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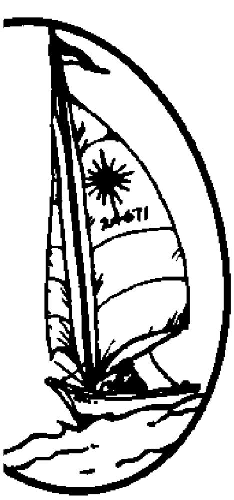
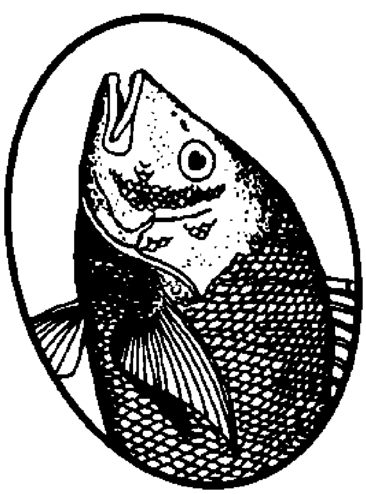
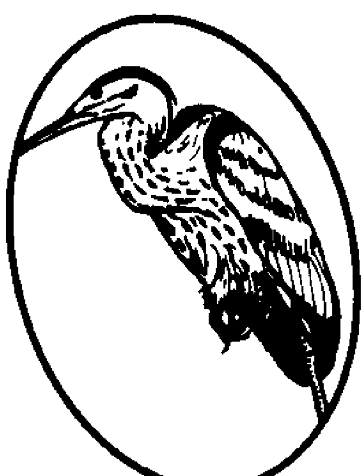
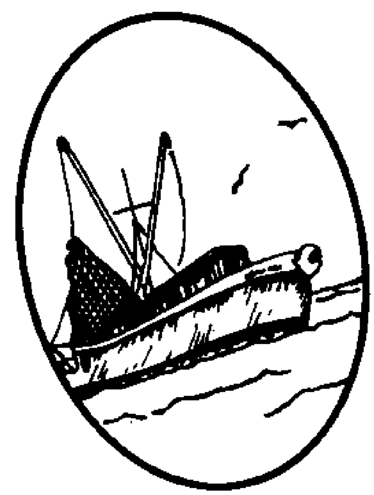
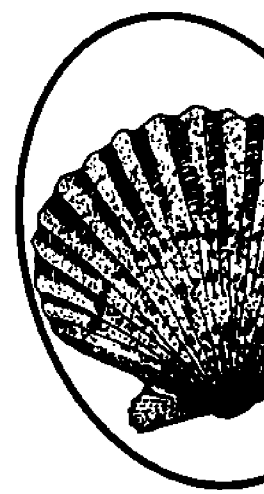
Effects of Upland Drainage On Estuarine Nursery Areas Of Pamlico Sound, North Carolina

Preston P. Pate, Jr. and Robert Jones

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EFFECTS OF UPLAND DRAINAGE ON ESTUARINE NURSERY AREAS OF PAMLICO SOUND, NORTH CAROLINA

by

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ABSTRACT

The study reported herein was designed to measure the effects of upland drainage on primary nursery areas of northern Pamlico Sound, North Carolina. To make this determination, four sampling stations were established and sampled three days per week. The four stations received either heavy, moderate or no drainage through man-made water courses. All stations functioned as primary nursery areas during periods of low rainfall and high salinity (1977). Brown shrimp production at all sites was depressed during periods of extremely high rainfall and low salinities (1978). Salinities at the unaltered sites were more stable during periods of high runoff than those recorded at two sites receiving drainage through ditches. Recovery times at the altered sites were approximately ten days. The most significant reduction in production of juvenile brown shrimp occurred at the extensively ditched site during periods of moderate to heavy rainfall. Five additional species of fish and shellfish appeared to prefer the unaltered nursery areas. Productivity of these species was significantly higher at the unaltered sites each year. Rapid pulses of freshwater appeared to be a dominant stress of juvenile organisms.

INTRODUCTION

A constant supply of freshwater flow is necessary to establish and maintain an estuary. Dilution of seawater by freshwater creates the medium salinity environment that produces most of the economically important species of fish and shellfish. Alteration of the volume of freshwater inflow into estuaries has created unacceptable environments in many parts of the United States, particularly in the West Coast and Gulf Coast states. Diversion of flows from estuaries for irrigation, navigation and public water supplies has created hypersaline conditions inimical to estuarine organisms. The opposite problem of unregulated, accelerated freshwater flow and the subsequent reduction of salinities is being experienced in the estuaries of central and northern coastal North Carolina.

The North Carolina Division of Marine Fisheries has identified areas of the sounds and bays in North Carolina which serve as nursery grounds for economically important species of fish and shellfish. The most productive and sensitive of these areas were subsequently classified as "primary nursery areas." Regulations were adopted which gave the primary nursery areas special consideration for limiting commercial fishing activity and protection from alteration through dredging and filling (N. C. Administrative Code 15NCAC 3 (b) .1400 et seq.). Primary nursery areas were found to be the upper reaches of small tidal creeks which have soft mud sediments. They are surrounded by regularly or irregularly flooded marshes and have salinities ranging from 5 to 15 parts per thousand (ppt).

Data collected over a four-year period prior to this study indicate the primary nursery areas that were receiving upland drainage through man-made ditches and canals had less stable salinity patterns and were relatively less productive than creeks with unaltered drainage basins. This encouraged a more thorough investigation of the impacts of freshwater drainage into primary nursery areas on the production of brown shrimp (*Penaeus aztecus*). Brown shrimp were chosen as the target organism since they have a short nursery period and are the chief users of the nursery areas from April through mid-June. The brown shrimp comprises the largest commercial shrimp harvest in North Carolina and contributes a large percentage of the dollar value of North Carolina commercial seafood products. Low production of brown shrimp has also been shown in prior studies to be correlated with heavy rainfall (Barrett and Gillespie, 1973).

North Carolina has 2,032,875 acres of estuaries. They possess a variety of physical characteristics which influence their productivity, such as bottom type, depth, bottom vegetation, bordering vegetation and salinity range. Man's activities and development within the land areas contingent to the estuaries has introduced another variable which appears to be influencing estuarine productivity. Sampling indicates that accelerated freshwater drainage into the nursery areas adversely affects productivity.

The history of land clearing and drainage in low-lying areas of coastal North Carolina began with the first settlers of the region about 1770. However, conversion of large areas of woodland into agricultural production did not begin until the technology was available to economically clear and drain low-lying areas on a large scale. This type of development is particularly prevalent in the large peninsula lying between Albermarle Sound and Pamlico Sound in northeastern North Carolina. Extensive conversion of forest land to farmland in this area, with the associated drainage into both sound systems, has led to speculation that changes in water quality could be the most serious future impact from this type of development. Drainage of the Albemarle/Pamlico peninsula has proceeded by using a system of canals and field ditches as described by Heath (1975). An analysis of aerial photography and primary nursery area maps shows that the nearest natural water bodies to receive drainage from these systems are often those identified as primary nursery areas. Heath identified in his report that runoff from the Albemarle/ Pamlico peninsula could be the most important problem posed by agricultural development. He also explained that overall salinities in the Pamlico Sound will probably not be significantly affected by runoff from this region since it contributes such a small proportion (6 to 8%) of the total freshwater inflow. A more dramatic effect on salinities would occur with drainage into the smaller streams and bays. Prior studies on the hydrology of the Pamlico Sound region have dealt with the large open-water areas. Our attention in this study was focused on the lateral estuaries which comprise a large and important part of the total Pamlico Sound system. The study compares species utilization of nursery areas with and without drainage through man-made water courses. It evaluates the impacts of accelerates drainage on primary nursery areas, and makes recommendations on ways to avoid adverse impacts.

