surf zone fishes: all-year residents, spring-summer residents, summer residents, and winter residents. Of the major species common to both McFarland's study and ours, sea catfish, *Arius felis*; *Mugil cephalus*; and *L. rhomboides* were considered as all-year residents, whereas *H. jaguana*; *Anchoa* sp.; *T. carolinus*; *Menticirrhus littoralis*; king whiting, *M. saxatilis*; and southern kingfish, *M. americanus*, were classified as spring-summer residents. McFarland noted, as we have, that fishes characteristic of the spring and summer dominated the numerical component of the ichthyofauna.

The influx of denatant migrants collected within the surf zone during the winter in our study has not been reported previously. However, the annual movement of larval menhaden and sciaenids into estuaries along the Gulf of Mexico and Atlantic coasts during the winter is well documented (Gunter 1967; Dahlberg 1972; Christmas and Waller 1973). These species likely did not utilize the surf zone specifically, but were concentrated along the island before moving through the barrier island passes. Therefore, their appearance within the surf zone habitat appears dependent more upon wind and current movements rather than habitat preference.

Throughout our study *A. lyolepis* and *H. jaguana* clearly dominated the numerical component of the surf zone ichthyofauna; however, differences in the rank of the remaining species did occur. Gunter (1958) suggested that intraseason species abundance in the surf zone of Mustang Island changed annually, although *T. carolinus* and *H. jaguana* were generally present in considerable numbers. Reid (1956) observed that the greater number of the surf zone ichthyofauna along the Texas coast, with the exception of *B. patronus*, was similar during successive summers. Star drum, *Stellifer lanceolatus*, was considerably more abundant during the second summer as were *T. carolinus*, *M. littoralis*, and *M. americanus*. During the first summer of a 3-yr study, Schaefer (1967) observed butterfish, *Peprilus triacanthus*, as the numerically dominant species within the surf zone of Fire Island, N.Y. In the remaining two summers of his study, northern puffer, *Sphoeroides maculatus*, was the most numerous species.

Factors Affecting Occurrence

The dominant factors affecting the abundance of fishes within the surf zone of Horn Island were tide level, time of day, and temperature. The frequency of engraulids and clupeids was closely associated with time and tide. However, during the summer sampling periods, when fish abundance was greatest in the early morning, tide levels were also highest. Consequently, the effect of the two factors is difficult to separate. Subsequent research (Ross unpubl. data) indicates that both may be important, although Roessler (1970) found that the frequency of *H. jaguana* collected from southern Florida was not significantly related to tidal fluctuation. Seasonal changes in temperature appeared to be of most importance in affecting the frequency of *T. carolinus* and *M. littoralis*.

The pronounced daily variation in occurrence of the most abundant fishes (i.e., *A. lyolepis*, *A. hepsetus*, and *H. jaguana*) indicates that they are not as permanently associated with the surf zone habitat as the gulf kingfish and the Florida pompano. Diel catch rates showed that engraulids and clupeids largely moved out of the surf zone during the day, whereas, the gulf kingfish and Florida pompano exhibited little change in daily abundance. Predator avoidance may be an important reason for the high early morning densities of the clupeoid fishes.

Other studies have also documented the influence of time of day and tidal cycle on fish abundance in surf areas. Merriman (1947) found that shore zone fishes in Connecticut had activity patterns associated with tide level. The greatest number of fishes occurred during high tide when fish appeared to be actively feeding. Daly (1970) also described daily activity patterns in anchovies collected along south Florida beaches. Anderson et al. (1977) suggested that temperature was the primary factor affecting fish abundance along a South Carolina beach; however, diel changes were not investigated. de Sylva et al. (footnote 3) also found that temperature was the greatest factor in determining frequency of most fishes, whereas salinity was secondary in importance and turbidity had little effect. The importance of temperature and salinity to the abundance and distribution of fishes has been discussed in depth by Gunter (1938, 1945, 1950, 1957) and to some extent by Warfel and Merriman (1944). Warfel and Merriman reported that the greatest and lowest number of fishes appeared relative to high and low temperatures, but that no direct correlation could be made. Gunter (1945, 1957) suggested that temperature was the dominant factor in initiating seasonal migrations and other cyclic activities of fishes along the Texas coast. The interaction of wind direction (i.e., inshore winds) with temperature may further increase the number of fishes in the Horn Island surf zone.

In summary, the Horn Island surf zone is utilized primarily by *H. jaguana*, *A. lyolepis*, *A. hepsetus*, *M. littoralis*, and *T. carolinus*. There is strong seasonal periodicity with the greatest abundance in spring and summer, as well as daily fluctuations due to tide level and time of day. Since the individuals of the above species were primarily late larval and juvenile forms, the importance of surf zone habitats as nursery and refuge areas for certain species should be recognized.

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