PRECONSTRUCTION STUDY OF THE FISHERIES OF THE ESTUARINE AREAS TRAVERSED BY THE MISSISSIPPI RIVER-GULF OUTLET PROJECT[1,2]

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ABSTRACT

Hydrographical and biological data were collected from April 1959 through March 1961 at selected stations in the marsh and bayou areas traversed by the Mississippi River-Gulf Outlet Channel between New Orleans and Breton Sound to provide preconstruction data needed for later assessment of the effects on the fauna of such a wide and deep channel connected at the Gulf end with water of high salinity. The channel will raise salinities over most of the project area. This should not greatly affect the fishes of the area which are preponderately euryhaline. It should have an adverse effect on abundance of the blue crab. The possible effect on the white shrimp is obscured by their avoidance of the open waters of Lake Borgne and their preference for the shoal protected marshes.

The Mississippi River-Gulf Outlet Project of the Corps of Engineers is a deep-water navigation channel from New Orleans to the Gulf of Mexico (fig.1). The route traverses the marshes along the southwestern shore of Lake Borgne and then cuts across the intricate system of bayous to Breton Sound. The deep channel crosses Breton Sound just to the north of Breton Island. The completed channel will be 36 feet deep and 500 feet wide at the bottom. The channel was dredged in three stages: first, an access channel 18 feet deep by 140 feet wide, second, an interim channel 36 feet deep by 250 feet wide; and third, the full-scale channel.

The channel traverses a marsh and estuarine area of great value for waterfowl, muskrats, oyster culture, sport and commercial fishing, and, perhaps the most important, for a nursery area utilized by the young of fish and shrimp that are later harvested in great quantities in deeper water outside of the project area.

The principal aim of this study was to determine the environmental and biological conditions prevailing prior to channel construction from the fishery standpoint. A preconstruction study on such a large scale was lacking, and it was hoped that comparison with a later postconstruction study of the same area would be invaluable, both in deciding on what effects, if any, could be attributed to the present project, and in forming a basis on which to predict the effect of similar projects in the future.

Note.—Approved for publication April 9, 1963.

[1] The data on which this report is based were collected by the Texas A. and M. Research Foundation for the Bureau of Sport Fisheries and Wildlife of the U.S. Fish and Wildlife Service under Contracts No. 14-16-008-523; No. 14-16-008-572; and No. 14-17-008-119. The Foundation released three mimeographed reports referred to as Reference 59-5T, Reference 59-21T, and Reference 61-20F. The original data are archived at the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex. All species identifications are by the Research Foundation. The author assumes sole responsibility for this analysis and the conclusions reached.

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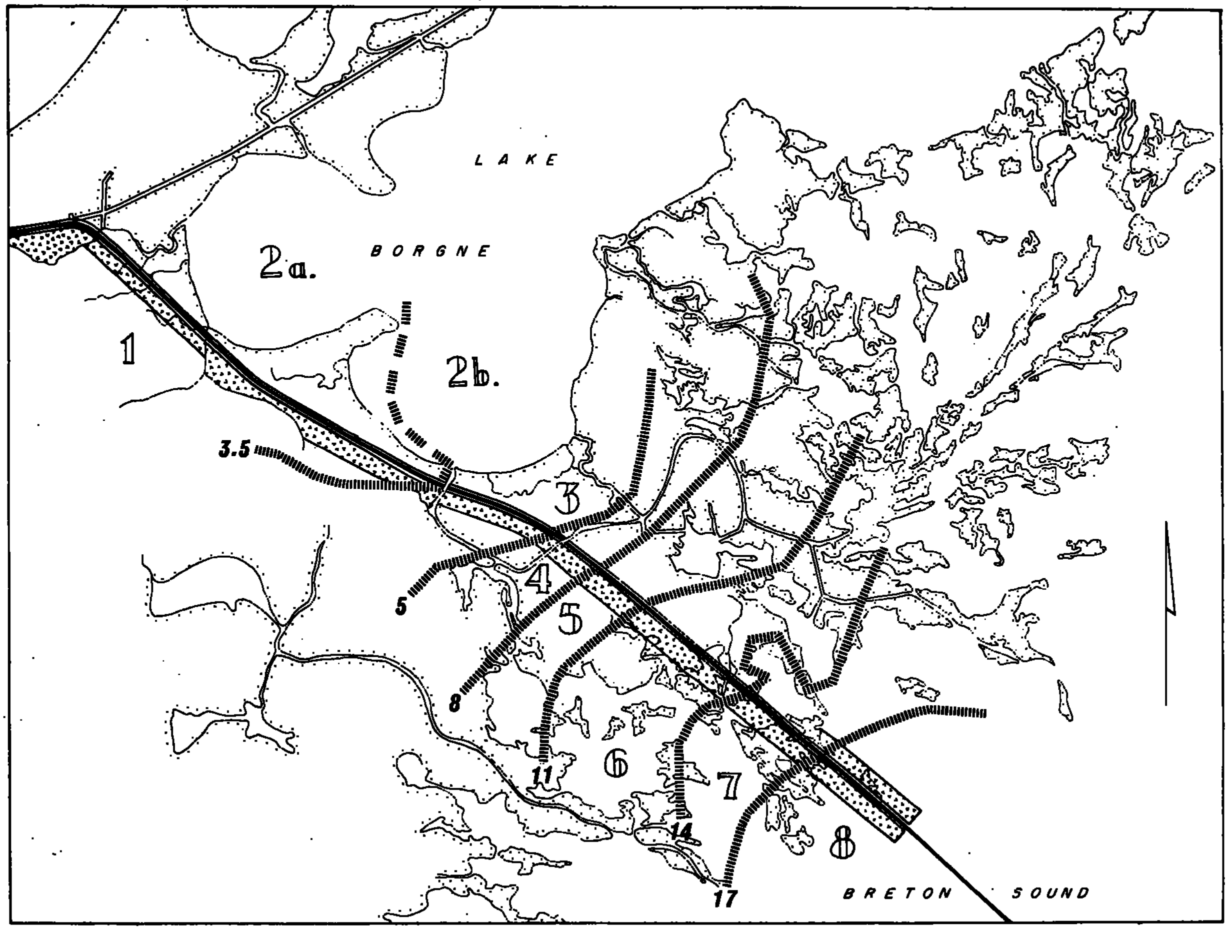

FIGURE 1.—The project areas showing the alignment of the Gulf Outlet channel as far as Breton Sound. (The shaded area along the southwest border of the channel is the 4,000-foot strip used as a spoil area. The shaded lines crossing the channel are isohalines that effectively divide the project area into smaller areas. The isohalines are based on average 24-month salinities.)

Dredging of the small access channel was commenced at the Gulf Intracoastal Waterway in May of 1959 and completed to Breton Sound by March of 1961. Some segments of the channel were dredged to the "interim" cross section during this period. Where they crossed the channel, certain bayous were kept open: Bayou Bienvenue, Bayou Villere, Bayou Dupre, Bayou Yscloskey, and Bayou La Loutre.

Following recommendations of the Fish and Wildlife Service, the Corps erected spoil retention dikes around a 4,000-foot strip along the southwestern boundary of the channel so that the solids could settle out from the liquid mud poured out from the hydraulic dredges. This measure effectively kept down sedimentation in the adjacent bayous.

HYDROGRAPHIC METHODS

Commencing in April 1959, stations were occupied at various points throughout the project area. At this time the exact route of the southern portion of the channel had not been decided but a route slightly northeast of the one finally chosen was then being favorably considered. Consequently, several stations occupied for a few weeks early in the study period were later abandoned, and a few more southerly stations added. The station locations are shown in figure 2. Table 1 lists the stations and the months each was occupied for hydrographical and biological observations.

Hydrographic observations were taken at each visit to a station (about once each 10 days through August 1960 and twice a month thereafter), and

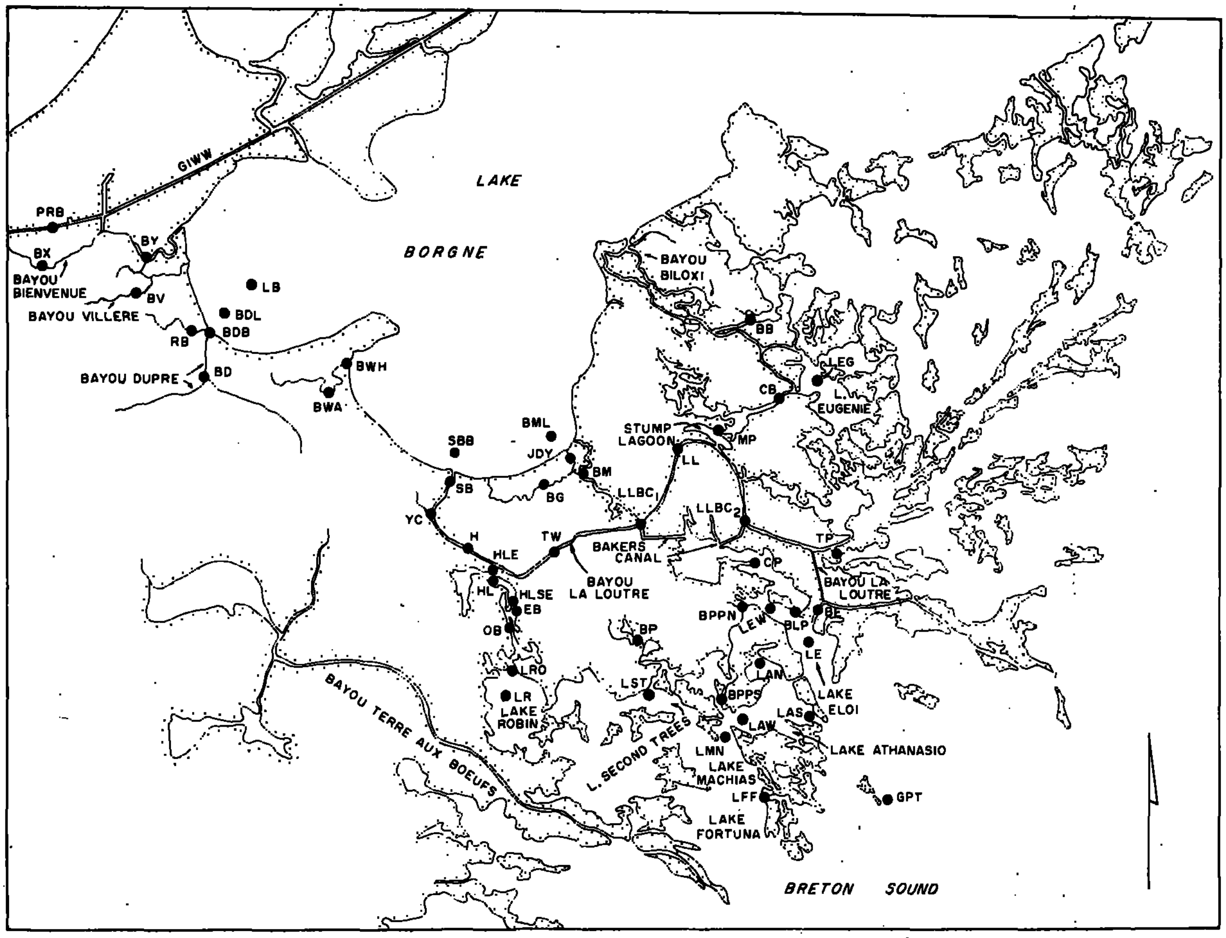

FIGURE 2.—The project area showing all of the sampling stations mentioned in this report. (For details see table 1.)

about three times daily (except on weekends) at the base station at Hopedale. They included salinity, temperature, dissolved oxygen, phosphates, turbidity, and alkalinity.

Salinity

At the base station at Hopedale, about 43 percent of the salinities were determined by titration, the remainder by use of a portable battery-operated conductivity meter. A continuously recording conductivity meter was also used at Hopedale, but checks against titrations show the records to be too unreliable for use.

Water temperature

Water temperature was measured in centigrade from bucket samples of surface water. The temperatures were similar at any one time throughout the project area; and therefore, are without value in characterizing the bodies of water.

Dissolved oxygen

Dissolved oxygen in milliliters per liter was determined by a modified Winkler method. Oxygen values fluctuated so erratically from day to day at the base station that their usefulness is very questionable. Only in a very few instances in which heavy sewage contamination was suspected, were the oxygen values sufficiently low to be detrimental to the fauna.

