Technical Report to the

TEXAS WATER DEVELOPMENT BOARD

January, 1973 - June, 1975

A Study of the Effects of Fresh Water on the Plankton, Benthos, and Nekton Assemblages of the Lavaca Bay System, Texas

by

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ABSTRACT

This study was typified by above-normal freshwater inflow. The average inflow into the Lavaca Bay system during this 30-month study (1944 cfs) was about 59% above normal (1,254 cfs). Inflow was greater than 4000 cfs during 10% (3 months) of the study and daily inflow ranged from 100 to 94,949 cfs.

A total of 156 phytoplankton taxa representing 6 divisions were identified. Phytoplankton taxa diversities generally declined with increased freshwater inflow. Minimum phytoplankton density was associated with high river discharge (above 2000 cfs) while maximum standing crops occurred with blooms of small microflagellates and diatoms as the bay salinity began to stabilize after high inflow. Chlorophyll *a* values seemed negatively related to high river discharge (above 2000 cfs).

A total of 201 zooplankton taxa representing 14 phyla were identified. Barnacle nauplii, *Acartia tonsa*, and *Oithona* spp. populations comprised 80% of the total zooplankton standing crop. No significant correlations were found between zooplankton standing crops or taxa diversity and freshwater inflow; however, taxa diversity generally increased when river inflow increased to above 2000 cfs. Standing crops were inversely related to water temperature and directly related to salinity.

A total of 169 benthos taxa representing 9 phyla were identified. The numerically most abundant benthos taxa included *Littoridina sphinctostoma*, *Mediomastus californiensis*, *Rangia cuneata*, *Mulinia lateralis*, and *Streblospio benedicti*. Benthos taxa diversity was positively related to bottom salinity and negatively related to bottom turbidity and nutrients. Taxa diversity declined from the high salinity lower bay to the low salinity upper bay and river area. Benthos standing crops were not significantly correlated to freshwater inflow; however, standing crops were related to salinity, turbidity, total carbon, organic nitrogen, and nitrate. No relation between benthos populations and bottom sediment types was found. Benthos populations were generally lowest at dredged channel sites.

A total of 70 nekton taxa representing 3 phyla were identified from trawl samples. The five numerically dominant species were *Anchoa mitchilli*, *Micropogon undulatus*, *Brevoortia patronus*, *Penaeus setiferus*, and *Leiostomus xanthurus*. Nekton populations appeared to be affected more by water temperature than by freshwater inflow.

INTRODUCTION

The Gulf Coast of Texas is about 603 km (375 mi) long and contains numerous embayments (estuaries). Estuaries are semienclosed coastal bodies of water which have a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage (Pritchard, 1967). Thus, Texas estuaries represent ecotones between the fresh water of the river systems and the salt water of the Gulf of Mexico. Estuaries have physical, chemical, and biological characteristics which are unlike those of either the fresh or oceanic water. They are normally rich in fauna and, in many instances, represent resources which support major commercial and sports fisheries.

The increasing need for fresh water dictates that some fresh water entering estuaries be diverted for other uses. In 1960, Texas industry, agriculture, and municipalities used more than 15 million acre-feet of fresh water (Chapman, 1971). It is estimated that with the Texas population projected to increase from 9.6 million people in 1960 to 30.5 million people in 2020, together with industrial and agricultural expansion, Texas will require more than 29 million acre-feet of fresh water annually for municipalities, industry, and agriculture. These are in addition to fresh water needs for mining, pollution control, the estuaries, and to replace evaporation losses. Since ground water supplies are diminishing, most of the future fresh water needs must be supplied by surface water. To supply this surface water, dams are being built on the major rivers which flow into the estuaries. One such dam (Palmetto Bend) is being constructed on the Navidad River about 8 km (5 mi) south of Edna, Texas. This dam is scheduled for completion in 1978. Once completed, this dam will alter existing conditions in the Lavaca Bay system by changing the amount of freshwater inflow and by varying the water interchange patterns. The effects of environmental changes on the abundance and species diversity of plankton, benthos, and nekton are of major concern.

In an estuarine food chain, phytoplankton utilize nutrients, carbon, and sunlight in the process of primary production. Phytoplankton provide a source of food for zooplankton and benthic invertebrates; and, in turn; phytoplankton, zooplankton, and benthic invertebrates are used as food by many of our economically important fish and shellfish.

The principal objectives of this study were: 1) to determine standing crops and species compositions of the phytoplankton, zooplankton, and nekton assemblages, and 2) to determine how freshwater inflow and water quality of the Lavaca Bay system affected these assemblages.

AREA DESCRIPTION

This 30-month study (January 1973 - June 1975) took place in the Lavaca Bay system (Lavaca Bay, Fig. 1; plus the lower Lavaca River area, Fig. 2). Lavaca Bay is a secondary bay of the Matagorda Bay system which is located at latitude 28°40' north and longitude 96°36' west. Lavaca Bay is a shallow oligohaline coastal plain estuary with a surface area of about 16,576 ha (40,960 ac) and a maximum natural depth of about 2.4 m (8 ft). Three main channels, 3.7 m (12 ft) to 11 m (36 ft) deep, have been dredged in the bay. Accumulated spoil from channel dredging has created numerous islands along the dredged channels. Bottom sediments range from soft mud to coarse shell. The shoreline generally lacks *Spartina* marshes and the bay contains only sparse amounts of submergent vegetation. Freshwater inflow into Lavaca Bay comes principally from the Lavaca and Navidad rivers; however, Garcitas, Venado, and Chocolate creeks also contribute fresh water to the bay. Salt water intrudes into Lavaca Bay from the Gulf of Mexico through Pass Cavallo and the Matagorda Ship Channel via Matagorda Bay.

The lower Lavaca River area includes the 8 km (5 mi) of the Lavaca/Navidad confluence to Lavaca Bay, Redfish Lake, and Swan Lake. The Lavaca River arises in Gonzales County, flows southeast for about 113 km (70 mi) and discharges into Lavaca Bay. The Navidad River, the principal tributary of the Lavaca River, arises in southern Fayette County and generally parallels the Lavaca River for about 97 km (60 mi) to their confluence, approximately 8 km (5 mi) north of Lavaca Bay. The Lavaca/Navidad drainage basin is about 129 km (80 mi) long, 80 km (50 mi) wide, and has a drainage area of approximately 6,410 km^2 (2,475 mi^2). The lower 8 km (5 mi) of the Lavaca/Navidad confluence has been dredged to a maximum depth of about 4 m (13 ft). Bottom sediment ranges from coarse sand in the main channel to sandy mud near the river banks.

Redfish Lake is about 4.8 km (3 mi) and Swan Lake is about 1.6 km (1 mi) north of Lavaca Bay (Fig. 2). The area of Swan Lake is estimated to be about 259 ha (1 mi^2) and the area of Redfish Lake is estimated to be about 194 ha (0.75 mi^2). Both lakes have maximum depths of about 1.2 m (4 ft) and have firm bottoms of sandy mud. The lakes are often filled with brackish water due to tidal influx and may be considered small tertiary bays. Swan Lake is closer to the bay and is generally more saline than Redfish Lake.

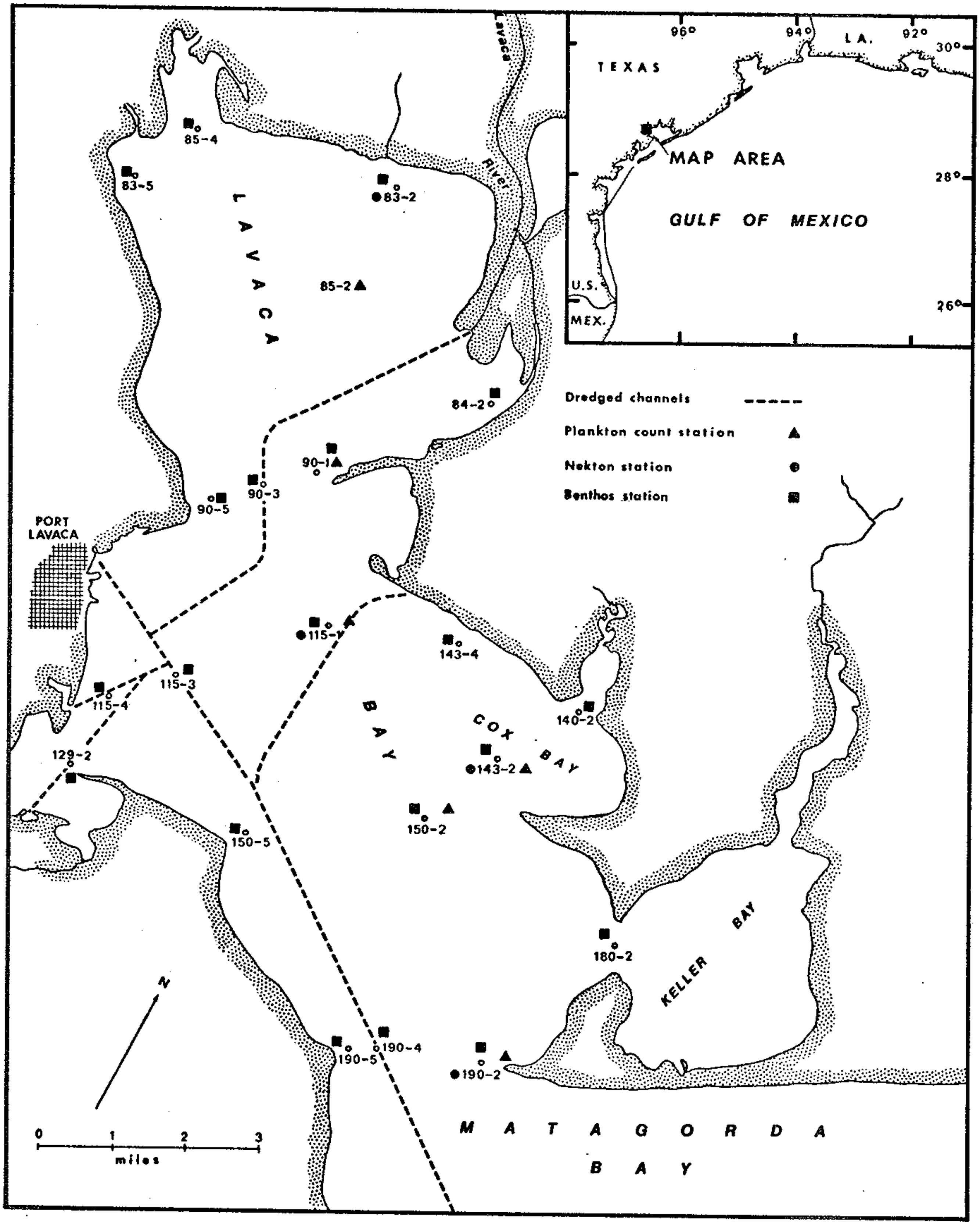


Figure 1. Map showing Lavaca Bay with sample sites. Insert shows study area on Gulf Coast.

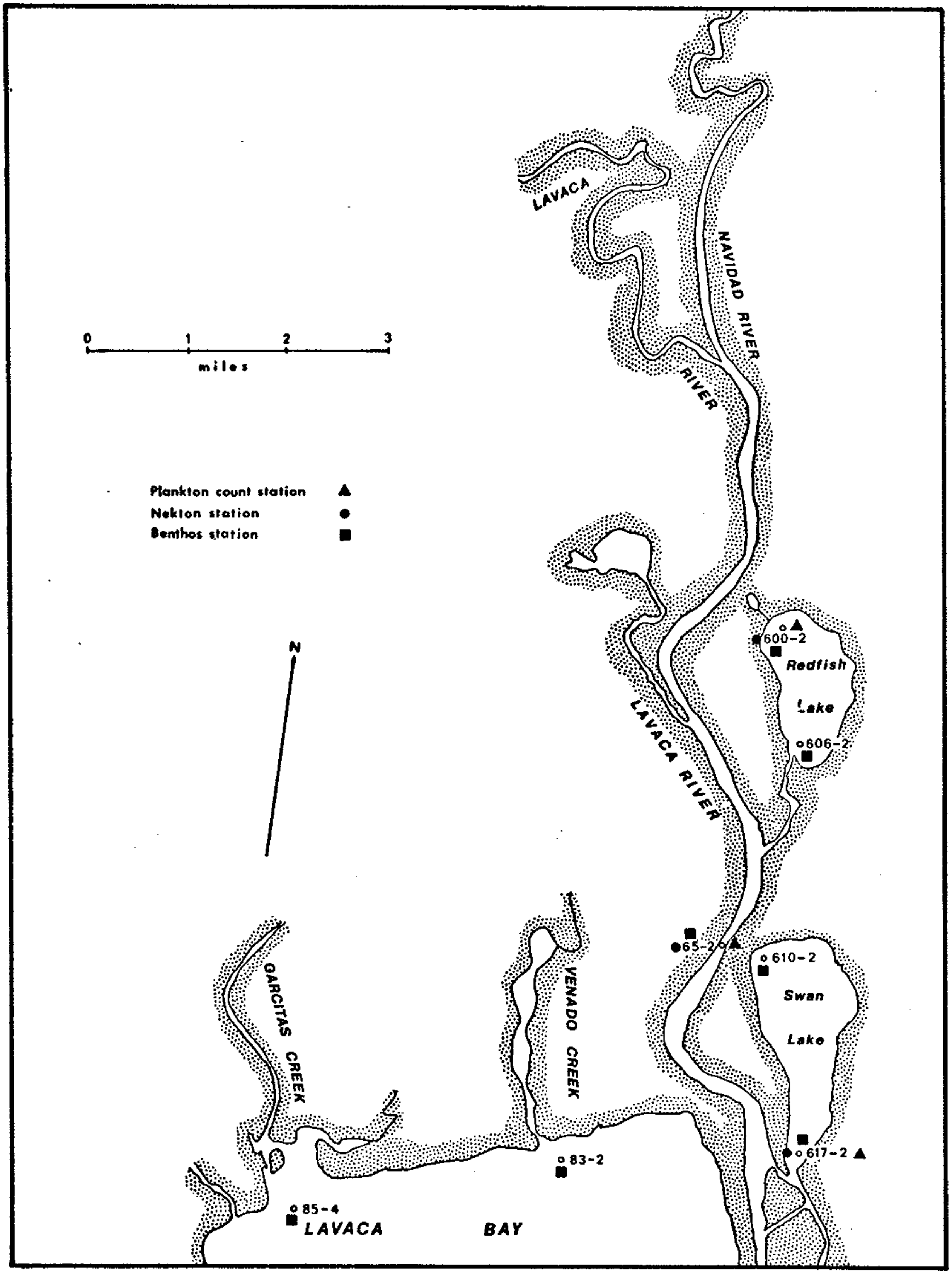


Figure 2. Map showing Lavaca River area with sample sites.

SECTION I. HYDROLOGY AND BOTTOM SEDIMENT

John Means

INTRODUCTION

Any consideration of the ecology of estuarine organisms, that is the relationship between these organisms and their physico-chemical and biological environment, almost inevitably involves monitoring the environment. The estuarine environment is monitored in part by measuring hydrological parameters common to the system. These parameters may include salinity, water temperature, turbidity, pH, nutrient levels, and carbon levels.

LITERATURE REVIEW

Several published studies have included some Lavaca Bay system hydrological data. Blanton *et al*. (1971), in a study of the ecology of Lavaca Bay, monitored water temperature, hydrogen ion concentration (pH), dissolved oxygen (D.O.), turbidity, nitrates, nitrites, phosphates, organic matter, and chlorinity on a monthly basis at 18 stations from March 1970 through March 1971. Moseley and Copeland (1971, 1972, and 1974) included some hydrological data in a study of the ecology of Cox and Keller bays (secondary bays of the Lavaca Bay system). They monitored D.O., salinity, pH, and water temperature on a monthly basis at eight stations from August 1969 through June 1973. Several state and federal agencies have monitored hydrological parameters for the Lavaca Bay system. Personnel from the United States Geological Survey, in conjunction with the Texas Water Development Board, have been periodically monitoring pH, D.O., specific conductance, and water temperature at 16 sites in Lavaca Bay starting in 1968 (Hahl and Ratzlaff, 1970 and 1972). They have also analyzed water samples for nitrate, nitrite, ammonium, and phosphate concentrations. Personnel from the Texas Parks and Wildlife Department have been monitoring salinity, turbidity, water temperature, pH, and D.O. on a monthly basis at several stations in Lavaca Bay since 1969 (Martinez, 1970 and 1971).

MATERIALS AND METHODS

Hydrological parameters were monitored on a monthly basis at all sites (21 bay sites and 5 river area sites; Figs. 1 and 2) from January through September 1973. Starting in October, parameters were monitored at all sites toward the end of each month and at 9 of the 26 sites (600-2, 65-2, 617-2, 85-2, 90-1, 115-1, 143-2, 150-2, and 190-2) during the middle of the month. Most sites were located on line-site transects established in 1967 during a Texas Water Development Board/ United States Geological Survey study. One or two samples were taken at each site depending on the water depth. At sites with a water depth of less than 1 m, a single surface sample was taken, while at sites with a water depth over 1 m, surface and bottom samples were collected. Salinity, D.O., water temperature, turbidity, and pH were determined for each sample. An Americal Optical T/C refractometer was used to determine salinity to the nearest 1 part per thousand ($^{o}/oo$). A Yellow Springs Instrument (YSI) Model 54 oxygen meter was used to measure D.O. to the nearest 0.1 part per million (ppm) and water temperature to the nearest

1°C. A mercury-in-glass thermometer was also used to check the water temperature. A Hach Chemical Company direct reading colorimeter was used to measure turbidity to the nearest Jackson Turbidity Unit (JTU). A Sargent-Welch or Beckman pH meter was used to determine pH to the nearest 0.1 standard unit.

Surface water samples, collected on a monthly basis, were analyzed by the Texas State Department of Health for nutrients: nitrate nitrogen NO_3-N, NH_3-N, organic nitrogen, nitrite nitrogen NO_2-N, and ortho- and total phosphates. Water samples for nutrient analysis were collected in 0.95 liter (1 qt) polyethylene cubitainers and held on ice until analyzed. Nutrient concentrations were recorded to the nearest 0.01 mg/l. Bottom water samples, collected on a monthly basis, were analyzed for total carbon by the University of Texas School of Public Health or by the Texas State Department of Health. Water samples for carbon analysis were held in either 25-ml glass screw-cap vials, 20-ml ampules, or 0.95 liter (1 qt) polyethylene cubitainers. Carbon concentrations were recorded to the nearest 1 mg/l.

Sediment samples were analyzed for percent composition of sedimentary particle sizes. Bottom samples were collected with a 0.1 m^2 Peterson grab at 25 of the sample sites on 10 July 1973. About 200 gm of sediment were scooped from the upper 5 cm of the total sample and stored in a small glass jar. Sieve and pipette analyses were made for each 200-gm sample using methods described in A Field and Laboratory Manual of Oceanographic Procedures (Florida State University, 1964). The percentage composition of the sediment was calculated by weight, and the percentages were then used to classify (shell, sand, and silt-clay) each sample using a triangular diagram (Fig. 3).

RESULTS

Salinity.--Salinities ranged from 0 (upper bay sites during spring and summer) to 33 °/oo (bottom value at site 190-4 on 27 December 1973 and 25 February 1975) and averaged 10 °/oo for the 30-month study (Table 1). Surface values were similar to bottom values for all hydrological parameters; therefore, surface and bottom values were combined to compute sample date and yearly means. Mean salinity in 1975 (13 °/oo) was higher than in 1973 (8 °/oo) or in 1974 (10 °/oo); however, only six months of hydrological data were collected in 1975. No seasonal trend was evident for salinity (Figs. 4, 5, and 6). Mean salinity values by site for the study increased from upper (600-2) to lower (190-4) bay (Table 2). Each site had a wide salinity range.

Water Temperature.--Water temperatures ranged from 7 (bottom value at channel sites 115-3 and 190-4 on 16 January 1973) to 34°C (bottom value at site 143-4 on 10 July 1973) and averaged 21°C (Table 1). Mean water temperature for each year was 21°C. Water temperatures followed a seasonal trend throughout the study (Figs. 4, 5, and 6). Sample date means were generally low in winter (10°C) and high in summer (31°C). Mean temperatures were similar between sites (less than 4°C difference)(Table 2). Each site had a wide temperature range.

Dissolved Oxygen.--Dissolved oxygen values ranged from 2 (surface value at site 115-4 on 24 June 1975) to 18 ppm (bottom value site 65-2 on 31 December 1974) and averaged 8.6 ppm (Table 1). Oxygen values above 13 ppm probably occurred due to a malfunctioning oxygen meter. Average dissolved oxygen was higher in 1973 (9.4 ppm) than in 1974 (8.6 ppm) or in 1975 (7.5 ppm). No seasonal trend

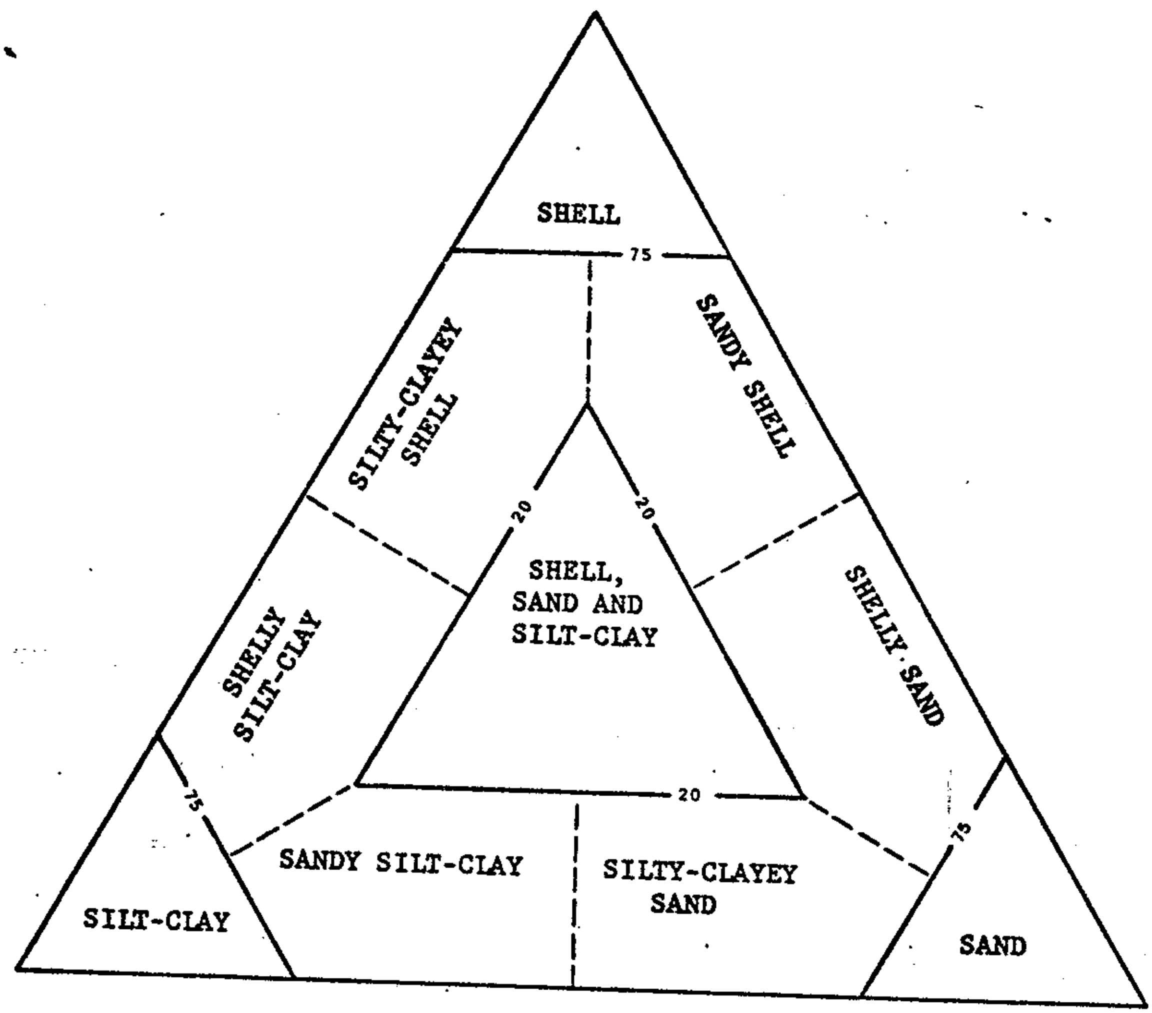


Figure 3. Triangular diagram used to classify sediment samples by percent shell, sand, and silt-clay.

Table 1. Means and ranges by date for surface and bottom salinity, water temperature, dissolved oxygen, turbidity, and pH in the Lavaca Bay system (January 1973 - June 1975).

Date (D-M-Y)		Salinity (°/oo)		Water Temperature (°C)		Dissolved Oxygen (ppm)		Turbidity (JTU)		pH	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
16- 1-73	S	16	0-24	10	8-16	11.2	9.5-13.2	20	5-50	8.1	7.4-9.0
	B	16	7-24	10	6-16	11.0	9.0-13.2	19	5-40	8.1	7.4-8.9
18- 2-73	S	16	5-24	11	10-13	12.7	11.4-14.5	7	0-45	8.2	7.5-8.6
	B	18	5-24	11	10-13	12.7	11.0-14.6	10	0-80	7.8	7.5-8.5
6- 3-73	S	12	2-20	21	19-25	8.1	6.8-10.4	42	5-150	7.8	7.2-8.2
	B	12	3-24	20	15-23	7.6	5.5-9.8	46	15-150	7.7	7.1-8.2
10- 4-73	S	9	0-19	16	14-18	12.6	8.2-17.5	N.D.	N.D.	7.9	7.7-8.2
	B	10	0-21	16	14-18	12.3	7.9-17.5			7.9	7.7-8.3
10- 5-73	S	3	0-10	23	19-30	8.1	6.7-11.0	78	25-185	8.1	7.9-8.5
	B	4	0-15	23	19-26	8.1	6.2-10.0	96	20-300	8.1	7.9-8.6
5- 6-73	S	6	0-11	27	20-31	8.2	6.5-10.9	N.D.	N.D.	8.0	7.9-8.4
	B	6	0-11	27	21-31	8.0	6.5-11.3			8.0	7.9-8.4
10- 7-73	S	2	0-10	30	29-34	7.6	6.5-13.8	108	60-200	8.1	7.8-8.4
	B	4	0-28	29	23-32	7.3	5.2-13.6	112	22-160	8.0	7.7-8.5
2- 8-73	S	5	0-13	28	24-32	N.D.	N.D.	47	10-110	8.0	7.2-8.8
	B	6	0-17	29	25-32			50	10-140	8.0	7.2-8.6
25- 9-73	S	3	0-12	27	23-29	8.7	7.5-11.0	61	18-200	7.9	7.5-8.5
	B	3	0-15	26	23-32	8.7	6.5-11.0	96	15-300	7.8	7.5-8.5
15-10-73	S	1	0-8	24	23-29	6.9	6.0-8.0	74	15-150	7.8	7.2-8.2
	B	2	0-8	24	23-28	7.1	6.1-9.8	82	15-180	7.8	7.2-8.2
30-10-73	S	4	0-12	23	21-25	N.D.	N.D.	51	5-200	8.2	7.7-8.5
	B	6	0-26	23	21-24			52	5-200	8.1	7.7-8.5

Table 1---continued.

Date (D-M-Y)		Salinity (°/oo)		Water Temperature (°C)		Dissolved Oxygen (ppm)		Turbidity (JTU)		pH	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
13-11-73	S	6	0-12	24	22-25	7.5	6.3-10.0	20	0-44	8.0	7.5-8.2
	B	7	5-12	24	22-25	7.8	6.3-10.0	22	0-44	8.0	7.5-8.2
29-11-73	S	10	0-28	18	16-20	8.6	6.4-10.4	29	10-50	N.D.	N.D.
	B	11	6-28	18	16-20	9.0	6.8-10.4	43	10-200		
14-12-73	S	14	10-19	19	18-21	11.1	8.5-13.8	12	2-25	8.4	8.3-8.8
	B	14	17-19	19	18-21	11.4	8.3-13.8	13	2-30	8.4	8.3-8.8
28-12-73	S	17	1-26	14	12-20	11.1	8.2-17.2	2	0-20	8.3	7.5-8.7
	B	18	19-33	15	12-19	11.0	8.6-17.2	6	0-50	8.3	8.5-8.7
10- 1-74	S	17	0-25	16	14-18	8.9	7.6-12.2	3	0-10	8.3	7.4-8.6
	B	17	0-25	16	14-17	9.1	7.2-12.2	8	0-60	8.4	8.2-8.6
29- 1-74	S	6	0-19	17	14-20	8.1	6.4-11.6	57	0-180	7.8	6.8-8.6
	B	8	0-22	17	14-20	9.0	6.5-12.4	89	0-250	7.8	6.8-8.4
12- 2-74	S	8	0-17	16	15-17	8.5	7.4-10.6	29	0-150	7.8	6.1-8.5
	B	9	7-18	16	15-17	8.4	7.4-10.6	35	0-150	7.8	6.1-8.4
26- 2-74	S	13	0-21	12	11-15	10.4	8.2-12.9	8	0-72	8.3	8.1-8.6
	B	14	6-30	12	11-14	10.4	8.2-13.0	19	0-180	8.2	7.4-8.6
11- 3-74	S	15	2-23	23	23-24	8.0	7.2-8.3	40	15-70	8.2	8.2-8.3
	B	15	2-23	23	23-24	8.0	7.2-8.4	54	38-90	8.2	8.2-8.3
27- 3-74	S	15	2-22	16	13-18	9.7	8.8-12.2	1	0-10	7.7	6.7-8.2
	B	17	12-23	15	12-19	9.8	8.4-12.2	2	0-14	7.5	6.6-8.2
10- 4-74	S	16	6-23	22	21-23	9.4	6.0-10.4	63	0-120	7.8	7.2-8.0
	B	15	7-23	22	21-23	9.3	6.0-10.4	75	0-155	7.8	7.2-8.1

Table 1---continued.

Date (D-M-Y)		Salinity ($^{o}/oo$)		Water Temperature (^{o}C)		Dissolved Oxygen (ppm)		Turbidity (JTU)		pH	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
23- 4-74	S	14	2-22	23	22-25	7.8	6.4-8.8	16	0-75	7.8	7.1-8.3
	B	16	2-25	23	22-25	7.8	4.8-9.4	22	0-90	7.8	7.1-8.2
13- 5-74	S	6	0-14	25	24-27	6.9	5.3-8.0	95	20-220	8.0	7.6-8.7
	B	5	0-14	25	24-27	6.9	5.4-8.4	111	20-220	7.9	7.2-8.8
23- 5-74	S	6	0-14	31	27-33	7.6	5.6-10.0	38	15-95	8.1	7.8-8.5
	B	7	0-20	31	27-33	7.6	5.5-10.0	47	20-110	8.0	7.4-8.4
11- 6-74	S	6	1-13	26	25-27	7.1	5.4-8.0	47	0-250	8.2	7.7-9.0
	B	6	1-16	26	25-27	7.1	5.4-9.2	45	0-230	7.9	7.2-9.0
26-6-74	S	8	0-19	25	22-29	9.0	7.1-12.0	35	0-100	8.1	7.7-8.9
	B	10	0-25	25	21-28	8.5	6.0-11.0	49	0-145	7.9	7.4-8.8
17- 7-74	S	11	1-22	26	23-29	7.5	6.4-8.5	28	5-43	8.4	8.0-9.0
	B	11	1-22	27	23-29	7.0	5.5-8.3	36	5-63	8.1	7.2-9.0
24- 7-74	S	12	0-23	29	28-31	N.D.	N.D.	30	10-76	8.2	7.2-8.6
	B	12	0-27	29	28-31			41	10-180	8.0	7.2-8.4
15- 8-74	S	12	1-25	30	30-31	7.1	5.0-9.2	22	0-30	7.8	7.7-8.2
	B	11	7-25	30	30-32	6.8	4.0-9.2	27	0-45	7.4	7.1-7.8
28- 8-74	S	16	2-27	27	26-30	6.6	5.0-8.6	47	23-75	8.0	7.1-8.7
	B	17	4-28	26	26-28	6.5	5.0-8.4	74	23-195	7.8	7.2-8.5
16- 9-74	S	10	1-23	26	26-27	7.6	4.7-9.2	90	20-350	7.7	6.8-8.5
	B	14	7-23	26	23-28	7.4	5.8-9.4	66	20-275	7.4	6.8-7.7
25- 9-74	S	4	1-14	23	21-30	N.D.	N.D.	64	20-130	8.0	7.2-8.9
	B	5	1-21	23	21-28			80	38-185	8.0	7.2-8.8

Table 1---continued.

Date (D-M-Y)		Salinity ($^{o}/oo$)		Water Temperature (^{o}C)		Dissolved Oxygen (ppm)		Turbidity (JTU)		pH	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
16-10-74	S	7	1-16	18	16-21	9.6	8.2-12.2	71	50-95	8.0	7.8-8.4
	B	8	1-16	18	16-21	11.0	9.0-14.0	72	50-80	7.9	7.3-8.4
4-11-74	S	9	3-17	24	22-25	7.9	6.8-9.8	89	30-220	8.0	6.5-8.6
	B	10	3-17	24	21-25	8.4	6.8-12.0	117	30-250	8.0	7.3-8.6
13-11-74	S	8	1-16	16	15-18	N.D.	N.D.	50	0-70	8.6	8.2-8.9
	B	7	1-18	16	15-18			53	10-220	8.6	8.2-9.1
25-11-74	S	8	0-18	15	13-20	8.4	7.2-11.7	176	58-700	8.2	7.3-8.5
	B	9	0-23	15	13-20	8.4	7.2-11.7	206	58-800	8.2	7.3-8.5
9-12-74	S	7	3-15	11	9-13	11.0	10.2-12.6	71	15-210	8.0	6.9-8.6
	B	7	0	11	9-13	11.1	10.2-12.6	76	15-215	8.0	7.3-8.5
31-12-74	S	14	1-22	16	15-23	14.0	8.0-16.0	21	1-135	8.3	8.0-8.8
	B	15	10-27	16	13-17	11.2	9.0-18.0	28	7-135	8.2	7.9-8.7
14- 1-75	S	11	1-20	10	8-12	10.7	9.0-11.8	N.D.	N.D.	8.3	8.2-8.5
	B	14	1-22	10	8-12	12.4	11.0-14.8			8.3	8.1-8.4
30- 1-75	S	20	8-24	21	19-23	6.6	5.8-8.8	N.D.	N.D.	7.6	7.1-8.2
	B	18	12-29	21	20-23	6.6	5.8-7.8			7.8	7.4-10.3
13- 2-75	S	15	4-22	14	13-16	8.2	7.3-10.8	20	5-40	8.1	7.2-8.6
	B	16	12-22	14	12-16	8.2	7.2-10.8	19	10-35	7.9	6.8-8.6
25- 2-75	S	16	3-22	17	12-21	7.7	6.5-10.4	24	0-68	8.3	8.1-8.4
	B	16	10-33	17	12-21	7.6	6.4-9.6	34	10-105	8.3	7.9-8.4
11- 3-75	S	17	6-23	19	19-20	6.9	6.6-7.3	29	10-65	7.5	7.4-7.9
	B	17	11-23	19	19-21	7.1	6.7-7.7	47	25-80	7.6	7.4-7.8

Table 1---continued.

