

# PHYSICAL AND CHEMICAL CHARACTERISTICS

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## SURFACE ELEVATION

When Hoover Dam was completed in the late 1930's more water became available for irrigation in the Imperial Valley, and the Salton Sea rose from about  $-243$  feet to  $-240$  in 1948 and  $-234.5$  in 1956. In 1956, the maximum depth of the Sea was approximately 40 feet, and it covered about 340 square miles (Figure 2).

The increase in surface elevation from 1953 to 1956 and the annual fluctuations in height are shown in Figure 3. These figures are based on records from the Figtree John's gauging station maintained by the Coachella Valley County Water District. Other agencies concerned with the Salton Sea use different datum levels for elevations in the Salton Sink. Highest elevations have occurred in the spring, and lowest in autumn. There was a net rise of one foot from November 1953 to October 1954, and a rise of 0.4 foot from the fall of 1954 to the fall of 1955.

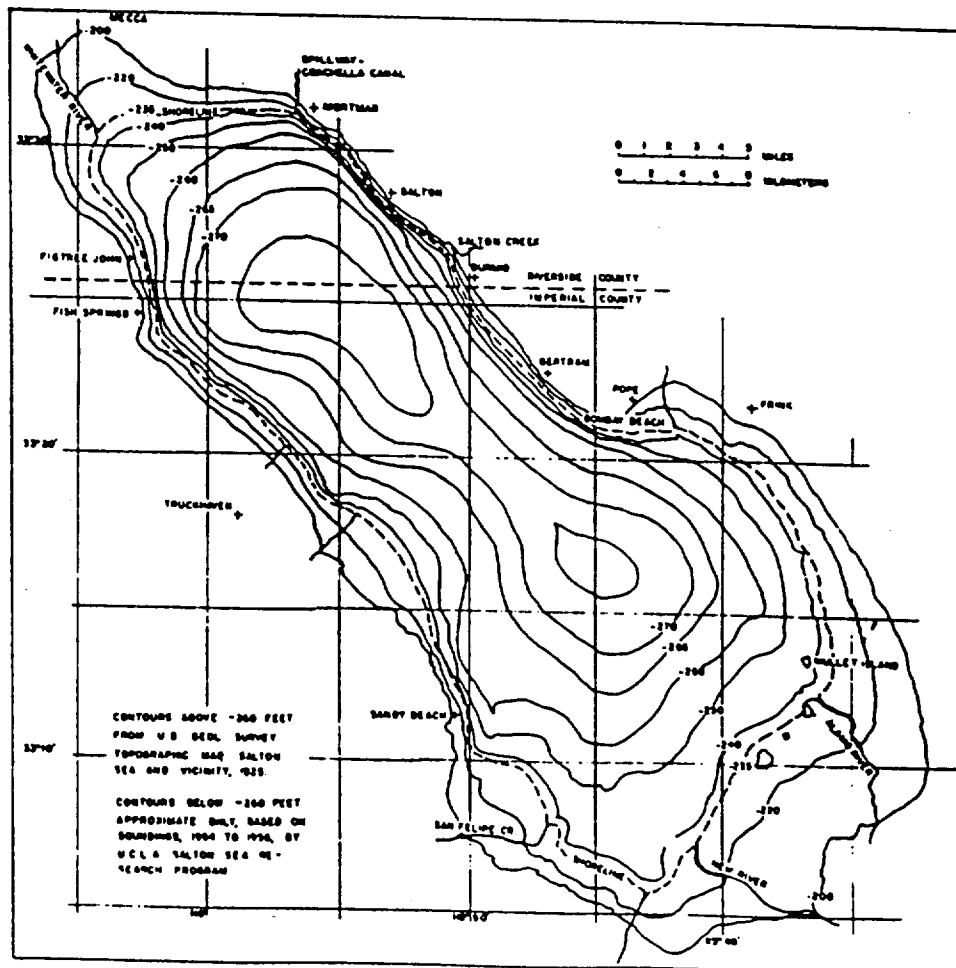


FIGURE 2. Depth contours of Salton Sea. Contours above  $-260$  feet from U. S. Geological Survey, 1925. Contours below  $-260$  feet are approximate only, based on soundings by U.C.L.A. Salton Sea Laboratory, 1954-1956.

