Natural and Altered Estuarine Habitats of Penaeid Shrimp[1]

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Abstract

This study demonstrates what can happen to a shrimp nursery area when it is altered by bulkheading. Two areas were chosen — one adjacent to an unaltered vegetative shore and the other near a concrete bulkhead. Both had similar hydrology and sediment types, but differed in the amount of organic detritus in the bottom sediments and in water depth. Intensive sampling over a 10-month period produced 2.5 times more brown shrimp *(Penaeus aztecus)* and fourteen times more than white shrimp *(P. setiferus)* from the natural habitat than the bulkheaded area. This preference for the unaltered habitat depended on the physical rather than the hydrologic characteristics of the habitat.

INTRODUCTION

THE NATURAL HABITATS of the borders of estuaries of the Gulf coast are being altered or destroyed by man. Bulkheading is a common mode of alteration in Galveston Bay, Texas. This study was initiated to determine the effects on populations of postlarval and juvenile brown and white shrimp *(Penaeus aztecus* and *P. setiferus)* of bulkheading natural vegetated shore zones. Some physical and hydrographic measurements were carried out concurrently with the biological sampling to learn what differences in shrimp abundance might be associated with differences in specific estuarine characteristics. The areas chosen for study were in Clear Lake, a small body of water forming a portion of the Galveston Bay system.

DESCRIPTION OF AREA

Clear Lake is a small, protected, brackish-water estuary connected to upper Galveston Bay (Fig. 1). It is about 2.5 miles long, less than 1 mile wide and has a surface area of about 1,000 acres. Average depth is 3-4 feet, excluding a channel dredged to a depth of 6 feet. The channel extends the entire length of Clear Lake and joins a natural channel which links the estuary with upper Galveston Bay. Clear Creek, which discharges into the western end of Clear Lake, provides most of the fresh water although some enters from Mud and Taylor Lakes (Fig. 1). Sediments throughout Clear Lake are fairly uniform and vary mostly in the amount of sand present.

According to the classification scheme of Shepard and Moore (1955), sediments are predominantly silty clays in the center of the estuary, and grade into a mixed zone of sand-silt-clay along the shore.

[1]Contribution No. 223, Bureau of Commercial Fisheries Biological, Galveston, Texas.

This pattern is complicated because the sources of material, topography, water circulation, and modifications by man have altered the arrangement.

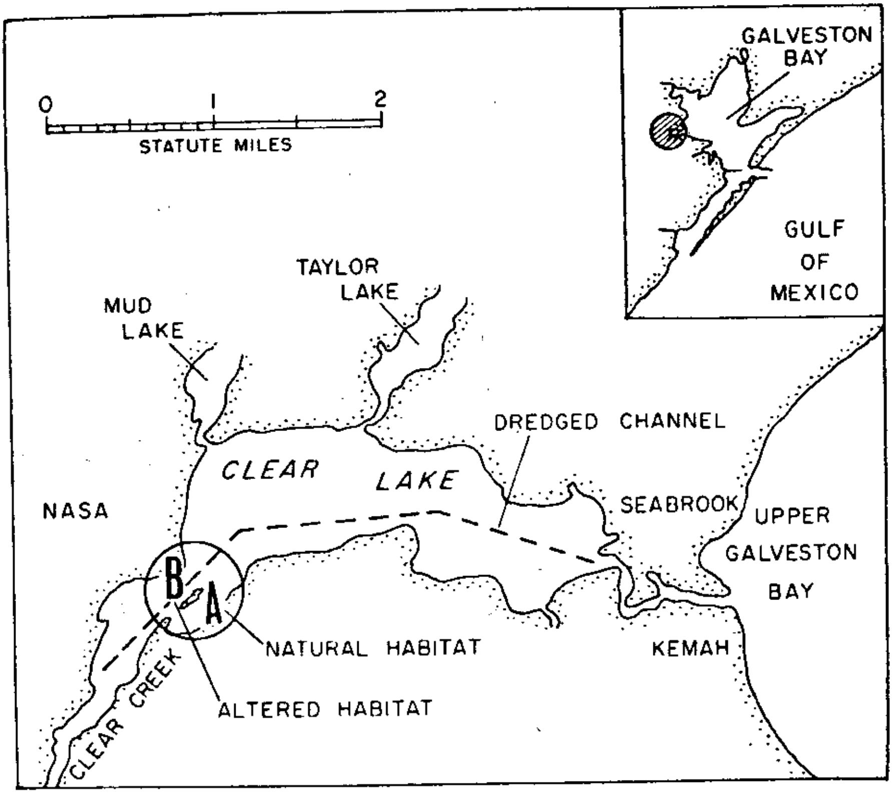

Fig. 1. Map of Clear Lake, Texas, and vicinity.

