ABUNDANCE OF MACROCRUSTACEANS IN A NATURAL MARSH AND A MARSH ALTERED BY DREDGING, BULKHEADING, AND FILLING[1]

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ABSTRACT

Indices of abundance of macrocrustaceans during March-October 1969 in West Bay, Tex., were determined for day and night and statistically compared between 1) a natural marsh area, 2) upland and bayward canal areas of a housing development, and 3) an open bay area. Significance levels of 5% or 1% were used in the statistical comparisons. Catches of brown shrimp, *Penaeus aztecus*; white shrimp, *P. setiferus*; blue crab, *Callinectes sapidus*; and pink shrimp, *P. duorarum*, were significantly greater at night than during the day at one or more stations in the marsh. More grass shrimp, *Palaemonetes* sp., were caught at night than during the day, but the differences were not statistically significant. Individuals of each species appeared to migrate into the more shallow areas of the marsh at night. At night, brown shrimp and blue crabs were significantly more abundant in the marsh and bayward canal areas than in the upland canal and bay areas, white shrimp were significantly more abundant in the marsh area than in the other three areas, and pink shrimp were significantly more abundant in the marsh than in the upland and bayward canal areas. During the day, brown shrimp were significantly more abundant in the bayward canal area than in the upland canal and bay areas, while pink shrimp were significantly more abundant in the marsh area than in the upland canal area. The generally lower catches of each species in the open bay and upland canal areas when compared with the marsh and bayward canal areas were attributed to: 1) permanent loss of intertidal vegetation in the housing development; 2) low abundance of detrital material and benthic macroinvertebrates in the open bay and upland canal areas; and 3) eutrophic conditions in the upland canal area.

Development of bayshore property into housing sites by dredging, bulkheading, and filling is occurring in many estuaries. When this property is developed, shallow bay and tidal marsh areas are often dredged or filled with spoil, thus changing the environment for marine organisms. Information is available on some of the environmental changes that are critical, but the effects of these changes on the abundance of macrocrustaceans in Gulf coast estuaries are poorly known.

Ecological studies conducted by personnel of the National Marine Fisheries Service in the Jamaica Beach housing development in West Bay, Tex., during 1969 were reported by Trent et al. (1972). That report described the study area and included summary information on phytoplankton production, oyster production, benthic organisms, sediments, hydrology, and the abundance of macrocrustaceans and fishes. Detailed analyses were reported by Corliss and Trent (1971) on phytoplankton production, Moore and Trent (1971) on oyster production, and Gilmore and Trent (1974) on benthic organisms and sediments.

Mock (1966) studied the abundance of brown shrimp, *Penaeus aztecus*, and white shrimp, *P. setiferus*, in Galveston Bay, Tex., after the bayshore was altered by bulkheading. He stated that catches of brown shrimp were 2.5 times greater, and catches of white shrimp were 14 times greater in a natural habitat than in a bulkhead area.

The objectives of this study in the Jamaica Beach area during 1969 were to evaluate relative abundance of selected macrocrustaceans between: 1) day and night; 2) housing development canals, natural marsh areas, and open bay areas; and 3) areas with different concentrations of dissolved oxygen.

STUDY AREA AND METHODS

The study area, located in West Bay, included a natural marsh area, an open bay area, and a canal area. The canal area was similar to the natural marsh before it was altered by channelization, bulkheading, and filling (Figure 1). The altered area, which included, prior to alteration,