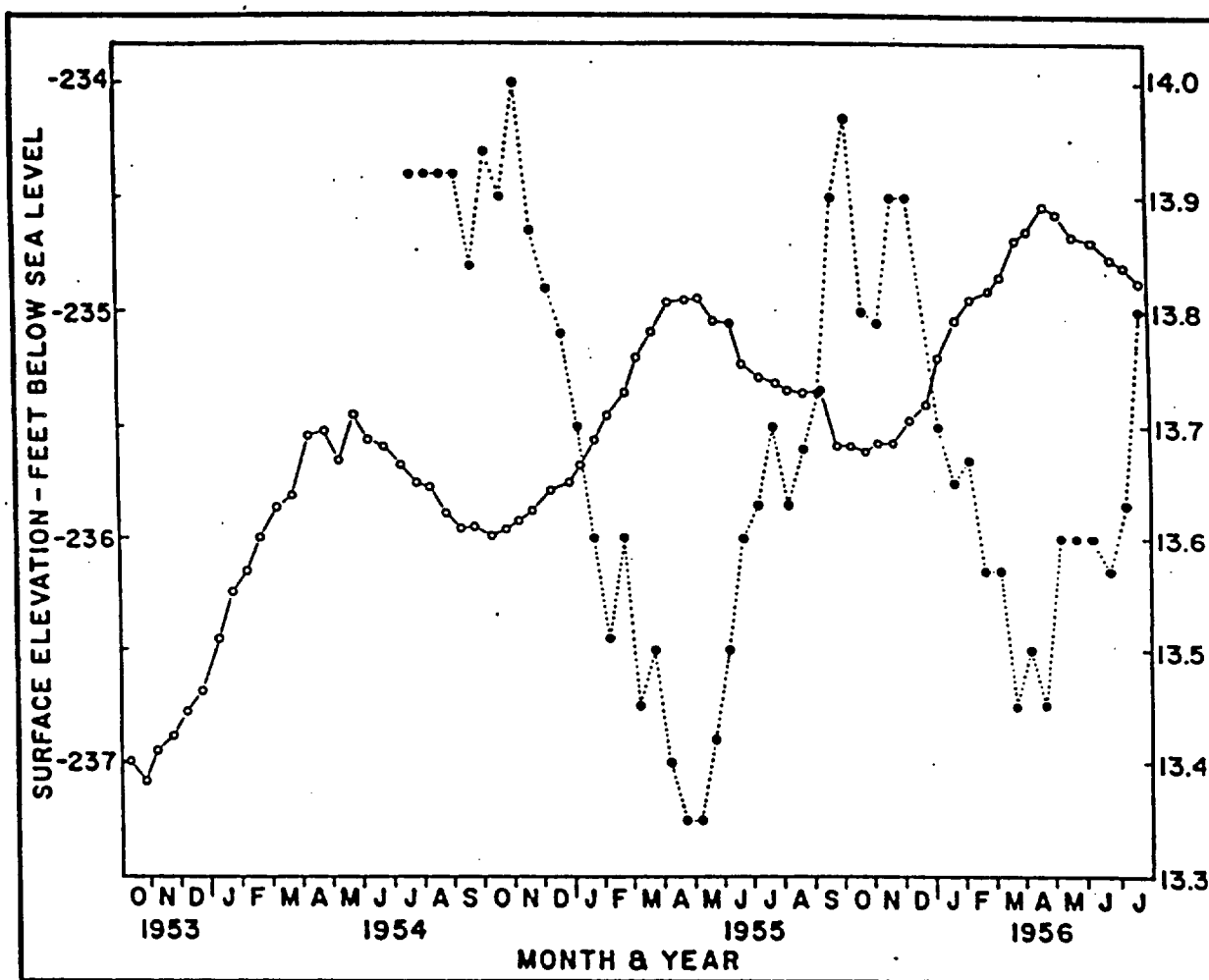


FIGURE 3. Surface elevation (solid line) at Figtree John and chlorinity (dotted line) off Fish Springs, Salton Sea.

