JOB REPORT

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Project No. M-2-R-1 Date: July 22, 1959

Project Name: Basic Ecological Survey of Area M-2.

Period Covered: 25 May 1958 to 9 July 1959. Job No: F-2

Chemical and Physical Analysis of the Water of Area M-2

Objectives: To determine the chemical and physical dynamics of the water in the area and their effects upon the biological components.

Procedure: Observations and analysis of the various features of the water were made using dye, thermometers, chemical tests, and other appropriate methods. Information and data were also collected from numerous publications and other sources.

Findings: The following accounts deal with fish mortalities which were caused by chemical and physical alterations in the waters of Area M-2.

Houston Ship Channel Survey

The Houston Ship Channel above Morgan's Point is an area of intense industrial activity and the waste materials emptying into it undoubtedly have a profound (but as yet unknown) effect upon the fauna of Area M-2. In an attempt to establish some biological index to the quality of the waters of this area a sampling program was instituted. Regular collections were made in the area to get some rough determination of the point at which pollution is too severe to allow marine life.

The general procedure was to make fifteen minute trawl hauls at intervals up the channel until the hauls no longer produced any fish, shrimp, or crabs.

The following chart and table show the results of this survey. With examination of the data it becomes apparent that the critical area for bottom life during most months of the year lies in sections I through VIII. This area is probably influenced by water from the San Jacinto River.

It must be emphasized that all collections were made on the bottom and chemical tests show that there is ordinarily less dissolved oxygen here. It might well be that strata of water above the bottom were of better quality and allowed marine life to subsist at times when life was nil on the bottom.

Through the courtesy of the Houston Lighting and Power Company the chemical data included in the second table were obtained. Even this far down the channel the amount of oxygen dissolved in the water appears to be marginal (at best) during most of the year.

Figure I
HOUSTON SHIP CHANNEL

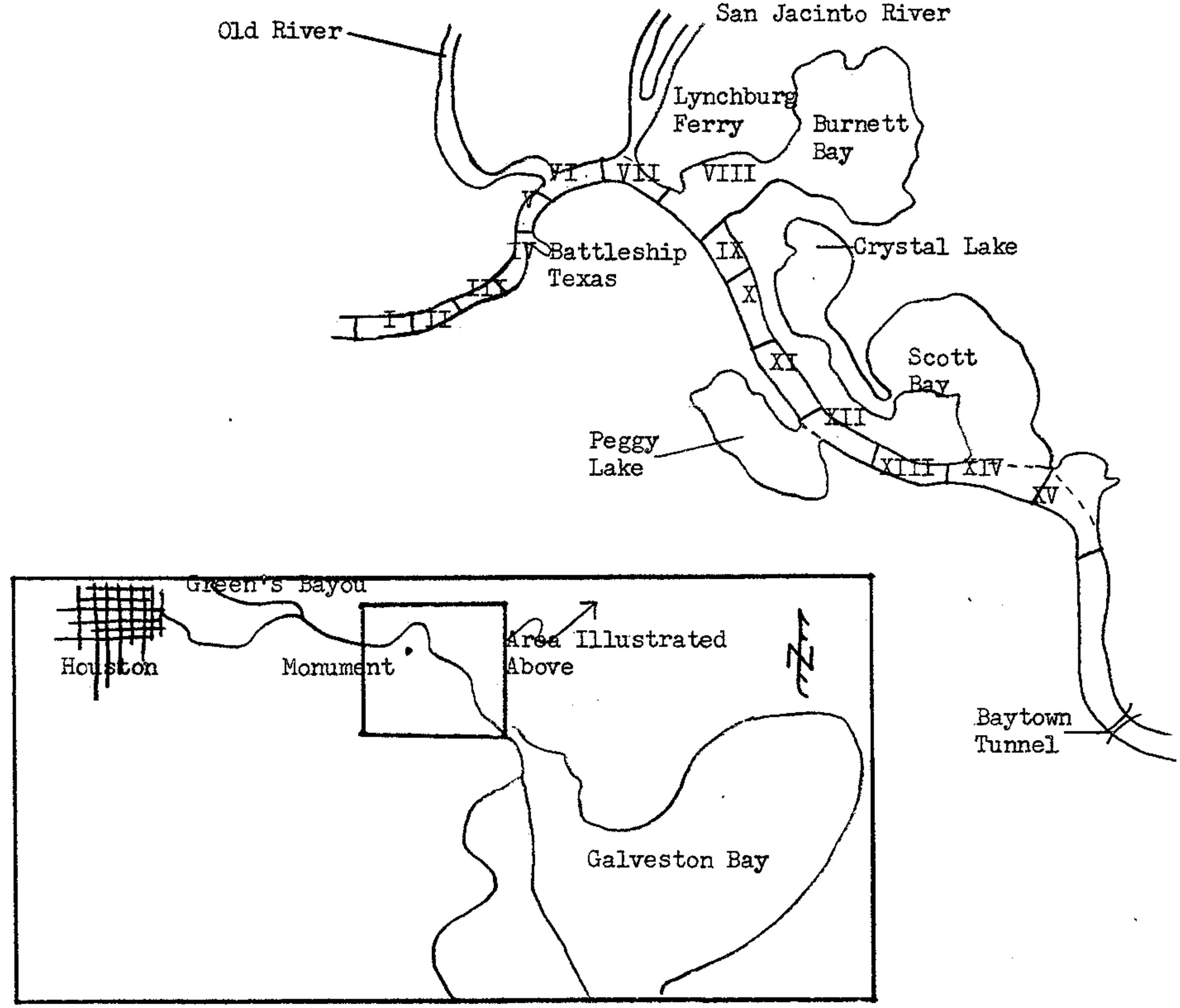


Figure II

HOUSTON SHIP CHANNEL COLLECTIONS

Results of Bottom Trawls in the Channel as an Index of Water Quality

- Numbers in Parenthesis Identify the Organisms Present -

Date	No Life Found	Marine Animals Found
9 June 58	west of IV	in V (1, 2, 3)
15 July	in VIII	in IX (1,2,4,5,6,7,8)
29 July	in VI	in VI (1,2,3,5,6,7,8,10)
13 August	in IV	in VIII (1, 10)
12 September	in VII	in VIII (1,10)
30 September	in IV	not determined
17 October	in IV	in VI (1,2,3,4,5,7,8,10)
7 November	west of Green's Bayou	west of I (1,2,4,7,10)
1 December	at Green's Bayou	in IV (1,4,7,8,10)
8 January	in IV	in V (1,8,10)
16 February	in IV	in VII (8)
12 March	west of I	in IV (8, 10)
3 April	west of VII	in VII (1)
30 April	in VII	not determined
28 May	in IV	in VII (1,2,7,8)
29 June	in IV	in VII (1,2,7,10)

