DISTRIBUTION OF AQUATIC MACRO-FAUNA IN A MARSH ON WEST GALVESTON BAY, TEXAS AND POSSIBLE EFFECTS THEREON RESULTING FROM IMPOUNDMENTS FOR SHRIMP CULTURE

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A survey was conducted to identify the macro-fauna of a marsh adjacent to West Galveston Bay, Texas. The factors affecting their distribution were studied for evaluation of changes which might result from large areas of marsh being impounded for shrimp culture.

Results indicate that construction of large-scale impoundments for shrimp culture, at the expense of removing flooded grasslands, would alter the physical features of the marsh and reduce habitats suitable for year-round survival of the stable macro-fauna. In addition, competitor and predator control in these ponds would require the removal of all aquatic macro-fauna other than shrimp. The impact of these changes on the total marsh ecosystem is not known but should be considered and studied in detail before ponds are constructed. Conceivably, marsh areas could be managed so as to insure a reasonable amount of habitat for the stable macro-fauna while allowing ample lands for shrimp culture.

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ABSTRACT

A survey was conducted to identify the macro-fauna of a marsh adjacent to West Galveston Bay. The factors affecting their distribution were studied to help evaluate changes which might result in the event that large areas of the marsh were impounded for shrimp culture.

As a result of frequent tidal floods, saline conditions generally prevailed within the marsh. Freshwater floods resulting from local rainfall were common, but salt leached from the bottom sediments coupled with subsequent tidal floods readily re-established saline conditions.

The fauna consisted of a variety of marine and estuarine species. Those species that were abundant throughout the year and constituted the stable macro-fauna were *Cyprinodon variegatus*, *Fundulus grandis*, *Poecilia latipinna*, *Mugil cephalus*, *Menidia beryllina*, *Palaemonetes sp.*, and *Callinectes sapidus*. These are among the hardiest of coastal aquatic animals and exhibited broad temperature and salinity tolerances.

Marine dependent species were able to enter the marsh during tidal floods and many were trapped when waters receded. Post-larvae of some of these species were able to invade the marsh at normal tide level through narrow, vegetation clogged ditches leading inland from the bay. Conditions were seldom favorable, however, for the return of marine species to the bay. They usually

died as a result of low temperatures during the winter or drought conditions during the summer. These species generally disappeared from the marsh following freshwater floods and it was assumed that they were either forced out into the bay or died as a result of the rapid salinity decline which typically occurred.

Construction of large-scale impoundments for shrimp culture, at the expense of removing flooded grasslands, would alter the physical features of the marsh and reduce habitat suitable for year-round survival of the stable macro-fauna. In addition, competitor and predator control in these ponds would require the removal of all aquatic macro-fauna other than shrimp. The impact of these changes on the total marsh ecosystem is not known but should be considered and studied in detail before ponds are constructed. Conceivably, marsh areas could be managed so as to insure a reasonable amount of habitat for the stable macro-fauna while allowing ample lands for shrimp culture. This could best be accomplished by restricting shrimp culture practices to open water areas, thus avoiding the removal of flooded grasslands. In addition, the pond flumes could be opened to the surrounding marsh during the winter months when temperatures are too low for shrimp culture, allowing the impounded areas to return to a more or less natural state.

INTRODUCTION

The utilization of Texas coastal marshlands has, from an economic standpoint, lagged far behind that of other coastal lands of higher elevation. Historically, these lands have provided fall and winter grazing areas for cattle, and wintering grounds for waterfowl. As our coastal economy expands, however, new demands for these lands are evolving which necessitate extensive modification of existing conditions. To insure that these marshes are developed wisely, a cooperative research program between Texas A&M University, through its Agricultural Experiment Station and Agricultural Extension Service, and the Brazoria County Mosquito Control District, the Dow Chemical Company, and Texaco, Inc., was initiated to study the potential of coastal marshlands in terms of livestock production, waterfowl utilization, and mariculture. This paper deals with those areas of research related to mariculture.

Skud and Wilson (1960) and Diener (1964) have noted, in discussing the productivity of Gulf of Mexico estuaries, that marsh drainage contributes significant quantities of nutrients to estuarine systems. Concern that future large-scale water management practices for mariculture might seriously alter the marsh ecosystem and its relationship with the adjoining estuary prompted a survey to identify the aquatic macro-fauna inhabiting the coastal marshes and the factors affecting their distribution. During the course of this survey three natural marsh ponds were leveed and ten rectangular-shaped ponds were built on dry land for mariculture research. Mariculture has, as yet, been researched only in terms of shrimp culture, but some insight was gained concerning changes in the distribution of the aquatic macro-fauna natural to the area should shrimp rearing practices be instigated on a large scale.

DESCRIPTION OF THE AREA

The research site was a segment of marsh covering some 12,145 ha on the shore of West Galveston Bay in Brazoria County (Figure 1). The area to which this survey was directed was a flooded basin lying between Hayes Ridge and the Intracoastal Canal spoil bank. It consisted of flooded grasslands surrounding a number of stagnant and tidewater ponds. Seahorse saltgrass (Distichlis spicata L. Greene) was the dominant vegetation throughout the flooded grasslands and around the stagnant ponds. Patches of Gulf cordgrass [Spartina spartinae (Trin.) Merr.], marshay cordgrass [S. patens (Ait.) Muhl.], toad rush (Juncus bufonius L.) and common reed (Phragmites communis Trin.) were scattered intermittently within the seahorse saltgrass field and frequently around the edges of stagnant ponds. During the warmer months, many of the stagnant ponds were clogged with widgeongrass (Ruppia maritima L.). Tidewaters in the vicinity of Oyster Lake, and stations A and B were bordered almost exclusively by smooth cordgrass (Spartina alterniflora Loisel). The bayou extending inland from station B was

