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THE IMPACT OF THE 1973 FLOODING OF THE MOBILE RIVER SYSTEM ON THE HYDROGRAPHY OF MOBILE BAY AND EAST MISSISSIPPI SOUND [1]

by

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ABSTRACT: Hydrographic conditions in lower Mobile Bay and East Mississippi Sound are documented during two flooding intervals of the Mobile River System. The flooding river waters so dominated Mobile Bay that a near limnetic system prevailed for over 30 days except in the deeper areas. East Mississippi Sound was also greatly influenced by river waters, but to a lesser extent than Mobile Bay. Dissolved oxygen concentrations were decreased in both locations as flooding progressed. No significant temperature differences between flooding, estuarine or Gulf of Mexico waters were observed.

During March, April, and May, 1973, coastal Alabama (Fig. 1) was subjected to two periods of flooding from the Mobile River System. Figure 2 presents the daily average discharges of the Mobile River System[2] and illustrates the two flooding intervals. Utilizing Figures 32 and 33 in Pierce (1966), the first flooding period, with discharges of 9.5×10^3 m^3 sec^{-1}, is classified as a five-year flood, while the second period, with a maximum discharge of 7.5×10 m^3 sec^{-1}, was of a magnitude equivalent to the mean annual flood.

Recognizing the importance of understanding the impact that flooding of the Mobile River system has on Mobile Bay and Mississippi Sound, eleven hydrographic cruises were undertaken in these areas between April 16 and May 15, 1973 (Table 1). Specifically, the objective of these cruises was to document the extent of the river water influence on lower Mobile Bay and East Mississippi Sound.

Previous studies provide a limited picture. McPhearson (1971) presents

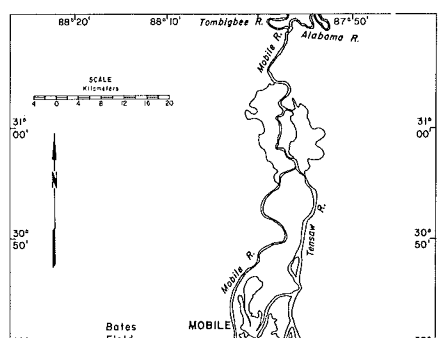

Figure 1. — Map of Coastal Alabama.

[1] Marine Environmental Sciences Consortium Contribution No. 020.

[2] Mobile River System discharges are computed using 1973 U.S. Geological Survey Surface Water Records (Alabama) of the flows of the Tombigbee River at Coffeeville (02469761), Alabama, and of the Alabama River At Claiborne (02429500), Alabama. To calculate the discharge of the System, the flows at these two gauging stations are added together and multiplied by 1.07. Because of the distance between Mobile Bay and these gauging stations, a lag period for transit time of five to nine days is needed.

average surface and bottom salinity patterns for the bimonthly period of highest river discharge (March-April) during his surveys of 1963-64 and 1965-66. Bault (1972) combines his data of 1968-69 with McPhearson's and also presents average bimonthly surface and bottom salinity patterns. No references to specific high or flood discharge intervals are made in either paper. May (1971) reviews the literature on the impact of floods on Alabama's oyster resources from 1893 through 1965. Also May (1972) reports on the effects of the 1970 and 1971 flood waters on oysters in Mobile Bay. Both of these publications only generalize on the hydrographic conditions. Salinity data for Mobile Bay during non-flooding periods can be found in McPhearson (1971), Bault (1972) and Schroeder (1976 & 1977).

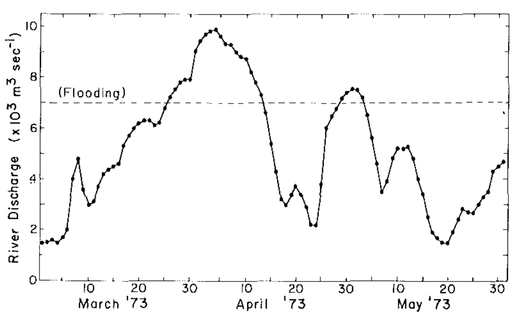

Figure 2. — Mobile River System daily average discharges. See footnote[2].