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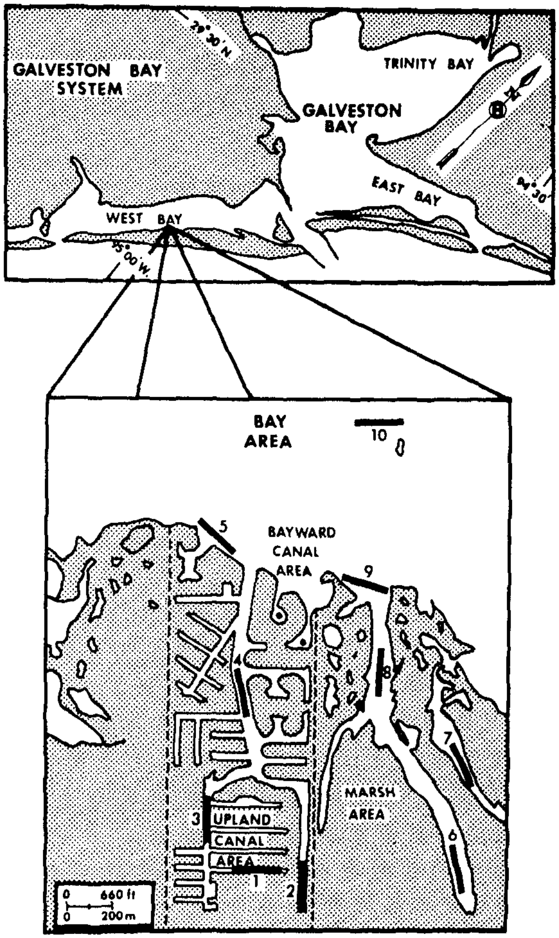

FIGURE 1.—Study area and sampling locations in the Jamaica Beach area of West Bay, Tex.

about 45 hectares of emergent marsh vegetation (predominantly *Spartina alterniflora*), intertidal mud flats, and subtidal water area was reduced to about 32 hectares of subtidal water area by dredging and filling; water volume (mean low tide level) was increased from about 184,000 m^3 to about 394,000 m^3. Ten sampling stations were established in the study area. Average water depths (mean low tide level) at stations 1 through 10 were 1.6, 2.6, 2.2, 1.4, 1.3, 0.5, 0.2, 0.4, 0.5, and 1.0 m, respectively.

Samples of water and crustaceans were collected during the day between 1000 and 1400 h and at night between 2200 and 0200 h at 2-wk intervals from 25 March to 21 October 1969 at each station. Water samples for determining dissolved oxygen were taken 30 cm above the bottom. Oxygen was measured using a modified Winkler method (Carritt and Carpenter 1966). Crustaceans were collected in a trawl that had a mouth opening of 0.6 m by 3.0 m and a stretched mesh of 28.0 mm in the body and 2.5 mm in the cod end. At each station the trawl was towed 200 m at about 2 knots. "Abundance" and "catch" are used synonymously in this report as our index of relative abundance. These terms refer to either the number or average number of animals caught per 200-m tow with the trawl.

Data were treated differently than those reported by Trent et al. (1972) in that stations 1-5 in the altered area were subclassified into upland canal area (stations 1-3) and bayward canal area (stations 4, 5); classification of stations 6-9 in the marsh and station 10 in the bay remained the same.

The data were treated statistically as follows for the five species caught in greatest abundance (Table 1): differences in catches between day and night were tested with a paired-comparison *t*-test using individual catches at a station as observations; differences between areas were tested with Tukey's *w*-procedure (Steel and Torrie 1960) using the average catch by area, date, and time of day as observations.

COMPARISONS OF CATCH BETWEEN DAY AND NIGHT

Eight genera and at least 11 species were represented in the catches (Table 1). Four species and members of the genus *Palaemonetes* were

TABLE 1. — Species or genera and total numbers of crustaceans caught by area during the study.

Species	Upland canal	Bayward canal	Marsh	Bay
Brown shrimp, *Penaeus aztecus*	6,112	16,195	27,063	2,505
White shrimp, *P. setiferus*	1,150	2,738	10,961	172
Grass shrimp, *Palaemonetes* sp.	54	23	8,336	21
Blue crab, *Callinectes sapidus*	181	583	1,149	59
Pink shrimp, *Penaeus duorarum*	78	80	636	61
Mantis shrimp, *Squilla* sp.	2	70	7	7
Brokenback shrimp, *Trachypenaeus* sp.	0	8	1	9
Stone crab, *Menippe mercenaria*	0	2	0	0
Mud crab, *Eurypanopeus* sp.	0	0	0	2
Swimming crab, *Callinectes similis*	1	0	0	1
Pistol shrimp, *Alpheus* sp.	0	0	1	0

caught in sufficient numbers for detailed analyses.