Code to Species Found

1 Micropogon undulatus
2 Brevoortia patronus
3 Leiostomus xanthurus
4 Cynoscion arenarius
5 Galeichthys felis
6 Bagre marinus
7 Penaeid shrimp
8 Callinectes sapidus
10 Others

Figure III

CHEMICAL DATA

SAM BERTRON PLANT, HOUSTON LIGHTING AND POWER COMPANY

Water Samples Taken at the Canal Inlet on Ship Channel

Dissolved Oxygen in ppm

	Depth		
1958	5 ft.	15 ft.	25 ft.
28 May	1.0	0.8	0.8
4 June	3.6	2.2	2.4
11 June	2.2	1.0	0.6
25 June	3.8	4.4	0.8
9 July	4.6	1.6	0.6
16 July	1.2	0.6	0.0
23 July	0.8	0.3	0.1
7 August	2.2	0.3	0.2
14 August	0	0	0
27 August	0.1	0.4	0.4
3 September	2.2	0.3	0.2
11 September	0.6	0.8	0.6
17 September	1.4	0.1	0.1
24 September	0.4	0.2	0.2
1 October	0.4	0.2	0.2
8 October	3.0	2.2	0.2
15 October	4.4	3.8	3.8
22 October	1.2	1.0	0.8
26 November	0.4	0.4	0.6
3 December	2.6	6.8	7.8
17 December	0.2	1.2	1.6
26 December	5.6	3.4	8.6
1959			
26 March	8.8	7.6	6.8
1 April	5.6	5.4	6.6
4 May	2.4	2.4	1.4
13 May	0	0	0

Figure IV

CHEMICAL DATA

SAM BERTRON PLANT, HOUSTON LIGHTING AND POWER COMPANY

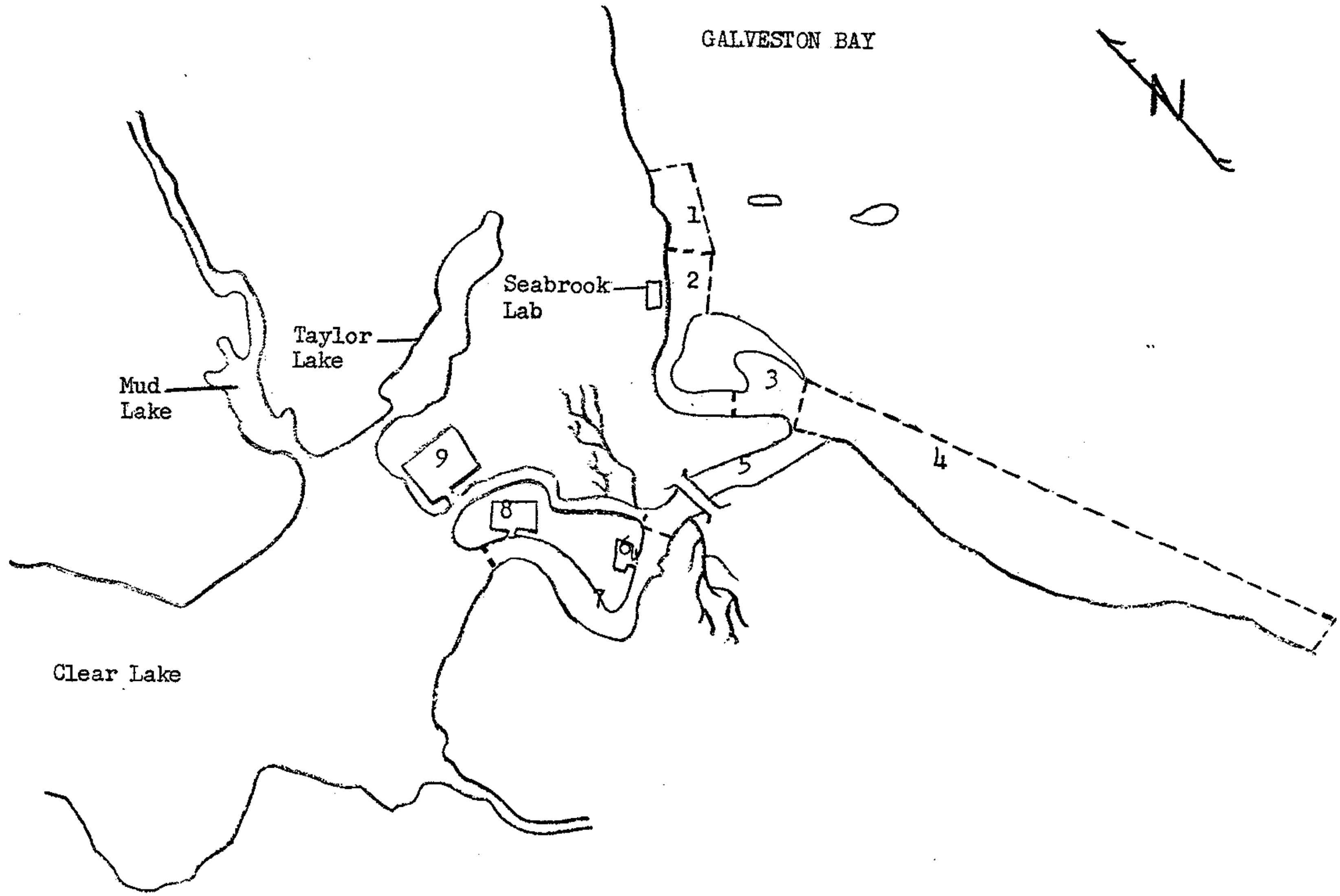
Monthly Averages of Dissolved Oxygen in ppm