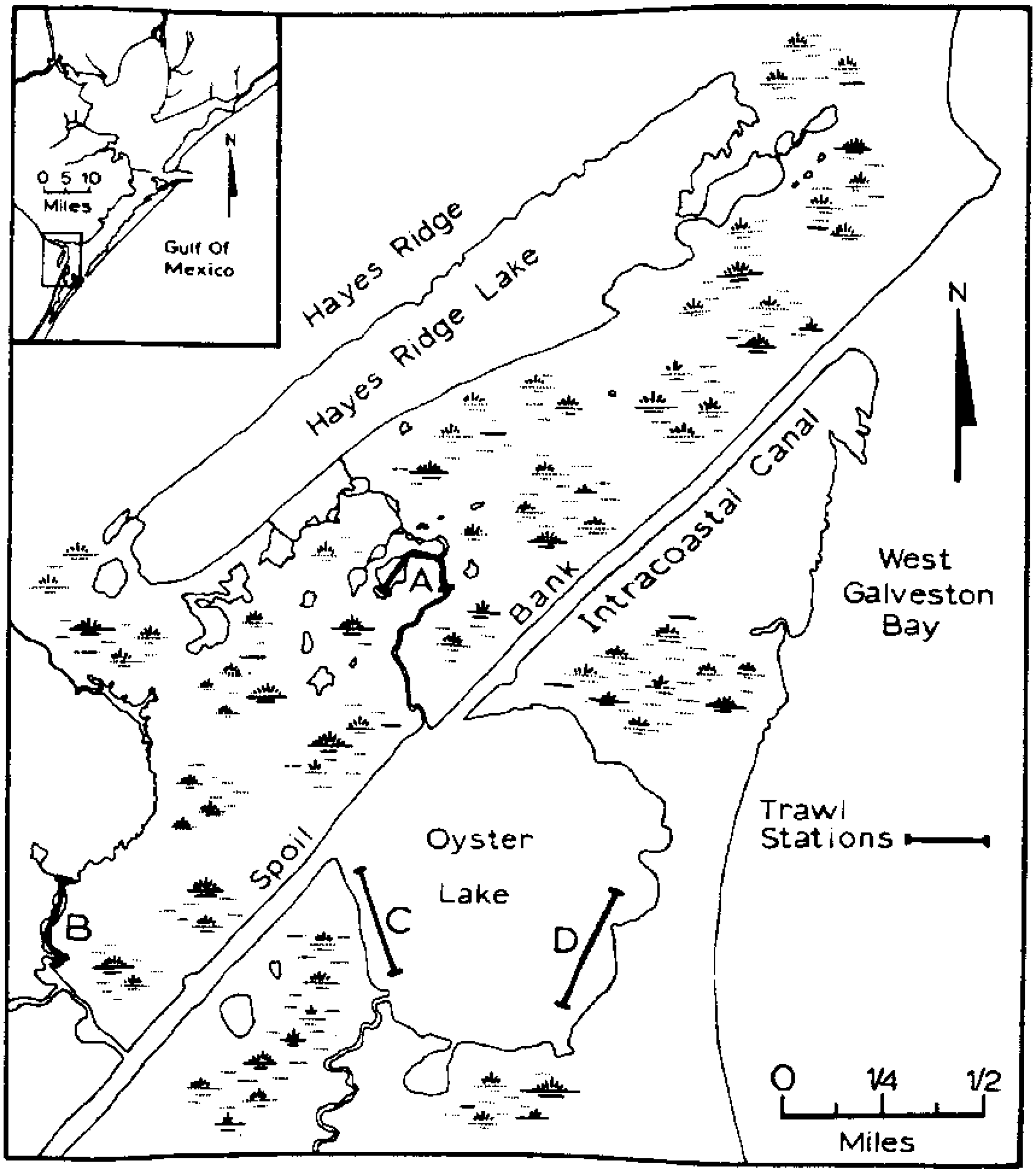

Figure 1. Map of the study area with the location of semi-monthly trawl stations.

bordered primarily by Gulf cordgrass and patches of marshay cordgrass, and toad rush. The seahorse saltgrass occasionally extended to the banks of this bayou. During the spring and fall, tidewaters were clogged with a dense growth of the filamentous brown algae *Ectocarpus siliculosus* (Dillwyn) Lyngbye. The elevation of the flooded marsh varied from mean sea level by approximately ±0.6 m. The highest elevations on Hayes Ridge and the Intracoastal Canal spoil bank were 1.8 and 3.6 m, respectively.

A small bayou carried tidewater into the marsh from Oyster Lake. It narrowed to a shallow ditch of not more than 0.6 m in depth midway between Oyster Lake and Hayes Ridge Lake, and its flow was further restricted by vegetation so that no measurable daily tidal fluctuation occurred in Hayes Ridge Lake. All tidewaters, including the lakes and ponds connected by this bayou as well as the bayou where station B was located were bordered by a natural levee (reaching a height of not more than 0.7 m above mean sea level) that also restricted tidal flow into the marsh. The latter bayou drained approximately 4,048 ha to the west of Hayes Ridge and served as a major channel to the Intracoastal Canal for runoff from local rainfall.

As a result of frequent tidal floods, saline conditions generally prevailed within the marsh. Fresh-water floods resulting from local rainfall were common, but salt leached from the bottom sediments coupled with subsequent tidal floods readily re-established saline conditions. Hypersalinities frequently resulted during extended periods of drought.

MATERIALS AND METHODS

Specimens were collected primarily with an otter trawl of 35 mm stretched mesh in the body and 25 mm stretched mesh in the cod end and measuring 3 m between the boards. A liner of 6 mm stretched mesh netting was attached around the outside of the cod end to collect smaller organisms which filtered through the trawl. The trawl was towed behind a 4.9 m airboat. On occasion, specimens were also collected with cast nets, small seines, and rotenone. When collections were made, water temperature was measured with a Celsius thermometer to the nearest ^{o}C and salinity with an optical density meter to the nearest $^{o}/oo$.