The rise has been due to an excess of inflow over evaporation, which has resulted in a net increase in quantity of water in the Sea. Calculations by Holbrook (1927) showed that as the surface elevation rose, relatively more evaporation was possible because the surface area of the shallow Sea increased more rapidly than its capacity. At the 1956 elevation (—235 feet), the capacity of the Sea was 5.5 million acre feet with an area of 220,000 acres. The recent annual increases in elevation (Figure 3) were smaller than the rises that occurred from 1951 to 1952, for example.

Systematic gathering of physical and chemical data for the Salton Sea Research Program ended in July 1956. During the period 1956 to 1959 the surface elevation continued its usual fluctuation of about one

was 0.07 foot lower than in 1956, and in 1959 the highest elevation was 0.07 foot higher than in 1956. Thus there was a difference of only an inch or so in surface elevation during this period, indicating near stabilization at this time.

IONIC COMPOSITION

When the present Salton Sea was formed, it was due, as in previous fillings, to inflow of the Colorado River into the Salton Sink. The salinity of the Colorado at the head of the irrigation canal (whose destruction by flood led to the 1905-1907 inflow via the Alamo channel) was reported by Ross (1914) to have been 0.7 o/oo (parts per thousand). Analyses by Ross showed the water of the newly-formed Sea to have had a salinity of 3.6 o/oo in 1907. The greater salinity of the Sea, relative to that of the river, was due to salts leached from the bottom deposit left by evaporation on previous occasions.

The proportions of ions in the Salton Sea had changed since 1907 (Table 2). Calcium had decreased slightly while the proportions of

TABLE 1  
Salton Sea Surface Elevations, 1956 to 1959

	Highest		Lowest	
	Elevation	Date	Elevation	Date
1956.....	-234.54	23 April	-235.55	8 October
1957.....	-234.64	22 April	-235.78	21 October
1958.....	-234.47	23 June	-235.59	24 November
1959.....	-234.61	27 April	.....	.....

TABLE 2  
Ionic Composition of Salton Sea Water, 1907 to 1955, and of River Waters Entering the Sea

Date	Ca o/oo	Mg o/oo	Na o/oo	K o/oo	CO <sub>2</sub> o/oo	HCO <sub>3</sub> o/oo	SO <sub>4</sub> o/oo	Cl o/oo	Analysed o/oo	Total o/oo
1907 <sup>1</sup> .....	0.099	0.064	1.110	0.023	0.066	--	0.476	1.697	3.55	3.65
1910 <sup>1</sup> .....	0.137	0.098	1.893	0.035	0.064	--	0.764	2.809	5.6	6.04
1913 <sup>1</sup> .....	0.197	0.161	3.231	0.035	0.113	--	1.246	4.739	9.72	10.025
1916 <sup>1</sup> .....	0.298	0.272	5.289	0.057	0.114	--	2.079	7.876	15.93	16.47
1929 <sup>2</sup> .....	0.196	0.588	3.921	as Na	0.102	--	1.37	6.39	12.47	14.43
1945 <sup>3</sup> .....	0.850	0.920	11.345	--	0.207	--	6.924	16.241	36.43	37.57
1948 <sup>3</sup> .....	0.804	0.992	11.824	0.192	0.021	0.171	7.55	16.99	38.55	40.425
1955 <sup>4</sup> .....	0.764	0.951	9.938	0.224	0.021	0.159	6.806	14.422	33.29	33.68
Colo. River (1907) <sup>1</sup> .....	0.072	0.022	0.138	0.015	0.091	--	0.20	0.138	0.68	0.606
Alamo River (1951) <sup>3</sup> .....	0.157	0.113	0.410	0.011	--	0.199	0.529	0.66	2.08	2.256
New River (1951) <sup>3</sup> .....	0.141	0.066	0.435	0.01	--	0.209	0.444	0.605	1.91	1.93
Ocean <sup>1</sup> .....	0.413	1.27	10.55	0.38	--	0.014	2.649	*19.15	34.22	34.48

<sup>1</sup> Analyses from Ross (1914); <sup>2</sup> Analyses from Sykes (1937); <sup>3</sup> Analysis from Coleman (1929); <sup>4</sup> Analysis by

magnesium and sulphate ions increased. Sodium and potassium were still present in about the same proportions as in 1907; chloride ion had decreased slightly in proportion to total, and bicarbonate had decreased from 1.9 percent in the original Sea to about 0.5. The proportions of salts in 1956 bore out the 1907 observation of Ross that they were due to concentration of Colorado River salts. Comparison of the analyses of Colorado River water in 1907 with analyses of New and Alamo River waters in 1951 showed that greater quantities of salts were now entering. The New and Alamo Rivers contain more salts than the Colorado because they carry water that has been used for irrigation.