Two areas were selected in Clear Lake for comparison (Fig. 1). Area A, a typical, vegetated shoreline, still in its natural development, represents the unaltered habitat. Area B was altered by a concrete bulkhead in 1958 (Fig. 2). Even though the two areas are about 1/3 mile apart and opposite each other, their hydrology was nearly identical.

In Area A, a vegetated zone about 120 feet wide extends from the base of a 15-foot bank to the water's edge. Two tidal zones, an upper and lower slope, were distinguished by the height of the tide and vegetation present (Fig. 3).

The shoreline of B (Fig. 3) consists of a concrete bulkhead about 1,000 feet long and 4 feet high with a 1:4-foot slope. The area directly behind the bulkhead, once a vegetated shoreline, was filled with sediments dredged from the lake side of the bulkhead. Private homes and Bermudagrass lawns now cover the area; no natural vegetation is present. Differences in water depths between the two areas are attributed to the bulkhead at B and to dredging in the adjacent bay area (Fig. 3).

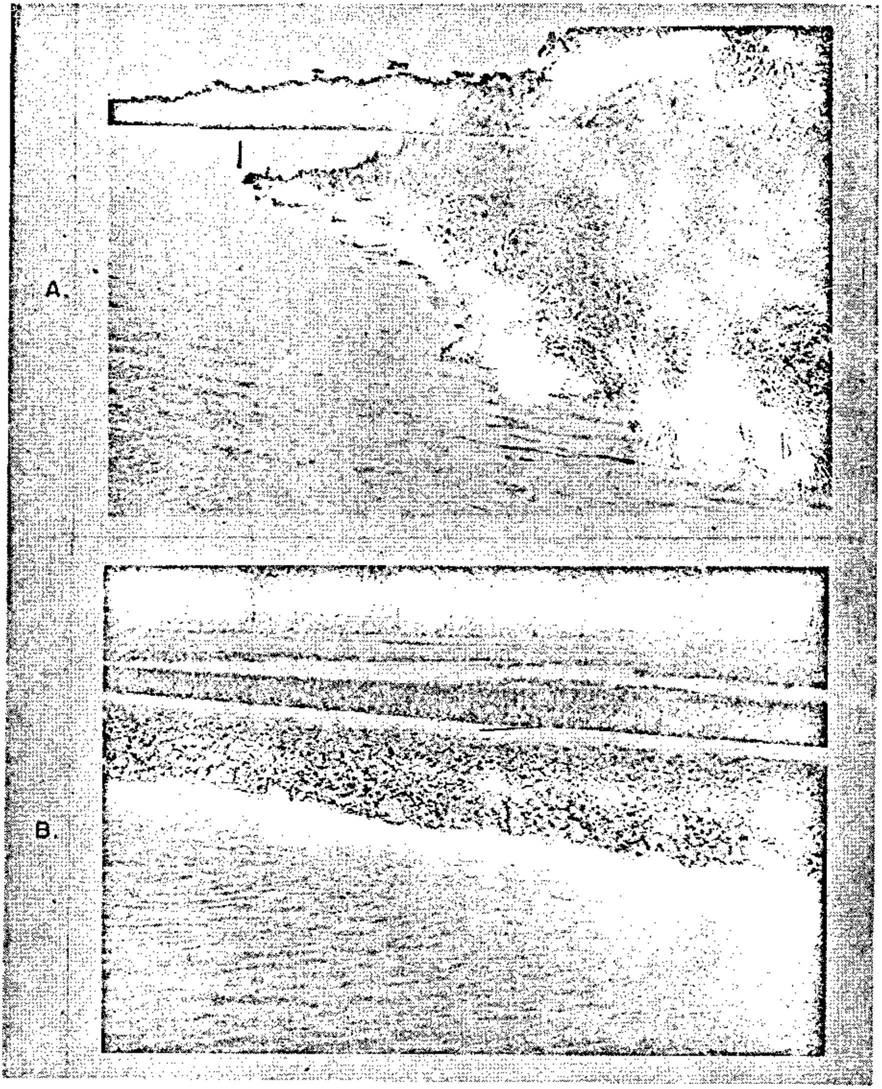

Fig. 2. Study areas. A = Unaltered Area; B = Altered Area.