MATERIALS AND METHODS

The study began in 1977 with the selection of three sampling areas to compare salinity patterns and habitat utilization between areas with natural drainage patterns and areas receiving drainage through man-made waterways. Site selection was based on data collected by prior sampling and on aerial photography that show the locations of drainage ditches. The sites were chosen for similarity in species utilization, bottom type, depth and bordering vegetation. A fourth sampling station was added in 1978 to give an equal number of altered and unaltered locations in the study. The sampling stations are shown on Figure 1 and designated A-1 and A-2 for the altered areas and U-1 and U-2 for the unaltered areas. Recording salinometers were installed at three sites (A-1, A-2 and U-1) to continuously record salinity changes. Salinities were recorded approximately 12 inches from the bottom since near-bottom, salinity changes would have the most effect on utilization of the area by juvenile shrimp that are characteristically found in the substrate. A weather station was installed within the Rose Bay drainage system to record wind direction, wind speed and rainfall. A tide gauge was installed to constantly measure tidal fluctuations within Rose Bay.

Sampling was initially conducted at two locations within each sampling area. Data from within stations were later combined when it was shown that there was no significant difference between the numbers and types of organisms sampled at the two locations. Each station was sampled with a 13 ft. (3.96 meter) headrope, flat otter trawl with a 1/4 inch (.64cm) bar-mesh knotted wings and body, and a 1/4 inch (0.63cm) bar-mesh knitted tail bag. Each sample consisted of towing this trawl a measured distance of 147.6 ft. (45 meters) between fixed markers. Salinity and temperature recordings were taken with each sample by a portable meter to later verify readings by the recording salinometers. Each station was sampled three times a week during the shrimp season (May through July). Each sample was preserved in the field and recorded in the laboratory. All organisms taken were identified and measured.

There are many miles of drainage ditches in the Albemarle/ Pamlico Sound peninsula (Fig. 1). Many of the main collector ditches for drainage of this area were dug during the period of agricultural development of Lake Mattamuskett. Some of these ditches enter the headwaters and tributaries of Rose Bay, Swan Quarter Bay and Juniper Bay.

Station A-1 (Rose Bay Creek) has a number of small ditches draining individual farms and one large canal used as a water-control outlet for management of Lake Mattamuskeet. Rose Bay Creek is bordered on each side by a marsh area dominated by black needlerush (Juncus roemerianus) and saw grass (Cladium jamaicensis). Water depths range from six ft. to nine ft. (2-3 meters) and the bottom type may be characterized as being muddy and overlain with coarse organic detritus.

Station A-2 (Caffee Bay) also receives drainage from an extensive inland area. The main differences between this location and Station A-1 are that flow into the nursery area is confined to two main ditches which have to drain through an extensive bordering marsh of black needlerush. There are four additional ditches draining into Caffee Bay that originate in the adjacent wetland

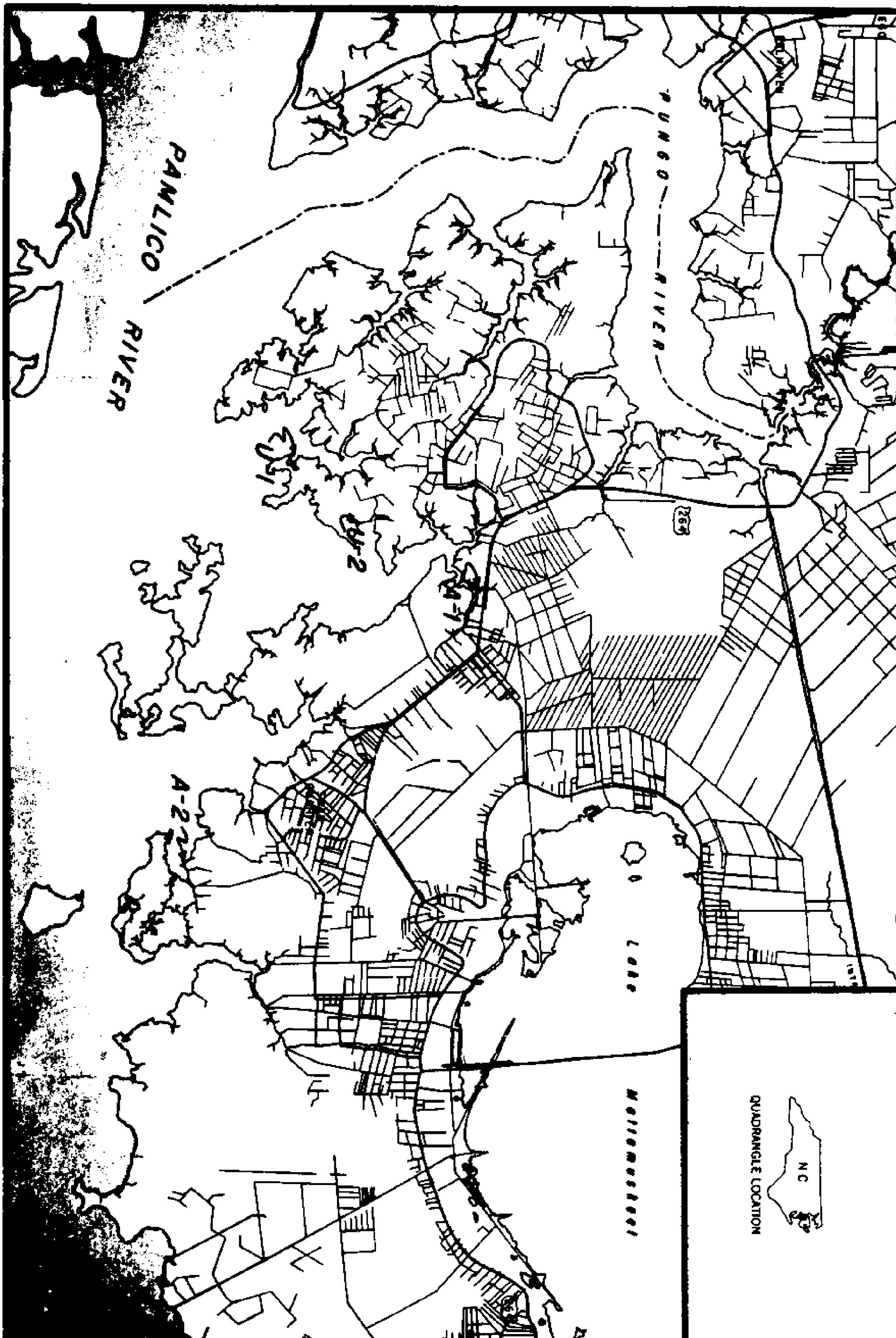

Figure 1. Location of study area, sampling sites and ditches draining into tributaries of northern Pamlico Sound. (Base map from Daniel, 1978)

area and do not appear to carry any non-wetland drainage. Water depths at this site range from two to three ft. (0.75 meter to 1.0 meter) and the bottom type consists of a mixture of mud and detritus.

Station U-1 (Germantown Bay) is completely surrounded by an undisturbed marsh of black needlerush. There are no man-made ditches entering this system. Water depths are two to four ft. (.75 meter to 1.3 meters) and the bottom type consists of a mixture of soft mud and detritus.

Station U-2 (Tooley Creek) is also surrounded by a large expanse of black needlerush marsh and a pocosin vegetated with pond pine. There are two ditches entering the headwaters of this creek; however, they do not carry drainage from any non-wetland areas. Therefore, the creek was considered as being unaltered. Water depths range from one to four ft. (.3 meter to 1.3 meters) and the bottom type is a mixture of deep mud, detritus and marine shells. This is the only station which did not have a 24-hour salinity recorder.