Trawls of 3-minute duration were made in tide waters once every 2 weeks from October 29, 1967, through October 15, 1968, at two stations in the marsh and two stations in Oyster Lake (Figure 1). Seine samples were taken once each season during this period in randomly selected stagnant ponds. Specimens were also sampled from Hayes Ridge Lake in September, 1967, prior to and following a hurricane-produced tide and once the following spring.

Thirteen ponds were constructed between February and July, 1969, for shrimp culture research. Ten were rectangular-shaped, 0.2 ha ponds located on Hayes Ridge at the northeast end of Hayes Ridge Lake. Three natural marsh ponds (their size varied between 1/2 and 1 ha) located near trawl station A were also leveed.

Water levels in these ponds never exceeded 1 m. Weekly seine samples were taken in each of these ponds from April through November, 1969. The results of the shrimp culture experiments are not discussed in this paper, however, information gained during the course of these experiments pertaining to the distribution of the macro-fauna is included.

DISTRIBUTION OF MACRO-FAUNA

Species Present

The tidewater marsh ecosystem is complex and constantly undergoing change. As a result, the species which successfully reside there must be able to adapt to a wide range of conditions. The waters are shallow and afford little protection from low or freezing temperatures during the winter. Gunter and Hildebrand (1951) have reported on fish kills in similar areas resulting from a sudden drop in temperature following a severe cold front. Freshwater flooding, although generally of short duration, prevents these waters from serving as permanent habitat for marine organisms. Summer drought conditions coupled with low tides are equally restrictive to all but the species which are tolerant to extremely high temperatures and salinities. In addition, the destruction of the marsh resulting from the turbulence generated by hurricanes can be a severe limiting factor. Tabb and Jones (1962) found dead marine fish and invertebrates in a Florida marsh following a hurricane tide and attributed death to oxygen depletion caused by the build-up of organic matter. They also found fish and invertebrates killed either by mud suffocation or turbulence.

The species found during the survey are listed in Table 1. Those that were known to be marine dependent (i.e., spend, as a necessity, some portion of their life cycle in the Gulf or estuary) are denoted by the letter M. Based on their frequency of occurrence in samples, the relative abundance of these species was indicated on a seasonal basis in both tidal and stagnant waters as rare (R), uncommon (U), common (C), and abundant (A).

Those species that were abundant in both tidal and stagnant waters throughout the year, were Cyprinodon variegatus, Fundulus grandis, Poecilia latipinna, Mugil cephalus, Menidia beryllina, Palaemonetes sp., and Callinectes sapidus. These species represented the stable aquatic macro-fauna of the marsh and appeared to be capable of surviving over a wide temperature and salinity range. They were observed alive in temperatures ranging from 5 to 37 C and in salinities ranging from 1 to 45^{o}/oo. Gunter (1950) found these fish species common in salt marshes on the Aransas Wildlife Refuge. Renfro (1960) considered them among the hardiest of the smaller fishes along the Gulf coast and found them in his collections when temperature and salinity were at extreme levels. Parker (1965) listed these fish species among those common year round in the shallow waters of Galveston Bay. Strawn and Dunn (1967) found Cyprinodon variegatus and Fundulus grandis tolerant to temperatures

TABLE 1. Seasonal abundance of species found in a marsh and tidewater area adjacent to West Galveston Bay, Texas.

SPECIES	RELATIVE ABUNDANCE							
FISHES	Tidewater				Stagnant Water			
	W	S	S	F	W	S	S	F
Dasyatis sabina (Atlantic stingray) M		C	C					
Lepisosteus osseus (Longnose gar)		U	U					
Lepisosteus spatula (Alligator gar)	C	C	C	C				
Elops saurus (Ladyfish) M		C	C			R	R	
Brevoortia patronus (Large-scale menhaden) M	U	A	A	C	R	C	C	C
Dorosoma petenense (Threadfin shad)		U	U					
Anchoa mitchilli (Bay anchovy) M	A	A	A	A	R	C	C	C
Synodus foetens (Inshore lizardfish) M	U	C	C	C				
Cyprinus carpio (Carp)			R					
Bagre marina (Gafftopsail catfish) M	U	C	C	C				
Galeichthys felis (Sea catfish) M	U	C	C	C				
Myrophis punctatus (Speckled worm eel) M	U	U	U	U			C	
Adinia xenica (Diamond killifish)							U	
Cyprinodon variegatus (Sheepshead minnow)	A	A	A	A	A	A	A	A
Fundulus grandis (Gulf killifish)	A	A	A	A	A	A	A	A
Fundulus similus (Longnose killifish)	C	C	C	C	C	C	C	C
Fundulus pulvereus (Bayou killifish)			U				U	
Lucania parva (Rainwater killifish)			U				U	
Gambusia affinis (Mosquitofish)			U			C	C	
Poecilia latipinna (Sailfin molly)	A	A	A	A	A	A	A	A
Chloroscombrus chrysurus (Bumper) M			R					
Orthopristis chrysopterus (Pigfish) M	U	C	C	C			C	
Bairdiella chrysura (Silver perch) M		U	C	R				
Cynoscion arenarius (Sand seatrout) M	C	C	C	C				
Cynoscion nebulosus (Speckled seatrout) M	C	C	C	C				
Leiostomus xanthurus (Spot) M	A	A	C	C		A	C	
Menticirrhus americanus (Southern kingfish) M			U					
Micropogon undulatus (Atlantic croaker) M	A	A	A	C		C	U	
Pogonias cromis (Black drum) M	C	C	C	C			C	
Sciaenops ocellata (Red drum) M	C	C	C	C			U	
Stellifer lanceolatus (Star drum) M		U	C	U				
Archosargus probatocephalus (Sheepshead) M	C	C	C	C				
Lagodon rhomboides (Pinfish) M	C	C	C	C		C	C	
Trichiurus lepturus (Atlantic cutlassfish) M	C	C	C	C				
Gobionellus boleosoma (Darter goby) M		U	U	U				
Gobionellus hastatus (Sharptail goby) M		U	U	U				
Gobiosoma bosci (Naked goby) M		U	U	U				
Prionotus tribulus (Bighead searobin) M		U	U	U				
Mugil cephalus (Striped mullet)	A	A	A	A	A	A	A	A
Menidia beryllina (Tidewater silversides) M	A	A	A	A	A	A	A	A
Polydactylus octonemus (8-fingered threadfin) M	U	C	C	C				
Citharichthys spilopterus (Bay whiff) M	U	C	C	U				
Paralichthys lethostigma (Southern flounder) M	C	C	C	C		U	U	
Symphurus plagiusa (Blackcheek tonguefish) M	U	C	C	C				
Sphaeroides nephelus (Southern puffer) M	U	C	C	C				
Opsanus beta (Gulf toadfish) M			U					
CRUSTACEANS								
Penaeus aztecus (Brown shrimp) M		C	C	U		C	C	U
Penaeus setiferus (White shrimp) M	U		C	C			C	C
Palaemonetes sp. (Grass shrimp)	A	A	A	A	A	A	A	A
Callinectes sapidus (Blue crab) M	A	A	A	A	A	A	A	A