The modified Winkler method used employed 100 g. of KOH and 50 g. of KI per 1,000 ml. of distilled water. This has been found to be an unreliable method for most estuarine waters because of the high organic content. Marvin,

TABLE 1.—*List of stations by area and months sampled*

Area	Station		Months sampled					
			Hydrography			Biology		
	Symbol	Name	1959	1960	1961	1959	1960	1961
1	BX	Bayou Bienvenue at Paris Road.	7	12	3	----	----	----
	PRB	Intracoastal Waterway at Paris Road Bridge.	7	8	----	----	----	----
	BV	Bayou Villere	3	12	3	----	----	----
	BY	Bayou Bienvenue at Y	7	12	3	----	----	----
	BD	Bayou Dupre	7	12	3	4	12	3
	RB	*Rotten* Bayou	2	12	3	4	12	3
	BDB	Bayou Dupre Beacon	7	12	3	4	10	3
	BWH	Bayou Lewis	7	12	3	----	----	----
	BWA	Bayou Grand	7	8	----	----	----	----
2a	BDL	Bayou Dupre Light	7	12	3	4	12	3
	LB	Lake Borgne (off Bayou Dupre).	----	12	3	----	12	3
2b	SBB	Shell Beach Beacon	9	12	3	----	----	----
	BML	Bayou St. Malo Light	8	12	3	4	12	3
3	SB	Shell Beach	9	12	3	----	8	3
	YC	Bayou Yscloskey	9	12	3	----	----	----
	H	Hopedale	9	12	3	----	----	----
	BM	Bayou St. Malo	9	12	3	4	12	3
	BG	Bayou Guyago	8	12	3	4	12	3
	JDY	Jahnckes Ditch at Y	2	12	3	4	12	3
4	BB	Bayou Biloxi	6	----	----	----	----	----
	MP	Mike's Pass	5	----	----	----	----	----
	LL	Bayou La Loutre	6	----	----	----	----	----
	LLBC 1	La Loutre-Bakers Canal, west.	9	12	3	----	----	----
	TW	Bayou La Loutre Survey Tower.	9	12	3	----	----	----
	HLE	Hopedale Lagoon entrance.	1	----	----	----	----	----
	HL	Hopedale Lagoon	9	12	3	----	----	----
	HLSE	Hopedale Lagoon, southeast.	2	----	----	----	----	----
	EB	East Bayou	2	----	----	----	----	----
	OB	Oyster Bay	9	12	3	----	----	----
5	LEG	Lake Eugenie	6	----	----	----	----	----
	CB	Crooked Bayou	6	----	----	----	----	----
	LLBC 2	La Loutre-Bakers Canal, east.	9	8	----	----	----	----
	CP	China Pass	----	5	3	----	----	----
	LRO	Lake Robin-Oyster Bay	2	3	----	----	2	----
	LR	Lake Robin	9	12	3	----	----	----
6	TP	Treasure Pass	9	8	----	----	----	----
	BE	Bayou Eloi	----	----	----	1	----	----
	LE	Lake Eloi	9	12	3	----	----	----
	LEW	Lake Eloi, west	----	----	----	1	----	----
	BPPN	Bayou Pointe en Pointe, north.	9	12	3	4	12	3
	BPPS	Bayou Pointe en Pointe, south.	9	6	----	----	----	----
	LST	Lake of Second Trees	9	12	3	----	----	----
	BP	Bayou Pisana	9	11	3	----	----	----
	BLP	Blind Pass	----	----	----	1	----	----
7	LAS	Lake Athanasio, south	3	12	3	3	11	3
	LAN	Lake Athanasio, north	3	8	----	3	7	----
	LAW	Lake Athanasio, west	2	----	----	2	----	----
	LMN	Lake Machias, north	2	12	3	2	11	3
8	LFF	Lake Fortuna, at Bayou Frenepiquant.	2	12	3	1	11	3
	GPT	Grace Point	----	3	3	----	3	3

Zein-Eldin, May, and Lansford (1960) use 900 g. of NaI and 400 g. of NaOH in only 550 ml. of distilled water to overcome the errors produced from high turbidities.

Inorganic phosphate

Inorganic phosphate was determined by a colorimetric method. The values show great and erratic variations, which could be caused by particulate phosphate in the unfiltered samples. This explanation is corroborated by an apparent correlation between turbidity and phosphates.

Turbidity

Turbidity was measured with a Klett colorimeter. The readings were converted into grams per liter of oven-dried suspended solids by comparison with a predetermined curve. The samples were shaken vigorously before making readings so that the values include heavy particles which might not be transported any distance by the water, but be present in the samples wholly because of local wave action.

Average turbidities were slightly lower in general in areas of higher salinity. The dredging operations occasionally caused much higher than average turbidities. Thus, the turbidity at Shell Beach (SB) and Yscloskey (YC) was extremely high (twice the average) during February and March 1961. The interim channel dredging from Bayou Dupre to Bayou Yscloskey reached Bayou Yscloskey in February 1961 and might easily account for extreme turbidities in these closely adjacent stations.

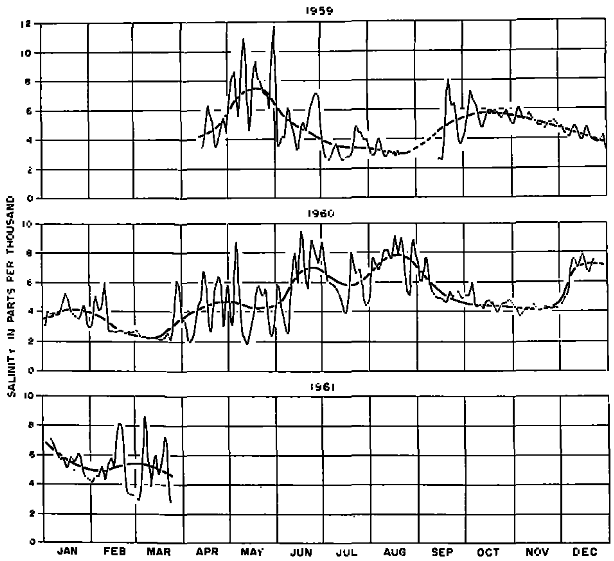

FIGURE 3.—Daily salinities at the base station (H) in Hopedale. (See text for details.)

SALINITY

The hydrographical changes that the Gulf outlet channel might be expected to cause would be chiefly changes in salinities and currents. For this reason, we have paid particular attention to these two features. The daily salinities at the base station at Hopedale (see H, fig. 2) are given in table 2. These were smoothed by first interpolating for the missing weekend days and then smoothing by 3–s with double weight on the center item (fig. 3). The trend line has been drawn by eye.

TABLE 2.—*Mean daily salinity at Hopedale, La.*

[Parts per thousand]

Day	Month 1959: Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	-----	5.64	9.95	3.87	-----	-----	4.36	-----	4.85
2	-----	6.53	3.45	4.30	-----	-----	4.16	4.76	5.03
3	-----	8.63	3.18	2.85	2.76	-----	-----	5.33	4.17
4	-----	8.33	3.81	-----	2.91	-----	-----	6.20	4.34
5	-----	8.62	4.24	-----	3.22	-----	7.69	6.38	-----
6	-----	8.73	-----	2.44	4.05	-----	7.06	5.50	-----
7	-----	5.90	-----	2.90	4.16	-----	6.20	-----	4.07
8	-----	4.54	4.00	3.06	-----	-----	6.73	-----	4.09
9	-----	-----	7.35	3.45	-----	-----	6.13	5.25	4.70
10	-----	-----	6.08	3.93	2.72	-----	-----	5.83	4.83
11	-----	11.49	4.55	-----	2.78	-----	-----	5.32	4.94
12	-----	10.90	5.34	-----	2.77	-----	4.72	5.97	-----
13	3.01	7.42	-----	2.62	3.13	2.34	4.47	5.38	-----
14	3.06	6.10	-----	2.68	3.20	2.36	5.28	-----	3.79
15	3.68	3.36	2.08	2.52	-----	2.96	5.37	-----	3.92
16	3.88	-----	3.32	2.65	-----	2.58	5.94	5.04	3.72
17	5.30	-----	3.75	2.74	2.91	2.47	-----	4.79	4.59
18	6.62	8.77	5.86	-----	2.67	2.57	-----	4.77	5.17
19	-----	10.80	4.88	-----	3.19	-----	5.91	5.13	4.47
20	5.07	6.84	-----	2.79	3.91	-----	5.76	4.51	-----
21	5.82	8.92	-----	3.06	4.26	9.10	6.08	-----	3.91
22	3.40	7.78	4.42	3.80	-----	6.94	5.94	-----	3.88
23	3.38	-----	6.36	5.62	-----	6.07	5.51	5.00	3.70
24	3.42	-----	6.29	4.29	-----	6.07	-----	5.19	3.76
25	-----	6.93	6.42	-----	-----	6.80	-----	4.96	3.57
26	-----	7.15	7.14	-----	-----	-----	5.32	-----	-----
27	-----	7.17	-----	4.44	-----	-----	5.73	5.32	-----
28	5.97	6.56	-----	3.51	-----	3.51	6.08	-----	3.93
29	4.82	3.94	7.21	3.95	-----	3.38	5.71	-----	4.59
30	3.62	14.41	6.14	4.18	-----	4.07	5.30	4.72	3.78
31	-----	11.25	-----	3.30	-----	-----	-----	-----	2.82
Days	14	25	22	23	15	14	22	20	24
Average salinity	4.36	7.87	5.30	3.43	3.24	4.37	5.70	5.27	4.19
Number of observations	54	92	84	98	45	42	65	60	62
Titrated observations [1]	54	92	84	90	1	33	1	4	6

Day	Month 1960: Jan.	Feb.	Mar.	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1961: Jan.	Feb.	Mar.
1	-----	3.01	2.67	4.21	-----	6.66	-----	4.87	8.09	-----	4.14	4.42	-----	4.14	2.98
2	-----	3.06	3.14	-----	2.62	5.89	-----	9.41	5.14	-----	4.35	4.34	-----	4.48	3.01
3	-----	3.97	2.25	-----	2.94	4.36	-----	6.61	-----	5.00	3.87	-----	7.21	4.67	2.82
4	4.27	6.20	2.25	1.79	3.75	-----	-----	7.96	-----	5.23	3.45	-----	7.12	-----	-----
5	3.70	4.02	-----	1.95	10.20	-----	5.61	6.68	7.84	6.90	-----	5.29	7.21	-----	-----
6	3.92	-----	-----	1.98	9.17	3.37	6.28	-----	7.81	5.14	-----	4.59	6.83	4.46	9.28
7	3.96	-----	2.32	2.32	-----	2.38	5.66	-----	7.06	4.11	4.11	6.78	-----	5.65	9.04
8	3 89	4.23	2.25	2.62	-----	2.33	5.95	7.03	5.29	-----	4.31	7.08	-----	5.22	5.22
9	-----	5.11	2.28	-----	1.66	3.30	-----	7.97	5.46	-----	4.24	7.89	6.26	3.46	3.94
10	-----	8.20	2.17	-----	2.76	5.14	-----	8.51	-----	4.59	4.14	-----	5.60	4.98	3.33
11	3.74	2.87	2.18	5.00	1.65	-----	5.51	7.75	-----	4.31	4.21	-----	5.60	-----	-----
12	4.06	2.60	-----	4.14	1.76	-----	5.60	8.41	4.79	4.06	-----	6.72	5.91	-----	-----
13	4.87	-----	-----	5.58	1.75	8.76	4.81	-----	5.05	4.36	-----	7.21	5.83	5.91	6.91
14	4.79	-----	2.26	7.13	-----	7.05	4.91	-----	4.91	4.85	4.67	7.48	-----	5.68	4.67
15	5.54	2.70	2.22	7.12	-----	3.77	3.60	7.05	-----	-----	4.02	8.43	-----	4.78	4.32
16	-----	2.76	2.20	-----	3.49	8.90	-----	8.82	-----	-----	4.03	7.44	4.68	5.48	5.14
17	-----	2.51	2.12	-----	4.77	10.20	-----	9.65	-----	4.53	4.11	-----	6.17	8.13	5.44
18	4.29	2.71	2.09	2.32	4.96	-----	4.40	8.21	-----	4.53	4.00	-----	5.78	-----	-----
19	3.87	2.75	-----	2.29	6.21	-----	7.51	7.62	4.51	4.56	-----	6.43	5.86	-----	-----
20	4.03	-----	-----	3.68	5.67	6.06	9.09	-----	5.37	3.80	-----	6.78	5.33	8.13	8.24
21	3.70	-----	2.32	6.28	-----	5.06	6.75	-----	5.57	3.88	4.45	7.35	-----	7.84	4.32
22	3.63	2.70	3.05	5.56	-----	5.63	6.52	9.74	4.85	-----	4.22	7.44	-----	4.96	3.28
23	-----	2.43	2.02	-----	4.83	8.88	-----	6.44	4.88	-----	4.18	7.85	6.23	3.53	2.52
24	-----	2.58	1.93	-----	5.97	9.17	-----	5.36	-----	4.63	4.31	-----	6.18	3.32	2.67
25	3.53	2.66	2.44	6.92	5.68	-----	6.93	5.57	-----	4.50	4.14	-----	5.19	-----	-----
26	4.17	2.61	-----	4.46	3.91	-----	6.89	4.22	5.51	4.70	-----	-----	5.00	-----	-----
27	4.85	-----	-----	2.56	2.09	7.44	4.60	-----	5.05	4.37	-----	-----	4.48	3.32	-----
28	4.34	-----	6.57	2.21	-----	7.22	4.44	-----	4.79	4.97	4.28	-----	-----	3.04	-----
29	2.99	2.65	6.33	7.38	-----	7.00	4.36	10.23	4.76	-----	4.20	-----	-----	-----	-----
30	-----	-----	4.53	-----	2.80	9.47	-----	7.24	5.02	-----	4.23	-----	4.38	-----	-----
31	-----	-----	2.12	-----	4.16	-----	-----	7.39	-----	4.45	-----	-----	4.13	-----	-----
Days	20	21	23	21	21	22	19	23	20	21	22	17	21	20	18
Average salinity	4.11	3.44	2.77	4.17	4.41	6.27	5.76	7.51	5.59	4.64	4.17	6.68	5.76	5.06	4.84
Number of observations	57	61	69	61	63	60	50	56	39	42	44	33	41	38	35
Titrated observations [1]	8	61	54	61	24	9	2	15	0	1	0	0	0	0	0

[1] All nontitrated observations made with a portable conductivity meter.

Two facts are clearly shown by figure 3: the day-by-day variations in salinity are extreme, and over the 2-year period there is no consistent seasonal pattern.

The first step in determining the cause of salinity variations was to obtain as nearly as possible a picture of the average salinities in different sections of the project area over the entire 24-month period. The average monthly salinity at each station is given in table 3. In some cases, it has been possible to interpolate missing data on a proportional basis from adjacent stations with similar characteristics. These interpolated values are shown in parentheses.