RESULTS AND DISCUSSION

Low to medium salinity estuaries present an environment which is naturally stressful. Fluctuations in temperatures, salinity, turbidity and nutrient levels reduce the number of species which can adapt to these stresses and take advantage of conditions conducive to high levels of productivity. Those that do adapt usually flourish during periods of peak productivity.

One major stress to organisms present in these estuaries is rainfall and the consequent changes in salinity. Salinity patterns in the area are influenced by the amount of rainfall over a given period, the effects that wind and tidal fluctuations have on the distribution of brackish water and the nature of the drainage basin. Total freshwater inflow from natural drainage basins within the Albemarle/Pamlico peninsula is probably not significantly changed by man's efforts to alter land use, but man's use of the drainage basins changes the rate of freshwater discharge into the receiving waters. A typical ditching system used in this area to prepare land for development is designed to efficiently remove surface water from the cultivated fields. It alters the ability of inland areas and associated vegetation to act as a natural regulator of surface runoff. The results are increased peak run-off rates which occur earlier and are three to four times higher on developed lands than on similar undeveloped lands (Skaggs et al, 1980). Salinities in the receiving waters respond quickly and dramatically to these rapid pulses of freshwater. The unstable salinity conditions characteristically occur during rainfall events; however, Heath (1975) reported increases in runoff during fair weather also because the ditches and canals penetrate the shallow groundwater system.

When this study was designed it had been hoped the study would correlate juvenile shrimp movement in response to freshwater inflow. The ideal study would begin in the spring with high salinity (10 to 15 ppt) and high density of shrimp larvae. Before the larvae matured and began their natural migration, there would be enough rainfall to cause a substantial reduction of salinities in the altered nursery areas, but minimal changes in the unaltered areas. We were never afforded a set of ideal conditions, however, to say definitely that migration occurred as a direct result of rapid freshwater runoff. In fact, we had a range of rainfall conditions from extremely dry in 1977 to extremely wet in 1978.

Brown shrimp have a one-year life cycle which begins with spawning in the ocean near inlets. Postlarval shrimp migrate through the inlets in search of suitable habitat to begin their development. Utilization of nursery areas by juveniles in North Carolina is normally April through June (Purvis, personal communication, 1980). This is considered to be the most critical period for optimum conditions in the nursery environment. Annual rainfall for April, May and June for the four-year study period is presented in Table 1 with the total commercial harvest of shrimp for each year.

Table 1. Total rainfall (April - June) and commercial shrimp harvest for each year 1977-1980 from Pamlico Sound

	Total rainfall (inches)				Shrimp har- Shrimp har- vest (lbs)
	April	May	June	Total	Heads off*
1977	1.87	3.36	2.00	7.23	1,652,500
1978	7.80	7.79	3.32	18.91	460,954
1979	4.33	6.13	2.37	12.93	463,566
1980	3.00	2.97	6.72	12.69	2,113,685

*Unpublished N. C. Marine Fisheries data

Total rainfall at the recording station for the period April 1 through June 30 for 1977, was 7.23 in. Peak salinities at the four sampling stations for May through July of that year ranged from 10ppt to 17.6ppt as compared to 1978 readings for the same period of 3ppt to 7ppt when rainfall was 18.91 in. Rainfall during 1978 was sufficient to lower salinity levels at all stations during periods of peak recruitment. Catches of juvenile shrimp in 1978 dropped 93% to 100% at the four sampling stations when compared to 1977 samples. Nursery-area sampling throughout the entire region in 1978 reflected the lowest level of juvenile recruitment recorded by the Division of Marine Fisheries over an eight-year period. Commercial harvest for that year was a record low of 1,532,154 lbs. (heads off). These impacts correspond to the conclusions reached by Skaggs et al (1980). They stated that the drainage canal network in this area does not have the capacity to remove water at the rate that it can drain from developed fields. Therefore, there may be little difference between runoff rates from developed and undeveloped lands during the largest runoff events. Complete soil saturation, high runoff rates and dilution of salinities in all nursery areas during 1978 had a disasterous effect on shrimp production.

Sampling during the dry period in 1977 established that all the sampling areas can function as valuable nursery areas when salinity conditions are suitable. This was particularly important with regards to Station A-1 which is considered to be the most altered system. Sampling prior to this study showed that Rose Bay Creek could be considered only marginally productive with regards to total numbers of organisms sampled, and no effort was made to correlate the catches with salinity levels. Sampling in 1977 at A-1 yielded catches of juvenile brown shrimp equal to, or exceeding, those at every other station.

Results from salinity measurements show that there is a marked difference between the relative stability of salinity levels between the altered and unaltered study areas (Fig. 2). A 2.2 inch rainfall accompanied by 20 to 30 mph southeasterly winds was recorded during a 24-hour period on May 21, 1980. Salinities ranged from 5 to 7 ppt among the three recording points prior to the rainfall. The unaltered drainage basin (U-1) clearly shows the most stable salinity pattern. Salinity readings dropped sharply from 6.5 to 5.8 ppt, but recovered quickly to stabilize at 6.5ppt within 24 hours. Salinity readings at the two recording stations within altered drainage basins showed rapid pulses in salinity levels during this period. The pulses had a frequency of approximately 1.5 hours and a range as wide as 3ppt. Salinity readings at A-2 quickly stabilized to approximately 6.5ppt once the rains ended. Salinities at Station A-1 were erratic throughout the sampling period and reflect the impacts of continued long-term drainage of saturated soils.

The erratic patterns of salinity fluctuations at the altered stations in Fig. 2 show the effects of combined influence of rapid runoff and high winds in an area in which tides are almost completely controlled by the prevailing winds. These effects can occur days after a heavy rainfall and are dependent upon the direction, speed and duration of the winds. Northeasterly winds in Pamlico Sound tend to increase tide levels and retain surface waters in the field ditches, thereby reducing the effect on salinities in the receiving waters. Southwesterly winds, conversely, tend to lower tide levels and pull water out of the drainage ditches into the receiving waters. Tide fluctuation (Fig. 3) indicates that the effects of lunar tides in the sampling area are closely masked by the influence of winds and distances from inlets to the Atlantic Ocean. Changes in tide levels during the period with no rainfall did not affect salinity levels at the recording stations (Fig. 3). Tide levels and salinities were recorded for the period July 20 through July 25, 1979, when a total of 2.99 inches of rainfall was recorded (Fig. 4). Salinity patterns for the period immediately preceeding that, shown in Figure 4, were normally affected by light rainfall and changes in tide levels. During the period of extensive rain covered by Figure 4, salinity recordings show a constant depression due probably to the complete saturation of the basin and a constant runoff of freshwater. In this situation changes in tide levels had no recognizable effects on salinity.

Catches of juvenile brown shrimp normally peak during late May to mid June (Figures 5 through 8). Recruitment into Station A-1 was later than at other locations. This was most apparent during 1979 and 1980 when recruitment was generally good and rainfall was light during the recruitment period. Recruitment times for these two years at Station A-1 also correspond with periods of higher and more stable salinities (Figures 7 and 8).

Total species composition at the four sampling stations was basically the same for each year. Samples yielded eleven species of fish and crustaceans. Spot (Leiostomus xanthurus), manhaden (Brevoortia tyrannus) and brown shrimp were the dominant species sampled each year at all sampling sites.

A statistical analysis was made to measure the difference in utilization of altered and unaltered sites by five species: spot, croaker (Micropogon undulatus), southern flounder (Paralicthys lethostigma), blue crab (Callinectes sapidus) and brown shrimp. A student's t-test (Snedecor & Cochran, 1967) was used to measure the difference of catch-per-unit-of-effort (CPUE) of organisms caught at each station during each month of each sampling year. These species were chosen on the basis of their economic importance, their uniform occurrence throughout the study area and their similar susceptibility to capture with the sampling gear.