In 1956, the salinity of the Salton Sea (about 33 o/oo) was only slightly below the total salt content of the oceans, but its waters contained relatively less magnesium, potassium, and chloride ion; about the same proportion of sodium; and more sulphate, calcium, bicarbonate and carbonate ions than are present in ocean water (Table 2).

The total salt content of the Salton Sea increased gradually from 1907 to 1948 (when the salinity was 11 times greater than the original value), and then decreased from 1948 to 1956 as a result of dilution (Table 2). That is, prior to 1948 less water entered the Sea than evaporated, so the surface elevation fell and the salinity increased. Subsequent to 1948 evaporation did not equal inflow, so the surface elevation rose and the salinity decreased.

#### CHLORINITY

The ratio of chloride to total salts in the Salton Sea is not the same as in the oceans (Table 2). Similar to the use of the term "chlorinity" in chemical oceanography, it is used in this discussion for total halides, expressed in parts per thousand (o/oo), determined by titration with silver nitrate. The ratio of chlorinity to total salts (salinity) has averaged 2.36 (within a range of 2.42 to 2.31), in analyses made since 1949. Salinity was thus, roughly,  $2.36 \times$  chlorinity, compared to the Cl o/oo S o/oo ratio of roughly 1.805 in the ocean (Sverdrup *et al*, 1942). During the years of this study, 1954-1956, chlorinity in the main body of the Sea ranged from 13.3 to 14 o/oo, corresponding to a salinity of 31.4 to 33 o/oo.

The main body of the Sea had a relatively uniform salinity. For example, at the end of November 1954, the chlorinity near shore was 13.6 o/oo at the northern end (off the mouth of the Whitewater), 13.9 on the western side (off Fish Springs and Truckhaven); and 13.7 on the eastern side (off Bombay Beach). Samples from the center of the Sea had values of 13.8 and 13.9.

The slightly lower chlorinity at the north shore was due to drainage from the Whitewater River and the Coachella spillway. The southwestern part of the Sea had a chlorinity only slightly below that of the northern portion. The mean annual chlorinity at the southwest shore was 12.9 o/oo (with a range of 12.3 to 13.5) during a one-year period from May 1955 to May 1956. During this period, the chlorinity in the northern part of the Sea ranged from 13.3 to 14 o/oo. The greatest dilution occurred in the southeastern corner of the Sea, where most of the entering water came in via the New and Alamo Rivers. In contrast to the relative uniformity...

The discharge of the Alamo River was eastward toward Mullet Island during the time of this study. Data obtained on November 8 and 10, 1954 illustrated the effect of fresh water flowing eastward from the mouth of the Alamo. A mile west of the Alamo mouth the chlorinity was 13.9 o/oo at the bottom and 13.5 o/oo at the surface. A quarter of a mile east, however, it was 4.1 o/oo, and at the west shore of Mullet Island it was 9.6. Two and one-half miles north of the island, along the east shore of the Sea, surface chlorinity was 10.2 o/oo, and two miles further north (about four miles from the mouth of the river) the surface value was 12.5 at shore, 12.9 a mile offshore, and 13.3 at the bottom (four meters).

At Mullet Island the average annual chlorinity was 10.8 o/oo, with a range of 1.5 to 13.6 o/oo. Chlorinity of 1.5 o/oo was only about twice that of Alamo River water prior to entry into the Sea. The influence of fresh water was noted as far north as Bombay Beach, approximately 10 miles from the river mouth. In general, the lower salinity was noticeable only along the southeast shore, and there seemed to be considerable delay before the effect of dilution became apparent in the northern part of the Sea. The evaporation of fresher water, which tended to float on the surface, seemed to modify the dilution which spread slowly throughout the Sea by diffusion and a generally counter-clockwise current.