TABLE 3.—*Mean monthly salinity at each station*

[Parts per thousand]

Date	Station [1]																	
	BX		PRB		BD		BV		BY		RB		BDB		BDL		LB	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
1959																		
April	------	(1.50)	------	(1.91)	------	(2.21)	------	(2.26)	------	(2.32)	------	(2.53)	------	(2.58)	------	(2.74)	------	(2.82)
May	5	1.15	2	1.58	8	1.79	------	(1.48)	8	1.52	------	(1.70)	8	1.73	5	2.13	------	(2.20)
June	4	0.91	4	1.55	4	1.55	------	(1.42)	4	1.45	------	(1.68)	4	1.71	4	1.83	------	(1.89)
July	5	1.15	5	1.38	5	1.49	------	(1.44)	5	1.48	------	(1.55)	5	1.58	5	1.80	------	(1.86)
August	1	0.82	1	1.10	1	1.53	------	(1.46)	1	1.50	------	(1.50)	1	1.53	1	1.68	------	(1.73)
September	------	(1.00)	------	(1.27)	------	(1.47)	------	(1.51)	------	(1.55)	------	(1.69)	------	(1.72)	------	(1.83)	------	(1.89)
October	3	2.82	3	2.64	3	2.82	3	3.87	3	4.00	------	(4.73)	4	4.82	4	5.13	------	(5.29)
November	3	2.27	3	3.19	3	3.04	3	3.42	3	3.52	1	3.24	3	3.23	3	3.38	------	(3.48)
December	3	2.41	3	2.32	4	3.01	3	2.95	3	2.99	4	3.01	4	3.13	4	2.97	------	(3.06)
1960																		
January	3	1.37	3	1.87	2	2.36	3	2.47	3	2.03	2	2.60	2	2.53	2	2.74	1	2.26
February	3	1.02	3	1.32	3	1.62	3	1.85	3	1.46	3	1.62	3	1.70	6	1.99	3	1.79
March	3	0.80	3	1.37	3	1.58	3	1.86	3	1.48	3	1.52	3	1.59	3	1.58	3	1.58
April	3	0.95	3	1.06	3	1.09	3	1.23	3	1.46	3	1.28	3	1.54	3	1.36	3	1.21
May	3	1.11	3	1.25	3	1.29	3	1.18	3	1.29	3	1.27	3	1.32	3	1.31	3	1.25
June	3	1.27	3	1.36	3	1.67	3	1.53	3	1.51	3	1.53	3	1.62	3	1.37	3	1.69
July	3	2.23	3	2.45	3	3.09	3	1.62	3	2.71	3	3.36	3	3.23	3	3.63	3	4.08
August	3	1.63	2	3.38	3	3.39	3	3.31	3	3.45	3	3.80	3	3.88	3	4.23	3	4.83
September	2	2.82	------	(3.58)	2	4.79	2	4.18	2	4.38	2	4.49	2	5.26	2	5.34	2	5.72
October	2	1.56	------	(1.98)	2	3.13	2	3.04	2	3.40	2	3.54	2	3.53	2	3.98	2	4.16
November	2	1.98	------	(2.51)	2	3.35	2	3.35	2	3.26	2	3.40	2	3.54	2	3.64	2	3.35
December	2	4.16	------	(5.28)	2	5.97	2	5.59	2	5.48	2	6.20	2	6.30	2	6.48	2	6.87
1961																		
January	2	1.66	------	(2.11)	2	1.88	2	3.34	2	4.22	2	4.40	2	4.11	2	4.76	2	5.07
February	2	1.14	------	(1.45)	2	1.81	2	2.48	2	2.35	2	3.12	2	2.75	2	3.10	2	3.36
March	2	1.24	------	(1.57)	2	1.32	2	1.92	2	1.42	2	1.76	2	1.80	2	1.84	2	2.12

[Parts per thousand]

Date	Station [1]																	
	BWA		BWH		SBB		SB		JDY		BML		BG		YC		BM	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
1959																		
April	------	(3.00)	------	(3.02)	3	3.49	10	3.77	------	(4.04)	------	(3.81)	------	(4.26)	11	3.78	2	4.42
May	2	2.26	2	2.24	2	3.71	3	7.15	------	(5.43)	1	6.07	3	4.62	3	7.59	4	5.93
June	4	2.23	4	2.22	4	2.79	4	3.88	------	(3.39)	4	3.31	4	3.50	4	3.98	4	3.70
July	5	2.00	5	1.96	5	2.83	5	2.70	------	(3.34)	5	3.13	5	3.30	5	2.73	5	3.65
August	1	2.08	1	1.92	1	2.97	1	3.02	------	(2.53)	1	2.66	1	3.21	1	2.82	1	2.77
September	------	(2.01)	------	(2.02)	1	2.33	1	2.25	------	(2.21)	1	2.31	1	2.54	1	2.29	1	2.41
October	3	4.98	3	5.26	3	6.21	3	6.42	------	(5.72)	3	6.50	3	5.96	3	5.91	3	6.25
November	3	4.67	3	4.72	3	5.14	3	5.10	1	4.85	3	5.19	3	5.48	3	4.68	2	5.24
December	3	3.66	3	3.57	3	4.07	3	4.29	3	4.14	3	3.93	3	4.17	3	3.99	3	4.07
1960																		
January	3	3.21	3	3.58	3	3.60	3	3.99	2	3.66	2	3.73	2	3.84	3	4.01	2	3.58
February	3	2.79	3	2.59	3	2.68	3	2.68	3	2.99	3	2.89	5	2.29	3	2.80	3	3.18
March	3	2.03	3	2.20	3	2.20	3	2.24	3	2.50	3	2.32	3	2.50	3	2.14	3	2.49
April	3	1.78	3	1.52	5	1.74	3	1.79	3	1.91	3	1.63	3	2.67	3	3.76	3	2.16
May	3	1.61	3	1.56	6	2.09	3	2.28	3	2.29	3	2.18	3	3.14	3	3.42	3	3.42
June	4	2.08	4	2.00	7	2.78	4	2.59	3	3.69	3	3.69	3	4.24	4	6.08	3	6.23
July	2	3.15	2	3.07	5	4.02	2	3.62	3	5.40	3	5.43	3	6.07	2	6.50	3	5.49
August	2	3.30	3	3.72	3	4.50	3	4.68	3	4.89	3	5.13	3	5.25	3	7.61	3	5.57
September	------	(4.95)	2	4.98	3	5.21	3	5.11	3	5.41	3	5.37	8	5.61	3	5.30	3	5.45
October	------	(4.27)	2	4.30	4	4.28	2	4.47	2	4.24	2	4.20	2	4.40	2	4.32	2	4.36
November	------	(3.75)	2	3.78	4	3.83	2	3.59	2	3.93	2	4.07	2	4.01	2	3.95	2	3.99
December	------	(7.73)	2	7.78	4	6.15	2	6.26	2	5.84	2	6.48	2	5.84	2	6.16	2	6.40
1961																		
January	------	(4.71)	2	4.74	4	6.42	2	6.29	2	6.60	2	6.80	2	6.54	2	5.83	2	6.70
February	------	(3.40)	2	3.42	4	4.24	2	5.28	2	4.74	2	4.52	2	5.04	2	3.02	2	4.90
March	------	(2.09)	2	2.10	4	3.12	2	3.15	2	4.48	2	3.38	2	4.98	2	3.99	2	5.02

See footnotes at end of table.

TABLE 3.—*Mean monthly salinity at each station*—Continued

Date	Station [1]																	
	HLE		HL		TW		HLSE		$LLBC_1$		EB		LL		BB		OB	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
1959																		
April	4	5.38	12	6.24	4	5.93	7	6.31	5	7.27	4	6.62	5	7.33	1	7.88	4	7.58
May	------	------	4	10.77	5	10.67	1	8.71	6	14.98	1	9.06	5	13.96	2	12.52	4	12.38
June	------	------	4	8.90	4	3.70	------	------	8	9.79	------	------	4	11.09	4	9.06	4	10.44
July	------	------	5	4.95	6	5.26	------	------	10	6.27	------	------	7	6.37	5	7.24	5	6.63
August	------	------	1	4.87	1	4.28	------	------	1	7.49	------	------	1	6.67	1	6.70	1	5.97
September	------	------	1	4.59	3	5.44	------	------	3	4.64	------	------	1	8.73	1	9.03	1	5.41
October	------	------	2	5.26	2	6.16	------	------	4	5.66	------	------	------	------	------	------	2	5.74
November	------	------	3	5.69	2	5.40	------	------	5	6.13	------	------	------	------	------	------	3	6.34
December	------	------	3	4.80	3	6.66	------	------	3	5.73	------	------	------	------	------	------	3	6.32
1960																		
January	------	------	3	5.02	3	4.93	------	------	3	5.49	------	------	------	------	------	------	3	5.87
February	------	------	3	3.92	3	3.78	------	------	2	3.13	------	------	------	------	------	------	3	5.24
March	------	------	3	2.66	5	4.73	------	------	3	3.30	------	------	------	------	------	------	3	4.26
April	------	------	3	6.28	2	4.76	------	------	3	6.47	------	------	------	------	------	------	3	6.44
May	------	------	3	3.94	3	5.71	------	------	3	6.61	------	------	------	------	------	------	3	6.80
June	------	------	3	9.21	3	10.85	------	------	3	11.91	------	------	------	------	------	------	3	11.57
July	------	------	3	9.55	3	10.60	------	------	3	11.96	------	------	------	------	------	------	3	11.08
August	------	------	3	9.72	3	7.50	------	------	3	8.40	------	------	------	------	------	------	3	12.57
September	------	------	3	7.10	2	5.51	------	------	3	6.86	------	------	------	------	------	------	3	9.52
October	------	------	2	5.54	2	4.68	------	------	2	5.60	------	------	------	------	------	------	2	7.04
November	------	------	2	4.07	2	4.18	------	------	2	4.74	------	------	------	------	------	------	2	4.36
December	------	------	2	6.81	2	7.86	------	------	2	7.84	------	------	------	------	------	------	2	8.14
1961																		
January	------	------	2	6.37	2	8.91	------	------	2	6.44	------	------	------	------	------	------	2	6.60
February	------	------	2	6.64	2	5.59	------	------	2	6.49	------	------	------	------	------	------	2	7.79
March	------	------	2	5.95	2	6.27	------	------	2	6.68	------	------	------	------	------	------	2	7.80

Date	Station																	
	MP		LRO		CB		LR		LEG		CP		$LLBC_2$		BP		BPPN	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
1959																		
April	------	(8.50)	5	8.13	1	8.72	4	9.43	1	8.57	------	------	4	10.68	2	12.80	2	12.96
May	3	14.00	2	14.02	2	14.36	2	11.89	2	15.63	------	------	4	18.49	3	16.20	2	19.58
June	4	11.74	------	------	4	11.86	6	6.38	4	12.61	------	------	4	14.08	4	14.12	4	16.49
July	5	7.82	------	------	5	8.82	5	7.70	5	9.34	------	------	5	11.61	5	9.75	5	11.22
August	1	8.35	------	------	1	9.09	1	7.45	1	8.35	------	------	1	11.18	1	9.39	1	12.37
September	1	10.00	------	------	1	10.12	1	8.45	1	10.00	------	------	1	6.02	1	8.77	1	8.38
October	------	------	------	------	------	------	2	7.68	------	------	------	------	2	8.40	2	9.75	2	10.92
November	------	------	------	------	------	------	3	8.19	------	------	------	------	4	8.25	3	11.98	3	9.64
December	------	------	------	------	------	------	3	7.60	------	------	------	------	3	8.90	2	11.99	3	9.47
1960																		
January	------	------	------	------	------	------	3	6.36	------	------	------	------	3	8.52	3	9.50	1	10.92
February	------	------	------	------	------	------	3	8.41	------	------	------	------	3	6.01	2	11.57	4	7.63
March	------	------	------	------	------	------	3	7.40	------	------	------	------	3	5.66	3	9.79	3	6.29
April	------	------	------	------	------	------	3	8.42	------	------	------	------	3	9.39	3	9.76	3	10.56
May	------	------	------	------	------	------	3	6.49	------	------	------	------	3	8.25	3	9.77	3	9.45
June	------	------	------	------	------	------	3	12.34	------	------	------	------	3	16.80	3	15.47	3	17.83
July	------	------	------	------	------	------	3	13.57	------	------	------	------	3	14.29	3	14.72	3	17.12
August	------	------	1	10.57	------	------	3	14.29	------	------	1	12.60	2	11.70	3	13.42	3	13.78
September	------	------	3	9.20	------	------	3	10.20	------	------	3	7.32	------	(7.40)	3	9.86	3	9.21
October	------	------	1	8.90	------	------	2	8.06	------	------	2	7.32	------	(6.83)	1	7.91	2	11.13
November	------	------	------	------	------	------	2	5.88	------	------	2	6.06	------	(5.34)	2	7.94	2	6.96
December	------	------	------	------	------	------	2	9.10	------	------	2	9.46	------	(10.74)	------	(16.50)	2	11.60
1961																		
January	------	------	------	------	------	------	2	8.40	------	------	2	10.19	------	(10.32)	1	12.60	2	11.76
February	------	------	------	------	------	------	2	8.40	------	------	2	9.52	------	(9.81)	1	9.97	2	11.78
March	------	------	------	------	------	------	2	9.49	------	------	2	8.59	------	(9.93)	2	11.64	2	11.69

See footnotes at end of table.