STUDY AREA

Mobile Bay is the terminus of the fourth largest river system, in terms of discharge, in the United States (Morisawa, 1968) and sixth largest on the North American Continent (Chow, 1964). The System (Fig. 1), commonly referred to as the Mobile River System is a complex one. It starts with the Mobile River, which is formed by the confluence of the Alabama and Tombigbee Rivers. The Mobile River flows as a single channel for only eight kilometers before it enters an old deltaic flood plain. The river then branches into three major distributary streams and numerous smaller ones. This complex network of channels extends southward for approximately 50 km to Mobile Bay. The average discharge of the System into the bay is approximately 1750 m^3 sec^{-1} and the 10 and 90 percentile discharges are approximately 4250 and 370 m^3 sec^{-1} (unpublished Mobile District U.S. Army Corps of Engineers data).

Mobile Bay is triangular in shape with the apex inland to the north and the long axis (50 km) oriented perpendicular to the coastline. It has an average width of 17 km and a maximum width of 38 km. Its average depth at mean high water is approximately 3 m and its maximum depth, located at East Main Pass, is 13 m. The volume of Mobile Bay is calculated to be 3.2 x 10^9 m^3 at mean high water (Crance, 1971). A 120 m x 12 m ship channel is dredged from Main Pass to the Port of Mobile.

Geomorphologically, the bay is a submerged river valley. The lower bay is enclosed by Dauphin Island on the west and Morgan Peninsula on the east. The two openings, Main Pass and Pass aux Herons, provide access to the Gulf of Mexico and East Mississippi Sound, respectively. Main Pass is responsible for approximately 85% and Pass aux Herons for approximately 15% of the exchange of waters in and out of Mobile Bay.

East Mississippi Sound is rectangular in shape. Its boundaries are: (1) to the west the 88° 30′ meridian of longitude; (2) to the east the narrowest passage between the mainland and Little Dauphin Island; (3) to the north the shoreline of the mainland, and (4) to the south Dauphin and Petit Bois Islands. The maximum east-west and north-south dimensions are approximately 35 km and 20 km,

Table 1. - Cruise Statistics

Cruise Number	Date (1973)	Identification Number	Time	Number of Stations	Area
1	4-16	A-73-05	0900-1500 CST	15	East Mississippi Sound
2	4-17	A-73-06	0900-1600 CST	16	Lower Mobile Bay
3	4-18	A-73-07	1100-1400 CST	7	East Mississippi Sound
4	4-25	A-73-10	0930-1300 CST	6	East Mississippi Sound
5	4-27	A-73-11	0900-1400 CST	13	Lower Mobile Bay
6	4-30	A-73-13	0900-1500 CDT	18	Lower Mobile Bay
7	5-4	A-73-15	1200-1430 CDT	5	East Mississippi Sound
8	5-7	A-73-16	0830-1330 CDT	15	East Mississippi Sound
9	5-8	A-73-17	0830-1700 CDT	25	Lower and Central Mobile Bay
10	5-9	A-73-18	1030-1430 CDT	11	East Mississippi Sound
11	5-15	A-73-23	0900-1730 CDT	22	Lower and Central Mobile Bay

respectively. Its average depth at mean high water is approximately 3.0 m. The volume of East Mississippi Sound is calculated to be 1.2 x 10^9 m^3 at mean high water (Crance, 1971).

METHODS

All eleven hydrographic cruises were made aboard the University of Alabama System's 20 m research vessel Aquarius (now the R/V G. A. Rounsefell). Station positions were determined by a combination of radar fixes and bathymetric soundings. Cruise tracks were constructed partially from preselected stations and partially from the observed salinity fields during individual cruises. Sampling at each station consisted of vertically profiling the water column from the surface to the bottom. Parameters measured were conductivity (salinity), temperature and dissolved oxygen. Instrumentation consisted of a Beckman RS-5 and a Delta S-85. Each unit was routinely maintenanced and properly calibrated.

RESULTS AND DISCUSSION

Utilizing both Figure 2 and unpublished U.S. Army Corps of Engineers data, best estimates have the first flooding conditions, discharges of 7.0 x 10^3 m^3 sec^{-1} or greater, impacting Mobile Bay starting March 30. The maximum discharge, of approximately 9.5 to 10.0 x 10^3 m^3 sec^{-1}, occurred sometime during April 9-10. The end of this flooding period was around April 18. The average river system discharge over the 20 days of flooding was approximately 8.8 x 10^3 m^3 sec^{-1} which is equivalent to approximately 15.2 x 10^9 m^3 or 4.8 X the mean high water volume of the bay.