1958	2' Depth	17' Depth
June	1.3	0.8
July	1.0	0.4
August	0.8	0.5
September	0.8	0.2
October	1.0	1.0
November	2.0	3.0
December	4.0	5.0
1959		
January	4.0	5.0
February	2.5	3.3
March	2.5	2.3
April	4.0	3.5
May	2.0	2.2

Figure V

Seabrook Area

(Sections in the area in which menhaden mortalities occurred)



Menhaden Mortalities in Area M-2

During the last 6 months of 1958 an abnormally high number of mass mortalities of the menhaden (Brevoortia patronus) occurred in the Seabrook area and at scattered points around the area. Long-time residents frequently commented on the number and extent of the "kills" which occurred in the area and could not remember other years when "kills" were so prevalent.

Following are the accounts of fish mortalities which occurred in Area M-2. Unless otherwise noted the dead fish were Brevoortia patronus only. The attached map of the area has been sectioned off so as to easily identify the location of the "kill".

4 June 1958. The first kill of the year occurred in Section 3 in the shallow pocket of the island in front of Seabrook. The dead fish were observed at 0800 hours and formed a continuous sheet over the surface of the water. It was estimated that the dead menhaden covered an area of 36,000 square feet approximately 450 fish within any square foot. Thus a conservative estimate for the number of dead menhaden would be more than 15 million (this does not take into consideration any dead fish laying on the bottom). The surface water temperature was 30.4°C and at 1100 the amount of oxygen dissolved in the surface water in the pocket was 2.5 parts per million (ppm). Other dead fish noted included numerous small croakers (Micropogon undulatus), a few hogchokers (Trinectes maculatus), an occasional spot (Leiostomus xanthurus), one or two silver perch (Bairdiella chrysura), and a few shad (Dorosoma cepedianum).

17 June 1958. Dead menhaden were found in Section 2 (behind the Seabrook Laboratory) at 0800. Surface water temperature was 28.0°C and D.O. was 2.2 ppm. No attempt to estimate the numbers dead was made although it was felt that there were no more than half as many dead fish as in the first kill. A few small shad (Dorosoma cepedianum) were also found dead.

19 June 1958. This kill occurred in Sections 1 and 2. An estimated 18 million dead menhaden were observed along with a few small flounders (Paralichthys lethostigmus) and hardhead catfish (Galeichthys felis). One "hardhead" 250 mm in standard length had consumed 15 menhaden averaging 45 mm long before it died. Hermit and blue crabs left the water and made their way up the banks. At Oddo's Bait Camp (in Section 2) crabs and bait shrimp being held in slatted boxes suspended in the water had died but bait shrimp held in his concrete tanks were apparently unharmed (the water being fed into the concrete tanks is aerated). A school of small menhaden was observed gasping for air on the surface and dying in the shallow water behind the laboratory. Dissolved oxygen here was measured at 0.3 ppm. Twenty feet offshore at a depth of 1 foot D.O. was 1.0 ppm. Seventy-five feet from shore D.O. was 2.1 ppm and at 300 feet it was 6.5 ppm.

8 July 1958. Widely scattered kills were observed on this date. Kills occurred in the Houston Yacht Club basin and in Sections 2 and 4. At 0715 D.O. was 0.7ppm in the water behind the laboratory. Surface water temperature was 26.9°C. No estimate was made on the numbers dead.

13 July 1958. A small number of fish began dying at 2300 hours in Section 2 on the night before. At 0800 D.O. was 5.0 ppm and water temperature was 29.4°C. Again shrimp and crabs being held in wooden slat boxes suspended in the water at Oddo's Camp died while shrimp in his concrete tanks containing aerated water survived. At 1400 some menhaden were still dying. The surface water temperature at this time was 30.5°C and D.O. was 5.8 ppm. The dissolved oxygen content on this date seemed too high to cause mortality and there is a possibility that the reagents used were not of the correct concentration thus causing erroneous readings.

17 July 1958. A large kill covering the entire surface area in side the Houston Yacht Club basin occurred on this date. At 1400 the D.O. was 2.2 ppm and surface water temperature was 32.2°C. Other fishes dead were small mullet (Mugil cephalus), small croakers (M. undulatus), toadfish (Opsanus beta), hardhead catfish (G. felis), and gafftopsail catfish Bagre marinus). At the time small hardheads and gafftopsails were still dying.

19 July 1958. A small kill of menhaden was reported on the morning of 19 July in Section 8. No observations were made.

22 July 1958. Bait camp operators in Section 5 reported that from 0600 to 0900 on this morning they were unable to keep bait shrimp alive when placed in slatted boxes and suspended in the water. D.O. was 2.6 ppm and at 1600 it was 4.2 ppm (these oxygen determinations were made by Mr. Marek, Chemist, Seabrook Laboratory).

23 July 1958. In Section 8 at 0800 D.O. was 1.9 ppm and several small schools of menhaden were observed gasping at the surface and dying. When a boat engine was started nearby the fish began swimming frantically and with this exertion most of them died. D.O. in Section 5 by the bridge was 2.9 ppm and shrimp held in live boxes appeared in good condition.