An annual cycle of variation in chlorinity in the main body of the Sea, was related inversely to the highest and lowest surface elevations during the year. During 1954-1956, highest chlorinity occurred in autumn and early winter, after high summer evaporation had lowered the surface elevation to the yearly low. The lowest chlorinity occurred in spring following the period with least evaporation (Figure 3).

Lowest chlorinity in the main body of the Sea during 1955 was only slightly below the lowest observed in 1956. It would appear that the decrease in chlorinity which occurred from 1948 to 1956 ended as the result of a new balance between evaporation and rate of inflow. The records of Blaney (1954) show that during the early 1950's the annual inflow was about 1.5 million acre feet. All but about 220,000 acre feet evaporated, but so long as there was a net increment in volume, the Sea was diluted and salinity fell. There was a decrease from nearly 40 o/oo in 1948 to 33 o/oo in 1956. When the elevation of the Sea becomes stabilized, salinity will increase again. If stabilization occurs at -235 feet, the increase in salinity can be calculated from the capacity at that elevation (which is 5.5 million acre feet or  $67.8 \times 10^9$  cubic meters according to Holbrook, 1927), and from the known annual inflow of salt (3.0 million tons [ $2.7 \times 10^9$  kg.] according to Dowd, 1952). The salinity would increase at the rate of 0.4 parts per thousand per year. In a little less than 20 years (in the mid 1970's) it would be 40 o/oo which might be considered the upper limit of the Sea as a favorable environment for marine organisms.

However, if the estimate made by Blaney should prove true (that the Sea will stabilize at -220 feet when it has a capacity of 9.1 million acre feet) the salinity would decrease to about 25 o/oo at the time of stabilization in 1970-1980 and then it would increase and reach about