Date (D-M-Y)		Salinity (^{o}/oo)		Water Temperature (^{o}C)		Dissolved Oxygen (ppm)		Turbidity (JTU)		pH	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
19- 3-75	S	19	10-23	18	14-22	7.2	6.3-8.5	26	10-68	8.2	8.0-8.4
	B	20	17-23	18	14-20	7.1	6.3-8.7	61	15-475	8.2	8.1-8.3
10- 4-75	S	15	1-23	22	22	7.5	7.4-7.6	27	9-100	7.8	7.7-8.1
	B	16	3-23	22	22	8.0	7.8-8.7	26	10-60	7.8	7.7-8.1
29- 4-75	S	15	2-23	26	25-28	6.9	5.5-7.5	37	2-105	7.9	7.5-8.4
	B	15	7-23	26	25-28	6.8	4.5-7.8	52	5-120	7.8	7.5-8.4
15- 5-75	S	8	1-20	25	24-26	6.6	5.5-7.4	78	50-130	8.1	7.9-8.3
	B	9	1-20	25	24-26	6.5	5.5-7.4	94	70-180	8.1	7.8-8.3
4- 6-75	S	2	0-10	27	26-32	7.5	4.5-9.7	86	20-300	8.1	7.7-8.8
	B	3	0-13	27	26-29	7.2	3.0-9.7	131	20-700	8.1	7.4-8.8
14- 6-75	S	5	0-13	31	28-33	6.8	2.0-8.0	58	30-120	8.4	7.8-8.7
	B	6	1-16	30	28-34	6.2	5.0-7.0	77	40-150	8.3	8.1-8.5

N.D. No Data taken.
S Surface
B Bottom

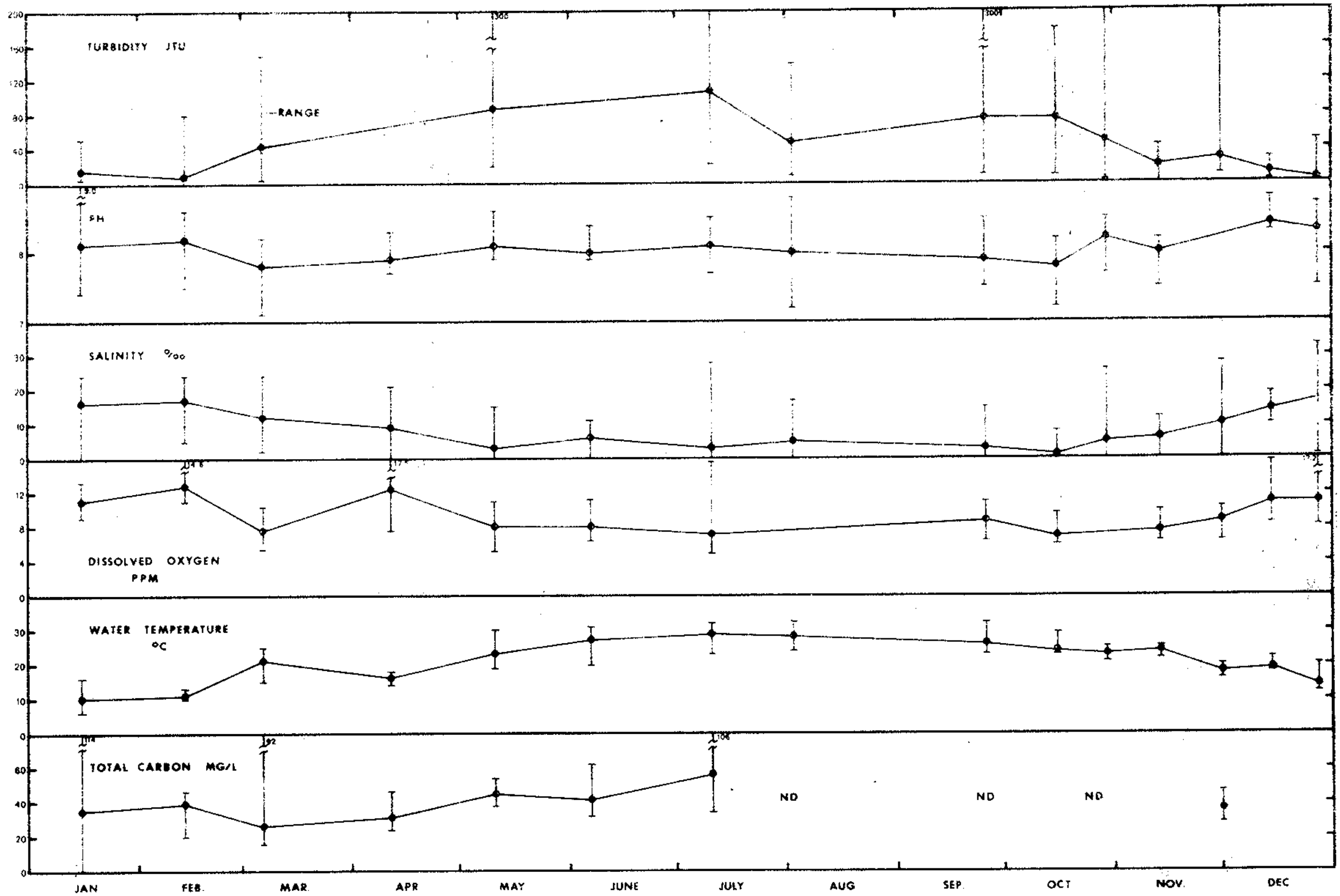


Figure 4. Sample date means and ranges (surface and bottom values combined) for hydrological parameters from the Lavaca Bay system during 1973.

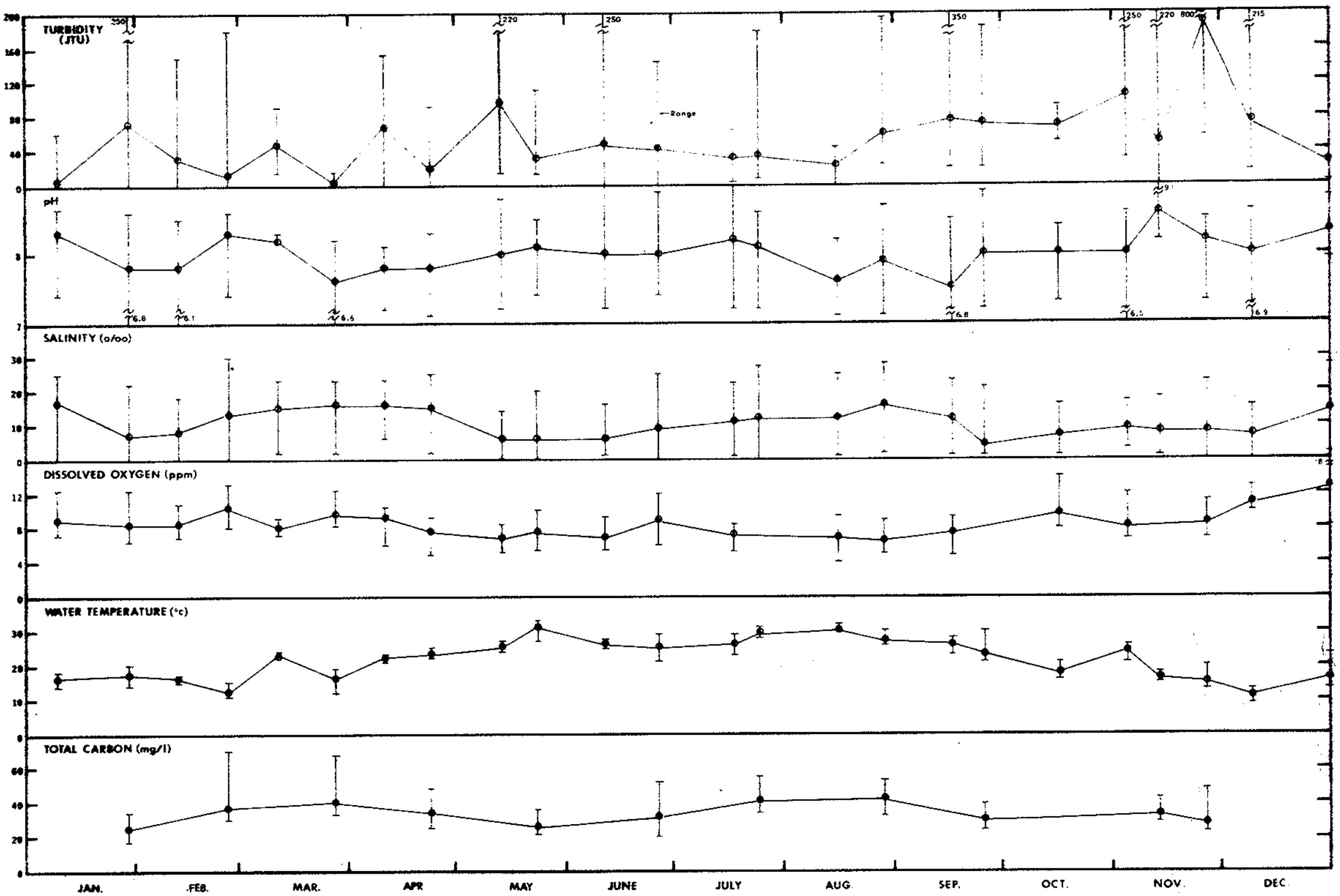


Figure 5. Sample date means and ranges (surface and bottom values combined) for hydrological parameters from the Lavaca Bay system during 1974.

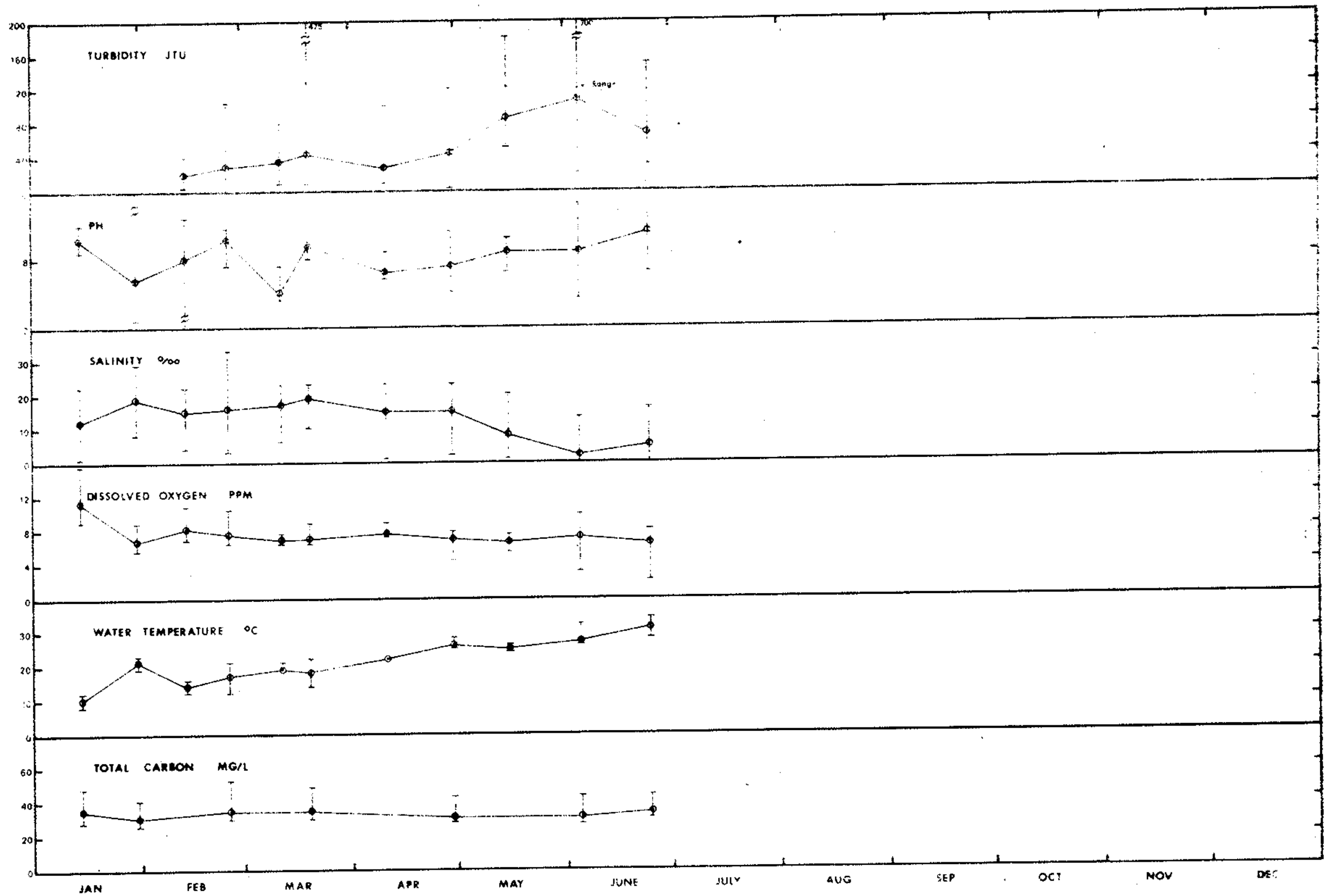


Figure 6. Sample date means and ranges (surface and bottom values combined) for hydrological parameters from the Lavaca Bay system during 1975.

Table 2. Study period (January 1973 - June 1975) mean values and ranges by site for six hydrological parameters monitered in the Lavaca Bay system.

	Salinity ($^{o}/oo$)		Water Temp. (^{o}C)		D. O. (ppm)		pH		Turbidity (JTU)		Total Carbon (mg/1)	
Sites	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
83-2	7	0-19	22	10-32	8.1	5.0-14.4	8.1	7.3-8.6	66	0-230	37	23-106
83-5	6	0-19	22	10-32	8.1	5.8-12.8	8.1	6.8-8.8	101	0-800	35	20-73
84-2	7	0-21	22	11-31	8.1	5.8-12.0	7.8	6.9-8.6	61	0-275	37	22-50
85-2	9	0-22	22	11-32	7.8	5.0-12.2	8.1	7.1-8.9	67	0-250	34	24-45
85-4	6	0-17	22	11-32	8.1	4.8-12.0	8.1	6.5-8.8	96	0-480	39	23-114
90-1	10	0-23	21	9-32	8.1	4.0-15.0	8.1	7.1-9.1	65	0-350	33	21-63
90-3	10	0-22	22	8-32	8.6	5.9-15.0	8.0	7.4-8.7	86	0-700	33	20-66
90-5	9	1-20	22	9-32	8.7	5.9-15.0	8.1	7.1-8.7	60	0-200	33	19-64
115-1	13	0-25	21	9-32	8.2	5.0-13.5	8.1	7.2-8.7	48	0-230	32	16-58
115-3	13	1-26	20	7-31	9.3	5.0-16.0	8.1	7.4-10.3	63	0-475	33	17-62
115-4	12	2-25	20	9-32	8.5	2.0-14.2	8.1	7.4-8.6	53	0-167	32	20-62
129-2	11	2-22	21	11-31	8.8	5.0-14.5	8.1	7.2-8.8	56	0-195	36	25-92
140-2	15	4-23	22	11-31	8.5	5.5-17.5	8.0	7.4-8.6	42	0-190	31	17-52
143-2	16	5-23	21	9-32	8.6	6.0-14.5	8.0	7.2-8.8	32	0-195	32	23-50
143-4	15	4-22	24	12-34	8.6	6.2-15.0	8.0	7.2-8.5	56	0-275	32	17-52
150-2	16	5-24	21	9-32	8.7	5.7-16.0	8.0	7.1-8.5	35	0-150	33	17-57
150-5	13	3-23	21	8-31	8.8	6.4-14.6	8.0	7.1-8.6	51	0-280	33	23-55
180-2	17	5-24	21	9-31	8.7	6.0-13.0	8.1	7.4-8.5	31	0-220	33	17-57
190-2	18	0-28	21	8-33	8.5	5.4-14.4	8.0	7.3-8.7	28	0-130	33	21-62
190-4	20	5-33	20	7-32	8.8	5.2-15.0	8.0	7.3-8.6	49	0-300	33	21-52
190-5	16	5-26	21	8-32	9.0	6.0-13.0	8.0	7.3-8.5	37	0-170	32	22-52
65-2	2	0-13	21	10-31	8.7	3.0-18.0	7.9	6.6-8.8	76	0-700	43	0-70
600-2	1	0-7	22	9-33	8.7	5.0-14.6	8.0	6.1-9.0	48	0-225	43	29-59
606-2	1	0-8	22	12-32	8.9	4.5-17.2	7.9	6.8-8.5	38	0-80	45	23-64
610-2	3	0-12	21	13-32	9.4	6.0-14.2	7.6	7.1-8.7	28	0-125	40	30-53
617-2	5	0-19	21	11-32	8.9	4.7-16.0	7.8	6.8-9.0	58	0-275	38	17-56

was evident for dissolved oxygen (Figs. 4, 5, and 6). Mean values were similar between sites (less than 2 ppm difference)(Table 2). Each site had a wide dissolved oxygen range.

Hydrogen Ion Concentration (pH).--Values for pH ranged from 6.1 (site 600-2 on 12 February 1974) to 10.3 (site 115-3 on 30 January 1975) and averaged 8.0 (Table 1). Mean pH was 8.0 for each year during the study. No seasonal trend in pH was observed during this study (Figs. 4, 5, and 6). Mean values were similar between sites (< 0.5 units difference)(Table 2). Each site had a wide range of values.

Turbidity.--Turbidities ranged from 0 (all sites) to 800 JTU (site 83-5 on 26 November 1974) and averaged 54 JTU (Table 1). Surface turbidity of 0 JTU was recorded at each site at sometime during the study. Mean turbidity values were greater in 1974 (58 JTU) than in 1973 (51 JTU) or in 1975 (54 JTU). No seasonal trends were evident (Figs. 4, 5, and 6). Mean values between sites varied as much as 73 JTU and each site had a wide range of values (Table 2).

Total Carbon.--Total carbon values ranged from 0 (site 65-2 on 15 January 1974) to 114 mg/l (site 85-4 on 15 January 1974) and averaged 35 mg/l (Table 3). Mean total carbon values were higher in 1973 (38 mg/l) than in 1974 (30 mg/l) or in 1975 (33 mg/l). Total carbon did not follow a seasonal pattern (Figs. 4, 5, and 6). Mean total carbon values were similar between sites (< 4 mg/l difference)(Table 2). Mean values showed a slight decrease from upper to lower bay. Each site had a wide total carbon range for the study.

Ammonia.--Lavaca Bay system ammonia values ranged from < 0.1 (all sites) to 0.7 mg/l (site 600-2 on 6 March 1973) and averaged 0.1 mg/l for the 30-month study (Table 4). Nutrient concentrations below 0.1 mg/l were recorded as < 0.1 mg/l. All "less than" values were divided by two and the quotient was used for plotting sample date means. Average ammonia was higher in 1973 (0.1 mg/l) than in 1974 (0.05 mg/l); however, only five months of nutrient data were collected in 1975. In 1973, the high mean value (0.2 mg/l) occurred in March and the low mean value (0.05 mg/l) persisted from September through December (Fig. 7). Mean values for each month in 1974 and 1975 were the same (0.05 mg/l)(Figs. 8 and 9). Mean ammonia concentrations were similar between sites (< 0.06 mg/l difference) for the study (Table 5). Upper bay sites had higher nutrient concentrations than lower bay sites.

Organic Nitrogen.--Organic nitrogen values ranged from 0.07 (site 143-2 on 10 July 1973) to 4.8 mg/l (site 115-3 on 29 January 1974) and averaged 0.5 mg/l for the study (Table 4). Average organic nitrogen values were higher in 1974 (0.6 mg/l) than in 1973 or 1975 (0.5 mg/l). No seasonal trends were evident for organic nitrogen (Figs. 7, 8, and 9). Mean values between sites were similar (< 0.5 mg/l difference) for the study (Table 5). Upper bay sites had higher nitrogen concentrations than lower bay sites.

Nitrate.--Nitrate values ranged from < 0.02 (all sites) to 1.06 mg/l (site 83-5 on 29 January 1974) and averaged 0.08 mg/l for the study (Table 4). Average nitrate was higher in 1974 (0.1 mg/l) than in 1973 (0.06 mg/l) or 1975 (0.04 mg/l). No seasonal trends were evident (Figs. 7, 8, and 9). Upper bay sites had higher nitrate concentrations than lower bay sites (Table 5).

Nitrite.--Nitrite values ranged from < 0.003 (most sites) to 0.12 mg/l (site 83-5 on 4 June 1975) and averaged 0.01 mg/l for the study (Table 4).

Table 3. Mean total carbon (mg/l) by sample date for the Lavaca Bay system.

Date (D-M-Y)	Mean	Range
16- 1-73	35	0-114
18- 2-73	39	20-46
6- 3-73	25	16-92
10- 4-73	31	24-46
10- 5-73	45	38-53
5- 6-73	41	33-63
10- 7-73	56	34-106
2- 8-73	N.D.	N.D.
25- 9-73	N.D.	N.D.
30-10-73	N.D.	N.D.
29-11-73	36	29-47
28-12-73	N.D.	N.D.
29- 1-74	25	17-33
26- 2-74	37	30-70
27- 3-74	41	33-67
23- 4-74	34	26-48
23- 5-74	26	22-36
26- 6-74	31	20-51
24- 7-74	41	34-55
28- 8-74	42	33-53
25- 9-74	30	24-39
16-10-74	N.D.	N.D.
4-11-74	N.D.	N.D.
13-11-74	33	29-43
25-11-74	28	23-38
31-12-74	N.D.	N.D.
14- 1-75	35	29-48
30- 1-75	31	26-41
25- 2-75	35	30-53
19- 3-75	35	30-49
29- 4-75	31	28-43
4- 6-75	31	27-43
24- 6-75	34	30-44

N.D. No Data taken.

Table 4. Means and ranges by date for ammonia, organic nitrogen, nitrate, nitrite, ortho-phosphate, and total phosphate in the Lavaca Bay system (January 1973 - June 1975).

Date (D-M-Y)	Ammonia NH_3-N (mg/l)		Organic Nitrogen (mg/l)		Nitrate NO_3-N (mg/l)		Nitrite NO_2-N (mg/l)		Ortho-Phosphate (mg/l)		Total Phosphate (mg/l)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
16- 1-73	.13	.1-.3	.3	.1-1.5	.09	.03-.43	.005	.005-.016	.03	.01-.07	.04	.01-.23
18- 2-73	.12	.1-.2	.3	.1-1.1	.03	.03-.07	.005	.005-.009	.01	.01-.03	.02	.01-.07
6- 3-73	.20	.1-.7	.6	.1-1.6	.05	.03-.20	.009	.005-.026	.01	.01-.09	.06	.01-.25
10- 4-73	.13	.1-.5	.6	.3-1.1	.10	.03-.44	.015	.005-.027	.04	.01-.09	.08	.03-.24
10- 5-73	.16	.1-.4	.6	.3-1.0	.20	.03-.41	.026	.010-.098	.06	.01-.16	.12	.03-.27
5- 6-73	.13	.1-.4	.6	.1-1.3	.03	.03-.30	.009	.005-.010	.02	.01-.07	.08	.03-.19
10- 7-73	.11	.1-.2	.7	.1-1.1	.04	.03-.11	.012	.010-.280	.07	.03-.12	.12	.04-.24
2- 8-73	.10	.1	.5	.4-0.8	.04	.03-.09	.006	.005-.021	.12	.03-.80	.12	.05-1.9
25- 9-73	.10	.1	.6	.2-1.1	.04	.03-.12	.012	.005-.020	.07	.02-.14	.12	.03-.26
30-10-73	.10	.1	.6	.2-1.6	.04	.03-.15	.006	.003-.025	.07	.03-.44	.10	.04-.57
29-11-73	.10	.1	.3	.2-0.6	.04	.03-.13	.005	.005	.04	.02-.07	.07	.05-.13
28-12-73	.10	.1-.5	.3	.2-0.6	.05	.03-.29	.005	.003-.010	.03	.02-.15	.05	.03-.19
29- 1-74	.10	.1	.9	.3-4.8	.35	.03-1.06	.010	.003-.030	.05	.01-.15	.10	.03-.41
26- 2-74	.10	.1-.2	.6	.4-1.4	.03	.03-.25	.006	.003-.056	.03	.01-.09	.07	.03-.21
27- 3-74	.10	.1	.5	.3-0.9	.04	.03-.14	.006	.005-.017	.02	.01-.05	.04	.01-.07
23- 4-74	.10	.1-.4	.6	.1-1.2	.22	.03-.60	.013	.005-.029	.03	.01-.07	.05	.01-.14
23- 5-74	.10	.1-.2	.8	.6-0.9	.06	.03-.39	.011	.005-.032	.02	.01-.07	.05	.03-.12
26- 6-74	.10	.1	.6	.3-1.1	.03	.03-.03	.005	.005	.03	.01-.08	.04	.02-.10
24- 7-74	.10	.1	.5	.3-1.0	.03	.03	.050	.050	.02	.01-.06	.04	.02-1.0
28- 8-74	.10	.1	.6	.4-1.1	.03	.03	.050	.030-.050	.04	.01-.09	.07	.03-.13
24- 9-74	.10	.1	.6	.3-0.9	.09	.03-.14	.050	.050	.07	.02-.13	.11	.05-.18
10-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
13-11-74	.10	.1-.2	.7	.5-1.0	.11	.03-.32	.050	.050	.05	.01-.10	.07	.03-.15
25-11-74	.10	.1-.2	.8	.4-1.6	.19	.03-.53	.050	.050	.06	.01-.13	.12	.03-.39
12-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
14- 1-75	.10	.1	.4	.3-0.7	.06	.02-.26	.010	.010-.020	.02	.01-.07	.04	.02-.07
30- 1-75	.10	.1	.5	.4-1.3	.02	.02	.010	.010-.040	.02	.01-.06	.04	.02-.12
25- 2-75	.10	.1	.4	.3-0.9	.02	.02-.13	.010	.010-.050	.01	.01-.04	.04	.03-.09
19- 3-75	.10	.1	.4	.3-0.8	.02	.02-.02	.010	.010-.010	.01	.01-.03	.03	.01-.04
29- 4-75	.10	.1-.2	.5	.3-0.8	.07	.02-.14	.020	.010-.040	.01	.01-.05	.05	.02-.10
5-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Table 4---continued.

Date (D-M-Y)	Ammonia NH_3-N (mg/1)		Organic Nitrogen (mg/1)		Nitrate NO_3-N (mg/1)		Nitrite NO_2-N (mg/1)		Ortho-Phosphate (mg/1)		Total Phosphate (mg/1)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
4- 6-75	.10	.1-.2	1.0	.4-1.5	.12	.02-.23	.020	.010-.120	.04	.01-.08	.12	.05-.24
24- 6-75	.10	.1	.8	.6-1.6	.02	.02	.020	.020	.02	.01-.07	.05	.02-.10

N.D. No Data taken.

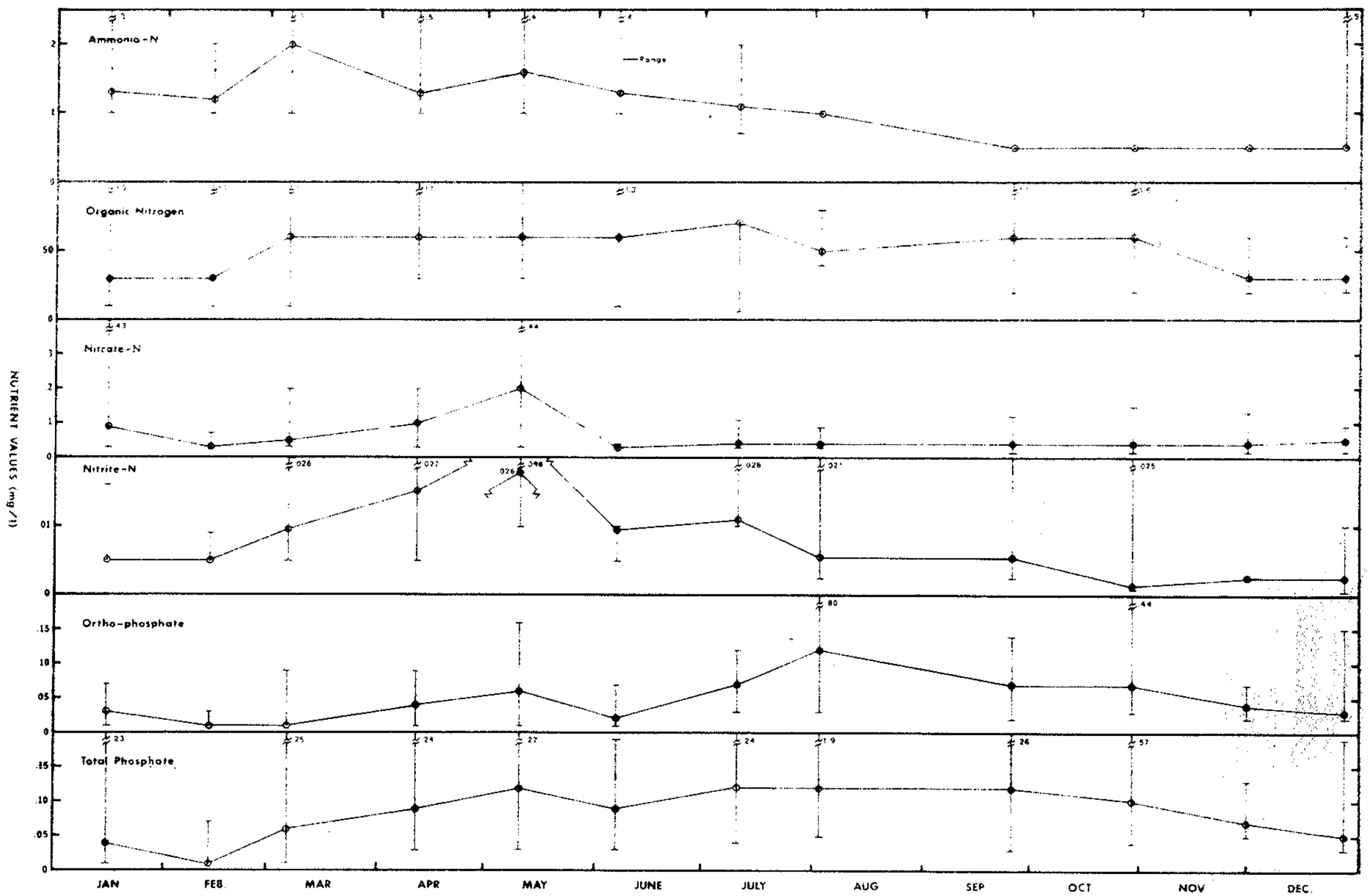


Figure 7. Sample date means and ranges for nutrients from the Lavaca Bay system during 1973.

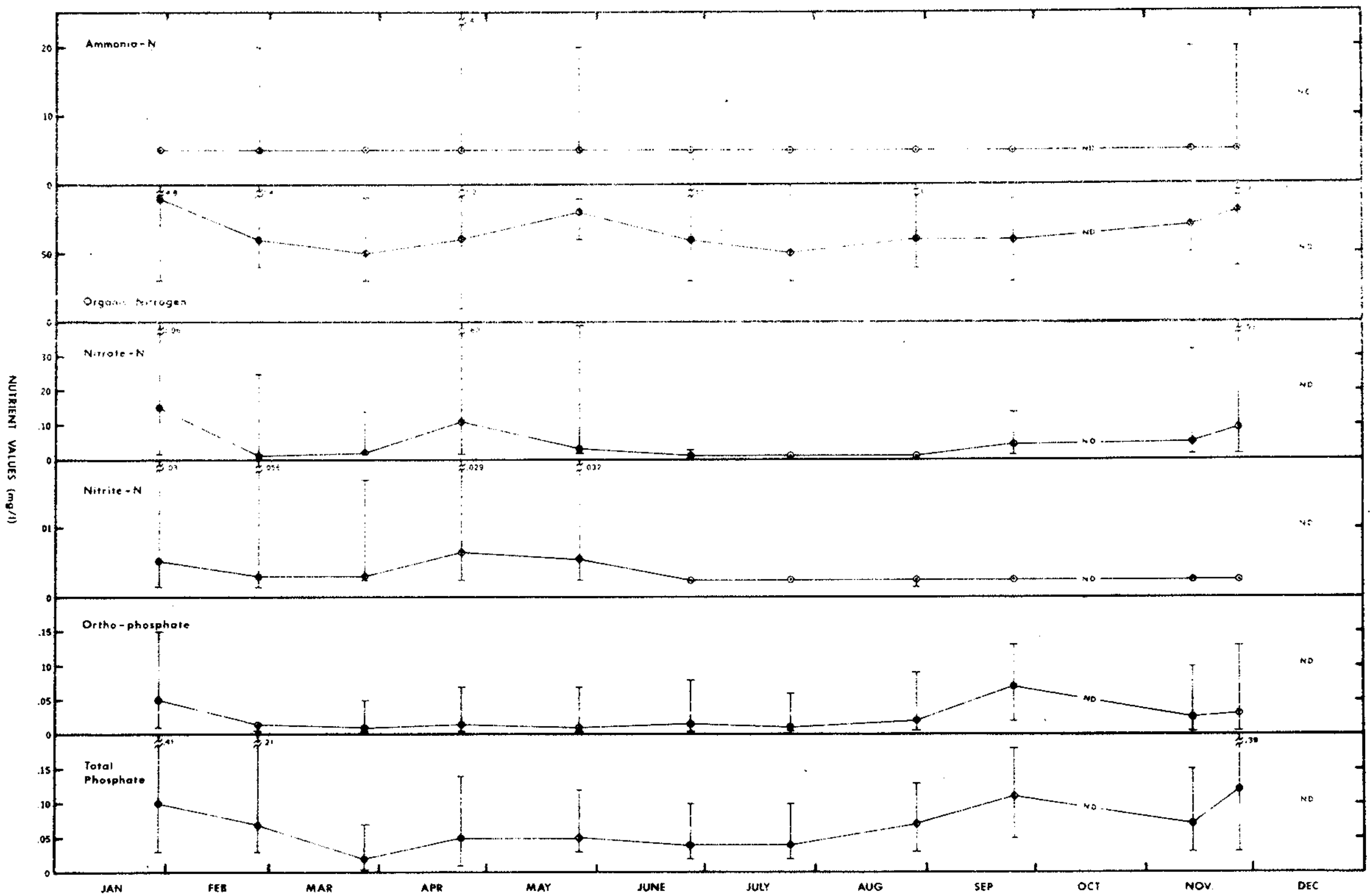


Figure 8. Sample date means and ranges for nutrients from the Lavaca Bay system during 1974.

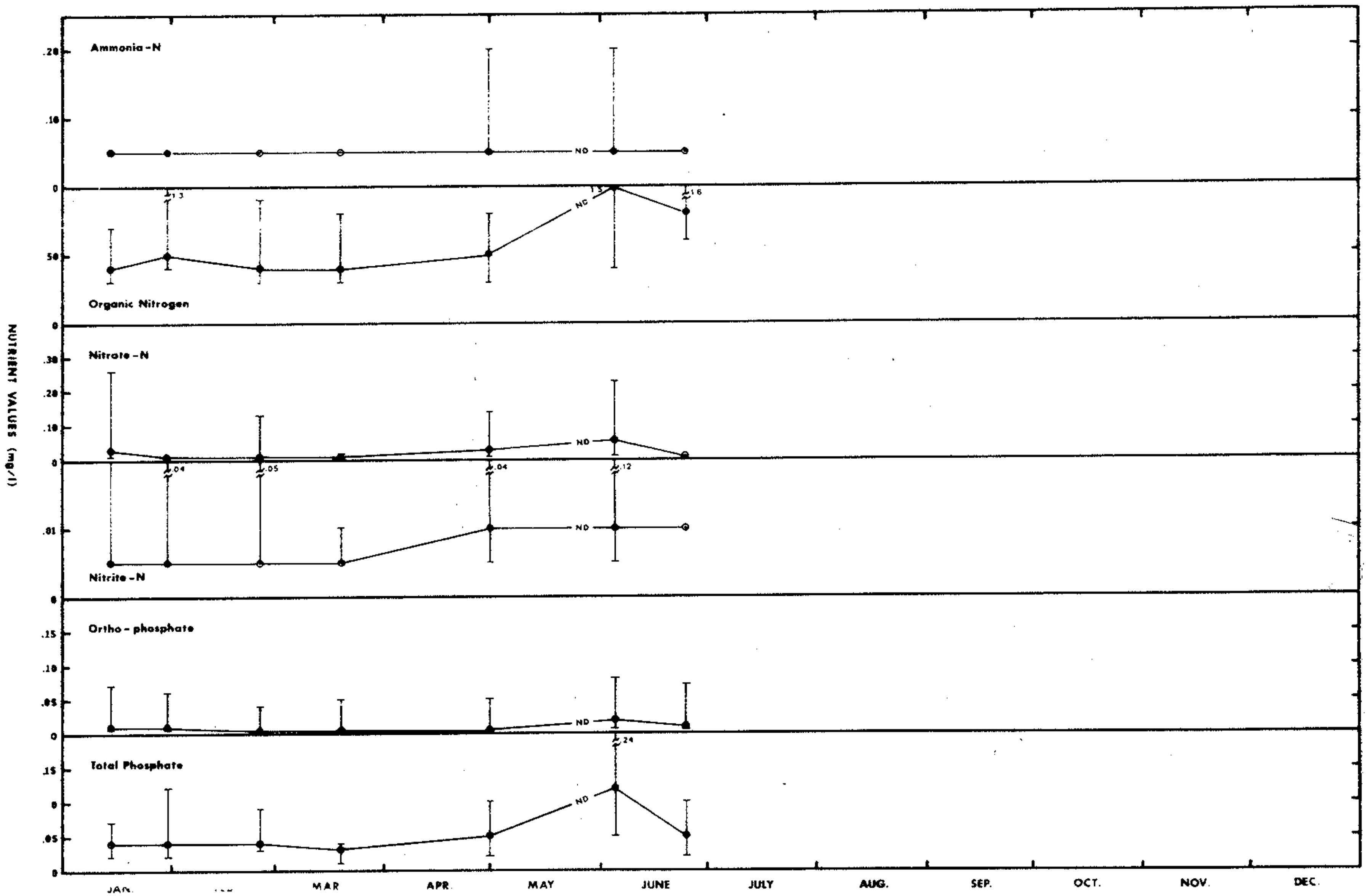


Figure 9. Sample date means and ranges for nutrients from the Lavaca Bay system during 1975.