up to 42 C throughout the salinity range 0 to 22^{o}/oo and considered salt-marsh fishes to be well adapted to brackish waters at normal temperatures. Wood (1967) found Palaemonetes pugio tolerant to salinities ranging from 0.1 to 33.9^{o}/oo. Hedgpeth (1950) noted that the dominant invertebrate of salt flats on the Aransas Wildlife Refuge was Callinectes sapidus and that Palaemonetes intermedius was probably ubiquitous on the area. Conte (1971) observed Palaemonetes pugio and P. vulgaris common throughout the survey area shown in Figure 1.

Of these stable macro-fauna, Cyprinodon variegatus, Fundulus grandis, Poecilia latipinna, and Palaemonetes sp. were periodically observed in spawning condition in the leveed natural salt-marsh ponds used for shrimp culture experiments. The later appearance of young-of-the-year in these ponds established the ability of these four species to complete their entire life cycle within the marsh.

Three fresh-water species, Lepisosteus osseus, L. spatula, and Cyprinus carpio, were collected at station B during a period of fresh-water flooding. These fish probably come from a rice canal which emptied into the other fork of the bayou. This canal was the nearest permanent fresh-water source.

Effect of Tidal Flooding

The waters of the marsh which flow with the tide serve as a nursery area for many of the marine-dependent animals. The most common of these were Brevoortia patronus, Anchoa mitchilli, *Cynoscion arenarius*, *C. nebulosus*, *Leiostomus xanthurus*, *Micropogon undulatus*, *Pogonias cromis*, *Sciaenops ocellata*, *Penaeus aztecus*, *P. setiferus*, and *Callinectes sapidus*.

Trent (1969) found, in studying the abundance of aquatic macrofauna in a West Galveston Bay marsh, that young *Leiostomus xanthurus* concentrated at stations fartherest from the bay. He also noted that *Brevoortia patronus*, *Anchoa mitchilli* and *Micropogon undulatus* were abundant throughout his study area. Parker (1971B) observed high concentrations of young *L. xanthurus* (about 92 percent of his catches) at marsh stations A and B (Figure 1) and high concentrations of young *M. undulatus* at station B. He concluded that the shallow waters of Galveston Bay (water depths less than 1.2 m), and especially those in the vicinity of marshes, were the prime nursery grounds for both species. Trent (1969) found *Penaeus aztecus* abundant throughout a West Galveston Bay marsh and Conte (1971) found high concentrations of *Penaeus aztecus*, and *P. setiferus* throughout the tidewaters shown in Figure 1. Parker (1971A) noted that the shallow waters of Galveston Bay, and especially those in the vicinity of marshes, were prime nursery grounds for *P. aztecus*.

Tidewaters periodically flood the marsh behind the natural levees bordering the normal tidal zone, and on these occasions, marine-dependent animals are able to invade this area. The frequency of tidal flooding in this marsh during the period from September, 1967 through August, 1968 is indicated in Figure 2.