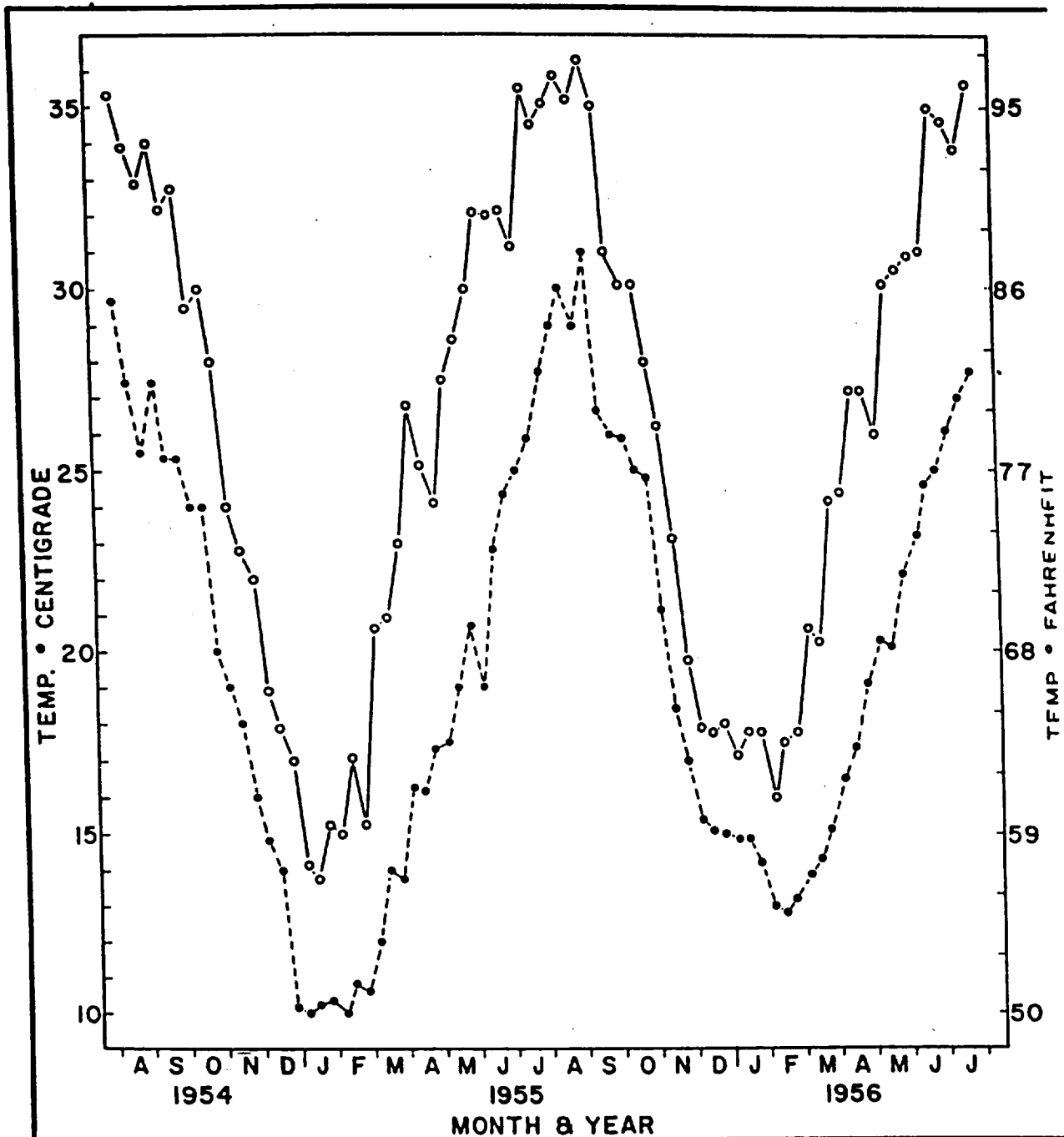


FIGURE 4. - Water temperatures at Sandy Beach, Salton Sea, for the period August 1954 to July 1956. The surface maximum temperature is indicated by the continuous line, the bottom (at three meters) minimum temperature by the hatched line.

50 years. Although it seems that the best estimate is based on stabilization at the -235 foot level, accurate prediction is impossible because the amount of Colorado River water available to the Salton Sink in the future is uncertain.

The chlorinity was not determined at regular intervals after July 1956. However, water samples taken from mid-Sea two years later, on August 13, 1958, ranged from 14.0 to 14.15 for an average of 14.1 o/oo (salinity 33.27 o/oo). In July 1956 the chlorinity was 13.8 o/oo (salinity 32.57 o/oo).

The increase in salinity from 1956 to 1958 of 0.7 parts per thou-

begun, the slight increase in salinity was within the range of variation due to the annual cycle of elevation. However, it seems to bear out the estimate, based on calculations given previously, that salinity will increase at about 0.4 parts per thousand per year, so long as the surface remains constant at the present level.

**WATER TEMPERATURE**

Temperatures were taken by a dual recording thermometer located on a dock at Sandy Beach where the maximum depth was three meters (Figure 4). The extreme range during the two-year period was from 10 to 36 degrees C (50-97 degrees F). Readings obtained by the California Department of Fish and Game with a recording thermometer at Date Palm Beach during 1936, and by the U. S. Geological Survey at Sandy Beach during 1953 were not significantly different from our data. Mean water temperatures were highest in August, but maximum temperatures may be reached during June, July, and September. Coldest water of the year may occur in December, but more often in January or February.

Beginning in April and May air temperatures equal or exceed water temperatures (Figure 5). In June, the increased solar radiation may warm the water surface so rapidly that, although the maximum depth of the Sea is only 40 feet (12 meters), there may be a significant difference between temperatures at surface and bottom (Table 3). At the end of May, there was a difference of only 0.7 degrees C between surface and bottom. On June 8, however, the difference was 5.3 degrees C (9.5 degrees F), but this was temporary and decreased to 2.2 degrees C by June 14, to 1 degree C on June 30 (not shown) and 1.4 degrees C on July 7. The difference in surface and bottom temperature remained slight until July 18 when at mid-day the surface was 3.9 degrees C warmer than the bottom; the next day (July 19) the surface was 3.2 degrees warmer than the bottom at 6 AM, and by 6 PM the difference had increased to 3.9 degrees C (Table 6). By the end of July, the bottom had warmed to nearly 30 degrees C, and its temperature was only 1.1 degrees C below that of the surface. During August, the maximum observed difference was 0.8 degrees C, and at times surface and bottom temperatures were equal (as on August 24). From September until May, the usual difference between surface and bottom was 1 degree C or less.