Table 5. Study period (January 1973 - June 1975) mean values (mg/1) and ranges by site for six nutrients monitered in the Lavaca Bay system.

	Ammonia NH_4		Organic Nitrogen N		Nitrate NO_3		Nitrite NO_2		Ortho-phosphate $O-PO_4$		Total Phosphate	
Sites	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
83-2	0.10	0.1-0.2	0.7	0.3-1.5	0.08	0.02-0.37	0.01	0.003-0.05	0.04	0.01-0.10	0.08	0.02-0.18
83-5	0.11	0.1-0.3	0.7	0.3-2.0	0.17	0.02-1.05	0.02	0.003-0.12	0.05	0.01-0.13	0.10	0.03-0.39
84-2	0.11	0.1-0.3	0.7	0.3-1.2	0.09	0.02-0.48	0.02	0.003-0.05	0.05	0.01-0.09	0.10	0.03-0.27
85-2	0.10	0.1	0.7	0.4-1.4	0.09	0.02-0.39	0.02	0.003-0.05	0.04	0.01-0.13	0.08	0.04-0.19
85-4	0.12	0.1-0.5	0.7	0.1-1.6	0.14	0.02-1.00	0.01	0.005-0.05	0.05	0.01-0.14	0.10	0.03-0.26
90-1	0.10	0.1-0.2	0.6	0.3-1.3	0.10	0.02-0.90	0.01	0.003-0.05	0.03	0.01-0.12	0.07	0.01-0.18
90-3	0.10	0.1	0.6	0.3-1.2	0.08	0.02-0.48	0.01	0.005-0.05	0.04	0.01-0.11	0.09	0.04-0.41
90-5	0.10	0.1-0.2	0.6	0.1-1.2	0.07	0.02-0.39	0.01	0.003-0.05	0.04	0.01-0.12	0.08	0.01-0.18
115-1	0.11	0.1-0.3	0.5	0.1-1.2	0.05	0.02-0.30	0.01	0.005-0.05	0.02	0.01-0.08	0.05	0.01-0.17
115-3	0.10	0.1-0.2	0.8	0.3-4.8	0.07	0.02-0.35	0.01	0.005-0.05	0.03	0.01-0.12	0.08	0.01-0.30
115-4	0.10	0.1-0.2	0.5	0.3-1.9	0.09	0.02-0.56	0.01	0.005-0.05	0.04	0.01-0.10	0.08	0.01-0.25
129-2	0.10	0.1-0.2	0.6	0.2-1.4	0.10	0.02-0.54	0.02	0.005-0.10	0.04	0.01-0.12	0.07	0.01-0.19
140-2	0.10	0.1	0.5	0.2-1.2	0.03	0.02-0.11	0.01	0.003-0.05	0.01	0.01-0.04	0.04	0.01-0.09
143-2	0.11	0.1-0.4	0.5	0.1-0.9	0.03	0.02-0.07	0.01	0.003-0.05	0.01	0.01-0.04	0.04	0.01-0.10
143-4	0.10	0.1-0.2	0.5	0.2-0.9	0.03	0.02-0.09	0.01	0.005-0.05	0.02	0.01-0.05	0.04	0.01-0.13
150-2	0.10	0.1-0.2	0.5	0.2-0.9	0.03	0.02-0.08	0.01	0.003-0.05	0.02	0.01-0.05	0.05	0.01-0.13
150-5	0.10	0.1-0.2	0.6	0.2-1.4	0.06	0.02-0.38	0.01	0.003-0.05	0.03	0.01-0.12	0.07	0.01-0.19
180-2	0.10	0.1-0.2	0.5	0.2-1.3	0.02	0.02-0.05	0.01	0.003-0.05	0.02	0.01-0.11	0.04	0.01-0.18
190-2	0.10	0.1-0.2	0.4	0.1-0.9	0.03	0.02-0.19	0.01	0.003-0.05	0.01	0.01-0.04	0.04	0.01-0.08
190-4	0.10	0.1-0.2	0.5	0.2-1.4	0.03	0.02-0.11	0.01	0.003-0.05	0.02	0.01-0.11	0.04	0.01-0.19
190-5	0.10	0.1-0.2	0.5	0.2-1.0	0.04	0.02-0.32	0.01	0.005-0.05	0.02	0.01-0.08	0.04	0.01-0.11
65-2	0.15	0.1-0.5	0.7	0.1-1.6	0.15	0.02-0.60	0.02	0.005-0.05	0.06	0.01-0.15	0.11	0.05-0.23
600-2	0.13	0.1-0.7	0.7	0.4-1.2	0.10	0.02-0.31	0.02	0.005-0.06	0.06	0.01-0.14	0.10	0.03-0.27
606-2	0.13	0.1-0.4	0.6	0.4-1.1	0.15	0.02-0.43	0.02	0.005-0.05	0.07	0.01-0.44	0.11	0.02-0.57
610-2	0.11	0.1-0.3	0.6	0.2-1.6	0.08	0.02-0.49	0.01	0.005-0.05	0.04	0.01-0.16	0.07	0.03-0.22
617-2	0.11	0.1-0.2	0.6	0.3-1.3	0.11	0.02-0.59	0.01	0.003-0.05	0.05	0.01-0.11	0.09	0.01-0.21

Average nitrite was higher in 1974 (0.02 mg/1) than in 1973 (0.009 mg/1) or in 1975 (0.01 mg/1). No seasonal trends were present for nitrite (Figs. 7, 8, and 9). Mean values between sites were similar (less than 0.02 mg/1 difference) for the study (Table 5). Upper bay sites had higher nitrite concentrations than lower bay sites.

Ortho-phosphate.--Ortho-phosphate values ranged from < 0.01 (all sites) to 0.8 mg/1 (site 83-5 on 2 August 1973) and averaged 0.04 mg/1 for the study (Table 4). Average ortho-phosphate was higher in 1973 (0.04 mg/1) than in 1974 (0.03 mg/1) or in 1975 (0.02 mg/1). A seasonal trend for ortho-phosphate was not evident (Figs. 7, 8, and 9). Mean values between sites were similar (< 0.07 mg/1 difference) (Table 5). Upper bay sites had higher nutrient concentrations than lower bay sites.

Total Phosphate.--Total phosphate values in the Lavaca Bay system ranged from 0.01 (most sites) to 0.57 mg/1 (site 606-2 on 29 October 1973) and averaged 0.07 mg/1 (Table 4). Nutrient concentrations below 0.01 mg/1 were recorded as < 0.01 mg/1. Average total phosphate was higher in 1973 (0.07 mg/1) than in 1974 (0.06 mg/1) or in 1975 (0.05 mg/1). Total phosphate showed no seasonal trend (Figs. 7, 8, and 9). Mean values between sites were similar (< 0.07 mg/1 difference) (Table 5). Upper bay sites had higher nutrient concentrations than lower bay sites.

Bottom sediment.--Bottom sediment at most sites was silt-clay (particle diameter of < 0.062 mm) (Table 6). Shell (particle diameter of > 2.00 mm) was not present in most sediment while sand (particle diameter of 0.062-2.00 mm) generally made up a small percentage of the total sample. Volatile solids for the river area sediments ranged from 9,480 mg/kg at site 617-2 to 19,9777 mg/kg at site 65-2 (Table 6). Bay sediment volatile solids ranged from 7,905 mg/kg (site 85-4) to 115,140 mg/kg (site 180-2).

DISCUSSION

The average freshwater inflow into the Lavaca Bay system (Navidad and Lavaca rivers plus Garcitas Creek) during this study (1,994 cfs) was about 59% above normal (1,254 cfs) based on 1939 - 1974 Lavaca River gaugings, 1940 - 1974 Navidad River gaugings, and 1972 - 1974 Garcitas Creek gaugings. Inflow from Garcitas, Venado, and Chocolate creeks primarily influenced the bay area near the creeks while the Lavaca and Navidad rivers influenced the whole bay. The Coriolis effect probably caused fresh water to move to the west, while spoil islands helped inhibit water movement to the east. West bay salinities were about 2 $^{o}/oo$ lower than east bay salinities (Table 2).

Freshwater inflow rates were gauged 24 to 40 km north of the bay system. Correction factors (ratio of drainage area above gauging station to drainage area below gauging station) were calculated for Lavaca River (1.17), Navidad River (1.31), and Garcitas Creek (3.03) to compensate for fresh water entering the river or creek below the gauging stations.

Correlation analyses were used to test the relation of mean salinity (measured monthly or semimonthly) of 20 sites in Lavaca Bay to the $\log_{10}$ of mean daily river discharge (Lavaca and Navidad rivers plus Garcitas Creek) for 4, 6, 9, 15, and 30 day periods ending two days prior to a salinity

Table 6. Sedimentary particles size distribution and volatile solids for bottom sediment collected at 25 sites in the Lavaca Bay System, Texas.

	Per Cent Composition				
Station	Shell	Sand	Silt-Clay	Sediment Classification	Volatile Solids (mg/kg)
600-2	5	8	87	Silt-Clay	19,151
606-2	0	51	49	Silty-Clayey Sand	14,511
65-2	0	100	0	Sand	19,977
610-2	0	48	52	Sandy Silt-Clay	11,248
617-2	0	57	43	Silty-Clayey Sand	9,480
83-2	0	44	56	Sandy Silt-Clay	36,074
83-5	0	8	92	Silt-Clay	51,641
84-2	0	23	77	Silt-Clay	40,304
85-4	0	12	88	Silt-Clay	7,905
90-1	0	24	76	Silt-Clay	60,261
90-3*	0	4	96	Silt-Clay	85,451
90-5	0	28	72	Sandy Silt-Clay	42,048
115-1	0	1	99	Silt-Clay	100,485
115-3*	0	0	100	Silt-Clay	84,829
115-4*	55	30	15	Sandy Shell	50,332
129-2*	0	7	93	Silt-Clay	31,100
140-2	0	12	88	Silt-Clay	35,292
143-2	0	3	97	Silt-Clay	71,044
143-4	0	1	99	Silt-Clay	51,858
150-2	5	57	38	Silty-Clayey Sand	66,171
150-5	0	37	63	Sandy Silt-Clay	8,661
180-2	1	6	93	Silt-Clay	115,140
190-2	0	99	1	Sand	30,890
190-4*	3	4	93	Silt-Clay	8,222
190-5	0	9	91	Silt-Clay	58,089

* Channel Sites

determination. Inflows gauged the day salinity measurements were made plus inflow gauged the preceding day were excluded because of the time lag for gauged water to reach the bay. The nine day inflow produced the highest correlation (r=-0.59**, d.f.=47). Data used for the correlation analysis were plotted, a line was fitted to the data, and confidence intervals were calculated (Fig. 10). This figure can be used to determine the amount of inflow needed to maintain a selected mean bay salinity; however, the confidence intervals indicate that the predictability of daily mean bay salinity is low while the predictability of the 30 - month study period mean bay salinity is high.

Bay nutrient levels were directly related to 9-day lag inflow at the 1% (**) significance level.

	r value	df
Organic nitrogen	.32**	413
Nitrate	.18**	413
Nitrite	.29**	413
Ortho-phosphate	.15**	413
Total phosphate	.27**	413

High precipitation in the river drainage basins washed nutrient and organic materials into the rivers and this material was then transported to the bay. When river discharge rates were high (above 6000 cfs), marshes were inundated and nutrient material from the marshes washed into the bay. High tides also caused marsh inundation and nutrient release to the bay.

Turbidities were affected by wind speed, wind direction, and river inflow. The shallow upper bay area generally had the highest turbidities.

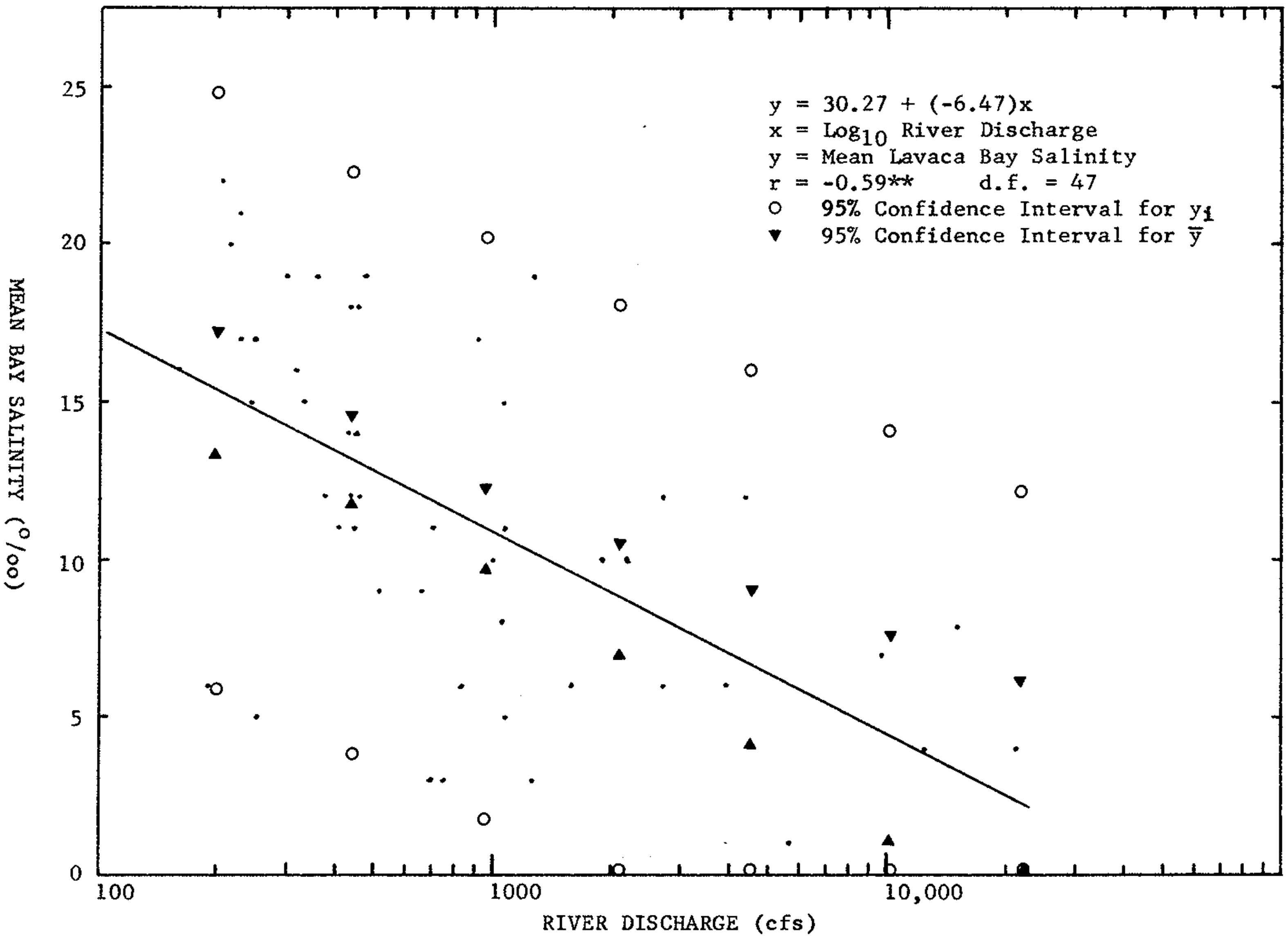


Figure 10. Relationship between semimonthly mean salinity of 20 sites in Lavaca Bay and mean daily river discharge (Lavaca and Navidad rivers plus Garcitas Creek) for a nine day period ending two days prior to a salinity determination.

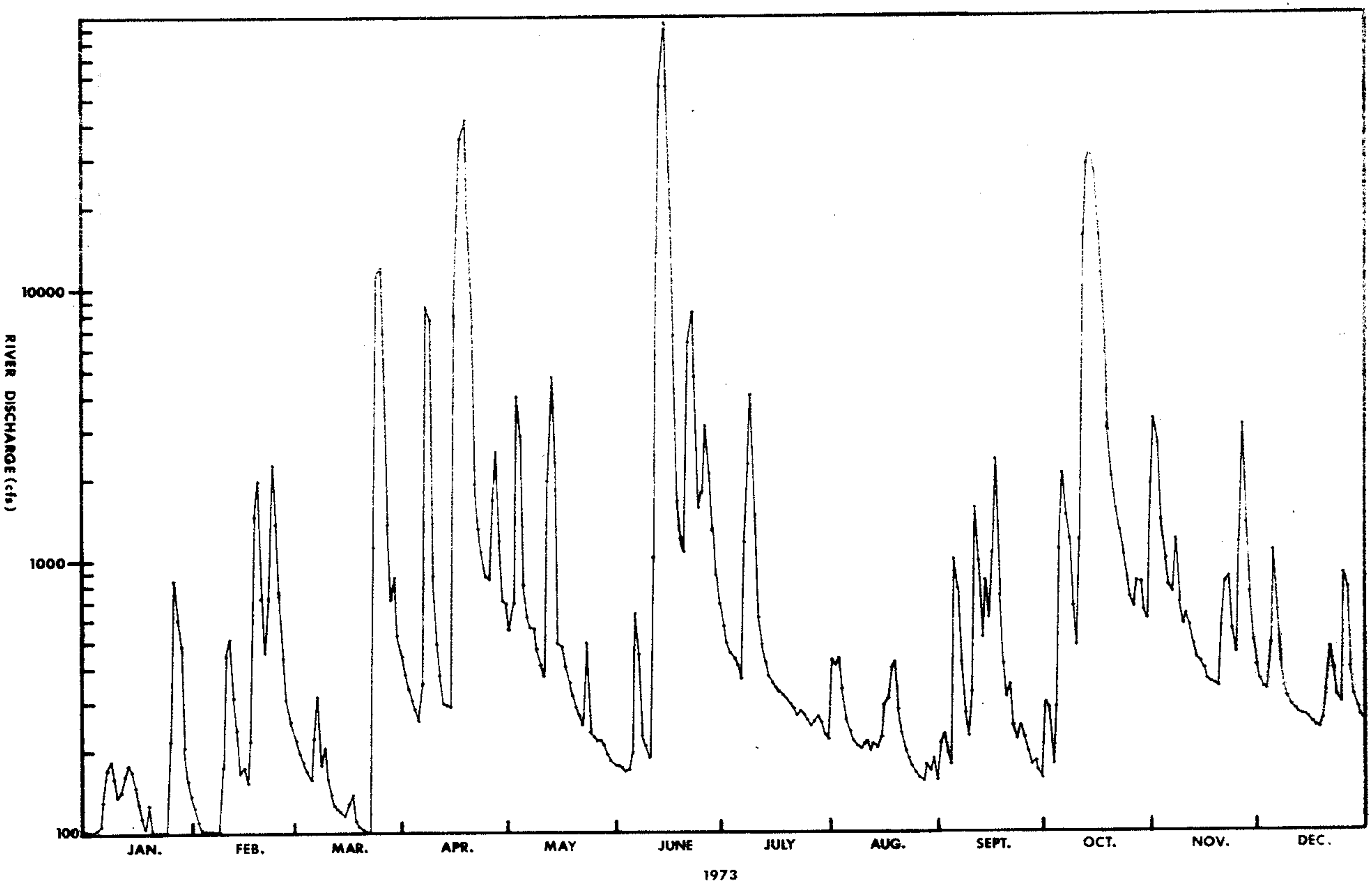


Figure 11. Combined mean daily discharge for the Lavaca and Navidad rivers plus Garcitas Creek during 1973.

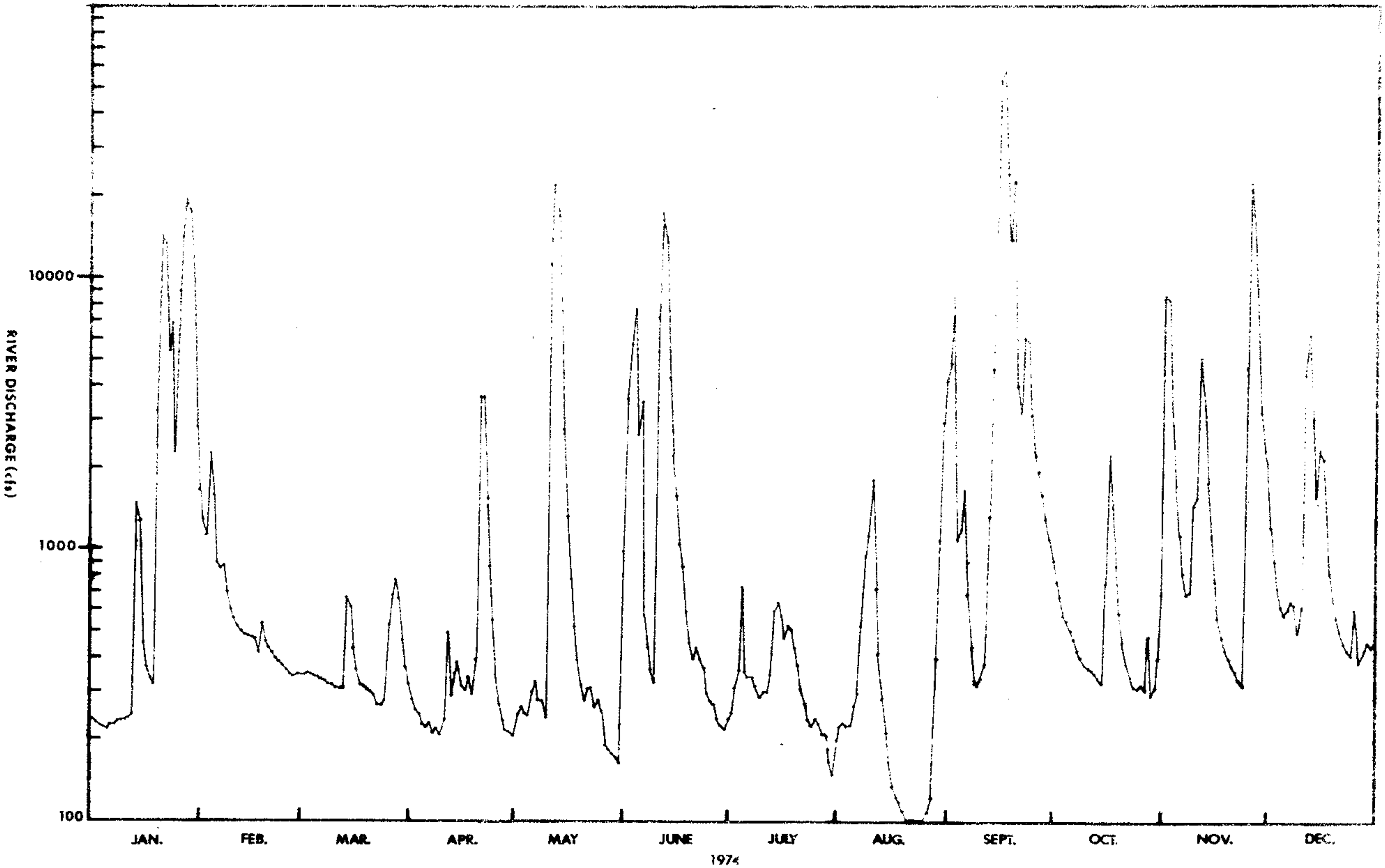


Figure 12. Combined mean daily discharge for the Lavaca and Navidad rivers plus Garcitas Creek during 1974.

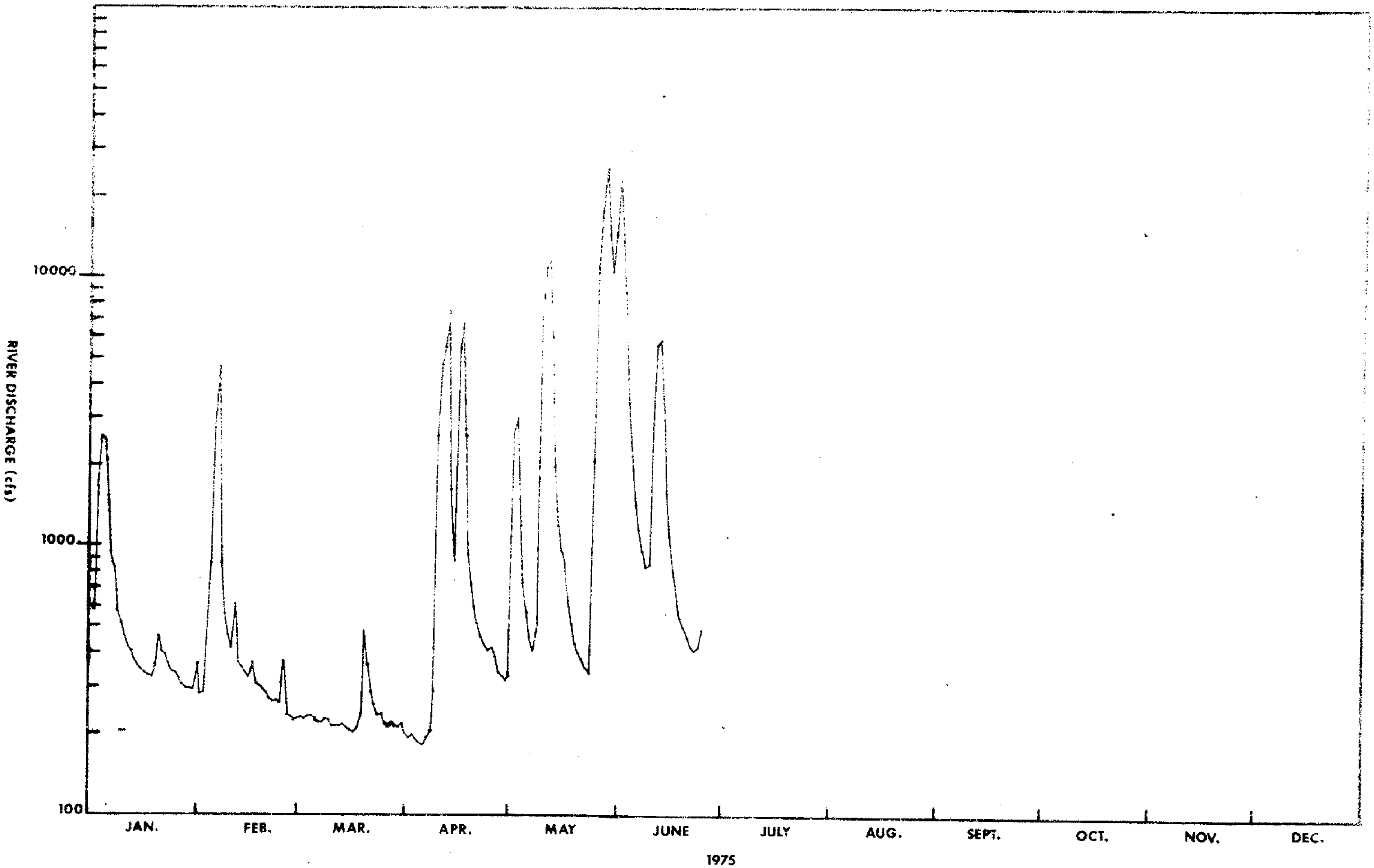


Figure 13. Combined mean daily discharge for the Lavaca and Navidad rivers plus Garcitas Creek (January - June 1975.

SECTION II. PHYTOPLANKTON

Norman Hannebaum

INTRODUCTION

Phytoplankton play several important roles in estuaries (Lackey, 1967). These microscopic plants utilize water, nutrients, and carbon in the presence of sunlight to produce organic matter, a primary link in the estuarine food chain. Water reaeration is a by-product of this activity. Some forms degrade organic matter. Various groups are associated with certain hydrological conditions thus lending a connotation of water quality by their presence. Phytoplankton also produce substances which play a determinative role in species succession and sometimes involve toxins and antibiotic compounds which affect other estuarine organisms and man (Johnston, 1955; Whittaker and Feeny, 1971).

LITERATURE REVIEW

Several phytoplankton studies of Texas bays and estuaries contain information pertinant to this study. Freese (1952) studied diatoms of the Rockport Bay area from August 1949 to July 1950. He towed a no. 25 (200 mesh/in^2) net for 10 minutes at each station once a month. He found that pelagic (both neritic and oceanic) species were more numerous in channels and bayous than farther back in the bays. He attributed this to the channels and bayous being passageways for currents between the bays and the Gulf. He thought oceanic species were carried toward the back of the bays by wave and tidal action, and when such species were present a sample check of stations near the bay mouth revealed a heavy population of those same species approximately a month previous to the date in question. Freese noted that plankton blooms began in January 1950 and remained heavy through February and March, but he did not quantify his data.

Steed (1971) studied carbon transport in San Antonio Bay from August 1967 to August 1968 and found that chlorophyll a concentrations near the mouth of the San Antonio River were inversely related to river discharge. When river discharge was higher than 22 x $10^6/m^3$ per day, chlorophyll a values did not exceed 2.7 mg/m^3. When river discharge was below this rate chlorophyll a ranged from 2.7 to 48.9 mg/m^3. These differences were thought to be related to salinity and turbidity tolerances of the phytoplankters plus physical removal of the phytoplankton by the high discharge current. Steed also stated that photosynthesis increased during the following flooding of some bays but this occurred at areas further removed from the river mouth.

Clements (Matthews *et al.*, 1974) collected phytoplankton in San Antonio Bay from October 1973 to July 1974 by taking 1-liter surface water samples. He used a hemacytometer for identification and enumeration of cells. He reported 60 taxa but found this figure to be low as many ultraplanktonic ($<$ 20 u) flagellates were cataloged in the indefinite taxon "unidentified phytoflagellates." Chlorophyll a concentrations (determined on a semimonthly basis) ranged from 1.20 ug/l in March to 143 ug/l in February. Highest concentrations were always found in the upper bay and decreased with distance down the bay. Clements was able to correlate chlorophyll a concentrations with river inflow circulation patterns.

Groover and Sharik (1974) reported on a study of the Colorado River - Matagorda Bay system which took place from June 1973 to May 1974. Surface and bottom water samples from phytoplankton analysis were collected on a monthly basis while water samples for chlorophyll analysis were collected on a quarterly basis. Mean phytoplankton density ranged from 204 (June 1973) to 50,530 cells/ml (February 1974). Both values represent zones located in the Colorado River. Phytoplankton diversities ranged from 5 species in the Colorado River in June 1973 to 44.5 species near the river mouth in February 1974. The lowest chlorophyll a value was 0.0 mg/m^3 at stations in the Colorado River and Matagorda Bay during February and May 1974, while the highest recorded value was 43.8 mg/m^3 at an upriver station in February 1974.

Whitefield (Moseley and Copeland, 1972) studied the phytoplankton of Cox Bay from August 1969 through June 1971. Wood (Moseley and Copeland, 1974) continued the study through June 1973. Phytoplankton samples were collected every three weeks by towing a no. 20 (173 $meshes/in^2$) net near the water surface for 2 minutes at each station. A total of 189 taxa included 160 species of diatoms and 18 species of dinoflagellates. Maximum populations were observed in winter and reach 1,452,000 cells/ml in February 1972. He felt that net phytoplankton density was related to water temperature. Species diversity indices ranged from 0.0 in May 1970, and May and August 1972 to 2.8 in March 1970. Diatoms were the dominant net phytoplankton.

Blanton et al. (1971) studied the ecology of Lavaca Bay from March 1970 through February 1971. Plankton samples were collected by making 20-ft tows with a no. 25 (200 $meshes/in^2$) net. Sixty-five taxa consisted of 55 diatoms, 4 dinoflagellates, 4 chlorophytes, and 2 cyanophytes. Seasonal fluctuations of diatoms and dinoflagellates were the same as those observed by Moseley and Copeland. Temperature was thought to be the most important physical factor affecting net phytoplankton. An inverse relationship between phytoplankton and zooplankton was assumed to be due to zooplankton grazing.

Bishop (Davis, 1973) studied phytoplankton of the Lavaca Bay system from January through July 1973. He found bay and river standing crops to be about the same except during January when bay densities were about 10 times higher than those of the river area. Standing crops for the entire system peaked at 3.4×10^6 cells/l in January then declined to 1.5×10^5 cells/l in July. Bay phytoplankton diversities ranged from 12 to 14 species in winter to 8 species during spring and summer. River phytoplankton diversities ranged from 11 to 15 species in winter to 10 species during spring and summer.

MATERIALS AND METHODS

One liter surface water samples were collected at nine sites (6 in Lavaca Bay, 1 each in Redfish Lake, Swan Lake, and the Lavaca River) at semimonthly intervals from September 1973 through June 1975 (Figs. 1 and 2). Samples were immediately preserved with Lugol's solution and were then taken to the laboratory for analysis. Each sample was allowed to settle a minimum of 72 hours. Then the supernatant was drawn off until 25 ml remained. This 25-ml sample was transferred to a screw-capped glass vial and allowed to settle. Next, enough supernatant was withdrawn to leave 10 ml (i.e. a 100 fold concentration).

A Swift Series SRL Phase Master microscope was used in conjunction with an American Optical Company Bright-Line hemacytometer to ascertain phytoplankton taxa composition and number of cells per liter. Taxa composition was determined by resuspending the phytoplankton in the 10-ml sample, placing a drop of the sample between a microscope slide and coverslip, and viewing it through the scope. Thus, the high-power oil-immersion objective could be used for identification of unknown organisms. Next the number of cells per unit volume for each recognizable taxon was determined by filling the hemacytometer with sample and counting the phytoplankton in one entire chamber plus one-ninth of another chamber. This was equivalent to 0.001 ml of the 10-ml concentrate or to 1 ml of the original 1-liter sample. When a phytoplankton bloom or excessive turbidity occurred the 10-ml concentrate was diluted to a known volume to facilitate counting. Standing crops were considered as numbers of cells per liter. Individual cells were counted rather than colonies.

Chlorophyll a measurements were determined on a semimonthly basis for each of the nine phytoplankton count sites and on a monthly basis for the additional 17 sites (Figs. 1 and 2). Surface water collected at each site was vacuum filtered through a 3 u Millipore SSWP04700 filter. The volume of water filtered varied inversely with plankton density and turbidity. After filtration, the filter was immediately placed in a 15 x 125 mm screw-cap culture tube containing 5 ml of 90% acetone, shaken vigorously, and refrigerated until analysis (about 24 hours later).

Chlorophyll a concentrations were computed using the UNESCO trichromatic formula with turbidity correction. Readings were made at the 630 mu, 645 mu, 665 mu, and 750 mu wave lengths using a Bausch and Lomb Spectronic 100 spectrophotometer. The 750 mu reading was first subtracted from the other three readings to correct for turbidity. The corrected values were then used in the following formula:

$$(11.64)(D_{665}) - (2.16)(D_{645}) + (0.10)(D_{630}) = N$$

then: $$\frac{(N)(v)}{(Lp)(V)} = \text{mg chl. } \underline{a}/m^3 \text{ or ug chl. } \underline{a}/l$$

where: v = volume of acetone in milliliters
Lp = light path in centimeters
V = volume of water filtered in liters.