The second flooding period has been calculated to have occurred during May 5-7 and likely provided discharges just at the minimum flooding level of 7.0 x 10^3 m^3 sec^{-1}. Between these two flooding periods discharges decreased to 2.2 x 10^3 m^3 sec^{-1} and averaged for the 18 days approximately 4.6 x 10^3 m^3 sec^{-1}. Even though this is a non-flooding period the total discharge over the 18 days was approximately 7.2 x 10^9 m^3 which is equivalent to 2.2 X the mean high water volume of the bay.

The first three hydrographic cruises (Table I) were made after the maximum discharges but still during the first flooding period. The next three cruises (4, 5 & 6) were made between the two flooding intervals. The following four cruises (7, 8, 9 & 10) were prior to, during and after the second flooding period while the last cruise was carried out one week after the end of the second flooding period. Precipitation measurements made in coastal Alabama during the study are presented in Table 2. No apparent relationship between the precipitation data and the collected hydrographic date was noted. In order to simplify the presentation of results and the discussion salinity values have been divided into convenient groups (Table 3).

Table 2. — Precipitation measurements (mm) in Coastal Alabama April 16 - May 15, 1973 (U.S. Department of Commerce, Climatological Data, Alabama, Environmental Data Service, NOAA)

	Bates Field, Mobile	Fairhope	Gulf Shores
April 17	1.8	—	—
April 18	39.1	39.1	22.9*
April 19	—	—	
April 25	53.6	30.5	5.1
April 26	43.4	63.2	56.5
April 27	T	—	58.4
May 8	8.4	20.8	2.5
May 9	T	—	20.8

* 48 hour accumulation, April 18 and 19.

Cruises 1, 2 and 3:

The celestial tidal state during these cruises was high water to falling and the range of amplitudes was 0.3-0.5m. The wind fields were southeast ranging between 10-15k. Surface and bottom salinity fields for East Mississippi Sound (EMS), cruise 1, and the bottom salinity field for Lower Mobile Bay (LMB), cruise 2, are presented in Figures 3a, 3b and 4, respectively. The northern and central sections of EMS during cruise 1 were under the influence of low to moderately-low salinity (1-14 ppt) waters while the southern and western section waters were under the influence of moderate to moderately-high salinities (15-28 ppt). The higher salinity waters in the south and west illustrate the role that Petit Bois Pass plays in this area by providing access to the Gulf of Mexico. No pronounced vertical stratification was observed. Similar conditions existed in EMS during cruise 3 two days later.

The surface salinity values during cruise 2, in extreme LMB, were all <4ppt. Bottom salinities (Fig. 4) on the other hand ranged from river water to moderately-high (0-28 ppt) in less than 4 km. The intruding wedge of moderately-high salinty (22-28 ppt) water had only managed to move into the bay slightly to the north of Main Pass. The condition pictured in Figure 4 may represent the maximum influence from the Gulf of Mexico at this time because it was observed during a high tidal state complimented by a southeast wind.

Figure 5 illustrates the steep vertical gradients of salinity that were present during cruise 2 due to the hydraulic head produced by the flooding river waters. In particular, note the salinity structure at stations 6 and 15 where there was a compaction of the isohalines between 12 to 24 ppt in less than 1.5 m.

Water temperatures in both EMS and LMB ranged from 17.6-20.4°C. Only the bottom waters (5.0-5.5 m) at two stations exhibited temperatures below 18.2°C and these were the two southwesternmost stations in EMS bordering Petit Bois Pass during cruise 1 (Fig. 3). The largest vertical gradient measured was slightly over 1°C and no horizontal or vertical trends were observed. Generally oxygen values varied from 75% to 100% saturation (5.7-9.5 ppm) with the lower values all observed near the bottom. The exception occurred in the bottom waters of the same two stations where the lowest temperatures were recorded. Oxygen values of 3.4 ppm were measured which is equivalent to 42% saturation.