Brown shrimp was caught in greater numbers during the day in the canal and bay areas and in greater numbers at night in the marsh area except at station 6 (Table 2). In the canals, day catches were much greater than night catches at the upland canal stations but were only slightly greater than night catches at the bayward canal stations. In the marsh, night catches were significantly greater than day catches at stations 8 and 9, slightly greater than day catches at station 7, and less than day catches at station 6.

White shrimp was caught in greater numbers at night than during the day at all stations except station 5. The differences were statistically significant at stations 7-9.

Grass shrimp, *Palaemonetes* sp., was caught in greater numbers during the day at two of the canal stations and in greater numbers at night at the remaining stations; the differences were not statistically significant, however.

Blue crab, *Callinectes sapidus*, was caught in greater numbers during the day at the upland canal stations (significant at station 3) and in greater numbers during the night at the remaining stations (statistically significant at stations 5-8).

Pink shrimp, *Penaeus duorarum*, was caught in greater numbers at night than during the day at all stations except station 6. Differences were statistically significant at stations 5 and 8.

COMPARISONS OF CATCH BETWEEN AREAS

Statistically significant differences in night catches between areas were observed for four of the five species; day catches were significantly different between areas only for brown and pink shrimps (Table 3). Abundance of brown shrimp during the day was significantly greater in the bayward canal area than in the upland canal and bay areas, whereas at night, brown shrimp were significantly more abundant in the marsh and bayward canal areas than in the other two areas. Catches of white shrimp at night were significantly greater in the marsh area than in the other three areas. Blue crabs were significantly more abundant at night in the marsh and bayward canal than in the bay and upland canal areas. Catches of pink shrimp were significantly greater in the marsh than in the upland canal area during the day and significantly greater in the marsh than in both canal areas at night.

CATCH RELATED TO DISSOLVED OXYGEN

Mean dissolved oxygen values and mean catch of each species by date and area are shown in Figure 2. Mean oxygen values in the bayward canal, marsh, and bay areas were above 3.0 ml/liter throughout the study except on 1 July in the bayward canal and on 23 September in the

TABLE 2. — Comparisons between day and night catches (mean number caught per tow) by species and station (paired comparison *t*-test with 15 df).

Species and time of day	Upland canal stations			Bayward canal stations		Marsh stations				Bay station
	1	2	3	4	5	6	7	8	9	10
Brown shrimp:										
Day	194.4	27.6	77.3	222.9	298.1	210.7	137.1	212.5	93.5	81.4
Night	47.1	14.5	21.1	203.4	287.8	167.6	177.3	481.9	210.8	75.2
t-value	−1.90	−1.02	−1.24	−0.42	−0.18	−1.04	0.98	3.29**	4.43**	−0.20
White shrimp:										
Day	5.8	1.7	12.5	30.1	73.4	76.0	16.1	4.4	8.1	2.9
Night	11.9	3.3	36.7	35.0	32.6	127.6	188.6	178.4	85.8	7.9
t-value	0.79	1.42	1.23	0.75	−0.89	1.18	3.25**	2.93*	2.55*	2.00
Grass shrimp:										
Day	0.1	1.5	0.0	0.4	0.4	31.8	37.7	22.4	2.2	0.4
Night	1.0	0.4	0.4	0.1	0.6	320.4	43.0	61.0	2.5	0.9
t-value	1.45	−0.94	1.60	−1.23	1.00	1.03	0.21	1.40	0.18	1.09
Blue crab:										
Day	3.9	1.5	2.4	6.6	7.6	8.8	2.3	8.0	2.6	1.3
Night	1.6	0.8	1.1	7.4	14.8	18.8	10.7	16.2	4.4	2.4
t-value	−1.61	−1.74	−2.77*	0.46	2.74*	1.93	2.87*	2.85*	1.04	1.28
Pink shrimp:										
Day	0.1	0.1	0.1	0.5	0.2	4.8	2.1	1.1	0.2	1.0
Night	1.6	1.9	1.1	1.2	3.2	0.6	4.2	12.2	14.6	2.8
t-value	1.67	1.24	1.52	0.90	2.35*	−1.79	1.20	2.12*	2.04	1.93

*Significant at 5% level.
**Significant at 1% level.