RESULTS

A total of 156 taxa representing 7 divisions were identified (Table 7). Breakdown of taxa by division is as follows: Bacillariophyta (78), Chlorophyta (28), Pyrrophyta (24), Cyanophyta (13), Euglenophyta (7), Cryptophyta (4), and Chrysophyta (1). Populations in Redfish Lake, Swan Lake, and Lavaca River were composed primarily of cryptophytes while Lavaca Bay populations were mainly cryptophytes and bacillariophytes (Figs. 14, 15, and 16).

Taxa diversity ranged from 1 at site 65-2 on 11 June 1974 to 35 at site 85-2 on 10 April 1975 (Table 8). Average monthly diversity ranged from 5 taxa per site in May 1974 to 19 taxa per sample in December 1974, and February and April 1975. Mean diversities for the entire 22-month study were greatest at site 65-2 in the Lavaca River (13 species) and site 190-2 near Matagorda Bay

Table 7. Taxonomic list of phytoplankton collected in the Lavaca Bay system from September 1973 through June 1975.

BACILLARIOPHYTA

Achnanthes clevei var. *rostrata*?
Achnanthes sp.
Actinoptychus sp.
Amphiprora paludosa var. *hyalina*
Amphiprora sp.
Amphora sp.
Asterionella japonica
Bacillaria paradoxa
Biddulphia mobiliensis
Biddulphia regia
Biddulphia sp.
Campylosira sp.
Chaetoceros affinis
Chaetoceros constrictus
Chaetoceros decipiens
Chaetoceros didymus
Chaetoceros simplex?
Chaetoceros sp.
Cocconeis disculus
Cocconeis sp.
Coscinodiscus centralis
Coscinodiscus excentricus
Coscinodiscus lineatus?
Coscinodiscus sp.
Coscinodiscus sublineatus?
Cyclotella sp.
Cyclotella striata var. *ambigua*
Diatoma sp.
Diploneis bombus
Diploneis elliptica
Diploneis sp.
Ditylem brightwellii
Fragilaria sp.
Gyrosigma balticum
Gyrosigma fasciola
Gyrosigma hummii
Gyrosigma macrum?
Gyrosigma sp.
Gyrosigma spencerii
Hantzschia sp.
Hemiaulus hauckii
Leptocylindrus danicus
Leptocylindrus minimus
Melosira granulata
Melosira moniliformis
Melosira sp.
Melosira sulcata
Navicula spp.
Nitzschia apiculata
Nitzschia closterium
Nitzschia delicatissima
Nitzschia longissima
Nitzschia obtusa var. *scalpelliformis*
Nitzschia reversa
Nitzschia seriata
Nitzschia serpenticula
Nitzschia sigma
Planktoniella sol
Pleurosigma angulatum
Pleurosigma salinarium
Pleurosigma strigosa
Rhizosolenia calcar avis
Rhizosolenia setigera
Rhizosolenia stolterfothii
Skeletonema costatum
Striatella sp.
Synedra delicatissima
Synedra fasciculata var. *truncata*
Synedra filiformis var. *exilis*
Synedra sp.
Synedra supurba
Suriella sp.
Tabellaria sp.
Thallassionema nitzschioides
Thallassiosira rotula
Thallassiothrix frauenfeldii
Thallassiothrix sp.
Unidentified Pennate Diatom

PYRROPHYTA

Amphidinium sp.
Centrodinium intermedium
Ceratium furca
Ceratium fusus
Ceratium hircus
Ceratium longipes
Dinophysis caudata
Dinophysis ovum
Dinophysis sp.
Exuviaella compressa
Exuviaella sp.
Gonyaulax conjuncta
Gonyaulax sp.
Gymnodinium nelsoni?
Gymnodinium sp.
Katodinium pluristigmatum
Katodinium rotundatum
Katodinium? sp.
Peridinium pentagonum

Table 7---continued.

Peridinium sp.
Peridinium trochoideum
Prorocentrum micans
Prorocentrum minimum
Prorocentrum redfieldi

CHLOROPHYTA
Actinastrum Hantzschii
Ankistrodesmus convolutus
Ankistrodesmus falcatus
Carteria sp.
Chlamydomonas sp.
Chlorella sp.
Coelastrum microporum
Cosmarium sp.
Crucigenia rectangularis
Crucigenia tetrapedia
Cloeocystis sp.
Heteromastix sp.
Nannochloris sp.
Quadrigula? sp.
Palmellococcus sp.
Pyramimonas sp.
Scenedesmus acuminatus
Scenedesmus armatus
Scenedesmus armatus var. *bicaudatus*?
Scenedesmus bijuga
Scenedesmus dimorphus
Scenedesmus incrassatulus var. *mononae*
Scenedesmus quadricauda
Scenedesmus sp.
Schroederia setigera
Selenastrum gracile
Selenastrum sp.
Treubaria triappendiculata
Westella botroyoides

CYANOPHYTA
Anabaena sp.
Anabaenopsis sp.
Aphanocapsa sp.
Gomphosphaeria aponia
Gomphosphaeria sp.
Merismopedia sp.
Microcystis sp.
Nostoc sp.
Oscillatoria sp.
Spirulina sp.
Stichococcus sp.
Synechocystis sp.
Unidentified Coccoid Blue-green

CRYPTOPHYTA
Chroomonas minuta?
Chroomonas sp.
Cryptomonas sp.
Unidentified Microflagellates

EUGLENOPHYTA
Euglena deses?
Euglena mutabilis?
Euglena proxima
Euglena sp.
Eutreptia viridis
Phacus sp.
Trachelomonas sp.

CHRYSOPHYTA
Parachrysidolis sp.

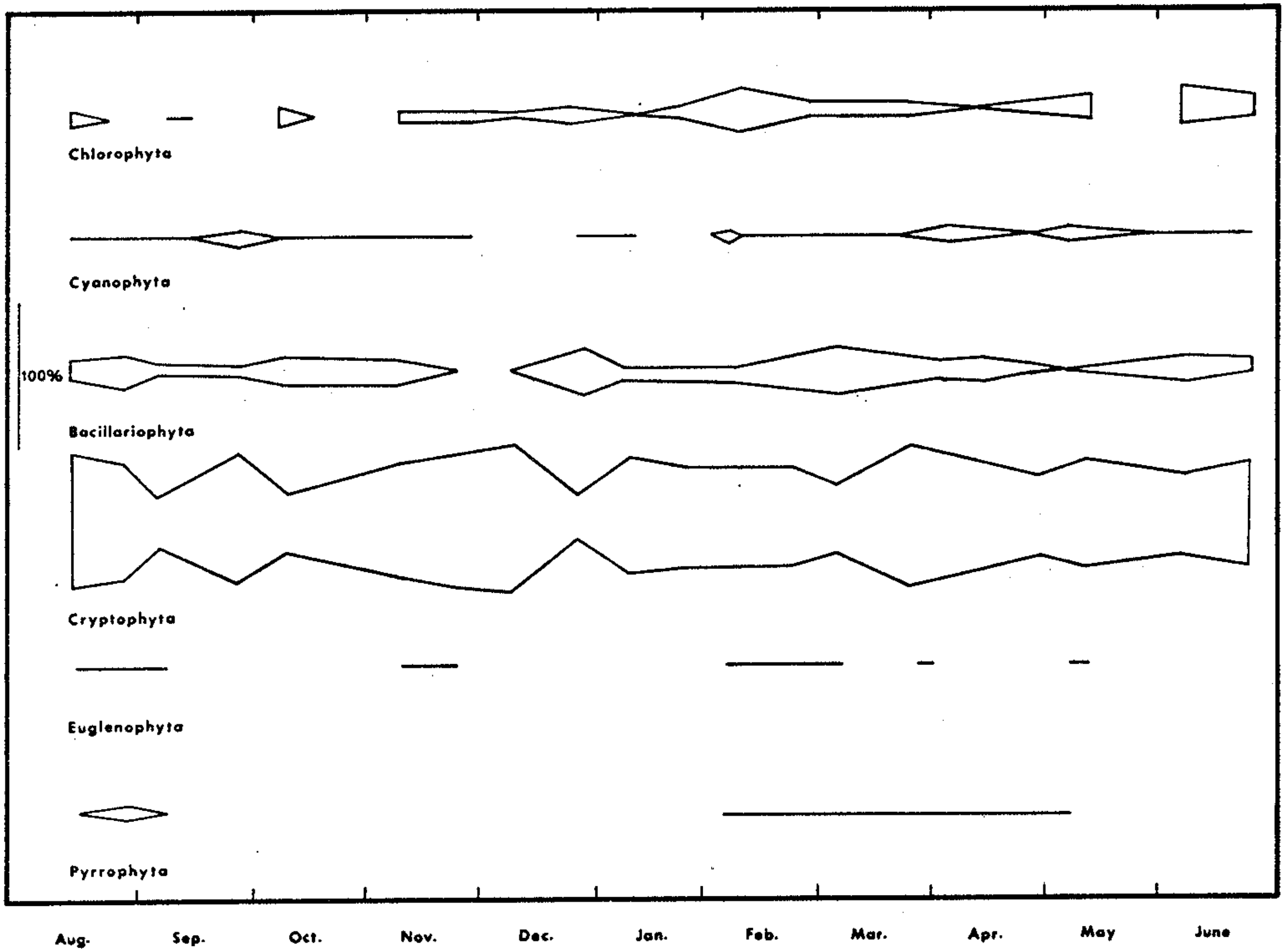


Figure 14. Percentage composition of six phytoplankton divisions present in semimonthly samples taken in Redfish and Swan lakes during 1974 - 1975.

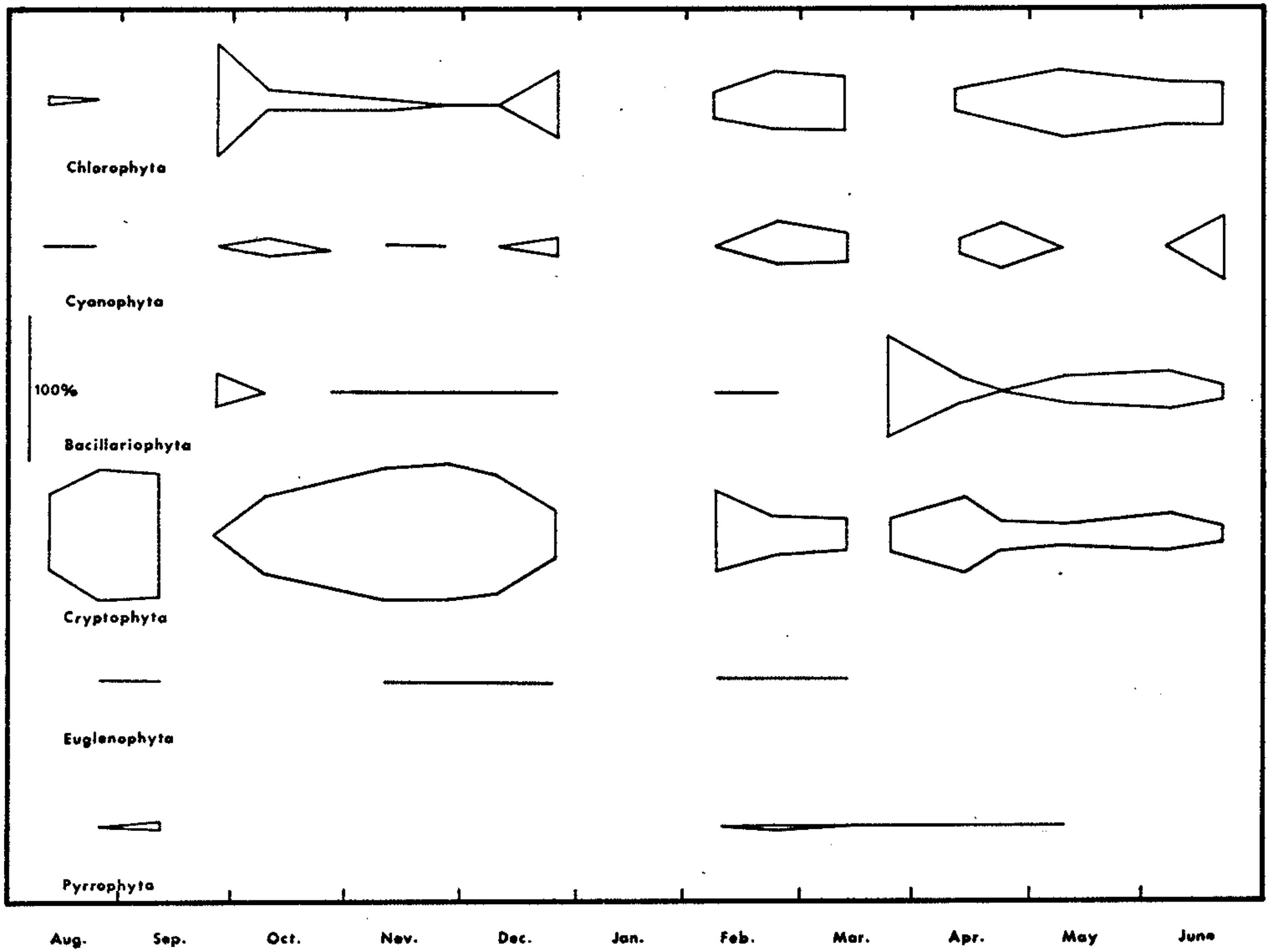


Figure 15. Percentage composition of six phytoplankton divisions present in semimonthly samples taken in the Lavaca River during 1974 - 1975.

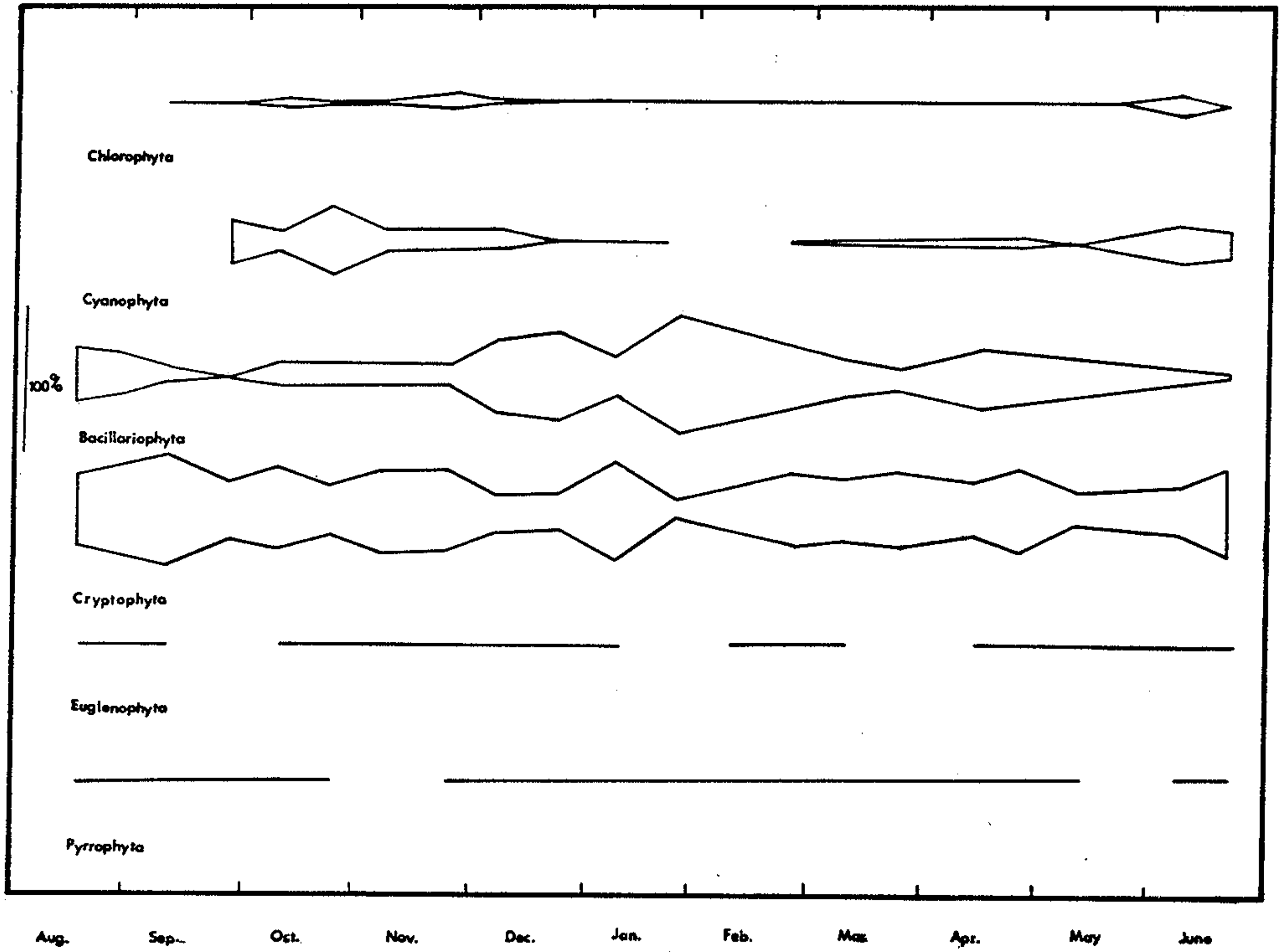


Figure 16. Percentage composition of six phytoplankton divisions present in semimonthly samples taken in Lavaca Bay during 1974 - 1975.

Table 8. Number of phytoplankton taxa by data and site.

Date (M-D-Y)	600-2	65-2	617-2	85-2	90-1	115-1	143-2	150-2	190-2	Means by Date
9-25-73	9	19	3	5	5	10	7	9	8	8
10-15-73	11	13	14	4	5	7	10	8	N.D.	9
10-30-73	4	18	12	6	N.D.	11	6	16	17	11
11-13-73	6	14	12	14	10	14	15	12	16	13
11-29-73	8	16	19	11	13	12	11	10	9	12
12-14-73	4	14	13	10	5	10	10	7	12	9
12-28-73	4	10	10	N.D.	N.D.	6	6	6	12	8
1-10-74	5	6	6	7	11	9	8	7	15	8
1-29-74	5	4	6	5	6	6	9	9	7	6
2-12-74	4	8	9	6	12	12	11	9	12	9
2-26-74	4	16	6	9	7	9	4	8	10	8
3-11-74	3	11	7	4	6	7	7	6	5	6
3-27-74	5	15	9	8	9	9	6	7	12	9
4-10-74	7	12	7	3	7	5	4	5	4	6
4-23-74	5	6	6	5	5	6	6	9	9	6
5-13-74	5	5	4	5	4	4	9	5	7	5
5-23-74	6	9	6	4	5	7	6	8	6	6
6-11-74	5	1	4	9	9	3	5	5	9	6
6-26-74	4	8	5	5	5	7	6	11	11	7
7-17-74	4	7	5	7	6	9	6	8	9	7
7-24-74	4	7	8	7	7	7	8	8	8	7
8-15-74	5	7	6	8	8	7	7	7	10	6
8-28-74	7	6	6	3	7	6	7	6	8	6
9-16-74	6	8	5	4	6	5	8	12	12	7
9-25-74	5	9	N.D.	6	12	13	17	7	10	10
10-16-74	15	25	17	5	15	12	11	6	11	13
11- 4-74	N.D.	N.D.	N.D.	18	20	8	20	16	10	15
11-13-74	10	8	18	15	16	11	14	17	20	14
11-25-74	9	11	N.D.	14	19	9	14	12	24	14
12- 9-74	2	5	7	13	17	21	24	18	16	14
12-31-74	6	17	18	17	23	21	21	23	22	19
1-14-75	5	N.D.	14	5	9	13	19	10	11	11
1-30-75	N.D.	N.D.	14	N.D.	11	10	15	14	12	13
2-13-75	14	16	13	19	13	24	11	12	17	15
2-25-75	9	26	12	19	20	22	18	23	22	19
3-11-75	12	17	17	12	14	N.D.	7	12	11	13
3-19-75	15	14	22	14	17	15	11	12	15	15
4-10-75	19	15	8	35	21	17	13	15	27	19
4-29-75	20	25	30	7	13	9	18	17	20	18
5-15-75	11	27	13	11	12	14	14	13	14	14
6- 4-75	21	16	17	11	17	15	25	17	27	18
6-24-75	12	29	18	12	17	10	12	20	27	17
Means by site	8	13	11	10	11	10	11	11	13	

N.D. No Data taken.

(13 species). Site 600-2 in Redfish Lake had the lowest mean diversity (8 species). Diversities rose in fall 1973 (13 species), declined in spring 1974 (5 species), fluctuated slightly during summer (6 to 7 species), increased in fall (19 species), and remained high through spring 1975 (11 to 19 species) (Fig. 17).

Phytoplankton standing crops ranged from 5 x 10^4 cells/l at site 90-1 on 15 October 1973 and site 85-2 on 16 September 1974 to 2,426 x 10^4 cells/l at site 115-1 on 23 May 1974 (Table 9). Monthly mean standing crops ranged from 18 x 10^4 cells/l on 15 October 1973 to 1,231 x 10^4 cells/l on 15 August 1974. The overall average standing crop was 370 x 10^4 cells/l for the 22-month study perios. The river site (65-2) averaged the highest standing crop for the study period (605 x 10^4 cells/l) while bay mouth site 190-2 had the lowest mean (295 x 10^4 cells/l).

Chlorophyll a values ranged from 0.0 ug/l at site 85-4 on 25 November 1974 to 44.1 ug/l at site 65-2 on 10 April 1974 (Table 10). Monthly mean values ranged from 0.4 ug/l on 15 May 1975 to 17.6 ug/l on 10 April 1974. The overall mean bay chlorophyll a (6.2 ug/l) was less than Lavaca River area chlorophyll a (7.1 ug/l). Site 190-2 averaged the lowest values (3.7 ug/l) while the river site (65-2) had the highest mean (13.0 ug/l). For the 1973 - 1974 study period, chlorophyll a concentrations were highest in spring (Fig. 17). Chlorophyll a values for the 1974 - 1975 study were highest in late fall and decreased in spring and early summer.

DISCUSSION

Phytoplankton were identified to genus or species level when possible. Organisms not so identified were placed in a descriptive taxon (e.g. unidentified pennate diatom, etc.). Microflagellates (excluding pyrophytes) presented special problems due to small size (< 10 u) and morphological changes which occurred during preservation. Recognizable microflagellates occurred with unidentified forms and are herein treated collectively.

Seasonal comparisons of taxa diversities cannot be made due to more thorough sample analysis from September 1974 through June 1975; however, diversities generally declined with increased inflow due to phytoplankton dispersal and rapidly changing salinities. Microflagellate blooms and increases in small (< 20 u) diatoms e.g. *Cyclotella* and *Navicula* immediately after high river discharge may have temporarily depressed taxa numbers (Fig. 17). As inflow decreased and bay salinity stabilized, diversities rose as neritic species became more abundant. High mean diversities at the river site 65-2 and at the bay mouth site 190-2 may indicate stability relative to other sites. Increased river discharge sometimes resulted in higher diversities at mid-bay sites when freshwater forms mixed with brackish water populations.

Mean standing crop for the entire study was 378 x 10^4 cells/l of which 239 x 10^4 were microflagellates, 52 x 10^4 were diatoms, and 36 x 10^4 were greens (exclusive of *Chlamydomonas* and *Pyramimonas*). Campbell (1973) found 50 x 10^4 phytoflagellate cells/l (including dinoflagellates) at Gales Creek. He stated that Williams and Murdoch, and Thayer found four times that number at Beaufort Channel and areas around Moorehead City, and Smayda found ten times that cell number in Narragansett Bay.

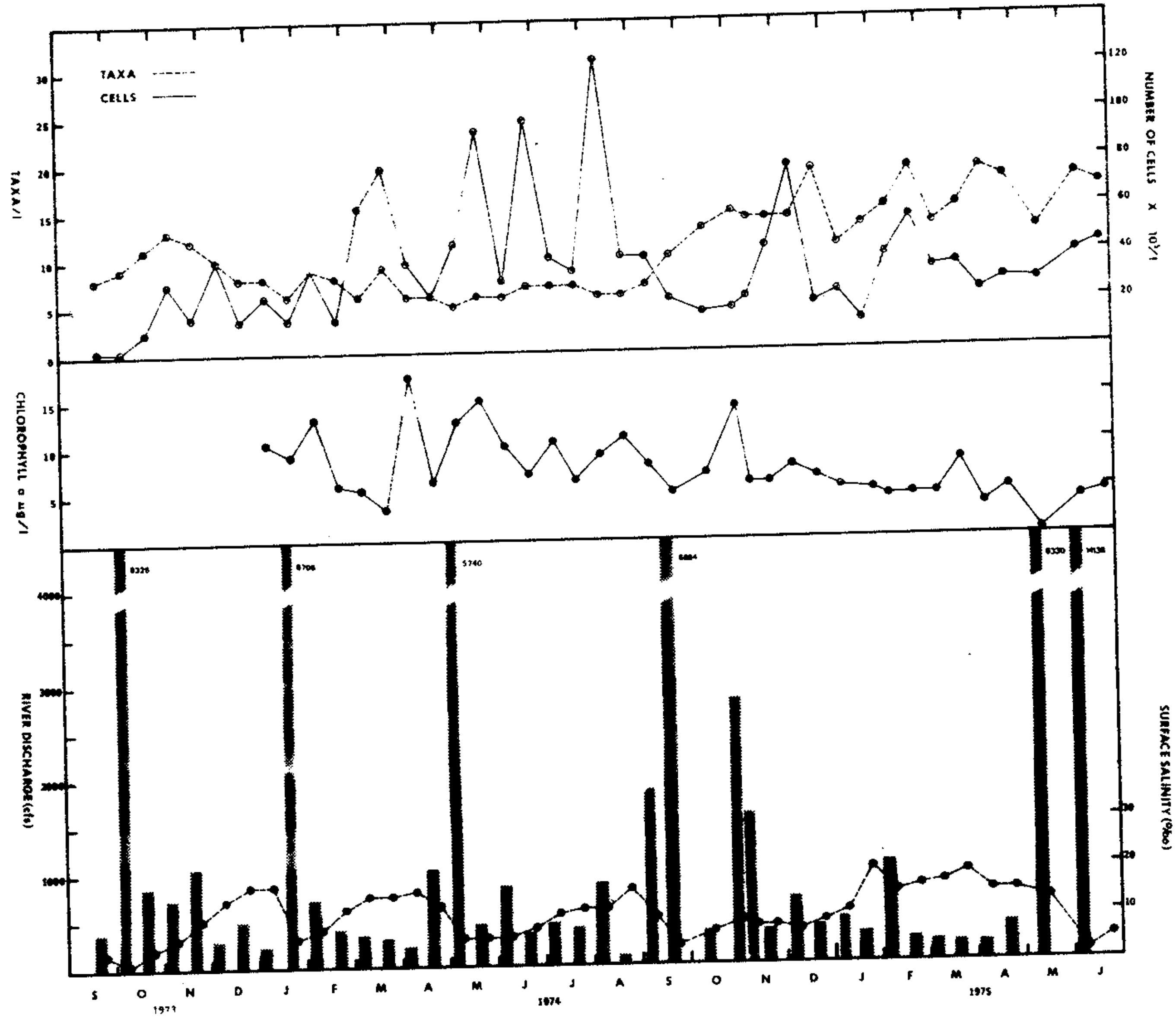


Figure 17. Phytoplankton diversity, standing crop, chlorophyll a, mean bay system salinity, and 9-day lag inflows by sample date (September 1973 - June 1975).

Table 9. Phytoplankton standing crop (n x 10^4) by date and site.

Date (M-D-Y)	600-2	65-2	617-2	85-2	90-1	115-1	143-2	150-2	190-2	Means by Date
9-25-73	30	59	10	13	9	20	26	19	14	22
10-15-73	16	21	48	6	5	7	32	11	N.D.	18
10-30-73	26	1,190	101	52	N.D.	112	126	154	196	245
11-13-73	116	408	234	532	700	562	120	29	48	305
11-29-73	51	166	122	447	426	58	62	98	25	163
12-14-73	2,009	1,103	490	571	227	553	542	221	311	670
12-28-73	272	73	48	N.D.	N.D.	39	83	177	205	128
1-10-74	60	89	144	418	87	156	469	463	349	248
1-29-74	57	62	66	128	38	197	300	140	135	125
2-12-74	58	56	84	113	135	260	2,348	56	40	350
2-26-74	375	231	121	70	65	403	87	20	25	155
3-11-74	598	704	699	694	462	819	218	664	663	613
3-27-74	493	1,455	1,085	871	1,059	206	394	810	662	782
4-10-74	881	1,988	442	10	35	14	48	16	18	384
4-23-74	330	180	124	57	66	35	300	72	194	151
5-13-74	989	30	9	280	270	676	689	505	299	416
5-23-74	1,159	1,157	540	1,646	1,624	2,426	1,142	690	852	1,248
6-11-74	814	12	11	222	220	10	39	408	211	216
6-26-74	817	1,728	992	919	1,656	869	808	612	513	990
7-17-74	536	443	268	553	661	544	178	522	604	479
7-24-74	104	455	806	388	180	347	255	222	207	329
8-15-74	565	2,194	674	845	693	1,412	1,144	2,284	1,271	1,231
8-28-74	304	544	469	137	79	153	239	944	820	410
9-16-74	490	704	524	5	112	411	415	645	274	398
9-25-74	121	25	121	12	144	184	667	583	86	216
10-16-74	39	469	183	64	92	222	195	98	74	160
11- 4-74	N.D.	N.D.	N.D.	351	68	209	176	75	276	192
11-13-74	88	562	359	98	149	85	100	378	147	218
11-25-74	509	760	N.D.	528	593	104	356	618	120	448
12- 9-74	3,830	78	188	419	516	374	772	551	273	779
12-31-74	23	221	314	147	187	139	128	321	214	188
1-14-75	148	N.D.	98	856	179	112	250	219	97	245
1-30-75	N.D.	N.D.	89	N.D.	95	108	126	188	92	116
2-13-75	670	388	813	440	321	432	146	95	233	393
2-25-75	207	2,389	80	589	254	265	200	718	252	550
3-11-75	205	1,870	68	115	196	N.D.	295	118	53	365
3-19-75	616	116	751	763	401	242	114	116	112	359
4-10-75	257	79	133	527	313	294	121	202	147	230
4-29-75	352	666	708	88	415	77	108	102	87	290
5-15-75	318	509	214	186	772	95	197	103	221	290
6- 4-75	554	231	180	93	215	199	788	383	1,026	408
6-24-75	293	188	224	961	632	90	60	150	669	363
Means by site	485	605	316	380	359	330	354	352	295	

N.D. No Data taken.

Table 10. Chlorophyll a concentration (ug/l) for 26 sites in the Lavaca Bay system (January 1974 - June 1975).

Date (M-D-Y)	Sites 600-2	65-2	617-2	85-2	90-1	115-1	143-2	150-2	190-2
1-10-74	N.D.	N.D.	N.D.	3.8	2.8	3.2	1.3	3.1	20.6
1-29-74	7.7	4.2	0.6	4.2	23.9	9.1	7.6	7.8	6.2
2-12-74	39.8	11.0	12.4	15.5	9.4	13.6	5.9	6.3	3.0
2-26-74	2.0	5.4	2.2	10.2	4.8	4.5	3.1	4.1	3.4
3-11-74	9.4	14.9	10.5	10.9	11.2	6.1	3.0	3.9	2.6
3-27-74	0.7	14.6	7.7	5.1	7.1	1.7	1.0	1.4	3.0
4-10-74	14.7	44.1	20.4	34.8	10.7	9.6	6.7	8.4	9.2
4-23-74	22.6	15.8	12.7	11.8	20.4	9.8	3.1	8.2	4.9
5-13-74	14.7	12.7	12.3	8.1	13.5	15.2	10.4	14.5	12.8
5-23-74	18.6	28.4	20.1	10.2	25.3	9.4	5.5	7.4	3.1
6-11-74	7.2	14.0	18.1	10.2	12.0	8.8	8.3	5.1	7.2
6-26-74	5.5	12.6	8.5	9.3	5.9	4.9	4.0	3.3	10.3
7-17-74	9.6	21.1	12.2	6.0	9.7	6.9	9.1	14.0	6.2
7-24-74	3.8	5.0	9.2	6.2	5.1	8.1	3.9	6.2	3.1
8-15-74	19.4	6.4	9.5	4.8	6.4	9.7	7.2	11.4	5.9
8-28-74	11.6	10.2	12.3	6.0	13.8	9.4	11.6	9.7	21.0
9-16-74	5.1	19.1	9.9	13.1	5.1	7.5	3.5	5.8	4.0
9-25-74	3.1	2.2	2.2	13.1	5.1	3.0	9.1	5.4	6.5
10-16-74	3.0	7.9	5.5	7.3	6.8	4.9	11.5	9.6	8.5
11- 4-74	N.D.	N.D.	N.D.	8.3	14.6	15.7	19.3	22.2	16.9
11-13-74	4.4	3.2	8.2	4.5	8.5	4.9	9.8	6.5	8.5
11-25-74	3.1	4.7	1.2	3.5	5.8	5.0	6.4	7.8	10.5
12- 9-74	N.D.	N.D.	N.D.	15.7	7.0	7.6	17.8	19.7	8.1
12-17-74	9.5	15.1	3.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
12-31-74	14.9	4.6	8.3	15.7	7.0	5.0	2.5	3.0	4.1
1-14-75	1.8	15.5	9.6	6.2	2.6	N.D.	3.2	3.3	5.5
1-30-75	N.D.	N.D.	9.1	7.4	4.9	3.5	14.8	6.6	0.6
2-13-75	4.1	25.4	0.1	0.1	1.4	3.3	N.D.	0.9	2.0
2-25-75	3.5	17.5	3.1	4.0	4.3	3.6	3.2	2.6	3.3
3-11-75	4.0	12.5	4.4	3.7	4.5	3.5	1.5	2.8	3.0
3-19-75	8.3	6.4	6.5	11.9	17.0	11.4	3.0	3.9	N.D.
4-10-75	2.8	0.7	1.2	6.8	5.1	3.5	1.5	3.4	3.2
4-29-75	5.4	8.7	7.2	4.3	12.4	5.7	5.0	4.7	7.3
5-15-75	0.3	0.9	0.15	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
6- 4-75	N.D.	1.02	19.36	N.D.	0.48	N.D.	N.D.	2.21	0.14
6-24-75	5.0	9.0	10.3	3.8	5.0	2.2	1.7	2.8	3.0
Means by site	9.0	11.7	8.4	8.7	8.7	7.0	6.4	6.7	6.6

N.D. No Data taken.

Table 10---continued.

Date (M-D-Y)	Sites 115-3	129-2	150-5	190-5	190-4	115-4	180-2	140-2	143-4
1-10-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1-29-74	N.D.	N.D.	14.3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2-12-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2-26-74	5.8	6.1	4.2	5.0	3.8	7.3	4.3	4.7	5.7
3-11-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
3-27-74	4.5	3.3	2.2	1.5	3.8	2.6	0.8	1.0	1.6
4-10-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4-23-74	8.1	8.5	8.5	6.5	4.5	6.8	3.2	5.2	3.3
5-13-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
5-23-74	19.3	22.8	14.3	13.8	3.6	20.4	3.3	7.0	4.0
6-11-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
6-26-74	6.3	8.6	9.2	4.6	4.7	5.3	3.9	4.0	5.1
7-17-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
7-24-74	15.3	6.4	8.8	5.7	6.7	15.2	4.6	5.5	6.0
8-15-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
8-28-74	6.5	13.9	8.1	8.7	8.8	7.8	10.0	10.7	16.2
9-16-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
9-25-74	2.2	6.8	7.2	4.6	5.2	3.2	6.7	7.8	5.3
10-15-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
11- 4-74	15.3	15.2	29.1	12.6	13.3	14.1	10.4	17.2	13.4
11-13-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
11-25-74	8.7	10.5	14.0	0.1	10.5	8.5	14.0	4.1	2.6
12- 9-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
12-17-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
12-31-74	9.0	6.0	3.2	4.1	5.0	4.4	3.0	3.5	3.3
1-14-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1-30-75	11.3	6.4	4.0	1.8	1.6	4.4	3.5	2.3	8.4
2-13-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2-25-75	4.3	5.2	2.6	3.9	3.8	N.D.	2.9	2.9	3.9
2-11-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
3-19-75	4.4	1.1	2.2	1.3	2.3	N.D.	3.3	2.2	5.2
4-10-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4-29-75	4.1	3.7	3.5	2.2	2.0	16.4	3.2	1.5	1.6
5-15-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
6- 4-75	2.6	N.D.	N.D.	N.D.	.04	3.5	N.D.	.019	N.D.
6-24-75	6.0	5.2	0.7	N.D.	N.D.	8.0	N.D.	N.D.	N.D.
Means by site	7.8	8.1	8.0	5.0	5.0	8.5	5.1	5.1	5.7

N.D. No Data taken.