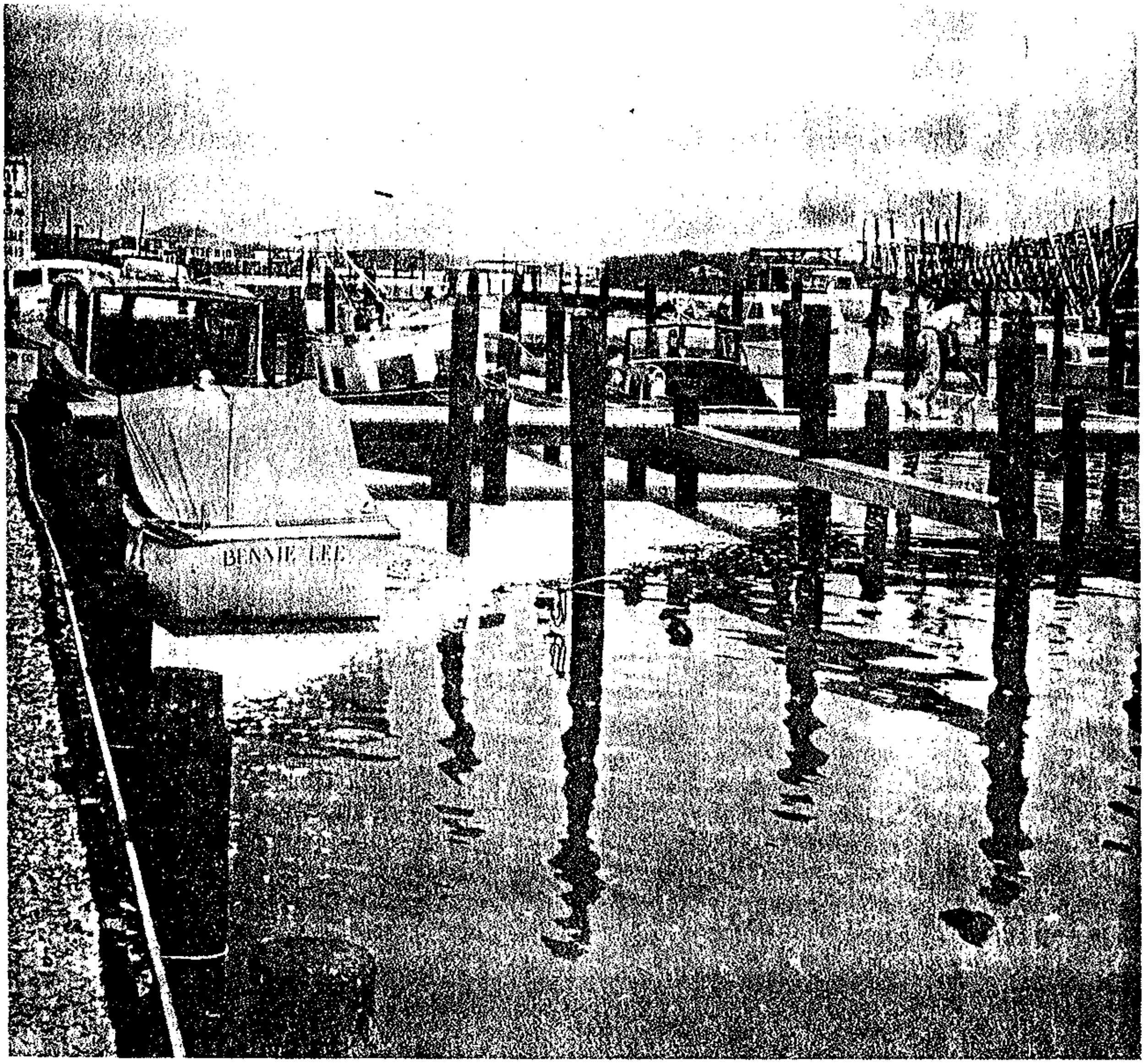
During the latter part of July and the first 10 days of August small schools of menhaden were observed to be in distress and a few individuals were found dead in the Seabrook area, but no mass mortalities occurred.

12 August 1958. A small kill was noted in Section 6. D.O. at 0930 was 1.4 ppm. There had been a series of rain showers during the previous two days.

14 August 1958. A fairly large kill of menhaden was observed in Section 2. At 0800 D.O. was 1.5 ppm. The day before a series of thunderstorms passed over the area accompanied by high winds and rain.

18 August 1958. A small kill was found in Section 8.

19 August 1958. At 0800 menhaden, anchovies (Anchoa mitchilli), and hardhead catfish (G. felis) were observed dying throughout Sections 7, 6, and 5. The D.O. in the bend of the creek in Section 7 was 1.0 ppm and from there nearly to the end of Section 5 D.O. was not above 1.6 ppm. In the bait camps along the channel shrimp held in slat boxes could not



A menhaden kill at Seabrook (Section 2).

be kept alive. However, at Seabrook Totem shrimp held in a large wooden tank were in good condition. The water fed into this tank is taken from the channel near the bridge and pumped through hoses. On the pump there is a valve so arranged that air is sucked into the water going into the tank thus aerating it. D.O. in the tank was 5.1 ppm.

During the last week in August, all of September and the first half of October general rains kept Clear Creek flowing with fresh water. As a result no menhaden mortalities occurred during this time.

17 October 1958. In the boat basin in Section 6 D.O. at 0800 was 0.8 ppm or less. Blue crabs and all species of shrimp were observed to be in distress and the kill of menhaden was large (although numbers were not estimated). Menhaden were gasping and dying at the time. Surface water temperature was 23.2°C.

21 October 1958. In Section 6 surface water temperature was 23.7°C and D.O. was 1.1 ppm. Several thousand dead menhaden were found and a few hardhead catfish (G. felis). Shrimp were also noticed swimming near the surface in distress.

23 October 1958. This was the last large kill of the year. It occurred in Section 6 and the total number of menhaden dead was estimated at approximately 13 million. Other fishes dead were gobies (Gobiosoma bosci), hogchokers (Trinectes maculatus), shad (Dorosoma cepedianum), speckled trout (Cynoscion nebulosus), sand trout (Cynoscion arenarius), croakers (M. undulatus), gafftopsail catfish (Bagre marinus), hardhead catfish (G. felis), and toadfish (Opsanus beta). A trawl haul on the bottom inside the basin took large numbers of dead menhaden, live blue crabs, and live hardhead catfish. D.O. at 0800 on the surface was 1.3 ppm and on the bottom less than 0.3 ppm. Surface water temperature was 23.8°C. Hourly dissolved oxygen determinations were made here during the next 28 hours. From 0800 to 1200 the amount of dissolved oxygen in the water gradually decreased with the increasing decay of dead fishes. After 1100 hours the D.O. on the surface and at the bottom remained zero. During this time of no dissolved oxygen, mosquitofish (Gambusia affinis), mollies (Mollienesia latepinna), and gars (Lepisosteus spatula), were observed to swim about in the water without sufferint any apparent harm. These three species are well known for their ability to utilize atmospheric air for breathing.