Date	Station [1]																			
	TP		LST		LE		BPPS		LAW		LAN		LMN		LAS		LFF		GPT	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
1959																				
April	5	13.19	2	12.97	2	15.20	2	14.06	-----	-----	-----	(15.12)	-----	(16.39)	-----	(17.12)	-----	(18.85)	-----	-----
May	4	20.88	3	17.23	4	22.39	3	20.39	-----	-----	-----	(21.27)	-----	(23.06)	-----	(24.09)	-----	(26.53)	-----	-----
June	4	18.99	4	15.78	4	17.50	4	18.00	-----	-----	-----	(17.86)	-----	(19.37)	-----	(20.23)	-----	(22.28)	-----	-----
July	5	13.64	5	11.38	5	13.56	5	13.51	-----	-----	-----	(13.39)	-----	(14.52)	-----	(15.16)	-----	(16.70)	-----	-----
August	1	14.35	1	10.87	1	15.40	1	13.86	-----	-----	-----	(14.11)	-----	(15.29)	-----	(15.98)	-----	(17.59)	-----	-----
September	1	10.40	1	10.40	1	14.30	1	13.00	-----	-----	-----	(13.26)	-----	(14.38)	-----	(15.02)	-----	(16.54)	-----	-----
October	2	12.52	2	11.55	2	14.80	2	13.49	2	14.44	2	13.50	-----	(15.34)	2	16.91	-----	(17.65)	-----	-----
November	3	10.12	3	12.83	3	12.05	3	12.30	1	13.00	3	12.76	2	12.36	3	13.14	-----	(16.66)	-----	-----
December	3	10.19	3	10.10	3	12.22	1	13.64	-----	-----	2	11.70	2	13.64	3	13.68	1	14.58	-----	-----
1960																				
January	3	10.55	3	8.49	3	11.07	2	11.13	-----	-----	2	14.16	2	12.03	1	13.93	2	14.88	-----	-----
February	3	8.12	3	11.36	3	8.47	3	12.16	-----	-----	3	11.97	3	12.43	3	12.41	3	13.39	-----	-----
March	3	5.57	3	9.88	3	9.53	3	9.63	-----	-----	3	10.15	3	10.41	3	11.10	3	12.74	-----	-----
April	3	12.13	3	11.26	3	12.73	3	11.97	-----	-----	3	11.90	3	12.53	3	14.77	3	15.18	-----	-----
May	3	9.75	3	9.53	3	10.43	3	9.63	-----	-----	3	12.73	3	12.26	3	14.39	3	12.30	-----	-----
June	3	17.12	3	16.59	3	18.85	3	18.14	-----	-----	3	19.16	3	20.48	3	21.83	3	20.79	-----	-----
July	3	15.89	3	15.86	3	16.80	-----	(18.03)	-----	-----	3	18.40	3	18.58	3	21.33	3	22.53	-----	-----
August	2	15.42	3	15.20	3	15.30	-----	(17.28)	-----	-----	2	13.84	3	15.41	3	16.73	3	17.61	-----	-----
September	-----	(9.09)	3	11.70	3	9.99	-----	(13.30)	-----	-----	-----	(11.47)	3	12.00	3	12.99	3	14.07	-----	-----
October	-----	(8.39)	2	8.05	2	9.22	-----	(9.15)	-----	-----	-----	(8.69)	2	9.76	2	9.84	2	10.64	2	9.98
November	-----	(6.56)	2	9.08	2	7.21	-----	(10.32)	-----	-----	-----	(8.62)	2	10.32	2	9.76	2	10.76	2	11.05
December	-----	(13.20)	2	17.59	2	14.50	-----	(20.00)	-----	-----	-----	(14.02)	1	17.80	2	15.88	2	22.33	2	20.36
1961																				
January	-----	(12.68)	2	13.55	2	13.93	-----	(15.41)	-----	-----	-----	(17.25)	2	16.23	2	19.54	2	20.78	2	19.76
February	-----	(12.05)	2	8.72	2	13.24	-----	(9.91)	-----	-----	-----	(11.69)	2	11.18	2	13.24	2	12.34	2	15.98
March	-----	(12.19)	2	13.32	2	13.40	-----	(15.14)	-----	-----	-----	(13.49)	2	18.24	2	15.28	2	19.40	2	20.84

[1] Means in parentheses interpolated by comparison of observed data with adjacent stations.
See table 1 for interpretation of symbols.

The data of tables 2 and 3 are summarized in table 4 by bimonthly periods. Observations are too scant, considering the degree of variation in respect to the mean, to be able to place reliance on means derived from any shorter period of time. A 24-month mean salinity is also shown for every station. Admittedly, the 24-month means may be somewhat unreliable when interpolated for stations with but a few months' data, but they are the best estimates available, and their consistency has given us considerable confidence in their use.

From the 24-month mean salinities of table 4, the isohalines of figure 1 are plotted. These have formed the basis for dividing the project area into the numbered areas shown, which will be referred to again under the discussion of the biology.

CURRENTS

The question now is what causes the observed 24-month salinity pattern and the short-term fluctuations therein. An attempt to utilize the data from hourly current observations taken for periods from 12 to 24 hours' duration was unsuccessful, chiefly because of the extremely limited number of stations occupied. (All but 4 out of 42 observation periods were taken at stations H and YC.)

Thereafter, resort was had to the 568 observations on the direction of flow at 10 different stations made at the times these stations were visited by field observers (table 5).

From these field observations, figure 4 has been plotted to show the percent of time the current flowed in various directions at each station at which currents were observed. Figure 4 has been made semidiagrammatic to show the main routes water can follow as it moves across the project area. There appears to be a residual current flowing north in Bayou La Loutre from $LLBC_2$ that continues around the loop in the bayou past station LL. At $LLBC_1$ a portion of this water together with some from Lake Borgne turns south, but a portion continues west where it meets a residual eastward-flowing current from station YC. These observations are of great interest for they indicate the presence of a residual southerly current from Lake Borgne, entering the bayou system at both Bayou Yscloskey (SB) and Bayou St. Malo (BM).

TABLE 4.—*Summary of mean salinities for all stations*

[Parts per thousand]

Station	24-month average	1959 Apr.–May	1959 June–July	1959 Aug.–Sept.	1959 Oct.–Nov.	1960 Dec.–Jan.	1960 Feb.–Mar.	1960 Apr.–May	1960 June–July	1960 Aug.–Sept.	1960 Oct.–Nov.	1961 Dec.–Jan.	1961 Feb.–Mar.	Mean of two bimonthly periods: High	Low	Difference
BX	1.62	1.32	1.03	0.91	2.54	1.89	0.91	1.03	1.75	2.22	1.77	2.91	1.19	2.72	0.91	1.81
PRB	2.06	1.74	1.46	1.18	2.91	2.10	1.34	1.16	1.90	3.48	(2.24)	(3.70)	(1.51)	3.59	1.17	2.42
BD	2.39	2.00	1.52	1.50	2.93	2.68	1.60	1.19	2.38	4.09	3.24	3.92	1.56	4.00	1.34	2.66
BV	2.45	(1.87)	(1.43)	(1.48)	3.04	2.71	1.86	1.20	1.58	3.74	3.19	4.46	2.20	4.10	1.32	2.78
BY	2.51	1.92	1.46	1.52	3.76	2.51	1.47	1.38	2.11	3.92	3.33	4.85	1.88	4.38	1.42	2.96
RB	2.73	(2.12)	(1.62)	(1.60)	3.98	2.80	1.57	1.28	2.44	4.14	3.47	5.30	2.44	4.72	1.42	3.30
BDB	2.78	2.16	1.64	1.62	4.02	2.83	1.64	1.43	2.42	4.57	3.54	5.20	2.28	4.88	1.52	3.36
BDL	2.95	2.44	1.82	1.76	4.26	2.86	1.78	1.34	2.50	4.78	3.81	5.62	2.47	5.20	1.55	3.65
LB	3.04	(2.51)	(1.88)	(1.81)	(4.38)	2.66	1.68	1.23	2.88	5.28	3.76	5.72	2.74	5.50	1.46	4.04
BWA	3.24	2.63	2.12	2.04	4.82	3.44	2.41	1.70	2.62	4.12	(4.01)	(6.22)	(2.74)	5.52	1.87	3.65
BWH	3.26	2.63	2.09	1.97	4.99	3.58	2.40	1.54	2.54	4.35	4.04	6.26	2.76	5.62	1.76	3.86
SBB	3.77	3.60	2.81	2.65	5.68	3.84	2.44	1.92	3.40	4.86	4.06	6.29	3.68	5.98	2.18	3.80
SB	4.03	5.46	3.29	2.64	5.76	4.14	2.46	2.04	3.10	4.90	4.03	6.28	4.22	6.02	2.25	3.77
JDY	4.09	(4.74)	(3.36)	(2.37)	5.28	3.90	2.74	2.10	4.54	5.15	4.08	6.22	4.61	5.75	2.24	3.51
BML	4.11	4.94	3.22	2.47	5.84	3.83	2.60	1.90	4.56	5.25	4.14	6.64	3.95	6.24	2.18	4.06
BG	4.31	4.44	3.40	2.88	5.72	4.00	2.40	2.90	5.16	5.43	4.20	6.19	5.01	5.96	2.64	3.32
YC	4.44	5.68	3.36	2.56	5.30	4.00	2.47	3.59	6.29	6.46	4.14	6.00	3.50	6.38	2.52	3.86
BM	4.47	5.18	3.68	2.59	5.74	3.82	2.84	2.79	5.86	5.51	4.18	6.55	4.96	6.20	2.69	3.51
Hopedale	4.95	6.12	4.36	3.80	5.48	4.15	3.10	4.29	6.02	6.55	4.40	6.22	4.95	6.38	3.45	2.93
HLE	5.34															
HL	6.20	8.50	6.92	4.73	5.48	4.91	3.29	5.11	9.38	8.41	4.80	6.59	6.30	8.94	4.01	4.93
TW	6.22	8.30	4.48	4.86	5.78	5.80	4.26	5.24	10.72	6.50	4.43	8.38	5.93	9.55	4.34	5.21
HLSE	6.81															
$LLBC_1$	7.08	11.12	8.03	6.06	5.90	5.61	3.22	6.54	11.94	7.63	5.17	7.14	6.58	11.53	4.42	7.11
EB	7.11															
LL	7.17	10.64	8.73	7.70												
BB	7.24	10.20	8.15	7.86												
OB	7.58	9.98	8.54	5.69	6.04	6.10	4.75	6.62	11.32	11.04	5.70	7.37	7.80	11.18	5.22	5.96
MP	7.92	11.25	9.78	9.18												
LRO	8.32	11.08								9.88						
CB	8.69	11.54	10.34	9.60												
LR	8.82	10.66	7.04	7.95	7.94	6.98	7.90	7.46	12.96	12.24	6.97	8.75	8.94	12.60	6.98	5.62
LEG	8.90	12.10	10.98	9.18												
CP	9.85									9.96	6.69	9.82	9.06			
$LLBC_2$	9.94	14.58	12.84	8.60	8.32	8.71	5.84	8.82	15.54	9.55	(6.08)	(10.53)	(9.87)	15.06	5.96	9.10
BP	11.47	14.50	11.94	9.08	10.86	10.74	10.68	9.76	15.10	11.64	7.92	14.55	10.80	14.82	8.50	6.32
BPPN	11.61	16.27	13.86	10.38	10.28	10.20	6.96	10.00	17.48	11.50	9.04	11.68	11.74	16.88	8.00	8.88
TP	12.21	17.04	16.32	12.38	11.32	10.37	6.84	10.94	16.50	12.26	(7.48)	(12.94)	(12.36)	16.77	7.16	9.61
LST	12.22	15.10	13.58	10.64	12.19	9.30	10.62	10.40	16.22	13.45	8.56	15.57	11.02	15.90	8.93	6.97
LE	13.42	18.80	15.53	14.85	13.42	11.64	9.00	11.58	17.82	12.64	8.22	14.22	13.32	18.31	8.61	9.70
BPPS	13.90	17.22	15.76	13.43	12.90	12.38	10.90	10.80	18.08	(15.29)	(9.74)	(17.70)	(12.52)	17.89	10.27	7.62
LAW	14.63															
LAN	14.60	(13.20)	(15.62)	(13.68)	13.13	12.93	11.06	12.32	18.78	12.66	(8.66)	(15.64)	(12.59)	17.21	9.86	7.35
LMN	14.75	(19.72)	(16.94)	(14.84)	13.85	12.84	11.42	12.40	19.53	13.70	10.04	17.02	14.71	19.62	10.73	8.89
LAS	15.60	(20.60)	(17.70)	(15.50)	15.02	13.80	11.76	14.58	21.58	14.86	9.80	17.71	14.26	21.09	10.78	10.31
LFF	16.96	(22.69)	(19.49)	(17.06)	(17.16)	14.73	13.06	13.74	21.66	15.84	10.70	21.56	15.87	22.18	11.88	10.30
GPT	17.27										10.52	20.06	18.41			

TABLE 5.—*Observations on current directions from regular sampling trips*

[Percent of observations]

Direction	Station: SB	YC	HL	OB	TW	BM	$LLBC_1$	LL	$LLBC_2$	TP	Average
No current	1.4	7.0	10.9	4.6	13.6	7.1	4.9	52.2	2.0	9.8	11.4
Toward Lake Borgne	38.6	26.8				39.3	20.5				31.3
Away from Lake Borgne	60.0	66.2				50.0	[1] 45.5				55.4
Toward Bayou La Loutre (north)			39.1	52.3							
Away from Bayou La Loutre (south)			48.6	43.1							
Toward Bayou Guyago (west)						3.6					
Toward $LLBC_1$ (east)			1.6								
Toward Hopedale (west)					74.2		30.6	39.1			48.0
Toward Stump Lagoon (east)					12.1		6.0	8.7			8.9
Toward LL (north)									49.0		
Away from LL (south)									6.1		
Toward Halfmoon Lagoon									33.7		
Away from Halfmoon Lagoon									7.1		
Toward Treasure Pass									2.0		
Away from Treasure Pass									73.0		
Toward Bayou Petre (north)										67.4	
Away from Bayou Petre (south)										21.5	
West on Bayou Petre										33.9	
East on Bayou Petre										55.6	
Number of days observed	70	71	64	65	66	28	81	23	49	51	56.8

[1] Toward Halfmoon Lagoon.