Table 10---continued.

Date (M-D-Y)	Sites 90-3	83-5	85-4	83-2	84-2	606-2	610-2	90-5	Means by Date
1-10-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	5.8
1-29-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	7.4	N.D.	8.4
2-12-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	13.0
2-26-74	4.5	9.5	11.8	21.8	1.1	23.0	0.8	5.2	6.3
3-11-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	8.0
3-27-74	4.6	3.8	4.9	4.3	4.2	11.7	1.9	4.1	4.0
4-10-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	17.6
4-23-74	13.0	17.5	17.6	17.3	10.7	16.3	9.8	9.9	10.6
5-13-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	12.7
5-23-74	23.4	17.7	10.7	13.3	31.4	17.3	8.7	27.6	14.8
6-11-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	10.1
6-26-74	4.9	12.6	15.7	7.2	6.0	6.4	5.8	7.4	7.0
7-17-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	10.5
7-24-74	6.9	5.7	19.3	6.7	7.5	4.0	2.5	7.3	7.1
8-15-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	9.0
8-28-74	11.6	8.1	12.6	14.9	14.2	9.1	8.5	11.6	11.0
9-16-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	8.1
9-25-74	1.8	2.2	0.3	9.2	9.1	1.7	3.7	1.2	4.9
10-16-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	7.2
11- 4-74	20.5	6.4	6.4	21.0	5.7	1.9	5.4	N.D.	13.8
11-13-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	6.5
11-25-74	5.4	23.3	0.0	0.8	4.7	4.7	4.7	5.8	6.5
12- 9-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	12.6
12-17-74	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	9.2
12-31-74	13.3	12.0	8.3	14.0	12.5	5.8	10.9	10.28	7.4
1-14-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	6.0
1-30-75	2.9	4.4	4.0	6.5	0.4	N.D.	6.8	N.D.	5.2
2-13-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	4.7
2-25-75	3.6	3.7	4.5	8.9	6.1	4.0	3.5	N.D.	4.5
3-11-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	4.4
3-19-75	2.6	11.8	14.5	22.1	6.4	N.D.	31.6	8.3	8.2
4-10-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	3.13
4-29-75	10.8	10.0	4.4	7.0	1.3	6.7	2.3	1.3	5.5
5-15-75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	.45
6- 4-75	6.9	2.2	7.6	2.9	2.7	N.D.	N.D.	6.69	3.9
6-24-75	1.0	N.D.	3.1	3.7	8.1	8.7	3.8	N.D.	4.8
Means by site	8.1	9.4	8.6	10.7	7.8	8.7	6.9	8.2	

N.D. No Data taken.

Relationships between phytoplankton and physical parameters varied and were not clear-cut. Correlation analyses were not strong except where indicated. Standing crops were positively correlated with temperature (r = 0.21; df = 93; 5% significance level). This is probably due to high diatom and microflagellate densities in spring and summer 1974.

Minimum phytoplankton density was associated with high river discharge while maximum standing crops occurred with blooms of very small microflagellates (< 10 u) and diatoms (< 20 u) as the bay salinity began to stabilize after high inflow (Figs. 11, 12, 13, and 17). Benthic and epiphytic forms, common after high river inflow, may have been flushed from the marsh area. As salinities increased and marine species returned to the bay, microflagellate populations often remained numerically dominant although reduced. Phytoplankton in the river area and upper bay consisted primarily of freshwater species while marine forms predominated in the lower bay. Marine species were often found in the river area when river discharge was less than ≈500 cfs. These organisms were transported in a saline bottom water layer. Freshwater phytoplankton were dispersed into the lower bay when river inflow exceeded ≈2000 cfs. High mean standing crops at site 65-2 may have been due to high nutrient levels, increased contribution from benthic flora, and volume sampling which favors turbid areas at the head of an estuary over euphoticly deeper mouth regions.

Many estuarine species are euryhaline and Simmons (1957) found Nitzschia closterium and Nitzschia longissima common in salinities of 40 - 45 °/oo; Navicula sp. common up to 60 °/oo; Synedra superba common in 30 - 50 °/oo; and Pleurosigma angulatum common up to 65 °/oo. Simmons also found Gyrosigma balticum and Rhizosolenia setigera to be prevalent in hypersaline conditions. However, Qasim et al. (1972) found that maximum phytoplankton growth for several marine species occurred in salinities lower than 35 °/oo including Nitzschia closterium (10 - 15 °/oo), Planktoniella sol (15 - 20 °/oo), and Asterionella japonica (10 - 20 °/oo). Williams (1964) found that Bacillaria paradoxa, Gyrosigma fasciola, Gyrosigma spencerii, Navicula spp., Nitzschia closterium, and Nitzschia sigma reproduced well within a salinity range from 10 - 30 °/oo salinities. Thus, many neritic species may be favored by 10 - 30 °/oo salinities in Lavaca Bay.

Nutrient levels recorded for this study were generally lower than values reported for the Matagorda Bay system by other investigators (Blanton et al., 1971; Groover and Sharik, 1974). However, Williams (1972) noted that phytoplankton are adapted to nutrient levels present in an estuary and Hulburt (1963) pointed out that large standing crops are indicative of ample nutrient supplies. Dugsdale (1967) suggested that supply rates may be more important than concentrations per se. Freshwater species dispersed into Lavaca Bay with high inflow disappeared as salinities increased and were probably remineralized.

Armstrong et al. (1975) found marshes at the head of Lavaca Bay to be significant in nutrient export to the adjoining bay area. Nutrient influxes consisted primarily of organic degradation products with carbon, organic nitrogen, ammonia, and total organic phosphorus rapidly produced from macrophyte breakdown. Apparently nitrite, nitrate, and ortho-phosphorus were removed from the water upon becoming available by marsh vegetation. Organic nitrogen and ammonia exported into the bay were probably used directly and/or converted ultimately to nitrate which was taken up by phytoplankton. Low nitrate values in February and June - August 1974 suggest that nitrate may have limited phytoplankton unable to use other nitrogen sources. Riley (1967) stated that nitrate may become limiting due to slow regeneration of nitrogenous substances. However, many algae use ammonia as readily as nitrate and others utilize nitrite, urea, uric acid, and amino nitrogen (Cupp, 1943; Ketchum, 1951; and North, 1975). Stephens (1972) noted that amino acid uptake has been observed in cyanophytes, chlorophytes, pyrrophytes, and bacillariophytes. Wheeler et al. (1974) found the following phytoplankters able to utilize amino acids for growth: Chlorella sp., Nitzschia sp., Navicula sp., Chlamydomonas sp., Chaetoceras affinis, Nitzschia salinarum, Skeletonema costatum, and Leptocylindrus danicus. De la Cruz and Poe (1975) found vascular plant detritus increased in amino acid and ammonia content due to microbial colonization. Campbell (1973) noted that some phytoflagellates are capable of using suspended particulate matter as a nitrogen source via phagocytosis.

Williams (1972) cited enrichment studies as indicating ample phosphorus relative to nitrogen in many estuaries. He noted that Pomeroy et al. found sedimentory phosphorus concentrations sufficient to maintain nutrient levels supportive of phytoplankton growth through absorption-desorption processes. McRoy et al. (1972) found that cordgrass pumped phosphorus from sediment and excreted it into surrounding water. Armstrong et al. (1975) stated that normal exchange processes seemed rapid enough in Lavaca Bay to prevent phosphorous depletion.

Qasim et al. (1972) postulated a correlation between phytoplankton dependence on increased nutrient levels and adaptability to low salinities as a mechanism for regulating high production rates in neritic and estuarine areas. They noted that lowered salinity caused by freshwater inflow seemed associated with the introduction of biologically active substances (e.g. humic acid). Paster and Abott (1970) suggested that hormones (e.g. gibberellic acid) leached from macrophyte detritus might cause phytoplankton blooms. Phytoplankton flora in Lavaca Bay is probably locally adapted and temporary disruptions produced by high river discharge are offset by nutrient enrichment and lowered mean salinities favorable for growth and photosynthesis of several species.

A negative correlation was found between phytoplankton density and zooplankton standing crops ($r = -.20$; $df = 93$; 5% significance level). Bainbridge (1953) found that mysids, decapod larvae, and copepods migrated into concentrations of Skeletonema, Thalassiosira, Biddulphia, Nitzschia, Chlamydomonas, and Peridinium. Rhyther (1969) stated that many neritic phytoplankters are large enough to be filtered and consumed directly by zooplankton (e.g. copepods). Raymont (1963) noted that nannoplankton (e.g. diatoms and phytoflagellates < 10 u) may be all important nutritionally to small larvae, e.g. veligers. Rhyther further stated that many colonial phytoplankton e.g. chain-forming diatoms can readily be eaten by larger fishes without special feeding adaptions. Prevalent colonial diatoms in Lavaca Bay included: Asterionella japonica, Biddulphia spp., Chaetoceras spp., Leptocylindrus spp., Melosira spp., Nitzschia spp., Rhizosolenia spp., Skeletonema costatum, Thalassionema nitzschoides, Thalassiosira rotula, and Thalassiothrix spp. Trophic affinities between phytoplankton and consumers are often difficult to discern because of indirect relationships, time lag, and current transport (FAO, 1957). Relationships are further complicated in that grazing circuits may be secondary to detrital pathways in Lavaca Bay.

Ranges in chlorophyll a values for the Lavaca Bay (0.0 - 44.1 mg/m^3 are comparable to values reported by Steed (1971) for the San Antonio Bay (0.0 - 48.9 mg/m^3) and Groover and Sharik (1974) for Matagorda Bay (0.0 - 43.8 mg/m^3). The overall mean of 6.4 mg/m^3 chlorophyl a for Lavaca Bay is within the mean value range listed by Steidenger (1973) for various Florida estuaries (2.13 - 14.9 mg/m^3).

Seasonal trends were not discernable due to large fluctuations between sample dates. Higher chlorophyll a values for the river area versus the bay may reflect organic detrital input from the surrounding marsh as detrital pigments were not deducted from chlorophyll a values.

Chlorophyll a values did not correlate with cell counts possibly due to physiological and volumetric differences between phytoplankton species. Chlorophyll a values seemed negatively related to high (above 2000 cfs) river discharge through standing crop changes caused by physical removal, increased turbidities, and rapidly changing salinities (Figs. 11, 12, 13, and 17). Chlorophyll a values appeared positively related to increased river inflow due to expanded amounts of pigmented detritus and elevated nutrient levels supportive to phytoplankton increases.

SECTION III. ZOOPLANKTON

Mario Garcia

INTRODUCTION

The term zooplankton refers to those usually small animals living in the water strata, and carried about more by water currents than by their own swimming abilities (Moseley and Copeland, 1970). Zooplankton can be divided into two major categories, the holoplankton and the meroplankton, separated by differences in their life cycle (Jeffries, 1967). Holoplanktonic animals (copepods, larvaceans, chaetognaths, cladocerans, and ctenophores) spend all stages of their life cycle in the water above the substrate. The meroplanktonic animals (polychaetes, pelecypods, gastropods, cirripedes, decapods, and the pelagic larvae of fish) spend only part of their lives in the water as free-swimming larval stages. Zooplankton play a significant role in the ecosystem by acting as an energy transferal link between phytoplankton and the higher trophic levels such as larval fish and shrimp.

LITERATURE REVIEW

Several studies of Texas bays and estuaries have included zooplankton sections. Four such published studies were located for the Lavaca Bay area. Blanton et al. (1971) studied zooplankton of Lavaca Bay from March 1970 to March 1971. A no. 25 mesh (53 u pore width) net with a mouth diameter of 24 cm was towed for 20 ft at each of 17 sites. Zooplankton standing crops were low in June, September, and October 1970 (1 to 5 organisms/1), and were high in May and November 1970, and January and February 1971 (10 to 20 organisms/1).

Bishop (Davis et al., 1973) studied the zooplankton of Lavaca Bay and river area from April through July 1973. Monthly samples were collected at 12 stations by towing a no. 10 mesh (about 150 u openings) net with a 0.5 m mouth diameter just below the water surface for one minute. Bay standing crops ranged from 100 to 15,840 organisms/m^3, while the river area standing crops ranged from 10 to 2,150 organisms/m^3. Taxonomy was limited and no analysis of data was presented.

Strithavatch (Moseley and Copeland, 1973) studied the zooplankton of Cox and Keller bays and the upper end of the Matagorda Ship Channel from 19 September 1971 to 11 October 1972. A Clarke-Bumpus plankton sampler with a no. 20 mesh net was towed obliquely for two minutes at each of 14 stations. A total of 102 species were found during the study, with *Acartia tonsa* being the most abundant zooplankter in all three study areas throughout the year. Zooplankton blooms (3) occurred only when the salinity was greater than 10 $^o/oo$ and the water temperature was greater than 24 ^oC. Standing crops ranged from 2,400 organisms/m^3 (Keller Bay during September 1971) to 104,600 organisms/m^3 (Cox Bay during June 1972).

Rennie (Moseley and Copeland, 1970) studied the zooplankton of Cox and Keller bays of the Lavaca Bay system from 20 September 1969 to 31 May 1970. A Clarke-Bumpus plankton sampler with a no. 20 mesh (50 u openings) net was towed obliquely for two minutes at each of 11 stations. He found 50 to 60 taxa, with crustaceans dominating zooplankton samples both in species numbers and numerical abundance. Major contributors were copepods and decapod and barnacle larvae. *Acartia tonsa*, the numerically dominant zooplankter, occurred throughout the study at all stations.

Several recent studies involving zooplankton of other Texas bays have been published. Matthews (Matthews *et al.*, 1974) studied zooplankton of the San Antonio Bay system (located 22.5 km or 14 mi southwest of Lavaca Bay) from August 1972 through July 1973. His sampling gear and collecting procedures were identical to those used by Bishop (Davis *et al.*, 1973). About 110 taxa were found, and included organisms from both fresh water and neritic Gulf water. The dominant zooplankter was *Acartia tonsa*, followed in order of abundance by barnacle nauplii. Standing crops ranged from 4 organisms/m^3 (September 1972) to 106,760 organisms/m^3 (February 1973).

Groover and Sharik (1974) reported on an ecological study of the lower Colorado River - Matagorda Bay system which was conducted from June 1973 through May 1974. Three sampling methods were employed to obtain an overall description of the zooplankton community. At each of 11 stations, macrozooplankton samples were collected monthly by making horizontal tows with a 0.5 m mouth diameter no. 10 mesh tapered net. At the same 11 stations, microzooplankton samples were collected with a submersible pump and an Isaacs-Kidd high speed sampler. A total of 282 species were recorded during the study, with protozoans, rotifers, copepods, and cladocerans being the most abundant and diverse groups. Microzooplankton densities ranged from 1,667 to 2,163,000 organisms/m^3 with a peak during the summer of 1973. Ciliates and tintinnids were the most abundant microzooplankters. Macrozooplankton densities ranged from 10 to 565 organisms/m^3.

Branch (Hildebrand and King, 1974) studied zooplankton collected in Oso Creek and the upper Laguna Madre (Pita Island area) from July 1972 through June 1973. A Clarke-Bumpus automatic plankton sampler using a no. 20 mesh (64 u openings) net was towed just below the water surface for one minute at each of nine stations. *Acartia tonsa* was the dominant zooplankter followed by barnacle nauplii.

Kalke (Holland, *et al.*, 1974) collected zooplankton samples from the Corpus Christi, Copano, and Aransas Bay systems from September 1972 to June 1973. A no. 10 mesh (153 u openings) net with a 0.5 m mouth diameter was towed obliquely for one minute at each of 36 sites. Standing crops in the Corpus Christi Bay system ranged from 180 organisms/m^3 in December 1972 to a peak of 210,908,132 organisms/m^3 in March 1973. This peak was associated with large catches of *Noctiluca scintillans*. Only minimal increases in standing crops occurred in Aransas and Copano bays as a result of increased numbers of *Noctiluca scintillans*. Standing crops for the Aransas Bay system ranged from 224 organisms/m^3 in January to 123,963 organisms/m^3 in February 1973.

MATERIALS AND METHODS

Zooplankton samples were collected semimonthly from six sites in Lavaca Bay (85-2, 90-1, 115-1, 143-2, 150-2, 190-2), and three sites in the Lavaca River area (65-2, 600-2, 617-2), from September 1973 through June 1975 (Figs. 1 and 2). A no. 10 mesh (about 150 u openings) nylon net 1.5 m long and 0.5 m in mouth diameter was towed for one minute just below the water surface at each site. The volume of water filtered during each tow was calculated from a number recorded by a flowmeter (General Oceanics, Inc. #2030) mounted in the center of the net mouth. The flowmeter was calibrated 10 times during the 22-month zooplankton study to assure constant and accurate meter readings.

Ctenophores and medusae hampered subsequent subsampling analysis, so they were removed by straining the contents of the net bucket through a 6.4 mm (0.25 in) mesh screen. The jellies were retained by the screen while the minute zooplankton were washed through the screen into a 950 ml (1 qt) collecting jar. Larval fish, shrimp, and crabs were hand-picked from the screen and put into the collecting jar, while the ctenophores and medusae on the screen were identified, counted, and discarded. The screen was then inverted and lightly sprayed with water to wash the remaining zooplankton into the jar. The bucket was replaced on the net and the net was sprayed from top to bottom with water to wash the zooplankton into the bucket. Contents of the bucket were washed into the collecting jar. The sample was immediately preserved with a 5% formalin solution. Laboratory analysis of the zooplankton samples was made by one of two methods.

Method I. This procedure was used to analyze zooplankton samples from September 1973 through May 1974. The sample was thoroughly mixed and an aliquot of known volume was removed with a Hensen-Stempel pipette. The aliquot was then washed from the pipette into a gridded petri dish where it was scanned with a dissecting microscope. If sufficient organisms were seen (generally between 200 and 2,000), the analysis continued; if not, additional aliquots were added to the petri dish until the desired number of organisms was obtained. The organisms in the dish were identified (to species level when possible) and counted using a dissecting microscope. The volume of the remaining sample was measured with a graduated cylinder and the volume of the aliquot or aliquots was added to this volume to determine the volume of the entire sample. Finally, the remaining portion of the sample was scanned with a dissecting microscope, and the larger, rarer taxa, such as fish, shrimp, and crab larvae, were identified and counted.

Method II. Zooplankton samples collected from June 1974 through June 1975 were analyzed by this method because the procedure was less complicated and less time consuming than method I. The plankton sample was allowed to settle, the supernatant was removed with a basting syringe, and the plankton were transferred to a graduated breaker. The sample was then diluted to a measured volume, thoroughly mixed, and 1, 2, or 5-ml aliquots (depending on the concentration of the zooplankton) were removed with the Hensen-Stempel pipette. The aliquot was washed from the pipette into a gridded petri dish and examined with a dissecting microscope. If sufficient organisms were seen (generally between 150 and 800), the analysis continued; if not, additional aliquots were added to the petri dish until the desired number of organisms were obtained. In April 1975, a Ward-Wildco counting wheel (Wildlife Supply Company) was substituted for the gridded petri dish because it was more accurate. Zooplankton samples collected from November 1974 through June 1975 were analyzed with the counting wheel. Following the first subsample, 50 ml were taken from the thoroughly mixed sample with a Hensen-Stempel pipette. Small portions of the 50-ml aliquot were then placed in a gridded petri dish and examined with a dissecting microscope until the whole aliquot had been analyzed. Organisms observed less than three times in the first subsample were identified and counted. The remaining sample in the breaker was washed through a no. 20 (841 u) sieve which retained the larger animals such as fish, shrimp, and crab larvae while the smaller zooplankton filtered through the sieve into a collecting jar. The larger animals were washed from the inverted sieve into a petri dish where they were identified and counted with a dissecting microscope.

The density of each taxon collected at a site on a given date was determined using data obtained from analysis of the site's sample. The density of each taxon found in an aliquot of the sample was calculated by the following formula:

$$D = \frac{N \times S}{A \times V}$$

where: D = density of the taxon (no./m^3)
N = number of individuals of the taxon in the aliquot
S = volume of the sample (ml)
A = volume of the aliquot (ml)
V = volume of the bay water filtered during the tow (m^3).

The density of each taxon of larger animals found in the whole sample was calculated by the following formula:

$$D = \frac{N}{V}$$

where: D = density of the taxon (no./m^3)
N = number of individuals of the taxon in the entire sample
V = volume of bay water filtered during the tow (m^3).

The zooplankton standing crop at a site on a given date was determined by summing the densities of all taxa present.

RESULTS

A total of 4,499,745 organisms representing 201 taxa in 14 phyla were identified from 360 samples collected during the 22-month zooplankton study. Arthropods accounted for 63% (127 taxa) of the taxa identified, with chordates accounting for 10% (19 taxa), rotifers for 7% (14 taxa), cnidarians for 4% (9 taxa), and protozoans for 3% (6 taxa). The remaining 13% (26 taxa) were distributed among the nine additional phyla (Table 11).

The number of taxa collected per sample ranged from 5 at site 85-2 on 13 November 1974 and site 600-2 on 9 December 1974 to 49 at site 617-2 on 13 May 1974 and averaged 19 per site for the entire study period (Table 12). The number of individuals per sample ranged from 6/m^3 at site 600-2 on 13 November 1974 to 127,381/m^3 at site 150-2 on 29 April 1975 and averaged 12,499/m^3 for the study period (Table 13).

The mean number of taxa identified per site by sample date showed considerable fluctuation during the study; however, three high periods were evident (Fig. 18). These high periods were 10 October 1973 (27 taxa), 13 May 1974 (35 taxa), and 15 May 1975 (31 taxa). Low periods, generally during winter months, occurred on 14 December 1973 (10 taxa), 12 November and 31 December 1974 (12 taxa), and 14 January 1975 (11 taxa).

The mean number of individuals per site (mean standing crop) by sampling period also fluctuated during the study (Fig. 18). These mean standing crops were generally high during spring and low during summer and fall. High mean standing crops were observed during February (24,373/m^3) and April 1975 (26,937/m^3). The periods of high zooplankton abundance were attributed to large numbers of *Acartia tonsa* and barnacle nauplii. Low mean standing crops were present in October 1973 (2,224/m), August 1974 (2,156/m^3) and June 1975 (3,475/m^3). Zooplankton diversity and standing crops were generally lower at upper bay sites than at lower bay sites (Tables 12 and 13).

Table 11. Zooplankton taxa found in Lavaca Bay, September 1973 - June 1975.

PROTOZOA
  SARCODINA
    Arcella sp.
    Difflugia sp.
    Foraminifera

  MASTIGOPHORA
    Noctiluca scintillans

  CILIOPHORA
    Colonial ciliate
    Tintinnids #1 and #2

CNIDARIA
  HYDROZOA
    Blackfordia virginica
    Bougainvillia sp.*
    Hydra sp.
    Hydromedusae
    Nemopsis bachei
    Tiaropsis sp.*

  SCYPHOZOA
    Chrysaora quinquecirrha
    Medusae*
    Stomolophus meleagris

CTENOPHORA
  TENTACULATA
    Mnemiopsis mccradyi

  NUDA
    Beröe ovata

PLATYHELMINTHES
  TURBELLARIA
    Polyclad worm (*Stylochus* sp.?)
    Rhabdocoel worm

  TREMATODA
    Monogenetic trematode
    Tremadode cercaria

RHYNCHOCOELA
    Nemertean worm

ROTIFER
  MONOGONATA
    Asplanchna sp.
    *Brachionus bidentala**
    Brachionus calyciflorus
    Brachionus plicatilis
    Brachionus quadridentata
    (*Conochilus* sp.?)
    Keratella quadrata
    Keratella sp.
    Lecane sp.
    *Platyias patulus**
    *Platyias polyacanthus**
    Platyias quadricornis
    Platyias sp.
    Rotifers #1-3

NEMATODA
    Nematode worm

ECTROPROCTA
    Cyphonautes larvae

ANNELIDA
  OLIGOCHAETA
    (*Stylaria proboscidea*?)

  POLYCHAETA
    Autolytus prolifer larvae*
    (*Neanthes succinea*?) larvae
    Phyllodoce sp. larvae*
    Polychaete larvae
    Polychaete larvae BH, OB, and ON

  HIRUNDINEA
    Leech

MOLLUSCA
  GASTROPODA
    Elysia chlorotica
    Gastropod veligers
    Nudibranch
    Trochophore larvae

  BIVALVIA
    Bivalve veligers

  CEPHALOPODA
    Lolliguncula brevis - juvenile*

ARTHROPODA
  CRUSTACEA
    Alona sp.
    Alonella sp.
    Bosmina sp.
    Camptocercus sp.

Table 11---continued.

Chydorus sp.
Cladoceran
Conchostracan
Daphnia sp.
Diaphanosoma sp.
Dunhevedia sp.
Ebranchipus sp.
Euryalona sp.
Evadne sp.
Ilyocryptus spinifer
Kurzia sp.
Latonopsis occidentalia*
Leydigia acanthocercoides
Macrothrix sp.
Moina sp.
Moinodaphnia sp.
Ostracods (7 types)
Penilia avirostris
Perissocytheridea sp.
Podon sp.
Scapholeberis mucronata
Sida crystallina*
Simocephalus sp.

COPEPODA
Acartia lilljeborgii (Acartia danae)
Acartia tonsa
Anomalocera sp.
Bryocamptus sp.*
Calagoid metanauplius
Caligus sp.
Centropages hamatus
Copepod Copepodids*
Copepod nauplii
Corycaeus sp.
Cyclopoid copepodids
Cyclopoids (6 types)
Cyclops sp.
Diaptomus spp.
Ectocyclops phaleratus
Ergasilus sp.
Eucalanus sp.*
Eucyclops agilis
Eurytemora affinis
Eurytemora hirundoides*
Eurytemora sp.
Euterpina acutifrons
Halicyclops sp.*
Harpacticoid (5 types)
Harpacticus sp.*
Labidocera aestiva
Macrocyclops sp.
Microcyclops sp.
Oithona spp. (Oithona brevicornis)
Oncaea sp.
Orthocyclops sp.*
Paracalanus crassirostris
Paracyclops fimbriatus
Parategastes sp.
Pontella sp.
Pseudodiaptomus coronatus
Saphirella tropica
Scottoland canadensis
Temora turbinata
Tortanus setacaudatus
Tropocyclops sp.*

BRANCHIURA
Argulus alosae
Argulus sp.

CIRRIPEDIA
Barnacle nauplii) Balanus eburneus?
Barnacle cyprids)

MALACOSTRACA
Acetes americanus louisianensis*
Acetes sp. protozoea*
Aegathoa oculata
Alpheus sp. zoea
Bowmaniella braziliensis
Brachyuran zoea
Brachyuran megalopa
Callidisca lunifrons*
Calianassa sp. zoea
Callinectes sapidus zoea*
Callinectes sapidus megalopa
Caridean zoea*
Clibanarius sp.*
Corophium louisianum
Cumacean
Cyclaspis (varians?)
Diastylis (sculpta?)
Edotea triloba
Gammarid*
Gammarus mucronatus*
Leptochelia rapax
Libinia sp. zoea*
Lucifer faxoni
Lucifer faxoni protozoea
Macrobrachium sp. zoea
Menippe mercenaria zoea

Table 11---continued.

Mysidopsis almyra
Mysidopsis bigelowi
Ogyrides limicola zoea
Pagurus sp. zoea
Palaemonetes sp. zoea
Penaeus aztecus--post larval
Penaeus setiferus--post larval
Penaeus sp.--post larval*
Petrolisthes armatus zoea
Pinnixia sp. zoea
Pinnotheres sp. zoea
Rhithropanopeus harrisi zoea
Uca sp. zoea
Upogebia affinis zoea*
Xanthid zoea

INSECTA
Caddisfly larvae
Chadobarus sp.
Coleopteran larva*
Corixid
Damselfly nymphs
Dipteran larvae
Dragonfly nymphs
Insect larvae
Mayfly nymphs
Midgefly larvae
Mosquito larvae
Palpomyia sp. larva*
Springtails

ARACHNIDA
Hydracarina (3 types)

ECHINODERMATA
OPHIUROIDEA
(*Micropholas* sp.?)
Ophiopluteus larvae

CHAETOGNATHA
Sagitta sp.
*Sagitta tenius**

CHORDATA
LARVACEA
Larvacean
Oikopleura sp.

OSTEICHTHYES
(*Achirus lineatus*?) larvae*
Anchoa mitchilli larvae
Blenny larvae
Brevoortia patronus juveniles*
(*Chasmodes* sp.?) larvae*
(*Etropus crossotus*?) larvae*
Fish eggs (*Anchoa mitchilli*?)
Fish larvae
(*Gobiosoma bosci*?) larvae
Gobiosox strumosus larvae
Lagadon rhomboides larva*
(*Membras martinica*?)*
(*Menidia berylina*?)
(*Microgobius* sp.?)*
Micropogon undulatus larvae*
(*Syngnathus scovelli*?)*
Syngnathus sp. larvae

*Taxa identified from samples collected after July 1974.

Table 12. Taxa diversity (taxa/sample) for nine sites in the Lavaca Bay system (September 1973 - June 1975).

Date	Sites									Means
(M-D-Y)	600-2	65-2	617-2	85-2	90-1	115-1	143-2	150-2	190-2	by Date
9-25-73	18	7	13	28	21	17	23	17	22	18
10-15-73	23	18	16	23	42	40	17	31	35	27
10-30-73	18	30	16	20	13	18	21	21	20	20
11-13-73	16	28	9	9	8	11	10	10	17	13
11-29-73	15	27	26	7	6	10	7	10	14	15
12-14-73	5	10	6	9	10	11	10	13	12	10
12-28-73	13	24	17	N.D.	N.D.	20	16	12	15	17
1-10-74	13	10	13	10	12	15	16	13	23	14
1-29-74	8	30	32	23	25	17	15	10	13	19
2-12-74	10	21	20	18	9	13	15	15	12	15
2-26-74	23	9	17	13	14	17	17	18	29	17
3-11-74	16	9	18	21	22	31	27	28	26	22
3-27-74	9	10	10	17	23	22	27	35	30	20
4-10-74	25	25	21	23	18	28	21	25	31	24
4-23-74	8	22	33	18	17	21	22	31	29	22
5-13-74	16	41	49	45	34	30	31	32	38	35
5-23-74	11	19	22	18	16	26	17	28	23	20
6-11-74	21	37	45	25	17	29	25	27	30	28
6-26-74	12	20	16	16	18	21	16	21	25	18
7-17-74	14	14	17	19	22	32	33	39	26	24
7-24-74	10	13	16	13	15	22	35	26	21	19
8-28-74	18	16	11	23	17	23	32	24	25	21
9-16-74	15	18	21	26	31	10	19	21	22	20
9-25-74	31	18	22	22	23	19	19	18	29	22
10-16-74	13	15	17	17	10	13	19	21	20	16
11- 4-74	N.D.	N.D.	N.D.	19	21	25	26	15	16	20
11-13-74	13	22	6	5	11	9	14	13	11	12
11-25-74	23	29	27	14	12	13	13	15	22	19
12- 9-74	10	21	22	12	10	13	12	10	17	14
12-31-74	14	11	14	11	11	11	11	10	15	12
1-14-75	17	9	7	10	11	12	12	10	14	11

Table 12---continued.

Date (M-D-Y)	Sites 600-2	65-2	617-2	85-2	90-1	115-1	143-2	150-2	190-2	Means by Date
1-30-75	N.D.	N.D.	8	15	9	21	16	14	17	14
2-13-75	13	18	15	15	11	11	14	12	14	14
2-25-75	11	13	9	16	14	14	20	20	22	15
3-11-75	17	9	19	18	16	22	21	24	19	18
3-19-75	N.D.	N.D.	15	16	20	24	18	22	29	20
4-10-75	11	26	26	21	14	23	26	29	23	22
4-29-75	21	15	22	22	21	39	37	41	36	28
5-15-75	18	36	17	33	36	29	35	32	39	31
6- 4-75	21	29	30	37	29	29	22	27	21	27
6-24-75	18	20	19	11	14	16	16	15	13	16
Means by site	16	20	19	18	18	20	20	21	22	

N.D. No Data taken.

Table 13. Zooplankton standing crops (number of individuals/m^3) for nine sites in the Lavaca Bay system (September 1973 - June 1975).

Date (M-D-Y)	Sites 600-2	65-2	617-2	85-2	90-1	115-1	143-2	150-2	190-2	Means by Date
9-25-73	859	1,718	168	13,611	30,416	2,485	9,453	1,586	1,646	6,882
10-15-73	372	422	1,801	1,459	1,914	7,591	1,895	3,116	7,943	2,946
10-30-73	31	22	102	715	1,389	383	1,730	2,464	6,682	1,502
11-13-73	163	13	270	615	478	2,493	3,276	1,208	5,839	1,595
11-29-73	44	67	78	6,540	1,289	6,469	2,472	4,196	25,673	5.203
12-14-73	53	30	18	1,368	1,702	12,408	6,007	3,385	4,242	3,246
12-28-73	85	84	338	N.D.	N.D.	15,338	5,834	9,202	2,204	4,726
1-10-74	261	397	2,039	795	2,505	43,212	5,872	35,880	1,732	10,299
1-29-74	83	3,080	3,710	1,937	915	3.059	12,536	3,956	14,598	4,875
2-12-74	61	431	2,669	8,115	11,686	9,809	14,953	8,166	2,959	6,539
2-26-74	808	451	3,338	10,593	123,601	111,091	46,474	39,916	43,591	42,207
3-11-74	551	154	4,097	40,144	71,040	87,093	72,603	93,125	74,245	49,228
3-27-74	32	100	748	2,240	2,311	8,038	28,904	17,993	11,679	8,005
4-10-74	255	121	2,358	34,967	10,967	25,808	20,420	28,535	28,850	16,920
4-23-74	123	915	804	6,400	13,752	13,151	19,766	38,506	60,463	17,098
5-13-74	43	1,800	1,298	2,463	1,196	4,755	20,869	8,718	23,713	7,206
5-23-74	59	87	4,287	5,543	8,646	7,840	3,686	11,168	7,034	5,372
6-11-74	112	1,104	543	5,064	2,966	14,519	3,082	10,204	22,690	6,698
6-26-74	43	233	2,424	13,901	18,447	14,043	3,892	7,597	12,705	8,143
7-17-74	171	342	17,952	3,394	11,381	40,793	19,110	10,260	3,675	11,898
7-24-74	28	33	427	336	579	2,773	12,261	2,544	78	2,118
8-28-74	167	5,309	455	6,632	3,156	418	1,497	337	1,432	2,156
9-16-74	861	1,840	2,382	10,161	550	5,721	1,242	8,885	998	3,627
9-25-74	15	248	386	147	535	795	12,628	8,772	16,154	4,409
10-16-74	11	25	2,459	14,383	6,540	6,706	1,918	7,901	7,300	5,249
11- 4-74	N.D.	N.D.	N.D.	9,699	881	18,346	9,183	6,076	7,602	8,631
11-13-74	6	850	36	365	469	14,250	8,463	14,270	22,106	6,757
11-25-74	18	393	665	19,090	2,752	7,841	11,773	9,567	21,465	8,174
12- 9-74	31	272	191	1,171	3,381	10,004	13,985	11,371	10,727	5,681
12-31-74	487	2,860	1,854	122,328	18,273	40,863	20,674	9,062	6,745	24,794
1-14-75	332	319	4,688	26,462	18,839	51,897	23,506	27,871	34,521	20,937

Table 13---continued.