Table 3. — Salinity Groupings

Salinity (ppt) Range	Group Name
<1	River Water
1-7	Low salinity
8-14	Moderately-low salinity
15-21	Moderate salinity
22-28	Moderately-high salinity
>28	High (Gulf of Mexico Water) salinity

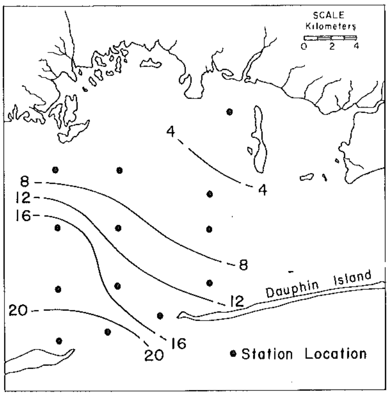

Figure 3a. — Surface salinity (ppt) field, East Mississippi Sound, Cruise 1, April 16, 1973. River discharges: >8 x 10^3 m^3 sec^{-1} (flooding); tidal state: high water to falling; wind: southeast 10-15 k.

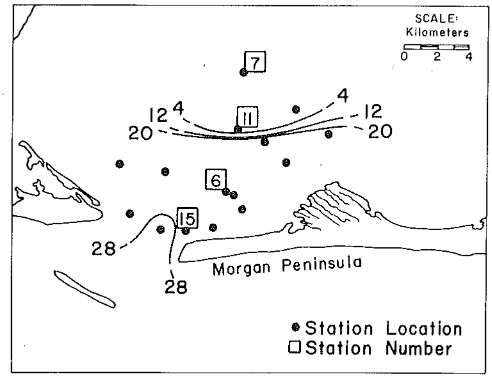

Figure 4 — Bottom salinity (ppt) field, lower Mobile Bay, Cruise 2, April 17, 1973. River discharge: >8 x 10^3 m^3 sec^{-1} (flooding); tidal state: high water to falling; wind: southeast 10-15 k.

Cruises 4, 5 and 6:

The celestial tidal state during cruises 4 and 5 was rising while during cruise 6 it was high water to falling. Tidal amplitudes ranged between 0.2-0.5 m. The wind field was variable 4-18 k during cruise 4, northwest 12-16 k during cruise 5 and southeast 12-19 k during cruise 6. Cruise 4, in central EMS, consisted of only six stations and is of limited use. However, the low (1-7 ppt) and moderately-low salinities (8-14 ppt) in both the surface and bottom waters indicate that no significant changes occurred in this area since cruises 1 and 3 which were made one week earlier.

Surface salinities in LMB, during both cruises 5 and 6, did not exceed 2.0 ppt and values at stations in and south of Main Pass were less than 1.0 ppt. Bottom salinity fields for cruises 5 and 6 are presented in Figures 6 and 7. Even though both of these cruises occurred during the lowest discharges, 2.2 x 10^3 m^3 sec^{-1}, between the flooding intervals, river waters are still prevalent in the lower bay.

During cruise 5 (Fig. 6) the northwest wind likely played a role, by complimenting river flow, in holding off any significant intrusion into the bay of Gulf of Mexico waters. The exception to this is the movement of high salinity

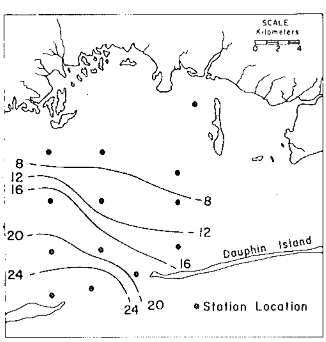

Figure 3b. — Bottom salinity (ppt) field, East Mississippi Sound, Cruise 1, April 16, 1973. River discharge: >8 x 10^3 m^3 sec^{-1} (flooding); tidal state: high water to falling; wind: southeast 10-15 k.