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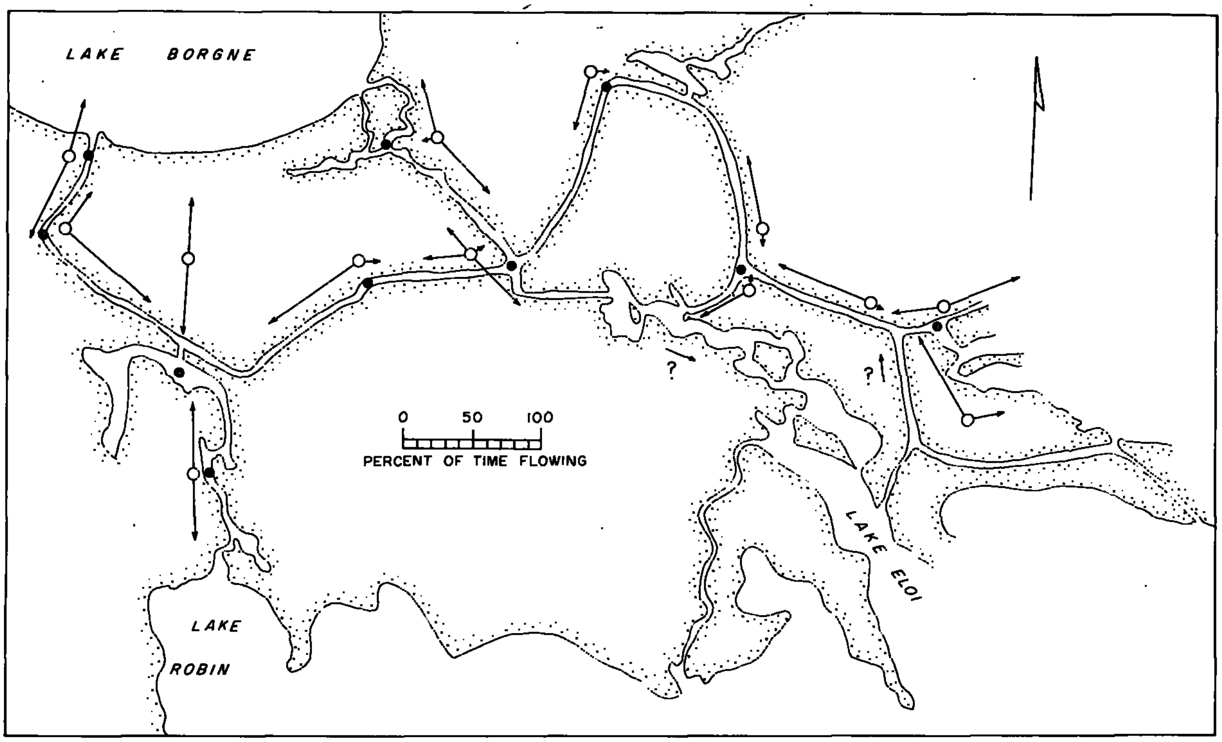

FIGURE 4.—Semidiagrammatic map of the project area showing the percent of time currents were flowing in each direction. Station locations shown by black dots. Length of arrows from adjacent open circles shows the percent of time in the indicated direction.

In addition to the two routes for water exchange between Lake Borgne and Breton Sound indicated in figure 4, there is a third route, via Bayou Biloxi, Lake Eugenie, Crooked Bayou, and Stump Lagoon (fig. 2), for which information is too scant to assess its actual significance. The effect of these main transport routes on mean salinities is shown in figure 5, in which 24-month salinities are plotted against distance from station SBB in Lake Borgne along the routes water would have to follow in order to circulate. The mean salinity along both the western and central routes between Breton Sound and where they meet the cross channels linking SB with LEG decreases at a rather uniform rate of 1‰ every 2 miles.

On the crosslinking channels running from LEG to SB the rate of decrease in salinity is also quite uniform but only 1‰ every 5 miles. This great contrast in the rate of decrease in salinity per mile between that of the two chief water routes from Breton Sound and that of the cross channel suggests that Lake Borgne dominates the water circulation north of Bayou La Loutre and

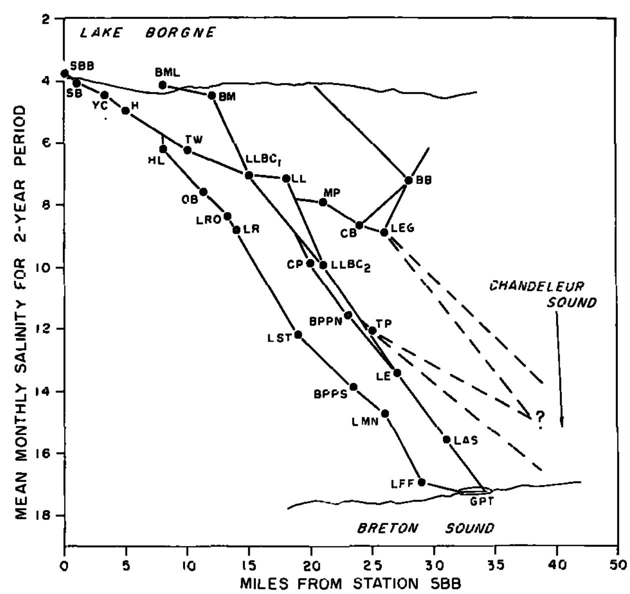

FIGURE 5.—Diagram to show the average relation between salinity and distance along the water exchange routes linking Lake Borgne with Breton and Chandeleur Sounds.

along Bayou La Loutre between Stump Lagoon and Lake Borgne.

The lack of data on the cross-sectional areas of the connecting waterways makes it difficult to estimate the relative importance of each route to the water exchange pattern. Some idea of their relative importance, however, can be gained by noting the relative variation in salinity, since the degree of variation should be positively correlated with the amount of water exchange.

Because of the paucity and nonorthogonal pattern of the sampling, I have been forced to utilize a very simple measure of variation; namely, the salinity difference between the average of the two highest bimonthly means and the average of the two lowest bimonthly means (table 4).

The logarithms of the resulting differences in salinity are plotted as the ordinate, labeled "salinity variation" in figure 6 using the mean monthly salinity for the entire 2-year period as the abscissa. Several features are of interest. The salinity variation in the central water transport system is considerably higher than in the western, indicating a greater water exchange. The great decrease in salinity variation between $LLBC_1$ and H on the linking stations tends to confirm this conclusion. It should also be noted that stations in Bayou Pisana (BP) and northern Lake Athanasio (LAN), which are in effect in cul-de-sacs without through movement of water, exhibit less variation than neighboring stations on the water transport route.

The four stations in Lake Borgne are similar in their degree of variation. The stations in area 3 (fig. 1) show approximately the same degree of variation as those of Lake Borgne. This tends to confirm my previous observation that a residual current flows southeastward from Lake Borgne since Lake Borgne obviously dominates these stations. In area 1, the stations exhibit a gradually lowering salinity coupled with decreased variation as they go from the lake shore toward Paris Road.

FACTORS AFFECTING SALINITY

Since the waters of Lake Borgne exert the major influence on salinities throughout the project area, I have attempted to determine to what extent certain measurable factors influence them. Table 6 gives data on the discharge of the Pearl River at Bogalusa, the intensity of the north and northeast wind components at the New Orleans Airport, and the average of the monthly salinities for four stations in Lake Borgne. As explained in the footnotes to the table, lagged averages have been used because both river discharge and wind take some time to effect major changes in salinity.

The isopleths for salinity of Lake Borgne plotted against these two variables are shown in figure 7. At low wind intensity from the north and northeast, there is a strong negative relationship between the discharge of the Pearl River and the resulting salinity in Lake Borgne. At higher wind intensities, the salinity rises considerably above the

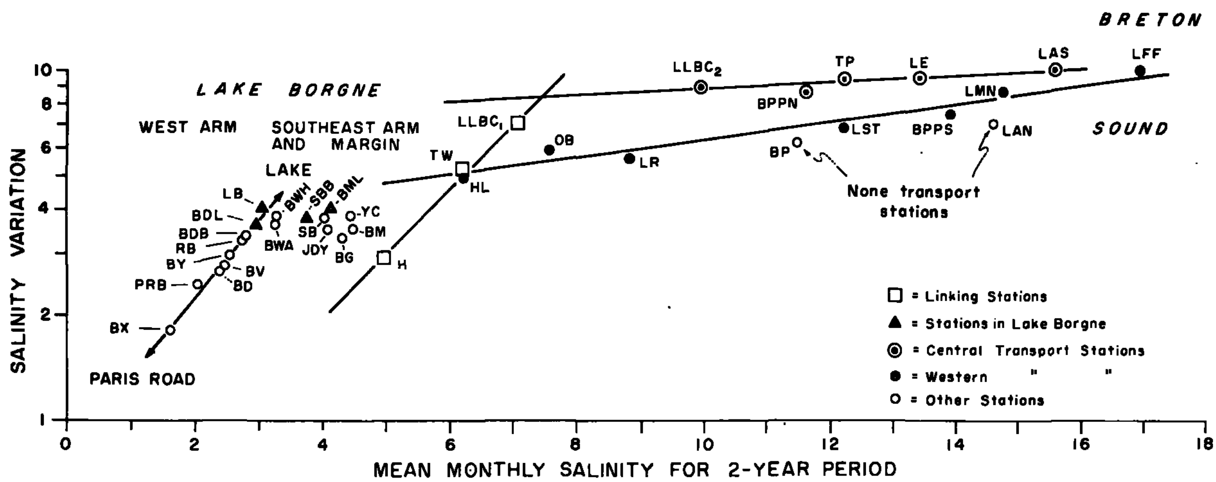

FIGURE 6.—Showing the variation in salinity in relation to mean salinity. The higher variation along the central transport route is indicative of a greater exchange of water through this system than through the western route.

Table 6.—*Factors influencing salinity of Lake Borgne*

Date	Fresh water: Pearl River discharge: Month listed	Fresh water: Pearl River discharge: Lagged average [3]	Wind: Wind intensity [1]: Month listed	Wind: Wind intensity [1]: Lagged average [4]	Salinity of Lake Borgne [2]
1959	*Thousand c.f.s.*	*Thousand c.f.s.*			‰
February	18.86	----	----	----	----
March	10.51	----	----	----	----
April	10.86	12.32	71.7	(71.7)	3.28
May	7.93	9.62	22.9	39.2	3.54
June	9.05	8.96	31.1	28.3	2.54
July	4.29	6.92	17.2	21.8	2.43
August	3.01	4.73	41.3	33.3	2.28
September	2.66	3.13	69.2	59.9	[5] (2.18)
October	3.18	2.94	121.8	104.3	5.78
November	4.44	3.58	121.4	121.5	4.60
December	6.99	5.21	60.1	80.5	3.64
1960					
January	11.50	8.28	86.2	77.5	3.41
February	20.91	14.36	57.6	67.1	2.54
March	24.48	20.46	71.4	66.8	2.08
April	9.47	17.76	45.3	54.0	1.56
May	9.95	12.66	50.4	48.7	1.79
June	2.27	6.78	31.0	37.5	2.46
July	1.85	3.64	42.4	38.6	4.04
August	4.30	2.91	26.2	31.6	4.40
September	2.39	3.05	96.5	73.1	5.22
October	1.88	2.57	58.1	71.9	4.19
November	2.06	2.05	96.1	83.4	3.83
December	2.39	2.16	83.8	87.9	6.72
1961					
January	7.41	4.33	----	----	5.68
February	22.75	12.54	----	----	3.82
March	39.47	26.37	----	----	2.61

[1] Number of days times mean speed in knots.
[2] For stations BDL, BWH, SBB, and BML.
[3] Average for a period including month listed, previous month and half of second preceding month.
[4] Average for 6-week period, derived from average of month listed and half of preceding month's average times ¾. Data are for New Orleans airport from U.S. Weather Bureau.
[5] Unreliable, only 2 salinity observations for Lake Borgne.

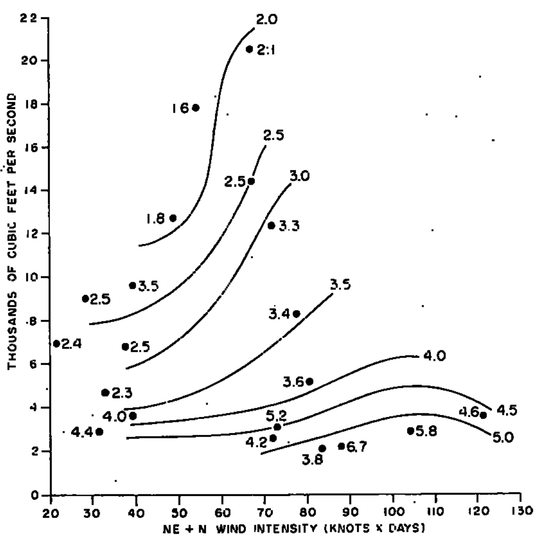

Figure 7.—Salinity isopleths in Lake Borgne under varying conditions of wind intensity and Pearl River discharge.

level dictated by river discharge. This is shown by the steep slope of the isopleths.

It would appear that the north and northeast direction of the wind causes intrusion into Lake Borgne of the more saline water of Mississippi Sound.

SUMMARY OF HYDROGRAPHY

In concluding the discussion of hydrography, several points can be noted:

1. Exchange between the low salinity waters of Lake Borgne and the higher salinity waters of Breton Sound takes place by three routes, the central route appears to carry more water than the western route.
2. Large, short-term fluctuations in salinity are especially pronounced in the bayous that form part of the water exchange route.
3. During the 24-month period of study, salinity trends at Hopedale were independent of season.
4. Salinity levels in Lake Borgne are controlled chiefly by fresh-water input (for which we used the discharge of the Pearl River) modified by wind direction and speed.
5. Pearl River discharge and wind intensity both require time to significantly affect salinities in the western end of Lake Borgne. This time lag appears to be several weeks for river discharge and about 2 weeks for wind intensity.
6. Salinity in areas 1 to 3 and the portion of area 4 from Bayou La Loutre northward is dominated by Lake Borgne salinity.

BIOLOGY

BIOLOGICAL SAMPLING

Biological sampling was carried out at selected stations since it was not considered feasible to collect at all stations. One of the major changes that could occur from the channel construction would be a change, probably a raising, in salinity levels. Therefore, it was decided to make collections in three areas that possessed relatively low, medium, and high salinity ranges. The mean bimonthly salinities for the stations actually sampled are given in table 7. It will be noted at once that hydrographical areas 4 and 5 shown in figure 1 were not sampled. Two-thirds of all of the otter trawl tows (the principal gear used) were made in areas 1 to 3 all of which are low salinity areas dominated by Lake Borgne.