METHODS

Twenty biological samples were obtained at irregular intervals between March 4 and December 8, 1965.

Personnel of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas, developed a new type of shrimp collecting gear

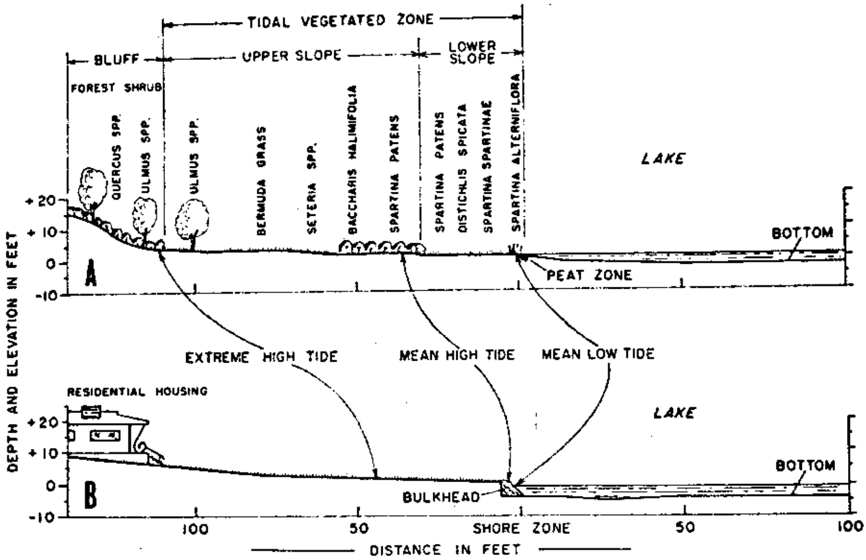

Fig. 3. Diagrammatic profile sketch of unaltered area A and altered area B.

(unpublished manuscript[3]) to obtain comparable samples from a variety of bottom types, including those which occur in areas A and B. A 93-foot line connected to a 7-foot bridle was attached to the front of this "marsh net." Dragging distance, therefore, was 100 feet and the area sampled was 176 square feet (16.3 square meters).

Three zones, one along the shore and the other two 50 and 100 feet from shore, respectively, were sampled parallel to the shoreline in each area. A 100-foot polyethylene line, marked at 50-foot intervals with corks, was positioned perpendicular to the shore; one end was anchored at the waterline and the offshore end was held in position by a weight placed on the bottom. After the transect line was set, the marsh net was lowered from the bow of the skiff to the lake bottom at the 100-foot cork. The skiff was then backed parallel to the shore until the 100-foot retrieving line was played out. The net was then pulled back to the skiff by hand. This method was repeated at 50 feet from shore and at the shore in each area, except along the shoreline of area A. There, the procedure was performed afoot (Fig. 4). Samples were preserved in 10% buffered (borax) formalin and lake water.

Biological samples were sorted in the laboratory, and brown and white shrimp were identified from the descriptive characteristics given by Pearson (1939) and Williams (1953). The shrimp then were divided into postlarval and juvenile groups on the basis of their total length

[3]"A net for sampling the intertidal zone of an estuary" by Edward J. Pullen, Cornelius R. Mock, and Robert D. Ringo, Bureau of Commercial Fisheries Biological Laboratory. Galveston, Texas. 6 Ms. pp., 2 figs.