TABLE 3. — Comparisons of catches between areas (bay; bayward canal, BC; marsh; upland canal, UC) by species and time of day (Tukey's w-procedure with 60 df).

Species and time of day	Area, mean catch ( ), and significance lines[1]			
Brown shrimp:				
Day	Bay (81.4)	UC (99.7)	Marsh (163.4)	BC (260.5)
Night	UC (27.6)	Bay (75.2)	BC (245.7)	Marsh (259.4)
White shrimp:				
Day	Bay (2.9)	UC (6.7)	Marsh (26.1)	BC (51.7)
Night	Bay (7.9)	UC (17.3)	BC (33.8)	Marsh (145.1)
Grass shrimp:				
Day	Bay (0.4)	BC (0.4)	UC (0.5)	Marsh (23.5)
Night	BC (0.3)	UC (0.6)	Bay (0.9)	Marsh (106.7)
Blue crabs:				
Day	Bay (1.3)	UC (2.8)	Marsh (5.4)	BC (7.1)
Night	UC (1.2)	Bay (2.4)	BC (11.2)	Marsh (12.5)
Pink shrimp:				
Day	UC (0.1)	BC (0.3)	Bay (1.0)	Marsh (2.0)
Night	UC (1.5)	BC (2.2)	Bay (2.8)	Marsh (7.9)

[1]Any two means not underscored by the same line are significantly different at the 5% level.

marsh. In contrast, mean oxygen values observed in the upland canal area remained below 3.0 ml/liter from 20 May to 12 August and were below 2.0 ml/liter on three occasions. From 20 May to 12 August, about 24% of the individual observations of oxygen values from the upland canal stations were below 1.0 ml/liter, whereas all individual observations from the other three areas were above 1.5 ml/liter.

The normal patterns of seasonal abundance were reflected for brown shrimp, white shrimp, and blue crabs by catches in the bayward canal, marsh, and bay areas (Figure 2). Immigration and emigration in Galveston Bay by brown and white shrimps occur during different seasons (Baxter and Renfro 1966; Trent 1967; Pullen and Trent 1969). Brown shrimp postlarvae immigrate in late winter and early spring and most of the juveniles emigrate in late spring and early summer. White shrimp postlarvae immigrate in the summer, and the juveniles emigrate in the fall or early winter depending on water temperature. Blue crabs are abundant throughout the year in Galveston Bay (Chapman 1965).