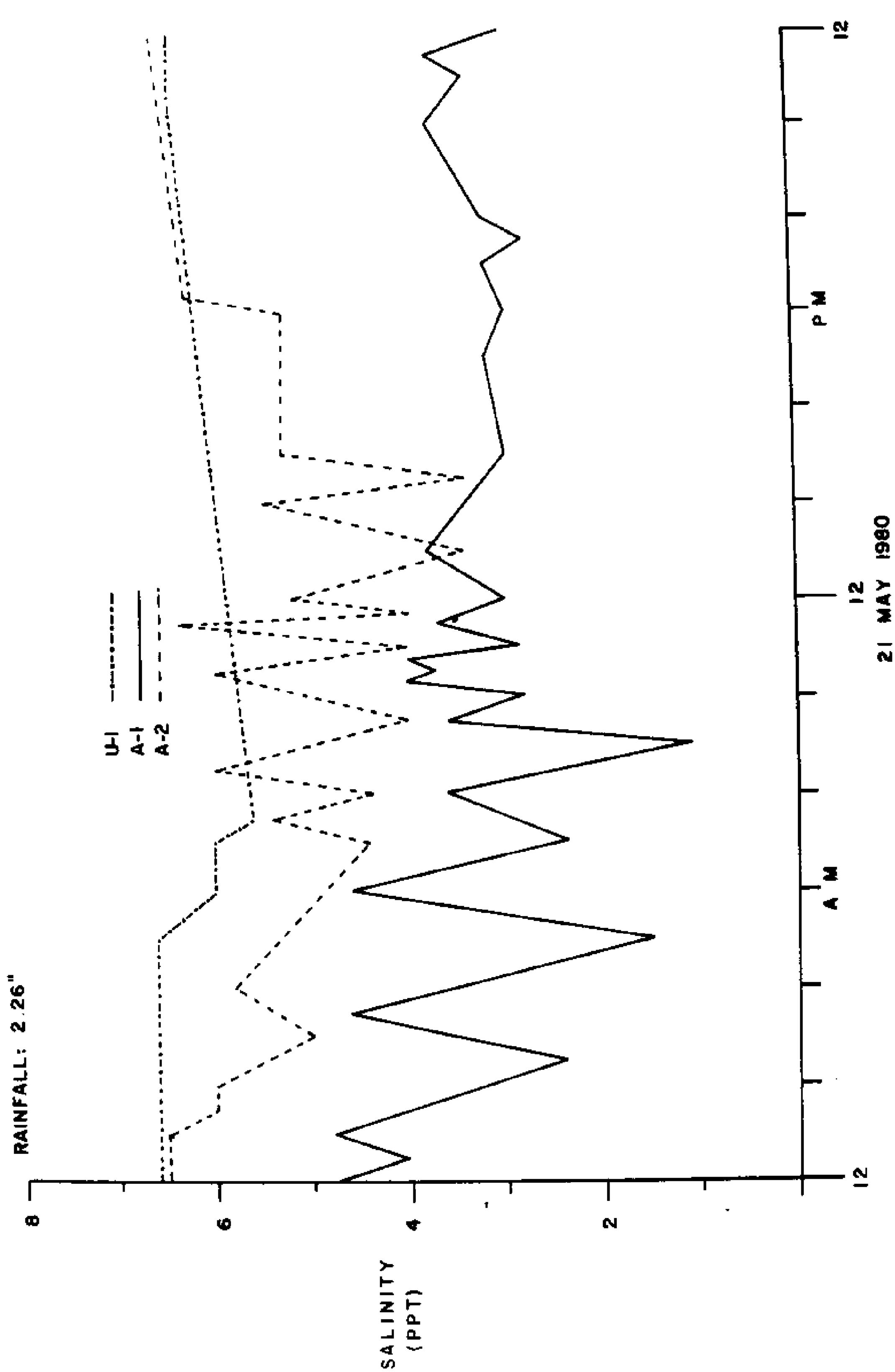

Figure 2.   Graph of salinity readings at three sites over a 24-hour period on 21 May 1980. (U-unaltered; A-altered).

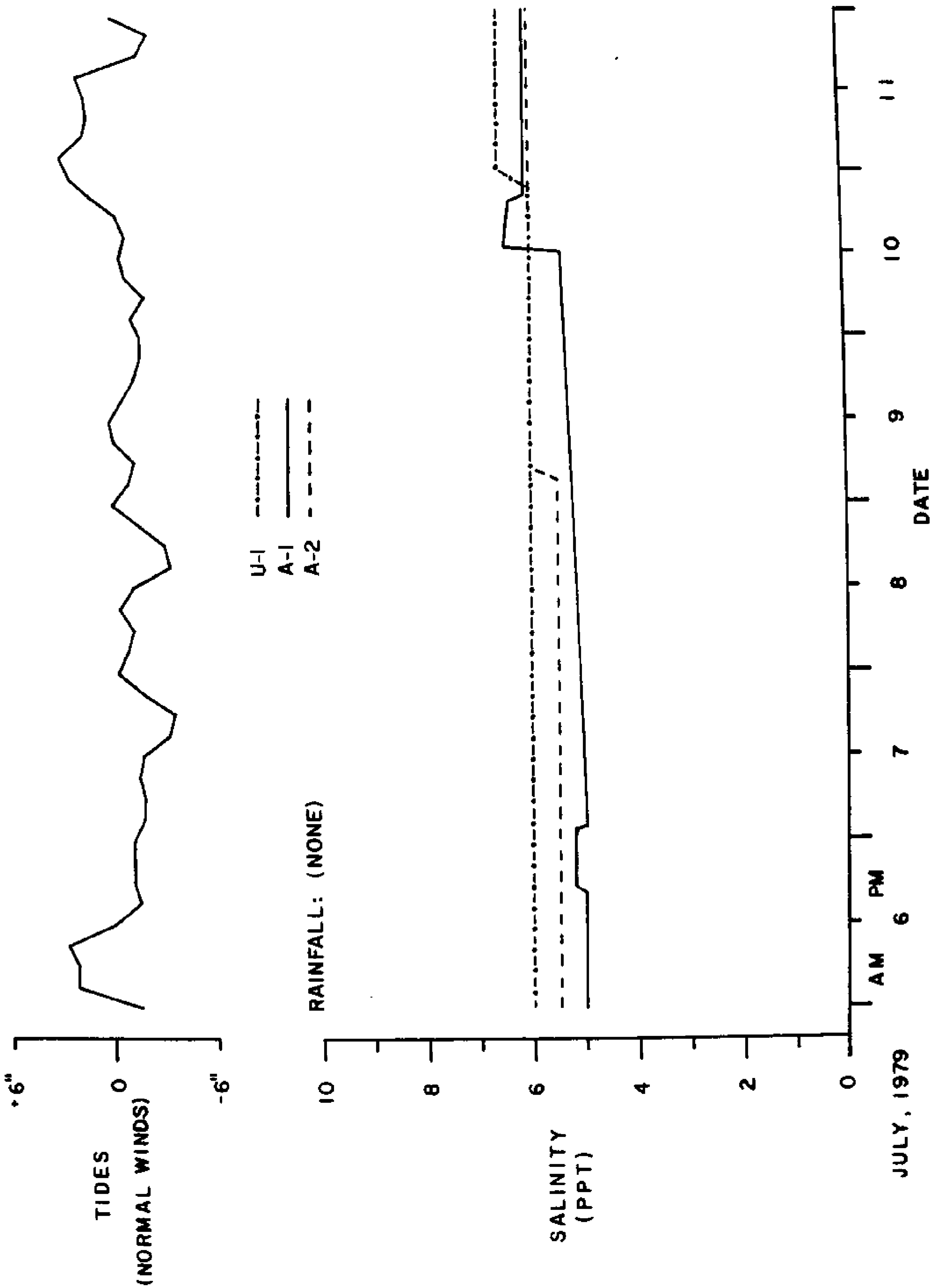

Figure 3. Tide fluctuations and salinity patterns during a period of no rainfall, 6 July - 11 July 1979.