14 November 1958. A small kill occurred in one of the boat basins at 0800 in Section 9. Surface water temperature was 22.3°C and D.O. was 2.0 ppm.

15 November 1958. A small kill was found in Section 2. At 1000 D.O. was 2.3 ppm and the water temperature was 23.3°C.

9 July 1959. During the spring of 1959 a boat basin was constructed on the point of land in the southeast corner of Section 3. On this date a kill of menhaden estimated at about 4 million dead fish occurred. Inside the basin at 0845 the D.O. was 1.0 ppm and surface water temperature was 29.2°C.

From the evidence available there appears little doubt that the primary cause for all the menhaden mortalities occurring around Seabrook was inadequate oxygen dissolved in the water. Menhaden are delicate fish, and it appears that they are more sensitive to lowered concentrations of dissolved oxygen than most other fish species. On several occassions experiments were attemped to determine by laboratory tests the critical levels of dissolved oxygen for menhaden at various temperatures, but because of their delicate nature and sensitivity to handling, the experiments were inconclusive.

The following possible causes for menhaden mortalities are advanced and commented upon:

1. Abrupt salinity changes - on a number of occasions menhaden kills came after rains however live menhaden could always be found in Clear Lake at the time of the kills in the Seabrook area.

2. Abrupt temperature changes - the same comment as above might apply.

3. Pollution (death due to various toxicants) - During several kills Mr. Marek ran extensive chemical tests for toxicants with negative results. In addition, it has been mentioned that shrimp died in holding boxes but lived in aerated tanks containing the same water.

4. Disease of parasitism - lesions caused by disease or parasites were never noted. Nearly all the mortalities occurred abruptly during the night, yet disease would be expected to affect the fish at any time of the day.

5. Suffocation due to clogging of gills by suspended solids - no evidence of this was noted. No kills occurred during the period when the area experienced highest turbidities.

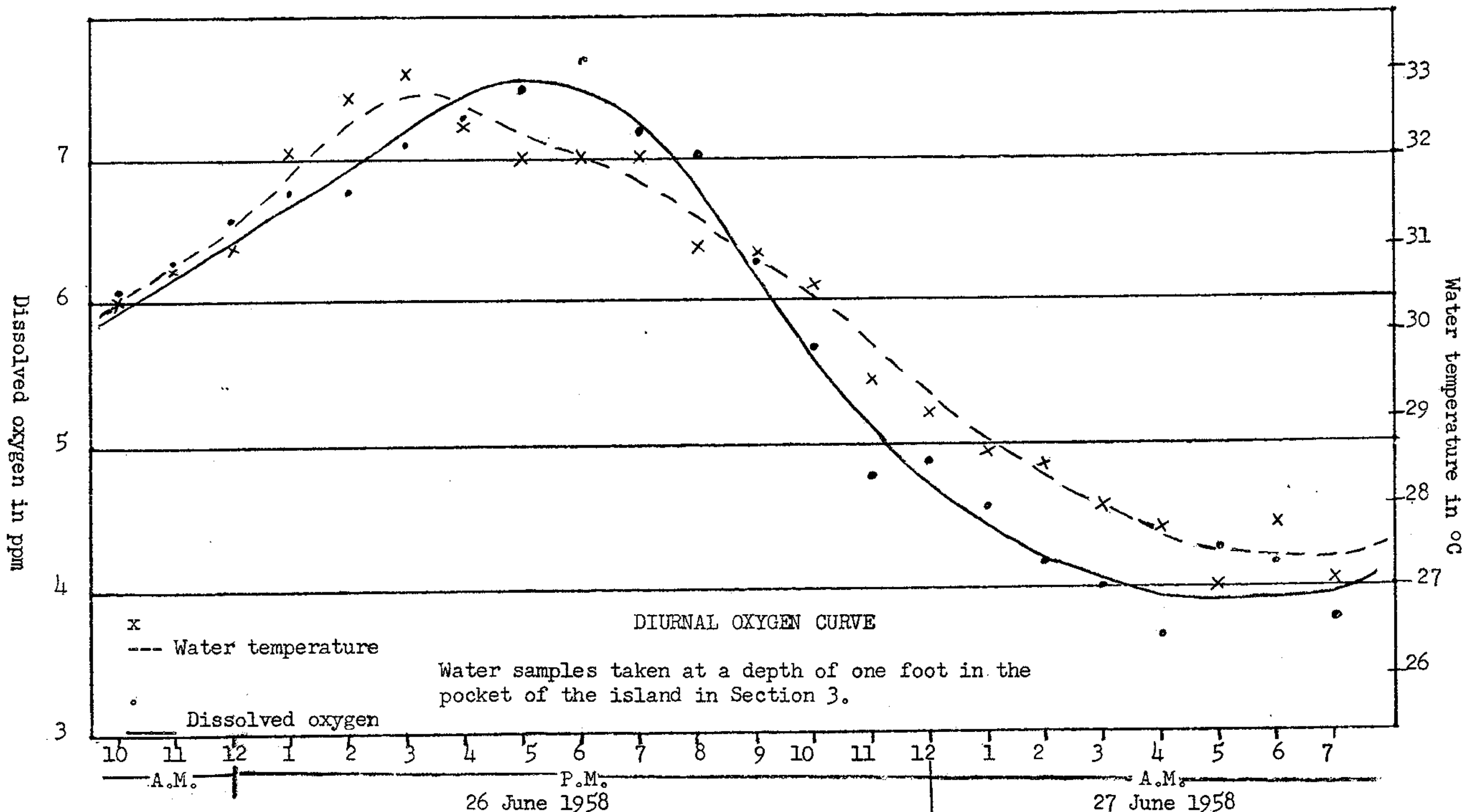
The following factors causing low dissolved oxygen in the Seabrook area are listed:

1. Respiration of plants and animals in the water - plants (planktonic or attached) which contain chlorophyll produce oxygen as a by-product of photosynthetic activity during daylight hours thus adding to the amount of oxygen dissolved in the water. In the absence of sunlight plants respire and subtract from the amounts of oxygen in the water. The attached graph was drawn from the results of hourly dissolved oxygen determinations made during one 26 hour period in the Seabrook area. It will be noted that lowest D.O. occurs in the early morning hours. Most of the menhaden kills were reported to begin during the night.