TABLE 7.—*Mean bimonthly salinities in areas of biological sampling during periods actually sampled*

[Parts per thousand]

Date	Areas and stations						
	1	2a	2b	3	6	7	8
	BD, RB, BDB	BDL, LB	SBB, BML	BM, BG, JDY	BPPN[1]	LAS, LAN, LMN[2]	LFF[3]
1959							
June–July	1.59	1.85	3.02	3.48	13.86	-------	-----
August–September	1.57	1.78	2.56	2.61	-------	-------	-----
October–November	3.64	4.32	5.76	5.58	10.28	14.00	-----
December–January	2.77	2.76	3.84	3.91	10.20	13.19	14.73
1960							
February–March	1.60	1.73	2.52	2.66	6.96	11.41	13.06
April–May	1.30	1.28	1.91	2.60	10.00	13.10	13.74
June–July	2.41	2.69	3.98	5.19	17.48	19.96	21.66
August–September	4.27	5.03	5.06	5.36	11.50	13.74	15.84
October–November	3.48	3.78	4.10	4.15	9.04	9.50	10.70
December–January	4.81	5.67	6.46	6.32	11.68	16.79	21.56
1961							
February–March	2.09	2.60	3.82	4.86	11.74	13.85	15.87
Monthly average	2.63	3.00	3.94	4.29	11.61	14.98	16.96

[1] Also samples from adjacent stations BE, LEW, and BLP during July, 1959.
[2] Also samples from LAW in October and November, 1959.
[3] Also samples from GPT from October 1960 to March 1961.

The number of otter trawl tows made in each area at different bimonthly salinities are shown in figure 8 and table 8. This concentration of biological sampling at one extreme of the salinity range has decreased the reliability of any prediction of the effects of moderate changes in salinity. Thus, table 7 shows no biological sampling in areas 4 and 5 leaving a gap between area 3 with an average salinity of 4.3‰ and area 6 with an average of 11.6‰.

TABLE 8.—*Sampling effort by otter trawl in each area*

[Number of 10-minute tows]

Date	Area						
	1	2a	2b	3	6	7	8
1959							
June–July	9	2.7	2	8	13.5	------	------
August–September	3	1	1	3	------	------	------
October–November	18	6	6	17.8	6	18.3	------
December–January	23	15.4	8	24.9	8	13	3
1960							
February–March	8.7	16	5	19	9	21	7
April–May	16.6	12	11	17.9	6	18	6
June–July	18	12	12	17.9	6	18	5
August–September	15	10	7	15	5	12	5
October–November	12	8	8	12	4	8	8
December–January	12	8	8	12	4	8	12
1961							
February–March	12	8	8	12	4	8	12
Total	147.3	99.1	76.0	159.5	65.5	124.3	58.0

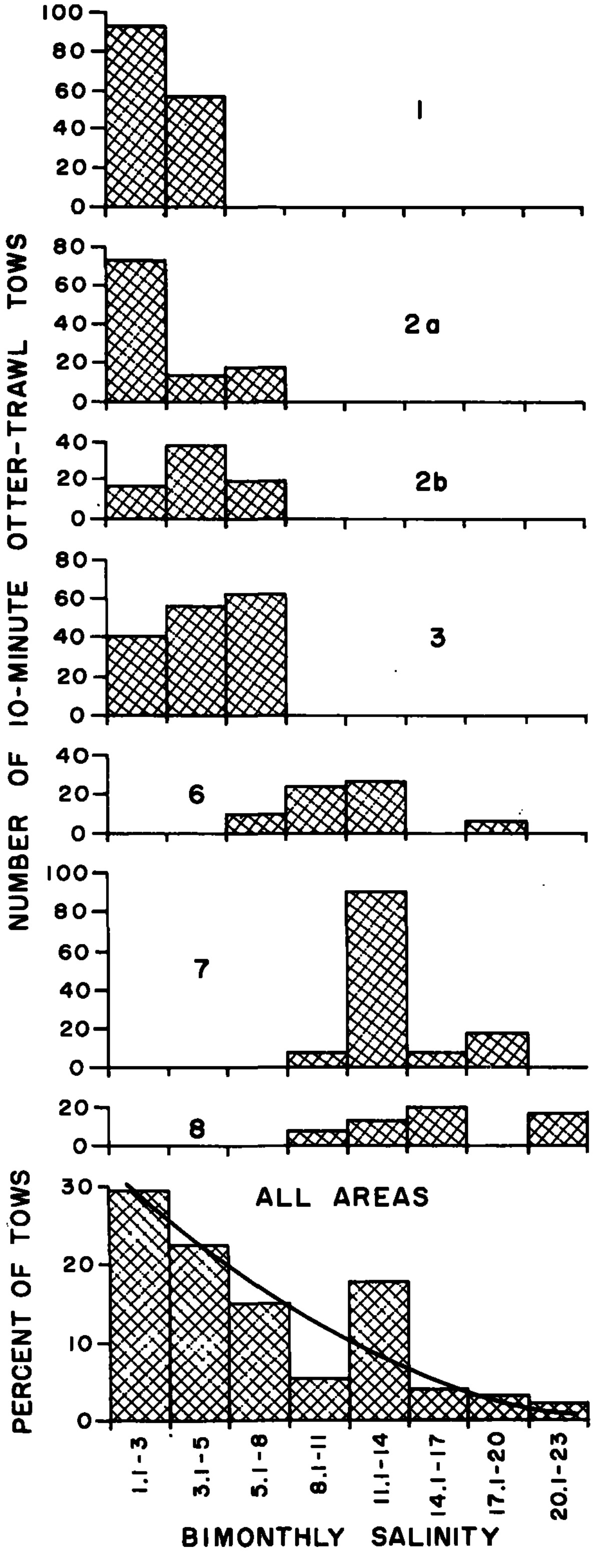

FIGURE 8.—Number of 10-minute otter trawl tows by the area and prevailing bimonthly salinity. The lower salinity sites are heavily oversampled.

GEAR

Several types of biological sampling gear were employed, but only the otter trawl could be called successful. The net measures 200 inches (16⅔ feet) across the headrope and 212 inches (17⅔ feet) along the footrope. The all cotton net has 9-thread 1¼-inch mesh, stretched measure, except for the cod end which has 12-thread 1⅛-inch mesh. The otter boards measure 10½ inches vertically by 24 inches horizontally by 1 inch in thickness with a steel reinforcing strap along the front and bottom edges. The boards were fastened directly to the ends of the wings. A galvanized iron chain, 13 links to the inch, and 18 feet long was suspended from the footrope. Four 3½-inch corks were attached to the headrope. The net was towed by two 75 foot lengths of ⅝-inch manila rope attached to a single warp.

A small net, described as a try net, was also used. It consisted of a triangle of ⅛ inch mesh nylon netting, 3 feet across the bottom in front, and attached to a 1½-inch, 3-foot length of galvanized pipe. The catch consisted chiefly of slow-moving forms such as larval and very small juvenile fishes. Catches were insufficient for making any quantitative analysis.

A larger cone of the same description was used in two ways; either attached to a 6-foot length of 2⅜-inch galvanized pipe, or attached to a rectangular pipe frame about 4½ feet wide and 13 inches high mounted on runners. Neither gear was used enough to provide sufficient material for analysis.

The small dredge used to collect mollusks had a mouth opening of only 16 inches. The bag was ¼-inch wire screen. The dredge when new had long teeth soldered onto the front blade. Through use the teeth were completely worn away, thus seriously biasing any quantitative comparisons.

Plankton tows were taken with a ½-meter net, but plankton volumes were not measured.

EFFECT OF SALINITY ON FISH DISTRIBUTION

One simple basis for predicting changes in fauna that might occur with any major changes in salinity is to determine the ranges of salinity in which various species of fish are found in reasonable numbers. The numbers of each species caught by otter trawl are shown in table 9. The numbers taken in each area are influenced by the number of tows made. To discount this variable, the total number of each species taken was distributed between areas on the basis of the number of tows. This gives the "expected" number that would be caught if tows alone were the deciding factor (ignoring for the moment, because of the paucity of sampling and low number involved, such other factors as seasonal occurrence). Determining the ratio of the observed to this expected number in each area and then comparing the ratios for all areas gives a rough measure of the areal distribution of each species.

The resulting relative abundance in numbers of all species of which 20 or more were taken by otter trawl is shown by area in table 10 and figure 9. The lack of samples from hydrographic areas 4 and 5 leaves a gap between the low salinity areas 1 to 3 and the higher salinity areas 6 to 8. It is quite obvious, however, that several species are confined to waters of low salinity; others to waters of higher salinity; with a larger number of species lying between that can apparently tolerate a fairly wide range of salinity.

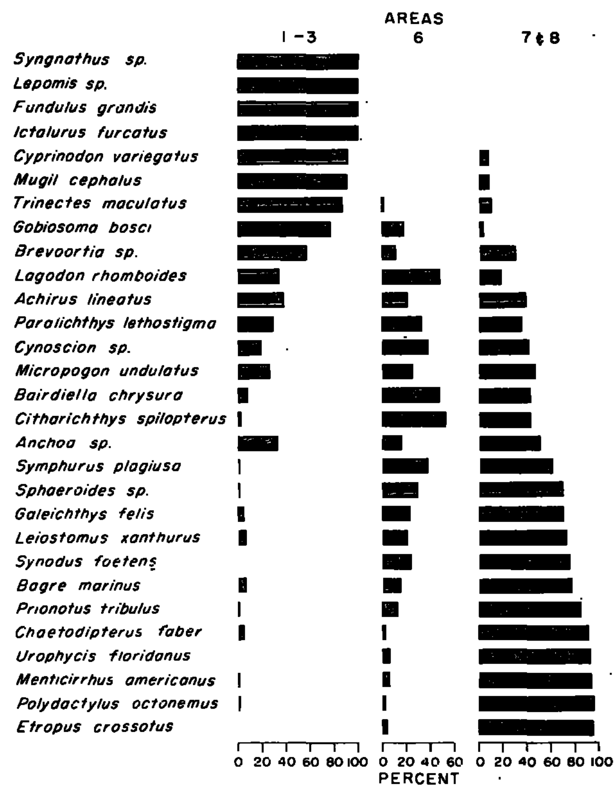

FIGURE 9.—Relative density of 29 species of fish in waters of low (areas 1–3), medium high (area 6), and high salinity (areas 7 and 8).

TABLE 9.—*Fish taken by otter trawl shown by species and area of capture*

[Number of fish]

Common name	Scientific name	Area of capture							
		1	2a	2b	3	6	7	8	Total
Spot	Leiostomus xanthurus	175	425	694	669	855	2,163	1,533	6,514
Croaker	Micropogon undulatus	547	1,518	581	320	375	449	311	4,101
Anchovy	Anchoa sp	515	853	511	529	166	156	361	3,091
Sea trout	Cynoscion sp	147	179	167	57	150	135	73	908
Blue catfish	Ictalurus furcatus	629	2	3	1	0	0	0	635
Sunfish	Lepomis sp	5	0	0	722	0	0	0	727
Hogchoker	Trinectes maculatus	206	258	46	35	2	8	4	559
Menhaden	Brevoortia sp	237	172	18	73	13	9	26	548
Sea catfish	Galeichthys felis	26	85	16	10	78	217	100	532
Fringed flounder	Etropus crossotus	0	0	0	0	11	133	146	290
Pinfish	Lagodon rhomboides	3	155	10	25	35	18	3	249
Spotfin whiff	Citharichthys spilopterus	2	22	9	2	83	57	34	209
Striped sole	Achirus lineatus	32	71	30	17	11	20	8	189
Eight-fingered threadfin	Polydactylus octonemus	0	4	12	0	4	65	86	171
Gulf killifish	Fundulus grandis	2	0	0	157	0	0	0	159
Puffer	Sphaeroides (3 species)	0	1	2	0	30	95	19	147
Silver perch	Bairdiella chrysura	7	8	17	21	42	29	19	143
Gafftopsail catfish	Bagre marinus	2	0	25	11	13	46	32	129
Sea robin	Prionotus tribulus	3	3	4	1	13	40	57	121
Spadefish	Chaetodipterus faber	2	2	2	8	1	20	22	57
Southern flounder	Paralichthys lethostigma	10	8	5	16	6	6	3	54
Lizardfish	Synodus foetens	0	1	0	0	9	23	11	44
Sheepshead minnow	Cyprinodon variegatus	1	0	0	41	0	1	0	43
Striped mullet	Mugil cephalus	2	0	0	39	0	1	0	42
Pipefish	Syngnathus sp	3	1	3	29	0	0	0	36
Naked goby	Gobiosoma bosci	4	2	1	27	1	1	0	36
Tonguefish	Symphurus plagiusa	0	1	0	0	11	13	11	36
Southern hake	Urophycis floridanus	0	0	0	0	2	13	19	34
King whiting	Menticirrhus americanus	1	0	0	0	1	12	9	23
Sheepshead	Archosargus probatocephalus	2	3	3	8	1	0	0	17
Threadfin shad	Dorosoma petenense	7	0	0	0	0	1	8	16
Cutlassfish	Trichiurus lepturus	0	0	1	0	2	8	5	16
Stingray	Dasyatis sabina	0	0	0	1	4	4	3	12
Sharp-tailed goby	Gobionellus hastatus	0	0	0	2	1	5	2	10
Toadfish	Opsanus beta	0	0	0	4	1	4	0	9
Miscellaneous species		22	3	4	27	12	12	26	106

TABLE 10.—*Relative abundance of principal species of fish according to areas taken*

Species	Areas			
	1–3	6	7	8
Ictalurus furcatus	100.0	0.0	0.0	0.0
Lepomis sp	100.0	.0	.0	.0
Fundulus grandis	100.0	.0	.0	.0
Syngnathus sp	100.0	.0	.0	.0
Cyprinodon variegatus	91.5	.0	8.5	.0
Mugil cephalus	91.3	.0	8.7	.0
Trinectes maculatus	87.6	2.4	4.7	5.3
Gobiosoma bosci	78.5	18.2	3.3	.0
Brevoortia sp	58.7	11.5	4.3	25.5
Achirus lineatus	39.9	21.6	20.9	17.6
Lagodon rhomboides	35.0	47.6	12.9	4.5
Paralichthys lethostigma	30.4	33.8	18.9	16.9
Micropogon undulatus	27.7	26.0	21.9	24.4
Cynoscion sp	19.8	39.4	19.0	21.8
Anchoa sp	33.1	16.9	8.4	41.6
Bairdiella chrysura	8.3	48.0	18.0	25.7
Citharichthys spilopterus	3.1	53.2	19.3	24.4
Symphurus plagiusa	.4	38.4	22.7	38.4
Galeichthys felis	5.7	23.9	35.4	34.9
Sphaeroides sp	.4	29.9	49.2	20.5
Leiostomus xanthurus	6.7	21.3	28.5	43.5
Synodus foetens	.3	24.4	35.6	39.7
Bagre marinus	6.6	15.8	30.6	46.9
Prionotus tribulus	1.6	13.2	21.3	63.9
Menticirrhus americanus	.9	6.2	37.2	55.8
Chaetodipterus faber	5.3	2.9	28.7	63.1
Urophycis floridanus	.0	7.3	23.7	69.0
Polydactylus octonemus	1.6	3.1	25.5	69.9
Etropus crossotus	.0	4.4	28.6	67.0
Bimonthly salinity (see table 7):				
Low	1.28	6.96	9.50	10.70
High	6.46	13.86	19.96	21.66
Average	3.48	11.61	14.98	16.96

In figure 9, an attempt has been made to rank the species of fishes in order of their preference from low to high salinity as shown by their relative abundance in the areas depicted.