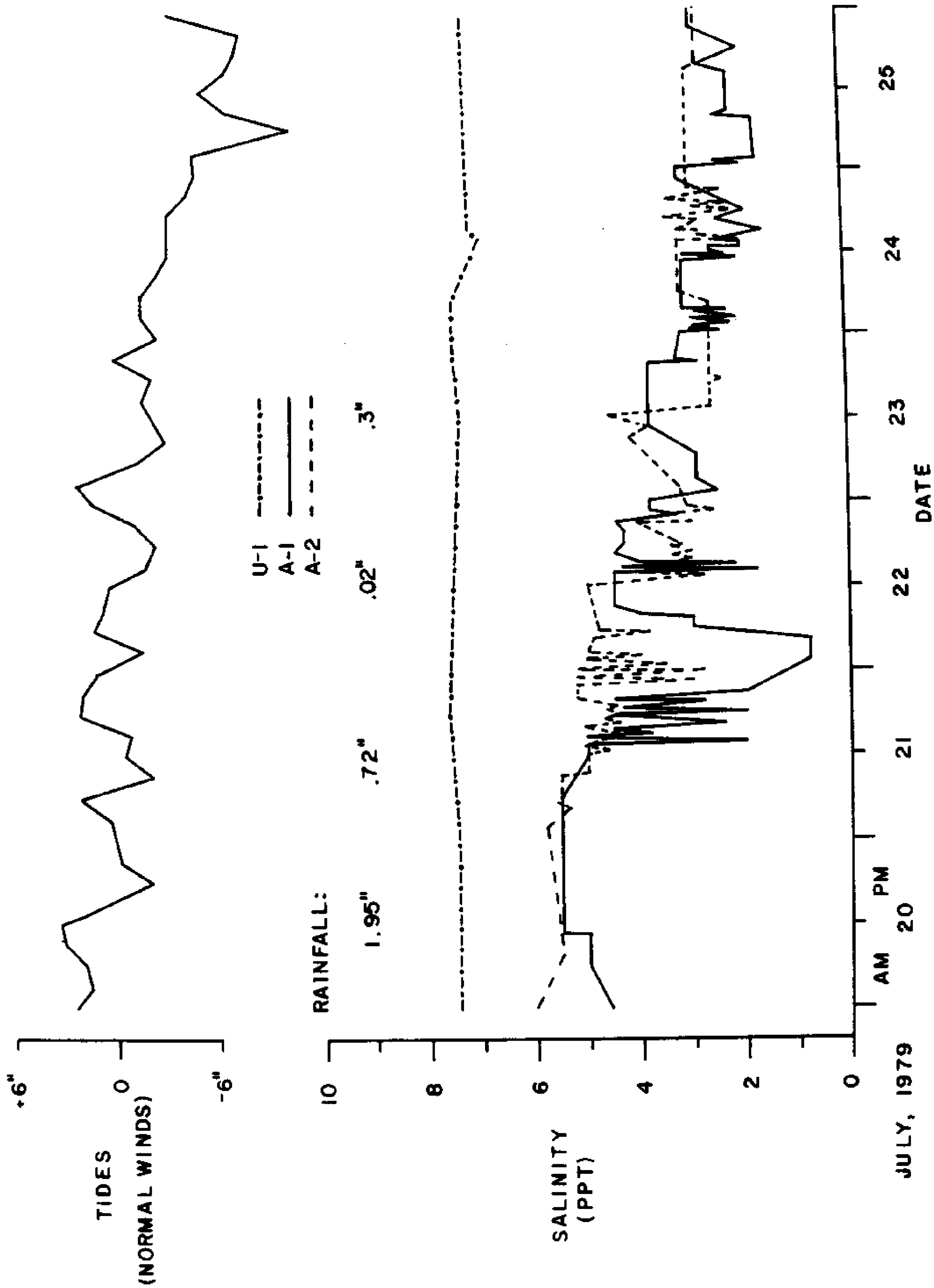

Figure 4. Tide fluctuations and salinity changes during a period of heavy rain, 20 July - 25 July, 1979.

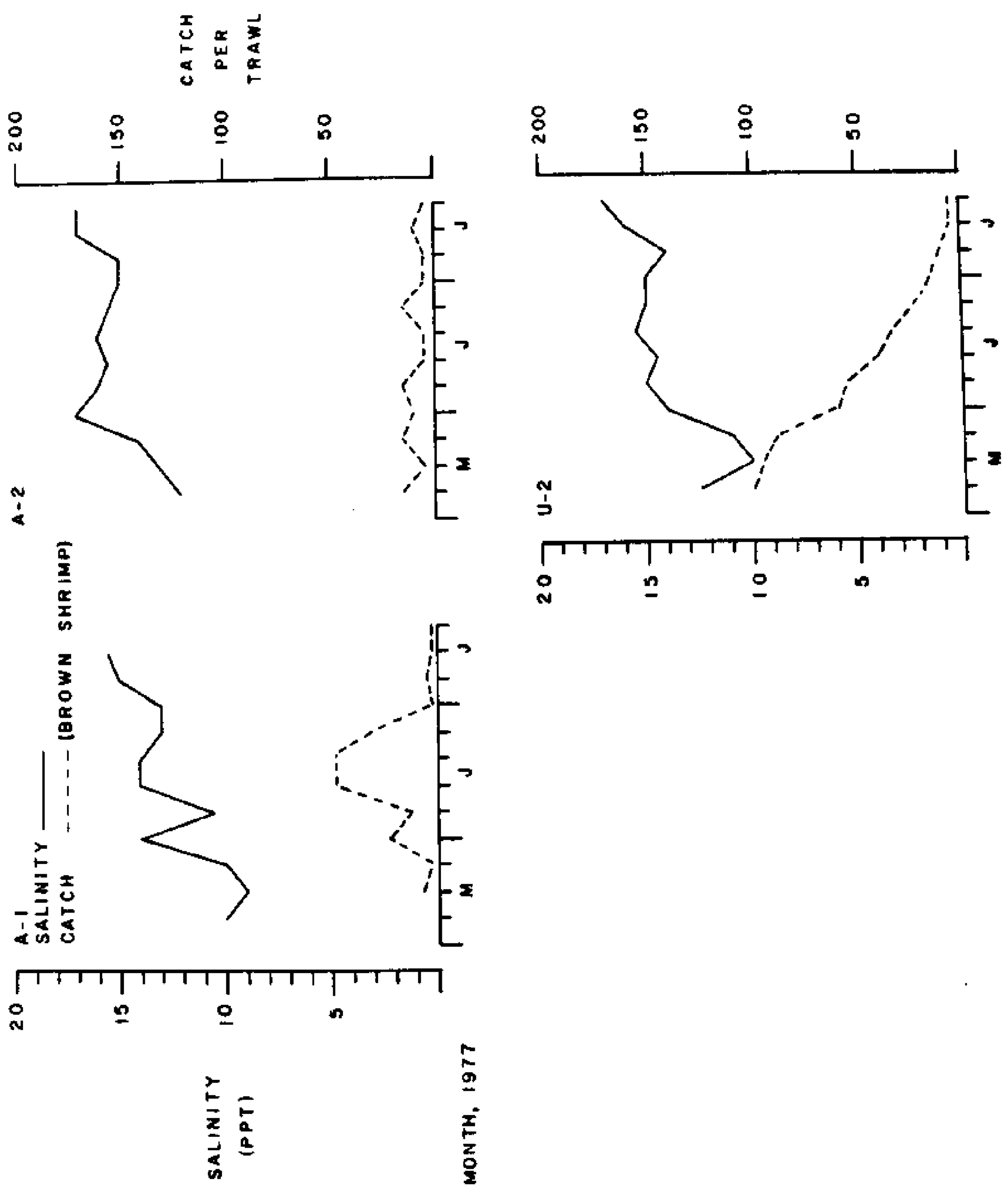

Figure 5. Weekly salinities and catch per trawl of juvenile brown shrimp (Peneaus aztecus) at three locations in 1977.