Date (M-D-Y)	Sites 600-2	65-2	617-2	85-2	90-1	115-1	143-2	150-2	190-2	Means by Date
1-30-75	N.D.	N.D.	39,390	9,683	7,088	17,532	12,882	16,458	4,480	15,359
2-13-75	38	531	303	11,251	704	8,260	59,402	72,064	13,097	18,406
2-25-75	295	3,821	18,766	18,214	18,931	21,749	58,790	33,865	37,297	23,525
3-11-75	48	453	28,806	29,727	42,498	63,273	74,263	84,784	33,911	39,751
3-19-75	N.D.	N.D.	65	5,223	1,698	34,385	29,526	31,474	31,387	19,108
4-10-75	1,204	2,249	1,535	6,655	8,429	48,127	16,760	31,583	39,315	17,317
4-29-75	31	25	538	14,561	13,129	55,005	49,612	127,381	68,725	36,556
5-15-75	493	5,779	196	18,844	8,189	25,416	53,390	48,345	32,526	21,464
6- 4-75	224	3,998	2,504	2,573	2,767	5,633	4,704	14,353	6,158	4,768
6-24-75	43	63	8,470	2,152	3,154	1,475	95	3,255	922	2,181
Means by site	225	1,069	4,079	12,238	11,979	21,240	19,009	22,180	18,515	

N.D. No Data taken.

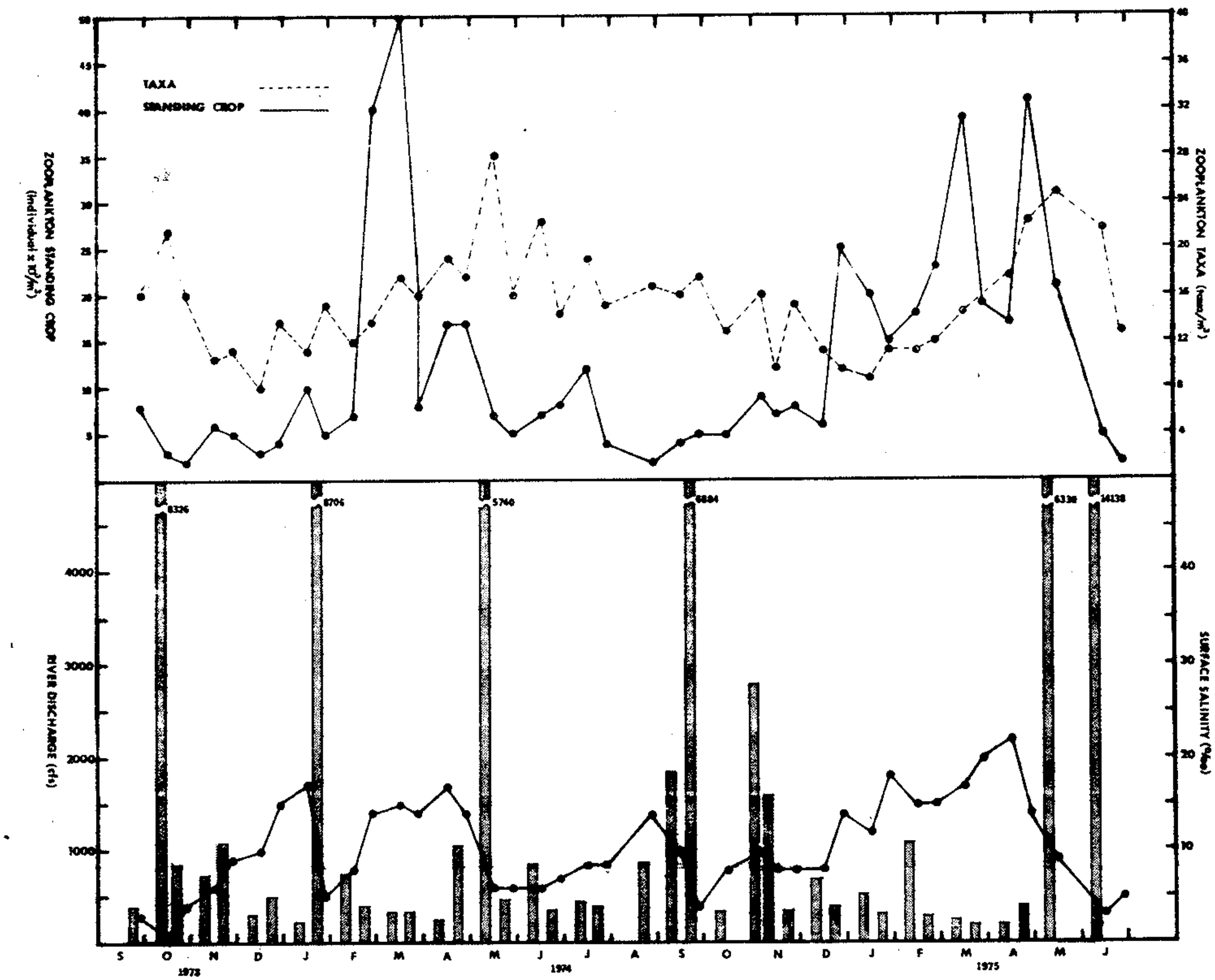


Figure 18. Zooplankton taxa diversity and standing crops in relation to surface salinity and 9-day lag inflow.

Three zooplankton species comprised 80% (3,606,734) of all the organisms collected during the study. Barnacle nauplii were the dominant zooplankters with 47% (2,110,943) followed by *Acartia tonsa* with 28% (1,280,342) and *Oithona* spp. with 5% (215,449). Standing crops for all three species increased from upper Lavaca Bay to lower Lavaca Bay. The total number of barnacle nauplii collected during the study by site ranged from 2,048/m^3 at site 600-2 to 492,234/m^3 at site 150-2. *Acartia tonsa* individuals ranged from 1,650/m^3 at site 600-2 to 315,912/m^3 at site 190-2. *Oithona* spp. ranged from 7/m^3 at site 600-2 to 55,553/m^3 at site 150-2.

DISCUSSION

Lavaca Bay species diversity was typical of a Gulf Coast estuary. Taxa ranged from minute protozoans (tintinnids and *Arcella* sp.) to larval fish and shrimp. Organisms originating in fresh, brackish, and marine waters were mixed together in varying degrees. Taxa included freshwater forms (*Daphnia* and *Cyclops*), neritic Gulf water forms (*Labidocera*, *Sagitta*, and *Oikopleura*), and estuarine forms (*Acartia tonsa*, *Oithona* spp., *Paracalanus crassirostris*, and *Pseudodiaptomus coronatus*).

The number of taxa identified during our study was higher (194) than the 102 found by Strithavatch (Moseley and Copeland, 1973) or the 60 found by Rennie (Moseley and Copeland, 1971) in Lavaca Bay. A larger study area, a longer study period, and more precise taxa identification probably accounted for our higher taxa diversity.

During our study, marine and estuarine organisms were most abundant in lower Lavaca Bay; however, they were also present in the upper bay and at the river site 65-2. These organisms were able to move up the river in a bottom salt water layer which was generally present when river inflow was less than 500 cfs. Freshwater species were generally limited to the upper bay and river area; however, when river inflow was above 2000 cfs these organisms were pushed into the lower bay.

Zooplankton taxa diversity generally increased when river inflow increased to above 2000 cfs (Fig. 18). This relationship was most evident in spring when meroplankton were abundant. Some meroplanktonic organisms inhabit shallow protected areas, and were flushed into the open bay during high river inflow.

Zooplankton standing crops were inversely related to water temperature and directly related to salinity (Table 14). Standing crops were highest in late winter and spring when water temperatures were increasing from a winter low to a summer high (Figs. 18 and 19). At this time, a large influx of meroplankton entered the bay and existing holoplanktonic organisms, including ctenophores and medusae, also increased in abundance. Costlow and Bookout (1969) stated that water temperature was an important factor in affecting the growth rate and survival of meroplankton. Strithavatch (Moseley and Copeland, 1973) reported a large influx of meroplankton in the spring months of her study. Moseley *et al.* (1975) and Matthews (Matthews *et al.*, 1975) found highest zooplankton standing crops in the spring.

Ctenophore and medusae populations peaked in the spring (Fig. 20). They were most abundant at salinities of 19 to 22 °/oo which is similar to the sa-

Table 14. Correlation coefficients obtained between zooplankton standing crop, zooplankton species diversity, phytoplankton standing crop, hydrological parameters, and river inflow. The degree of freedom was 108.

	Zooplankton Standing Crop	Zooplankton Species Diversity
Zooplankton Standing Crop	1	.32**
Zooplankton Species Diversity	.32**	1
Phytoplankton Standing Crop	-.20*	-.13
Chlorophyll *a*	-.167	-.17
Ammonia	.11	.01
Total Phosphate	-.23**	.19
Ortho-Phosphate	-.28**	.05
Organic Nitrogen	-.22**	.07
Nitrite	-.28**	.10
Nitrate	-.15	.07
Surface Salinity	.54**	.28**
Surface pH	-.08	-.38**
Surface Water Temperature	-.22**	.10
Surface Dissolved Oxygen	.09	-.13
Surface Turbidity	-.24**	.19*
Total Carbon	-.23**	-.39**
River Inflow (4-day average)	-.12	.20*
River Inflow (6-day average)	-.16	.03
River Inflow (9-day average)	-.16	.19*

* = 5% level of significance
** = 1% level of significance

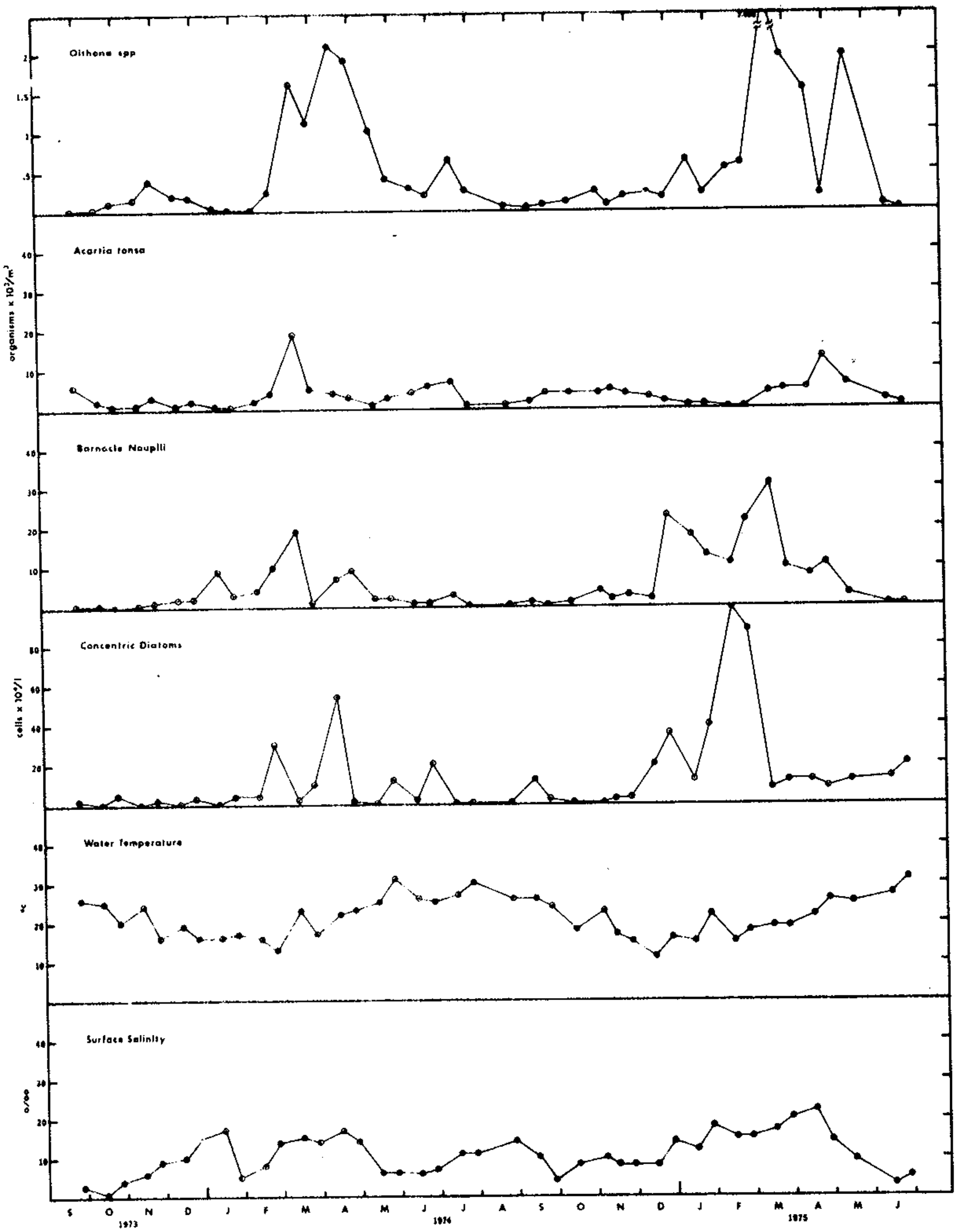


Figure 19. Oithona spp., Acartia tonsa, and barnacle nauplii standing crops and their relationship to concentric diatom populations, water temperature, and surface salinity.

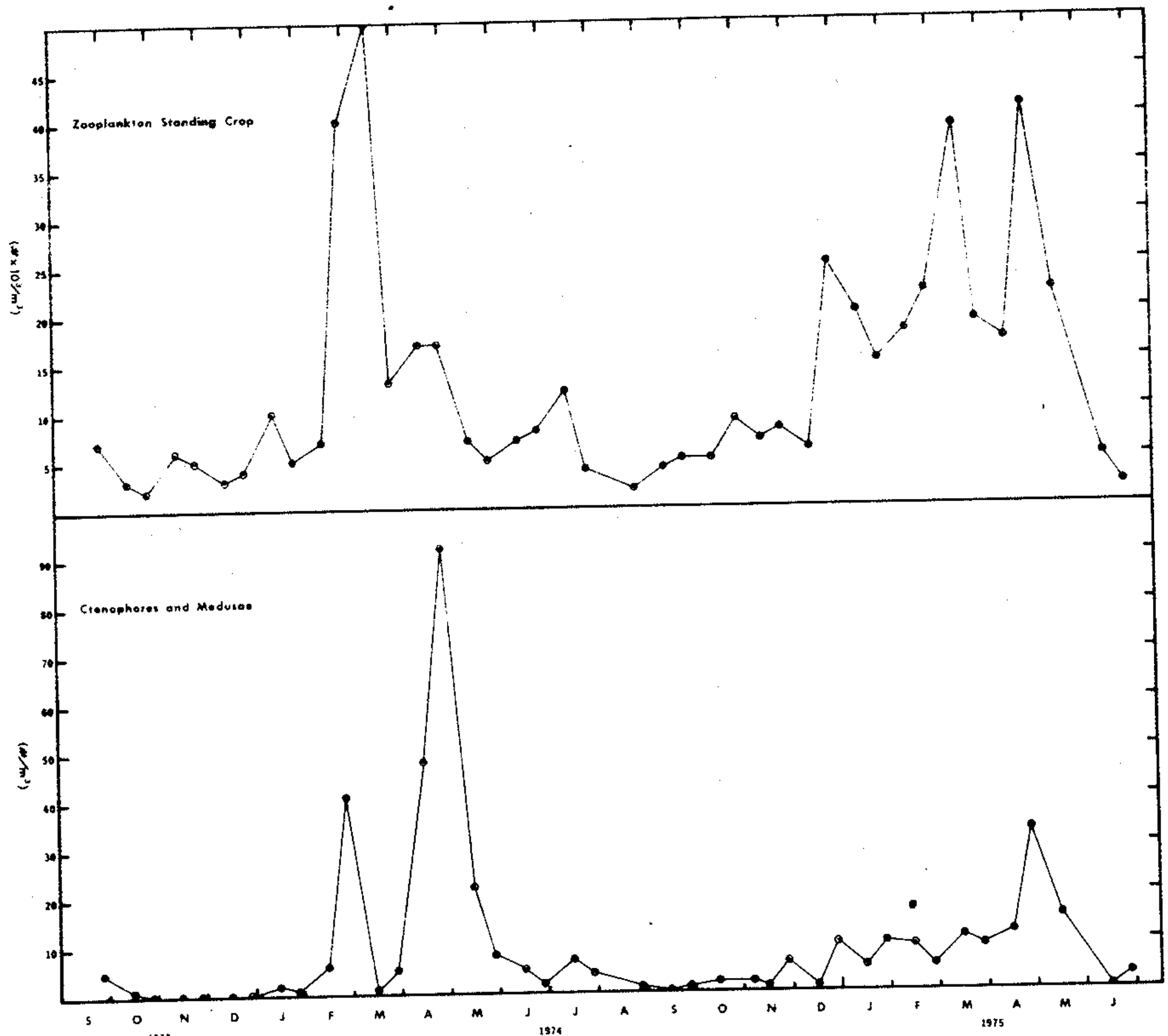


Figure 20. Mean zooplankton standing crops and ctenophore and medusae standing crops (combined) by sample date.

linity preference of the dominant zooplankton species (22 to 23 °/oo). Ctenophores were probably feeding on zooplankton. Medusae have also been known to consume zooplankton (Heinle, 1966).

Three zooplankton taxa (barnacle nauplii, Acartia tonsa, and Oithona spp.) comprised 80% of the total zooplankton standing crop for the study. Standing crops of Acartia and Oithona increased from upper to lower bay (Fig. 21). Barnacle nauplii and Acartia tonsa were most abundant at a salinity of 23 °/oo while Oithona spp. was most abundant at 22 °/oo. Oithona showed a low tolerance to salinities below 10 °/oo. Matthews (Matthews et al., 1975) found barnacle nauplii peaks at salinities ranging from 15 to 35 °/oo. Cronin et al. (1962) found maximum barnacle nauplii densities at salinities of 20 to 25 °/oo, with decreasing populations both up-estuary and toward the ocean. Several investigators found that Acartia tonsa preferred higher salinity waters (Cronin et al., 1962; Groover and Sharik, 1974; and Herman et al., 1968). Strithavatch (Moseley and Copeland, 1973) reported that Oithona increased only when salinity was 10 °/oo or greater.

Barnacle nauplii comprised 47% of all the organisms collected. High barnacle nauplii standing crops were evident during the winter and spring months of the study (Fig. 19). Barnacle nauplii populations peaked when water temperatures were between 15 and 26 °C, and decreased during summer and fall when temperatures were generally higher (above 26 °C). Barnacle nauplii need favorable water temperatures to complete their development and high water temperatures can delay development and increase their mortality rate.

Barnacle nauplii standing crops were inversely related to concentric diatom populations (Fig. 19). Nauplii standing crops generally peaked about two weeks after the concentric diatoms bloomed. Barnacle nauplii spend 7 to 14 days grazing on available food, before changing into the nonfeeding cyprid stage. The dominant concentric diatoms (Skeletonema costatum and Cyclotella spp.) ranged from 5 to 15 u in diameter. Dr. Edward T. Park (personal communication) stated that barnacle nauplii fed on small diatoms and other phytoplankters. Martin (1970) reported that barnacle nauplii selected Skeletonema over Rhizosolenia (a larger concentric diatom) during high concentrations of the two phytoplankters. He noted that the nauplii grazed on Rhizosolenia only when Skeletonema concentrations were low (300 cells/ml). In our study, barnacle nauplii concentrations peaked in winter and spring when Skeletonema and Cyclotella were abundant.

Acartia tonsa, the second most abundant zooplankter, comprised 28% of all the organisms collected during the study. Highest Acartia tonsa standing crops were in spring when water temperatures were increasing from a winter low to a summer high. Acartia's abundance in water temperatures between 20 and 30 °C suggests that these temperatures were optimum for growth and reproduction. Jeffries (1967) found that Acartia tonsa reproduced best in water temperatures above 20 °C. No relationship was found between Acartia tonsa and concentric diatom populations (Fig. 19). Acartia could utilize the dominant concentric diatoms (Skeletonema and Cyclotella), but it probably could not compete for food with barnacle nauplii. Barnacle nauplii densities were high, while Acartia populations were generally low during high concentric diatom concentrations. Conover (1956) found that Acartia was a selective feeder, preferring concentric diatoms (10 u diameter) or chain forms. Curl and McLeod (1961) reported that Acartia tonsa would select Skeletonema (5 to 15 u diameter) over larger diatoms (Rhizosolenia).

Oithona spp., the third most abundant zooplankter, comprised 5% of all the organisms collected during the study. *Oithona* peaked in spring when water temperatures rose above 15°C (Fig. 19). High concentrations of *Oithona* in the spring also coincided with large populations of concentric diatoms. Abundant food and favorable water temperatures are contributing factors to *Oithona*'s large populations during the spring.

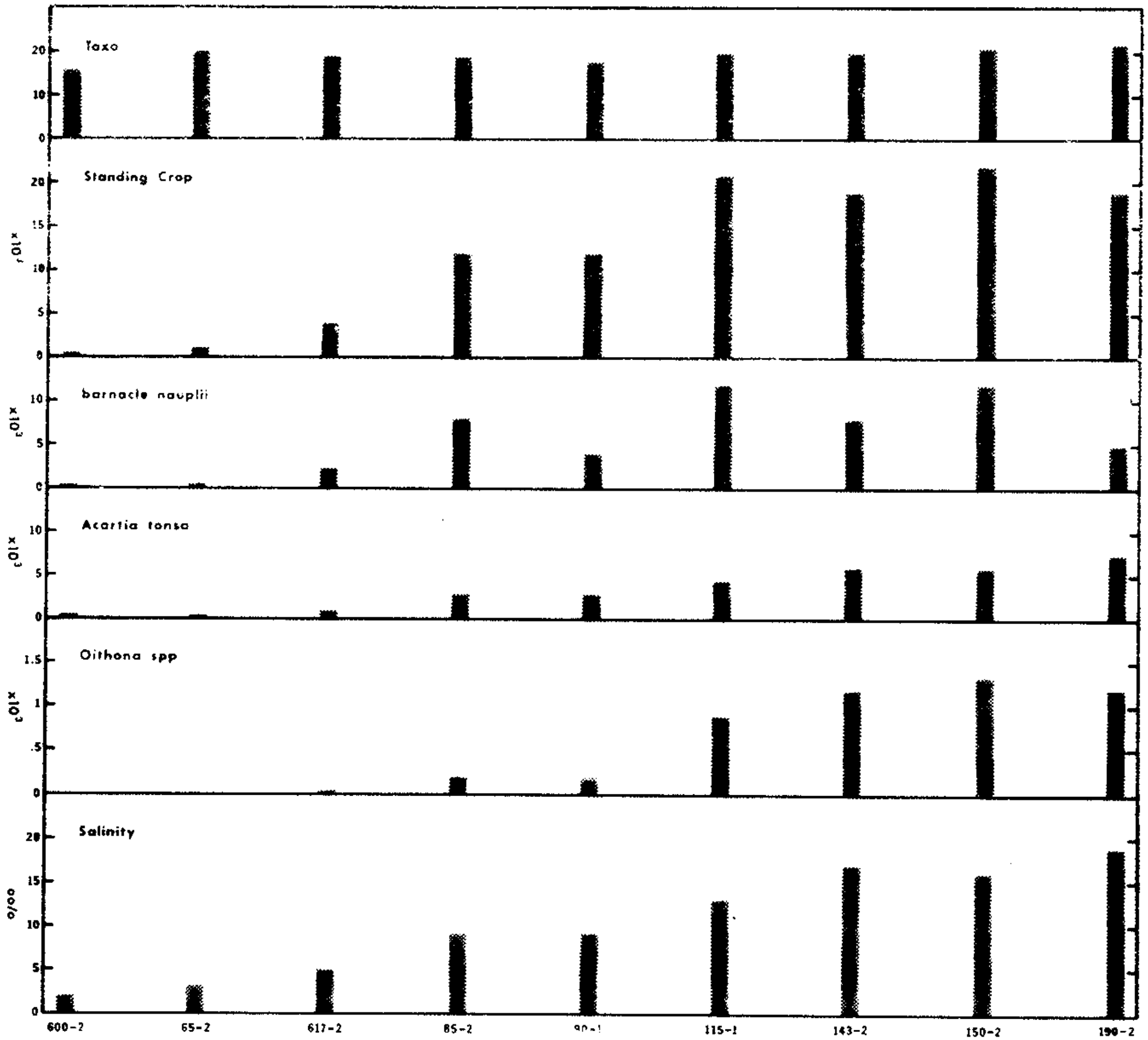


Figure 21. Study period (September 1973 - June 1975) mean by site for surface salinity, *Oithona* spp. numbers, *Acartia tonsa* numbers, barnacle nauplii numbers, standing crop, and taxa diversity.

SECTION IV. BENTHOS

Gill Gilmore

INTRODUCTION

The benthic macroinvertebrates (benthos) as discussed in this report are animals which live within or upon available substrates in a body of water and are large enough to be seen by the unaided eye and be retained by a U. S. Standard no. 35 sieve (32 meshes/in, 0.50 mm openings). The main taxonimic groups included are the mollusks, annelids, crustaceans, flatworms, and freshwater insects. Benthic macroinvertebrates occupy nearly all levels of the trophic structure. They may be herbivóres, omnivores, or carnivores, and in a well balanced system all types may be present.

The benthos are important members of the food web and their well-being is reflected in the well-being of the higher forms such as fish. Some species are important commercial and recreational species and many forms are important for digestion of organic material and recycling of nutrients. The characteristics of the community of benthic macroinvertebrates are sensitive to stress, and thus serve as a useful tool for detecting environmental changes.

LITERATURE REVIEW

Published accounts of the Lavaca Bay benthic macroinvertebrate fauna are sparse. Moseley and Copeland (1973) reported on a study of the benthic invertebrates in Cox and Keller bays (both bays are part of the Lavaca Bay system). Samples were collected with an Emory bottom sampler, partially sieved through a window screen sieve, and preserved in 5% formalin. In the laboratory, samples were completely sieved and organisms were identified and counted. The authors found that the largest number of individuals occurred during spring while the greatest number of species occurred in the winter. Of the 12 species of mollusks identified, *Mulinia lateralis* and *Tellina texana* were dominant. Twenty-five categories of polychaetous annelids were collected; however, most categories were not identified to species. The greatest standing crop of annelids and smallest standing crop of mollusks occurred during winter.

Mackin (1971) reported on a study of the effect of oil field brine effluents on benthic organisms in Lavaca Bay and in the Lavaca River area (Menefee Lakes and Bayou, Redfish Lake and Bayou, and the lower Lavaca River). Bottom samples were collected with an Ekman grab and were washed in a series of sieves--the smallest mesh size was about 0.2 mm. The material remaining in the sieves was preserved with neutral formalin and taken to the laboratory where the animals were picked from the debris, identified, and counted. In the river area, *Streblospio benedicti*, tendipes, *Mulinia lateralis*, *Corophium acherusicum*, and *Limnodrilus* sp. were most abundant. In the bay, *Mulinia lateralis*, *Mediomastus californiensis*, *Retusa canaliculata*, cumacea, and *Glycinde solitaria* were most abundant.

Blanton *et al*. (1971) studied the ecology of Lavaca Bay. Benthic samples were collected with a 0.04 m^2 Van Veen grab at monthly intervals from 19 stations in Lavaca Bay during 1971. Each sample was washed in a 250 u screen and the material remaining in the screen was preserved in 10% formalin. The authors found that polychaetous annelids contributed most to the biomass; however, nematodes, when present, were usually the most numerous. They concluded that Lavaca Bay appeared to be an ecologically undisturbed bay exhibiting little response to stress when consideration is given to climatic location, geomorphology, ecosystem type, benthos numbers, and benthos diversity.

Several benthic macroinvertebrate studies for other Texas bay systems are reviewed because they contain information pertinent to this study. Marcin (Matthews et al., 1975) studied the benthos of San Antonio Bay (located about 22.5 km or 14 mi southwest of Lavaca Bay) from April 1972 through July 1974. She used a Peterson grab to take monthly samples at 25 sites. The samples were sieved through a 0.5 mm mesh saran bag and the material remaining in the bag was preserved in 10% formalin. At the laboratory, organisms were separated from the remaining material, identified, and counted. Marcin identified 135 taxa representing eight phyla. The 12 predominant taxa collected were Hypaniola gunneri, chironomid larvae, Rangia cuneata, Littoridina sphinctostoma, Littoridina sp. B, Macoma mitchelli, Mediomastus californiensis, Parandalia fauveli, nemertines, Streblospio benedicti, Mulinia lateralis, and Neanthes succinea. Marcin found mainly high spring/summer and low fall/winter benthos populations. She says that the number of species declined with increased fresh water, but the total benthic standing crop increased due to increases in Littoridina sphinctostoma, Rangia cuneata, Hypaniola gunneri, and chironomid larvae populations.

Harper (1973) studied the distribution of benthic organisms in San Antonio Bay. Monthly benthic samples were collected with both a 5.1 cm (2 in) Plexiglas corer and an Ekman grab. Ekman grab samples were washed on a 0.125 inch mesh screen and the retained specimens were preserved with 70% ethanol, identified, and counted. Core samples were washed through a 500 u mesh sieve and the material retained by the sieve was also preserved with 70% ethanol. The animals were later picked from the debris, identified, and counted. Littoridina sphinctostoma, Mediomastus californiensis, Streblospio benedicti, Hypaniola gunneri, Rangia flexuosa, and Mulinia lateralis were numerically dominant. Harper stated that his data indicated an almost logarithmic decrease in the benthic populations with increasing salinity. Harper hypothesized that the decrease in benthic invertebrate populations reflected a decrease in available nutrients; the low-salinity area of the upper bay; therefore, appeared to be the most productive.

Holland et al. (1973) studied the benthos of the Corpus Christi, Copano, and Aransas Bay systems, Texas. Monthly bottom samples were collected with a Peterson grab at 31 sites from October 1972 through June 1973. Of the 331 species identified during the study, the five most common were Mediomastus californiensis, Glycinde solitaria, Prionospio pinnata, Neanthes succinea, and Gyptis vittata. The authors found that population peaks occurred in December and March-April at many stations. The maximum standing crop (11,896 individuals/.5 ft^3) occurred in December.

Holland et al. (1974) continued their study of the Corpus Christi, Copano, and Aransas Bay systems from July 1973 through April 1974. Sample collection and analysis methods remained unchanged from those given in the 1973 report. The maximum standing crop value during this study period was 3,903 individuals/.5 ft^3 (July 1973). Standing crops during the second study period decreased from the first study period. Three reasons were given for the decreased standing crops. First, several site locations were relocated and after relocation, standing crops at these sites decreased. Second, salinities were lower during the second study period and could have adversely affected the more marine benthic populations that had become established during the preceding year. Third, an oyster shell dredge deposited spoil mud on a productive site, after which, standing crops at that site decreased.

Groover and Sharik (1974) reported on a study of the benthic macroinvertebrates of the lower Colorado River - Matagorda Bay area. Benthic samples were collected in an Ekman dredge at 11 sites in June 1973. In August and November 1973 and February 1974, benthic samples were collected with a Ponar dredge at 11 sites each month. After collection, the benthic samples were washed in a 0.595 mm sieve-bottom bucket and preserved in 10% formalin. In the laboratory, the benthic samples were washed in a U. S. Standard Series no. 30 (600 micron) sieve, hand-sorted, identified, and enumerated. Polychaetes, oligochaetes, and chironomid larvae were important constituents of the benthos each month in terms of relative abundance and number of taxa. Benthic standing crops at individual stations ranged from 0 (August 1973) to 3,215 individuals/m^2 (February 1974). The number of taxa identified for individual stations ranged from 0 (August 1973) to 31 taxa (November 1973). The authors said that salinity was the primary ecological factor affecting species composition, abundance, and distribution.

MATERIALS AND METHODS

Monthly benthos samples were collected at 20 sites in Lavaca Bay and five sites in the lower Lavaca River area from January 1973 through June 1975. A 0.1 m^2 Peterson grab was used to sample at each site. Each sample (one grab) was washed in a saran bag of 0.5 mm mesh until most of the fine sediments passed through the bag. The material remaining in the saran bag, including benthic animals, was fixed in about 0.9 liter of 10% formalin. About 0.1 gm of rose bengal stain was added to the sample to facilitate picking animals from the remaining material.

The animals were separated and identified (usually to species) and the number of individuals in each taxon was recorded for each sample. As suggested by Holme (1964), only whole animals or portions of animals containing the anterior end were counted to avoid recounting the same animal. After the animals were counted, they were stored in 70% ethanol.

RESULTS

A total of 132,079 animals representing 169 taxa in 9 phyla were identified from the 730 benthic samples collected during this 30-month study. Most animals were identified to generic or specific level; however, some were classified only to a higher taxonomic category (Table 15). A breakdown of taxa by phyla is as follows: Annelida (56), Arthropoda (51), Mollusca (48), Chordata (8), Nemertinea (2), Coelenterata (1), and Echinodermata (1). The number of individuals collected per 0.1 m^2 sample ranged from 0 at site 65-2 on 10 April 1973 to 2,568 at site 85-4 on 10 July 1973 and averaged 181 for the entire study. The number of taxa identified per 0.1 m^2 sample ranged from 0 at site 65-2 on 10 April 1973 to 39

Table 15. Benthic taxa collected in the Lavaca Bay system from January 1973 - June 1975.

COELENTERATA
- ANTHOZOA
  - Anemone

PLATYHELMINTHES
- TURBELLARIA
  - *Stylochus ellipticus*

NEMERTINEA
- Nemertina
- *Tubulanus pellucidus*

NEMATODA
- Nematoda

MOLLUSCA
- GASTROPODA
  - *Anachis avara*
  - *Anachis obesa*
  - *Caecum glabrum*
  - *Caecum pulchellum*
  - *Corambella depressa*
  - *Crepidula plana*
  - *Littoridina sphinctostoma*
  - *Mitrella lunata*
  - Mollusca, unidentified
  - *Nassarius acutus*
  - *Odostomia bisuturalis*
  - *Odostomia impressa*
  - *Odostomia laevigata*
  - *Odostomia seminuda*
  - *Polinices duplicatus*
  - *Retusa canaliculata*
  - *Thais hemastoma*
  - *Turbonilla* sp.
- BIVALVIA
  - *Abra aequalis*
  - *Amygdalum papyria*
  - Bivalvia, unidentified
  - *Brachidontes exustus*
  - *Chione cancellata*
  - *Congeria leucophaeta*
  - *Crassostrea virginica*
  - *Cyrtopleura costata*
  - *Diplodonta semiaspera*
  - *Diplodonta soror*
  - *Diplothyra smythi*
  - *Ensis minor*
  - *Lyonsia hyalina floridana*
  - *Macoma brevifrons*
  - *Macoma constricta*
  - *Macoma mitchelli*
  - *Mactra fragilis*
  - *Martesia striata*
  - *Mulinia lateralis*
  - *Mysella planulata*
  - *Nuculana acuta*
  - *Nuculana concentrica*
  - *Periploma inequale*
  - *Petricola pholadiformis*
  - *Phacoides pectinatus*
  - *Rangia cuneata*
  - *Tagelus divisus*
  - *Tagelus plebeius*
  - *Tellina texana*
  - *Tellina versicolor*

ANNELIDA
- POLYCHAETA
  - *Anaitides mucosa*
  - *Aricidea* cf. *fragilis*
  - *Axiothella mucosa*
  - *Axiothella torquata calida*
  - *Branchioasychis americana*
  - *Capitella capitata*
  - Capitellidae
  - Cirratulidae
  - *Cossura delta*
  - *Diopatra cuprea*
  - *Drilonereis longa*
  - *Drilonereis magna*
  - *Eteone heteropoda*
  - *Eulalia* sp.
  - *Eunice* sp.
  - *Eupomatus* cf. *dianthus*
  - *Eupomatus protulicola*
  - Flabelligeridae
  - *Glycera americana*
  - *Glycinde solitaria*
  - *Gyptis vittata*
  - *Heteromastus filiformis*
  - *Hypaniola gunneri floridus*
  - *Laeonereis culveri*
  - *Lepidonotus sublevis*
  - *Lumbrineris* sp.
  - *Maldane sarsi*
  - Maldanidae

Table 15---continued.