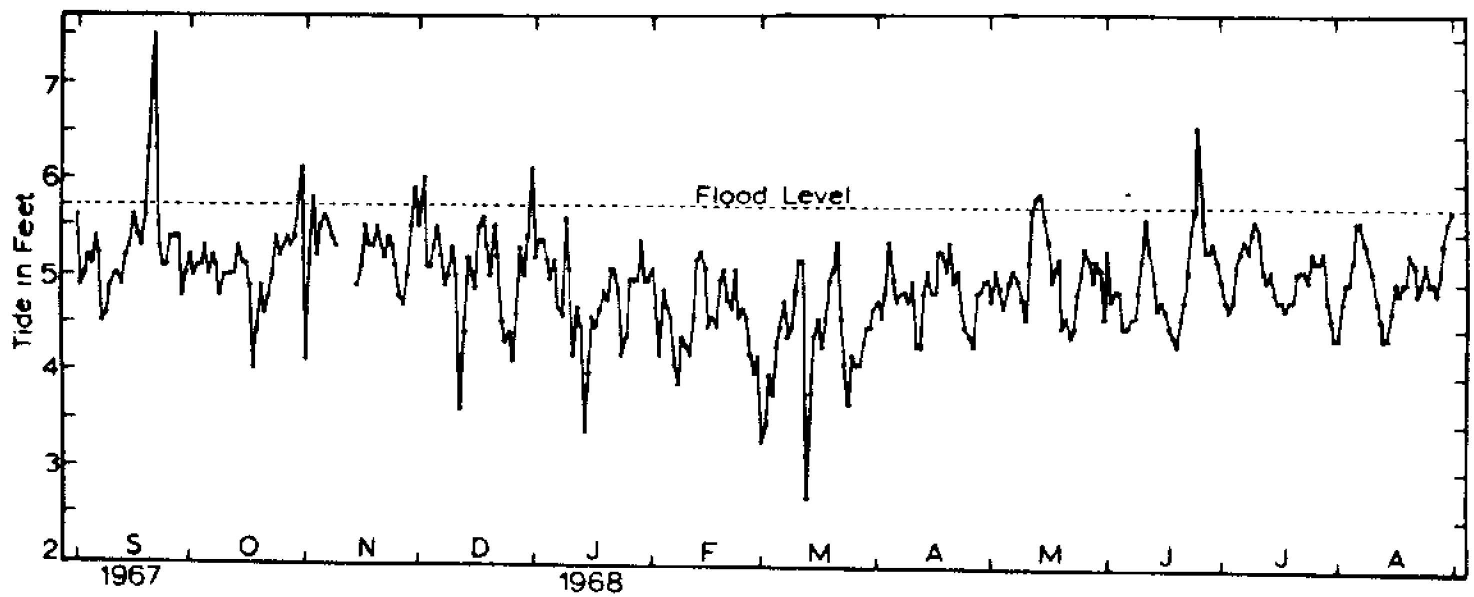

Figure 2. Daily high tides at Freeport, Texas, from September 1, 1967 through August 31, 1968 and the relative level at which marsh flooding occurred.

Tide readings were obtained from Dow Chemical Company's gauge at Freeport and were correlated with tidewater elevations in the marsh in order to establish the level at which flooding above the natural levees occurred. This tide gauge was located approximately 29 km south of the study area and about the same distance inland from the Gulf.

During the period from September 19 to 21, 1967, the marsh was flooded by tides from Hurricane Beulah which went inland September 20 near Brownsville, Texas. This tide reached a height of 1.2 m above mean sea level and was the first tidal flood of the year. Winds did not exceed 30 miles per hour. Trawl samples were taken in Hayes Ridge Lake on the morning of September 19, prior to flooding, and on September 26, after flood waters had receded. In both instances, the trawl effort consisted of one 20-minute and two 5-minute trawls. A trawl liner was not used for these samples. The organisms found before and after this tidal flood along with other relevant data are presented in Table 2.

Of the four fish species present before flooding, only Menidia beryllina remained after the tidewaters had receded and this species increased in numbers. Cyprinodon variegatus and Mugil cephalus were scarce before flooding and could easily have been missed in samples taken following the flood. Fundulus grandis was absent from samples taken before flooding, but was found in nearby ponds two weeks earlier and was evidently missed in these particular trawls. The

TABLE 2. Species collected from Hayes Ridge Lake before and after flooding by tides from Hurricane Beulah.

Species	Before Flooding Number Caught	Before Flooding Total Length Range (mm)	Before Flooding Mean Length	After Flooding Number Caught	After Flooding Total Length Range (mm)	After Flooding Mean Length
FISH						
Anchoa mitchilli				19	32-66	46
Cyprinodon variegatus	1	88				
Fundulus grandis				8	62-86	74
Chloroscombrus chrysurus				2	65-70	68
Menticirrhus americanus				1	51	
Pogonias cromis	10	156-216	173			
Archosargus probatocephalus				1	115	
Lagodon rhomboides				3	93-126	106
Prionotus tribulus				34	33-70	50
Mugil cephalus	1	183				
Menidia beryllina	33	56-107	78	107	46-99	65
Citharichthys spilopterus				8	46-71	56
Symphurus plagiusa				4	41-62	49
CRUSTACEANS						
Penaeus aztecus	20	112-148	126	51	49-123	84
Penaeus setiferus	47	124-146	136	275	31-126	73
Palaemonetes sp.	*			*		
Callinectes sapidus	9	115-159	135	379	18-171	42

*Present in abundance but not counted or measured.

disappearance of Pogonias cromis during the flood was probably evidence of the tendency of this species to migrate from the shallows to the open bay once they reach a length of about 100 mm (Pearson, 1929). These fish probably entered the lake through the small bayou connecting it to tidewaters during the spring and early summer, when they were common in the tidewaters and small enough to swim through the vegetation which clogs the bayou. They likely grew too large to re-enter the bayou and were trapped until the flood provided access to the bay.

The intrusion of marine fishes with this tide was evidenced by the appearance of Anchoa mitchilli, Chloroscombrus chrysurus, Menticirrhus americanus, Archosargus probatocephalus, Lagodon rhomboides, Prionotus tribulus, Citharichthys spilopterus, and Symphurus plagiusa.

Judging from the size range and mean length of Penaeus aztecus and P. setiferus, the majority of these shrimp present prior to flooding returned to the bay during the flood and were replaced by smaller forms. Both species, according to Lindner and Anderson (1956), Trent (1966), and Parker (1971A), were larger prior to the flood than are brown and white shrimp typically found emigrating to the Gulf. As with Pogonias cromis, their disappearance during the short period when tidewaters covered the marsh was probably indicative of their readiness to emigrate either to the open bay or the Gulf and suggests that no other exit from the lake was available to them prior to the flood. The smaller shrimp brought in from the bay with the tide were juveniles which had not attained emigration size.

Callinectes sapidus was present before and after flooding and the reduction in the mean length of both males and females following the flood resulted from the introduction of a larger number of small crabs from the bay. The numbers of large crabs was about equal before and after flooding and probably evidences the non-migratory habit of all but the gravid females of this species. According to Daugherty (1952), only the gravid female blue crab returns to the Gulf to spawn and no gravid females were observed either before or after tidal flooding.

Hayes Ridge Lake was not sampled again until March of the following spring. At that time only the stable, though scarce, macro-fauna--Cyprinodon variegatus, Fundulus grandis, Poecilia latipinna, Mugil cephalus, Menidia beryllina, Palaemonetes sp., and Callinectes sapidus--were present. Although the marsh was flooded by tides on three occasions between September and March, the water level did not rise above the vegetation. It is doubtful that many of those organisms present in September emigrated to the bay through the thick vegetation during these floods. Rather, it was assumed that those animals introduced by the September tidal flood, as well as many of the stable macro-fauna, were killed by low temperatures during the winter.