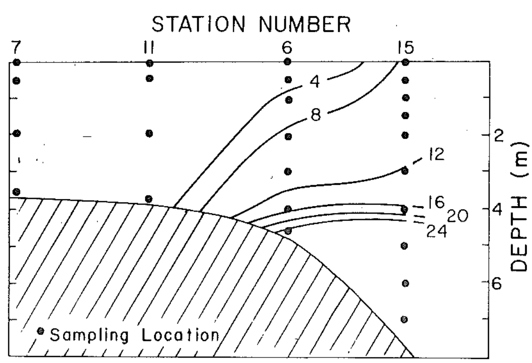

Figure 5 — Vertical section of salinity (ppt), lower Mobile Bay, Cruise 2, April 17, 1973. See Figure 4 for station locations.

water (>28 ppt) up the main ship channel (not shown in Figure 6). A cross-section of the salinity vertical gradients northeast of Main Pass, is presented in Figure 8. Just as in Figure 5 the observed salinity gradients, 16 ppt in less than 2.0 m at station 6, attest to the tremendous hydraulic head of the flooding river water.

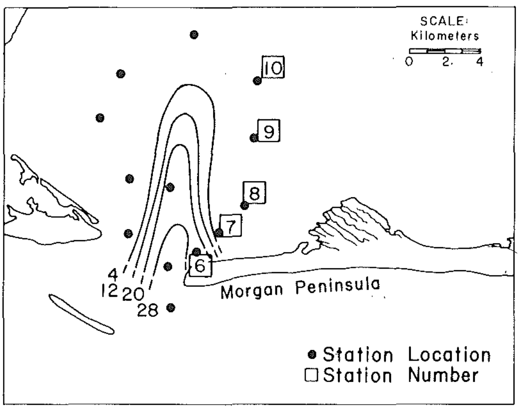

Figure 6 — Bottom salinity (ppt) field, lower Mobile Bay, Cruise 5, April 27, 1973. River dishcarge~3 x 10³ m³ sec⁻¹ (between flooding intervals); tidal state: rising; wind: northwest 12-16 k.

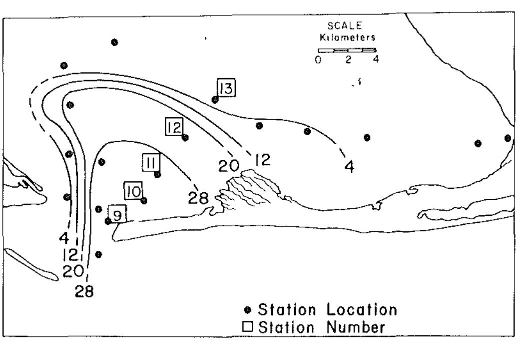

Figure 7 — Bottom salinity (ppt) field, lower Mobile Bay, cruise 6, April 30, 1973. River discharges:~3 x 10³ m³ sec⁻¹ (between flooding intervals); tidal state: high water to falling; wind: southeast 13-19 k.

The southeast winds during cruise 6 may have partially been responsible for the more extensive intrusion of Gulf of Mexico waters into the bay (Fig. 7). Here again, the conditions pictured in Figure 7 most likely represent the maximum

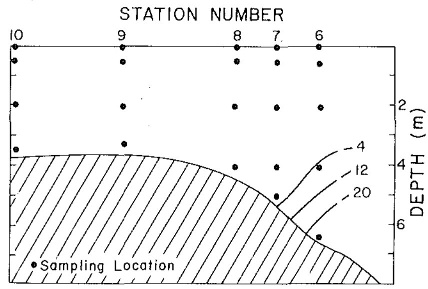

Figure 8 — Vertical section of salinity (ppt), lower Mobile Bay, Cruise 5, April 27, 1973. See Figure 6 for station locations.

influence from the Gulf of Mexico at this time, because it was observed during high tidal state complimented by southeast winds.

The highest salinities observed in the course of this study were during cruise 6 (32-34 ppt). Figure 9 illustrates the vertical salinity gradients observed northeast of Main Pass during cruise 6. When compared with Figures 5 and 8 the greater degree of salinity instrusion becomes even more apparent, but here again the hydraulic head of the flooding river system dominates over the Gulf of Mexico waters.