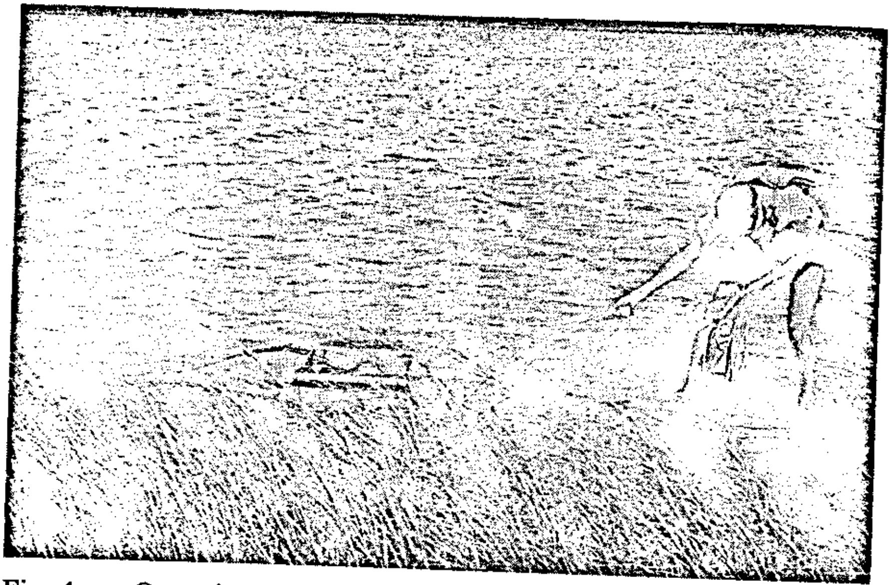

Fig. 4. Operation of the marsh net along the shore.

(from tip of rostrum to tip of telson) according to Renfro (1963). Shrimp 5 mm to 24.9 mm long were classified as postlarvae and those 25 mm to 89.9 mm long as juveniles.

Bottom water samples were collected with a Kemmerer sampler and salinities were determined in parts per thousand (ppt) (Marvin, Zein-Eldin, May, and Lansford, 1960). Bottom temperatures were measured *in situ* with a portable telethermometer and read to the nearest degree centigrade. Tidal stage and water elevation were noted visually during each collection.

On three occasions, sets of duplicate substrate samples were taken with an Eckman dredge at 5- and 10-foot intervals along each transect. Only ½ inch of sediment was removed from the dredge to sample the surface material of the bottom. These samples were analyzed for proportions of sand, silt, clay, and total organics. Sand was separated by means of standard sieves; silt and clay were identified with a soil hydrometer according to procedures employed by the U.S. Army Corps of Engineers.[3] Total organic content was determined by ignition of dried sediment samples at 1150F for 2 hours. Major types of vegetation were identified and a visual estimate made of their relative abundance.

PHYSICAL AND HYDROGRAPHIC CHARACTERISTICS

Bottom sediment along the shoreline zone at A contained a higher percentage of organic detritus than elsewhere (Fig. 5, Table 1). To pinpoint the extent of the organic material numerous samples were taken

[3]From unpublished report, Galveston District Soils Laboratory, Fort Point, Galveston, Texas.

along the measured transect line in each area. The organic mat, or peat bed, extended only 2 feet from the edge of vegetation toward the open water of the system. Examination of sedimentary facies from this zone revealed that the organic material always constituted more than 40% of the sample. Farther from shore, organics represented not more than 6% of the total sample. Corresponding samples tested from B never exceeded 6% organic matter, even along the shore.