Immigration of Marine Species Into the Marsh Under Normal Tidal Conditions

No tidal floods occurred in the marsh during 1967 prior to September, and it was assumed that the marine species present in Hayes Ridge Lake prior to the hurricane tide entered the lake from the bay as postlarvae during the spring and summer and grew to juvenile size by September. It was observed that postlarval shrimp invading the surrounding tidewaters saturate the area to such an extent that many could have found their way through the small winding bayous from the tidewaters into Hayes Ridge Lake. Presumably the postlarvae of other marine species could accomplish this same journey.

In an attempt to substantiate this assumption, efforts were made during 1969 to determine the extent to which brown and white shrimp penetrate this marsh under normal tidal conditions. Unfortunately, the influx of brown shrimp postlarvae and juveniles into the surrounding bay waters was meager and what few that were collected were not found beyond the near vicinity of the marsh trawl stations (A and B in Figure 1). White shrimp postlarvae, however, did enter the area in large numbers during October and November and were observed in Hayes Ridge Lake and throughout the small vegetation-clogged bayous connecting it with the tidewater lakes. Presumably, postlarvae of other marine species, when present in large concentrations, could distribute in much the same manner.

White shrimp juveniles were present in large numbers during the same period in the vicinity of the marsh trawl stations but were not observed in the small bayous leading to Hayes Ridge Lake. The waters were shallow and clear in this bayou and probably did not provide these juveniles adequate protection from predators. In any event these small bayous did not appear to provide suitable access to the bay for marine species reared in the marsh ponds.

Effect of Freshwater Flooding

The marsh was flooded as a result of heavy local rainfall on numerous occasions during the course of the survey. The extent to which conditions approached those of a fresh-water environment were short term and depended upon the amount of rainfall per unit time, the level of water in the marsh basin, and the height of tides during and following the rain. Fresh-water conditions occurred whenever rainfall amounted to enough to flood the basin above the level of the natural levees. A flushing action of flood waters over an extended period of time was necessary to remove the saline water. High tides dampened the flushing effect.

On April 28, 1968, 10.2 cm of rain fell in a 5-hour period. The salinity in Hayes Ridge Lake dropped from 14 to $1^{o}/oo$ within 24 hours, and the marsh was flooded to about 0.9 m above mean sea level. The only species present following the rain were *Cyprinodon variegatus*, *Fundulus grandis*, *F. similis*, *Poecilia latipinna*, Mugil cephalus, Palaemonetes sp. and Callinectes sapidus. Marine species which disappeared included Brevoortia patronus, Anchoa mitchilli, Leiostomus xanthurus, Micropogon undulatus, Menidia beryllina, and Penaeus aztecus, and it was assumed that these were either forced out into the bay or died as a result of the rapid salinity change. Tides during this period (Figure 2) were below the marsh flood level. Within 2 weeks, the salinity in Hayes Ridge Lake had risen to $12^{o}/oo$ as a result of salt leached from the bottom sediments. The variety of species present did not change, however, until tidal floods brought in marine fauna during mid-May and late-June.

Effect of Droughts

Drought conditions occurred to varying degrees in the marsh during July, August, and September in both 1968 and 1969, but seldom prevailed for extended periods. They were the combined result of low tides and lack of rain. Except under the most adverse conditions, the stable macro-fauna were usually able to tolerate the high temperatures and salinities which resulted. During a drought in July and August, 1969, the entire marsh was dry and all species trapped in this area perished. On one occasion before the waters evaporated, specimens of the stable macro-fauna were observed alive and apparently not under stress in a stagnant pond in which the temperature measured 37 C and the salinity $45^{o}/oo$. The drought ended when tidewaters flooded the marsh in September. The stable macro-fauna returned with this tide along with a number of marine species.

Effect of Temperature

The lethal effect of low temperatures on aquatic macro-fauna was observed on two occasions. Specimens of Cyprinodon variegatus were found both dead and in shock on January 6, 1968, in flooded grasslands where the water temperature measured 2 C. Specimens of Penaeus setiferus were observed dead and in shock in the rectangular ponds used for shrimp culture experiments following passage of two cold fronts during November, 1969. The first front reached the area on the afternoon of November 14 and the second on the afternoon of November 18. The daily high and low air temperatures from November 10 through November 25 are listed in Table 3 to illustrate the drastic temperature changes which occurred as a result of these fronts. Hundreds of shrimp were observed dead or in shock in each pond on the morning of the 14th and 15th and again on the mornings of the 19th, 20th, and 21st. On each of these days, many shrimp exhibiting shock symptoms in the early morning regained equilibrium after waters had warmed. However, the coloration of live shrimp darkened considerably after the first days exposure to low temperatures and did not return to normal even though the air temperature warmed to a high of 27 C. A total of 56,134 live shrimp were harvested from these ponds on November 19, 20, and 21. One of the leveed natural marsh ponds also contained

TABLE 3. High and low air temperatures (^oC) in the study area before and following passage of two cold fronts in November, 1969.

Date	High	Low
10	29	16
11	30	18
12	31	20
13	27	8
14	14	-3*
15	19	2*
16	23	18
17	27	21
18	26	3
19	13	-3*
20	17	0*
21	21	3*

* Shrimp mortalities observed.

white shrimp and specimens of all the stable macro-fauna prior to the passage of these fronts. This pond was devoid of any living macro-fauna forms two weeks later. Since the levee prevented escape for all but the blue crab, it was assumed that prolonged exposure to low temperatures proved lethal for these animals.

On those occasions when mortalities were observed to be the result of low temperatures, the air temperature had dropped below freezing suddenly following passage of a cold front. Although the water temperatures never reached freezing, the aquatic macro-fauna disappeared from the open waters of the marsh. Two weeks following the November 14, 1969, frontal passage, specimens of Cyprinodon variegatus were discovered in abundance, along with a few specimens of Fundulus grandis, Poecilia latipinna, and Palaemonetes sp. in the flooded grasslands throughout the marsh. The leveed pond where total mortality was observed did not contain flooded grasslands. The flooded grasslands as well as the deeper waters of the bays and bayous probably provide protection during all but the most severe freezes and serve essentially as a "wintering ground" for the hardiest of these species.