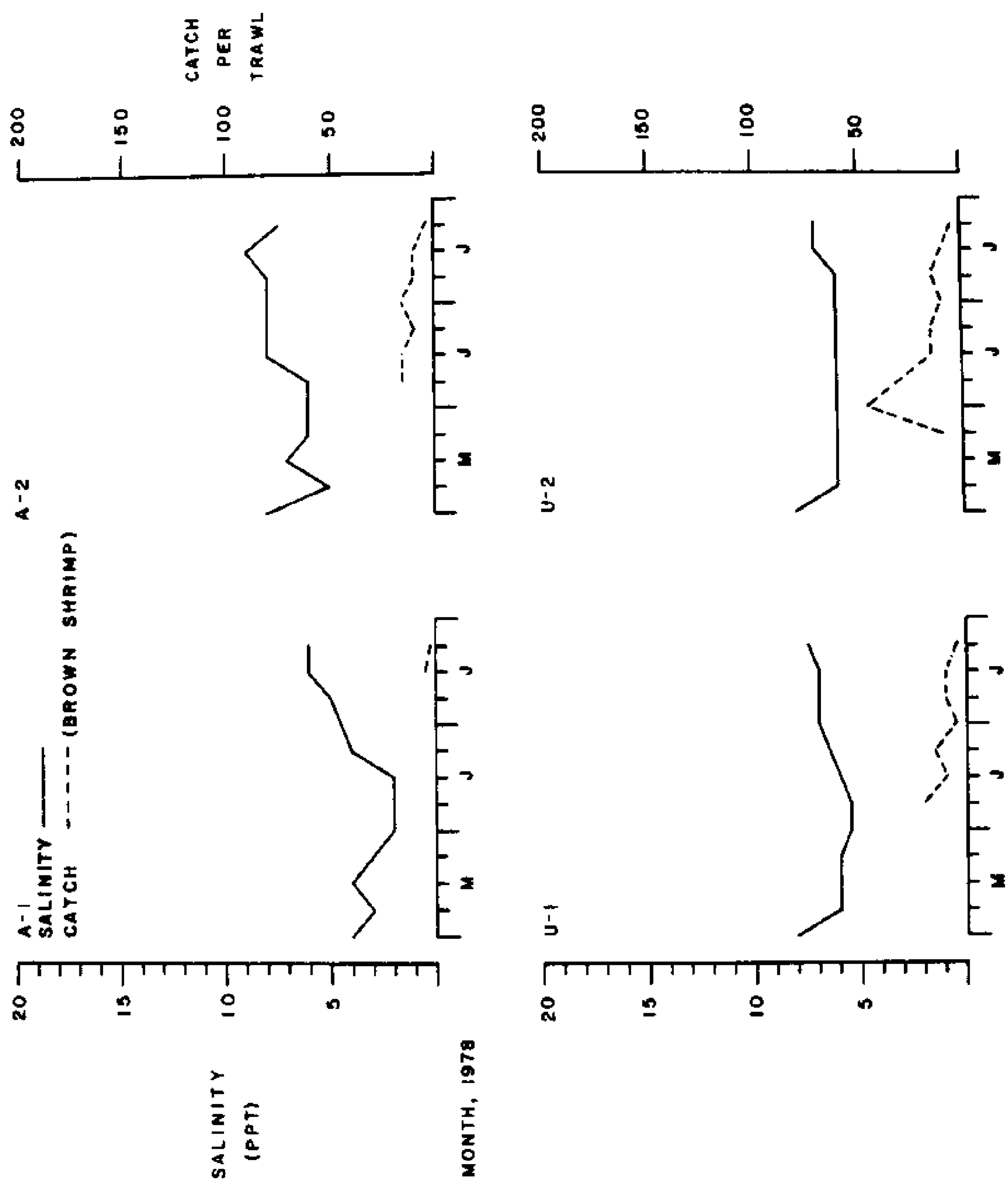

Figure 6. Weekly salinities and catch per trawl of juvenile brown shrimp (<u>Penaeus aztecus</u>) at four locations in 1978.

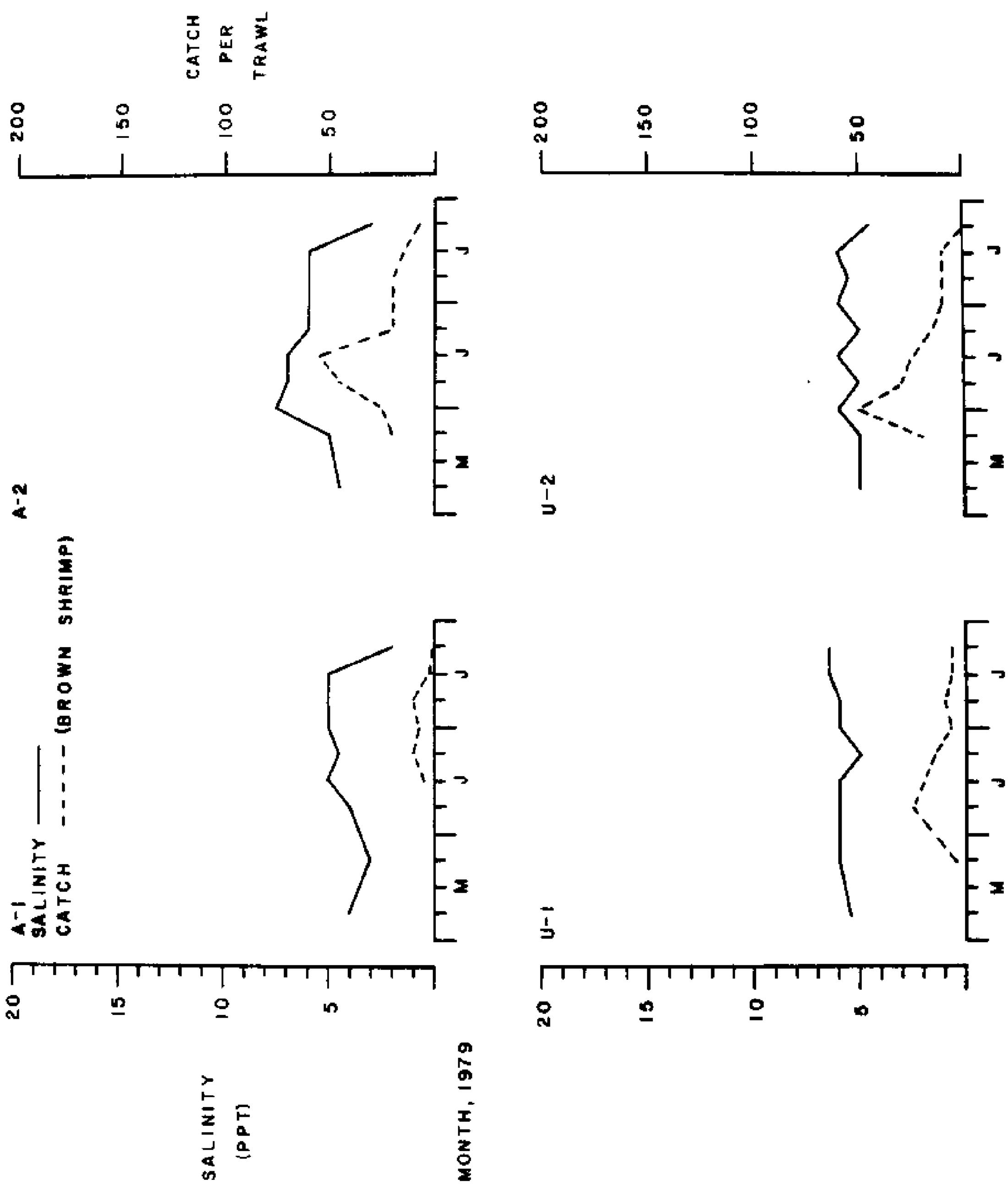

Figure 7. Weekly salinities and catch per trawl of juvenile brown shrimp (Penaeus aztecus) at four locations in 1979.