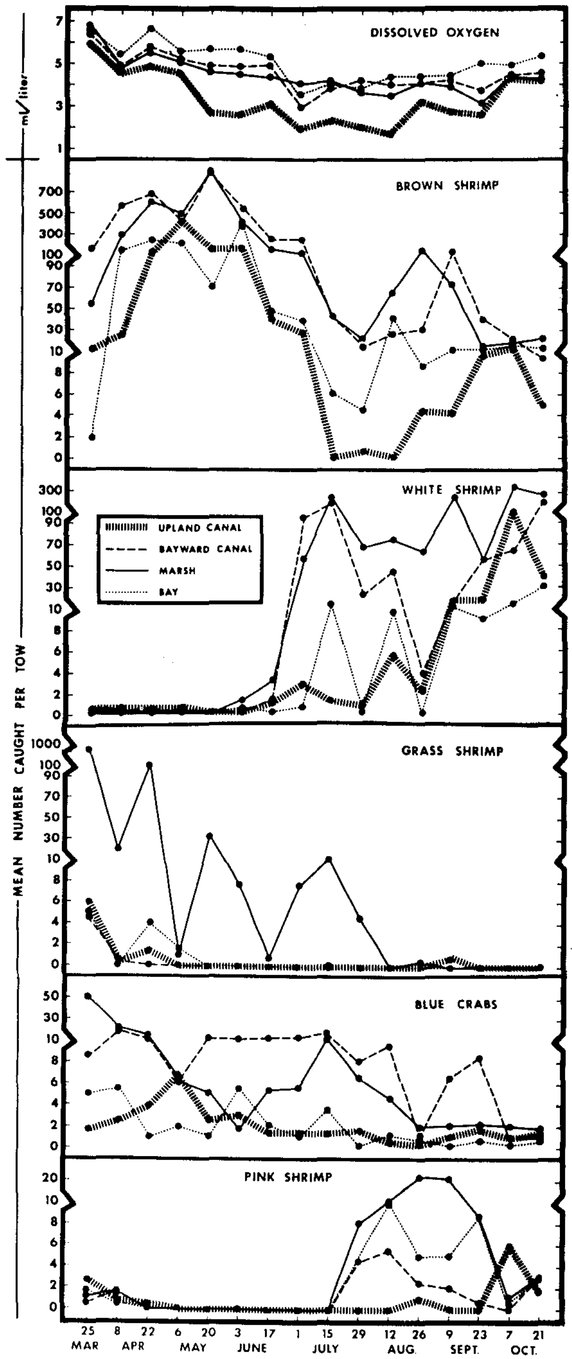

FIGURE 2.—Mean dissolved oxygen values, and mean catch of each species by area and time of year.

Patterns of seasonal abundance for grass and pink shrimps are not documented for the Galveston Bay system. In Redfish Bay, Tex. (about 150 miles southwest of our study area), Hoese and

Jones (1963) caught grass shrimp in greatest numbers during late winter and early spring and pink shrimp in greatest numbers during spring and early fall. Seasonal abundance patterns reflected by catches in this study were similar to those reported in Redfish Bay: for grass shrimp in the marsh area; and for pink shrimp in the bayward canal, marsh and bay areas during late summer and early fall.

Seasonal abundance of brown shrimp, white shrimp, blue crabs, and pink shrimp deviated from what we expected in the upland canal area. These deviations were probably caused by low dissolved oxygen. During the period of low dissolved oxygen (below 3.0 ml/liter; from 20 May to 12 August) in the upland canal area, mean catches of brown shrimp dropped and remained below the mean catches of brown shrimp in the other three areas; mean catches of white shrimp and blue crabs remained below mean catches of white shrimp and blue crabs in the bayward canal and marsh areas after 3 June. The abundance of pink shrimp increased on 29 July in all areas except the upland canal area and remained higher than in the upland canal area until 7 September. Grass shrimp were not caught in large numbers in any area except the marsh and therefore were not used to evaluate the effects of low dissolved oxygen.

DISCUSSION AND SUMMARY

Indices of abundance revealed differences in day-night distribution of brown shrimp, white shrimp, blue crabs, and pink shrimp in the study area. Assuming that our catch per unit effort data provided an index which unbiasedly represented density, migration of individuals of all four species into the more shallow areas of the marsh at night best explains these distributional differences. Inherent in the assumption that catch per unit effort unbiasedly estimates density is the equal vulnerability of the animals to capture during both day and night. Factors which could make this assumption invalid include: 1) burrowing or swimming above the trawl by the animals during one but not the other time period, and 2) avoidance of the trawl during the day or night. Regardless of the correctness of our assumption, the importance of sampling during both day and night to determine differences in abundance between areas was clearly shown.

All five species were more abundant in the marsh than in the upland canal area during both day and night. Brown shrimp, white shrimp, blue crabs, and pink shrimp were more abundant in the bayward canal area than in the upland canal area. The distributional patterns of pink shrimp and blue crabs in this study were similar to those reported by Lindall et al. (1975), who provided data showing that catches of blue crabs and pink shrimp were highest in the bayward portion of an upland canal in a housing development in Tampa Bay, Fla.

Four factors probably account for most of the differences observed in abundance of shrimps between areas. Intertidal vegetation was permanently eliminated by alteration of the natural area for the housing development. Detrital materials and abundance of benthic macroinvertebrates were lowest in the open bay area, low in the upland canal area, and highest in the bayward canal and marsh areas (Gilmore and Trent 1974). Eutrophic conditions observed represent the fourth factor.

Eutrophic conditions, indicated by the observed low values of dissolved oxygen in the upland canals of the housing development during the summer, probably account for the comparatively low catches of brown shrimp, white shrimp, pink shrimp, and blue crabs during that period. Further evidence of eutrophication in this area was provided by studies on: the American oyster, *Crassostrea virginica*, in which setting, survival, and growth rates were less in the upland canal area than in the marsh area (Moore and Trent 1971); phytoplankton in which production was higher in the upland canal area than in the marsh or bay areas (Corliss and Trent 1971); and benthic macroinvertebrates in which the abundance of the organisms declined drastically during the summer months in the upland canal area (Gilmore and Trent 1974). Symptoms of eutrophic conditions in the upland canals of the housing development include inadequate water exchange and high nutrient levels. These factors were discussed in detail by Moore and Trent (1971).