Water temperatures in both LMB and EMS during all three cruises ranged

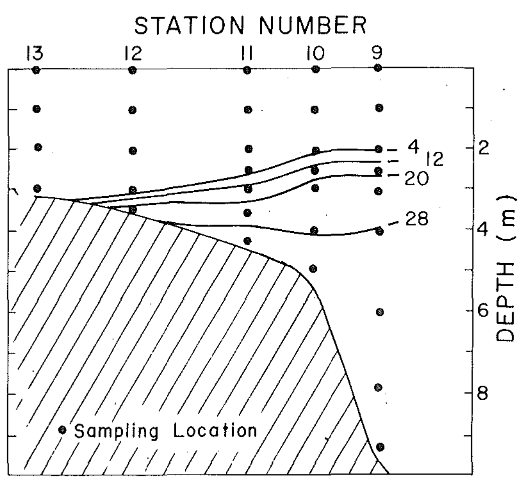

Figure 9 — Vertical section of salinity (ppt), lower Mobile Bay, Cruise 6, April 30, 1973. See Figure 7 for station location.

between 18.7-23.8° C. The only stations exhibiting temperatures less than 19.5° C were either the deeper stations in Main Pass or the main ship channel. Overall water temperatures decreased during the time span of these cruises in concert with a period of decreasing air temperatures (U.S. Department of Commerce, 1973). No horizontal patterns were observed and vertical gradients ranged from near uniform in shallow areas to 1.8° C in the deeper areas. Oxygen values were considerably depressed from the previous set of cruises. Concentrations in both surface and bottom waters in EMS, during cruise 4, ranged between 70-80% saturation (6.0-7.2 ppm). In LMB, during cruises 5 and 6, surface waters ranged between 60-90% saturation (5.0-7.5 ppm). No horizontal patterns were evident. Bottom waters in LMB exhibited concentrations ranging from 30-60% saturation (2.5-5.3 ppm). In these bottom waters the lowest concentrations were all associated with the deeper high salinity water while the higher concentrations were all associated with the shallower river water.

Cruises 7, 8, 9 and 10:

The celestial tidal state during cruise 7 was falling and during cruises 8, 9, and 10 it was rising to high water. Tidal amplitudes were 0.4-0.6 m. The wind fields were: (1) cruise 7, north, 0-10 k; (2) cruise 8, south-southeast, 7-16 k; (3) cruise 9, southwest, 4-22 k; and (4) cruise 10, northwest, 0-8 k. Cruise 7 was restricted to central EMS and consisted of only five stations. Surface salinities were comparable to previous cruises. Bottom waters of moderately-high salinities (22-28 ppt), on the other hand, indicated an increased influence from Gulf of Mexico waters. This is consistent with the fact that cruise 7 was made just at the end of the inter-flooding period.

The surface and bottom waters observed during cruise 8, three days after cruise 7, showed that EMS was again under the influence of low to moderate salinity (1-21 ppt) waters. The bottom salinity field for cruise 8 is illustrated in Figure 10. Cruise 10 exhibited very similar surface and bottom salinity fields to cruise 8. Cruise 9, in LMB, was made one day after the maximum river discharge of the second flooding period (Fig. 2). Surface salinity values were all

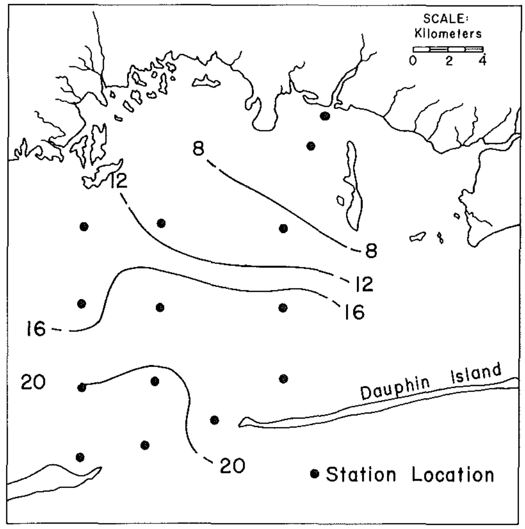

Figure 10 — Bottom salinity (ppt) field, East Mississippi Sound, Cruise 8, May 7, 1973. River discharge: > 7 x 10^3 m^3 sec^{-1} (flooding); tidal state: rising to high water; wind: south-southeast 7-16 k.