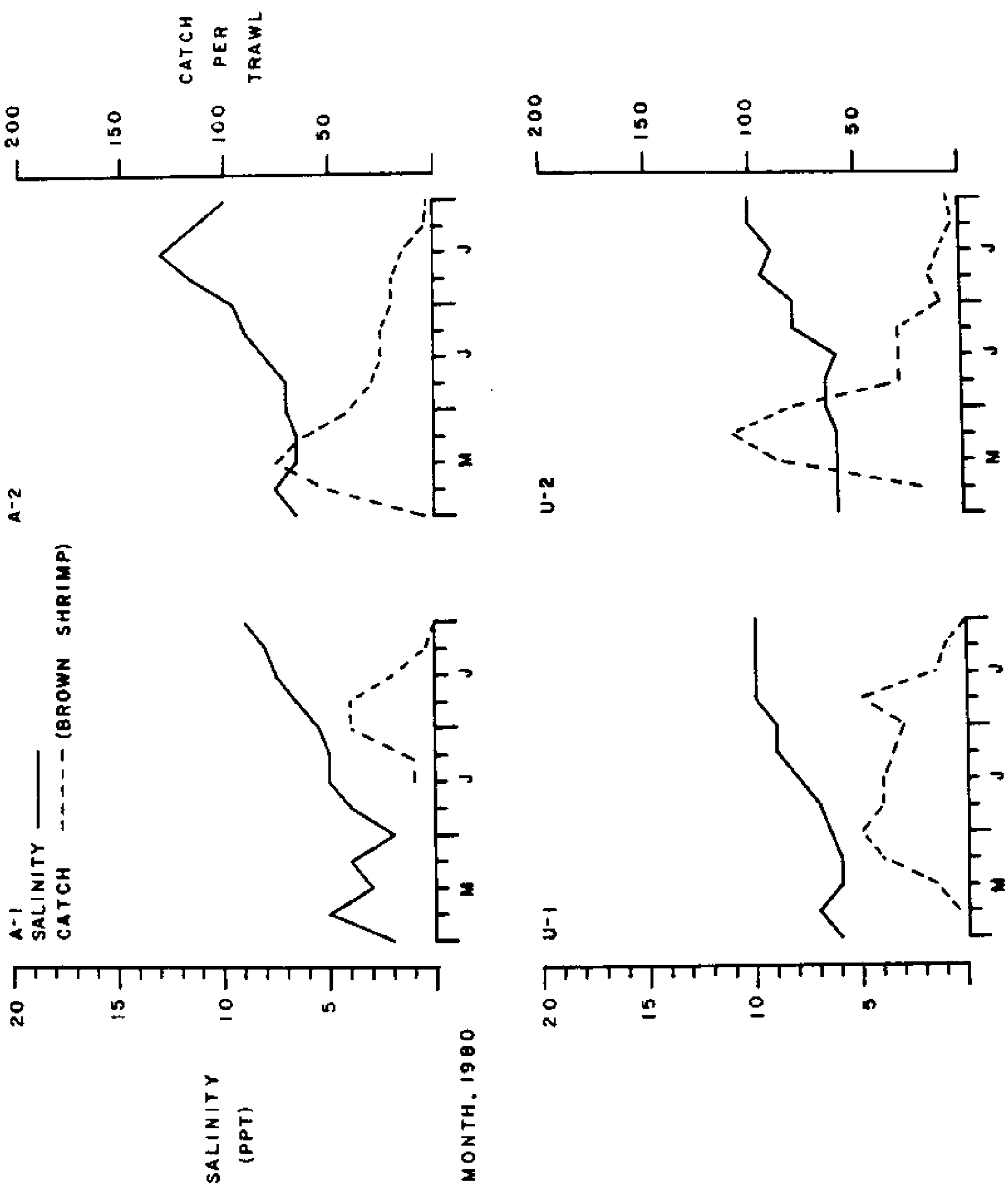

Figure 8. Weekly salinities and catch per trawl of juvenile brown shrimp (Penaeus aztecus) at four locations in 1980.

Earlier sampling by the Division of Marine Fisheries has established that the small tidal tributaries of Pamlico Sound are used by these species as nursery areas (Purvis, 1976). Heaviest utilization by the juvenile finfish usually occurs in April, May, June and July when the size range is 25 to 205mm. Juvenile blue crabs are most abundant during the same period when lengths range from 5 to 195mm. These are critical months for development of these species and, like the brown shrimp, they are seeking a protective nursery area offering an abundant food supply.

The unstable salinity patterns in the altered nursery areas correlate with the apparent preference for unaltered areas by all five species. The pattern of statistically significant preference for the unaltered areas is shown in the data presented in Tables 2 through 6. An exception to this trend was the distribution of croaker in 1977 and 1978 when the highest catches were in the altered nursery areas. Comparing the total numbers of croakers caught these two years with 1979 and 1980, shows productivity was relatively low in 1977 and 1978. When productivity was much higher in 1979 and 1980, the unaltered sites were the most productive. Spot, flounder and blue crab showed a definite preference for the unaltered areas each year.

A reason for preferring the more stable unaltered areas may be the availability of a preferred food supply. There appears to be some other factor besides direct stress caused by fluctuating salinities. This is indicated by the fact that during dry conditions (1977) and stable salinities in the altered areas, these species were still most abundant in the unaltered areas (excluding croaker). Production of the preferred food items (particularly juvenile benthic organisms) during years of low flow could be adversely affected by periods of rapidly fluctuating salinities in preceeding years. This could indirectly influence the productivity of commercially important species by reducing the food supply available during periods of stable salinity and otherwise suitable nursery area conditions.

Table 2.— Statistical analysis of differences in CPUE of spot (*Leiostomus xanthurus*) caught in altered and unaltered nursery areas, May - August, 1977-1980

	Altered Areas		Unaltered Areas		
	Number captured	CPUE	Number Captured	CPUE	t-value calculated
1977					
May	4,757	99.1	8,625	410.8	4.497*
June	6,005	77.0	5,470	140.3	5,006*
July	2,057	26.4	1,772	45.5	4,250*
August	1,019	12.2	1,615	38.5	7.824*
Total	13,838	48.1	17,482	124.0	5.841*
1978					
May	1,216	14.3	11,481	239.2	13.046*
June	529	11.5	3,870	84.2	9,692*
July	127	8.0	357	22.4	5.426*
August	75	3.8	305	15.3	6,144*
Total	1,947	15.0	16,013	223.2	22.809*
1979					
May	3,410	142.1	3,457	144.1	0,061
June	2,924	73.1	3,898	97.5	1.648
July	1,148	30.3	2,337	61.5	3.204*
August	238	14.9	770	48.2	2,853*
Total	7,720	65.5	10,462	88.7	2,276*
1980					
May	1,808	34.8	7,200	150.0	6,920*
June	877	27.4	1,573	52.5	4,804*
July	414	13.0	891	31.9	4,665*
August	231	8.3	786	34.2	8,480*
Total	3,330	23.2	10,450	81.0	7,430*

*Significant at 95% confidence level

Table 3.— Statistical analysis of differences in CPUE of Atlantic croaker (Micropogon undulatus) caught in altered and unaltered nursery areas, May - August, 1977-1980.