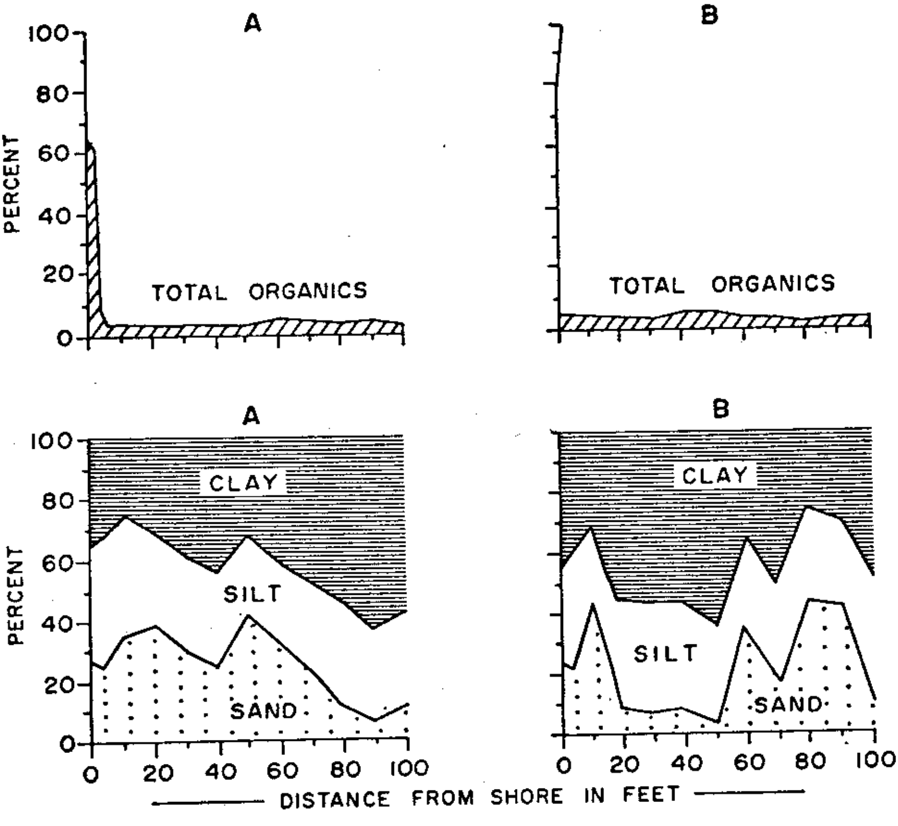

Fig. 5. Percentages of sand, silt, clay, and total organics along transect lines for the unaltered area A and the altered area B.

Sediment characteristics along the 100-foot transect at A consist of a rather uniform mixture classified as sand-silt-clay after Shepard and Moore (1955). Between 50 feet and 100 feet from shore, the amount of clay increases and sand decreases so that beyond 80 feet the sediments are silty clay. The amount of silt was almost constant throughout the transect, ranging from 25% to 43%. This orderly arrangement and progression of sediments was not present along the transect at B. Instead, sediments varied alternately between sand-silt-clay and silty clay.

TABLE 1a

PERCENTAGES OF SAND-SILT-CLAY AND TOTAL ORGANICS IN RELATION TO DISTANCE FROM SHORE FOR EACH AREA

Station and distance from shore (feet)	Water depth (inches) MLT[1]	Percent sand Mean	Percent sand Range	Percent silt Mean	Percent silt Range	Percent clay Mean	Percent clay Range	Percent organics Mean	Percent organics Range
Unaltered Area A									
Shore	4	26	22-39	39	20-42	35	30-41	63	42-84
1	4							58[2]	
2	5							60[2]	
3	7							3[2]	
4	10							3[2]	
5	11	25	20-30	43	41-47	32	29-34	3	2- 5
10	15	35	20-43	40	30-52	25	22-27	3	1- 5
15	20	37	32-44	35	26-44	28	25-30	4	2- 6
20	21	38	35-44	32	25-38	30	25-31	5	4- 6
30	21	29	25-33	32	26-38	39	35-41	4	4- 4
40	23	25	21-30	31	24-40	44	44-45	4	3- 4
50	23	42	40-46	26	20-31	32	30-34	3	1- 5
60	25	33	20-37	25	20-36	42	38-44	6	5- 6
70	25	23	20-30	30	28-33	47	37-52	5	5- 5
80	24	12	10-13	35	30-41	53	50-57	4	3- 5
90	26	6	4-10	30	28-34	64	62-68	5	4- 6
100	26	11	7-15	31	24-37	58	50-61	3	1- 5

[1]MLT—mean low tide.
[2]One set of samples.

TABLE 1b.