That errors can easily creep into this type of reasoning is illustrated by the fact that *Mugil cephalus* and *Brevoortia* sp. appear from the figure to be most abundant in waters of low salinity. Actually, this is possibly the case for the juveniles, which were easily captured in the small mesh trawl, but not true for the adults, which could usually escape the trawl. Barring such unusual circumstances, the order of ranking probably represents a fair approximation of the relative effect of salinity on the abundance of these species.

In considering further the subject of salinity tolerance it will be noted from table 9 that no *Lepomis* sp. or *Fundulus grandis* were taken in Lake Borgne (areas 2a and 2b). All but a very few were taken at the stations in area 3 (BM, BG, and JDY). Their occurrence at these stations was highly erratic; 146 out of 159 *Fundulus* were captured in a single haul. This causes me to speculate that these two predominately fresh-water species were living chiefly in some of the diked marsh areas; some occasionally escaping into the surrounding bayous, the salinity of which, during portions of the year, could be tolerated by them.

FISH DENSITY BY AREA

An important question is how productive in finfish were the areas with different salinity levels. To answer this I show in table 11 the catch per tow in numbers and in biomass of five selected species, namely, spot, croaker, anchovy, sea trout, and menhaden. These five species were selected because of their widespread distribution, their high level of abundance, and their economic importance. Although the anchovy is not utilized directly, it is by far the most important forage fish in the area. Out of 20,013 trawl-caught fish (table 9), 15,162 or 76 percent belonged to this selected group.

TABLE 11.—*Number and biomass of selected fishes by area and season* [1]

Date	1 and 2a	2b and 3	6	7 and 8	Sum
	Biomass per tow (in grams)				
1959					
October–November	190.3	61.9	242.6	204.0	699.1
December–January	140.0	20.0	130.4	39.0	329.4
1960					
February–March	77.7	12.9	21.8	5.9	118.3
April–May	210.3	218.6	184.6	351.0	964.5
June–July	120.4	406.6	504.7	431.8	1463.5
August–September	148.6	58.4	53.4	442.9	703.3
October–November	113.4	162.8	336.0	308.5	920.7
December–January	306.0	55.8	183.9	399.0	944.7
1961					
February–March	130.4	101.3	204.1	162.9	598.7
Average	159.7	122.0	206.9	260.6	--------
	Numbers per tow (5 cm. and over in length)				
1959					
October–November	12.5	2.4	15.2	9.6	--------
December–January	5.3	0.8	7.6	1.5	--------
1960					
February–March	13.7	1.7	2.6	1.5	--------
April–May	41.6	42.0	28.0	73.2	--------
June–July	17.5	38.1	78.8	56.1	--------
August–September	6.6	4.8	3.4	32.4	--------
October–November	5.9	8.5	16.0	12.9	--------
December–January	14.3	3.6	10.3	16.9	--------
1961					
February–March	15.7	9.8	13.8	12.5	--------
Average	14.8	12.4	19.5	24.1	--------

[1] Includes spot, croaker, anchovy, sea trout, and menhaden.

The numbers of fish per tow in table 11 are those of individuals 50 mm. or more in length. Smaller fish were captured in all areas, but because of the selectivity of the otter trawl mesh they were not captured consistently and so have been omitted.

The biomass per tow could only be obtained by estimation from the lengths of the fish, as weights were not taken. From length-weight data collected by C. R. Mock in Galveston Bay it was possible to estimate roughly what individual fish in each 5-cm. category should weigh during each 2-month period. The rough estimate of individual weight used in grams is:

Months	Fish lengths (cm.)			
	0–5	6–10	11–15	16 and more
February–March	1	2	27	74
April–May	1	4	24	70
June–July	1	6	15	66
August–September	1	9	18	55
October–November	1	12	21	66
December–January	1	12	24	72

In figure 10 are shown the estimated biomass (top) and the numbers of fish of 5 cm. and over (bottom), by area and bimonthly period. In both numbers and biomass the Lake Borgne and adjacent areas (1 through 3) were less productive than areas 6 through 8.

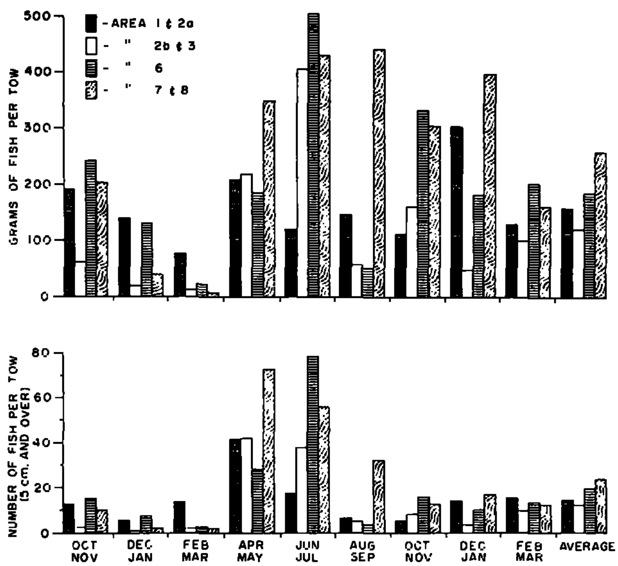

FIGURE 10.—Numbers and biomass of five selected species of fish by area and season.

CRUSTACEA

Enumerations and measurements were made of brown, white, and pink shrimp, and of blue crabs taken in the otter trawl samples. Only 122 pink shrimp were recorded; all were taken during the last 6 months of the 24-month period. One may speculate that during the earlier months more may have been caught that were classified as brown shrimp.

Out of 9,187 shrimp of all sizes taken, only 419 under 50 mm. were retained by the otter trawl, or 4.6 percent. By contrast 3,059 out of 5,200 blue crabs, or 58.9 percent were under 50 mm. The catch per unit of sampling effort for shrimp of 50 mm. and over is shown in table 12 and in figure 11 for the 18-month period from October 1959 to March 1961. In contrast with the white shrimp, few brown shrimp over 100 mm. were caught. This reflects the Gulf-wide behavior of brown shrimp, which leave the protected waters for the Gulf at a smaller size than do the white shrimp.

There appears to be little salinity preference. Brown shrimp below 100 mm. were taken in all areas. White shrimp below 100 mm. were abundant in three areas, but very scarce in the open waters of Lake Borgne, and only moderately abundant in the rather open waters of areas 7 and 8. Young white shrimp thus appear to prefer shoal, protected waters.

Shrimp are transient residents of the marsh areas. Figure 12 shows the bimonthly catch per 10 tows of white and brown shrimp 50 mm. and over. From December through March, shrimp are almost nonexistent in the areas. Brown shrimp appear in April and May and quickly increase in numbers. By the end of July the numbers of brown shrimp are falling rapidly as the larger sizes emigrate to the Gulf. The peak of abundance for white shrimp comes from 1 to 2 months later.

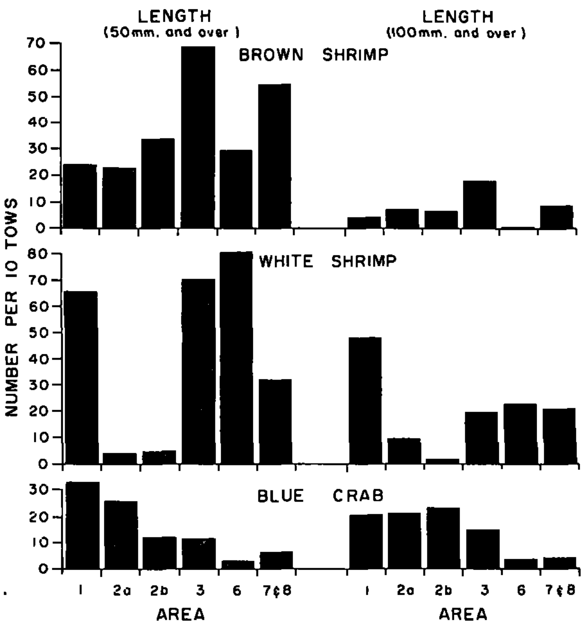

FIGURE 11.—Average catches by size of brown and white shrimp, and blue crabs, per 10 tows by area for the 18-month period, October 1959 to March 1961.

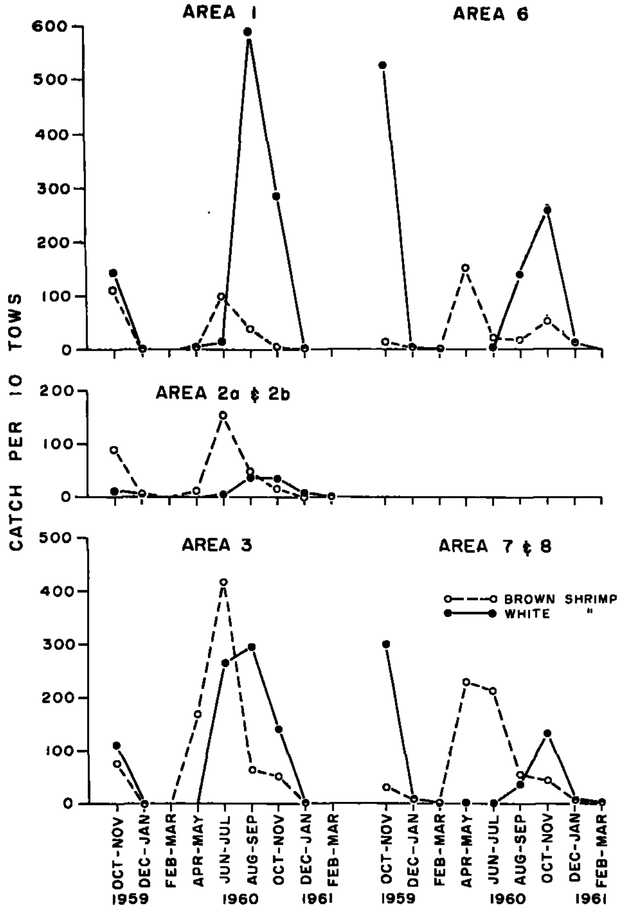

FIGURE 12.—Catches of brown and white shrimp per 10 tows by area and bimonthly period.

Blue crabs between 50 and 100 mm. (fig. 11) became progressively less abundant as salinity increased. The larger blue crabs (100 mm. and over) were about equally abundant in all of the areas bordering Lake Borgne, but like the smaller sizes they were scarce in areas 6 through 8. Mature female crabs are known to migrate considerable distances in a matter of a few days to reach higher salinity water for spawning (Fiedler, 1930). Salinities ranging from 23°/oo to 30°/oo were found by experiment to be optimal for hatching of blue crab eggs (Sandoz and Rogers, 1944). To

TABLE 12.—*Number of shrimp caught per 10 tows of an otter trawl*

Date	Area											
	1		2a		2b		3		6		7	8
	Length of shrimp (millimeters)											
	50–99	100 and more	50–99	100 and more	50–99	100 and more	50–99	100 and more	50–99	100 and more	50–99	100 and more
	BROWN SHRIMP											
1959												
October–November	111.7	-------	53.3	-------	121.7	3.3	76.4	2.2	16.7	-------	30.0	1.1
December–January	1.7	-------	0.6	-------	1.3	-------	0.8	-------	1.3	-------	7.5	-------
1960												
February–March	-------	-------	-------	-------	-------	-------	-------	-------	3.3	-------	2.9	-------
April–May	6.6	-------	3.3	-------	17.5	0.9	166.5	1.1	151.7	-------	226.3	2.9
June–July	71.7	25.6	94.2	38.3	127.5	46.7	288.8	129.6	21.7	-------	173.9	38.3
August–September	26.7	10.7	36.0	26.0	27.1	5.7	44.0	20.0	18.0	-------	20.0	33.5
October–November	2.5	2.5	21.3	1.3	8.8	1.3	40.0	12.5	47.5	2.5	36.9	3.8
December–January	0.8	0.8	-------	-------	2.5	-------	3.3	-------	7.5	-------	3.0	-------
1961												
February–March	-------	-------	-------	-------	1.3	-------	-------	-------	-------	-------	0.5	-------
Average	24.6	4.4	23.2	7.3	34.2	6.4	68.9	18.4	29.7	0.3	55.7	8.8
	WHITE SHRIMP											
1959												
October–November	93.9	50.6	8.3	-------	11.7	3.3	77.5	34.3	508.3	16.7	232.2	64.3
December–January	0.9	-------	1.3	-------	1.3	-------	-------	-------	3.8	-------	3.8	-------
1960												
February–March	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
April–May	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	0.8	-------
June–July	16.1	0.6	9.2	1.7	5.0	-------	262.0	3.9	1.7	-------	0.9	-------
August–September	365.3	223.3	12.0	45.0	17.1	4.3	236.0	60.0	98.0	40.0	11.8	23.5
October–November	118.3	163.3	6.3	41.3	10.0	8.8	56.7	85.0	107.5	152.5	30.6	102.5
December–January	-------	-------	1.3	-------	-------	-------	1.7	-------	10.0	-------	9.5	-------
1961												
February–March	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	2.0	1.5
Average	66.1	48.7	4.3	9.8	5.0	1.8	70.4	20.4	81.0	23.2	32.4	21.3

reach water of such salinity the female crabs in the project area would need to move at least as far as either Chandeleur Sound or Mississippi Sound. Darnell (1959) collected spawning females in Chandeleur Sound and the eastern end of Lake Borgne in a salinity range of 19.2°/oo to 31.5°/oo.