	Altered Areas		Unaltered Areas		
	Number captured	CPUE	Number Captured	CPUE	t-value calculated
1977					
May	31	0.7	5	0.3	1,060
June	39	0.5	18	0.5	0,191
July	39	0.5	4	0.1	2,928*
August	8	0.1	3	0.1	0,405
Total	177	0.4	30	0.3	2,143*
1978					
May	83	1.8	17	0.4	3,695*
June	93	2.1	88	1.9	0.214
July	41	2.6	25	1.6	1,408
August	27	1.4	13	0.7	0,348
Total	244	1.9	143	1.1	3.000*
1979					
May	351	14.7	1,174	49.0	5.263*
June	450	11.3	1,154	28.9	5.212*
July	162	4.3	548	14.5	6.758*
August	60	3.0	116	7.3	2.304*
Total	1,023	7.9	2,992	25.4	7.385*
1980					
May	817	15.8	2,292	47.8	5.694*
June	490	15.4	831	27.7	3.680*
July	162	5.1	423	15.1	5.483*
August	85	3.1	208	9.1	4.438*
Total	1,554	10.8	3,754	29.1	11.932*

*Significant at 95% confidence level

Table 4.— Statistical analysis of differences in CPUE of southern flounder (Paralicthys lethostigma) caught in altered and unaltered nursery areas, May - August, 1977-1980.

	Altered Areas		Unaltered Areas		
	Number captured	CPUE	Number Captured	CPUE	t-value calculated
1977					
May	54	1.2	51	2.5	2.664*
June	17	0.3	127	3.3	8.024*
July	9	0.2	22	0.6	2.901*
August	7	0.1	5	0.2	0,485
Total	87	0.3	205	1.5	7,139*
1978					
May	8	0.2	27	0.6	2,272*
June	2	0.1	36	0.8	4.972*
July	1	0.1	3	0.2	0,835
August	1	0.1	5	0.3	1.506
Total	12	0.1	71	0.6	5,281*
1979					
May	35	1.5	72	3.0	1.700
June	16	0.4	56	1.4	2.856*
July	8	0.3	59	1.6	4.385*
August	0	0	21	1.4	4,032*
Total	59	0.5	208	1.8	5,032*
1980					
May	83	1.6	299	6.3	6,387*
June	38	1.2	124	4.2	3,877*
July	15	0.5	89	3.2	3.997*
August	13	0.5	59	2.6	3,142*
Total	149	1.1	571	4.5	8,644*

*Significant at 95% confidence level

Table 5.— Statistical analysis of differences in CPUE of blue crab (*Callinectes sapidus*) caught in altered and unaltered nursery areas, May - August, 1977-1980.

	Altered Areas		Unaltered Areas		
	Number captured	CPUE	Number Captured	CPUE	t-value calculated
1977					
May	56	1.2	57	2.8	2.819*
June	25	0.4	112	2.9	6.567*
July	31	0.4	106	2.8	7.132*
August	49	0.6	92	2.2	4.971*
Total	161	0.6	367	2.6	11.291*
1978					
May	52	1.1	58	1.2	0.371
June	35	0.8	118	2.6	3.680*
July	11	0.7	86	5.4	3.481*
August	42	2.1	132	6.6	2.429*
Total	140	1.1	394	3.1	4.598*
1979					
May	33	1.4	253	10.6	3.476*
June	41	1.1	154	3.9	4.700*
July	36	1.0	130	3.5	3.874*
August	16	1.0	67	4.2	3.523*
Total	126	1.1	604	5.2	6.110*
1980					
May	109	2.1	781	16.3	5,080*
June	51	1.6	579	19.3	5.151*
July	34	1.1	231	8.3	5.108*
August	26	1.0	163	7.1	3.844*
Total	220	1.6	1,754	13.6	8.530*

*Significant at 95% confidence level

Table 6.— Statistical analysis of differences in CPUE of brown shrimp (*Penaeus aztecus*) caught in altered and unaltered nursery areas, May - August 1977 - 1980.

	Altered Areas		Unaltered Areas		
	Number captured	CPUE	Number Captured	CPUE	t-value calculated
1977					
May	536	11.2	2,459	117.1	15.027*
June	1,884	24.2	1,680	43.1	2.567*
July	323	4.2	386	9.9	4.500*
August	147	1.8	43	1.1	1.510
Total	2,939	10.2	4,568	32.4	8.324*
1978					
May	9	0.2	47	1.0	1.197
June	210	4.6	637	13.9	2.904*
July	63	4.6	78	4.9	0.187
August	101	5.1	51	2.6	1.700
Total	386	3.0	813	6.3	2.756*
1979					
May	112	4.7	156	6.5	0.563
June	772	19.3	1,051	26.3	1.506
July	334	8.8	268	7.1	0.944
August	26	1.7	41	2.6	0.927
Total	1,244	10.6	1,516	12.9	1.014
1980					
May	992	19.1	1,616	33.7	1.677
June	538	16.9	1,205	40.2	3.825*
July	537	16.8	416	14.9	0.399
August	87	3.1	79	3.5	0.367
Total	2,154	15.0	3,316	25.7	2.657*

*Significant at 95% confidence level

CONCLUSIONS

1. Drainage of surface water from upland areas into nursery areas through man-made ditches and canals created unstable salinity conditions when rainfall exceeds one inch in a 24-hour period. The unaltered nursery areas showed much more stable salinity readings during the same rain events.

2. The nursery areas appear to have the capacity to receive a certain amount of "unnatural drainage" and buffer the effects of rainfall on salinity except during periods of extended rain.

3. Extensive drainage into a single nursery area reduces its value as estuarine habitat by reducing average salinities and making it more sensitive to the effects of rainfall within the drainage basin.

4. Brown shrimp, spot, croaker, southern flounder and blue crab preferred nursery habitats with no man-made drainage and stable salinity patterns.

5. Drainage directly into nursery areas appears to create an unsuitable habitat for juvenile fish and shellfish during periods of normal rainfall. The degree of alteration of the nursery areas appears to be important since they can withstand some drainage without significant adverse effects.

RECOMMENDATIONS

The appeal that seafood has for consumers is obvious, judging from the increasing demand for a quality product and the annual rise in dockside and retail prices. It is also obvious that changing uses of lands surrounding the vital nursery areas is inevitable, given the current trends in the value of agricultural, residential and recreational developments. It is important that resource agencies stress the value and fragile nature of these small estuaries, manage them as a vital component of a larger system and encourage development of adjacent lands in such a way as to minimize its adverse impacts.

Identification of critical nursery areas must be made and protection of these areas enhanced with proper legislation. Local, state and federal agencies should develop joint comprehensive programs which will allow the wisest use of coastal lands and minimize degradation of water quality and wetland habitat. Particular attention should be placed on developing drainage programs which promote: (1) strict controls over construction of new drainage systems discharging directly into critical nursery areas;

(2) utilizing wooded swamps and marshes as natural filters for upland drainage; (3) maintenance of existing ditches and canals during periods of least biological activity in the receiving waters; (4) analysis of the hydrologic and biological impacts of expanding existing drainage systems; (5) development of water management and water control schemes which would limit discharge points and encourage drainage into less sensitive areas; (6) consideration of the cumulative impacts of extensive alteration of small estuaries.

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