Marphysa sanguinea
Mediomastus californiensis
Megalomma bioculatum
Melinna maculata
Nereis succinea
Nereidae
Notomastus hemipodus
Notomastus latericeus
Orbinidae
Parandalia fauveli
Paranoidae
Pectinaria gouldi
Phyllodoce sp.
Pista palmata
Podarke sp.
Polychaeta, unidentified
Polydora ligni
Polydora websteri
Polynoidae
Prionospio pinnata
Sabellidae
Scoloplos fragilis
Sigambra bassi
Streblospio benedicti
Tharyx setigera
Vermiliopsis annulata

OLIGOCHAETA
Oligochaeta, unidentified
Peloscolex gabriellae

ARTHROPODA
ARACHNIDA
Hydracarina

CRUSTACEA
Acartia tonsa
Ampelisca abdita
Amphipoda, unidentified
Ampithoe longimana
Balanus eburneus
Balanus sp.
Bowmanilla brasilliensis
Callianassa jamaicense
Callianassa zoea
Callinectes sapidus
caridean
Cassidinidea lunifrons
Cassidinidea sp.
Clibanarius vittatus
Copepoda, unidentified
Corophium louisianum
Corophium sp.
Decapoda, unidentified
Edotea triloba
Eurypanopeus depressus
Isopoda, unidentified
Labidocera astiva
Mysidopsis almyra
Mysidopsis sp.
Neopanope texana texana
Ogyrides limicola
Oxyurostylis smithi
Pagurus longicarpus
Pagurus sp.
Penaeidae
Penaeus setiferus
Petrolisthes armatus
Pinnixa cristata
Pinnixa cylindrica
Pinnixa sayana
Pinnixa sp.
Pseudodiaptomus coronatus
Rhithropanopeus harrisii
Sphaeroma quadridentatum
Tanaidacea
Xanthid crab

INSECTA
Ceratophogonidae larvae
Chaoborinae larvae
Chironomidae larvae
Coleoptera larvae
Elmidae larvae
Ephemeroptera nymph
Hemiptera larvae
Insecta larvae
Insecta nymph

ECHINODERMATA
OPHIUROIDEA
Micropholis atra

CHORDATA
ASCIDIACEA
Molgula manhattensis

AMPHIOXI
Branchiostoma caribaeum

Table 15---continued.

OSTEICHTHYS
- *Anchoa* sp.
- Gobiidae
- *Gobiosoma robustum*
- *Micropogon undulatus*
- *Myrophis punctatus*
- Sciaenidae

at site 190-2 on 30 December 1974 and averaged 10 for the study period.

Benthos standing crops were generally higher in 1974 (yearly mean of 223 animals/sample) than in 1975 (156) or 1973 (149); however, only six months (January - June) of data were collected in 1975. Annual trends in standing crops varied from year to year (Fig. 22 and Table 16). In 1973, monthly mean standing crops were high in May (246), July (262), and December (253). Low 1973 monthly mean standing crops occurred in January (75), February (78), and March (60). The 1974 monthly mean standing crops were high in March (268), April (325), and May (313) and low in September (152). In 1975, the high mean (214) was in June while the low mean (109) was in April. The mean standing crop by site for the entire study period ranged from 39 (site 115-3) to 864 (site 85-4)(Table 16). High standing crops at site 83-5 (610) and 85-4 (864) were due to high populations of Littoridina sphinctostoma and Rangia cuneata.

Benthos taxa diversities (yearly mean taxa/sample) were similar in 1973 (9), 1974 (10), and 1975 (11). Taxa diversities were generally high during winter-spring and low during summer-fall (Fig. 22 and Table 17). In 1973, monthly mean taxa diversities were high (14) in April then gradually decreased to a low (5) in September. The 1974 taxa diversities were high in February (11), March (11), and December (12) and low in June (8), July (8), and September (8). The 1975 taxa diversities gradually decreased from a high (13) in January to a low (8) in June. The mean number of taxa identified by site for the entire study period ranged from 5 (sites 65-2, 115-3, and 606-2) to 17 (site 190-2)(Table 17).

The 10 numerically dominant species, comprising 82% of the total population, were Littoridina sphinctostoma (29,435), Mediomastus californiensis (27,696), Rangia cuneata (15,856), Mulinia lateralis (13,069), Streblospio benedicti (10,058), Neanthes succinea (2,942), Cossura delta (2,674), Macoma mitchelli (2,284), Glycinde solitaria (1,915), and Prionospio pinnata (1,772)(Tables 18 and 19). A frequency of occurrence index was used to determine the salinities each dominant species occurred at most frequently. Index values by 1 $^{o}/oo$ salinity increments were calculated using the following formula:

$$I = \frac{O}{S} \times \log_{10}(m + 1)$$

where: I = index value
S = number of times salinity occurred
O = number of times species occurred at salinity
m = mean number of animals caught at salinity.

Mediomastus californiensis, S. benedicti, and M. mitchelli were abundant throughout a wide salinity range; G. solitaria, P. pinnata, C. delta, N. succinea, and M. lateralis were most abundant at salinities greater than 9 $^{o}/oo$; while R. cuneata and L. sphinctostoma were most abundant at salinities of 4 $^{o}/oo$ or less (Fig. 23). The mactrid bivalves, Rangia cuneata and Mulinia lateralis, are difficult to separate when young and counts of each of these species for low salinity areas may include members of the other species.

DISCUSSION

Three Lavaca Bay sites (90-3, 115-3, and 190-4) were located in dredged channels and had silt-clay bottom sediments (Table 6). The benthic standing crops and

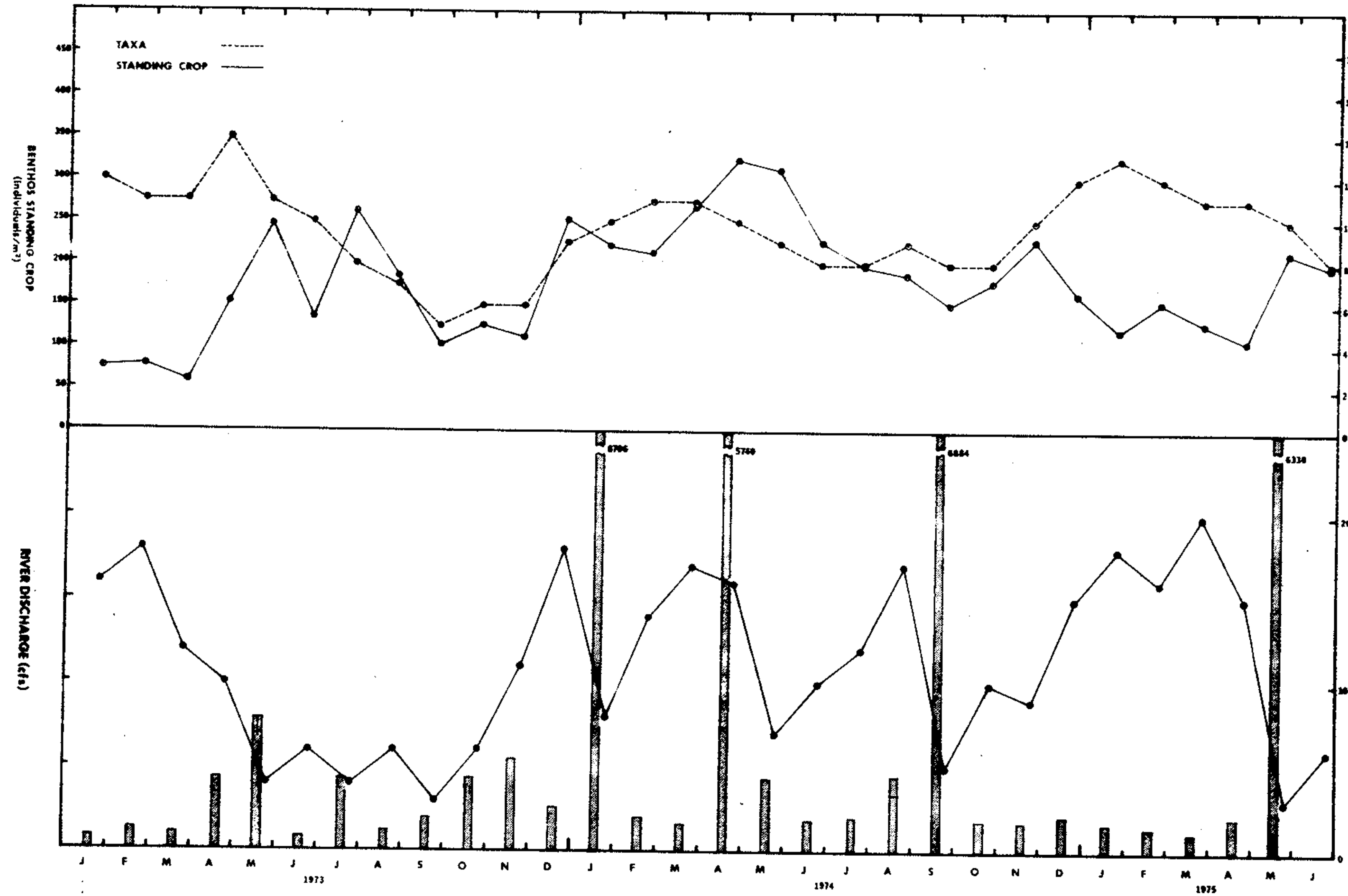


Figure 22. Monthly mean benthos standing crop, benthos taxa diversity, and bottom salinity plus 9-day lag inflow for the Lavaca Bay system.

Table 16. Benthic macroinvertebrate standing crops (individuals/m^2) for the Lavaca Bay system (January 1973 - June 1975).

	1973											
Sites	16 Jan	18 Feb	6 Mar	10 Apr	10 May	5 Jun	10 Jul	2 Aug	25 Sep	30 Oct	29 Nov	28 Dec
600-2	N.D.	12	54	N.D.	89	64	41	111	5	25	15	70
606-2	65	78	125	N.D.	54	63	25	97	95	82	17	49
65-2	5	12	49	0	1	18	3	3	67	3	10	32
610-2	23	27	82	N.D.	111	89	13	68	3	18	41	261
617-2	14	13	109	N.D.	209	105	31	52	16	22	14	64
83-2	12	115	45	8	530	166	389	907	276	458	21	94
83-5	44	49	27	87	901	685	682	716	929	315	455	1,057
84-2	14	N.D.	66	34	80	74	23	45	11	27	8	68
85-4	96	93	244	115	888	153	2,568	601	194	746	714	1,258
90-1	18	118	107	241	176	60	188	36	N.D.	7	34	49
90-3	13	7	1	36	38	1	70	2	5	4	49	67
90-5	21	47	29	656	242	76	160	111	19	36	126	22
115-1	31	52	56	273	239	49	227	126	3	32	84	87
115-3	23	N.D.	9	17	15	90	39	23	6	30	27	64
115-4	34	64	44	140	232	76	372	83	200	38	72	86
129-2	9	45	4	295	227	167	37	148	52	33	95	44
140-2	42	184	21	184	336	29	521	120	93	161	47	94
143-2	56	142	23	87	161	73	142	67	73	51	99	148
143-4	141	114	111	313	517	233	482	75	129	227	154	126
150-2	78	107	85	90	155	67	225	136	25	85	45	220
150-5	29	134	15	118	N.D.	171	152	243	50	63	N.D.	900
180-2	593	145	59	74	129	166	21	76	148	16	76	N.D.
190-2	109	25	59	208	238	379	44	40	65	416	154	167
190-4	3	38	35	64	N.D.	42	1	49	6	5	51	116
190-5	330	180	45	194	87	282	87	687	4	262	308	938
Means by date	75	78	60	154	246	135	262	185	103	126	113	253

Table 16---continued.

Sites	1974 29 Jan	26 Feb	27 Mar	23 Apr	23 May	26 Jun	24 Jul	28 Aug	25 Sep	4 Nov
600-2	22	90	35	24	38	43	36	44	64	210
606-2	179	143	115	95	40	71	79	42	13	45
65-2	146	14	1	152	193	67	73	51	4	10
610-2	63	60	72	43	71	28	35	20	40	54
617-2	45	129	165	52	262	168	142	156	70	100
83-2	231	37	150	262	104	90	38	47	147	82
83-5	599	827	418	802	911	1,079	1,328	1,265	475	951
84-2	47	32	64	10	33	23	32	47	35	117
85-4	1,558	1,138	1,941	1,715	1,045	1,592	1,135	1,257	1,268	901
90-1	204	266	265	229	162	156	108	119	64	N.D.
90-3	124	21	16	81	136	120	161	162	119	229
90-5	262	171	139	586	464	206	87	153	107	96
115-1	186	55	87	612	130	367	213	103	122	126
115-3	34	76	29	97	76	137	20	91	54	3
115-4	156	91	144	95	1,231	83	43	178	221	1
129-2	107	156	764	1,140	487	473	280	107	311	287
140-2	216	537	558	274	279	85	165	107	62	285
143-2	111	202	175	320	95	124	124	83	60	116
143-4	267	201	240	437	756	139	219	175	305	150
150-2	169	190	130	212	683	133	119	76	92	123
150-5	125	105	74	101	59	71	62	54	7	57
180-2	92	166	127	117	76	73	137	145	84	130
190-2	54	115	303	150	300	98	33	43	26	36
190-4	138	79	41	52	12	30	11	76	23	86
190-5	413	429	644	460	176	192	237	128	28	99
Means by date	222	213	268	325	313	226	197	189	152	179

Table 16---continued.

Sites	1974 25 Nov	1974 31 Dec	1975 30 Jan	1975 25 Feb	1975 19 Mar	1975 29 Apr	1975 4 Jun	1975 24 Jun	Means by Site
600-2	210	105	N.D.	114	N.D.	29	21	21	61
606-2	53	114	N.D.	83	N.D.	18	26	24	70
65-2	20	83	N.D.	505	N.D.	205	94	21	66
610-2	122	141	157	211	66	54	37	60	71
617-2	215	133	156	189	367	45	222	94	116
83-2	67	365	315	106	83	112	574	230	202
83-5	970	544	124	92	153	113	992	657	608
84-2	126	48	80	218	92	218	174	134	68
85-4	1,018	950	269	243	168	58	1,380	610	864
90-1	154	95	63	145	375	339	214	270	152
90-3	29	35	46	37	41	25	234	220	71
90-5	173	84	157	304	124	97	343	464	185
115-1	216	61	140	91	162	129	56	184	143
115-3	99	6	1	9	6	2	38	3	39
115-4	173	3	24	19	9	11	6	2	131
129-2	760	268	174	260	180	48	169	244	246
140-2	70	171	141	124	198	312	141	384	198
143-2	197	86	150	177	79	130	163	318	128
143-4	248	106	78	218	116	267	99	415	235
150-2	179	127	86	197	123	122	57	134	142
150-5	89	78	17	127	59	39	22	46	106
180-2	175	118	76	254	161	71	108	83	127
190-2	203	250	188	83	141	115	49	167	142
190-4	64	89	55	17	60	71	42	2	47
190-5	60	62	185	60	89	99	94	105	232
Means by date	228	165	122	155	130	109	214	196	

Table 17. Benthic macroinvertebrate taxa diversities (taxa/m^2) for the Lavaca Bay system (January 1973 - June 1975).

	1973											
Sites	16 Jan	18 Feb	6 Mar	10 Apr	10 May	5 Jun	10 Jul	2 Aug	25 Sep	30 Oct	29 Nov	28 Dec
600-2	N.D.	1	9	N.D.	8	6	7	7	3	2	3	6
606-2	8	9	12	N.D.	9	6	2	5	5	5	5	6
65-2	5	3	8	0	1	5	1	2	3	2	6	4
610-2	6	7	12	N.D.	15	10	4	7	3	5	6	4
617-2	9	8	15	N.D.	11	11	8	5	6	7	3	7
83-2	8	9	7	5	11	6	6	7	6	5	7	8
83-5	7	12	8	8	10	10	10	4	3	3	3	6
84-2	6	N.D.	13	4	9	10	5	7	2	3	2	11
85-4	18	14	15	9	10	10	8	7	4	4	8	5
90-1	13	13	8	12	8	10	9	8	N.D.	4	5	5
90-3	8	3	1	8	4	1	8	2	4	2	4	2
90-5	11	13	8	17	8	8	8	7	4	7	8	4
115-1	7	9	16	15	14	5	7	7	3	5	7	9
115-3	3	N.D.	6	3	5	9	1	3	1	2	6	4
115-4	6	11	10	12	7	14	20	10	6	7	3	7
129-2	7	14	3	16	10	12	8	8	6	5	7	8
140-2	11	16	8	22	12	7	15	7	12	13	4	12
143-2	11	13	11	18	14	11	8	8	5	5	8	7
143-4	15	14	12	16	14	8	9	6	5	7	6	12
150-2	15	17	19	13	13	7	13	10	7	11	6	18
150-5	10	16	8	15	N.D.	14	10	14	8	12	N.D.	18
180-2	33	29	23	17	14	20	7	9	18	6	12	N.D.
190-2	26	8	19	38	25	20	5	4	11	17	10	17
190-4	3	5	10	20	N.D.	10	1	7	3	1	3	12
190-5	36	19	9	19	13	16	11	20	3	20	19	20
Means by date	12	11	11	14	11	10	8	7	5	6	6	9

Table 17---continued.

Sites	1974											
	29 Jan	26 Feb	27 Mar	23 Apr	23 May	26 Jun	24 Jul	28 Aug	25 Sep	4 Nov	25 Nov	31 Dec
600-2	3	4	3	4	4	5	5	5	4	4	3	5
606-2	7	5	6	7	4	4	5	3	3	4	4	7
65-2	7	5	1	6	8	5	4	9	3	5	6	8
610-2	6	6	7	4	7	3	4	5	7	5	8	6
617-2	7	14	12	7	5	9	6	12	10	11	10	13
83-2	10	8	9	10	7	8	7	4	8	11	5	13
83-5	11	12	8	13	8	10	7	10	11	6	9	8
84-2	9	5	10	3	6	8	8	4	5	7	7	6
85-4	11	11	15	12	14	10	7	10	7	8	9	9
90-1	8	11	12	11	10	7	7	5	3	N.D.	10	11
90-3	10	7	3	7	7	4	9	11	9	8	2	6
90-5	10	12	10	12	8	6	6	10	9	10	14	13
115-1	10	9	11	12	9	8	10	9	9	10	11	13
115-3	6	6	10	9	6	8	6	8	8	3	6	6
115-4	12	13	9	11	8	5	6	9	6	1	8	2
129-2	12	11	17	8	9	9	5	5	13	7	12	14
140-2	16	16	14	12	18	14	20	15	13	11	13	17
143-2	10	13	9	11	9	10	11	12	8	11	12	17
143-4	13	12	11	14	9	6	5	3	7	10	16	17
150-2	11	14	13	11	18	10	16	13	12	8	15	16
150-5	13	11	13	13	9	8	6	9	3	12	9	13
180-2	9	15	12	13	17	15	13	14	25	10	13	12
190-2	10	19	21	17	15	16	10	9	10	13	19	39
190-4	9	16	9	10	4	10	3	11	8	10	10	14
190-5	19	19	24	25	17	16	24	14	11	12	8	12
Means by date	10	11	11	10	9	9	8	8	8	8	10	12

Table 17---continued.

	1975						Means
Sites	30 Jan	25 Feb	19 Mar	29 Apr	4 Jun	24 Jun	by Site
600-2	N.D.	5	N.D.	4	2	5	4
606-2	N.D.	6	N.D.	3	4	3	5
65-2	N.D.	9	N.D.	10	3	4	5
610-2	6	10	6	7	7	7	6
617-2	9	14	12	12	12	8	9
83-2	12	12	8	10	12	10	8
83-5	12	10	11	10	12	9	9
84-2	9	13	10	14	11	7	7
85-4	10	10	16	13	10	8	10
90-1	11	14	12	14	7	8	9
90-3	6	8	8	3	6	5	6
90-5	15	13	12	13	10	8	10
115-1	11	13	12	16	8	8	10
115-3	1	5	4	1	4	2	5
115-4	8	5	2	7	4	2	8
129-2	19	21	14	7	13	9	10
140-2	19	17	14	15	9	14	14
143-2	14	14	12	18	19	13	11
143-4	16	14	14	8	15	12	11
150-2	15	15	12	12	9	6	12
150-5	9	13	12	9	5	8	10
180-2	16	17	17	11	27	12	16
190-2	23	20	17	20	15	22	17
190-4	11	3	10	16	10	2	8
190-5	29	12	14	15	11	12	27
Means by date	13	12	11	11	10	8	

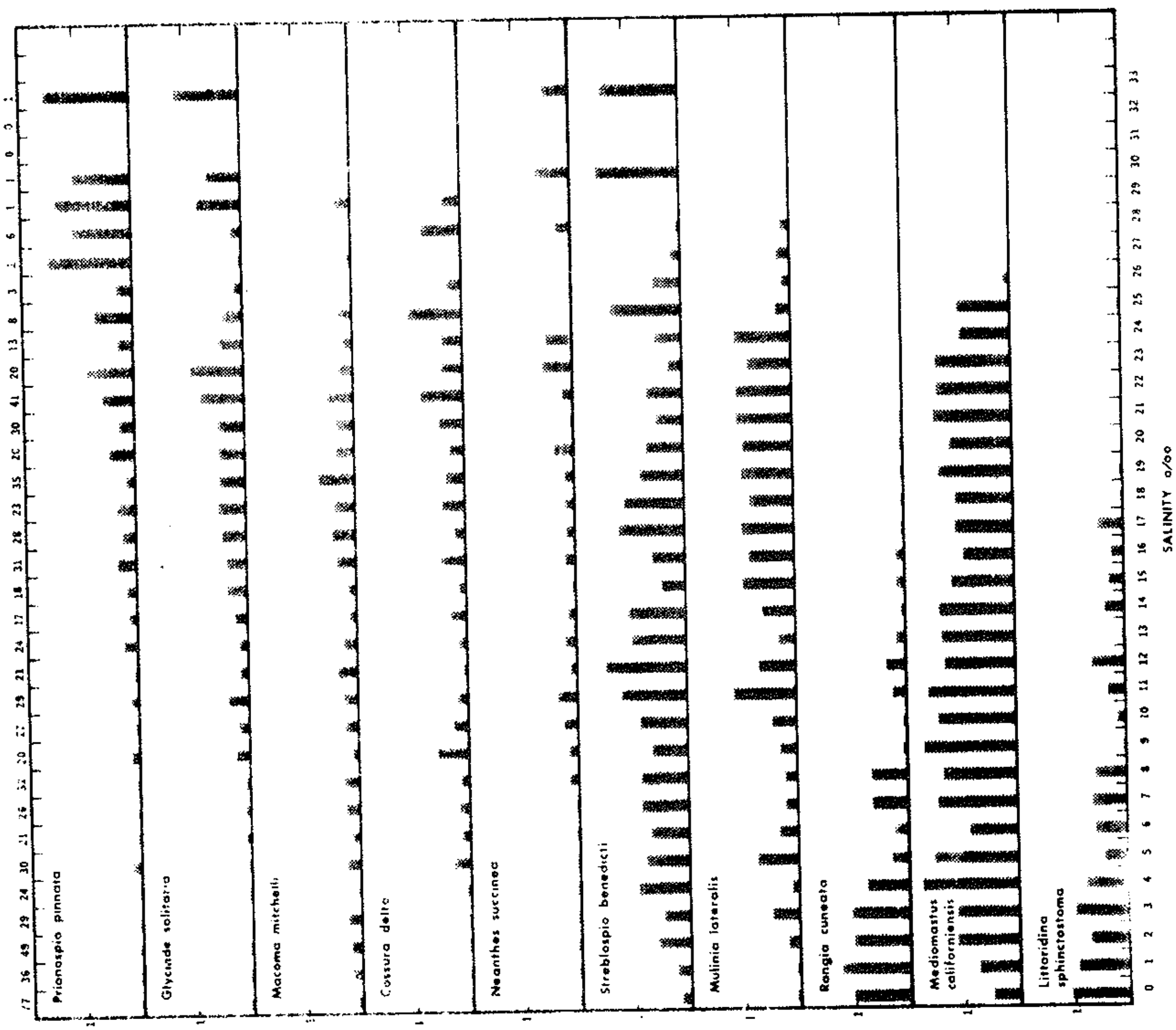
Table 18. Distribution of 10 dominant benthos species by date for the Lavaca Bay system.

Date (D-M-Y)	Littoridina	Mediomastus	Rangia	Mulinia	Streblospio	Neanthes	Cossura	Macoma	Glycinde	Prionspio
16- 1-73	1	453	0	16	5	233	2	82	52	27
18- 2-73	9	289	37	388	29	8	111	286	72	83
6- 3-73	60	237	47	163	114	5	40	194	28	44
10- 4-73	19	1,340	1 5	484	77	5	168	167	78	98
10- 5-73	1,236	2,219	861	189	99	2	93	253	0	18
5- 6-73	879	761	190	104	293	194	44	82	25	23
10- 7-73	3,170	1,856	398	110	178	114	132	45	0	2
2- 8-73	1,359	895	280	8	197	210	39	25	0	30
25- 9-73	1,391	438	68	6	37	47	85	1	73	5
30-10-73	1,206	530	76	7	230	217	73	1	10	6
29-11-73	1,172	516	30	7	168	123	160	0	11	63
28-12-73	2	301	53	35	679	473	133	62	28	46
10- 1-74	2,294	90	0	5	109	0	0	3	0	0
29- 1-74	2,014	721	134	232	892	109	70	193	43	104
26- 2-74	1,672	744	236	261	1,037	100	71	228	44	33
27- 3-74	2,037	1,581	269	284	809	289	114	131	216	33
23- 4-74	1,819	1,271	151	2,982	336	143	141	95	261	73
23- 5-74	850	1,284	374	3,646	286	390	40	30	153	53
26- 6-74	1,291	782	963	1,772	315	7	46	4	40	59
24- 7-74	768	246	2,030	277	318	89	71	9	51	47
28- 8-74	1,313	904	1,335	91	332	32	103	2	63	177
25- 9-74	942	656	848	31	804	9	84	2	16	74
4-11-74	904	1,217	921	33	351	0	92	20	62	86
13-11-74	11	45	46	0	0	0	0	0	0	0
25-11-74	1,156	1,620	804	64	787	10	121	46	89	121
31-12-74	855	793	760	86	162	30	79	38	83	75
30- 1-75	198	396	316	287	173	55	50	75	89	59
25- 2-75	143	582	347	509	99	17	96	86	80	66
19- 3-75	17	573	155	435	165	4	148	55	97	66
29- 4-75	9	641	289	450	58	9	106	26	75	47
4- 6-75	638	1,327	2,147	62	218	16	95	20	63	91
24- 6-75	0	1,888	1,566	45	701	2	67	21	13	63
	29,435	27,196	15,856	13,069	10,058	2,942	2,674	2,282	1,915	1,772

Table 19. Distribution of 10 dominant benthos species by site for the Lavaca Bay system.

Sites	Littoridina	Mediomastus	Rangia	Mulinia	Streblospio	Neanthes	Cossura	Macoma	Glycinde	Prionspio
600-2	7	7	260	0	4	0	0	0	0	0
606-2	140	15	692	0	46	0	0	7	0	1
65-2	41	10	429	0	22	0	0	28	0	2
610-2	88	139	344	0	48	1	0	4	0	3
617-2	307	549	803	46	249	0	0	123	2	0
83-2	1,900	605	1,154	34	1,046	2	0	190	7	0
83-5	9,209	516	5,801	854	109	0	1	120	13	0
84-2	88	584	480	23	135	0	1	122	4	0
85-2	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
85-4	17,340	491	4,931	1,890	372	3	2	110	7	0
90-1	47	2,186	105	649	484	3	3	334	31	3
90-3	6	1,302	178	212	207	1	11	73	16	7
90-5	194	2,280	670	1,049	434	0	3	73	51	2
115-1	6	2,183	4	1,014	244	9	314	86	143	75
115-3	4	240	0	224	172	0	265	15	23	132
115-4	13	1,212	1	1,169	550	124	212	96	53	147
129-2	24	2,770	4	1,924	1,766	70	53	117	88	57
140-2	6	2,785	0	307	888	47	27	148	220	50
143-2	1	1,362	0	601	212	12	575	224	170	129
143-4	11	3,979	0	950	998	7	113	78	169	91
150-2	0	1,276	0	625	278	456	319	158	153	166
150-5	1	463	0	515	337	326	28	76	31	11
180-2	0	1,049	0	243	98	202	331	75	265	115
190-2	0	987	0	407	132	426	42	14	307	83
190-4	2	73	0	16	127	36	32	3	77	594
190-5	0	633	0	317	1,100	1,217	342	10	85	104
	29,435	27,696	15,856	13,069	10,058	2,942	2,674	2,284	1,915	1,772

N.S. No Sample taken.



Frequency of Occurrence Values

Figure 23. Frequency of occurrence values by 1 °/oo salinity increments for the 10 dominant benthic species.

species diversities at these sites were normally lower than at nearby nondredged sites (Tables 16 and 17). Bottom sediments at these sites were probably not stable and benthic populations could not become established.

The mean standing crop for this study (181 animals/.1 m^2) compares to the 181 animals/.1 m^2 reported by Mackin (1971) for the Lavaca Bay and the 145 animals/.1 m^2 reported by Marcin (Matthews et al., 1975) for San Antonio Bay. Freshwater inflow was not significantly related to benthic standing crop; however, it was significantly related to salinity, turbidity, total carbon, organic nitrogen, and nitrate (see hydrologic discussion section). Benthic standing crop was significantly related to each of these hydrologic parameters (Table 20). Thus, inflow may have been indirectly related to standing crop. Harper (1973) found an increase in the San Antonio Bay benthic population with a decrease in salinity. He attributed this increase to an increased inflow of nutrient material transported into San Antonio Bay by the Guadalupe River; however, he had no nutrient data on which to base his theory.

Benthic standing crops showed a significant positive relation to bottom water temperature (Table 20). This relation probably resulted from high standing crops during spring when water temperature was increasing from a winter low.

Taxa diversity in the Lavaca Bay system was probably typical for a Gulf coast estuary. The majority of the species identified belonged to the phylum Annelida. The number of taxa identified during our study of Lavaca Bay (169) was higher than the 150 species reported by Mackin (1971), the 60 species reported by Blanton et al. (1971), or the 36 species reported by Moseley and Copeland (1975). Taxa diversity variation between studies was probably due to differences in sampling methods, study duration, and/or study area.

Taxa diversity during our study declined from the high salinity lower bay to the low salinity upper bay and river area (Table 17). A decline in taxa number from lower to upper bay as sea water becomes more dilute is documented by Gunter (1961). Taxa diversity was highest during late winter and early spring when sustained freshwater inflow was generally low. Low inflow was associated with high salinity, low turbidity, and low nutrient concentrations (see hydrologic discussion section). Thus, species diversity was positively related to bottom salinity and negatively related to bottom turbidity and nutrients (Table 20). Species diversity during late winter and early spring of 1974 was lower than in 1973 or in 1975. Low 1974 diversity was probably related to high (above 2000 cfs) freshwater inflow. Benthos taxa diversity at each site did not appear to be related to sediment particle size distribution at that site. However, sediment for analysis was collected only once (July 1973) and bottom sediments could have changed during the study.

The Palmetto Bend Dam will reduce Navidad River inflow and thus, increase bay system salinities. Species such as *Mediomastus californiensis*, *Streblospio benedicti*, and *Macoma mitchelli* were abundant at most salinities and at most sites (Fig. 23 and Table 19). A reduction in inflow would probably not drastically affect these species. Other species such as *Prionspio pinnata*, *Glycinde solitaria*, *Cossura delta*, *Neanthes succinea*, and *Mulinia lateralis* occurred most frequently at lower bay sites and at salinities greater than 9 $^o/oo$. A reduction in inflow would increase upper bay salinities and these species could move up the bay. *Littoridina sphinctostoma* and *Rangia cuneata* occurred most frequently at salinities ranging from 0 to 4 $^o/oo$ (Fig. 23). These species were most abundant at sites 85-4 and 83-5, located near Garcitas

Table 20. Correlation coefficients obtained between benthos standing crop, benthos species diversity, hydrological parameters, and freshwater inflow. The degrees of freedom was 413.

	Benthos Standing Crop	Benthos Species Diversity
Benthos Standing Crop	1	.23**
Benthos Species Diversity	.23**	1
Bottom Salinity	-.10*	.40**
Bottom pH	.05	.02
Bottom Water Temperature	.10*	-.12*
Bottom Dissolved Oxygen	-.05	.01
Bottom Turbidity	.13**	-.16**
Total Carbon	.14**	.04
Ammonia	-.02	-.05
Total Phosphate	.08	-.31**
Ortho-Phosphate	.04	-.35**
Organic Nitrogen	.17**	-.16**
Nitrite	.09	-.12**
Nitrate	.17**	-.08
River Inflow (4-day average)	.04	-.02
River Inflow (6-day average)	.03	-.02
River Inflow (9-day average)	.01	-.06

* = 5% level of significance
** = 1% level of significance

Creek (Table 19). A reduction in Navidad River inflow would probably not affect populations at these sites; however, populations at other upper bay sites may be reduced. A reduction in inflow will probably cause a northward (upper bay) migration of species; however, I doubt standing crops will be reduced.

SECTION IV. NEKTON

Jim Dailey

INTRODUCTION

Nekton refers to all the larger, aquatic, free-swimming animals whose movement is largely independent of currents or waves. Many species of nekton (shrimp, fishes, and crabs) inhabit Texas estuaries and support major commercial and/or sports fisheries. Texas commercial fisheries landings in 1970 amounted to 146 million pounds (mostly nekton) valued at 53.2 million dollars (Crance, 1971). In addition to commercial fishing, most of the same species support millions of man-days of sport fishing.

LITERATURE REVIEW

Jurgens (1957) conducted a five-month survey of the Lavaca and Navidad rivers. He found 24 species of freshwater fish and 8 species of estuarine fish. His southernmost sampling station was at the confluence of the two rivers.

Lyons (1973) collected 62 species of fish, 16 of which would be classified as estuarine, in a one-year study of the Lavaca and Navidad rivers. His southernmost sampling station was below the confluence of the two rivers.

Dailey and Weixelman (1973) studied the nekton of Chocolate Bay (part of the Lavaca Bay system) from May 1972 through August 1973. Trawl samples produced 46 vertebrate species and 11 invertebrate species. The bay anchovy (*Anchoa mitchilli*), golden croaker (*Micropogon undulatus*), spot croaker (*Leiostomus xanthurus*), gulf menhaden (*Brevoortia patronus*), and sand seatrout (*Cynoscion arenarius*) were the most abundant vertebrates. White (*Penaeus setiferus*) and brown shrimp (*Penaeus aztecus*) were the most numerous invertebrates.

Mackin (1971) studied the effect of oil field brine effluents on biotic communities in Lavaca Bay (lower Lavaca Bay off Magnolia Beach, and Keller Bay) and the Lavaca River area (Menefee Lakes and bayou, Redfish Lake and bayou, and the lower Lavaca River). Trawl samples produced 35 species of fish in Lavaca Bay, 22 species in the Lavaca River, 23 species in Menefee Lakes, and 17 species in Redfish Lake. Bay anchovy and golden croaker were the dominant vertebrates.

Blanton *et al.* (1971), in studies on the Lavaca Bay, reported 97 species of megafauna from trawl samples. Of the total, 42 species were chordates, 24 species arthropods, 25 species mollusks, 2 species echinoderms, and 4 species coelenterates.

Moseley and Copeland (1971), in studies conducted on Cox's Bay (part of the Lavaca Bay system), found 16 species of invertebrates and 69 species of vertebrates. The most abundant nektonic organisms found during the study were bay anchovies, white and brown shrimp, gulf menhaden, golden croaker, and spot croaker.

MATERIALS AND METHODS

Monthly trawl samples during the first eight months (January - August 1973) of the study were taken at four sites in Lavaca Bay (15 min. tow/site) and three sites in the Lavaca River area (5 min. tow/site)(Figs. 1 and 2). During the final 22 months (September 1973 - June 1975), semimonthly samples were collected by making a 10-min. tow at each site. A 3-m (10 ft) otter trawl made of 35 mm (1.4 in) stretch mesh netting with a 6 mm (.25 in) stretch mesh cod end liner was used to collect the samples. The trawl was pulled in an "s" shaped pattern at each site.

Samples were preserved with 10% formalin and taken to the laboratory. Animals in each sample were identified and counted. All shrimp were counted and up to 50 individuals of each species in a sample were measured (tip of rostrum to tip of telson). All crabs were counted and the carapace width (distance between lateral spines) was measured. Individual fish (up to 25) of each species in each sample were weighed and measured (standard length). If more than 25 fish of a species were caught in a sample, the total weight of all fish in the species was determined. The following formula was used to calculate the number of individuals caught per sample by species:

$$\frac{\text{Total weight}}{\text{Mean individual weight}} = \text{Total individuals.}$$

All measurements were made to the nearest 1 mm. Fish were weighed to the nearest 0.1 gm with a Mettler balance.