Effect of Impoundments for Shrimp Culture

The presence of large brown and white shrimp in Hayes Ridge Lake in September, 1967 points up the potential of this and similar bodies of water for mariculture. It has been shown, however, that the frequently occurring floods provide a means of escape for entrapped animals. Mariculture efforts, therefore, would not be successful unless waters were impounded by levees. Concern that these impoundments might seriously alter the distribution of the aquatic macro-fauna and hence the entire marsh ecosystem prompted an evaluation of the effects of both the impoundments and shrimp culture practices. The three leveed natural marsh ponds, located near station A (Figure 1), were used as pilot models and consideration was given to the results which might occur if waters were impounded on a large scale.

The physical alteration of the marsh resulting from the construction of levees is evident in Figure 3A. A ditch approximately 4.6 m wide and 1.5 m deep was dug around these ponds with a dragline to obtain enough mud to construct a levee 1.2 m high (Figure 3B). The consistancy of the mud was such that it began to slough away when attempts were made to increase the height of the levee. Once the levees had dried, however, additional height could be obtained and would probably be advisable on impoundments much larger than 2 ha. At each pond, a wooden flume (Figure 4) was installed in the levee to allow draining and filling with tide water which flowed in through a narrow ditch leading to tidewaters at station A.

Shrimp culture experiments conducted in these ponds were designed to measure growth, production, and survival resulting from supplemental feeding and competitor and predator control (i.e., the removal of fish and crustaceans which might compete with shrimp for

Figure 3A. Physical alteration of the marsh resulting from levee and ditch.

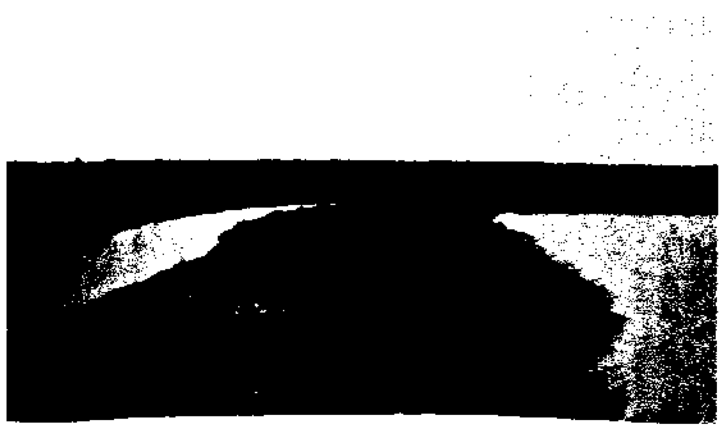

Figure 3B. Levee bordering natural marsh pond (right) and resulting ditch (left).

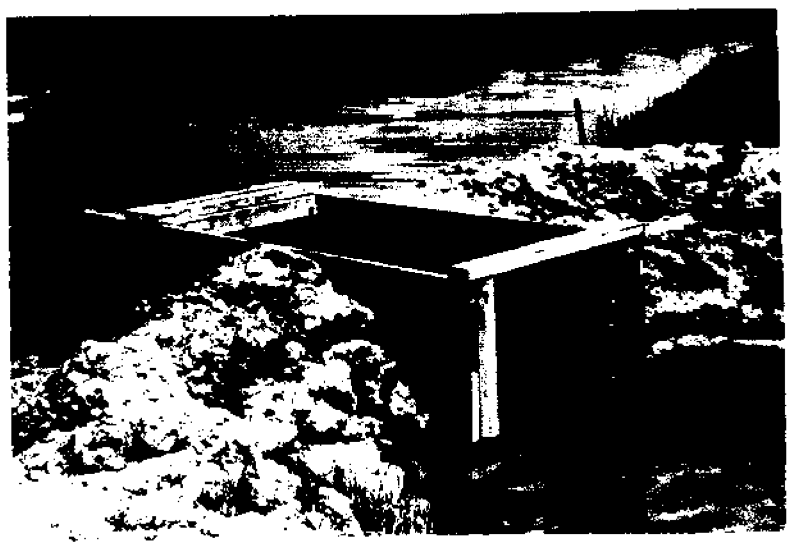

Figure 4. Drain flume installed in pond levee to allow tidal flow.

food or prey on them). The details of these experiments will be presented in a later paper. The results to date, however, have indicated that supplemental feeding significantly increased the growth rate and total production of white shrimp and that the control of fish and other crustaceans was advantageous primarily because these organisms compete with the shrimp for food. The effects due to predation have not yet been adequately evaluated.

The impoundments themselves provided suitable habitat for the natural aquatic macro-fauna during the warmer periods and effectively eliminated the problems associated with droughts. The levees restricted redistribution of animals during floods. Levees and high water levels, however, destroyed the vegetation around the inner edge of ponds, eliminating protective insulation against lethal low temperatures. The ditches around the outside of these impoundments provided waters deep enough to serve in the same capacity as the deeper bayous in protecting against low temperatures. If similar ponds were constructed on a large scale for shrimp culture, at the expense of removing flooded grasslands, the result would be a significant decrease in habitat suitable for year-round survival of the stable macro-fauna. In addition, shrimp culture practices would probably require the removal of competitor species during the warmer months thus effectively eliminating the natural macro-fauna from impoundments year-round. In essence, large areas of shrimp culture impoundments would change the physical features of the marsh as well as the diversity and distribution of the aquatic macro-fauna. The impact of these changes on the total marsh ecosystem is not known but should be considered and studied in detail before such changes are initiated. Conceivably, marsh areas could be managed so as to insure a reasonable amount of habitat for the stable macro-fauna while allowing ample lands for shrimp culture. This could best be accomplished by restricting shrimp culture practices to open water areas, thus avoiding the removal of flooded grasslands. In addition, the pond flumes could be opened to the surrounding marsh during the winter months when temperatures are too low for shrimp culture, allowing the impounded areas to return to a more or less natural state.