2. High temperatures - It was first thought that this was a major factor contributing to the menhaden mortalities. As temperature increases the capacity of water to dissolve oxygen decreases. High temperatures also reduce the resistance of fishes to lowered dissolved oxygen. Since kills occurred in water temperatures of less than 22°C, high temperatures do not appear to be as important as first thought.

3. Decomposition of wastes from boats and camps - organic material from

Figure VI



DIURNAL OXYGEN CURVE
Water samples taken at a depth of one foot in the pocket of the island in Section 3.
x
--- Water temperature
Dissolved oxygen
Dissolved oxygen in ppm
Water temperature in °C
3
4
5
6
7
26
27
28
29
30
31
32
33
10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7
A.M.
P.M.
26 June 1958
A.M.
27 June 1958

boats, shrimp trawl "culls", and dwellings placed in the water decays and demands oxygen.

4. Decomposition of organic material washed from back marshes and surrounding communities - sheet drainage of water from the area brings decaying material into the water and, as this material decomposes, there is a demand for the oxygen dissolved in the water.

5. Respiration of the highly organic bottom sediments - decaying organic material in the bottom sediments demand oxygen from the water. There is also usually present a thin layer of algae covering the bottom which demands oxygen in the absence of sunlight.

6. Calm winds - when winds are not present to stir and aerate the surface of the water the amount of dissolved oxygen in the water usually is lower.

7. Menhaden school respiration - menhaden school in great numbers and when they swim into a boat basin or other restricted body of water large amounts of oxygen must be required to support the school. This appears to be the major cause for death and the above factors contribute in that they cause the amount of oxygen dissolved in the water to be low before the fish school arrived.

8. Decomposition of fishes which died first - as the first menhaden to die float to the surface their decaying bodies demand oxygen. It was also noted that dead menhaden floating on the surface give off considerable quantities of (what appears to be) oil. It is conceivable that this film of oil floating on the surface hinders the diffusion of air into the water below.

Speckled Trout Mortality

On the morning of 14 January 1959, some 300 large speckled trout (*Cynoscion nebulosus*) were discovered floating in upper Galveston Bay near La Porte. The fish were not yet stiffened and therefore must have died during the night. A southeast wind was pushing them in toward shore. The smallest trout observed weighed $1\frac{1}{4}$ pounds in weight (only 8 specimens weighed less than 3 pounds).

Examination failed to show either internal or external physical injuries. Extensive chemical laboratory tests run by Mr. Marek and Mr. Ezell, chemists of the Seabrook Laboratory, failed to show any harmful toxicants in the water.

Unusual features of the dead trout were: very bright red gills, distended swim bladders, and blisters containing gas inside the membranes connecting the fin rays (see photograph figure 7). There were also occasional blisters under the skin on the sides of the body. Microscopic examination of the gill filaments showed that many of the branchial arterioles were completely filled with gas bubbles in long strings (attached is a photomicrograph of a section of gill tissue showing bubbles

Figure VII. Photomicrograph showing gas bubbles in fin rays of speckled trout.