RESULTS

A total of 73,868 animals representing 70 taxa in 3 phyla were identified from the 350 trawl samples collected during this 30-month study (Table 21). All vertebrates and most of the invertebrates were identified to the specific level. Some invertebrates were identified only to the generic level. A breakdown of taxa by phyla is as follows: Chordata (56), Arthropoda (12), Mollusca (2).

The numbers of individuals collected per minute ranged from 0 (at least one sample at all sites) to 982 (site 606-2 on 4 February 1975) and averaged 20 for the entire study (Fig. 24 and Table 22).

Nekton standing crops (yearly mean animals per sample) were higher in 1975 (30 animals/minute sample) than in 1974 (15) or in 1973 (21): however, only six months of data were collected in 1975. In 1973, the monthly mean standing crops ranged from 2 (December) to 52 animals/min trawl (May). The 1974 monthly mean standing crops ranged from 0.1 (January) to 55 (August). In 1975, the lowest mean standing crop (5) occurred in June while the highest (168) occurred in February (Fig. 24 and Table 22).

The mean standing crop by site for the entire study period ranged from 50.9 (site 606-2) to 93 (site 65-2). Site 65-2 (Lavaca River channel) had the lowest (9.3) standing crop catch while site 606-2 (Redfish Lake) had the highest catches (50.9). The high catch at site 606-2 was due primarily to a single large catch of bay anchovy (Anchoa mitchilli).

Table 21. Nekton taxa collected in the Lavaca Bay system (January 1973 - June 1974).

PHYLUM MOLLUSCA

CLASS BIVALVIA

Order Heterodontia

family Mactridae
- Rangia cuneata - common rangia

CLASS CEPHALOPODA

Order Teuthidida

family Loliginidae
- Lolliguncula brevis - brief squid

PHYLUM ARTHROPODA

CLASS CRUSTACEA

Order Decapoda

family Penaeidae
- Penaeus aztecus - brown shrimp
- Penaeus duorarum - pink shrimp
- Penaeus setiferus - white shrimp
- Trachypeneus similis - broken-neck shrimp

family Sergestidae
- Acetes americanus - fairy shrimp

family Palaemonidae
- Macrobrachium ohione - river shrimp
- Palaemonetes pugio - grass shrimp

family Homaridae
- Cambarus sp. - craw fish

family Diogenidae
- Clibanarius sp. - hermit crab

family Portunidae
- Callinectes sapidus - blue crab

family Xanthidae
- Menippe mercenaria - stone crab
- Neopanope sp. - mud crab
- Panopeus sp. - mud crab

Table 21--continued.

PHYLUM CHORDATA

CLASS CHONDRICHTHYES

Order Rajiformes

family Dasyatidae - stingrays
Dasyatis sabina - Atlantic stingray

CLASS OSTEICHTHYES

Order Semionotiformes

family Lepisosteidae - gars
Lepisosteus spatula - alligator gar

Order Elopiformes

family Elopidae - tarpons
Elops saurus - ladyfish

Order Anguilliformes

family Ophichthidae - snake eels
Myrophis punctatus - speckled worm eel

Order Clupeiformes

family Clupeidae - herrings
Brevoortia patronus - gulf menhaden
Dorosoma cepedianum - gizzard shad
Dorosoma petenense - threadfin shad
Harengula pensacolae - scaled sardine

family Engraulidae - anchovies
Anchoa hepsetus - striped anchovy
Anchoa mitchilli - bay anchovy

Order Myctophiformes

family Synodontidae - Lizardfishes
Synodus foetens - inshore lizardfish

Order Cypriniformes

family Cyprinidae - minnows and carps
Cyprinus carpio - carp

Order Siluriformes

family Ictaluridae - freshwater catfishes
Ictalurus furcatus - blue catfish

Table 21--continued.

family Ariidae - sea catfishes
Arius felis - sea catfish
Bagre marinus - Gafftopsail catfish

Order Batrachoidiformes

family Batrachoidae - toadfishes
Opsanus beta - oyster toadfish
Porichthys porosissimus - Atlantic midshipmen

Order Gadiformes

family Gadidae - codfishes
Urophycis floridanus - southern hake

Order Atheriniformes

family Atherinidae - silversides
Menidia beryllina - tidewater silverside

Order Perciformes

family Carangidae - jacks and pompanos
Caranx hippos - crevalle jack
Caranx latus - horse-eye jack
Chloroscombrus chrysurus - Atlantic bumper
Selene vomer - lookdown
Vomer setapinnis - Atlantic moonfish

family Gerreidae - mojarras
Eucinostomus gula - silver jenny

family Pomadasyidae - grunts
Orthopristis chrysoptera - pigfish

family Sparidae - porgies
Archosargus probatocephalus - sheepshead
Lagadon rhomboides - pinfish

family Sciaenidae - drums
Bairdiella chrysura - silver perch
Cynoscion arenarius - sand seatrout
Cynoscion nebulosus - spotted seatrout
Leiostomus xanthurus - spot
Menticirrhus americanus - southern kingfish
Micropogon undulatus - Atlantic croaker
Pogonias cromis - black drum
Sciaenops ocellata - red drum
Stellifer lanceolatus - star drum

family Ephippidae - spadefishes
Chaetodipterus faber - Atlantic spadefish

family Mugilidae - mullets
Mugil cephalus - striped mullet

Table 21--continued.

family Polynemidae - threadfins
<u>Polydactylus</u> <u>octonemus</u> - Atlantic threadfin

family Gobiidae - gobies
<u>Gobionellus</u> <u>hastatus</u> - sharptail goby
<u>Gobiosoma</u> <u>bosci</u> - naked goby

family Trichiuridae - cutlassfishes
<u>Trichiurus</u> <u>lepturus</u> - Atlantic cutlassfish

family Scombridae - mackerels and tunas
<u>Scomberomorus</u> <u>maculatus</u> - Spanish mackerel

family Stromateidae - butterfishes
<u>Peprilus</u> <u>alepidotus</u> - harvestfish
<u>Peprilus</u> <u>burti</u> - gulf butterfish

family Triglidae - searobin
<u>Prionotus</u> <u>tribolos</u> - blackfin searobin

Order Pleuronectiformes

family Bothidae - lefteye flounders
<u>Ancylopsetta</u> <u>quadrocellata</u> - ocellata flounder
<u>Citharichthys</u> <u>spilopterus</u> - bay whiff
<u>Etropus</u> <u>crossotus</u> - fringed flounder
<u>Paralichthys</u> <u>lethostigma</u> - southern flounder

family Soleidae - soles
<u>Achirus</u> <u>lineatus</u> - lined sole
<u>Trinectes</u> <u>maculatus</u> - hogchoker

family Cynoglossidae - tonguefishes
<u>Symphurus</u> <u>plagiusa</u> - blackcheek tonguefish

Order Tetraodontiformes

family Tetraodontidae - puffers
<u>Sphoeroides</u> <u>parvus</u> - least puffer

family Diodontidae - porcupinefishes
<u>Chilomycterus</u> <u>schoepfi</u> - striped burrfish

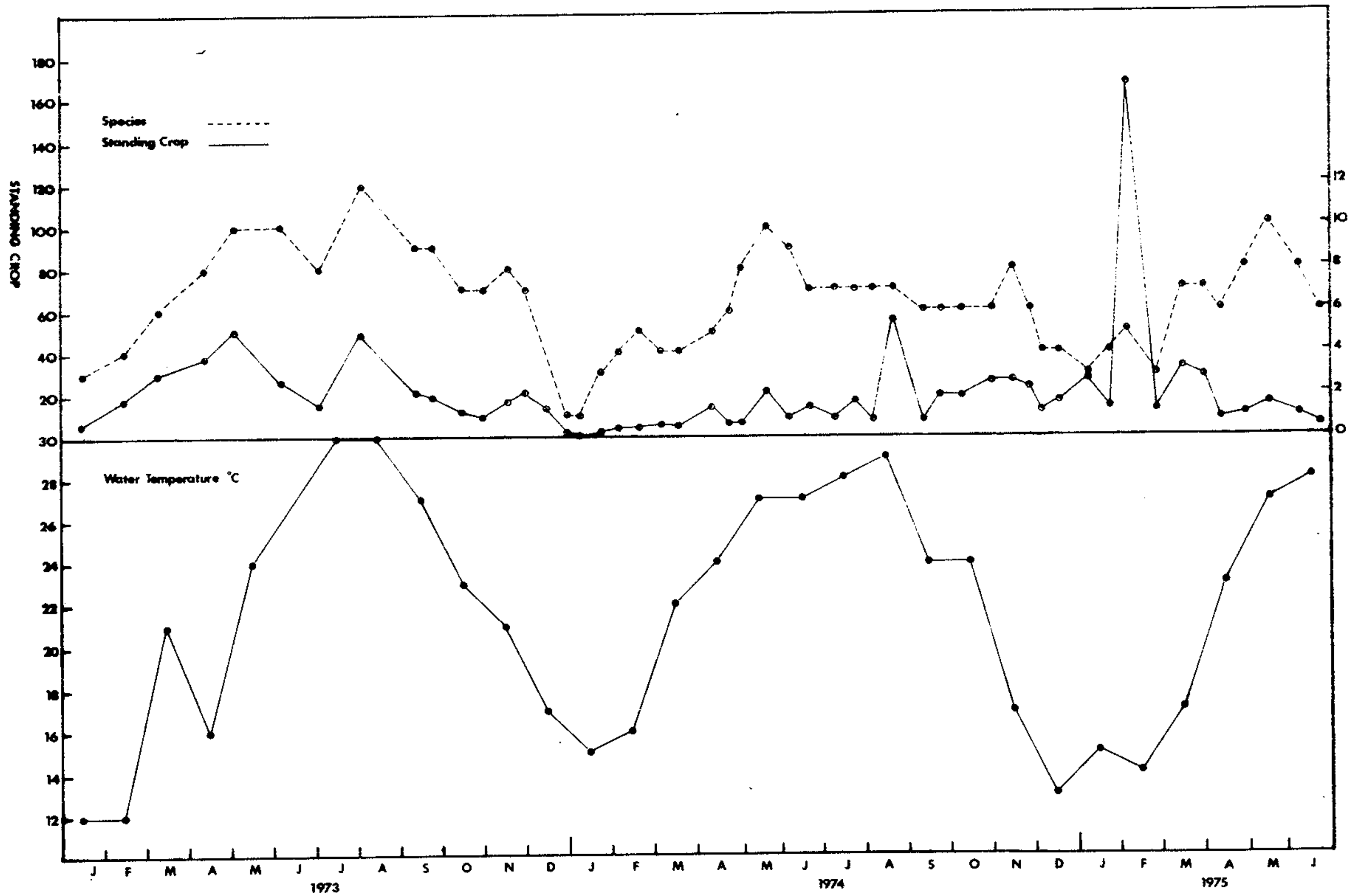


Figure 24. Monthly mean nekton standing crop, nekton species diversity, and water temperature for the Lavaca Bay system.

Table 22. Nekton standing crops (individuals/min) for the Lavaca Bay system (January 1973 - June 1975).

Date (M-D-Y)	Sites 606-2	65-2	617-2	83-2	115-2	143-2	190-2	Means by Date
1-16-73	N.D.	7.6	1.6	12.3	3.0	1.1	11.2	6.1
2-12-73	9.0	90.2	5.2	7.4	2.0	1.7	10.7	18.0
3- 8-73	18.4	2.6	8.8	116.6	34.2	9.6	15.1	29.3
4-11-73	61.8	7.2	23.6	54.9	25.0	57.1	30.1	37.1
5- 1-73	4.4	11.2	90.4	42.1	48.0	105.9	60.7	51.8
6- 4-73	15.0	4.0	23.8	57.5	16.2	34.2	39.0	27.1
7- 2-73	1.4	4.4	6.8	12.9	22.1	42.6	18.5	15.5
8- 1-73	9.0	21.8	30.0	39.1	34.1	55.3	16.7	29.4
9-12-73	25.0	0.3	54.1	9.6	44.4	11.4	5.9	21.5
9-24-73	18.3	3.3	9.3	40.7	21.6	33.7	9.4	19.5
10-15-73	11.0	0.1	23.4	12.4	28.8	5.0	3.1	12.0
10-30-73	2.6	4.8	8.2	13.3	14.6	8.2	17.5	9.9
11-16-73	24.2	4.5	10.7	8.0	37.4	27.8	9.3	17.4
11-30-73	47.7	3.6	8.8	33.4	8.5	15.2	31.2	21.1
12-14-73	N.D.	3.0	4.2	42.1	14.0	14.7	8.2	14.4
12-28-73	0	0	0.8	10.3	4.2	0	2.2	2.5
1- 8-74	N.D.	0.3	0.2	0	3.5	0	0	0.7
1-22-74	N.D.	5.1	N.D.	1.2	0.5	0	4.6	2.8
2- 6-74	N.D.	11.0	2.9	5.5	1.0	5.1	0.4	4.3
2-19-74	N.D.	8.3	4.2	6.1	1.2	6.4	0.6	4.5
3- 6-74	15.4	5.5	6.3	7.1	2.3	3.0	3.0	6.1
3-18-74	14.0	6.9	4.5	3.0	2.8	1.6	2.0	5.0
4-10-74	74.2	2.4	5.7	3.5	2.6	5.6	4.3	14.0
4-22-74	9.9	10.3	4.7	7.7	4.1	1.6	9.7	6.9
5- 3-74	8.2	11.6	3.7	1.6	4.7	6.7	10.9	6.8
5-20-74	13.9	11.3	37.8	11.8	52.1	13.7	11.5	21.7
6- 6-74	12.0	0.5	21.1	2.9	17.7	2.5	8.1	9.3
6-20-74	16.1	2.0	57.8	4.0	13.1	2.3	4.0	14.2
7- 8-74	20.1	5.6	7.7	14.9	6.8	1.3	8.4	9.3
7-23-74	48.4	11.3	22.9	0.7	7.6	21.7	5.5	16.9
8- 5-74	0.6	3.9	25.8	1.6	20.2	2.1	3.0	8.2
8-19-74	138.5	42.1	93.3	1-4.9	0.8	4.4	2.0	55.1
9-11-74	20.6	1.5	11.6	0.3	4.9	6.0	4.5	7.1
9-23-74	17.7	1.3	4.9	4.7	16.2	18.2	3.2	9.5
10- 8-74	28.9	13.2	74.2	0.7	9.0	8.7	1.2	19.4
10-28-74	45.5	3.3	52.9	1.7	27.3	21.2	32.7	26.4
11-13-74	100.5	2.8	4.8	4.2	29.9	11.8	34.1	26.9
11-26-74	30.1	1.4	4.1	17.9	63.4	45.2	2.5	23.5
12- 5-74	N.D.	1.7	62.7	2.0	8.2	0.7	0.3	12.6
12-17-74	34.1	7.0	25.3	34.5	15.3	0.4	0	16.7
1- 8-75	117.8	14.8	54.7	0.3	0.2	3.8	0.2	27.4
1-24-75	26.1	4.6	0.2	29.7	2.8	0.7	36.2	14.3
2- 4-75	981.9	7.8	4.1	161.2	15.2	1.5	1.1	167.5
2-27-75	0	10.8	8.3	59.0	1.4	4.3	0.6	12.1
3-14-75	100.5	43.7	37.1	9.5	16.0	19.3	3.4	32.8
3-31-75	79.7	26.1	44.8	12.2	23.6	1.0	12.0	28.5
4- 9-75	1.6	16.7	21.3	9.2	4.9	13.0	1.4	9.7
4-28-75	12.1	5.7	6.1	8.0	22.7	9.1	11.2	10.7
5-13-75	15.0	3.4	47.3	15.5	1.2	11.9	12.4	15.2

Table 22---continued.

Date (M-D-Y)	Sites 606-2	65-2	617-2	83-2	115-2	143-2	190-2	Means by Date
6- 4-75	1.8	2.6	14.5	15.2	11.2	21.9	6.3	10.5
6-23-75	7.1	0.5	6.7	3.1	4.6	8.5	11.1	5.9
Means by site	50.9	9.3	21.9	21.1	15.2	13.9	10.6	

N.D. No Data taken.

Nekton taxa diversities (yearly mean animals/sample) were similar during all three years (6 - 7). In 1973, monthly mean taxa diversities were high (12) in August and gradually decreased to the low (1) in December (Fig. 24 and Table 23). The 1974 taxa diversities were highest in May (10) and the lowest in January (1). In 1975, taxa diversities gradually increased from a low in January (3) to a high in May (10).

The mean number of taxa identified by site for the entire study period ranged from 4 (site 65-2) to 8 (site 115-2). Largest taxa diversities were found at the lower bay sites.

The eight numerically dominant species were Anchoa mitchilli (32,666), Micropogon undulatus (12,144), Brevoortia patronus (10,612), Penaeus setiferus (6,654), Leiostomus xanthurus (4,445), Penaeus aztecus (1,879), Acetes americanus louisianensis (1,530), and Cynoscion arenarius (867)(Table 24).

Anchoa mitchelli.--The bay anchovy was present at three or more sites during each month; however, it was most abundant at upper bay sites 606-2 (14,672) and 617-2 (5,600). High catches occurred from May 1974 through April 1975. The yearly mean catch/effort (organisms/1 min. trawl) was higher in 1975 (27.9) than in 1974 (17.7) or in 1973 (5.1)(Table 25). The monthly mean catch/effort ranged from 0.4 (July 1973) to 120.5 (February 1975).

Micropogon undulatus.--The golden croaker was caught during every month with peak numbers occurring during the spring of each year. Juveniles were caught in the fall of 1973 and 1974. The yearly mean catch/effort was higher in 1973 (9.1) than in 1974 (1.9) or in 1975 (4.9)(Table 25). The monthly mean catch/effort was lowest (0.2) in January 1974 and highest (23.7) in March 1973.

Brevoortia patronus.--The gulf menhaden was most abundant during the winter and spring of 1975 with the majority of the catch occurring at upper bay sites 606-2 and 83-2. Juvenile fish were caught in winter and spring of each year. The yearly mean catch per effort was higher in 1975 (14.2) than in 1974 (1.6) or 1973 (2.7). The monthly mean catch per effort ranged from .04 (December 1974) to 23.3 (March 1975)(Table 25).

Penaeus setiferus.--White shrimp were more abundant in 1973 (4,614) than in 1974 (1,947) or in 1975 (82); however, samples in 1975 were not collected during the months when white shrimp populations are normally high. Highest populations occurred during summer with juvenile shrimp first appearing in June of 1973 and July of 1974 and 1975. Highest catches occurred at sites 85-2 and 115-1. The monthly mean catch per effort ranged from 0 to 16.9 (Table 25).

Leiostomus xanthurus.--Spot were caught every month except January 1973 and February 1975. The spot was more abundant in 1973 (3,635) than in 1974 (279) or in 1975 (513). Peak catches occurred in late spring, summer, and early fall. The lower bay sites 143-2 and 190-2 had the highest standing crops. Juvenile fish first appeared February 1973 and in March of 1974 and 1975. Mean monthly catch per effort ranged from 0 (January 1973 and February 1975) to 18.2 (May 1973)(Table 25).

Penaeus aztecus.--Brown shrimp were more abundant in 1975 (773) than in 1974 (512) or in 1973 (556). Peak catches occurred in late spring of each year. Upper bay sites 617-2 and 85-2 had the highest standing crops (562 and 515 respectively). Juvenile shrimp were first detected in April 1973 and 1974 and in March 1975. Monthly mean catch per effort ranged from 0 to 6.7 (Table 25).

Table 23. Nekton taxa diversities (taxa/sample) for the Lavaca Bay system (January 1973 - June 1975). Samples based on 10-minute tow unless indicated otherwise.

Date (M-D-Y)	Sites 606-2	65-2	617-2	83-2	115-2	143-2	190-2	Means by Date
1-16-73	0*	4*	4*	4**	3**	1**	3**	3
2-12-73	4*	2*	5*	4**	3**	3**	6**	4
3- 8-73	7*	2*	5*	6**	6**	7**	6**	6
4-11-73	6*	4*	9*	8**	11**	9**	11**	8
5- 1-73	6*	5*	9*	10**	11**	11**	16**	10
6- 4-73	8*	6*	6*	11**	8**	12**	14**	9
7- 2-73	4*	4*	7*	7**	10**	13**	12**	8
8- 1-73	6*	9*	5*	12**	17**	15**	17**	12
9-12-73	6*	1*	9*	7**	21**	9**	11**	9
9-24-73	5*	7*	7*	11**	7**	11**	13**	9
10-15-73	7*	1*	8*	9**	13**	6**	7**	7
10-30-73	5*	4*	7*	8**	7**	7**	9**	7
11-16-73	8*	7*	5*	6**	10**	8**	9**	8
11-30-73	8*	6*	4*	7**	8**	11**	4**	7
12-14-73	N.D.	4*	2*	6**	6**	6**	7**	5
12-28-73	0*	0*	2*	1**	3**	0**	2**	1
1- 8-74	N.D.	3	1	0	2	0	0	1
1-22-74	N.D.	5	N.D.	3	3	0	3	3
2- 6-74	N.D.	4	3	4	4	3	3	4
2-19-74	N.D.	5	5	4	6	5	3	5
3- 6-74	4	5	4	3	3	5	4	4
3-18-74	4	6	2	4	5	5	3	4
4-10-74	7	3	3	4	3	8	7	5
4-22-74	10	8	3	4	8	7	4	6
5- 3-74	8	10	3	16	7	8	6	8
5-20-74	9	8	5	10	15	12	9	10
6- 6-74	9	5	5	8	12	10	11	9
6-20-74	8	7	6	9	7	6	9	7
7- 8-74	5	6	7	10	7	4	12	7
7-23-74	6	6	5	4	10	9	11	7
8- 5-74	4	8	7	3	13	7	9	7
8-19-74	4	6	6	12	5	12	6	7
9-11-74	4	1	2	2	13	9	11	6
9-23-74	7	3	5	4	11	4	6	6
10- 8-74	6	4	4	3	8	9	10	6
10-28-74	8	3	7	1	9	11	4	6
11-13-74	11	7	9	12	8	5	5	8
11-26-74	10	6	5	4	7	4	3	6
12- 5-74	N.D.	4	6	4	3	6	3	4
12-17-74	7	5	3	8	3	3	0	4
1- 8-75	6	3	4	2	2	2	1	3
1-24-75	7	4	1	4	5	3	5	4
2- 4-75	7	3	4	8	3	6	2	5
2-27-75	0	3	3	4	5	5	3	3
3-14-75	8	7	10	5	8	9	2	7
3-31-75	6	6	6	8	9	6	6	7
4- 9-75	4	5	9	3	7	5	6	6

Table 23---continued.

Date (M-D-Y)	Sites 606-2	65-2	617-2	83-2	115-2	143-2	190-2	Means by Date
4-28-75	6	5	7	9	9	8	14	8
5-13-75	6	5	10	11	9	15	11	10
5- -75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
6- 4-75	5	5	9	7	9	11	8	8
6-23-75	4	2	6	5	8	8	11	6
Means by Site	6	4	6	6	8	7	7	

* 5 min tow.
** 10 min tow.
N.D. No Data taken.

Table 24. Total number of individuals, size range, salinity range, and temperature range for each species of nekton collected in the Lavaca Bay system from January 1973 - June 1975.

Species	Total Individuals	Size Range	Salinity Range (°/oo)	Temperature Range (°C)
Anchoa mitchilli	32,666	15-115	0-36	9-32
Micropogon undulatus	12,144	8-194	0-36	10-32
Brevoortia patronus	10,612	18-155	0-36	8-32
Penaeus setiferus	6,654	22-166	0-21	8-32
Leiostomus xanthurus	4,445	14-300	0-24	11-32
Penaeus aztecus	1,879	12-180	0-22	12-30
Acetes americanus	1,530	12-24	6-21	13-30
Cynoscion arenarius	867	18-170	0-22	16-30
Ictalurus furcatus	555	26-400	0-8	12-30
Callinectes sapidus	381	5-176	0-25	12-30
Bagre marinus	330	50-120	0-24	23-31
Arius felis	280	35-248	16-30	0-21
Lolliguncula brevis	202	10-115	9-24	14-31
Polydactylus octonemus	184	23-127	2-21	21-31
Bairdiella chrysura	140	15-135	0-36	12-30
Palaemonetes pugio	132	7-40	0-22	11-29
Rangia cuneata	110	3-57	0-16	11-30
Sphoeroides parvus	93	10-75	0-21	12-30
Macrobrachium ohione	83	25-81	0-10	16-29
Chloroscombrus chrysurus	72	18-93	5-21	14-28
Setellifer lanceolatus	53	10-70	0-21	22-28
Paralichthys lethostigma	38	22-305	0-20	12-30
Trinectes maculatus	33	28-90	0-20	17-30
Citharichthys spilopterus	31	21-90	0-20	12-30
Synodus foetens	31	55-209	4-22	18-29
Lagodon rhomboides	28	20-110	2-22	12-31
Archosargus probatocephalus	24	27-406	0-12	11-30
Priontotus tribulus	21	8-36	0-6	13-26
Mugil cephalus	21	83-174	0-19	20-30
Dorosoma petenense	21	67-110	0-18	15-30
Panopeus sp.	19	12-23	0-22	12-30
Chaetodipterus faber	18	31-110	3-22	24-30
Trichiurus lepturus	17	179-492	12-22	19-30
Neopanope sp.	17	7-21	0-19	13-30
Caranx hippos	13	22-73	0-17	26-30
Pogonias cromis	12	68-380	0-12	11-28
Achirus lineatus	12	26-60	0-14	12-28
Symphurus plagiusa	8	80-108	3-26	22-30
Gobiosoma bosci	8	14-22	0-12	19-30
Lepisosteus spatula	6	137-1800	0-12	15-19
Dorosoma cepedianum	6	73-112	0-21	12-30
Caranx latus	6	22-72	5-21	26-29
Gobionellus hastatus	5	20-57	0-20	11-30
Etropus crossotus	5	80-95	10-21	24-29
Penaeus duroraum	4	83-112	21	15-26
Peprilus alepidotus	4	24-57	8-12	22-27
Menticirrhus americanus	4	28-192	12-6	16-30

Table 24---continued.

Species	Total Individuals	Size Range	Salinity Range (°/oo)	Temperature Range (°C)
Dasyatis sabina	3	270-367	0-9	19-30
Porichthys porosissimus	3	100-115	6-21	14-24
Menidia beryllina	3	14	0-16	34-50
Eucinostomus gula	3	43-75	0-22	18-25
Cynoscion nebulosus	3	117-150	2-31	10-18
Peprilus burti	3	33-75	16-18	15-27
Elops saurus	2		5-11	12-30
Myrophis punctatus	2	150-255	7-22	28-30
Cyprinus carpio	2	30-32	0	28
Urophycis floridanus	2	55-180	20-22	13-20
Selene vomer	2	56-65	8-10	28-29
Vomer setapinnis	2	47-68	5-10	29-30
Orthopristis chrysoptera	2	115-130	11-20	27-21
Scomberomorus maculatus	2	29-63	6-11	26-27
Cambarus sp.	2	28-30	0	23-27
Harengula pensacolae	1	75	8	28
Anchoa hepsetus	1	79		
Opsanus beta	1	115	11	26
Sciaenops ocellata	1	236	0	15
Ancylopsetta quadrocellata	1	103	16	27
Chilomycterus schoepfi	1	160	15	27
Trachypeneus similis	1	40	15	10
Menippe mercenaria	1	12	7	30

Table 25. Average catch per effort by month for the seven most numerous organisms caught.

	J	F	M	A	M	J	J	A	S	O	N	D	Yearly Means
1973													
Brevoortia patronus	0.3	2.9	5.5	4.4	10.9	0.3	0.3	3.5	1.1	0.1	0.5	2.0	2.7
Anchoa mitchilli	3.7	1.4	6.2	7.4	2.5	1.0	0.4	2.4	6.3	4.4	22.4	3.0	5.1
Leiostomus xanthurus	0	0.1	1.0	12.1	18.1	10.4	1.8	0.2	4.7	0.5	0.6	0.3	4.2
Micropogon undulatus	2.0	7.3	23.7	13.9	20.2	11.8	12.0	6.5	5.6	3.7	1.7	1.1	9.1
Cynoscion arenarius	0	0	0	0.01	0.1	0.7	0.9	1.0	2.7	1.2	0.4	0.03	0.6
Penaeus aztecus	0	0	0	0.4	0.7	5.4	0.6	0.2	0.2	0.03	0.03	0	0.6
Penaeus setiferus	0	0	0	0.1	0.4	0.04	2.8	15.2	16.9	9.9	12.2	7.1	5.4
1974													
Brevoortia patronus	0.03	0.5	4.9	10.6	0.5	0.2	0.8	0.7	0.2	0.1	0.4	0.04	1.6
Anchoa mitchilli	0.8	3.5	2.1	2.8	9.2	12.7	19.6	39.6	11.1	40.4	46.4	24.0	17.7
Leiostomus xanthurus	0.6	0.1	0.9	0.2	0.4	0.4	0.7	1.3	0.1	0.03	0.06	0.01	0.4
Micropogon undulatus	0.2	1.6	1.6	4.5	4.2	3.4	1.1	0.7	0.7	1.0	1.5	2.0	1.9
Cynoscion arenarius	0	0	0.01	0.07	0.5	1.1	0.6	1.4	0.07	0.3	0.4	0	0.4
Penaeus aztecus	0	0	0	0.4	3.8	2.8	0.1	0.1	0.1	0.1	0.1	0	0.6
Penaeus setiferus	0	0.4	1.4	1.7	1.0	0.7	1.0	16.3	2.4	2.4	0.6	0.03	2.3
1975													
Brevoortia patronus	9.1	57.4	23.3	3.4	0.1	0.3							15.6
Anchoa mitchilli	30.4	120.5	16.0	11.0	3.2	6.8							31.3
Leiostomus xanthurus	0.01	0	0.8	1.8	0.8	1.9							0.9
Micropogon undulatus	1.5	1.1	17.4	4.9	3.3	4.3							5.4
Cynoscion arenarius	0	0	0.01	0.09	0.5	0.1							0.1
Penaeus aztecus	0	2.0	1.0	6.7	1.3	0.2							1.9
Penaeus setiferus	0	0	0.1	0.6	0.1	0.03							0.1

Acetes americanus.--A single catch of 1,474 individuals at site 190-2 in July 1975 accounted for the total number of individuals in this species.

Cynoscion arenarius.--The sand trout was more abundant in 1973 (506) than in 1974 (298) or in 1975 (63). Highest catches occurred at the upper bay sites 85-2 (157) and 115-1 (279). Juvenile fish appeared in June 1973 and in April of 1974 and 1975. Small fish were also present in September 1973 and August 1974 samples. Monthly mean catch per effort ranged from 0 to 2.7 (Table 25).

DISCUSSION

The 3-m (10 ft) otter trawl is not a good device for sampling the total nekton of an estuarine area. It is designed to collect shrimp. Some species of juvenile fish (*Micropogon undulatus*, *Leiostomus xanthurus*, *Cynoscion arenarius*, and *Anchoa mitchelli*) can be monitored with this device, but larger fish are capable of avoiding the trawl. The otter trawl generally samples near the bottom and in water over 1 m deep, the surface water is not sampled. Also, shallow water ($< .5$ m) cannot be sampled with this device.

The occurrence of nekton in samples collected during this study did not appear to be directly related to freshwater inflow. Estuarine nekton are generally adapted to a continually changing environment. If fluctuations in inflow are stabilized, estuarine species may not be able to compete with marine or freshwater species. Also, many estuarine species migrate as they grow and are thus found throughout a wide salinity range during their life.

Hildebrand and Gunter (1953) showed that over a 15-year period there was a positive relation between rainfall of the previous year and white shrimp populations of the current year. However, we found no relationship between our white shrimp data and freshwater inflow of the previous years. Freshwater inflow during the study was about 59% above normal while white shrimp populations were low. High inflow (above 10,000 cfs) at a time when post larval shrimp were migrating into the bay may have reduced shrimp populations. No relation was found between brown shrimp populations and freshwater inflow; however, populations were highest at upper bay sites (617-2 and 85-2).

There was a direct relationship between species number and water temperature. According to Gunter (1945), the temperature cycle is responsible for seasonal movement and other recurrent cyclic activities of gulf estuarine fishes. Many of nekton species collected were most abundant during spring, summer, and/or fall when water temperature was high (Fig. 24).

CONCLUSIONS

Freshwater inflow into the Lavaca Bay system (Lavaca and Navidad rivers plus Garcitas Creek) during our study (1,994 cfs) was about 59% above the historical average (1,254 cfs) based on 1939 - 1974 Lavaca River gaugings, 1940 - 1974 Navidad River gaugings, and 1972 - 1974 Garcitas Creek gaugings. Correlation analyses were used to test the relation of mean salinity (measured monthly or semimonthly) of 20 sites in Lavaca Bay to the $\log_{10}$ of mean daily river discharge (Lavaca and Navidad rivers plus Garcitas Creek) for 4, 6, 9, 15, and 30 day periods ending two days prior to a salinity determination. The nine-day inflow produced the most significant correlation (r=-0.59**, d.f.=47). Data used for the correlation analysis were plotted, a line was fitted to the data, and confidence intervals were calculated (Fig. 10).

The Palmetto Bend Dam (stages 1 and 2) will reduce inflow to an annual average of 925 cfs. If an inflow of 925 cfs is maintained for a 30-month period, the estimated mean bay salinity will be about 11 0/00 (Fig. 10). Confidence intervals indicate that the predictability of long-term salinity is high while the predictability of daily salinity is low. Estuarine biota are probably affected more by daily salinity than by long-term salinity.

Reduced inflow will probably lower nutrient levels in Lavaca Bay since correlation analyses of our data indicates that bay nutrient levels were positively related to freshwater inflow (page 28). Armstrong et al. (1975) found that nutrient material was transported from a marsh to adjoining Lavaca Bay areas when high tides or fresh water inundated the marsh. We do not have sufficient information about marsh nutrient release to predict the bay nutrient levels after inflow has been reduced to 925 cfs.

Phytoplankton standing crops, species density, and chlorophyll *a* were not significantly correlated to freshwater inflow or to bay nutrient levels. The poor correlations may be caused by the fluctuation in our plankton data. Diversities generally declined with increased inflow due to phytoplankton dispersal and rapidly changing salinities. As inflow decreased and bay salinity stabilized, diversities rose as neritic species became more abundant. Minimum phytoplankton density was associated with high river discharge while maximum standing crops occurred with blooms of very small microflagellates and diatoms as the bay salinity began to stabilize after high inflows. Chlorophyll *a* values seemed negatively related to high (above 2000 cfs) river discharge through standing crop changes caused by physical removal, increased turbidities and rapidly changing salinities.

Zooplankton taxa diversity generally increased when river inflow increased to above 2000 cfs. We feel that this relationship was due to the flushing of meroplanktonic organisms from shallow protected areas into the open bay where our sample sites were located. Three zooplankton taxa (barnacle nauplii, *Acartia tonsa*, and *Oithona* sp.) comprised 80% of the total zooplankton standing crop. These taxa were most abundant at salinities of 22-23 °/oo and when inflows increased to above 2000 cfs, populations of these taxa decreased.

A reduction in inflow will cause a northward migration of benthos species; however, standing crops should not be affected provided a sufficient food supply is maintained. Species such as Mediomastus californiensis, Streblospio benedicti, and Macoma mitchelli will remain throughout the bay. Other species such as Prionospio pinnata, Glycinde solitaria, Cossura delta, Neanthes succinea, and Mulinia lateralis will move up the bay while populations of Littoridina sphinctostoma and Rangia cuneata will be reduced.

The 3-m otter trawl is not a good device for sampling the total nekton of an estuarine area. However, nekton species collected during this study were affected more by water temperature than by freshwater inflow. Species of nekton caught during this study generally had wide salinity ranges. Most economically important species found in the Lavaca Bay system have wide salinity limits; however, their optimum salinity ranges may be somewhat narrower.

Many economically important species either directly or indirectly feed on plankton and/or benthic organisms. If mean bay salinity is increased 1 or 2 $^{o}/oo$ and if bay nutrient levels are not significantly reduced, many of the plankton and benthos species found during this study will remain in the bay system and provide sources of food for the higher trophic level organisms.

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