SUMMARY

1. As a result of frequent tidal floods, saline conditions generally prevailed within the marsh. Freshwater floods resulting from local rainfall were common, but salt leached from the bottom sediments readily re-established saline conditions.

2. The fauna consisted of a variety of marine and estuarine species. Those that were abundant throughout the year and constituted the stable macro-fauna were Cyprinodon variegatus, Fundulus grandis, Poecilia latipinna, Mugil cephalus, Menidia beryllina, Palaemonetes sp., and Callinectes sapidus. These are among the hardiest of coastal aquatic animals and exhibited broad temperature and salinity tolerances.

3. Of these stable macro-fauna, Cyprinodon variegatus, Fundulus grandis, Poecilia latipinna and Palaemonetes sp. completed their life cycle within the marsh.

4. Marine dependent species were able to enter the marsh during tidal floods and postlarvae Penaeus setiferus were able to invade these areas through the narrow, vegetation clogged ditches leading from tidewaters. Conditions were seldom favorable for the return of marine species to the bay.

5. During freshwater floods only the stable macro-fauna

were found. Marine species were presumably either forced out into the bay or died as a result of the rapid salinity decline which typically occurred.

6. Drought conditions occurred to varying degrees during the summer months, producing abnormally high water temperatures and hypersalinities. The stable macro-fauna were more tolerand to these conditions than other species, but during severe droughts all aquatic macro-fauna perished.

7. The lethal effect of low temperatures was observed on two occasions. The hardiest individuals of those stable macro-fauna species that completed their life cycle in the marsh were apparently able to survive during these periods by seeking protection in the submerged vegetation or the deeper waters of the bays and bayous. Marine dependent species, with the exception of Callinectes sapidus, never survived throughout an entire winter.

8. It was determined that construction of large-scale impoundments for shrimp culture, at the expense of removing flooded grasslands, would alter the physical features of the marsh and reduce habitat suitable for year-round survival of the stable macro-fauna. In addition, competitor and predator control in these ponds would require the removal of all aquatic macro-fauna other than shrimp. Conceivably, marsh areas could be managed so as to insure a reasonable amount of habitat for the stable macro-fauna while allowing ample lands for shrimp culture.

This could best be accomplished by restricting shrimp culture practices to open water areas, thus avoiding the removal of flooded grasslands. In addition, the pond flumes could be opened to the surrounding marsh during the winter months when temperatures are too low for shrimp culture, allowing the impounded areas to return to a more or less natural state.

LITERATURE CITED

Conte, F. S. 1971. Ecological aspects of selected crustacea of two marsh embayments on the Texas coast. Ph.D. Dissertation, Texas A&M University. p. 1-227.

Daugherty, F. M., Jr. 1952. The blue crab investigation, 1949-50. Texas Journal of Science, 1952(1):77-84.

Diener, R. A. 1964. Effects of engineering projects on estuaries. Fish and Wildlife Service Circular, 183:55-59.

Gunter, G. 1950. Distribution and abundance of fishes on the Aransas National Wildlife Refuge, with life history notes. Publications of the Institute of Marine Science, University of Texas. 1(2):89-101.

Gunter, G. and H. H. Hildebrand. 1951. Destruction of fishes and other organisms on the South Texas coast by the cold wave of January 28, - February 3, 1951. Ecology, 32:731-736.

Hedgpeth, J. W. 1950. Notes on the marine invertebrate fauna of salt flat areas in Aransas National Wildlife Refuge, Texas. Publications of the Institute of Marine Science, University of Texas. 1(2):103-119.

Lindner, M. J. and W. W. Anderson. 1956. Growth, migrations, spawning, and size distribution of shrimp Penaeus setiferus. U. S. Fish and Wildlife Service Fishery Bulletin, 106, 56:555-645.

Parker, J. C. 1965. An annotated checklist of the fishes of the Galveston Bay System, Texas. Publications of the Institute of Marine Science, University of Texas. 10:201-220.

Parker, J. C. 1971A. Distribution of juvenile brown shrimp (*Penaeus aztecus* Ives) in Galveston Bay, Texas, as related to certain hydrographic features and salinity. Contributions in Marine Science, University of Texas. 15:1-15.

Parker, J. C. 1971B. The biology of the spot, *Leiostomus xanthurus* Lacepede, and Atlantic croaker, *Micropogon undulatus* (Linnaeus), in two Gulf of Mexico nursery areas. Ph.D. Dissertation, Texas A&M University. p. 1-172.

Pearson, J. C. 1929. Natural history and conservation of the redfish and other commercial sciaenids of the Texas coast. Bulletin of the U. S. Bureau of Fisheries, 44(1928):129-214.

Renfro, W. C. 1960. Salinity relations of some fishes in the Aransas River, Texas. Tulane Studies in Zoology, 8(3):83-91.

Strawn, K. and J. E. Dunn. 1967. Resistance of Texas salt and freshwater-marsh fishes to heat death at various salinities. Texas Journal of Science, 19(1):57-76.

Skud, B. E. and W. B. Wilson. 1960. Role of estuarine waters in Gulf fisheries. Transactions of the 25th North American Natural Resources Conference:320-326.

Tabb, D. C. and A. C. Jones. 1962. Effect of hurricane Donna on the aquatic fauna of North Florida Bay. Transactions of the American Fisheries Society, 91(4):375-378.

Trent, L. 1966. Size of brown shrimp and time of emigration from the Galveston Bay System, Texas. Proceeding of the Gulf and Caribbean Fisheries Institute, 19th Annual Session:7-16.

Trent, L. 1969. Ecology of western Gulf estuaries. Fish and Wildlife Service Circular, 343:25-31.

Wood, C. E. 1967. Physioecology of the grass shrimp, Palaemonetes pugio, in the Galveston Bay estuarine system. Contributions in Marine Science, University of Texas. 12:54-79.