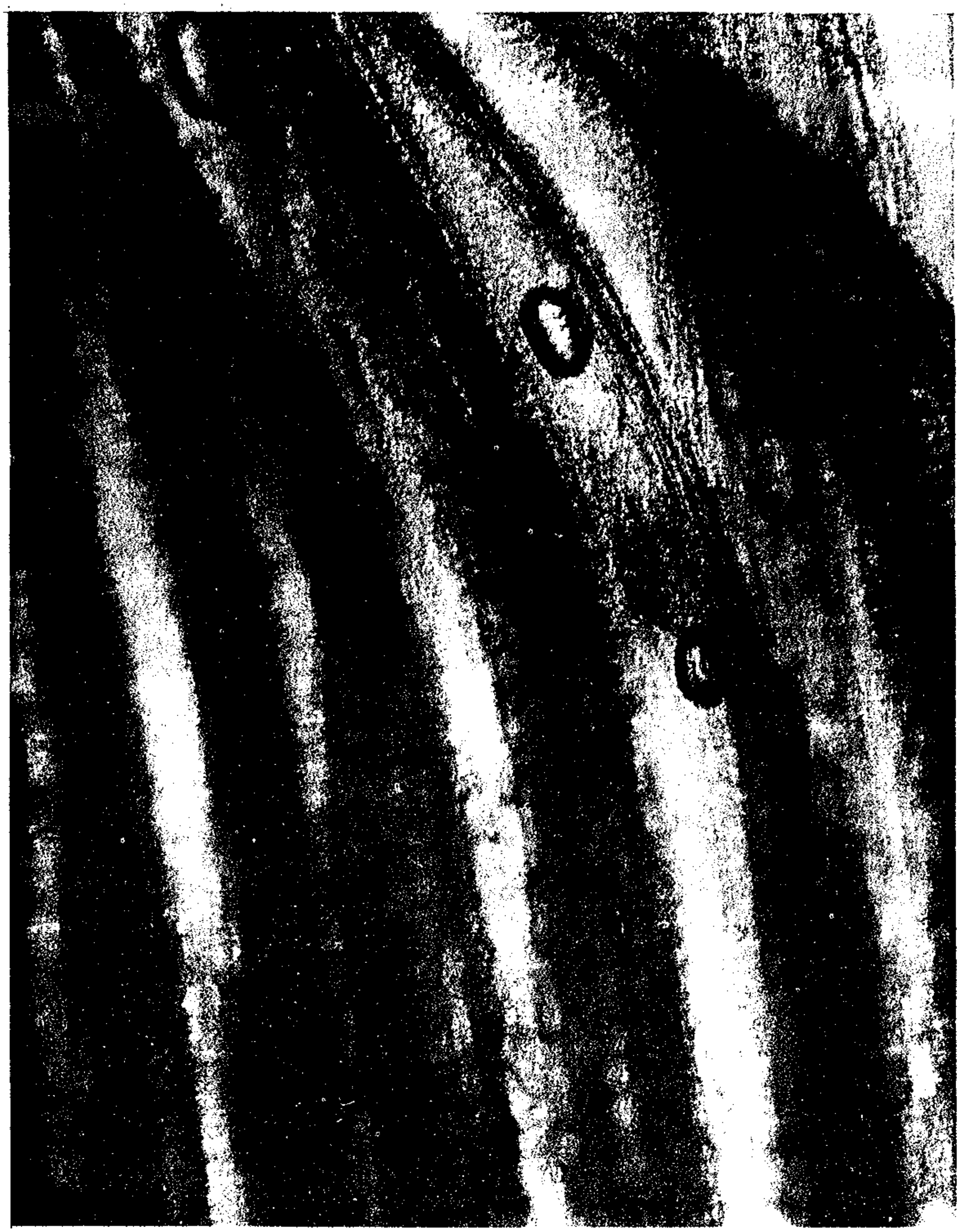


Figure VIII. Photomicrograph showing gas bubbles in a section of gill tissue.

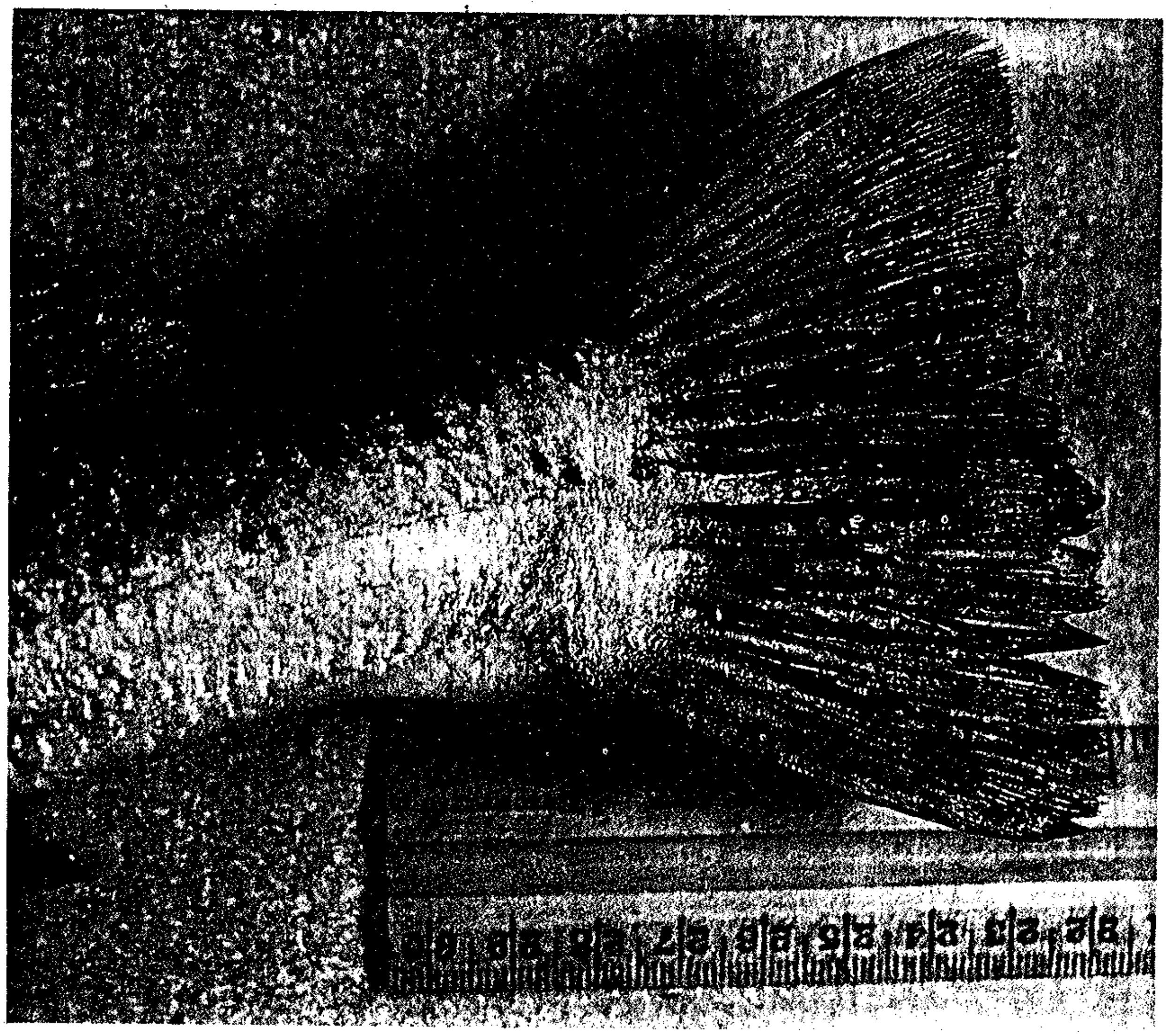
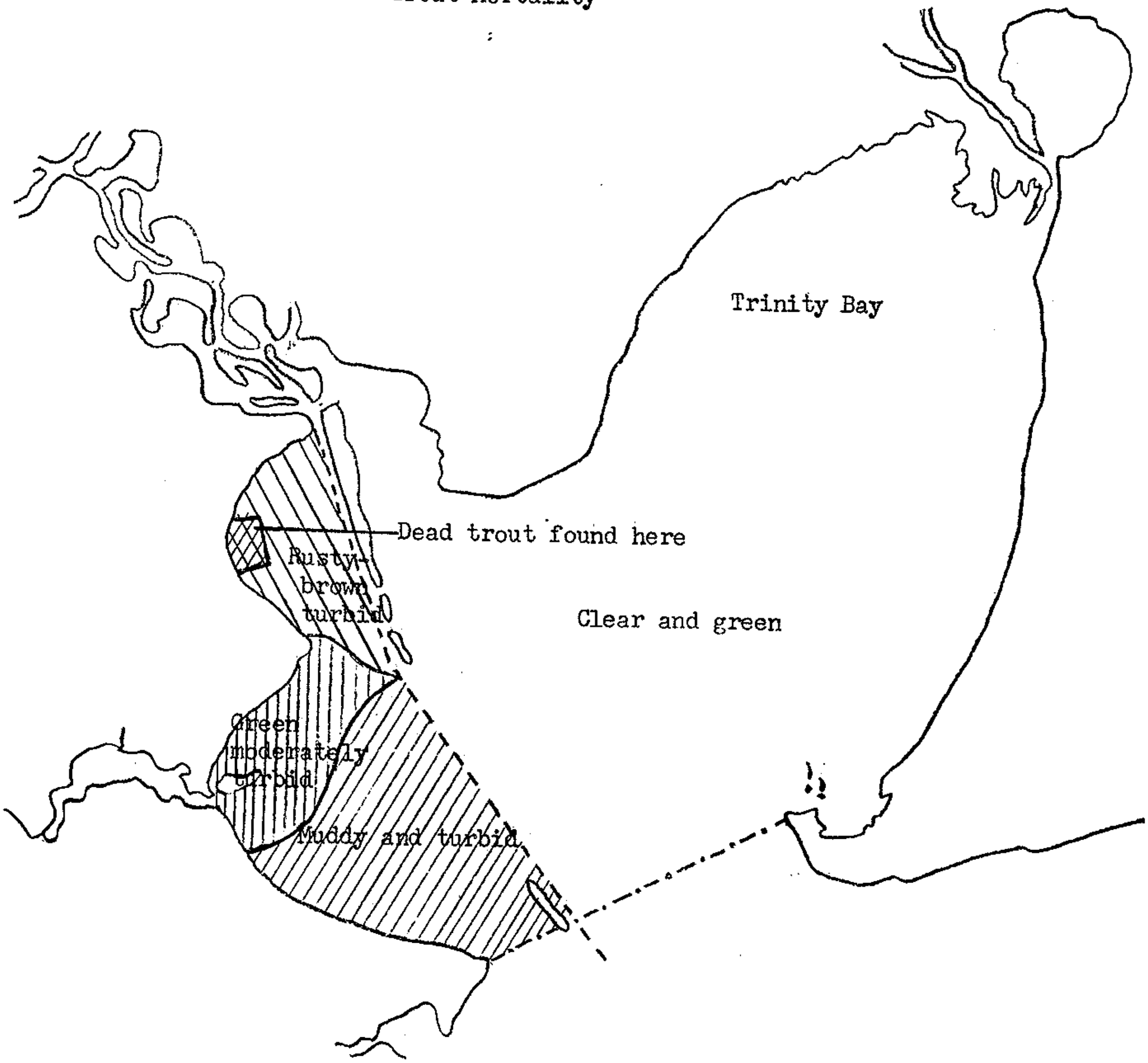