**TABLE 3**  
**Vertical Distribution of Water Temperatures in the Salton Sea, in Degrees C, 1955 \***

Depth in Meters	May 27	June 8	June 14	July 7	July 18	July 27	Aug. 24	Sept. 15	Sept. 20	Oct. 19	Nov. 15
0.....	23.0	28.2	26.2	28.0	30.9	30.9	31.2	32.7	29.0	25.8	20.0
1.....	--	28.0	--	27.6	--	--	--	--	--	--	--
2.....	--	27.5	--	27.0	--	--	--	--	--	--	--
3.....	--	24.8	25.5	26.8	30.4	--	--	--	--	--	--
5.....	22.4	24.0	25.0	26.6	30.0	30.2	31.3	31.8	28.2	25.5	19.8
7.....	--	--	--	--	29.7	--	--	--	--	--	--
9.....	--	23.5	--	--	27.9	--	--	--	--	--	--

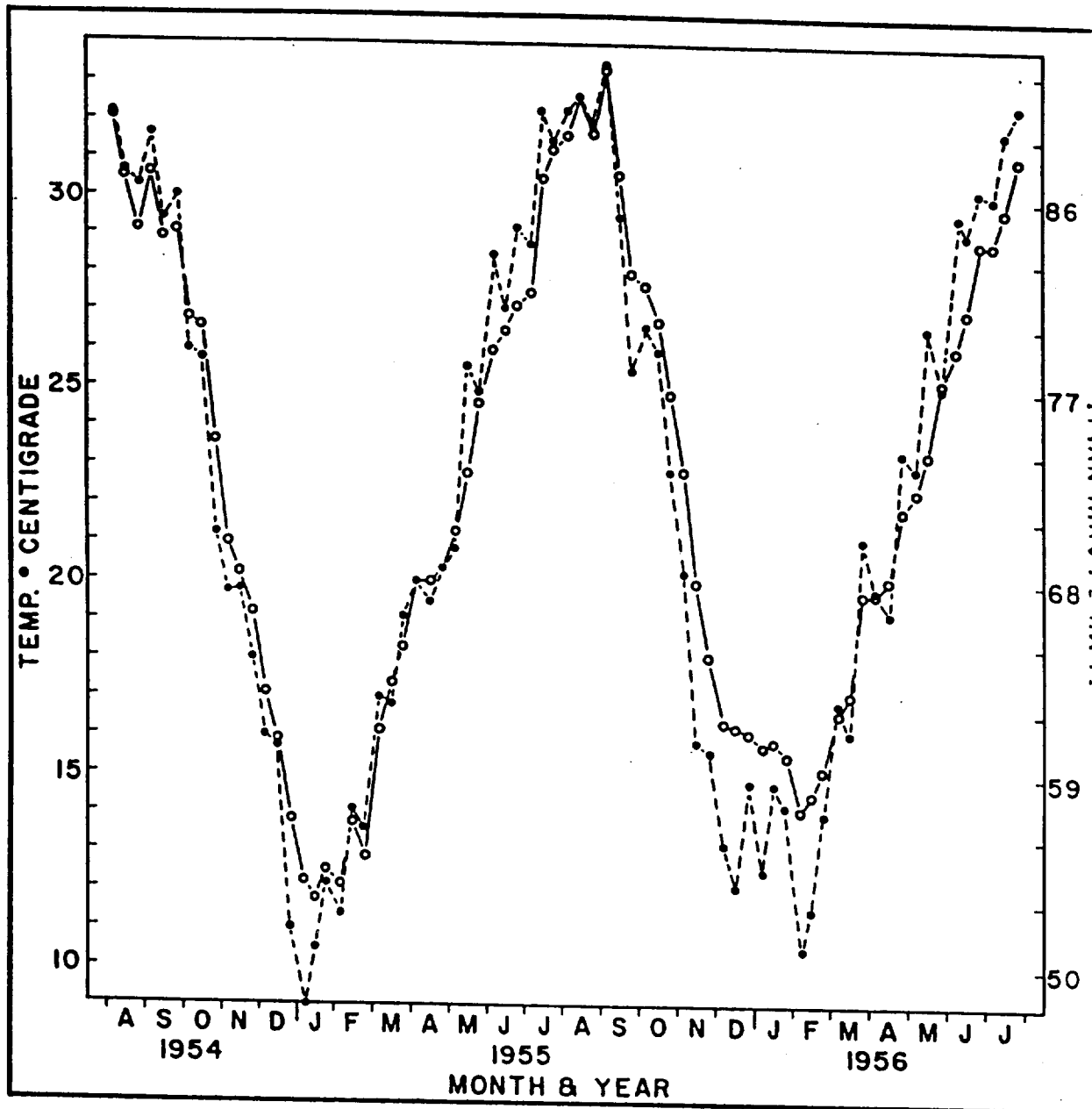


FIGURE 5. Mean water (solid line) and mean air (dotted line) temperature, Fish Springs, Salton Sea.

The temperature gradients that appeared during June and July correlated with changes in the weather. Air temperatures are indicative of the intensity of solar radiation and the warming of the surface on June 8 followed the first protracted period with air temperatures above 38 degrees C (100 degrees F). The rapid rise of water temperature on July 18 and 19 followed four days with a mean maximum air temperature of 40 degrees C (104 degrees F). In August, air temperatures were consistently high—the mean maximum for the entire month was 37.5 degrees C (99.4 degrees F)—and for the first 10 days of September it was 40 degrees C (104 degrees F). During the period of relatively constant air temperatures, the vertical distribution of water temperatures remained quite constant.

The bottom temperature did not fall below 30 degrees C until after mid-September. It fell to 25 degrees C in mid-October and to 20 degrees



and at the bottom during autumn were not great compared to those in June and July. The entire water column seemed to cool uniformly, as would be expected since mixing of cooler surface waters (which tend to sink) is less dependent on chance wind action than is mixing of warmer (and therefore, less dense) surface water in early summer. The appearance of a marked gradient seemed to be dependent on both rapid increase in solar radiation and lack of wind, so that the warmed surface water would not be mixed with the lower layers. Wind action mixes the shallow waters of the Sea thoroughly, as will be brought out in the section dealing with concentrations of dissolved oxygen.