Alteration of estuaries by dredging and filling for housing developments and boat basins results in an environment highly susceptible to recurrent low dissolved oxygen levels. This probelm of low oxygen has been shown also in Forida (Taylor and Saloman 1968; Lindall et al. 1973) and California (Reish 1961). Stresses resulting from low dissolved oxygen reduce the abundance of crustaceans and other animals in the stressed areas and may produce mass mortalities. Flow dynamics and sedimentation patterns should be carefully evaluated when new developments in estuaries are being considered in order to prevent areas of stagnant water from being created.

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LITERATURE CITED

BAXTER, K. N., AND W. C. RENFRO.
1966. Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas, with notes on species identification. U.S. Fish Wildl. Serv., Fish. Bull. 66:149-158.

CARRITT, D. E., AND J. H. CARPENTER.
1966. Comparison and evaluation of currently employed modifications of the Winkler method for determining dissolved oxygen in seawater; a NASCO report. J. Mar. Res. 24:286-318.

CHAPMAN, C. R.
1965. Estuarine program. *In* Biological Laboratory, Galveston, Tex. fishery research for the year ending June 30, 1964, p. 60-75. U.S. Fish Wildl. Serv., Circ. 230.

CORLISS, J., AND L. TRENT.
1971. Comparison of phytoplankton production between natural and altered areas in West Bay, Texas. Fish. Bull., U.S. 69:829-832.

GILMORE, G., AND L. TRENT.
1974. Abundance of benthic macroinvertebrates in natural and altered estuarine areas. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-677, 13 p.

HOESE, H. D., AND R. S. JONES.
1963. Seasonality of larger animals in a Texas turtle grass community. Publ. Inst. Mar. Sci., Univ. Tex. 9:37-47.

LINDALL, W. N., JR., W. A. FABLE, JR., AND L. A. COLLINS.
1975. Additional studies of the fishes, macroinvertebrates, and hydrological conditions of upland canals in Tampa Bay, Florida. Fish Bull., U.S. 73:81-85.

LINDALL, W. N., JR., J. R. HALL, AND C. H. SALOMAN.
1973. Fishes, macroinvertebrates, and hydrological conditions of upland canals in Tampa Bay, Florida. Fish. Bull., U.S. 71:155-163.

MOCK, C. R.
1966. Natural and altered estuarine habitats of penaeid shrimp. Proc. Gulf Caribb. Fish. Inst., 19th Annu. Sess., p. 86-98.

MOORE, D., AND L. TRENT.
1971. Setting, growth, and mortality of *Crassostrea virginica* in a natural marsh and a marsh altered by a housing development. Proc. Natl. Shellfish. Assoc. 61:51-58.

PULLEN, E. J., AND W. L. TRENT.
1969. White shrimp emigration in relation to size, sex, temperature and salinity. FAO Fish. Rep. 57:1001-1014.

REISH, D. J.
1961. A study of benthic fauna in a recently constructed boat harbor in southern California. Ecology 42:84-91.

STEEL, R. G. D., AND J. R. TORRIE.
1960. Principles and procedures of statistics, with special reference to the biological sciences. McGraw-Hill Book Co., N.Y., 481 p.

TAYLOR, J. L., AND C. H. SALOMAN.
1968. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida. U.S. Fish Wildl. Serv., Fish. Bull. 67:213-242.

TRENT, W. L.
1967. Size of brown shrimp and time of emigration from the Galveston Bay system, Texas. Proc. Gulf Caribb. Fish. Inst., 19th Annu. Sess., p. 7-16.

TRENT, W. L., E. J. PULLEN, AND D. MOORE.
1972. Waterfront housing developments: Their effect on the ecology of a Texas estuarine area. *In* M. Ruivo (editor), Marine pollution and sea life, p. 411-417. Fishing News (Books) Ltd., West Byfleet, Surrey.