PERCENTAGES OF SAND-SILT-CLAY AND TOTAL ORGANICS IN RELATION TO DISTANCE FROM SHORE FOR EACH AREA

Station and distance from shore (feet)	Water depth (inches) MLT[1]	Percent sand Mean	Percent sand Range	Percent silt Mean	Percent silt Range	Percent clay Mean	Percent clay Range	Percent organics Mean	Percent organics Range
Altered Area B									
Shore	36	23	20-23	32	30-32	45	43-47	5	5- 6
5	36	21	20-23	37	21-42	42	30-56	5	5- 6
10	39	45	42-50	25	20-29	30	30-32	5	5- 5
15	39	23	20-29	32	23-38	45	43-48	5	5- 5
20	39	10	8-15	34	27-41	56	55-58	4	5- 6
30	39	9	7-13	34	29-39	57	55-58	3	3- 4
40	37	10	10-11	33	33-34	57	56-57	6	5- 6
50	35	5	3- 7	31	28-35	64	60-65	6	5- 6
60	34	36	20-40	29	20-38	35	20-50	4	3- 5
70	33	17	15-20	33	29-38	50	48-52	4	4- 4
80	32	44	40-48	31	23-34	25	20-37	2	1- 3
90	32	43	23-49	28	24-30	29	20-43	3	3- 3
100	29	14	10-19	38	30-42	48	45-51	5	4- 6

[1]MLT—mean low tide.

A 15-foot bank which borders the vegetation zone of A serves as a local source of sediments. B is affected only by indirect sedimentation because the bulkhead and grass restrict erosion. Sediments are brought to this area by currents and wind-driven waves.

Bottom temperatures and salinities from each of the three zones (shore, 50, and 100 feet offshore) of areas A and B were usually identical. When differences between the two areas did occur, they never exceeded more than 2C or 2ppt salinity. The observed temperature range was 14-33C at A and 14-32C at B. The two areas each had a salinity range of 8-20ppt.

COMPARISON OF CATCHES IN NATURAL AND ALTERED AREAS

Area A yielded 75% of 1,532 shrimp (*P. aztecus* and *P. setiferus*) collected from the two areas (Table 2). About 2.5 times more *P. aztecus* and 12.5 times more *P. setiferus* were taken at A than at B. Area A also accounted for 76% of the postlarval and 64% of the juvenile stages of *P. aztecus*. The abundance of *P. setiferus* showed an even more marked difference between A and B. Ninety-six percent of the postlarval and 87% of the juvenile stages of *P. setiferus* collected during this study were taken at A.

TABLE 2

DISTRIBUTION OF BROWN AND WHITE SHRIMP BY AREA AND STAGE OF DEVELOPMENT

Species and stage	Area A Number	Area A Percent	Area B Number	Area B Percent	Total Number
Brown					
Postlarval	636	76	203	24	839
Juvenile	270	64	155	36	425
Total	906	72	358	28	1,264
White					
Postlarval	157	96	6	4	163
Juvenile	91	87	14	13	105
Total	248	93	20	7	268
Total	1,154	75	378	25	1,532

The number of shrimp captured along each zone — shore, 50, and 100 feet offshore in each area — revealed that the natural shoreline of A was the more productive (Table 3). This concentration of shrimp along the shore of A held for both species, but was particularly evident for white shrimp. Ninety-eight percent of the white shrimp captured at A were from the shore zone. Grouping the catch data by shrimp stages showed that distribution of postlarvae and juveniles was comparable to that noted for the species as a whole.

The distribution of postlarval brown shrimp of area B followed the same general pattern as that in area A, but numbers were fewer (Table 3). Juveniles of this species, however, were equally distributed along the shore and 50-foot zones of B. Almost all of the 358 shrimp collected from the three zones of B were brown shrimp; only 20 white shrimp were caught (Table 3). Although numbers were fewer, most of the postlarval and juvenile white shrimp were captured 100 feet from shore at B.

BIOLOGICAL AND ECOLOGICAL IMPLICATIONS

The significance of estuaries in the life cycle of white shrimp has been discussed by various workers (Weymouth, Lindner, and Anderson, 1933; Anderson, King, and Lindner, 1949; and Pearson, 1939).