Pearson (1948) says that the young blue crabs hatched in Chesapeake Bay begin to migrate toward brackish water and that this migration, halted by cold weather, is resumed in the spring. In the project area (table 13) crabs under 50 mm. are most abundant in winter (December through March). This difference between localities may be caused by the milder southern winters.

Since small blue crabs (under 50 mm.) were retained in large numbers by the otter trawl it is possible to arrive at some estimate of their abundance seasonally and by area (table 13 and figure 13). These very small crabs (under 50 mm.) are most abundant in the winter and early spring and extremely scarce from June through September. They are abundant in the open (and low salinity) waters of Lake Borgne, and scarce in the semi-open (and moderately high salinity) waters of areas 6 to 8. Although crabs of this small size were not particularly abundant in areas 1 and 3, the slightly larger crabs (50–99 mm.) were more abundant in the low salinity waters of area 1 than in Lake Borgne. This seems to indicate a migration of these smaller crabs toward shallow and low salinity areas as they grow.

SUMMARY OF BIOLOGY

1. Only the otter trawl samples are sufficiently extensive and consistent to warrant quantitative treatment.
2. Lack of samples in areas of intermediate salinities (areas 4 and 5) precludes any precise conclusions regarding the effect on the fauna of salinity changes.
3. The bulk of the fish species taken were euryhaline. This included the species caught in greatest abundance.

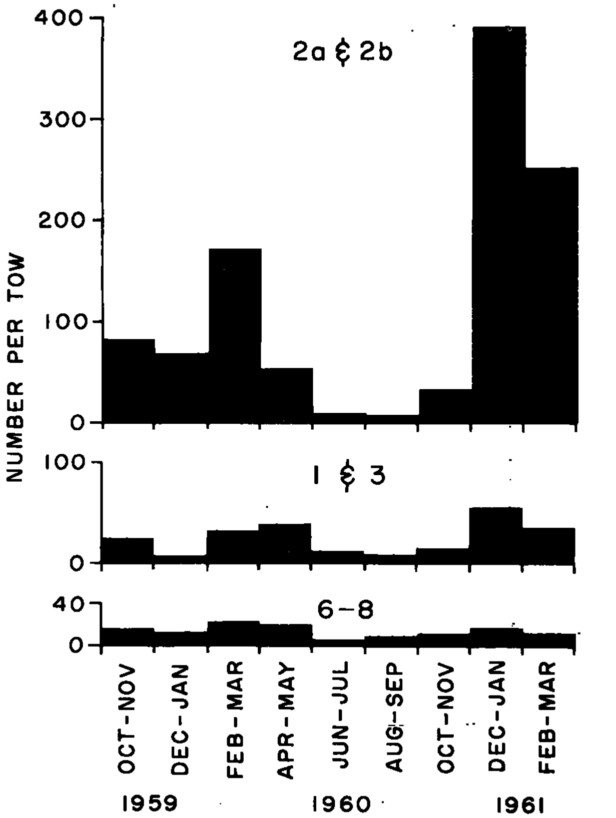

FIGURE 13.—Catches of very young blue crabs (under 50 mm.) by area and bimonthly period.

4. Seventy-six percent of the fish taken were of only five species.

5. In both numbers and biomass these five species were more abundant in areas 6 to 8 than in areas 1 to 3.

6. Neither brown nor white shrimp showed any significant salinity preference.

7. Smaller white shrimp were less abundant in open waters than in the shoal marshes.

8. From December through March shrimp are almost absent from the project area.

9. Smaller blue crabs (50 to 100 mm.) were most abundant in area 1 decreasing progressively to area 3; they were scarce in areas 6 through 8.

10. Larger blue crabs (100 mm. and larger) were about equally abundant throughout areas 1 to 3; but scarce in areas 6 through 8.

DISCUSSION

The Gulf outlet channel will apparently have some effect on the hydrography of the project area. Most probably the chief effect will be a raising of the salinity. This may be accomplished in three ways, first, by mixture of channel water with that of the surrounding bayous through intersection points. Secondly, by raising of the salinity in Lake Pontchartrain through movement of the denser and more saline water from the deeper layers of the channel into the lake. The higher salinities in Lake Pontchartrain would in turn raise salinities in Lake Borgne. The third means of raising salinities would be through the effect of the occasional abnormally high tides which would

TABLE 13.—*Number of blue crabs caught per 10 tows of an otter trawl*

Date	Area																	
	1			2a			2b			3			6			7 and 8		
	Length of crabs (millimeters)																	
	0-49	50-99	100 and more	0-49	50-99	100 and more	0-49	50-99	100 and more	0-49	50-99	100 and more	0-49	50-99	100 and more	0-49	50-99	100 and more
1959																		
October-November	37.2	31.7	12.8	88.3	53.3	3.3	73.3	6.7	23.3	11.2	12.9	22.5	8.3	1.7	5.0	23.5	2.2	3.3
December-January	13.0	24.8	2.2	108.4	7.1	19.5	27.5	13.8	37.5	2.8	21.7	19.3	11.3	------	------	12.5	5.6	1.9
1960																		
February-March	62.1	13.8	1.1	321.3	5.6	8.8	20.0	------	6.0	3.2	3.7	3.2	3.3	------	------	44.3	2.5	0.7
April-May	39.8	46.4	15.7	61.7	25.8	21.7	45.5	21.8	20.0	37.4	14.5	20.1	6.7	5.0	1.7	32.9	15.8	4.2
June-July	7.8	21.7	16.7	4.2	21.7	21.7	10.0	21.7	21.7	17.3	8.9	7.3	5.0	15.0	10.0	1.7	7.0	7.0
August-September	8.7	34.0	29.3	8.0	34.0	49.0	1.4	2.9	24.3	7.3	12.0	6.7	10.0	2.0	8.0	------	6.5	5.3
October-November	24.2	42.5	39.2	23.8	17.5	30.0	40.0	11.3	20.0	7.5	10.8	27.5	17.5	5.0	10.0	6.9	14.4	10.0
December-January	81.7	34.2	22.5	613.8	23.8	13.8	165.0	23.8	36.3	26.7	14.2	20.8	27.5	2.5	2.5	4.0	6.5	2.5
1961																		
February-March	55.0	50.0	48.3	277.5	46.3	27.5	227.5	11.3	22.5	14.2	10.8	10.0	15.0	2.5	------	10.5	2.0	6.5
Average	36.6	33.2	20.9	167.4	26.1	21.7	67.8	12.6	23.5	14.2	12.2	15.3	11.6	3.7	4.1	15.1	6.9	4.6

be heightened by the close proximity of highly saline water in the channel.

The effect of the Gulf outlet channel on the salinity in Lakes Pontchartrain and Borgne has been studied in a large model at the Waterways Experiment Station, Vicksburg, Miss. The fishery aspects of these experiments have been reported upon by the Bureau of Sport Fisheries and Wildlife.[3]

This report shows that salt-water intrusion in the Gulf outlet channel will be severe. With the outlets to Lake Pontchartrain partially closed by hurricane protection structures but with no control in the Gulf outlet channel the model indicates (their figure 3) a rise in Lake Pontchartrain salinity of about 4.3 ‰ in years of high fresh-water inflow and about 5.5 ‰ for years of low inflow. The model indicates that this condition can be considerably corrected by placing control structures in the Gulf outlet channel where it intersects the Industrial Canal.

Heightened salinities in Lake Pontchartrain will in turn raise salinities in Lake Borgne by 1 ‰ to 2 ‰. However, the marsh lying between Lake Borgne and the channel instead of being dominated by Lake Borgne will now have direct and easy access to the waters of the Gulf. Thus the model studies indicate that under the best conditions of control of channel flow into Lake Pontchartrain (lowest salinities occurred in the model when channel flow was 60 percent of capacity) the salinity in the channel at a point close to station BWA was about 12 ‰ at a depth of 6 feet and about 26 ‰ at a depth of 12 feet.

Obviously, this marsh area (1 and 3) with a preproject salinity of about 2 ‰ to 5 ‰ is due for a pronounced rise in salinity.

The portions of the project area lying south of the channel will also experience a rise in salinity. Before the project, water from Lake Borgne and from Breton Sound was exchanged through the bayou systems resulting in the long-term salinity gradients shown in figure 5. With the project completed, water from Lake Borgne can reach this southerly portion of the project area only by crossing the wide channel at the few intersection points. Obviously, the future exchange of Lake Borgne water with the water south of the channel will be very limited, and it will be mixed with channel water. Therefore, the areas southwest of the channel may be expected to experience a rise in salinity to a level higher than the portions of the project area between the channel and Lake Borgne.

Since the channel extends entirely across Breton Sound into the open Gulf the channel may have some elevating effect on the salinities in Breton Sound itself.

It is too soon to predict the final salinity changes engendered by the project, but it would appear that salinities in the project area with the optimum control of exchange at the northern end of the Gulf outlet channel will rise about 2 ‰ in Lake Borgne and at least 5 or more parts per thousand in the remainder of the project area.

The effect on the vertebrate fauna of such a rise in salinity will not necessarily be drastic. The principal species of fish in the area are obviously euryhaline, and of the remaining species, the majority are more adapted to higher than to lower salinities.

The brown shrimp shows no obvious salinity preference. The salinity preference of the white shrimp is somewhat obscured by the fact that the smaller juveniles apparently avoid the more open waters in favor of the shoal, protected marshes. On the whole the white shrimp may suffer some loss of what has been desirable nursery area, especially where the salinity rises appreciably above the 14 ‰ isohaline now separating areas 6 and 7.

The younger stages of the blue crab are now most abundant in the least saline waters (area 1), decreasing progressively and significantly as salinity increases toward area 3. Both young and adult crabs are scarce in areas 6 to 8. A rise in salinity should have an adverse effect on the abundance of crabs.

It is highly probable that a general rise in salinity will seriously affect the growing of oysters. Oyster beds, especially those used for collecting seed oysters, can be extensively harmed by only a slight rise in salinity, especially if it occurs when the salinity is at the borderline between suitability and unsuitability for oyster drills. Conversely, a rise in salinity may make some areas suitable for oyster growing where previously the average salinities have been consistently too low for successful oyster culture.

[3] A detailed report on Hurricane Study Area No. 1: Lake Pontchartrain and vicinity, Louisiana. 32 p., 1 map, 9 figs., processed (issued in 1962 by Region 4, Bureau of Sport Fisheries and Wildlife, Atlanta).

The idea that a possible benefit could offset damage to existing oyster beds is highly speculative.

In evaluating losses attributable to the project one must consider the value of the areas occupied by the channel and the resulting spoil. The Branch of River Basin Studies of the Bureau of Sport Fisheries and Wildlife has furnished careful measurements of these areas:

Acres occupied by the project

Original state	Channel	Spoil areas	Total
Open water	1,680	4,518	6,198
Marsh	4,868	12,540	17,408
Total	6,548	17,058	23,606

The above tabulation of project area between the Intracoastal Waterway and Breton Sound shows that it occupies 23,606 acres or 36.9 square miles. The portion originally designated as marsh includes such shallow marginal areas as are occupied by emergent vegetation. Much of the remainder of the marsh is under water during extreme tides, which occur especially during late summer. Thus, in addition to the 6,198 acres of open water a fair portion of the 17,408 acres of marsh must be considered as nursery area for shrimp, crabs, and juvenile fishes.

Since the channel itself will be open water (6,548 acres), there will be little change in the total surface of open water. However, the preproject open water consists of many shallow winding bayous that provide a very long shoreline adjacent to emergent vegetation—an ideal nursery area. The postproject open water is a deep channel along which the greatly reduced shoreline will be subjected to the constant wash of passing traffic. The shallow portions of the "marsh" areas bordering the bayous will be totally lost in the spoil areas.

The above losses of nursery habitat are permanent and irreplaceable.

It should be borne in mind that the effect of the project on the remainder of the area is not merely a narrowing of the coastwise belt of low salinity water. Such a situation would merely push the belt of marsh suitable for juvenile fauna farther inland. Instead, the channel carries saline water far inland so that Lake Pontchartrain will have higher salinity than Lake Borgne. Thus, fauna seeking to remain in the same salinity now prevailing in a large portion of the project area have lost the former bordering area of low salinity to which they could retreat.

This report is concerned wholly with the effect of the Gulf outlet channel on the commercial fisheries of the project area. The effects of salinity changes on the vegetation and directly or indirectly on waterfowl and furbearers is not touched upon.

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