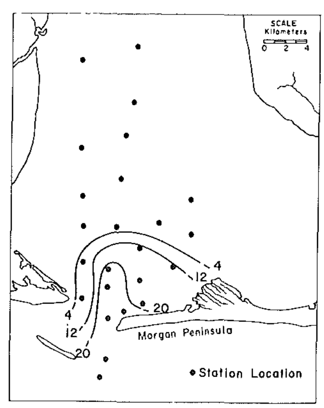

Figure 11 — Bottom salinity (ppt) field, lower and central Mobile Bay Cruise 9, May 8, 1973. River discharge: >7 x 10^3 m^3 sec^{-1} (flooding); tidal state: rising to high water; wind: southwest 4-22 k.

less than 4.0 ppt except in the immediate area of Main Pass where values reached 8.0 ppt. The bottom salinity field (Fig. 11) does not vary greatly from previous cruises. A small salinity wedge is evident north and northeast of Main Pass. No Gulf of Mexico waters were observed, even south of Main Pass. Water temperatures during these four cruises remained relatively constant. No horizontal or vertical trends were observed. No oxygen data are available because of a malfunction in the Delta S-85 unit during cruise 7.

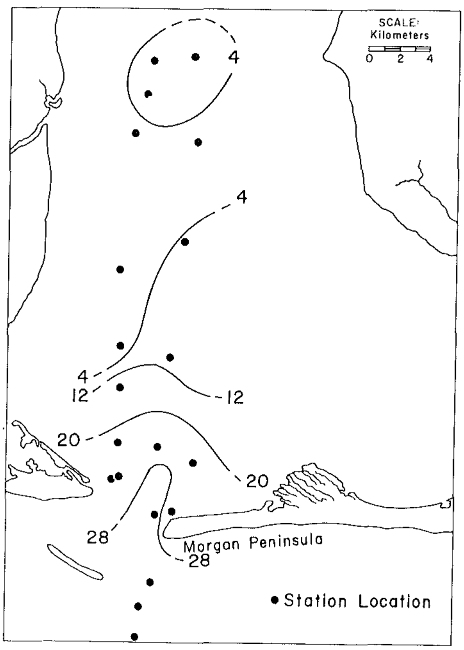

Figure 12 — Bottom salinity (ppt) field, lower and central Mobile Bay, cruise 11, May 15, 1973. River discharge: -5 x 10^3 m^3 sec^{-1} (flooding); tidal state: high water to falling; wind: northwest 4-10 k.

Cruise 11:

Cruise 11 was made during a high water to falling tide with an amplitude of 0.5 m and a northwest wind at 4-10 k. This cruise came one week after the peak of the second flood when river discharges had fallen off to less than 3.5 x 10^3 m^3 sec^{-1}. Surface salinity values were still less than 4.0 ppt within the Bay. The bottom salinity field (Fig. 12) shows the first evidence of the relaxation of the river system's hydraulic head. In particular the intrusion of the salinity wedge well north of Main Pass into LMB and what appears to be water moving up and out of the main ship channel west of Great Point Clear. Water temperatures ranged from 20.5-23.0° C. The high salinity bottom waters all fell below 22.0° C. The greatest vertical gradient observed was 1.7° C.

SUMMARY

1) The 1973 flooding of the Mobile River System rendered the majority of Mobile Bay a near limnetic system. The two areas which were only partially influenced by the flooding were the deeper portions of Main Pass and the main shipping channel. Specifically, for a period of no less than 30 days (April 16-May 15, 1973) greater than 75% of Mobile Bay contained water with maximum salinities < 4 ppt.

2) During the same flooding East Mississippi Sound waters ranged from river waters (< 1ppt) in the central and eastern portions to moderately-high salinity (22-27 ppt) waters in the southwestern portion next to Petit Bois Pass. The reduced impact from flooding in East Mississippi Sound is due to not directly receiving river waters.

3) Water temperatures associated with the flooding river waters were not significantly different from the water temperatures of Mobile Bay and East Mississippi Sound estuarine waters or Gulf of Mexico waters during the flooding periods.

4) Dissolved oxygen concentrations decreased as flooding progressed. It is speculated that this was a function of river-borne organic material entering the bay and sound and its subsequent oxidation. A suggested explanation for the lowest oxygen concentrations occurring in the high salinity bottom

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waters is that organic material accumulates in the deeper waters near the sediment-water interface where the denser more saline waters are located. The high degree of stratification of the water column (river & low salinity waters over high salinity water) would have effectively confined the organic material to the deeper bottom waters leading then to the more extensive oxygen depletions.

ACKNOWLEDGEMENTS

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