TABLE 3

DISTRIBUTION OF BROWN AND WHITE SHRIMP IN RELATION TO DISTANCE FROM SHORE AND STAGE OF DEVELOPMENT

Area	Species and Stage	Number of Shrimp Captured Per Zone: Shore	Offshore (50 feet)	Offshore (100 feet)
A	Brown			
	Postlarval	467	89	80
	Juvenile	185	54	31
	Total	652	143	111
	White			
	Postlarval	154	2	1
	Juvenile	89	1	1
	Total	243	3	2
	Total	895	146	113
B	Brown			
	Postlarval	109	64	30
	Juvenile	63	54	38
	Total	172	118	68
	White			
	Postlarval	1	0	5
	Juvenile	2	4	8
	Total	3	4	13
	Total	175	122	81
Grand Total		1,070	268	194

It is known that *P. setiferus* spawns in the saline offshore waters. The larvae develop in the open sea, then migrate to the estuarine waters where they adopt a benthic existence along the marginal areas. They remain in the brackish estuaries until they approach maturity, then return to the sea. Less is known about the life history of *P. aztecus*, but it is assumed that the life history of this species is similar to that of *P. setiferus* (Baxter, 1962; Chin, 1960; and Williams, 1965).

Since estuaries are the nursery areas for commercially important shrimp, it is necessary to evaluate accurately the effects of man's increasing activities on the suitability of these areas for young shrimp. The present study illustrates one way in which structural modification of estuaries may have detrimental effects. Comparison of the biological, hydrological, and physical data collected reveals similarities and differences between the unaltered and altered habitats in relation to small shrimp captured. Bottom-water temperatures and salinities were similar at all locations studied. Differences in the abundance of small shrimp, therefore, cannot be attributed to these factors.

100-Foot Zones

Shrimp yields, total organic materials, water depth and sediment types were similar at the 100-foot zones of areas A and B. These were the only two zones in which all characteristics measured were similar, including the relative abundance of shrimp.

50-Foot Zones

The 50-foot zones yielded comparable numbers of shrimp. Organics were low but similar, whereas water depths and sediment compositions differed. These differences evidently were not sufficient, however, to influence the number of shrimp occupying these zones.

Shoreline Zones

The environment of the two shoreline zones differs greatly. It is here that differences in the population of brown and white shrimp are truly significant. The natural shoreline harbors considerably more shrimp than the bulkheaded shoreline.

The organic content is much higher at A than at B, water depth is much less, and there is a lush growth of *Spartina alterniflora*. Sediments are similar at both zones. The shallow, tide-influenced waters at A permit the vegetation to flourish. This vegetation in turn contributes to the high organic content of the sediments. The bulkhead at shoreline B causes a deep-water zone which prevents emergent vegetation from growing.

The shore substrate of A resembles the material which Williams (1958) found satisfactory for shrimp. Although his experiments were confined to laboratory tanks, he found brown and white shrimp most frequently on the softer, muddier substrates — loose peat, sandy mud, and muddy sand. Because no penetrometer measurements were made for sediment densities or compactness at A or B, it is impossible for me to describe this characteristic accurately. Yet, the substrate I found supporting the most shrimp was primarily an organic mat mixed with sand-silt-clay.

Loesch (1965) recently presented field data indicating differences in the natural distribution, with respect to water depth and organic debris, of the two commercial species, *P. aztecus* and *P. setiferus*. He located young shrimp of each species concentrated in shallow waters among attached vegetation and in areas with large amounts of organic debris.

Area A: Summary Appraisal

The natural shoreline harbored significantly more brown and white shrimp than the 50- and 100-foot zones. Furthermore, consistently more small shrimp were caught at the natural shoreline than at any of the zones of B. The occurrence of these specimens indicates that the natural shoreline was the preferred habitat (of those sampled) for young shrimp.

Area B: Summary Appraisal

More postlarval brown shrimp were caught at the bulkheaded shoreline than 50 and 100 feet offshore. Juvenile brown shrimp, however, were equally distributed. So few white shrimp were captured in this area that it evidently did not provide a suitable habitat for this species.

CONCLUSION

The distribution of large numbers of small brown and white shrimp along the natural shoreline in preference to the bulkheaded shoreline was not random. Results of this study indicate that the physical nature of a shoreline may significantly affect its biological suitability for young shrimp. For example, the porous nature and high organic content of the natural substrate at station A may provide both shelter and food. It is evident, therefore, that estuarine shorelines must remain in their natural state if they are to support large numbers of young shrimp.

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