Figure IX. Caudal fin of speckled trout containing gas bubbles.

Figure X

Trout Mortality



Water Conditions
15 January 1959

At the risk of making these explanations much too long and unreadable, it seems advisable to stop for a moment and consider some of the factors which control the solubility of gases in water. The following statements are taken mostly from Limnology (Welch, P.S., McGraw-Hill, 1952, pp. 92-100):

1. When a gas is brought into contact with water, it dissolves in the water until a satae of equilibrium is reached in which the solution and the emission of the gas are balanced.

2. Total solubility is expressed in Henry's Law: the concentration of a saturated solution of a gas is proportional to the pressure at which the gas is supplied.

3. Dalton's law of partial pressure states: the pressure exercised by each component in a gaseous mixture is proportional to its concentration in the mixture, and the total pressure of the gas is equal to the sum of those of its components.

4. Other general conditions affecting the solubility of a gas are:

   a. Rising temperature reduces solubility.

   b. Increasing concentration of dissolved salts diminishes solubility.

   c. Rate of solution is greater when the gases are dry than when they contain water vapor.

   d. Rate of solution depends upon the degree of undersaturation of the water with the gases concerned. The greater the degree of undersaturation the greater the rate of solution.

   e. Rate of solution is increased by wave action and other forms of surface-water agitation.

With this background in mind we return to an examination of the conditions of climate and hydrography summarized in the table above. On several days before the mortality occurred the barometric pressure was high, water temperatures were low, there was little agitation from winds, and relatively little cloud cover (and thus a fairly high amount of isolation). These conditions would favor the build-up of high concentrations of dissolved oxygen produced by the plankton bloom. As the night of January 13th approached barometric pressure decreased and water temperatures increased thus lowering the partial pressure of gases dissolved in the water.

The following mechanism of the "gas-bubble disease" was explained (personal communication) by Dr. Peter Doudofoff (U.S. Public Health Service, Corvallis, Oregon). Fishes swimming in water tend to come into equilibrium with the concentrations of gases dissolved in the water. When the partial pressure of dissolved gases decrease, the excess of gases dissolved in the body fluids come out of solution in the form of bubbles. However the diffussion of excess dissolved gases in the water into the atmosphere is a very slow process. Thus the fishes continue to attempt to come into equilibrium with the excess dissolved gases contained in the water and process continues until the volume of gas bubbles inside the body of the fish becomes so great that circulation of blood is stopped (or perhaps, gas bubbles affect the brain or other vital organs killing the fish).

All available literature surveyed by the writer indicates that this is the first recorded occurrence of "gas-bubble disease" in salt water.

Other fishes affected were a long-nose gar (Lepisosteus osseus) found dead in the area and very small dead and dying anchovies (Anchoa mitchilli), small worm eels (Myrohpis punctatus), and small croakers (Micropogon undulatus) all of which appeared to have distended swim bladders.

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