There was no permanent thermocline in the Sea (Table 3). Sometimes, during the brief periods when surface and bottom temperatures were markedly different, a sharp thermocline developed. It could occur near the surface (between two and three meters on June 8) or at greater depth (between seven and nine meters on July 18). Sometimes there was a gradual uniform decrease in temperature with depth, with no thermocline. In any event, there was no permanent layering, but only temporary stratification following short windless periods, when a rapid increase in surface temperature was not dissipated by mixing with cooler sub-surface water.

#### DISSOLVED OXYGEN

Concentrations of dissolved oxygen were determined by the unmodified Winkler method (American Public Health Assoc., 1955). The unit of concentration used in this report is milliliter of gaseous oxygen per liter of water (abbreviated to ml/L). For conversion to milligram per liter, the factor is  $32/22.4 = 1.42$ ; for conversion to milligram-atom per liter, the factor is  $1.42/16 = 0.089$ . Saturation values for oxygen in Salton Sea water were approximately six ml/L at 10 degrees C, five ml/L at 20 degrees C, and four ml/L at 30 degrees C.

Near shore there were great diurnal changes in oxygen concentration. An example of this, at a time when water temperatures were at their yearly maxima, is shown in Table 4. The data are from water about three meters deep approximately 100 meters offshore on September 11, 1954. The water temperatures ranged from 29 to 32.4 degrees C. The evening concentration of 6 ml/L was well above the saturation value for the high temperature concerned.

During the colder part of the year, surface water also became supersaturated, with still higher concentrations of oxygen. The evolution of oxygen by an early bloom of phytoplankton on February 17, 1955 is

TABLE 4  
Dissolved Oxygen, September 11, 1954, Salton Sea

Depth	Concentration in ml/L			
	6:40 AM	8:30 AM	1:00 PM	6:20 PM
Surface.....	2.8	3.6	5.9	6.1

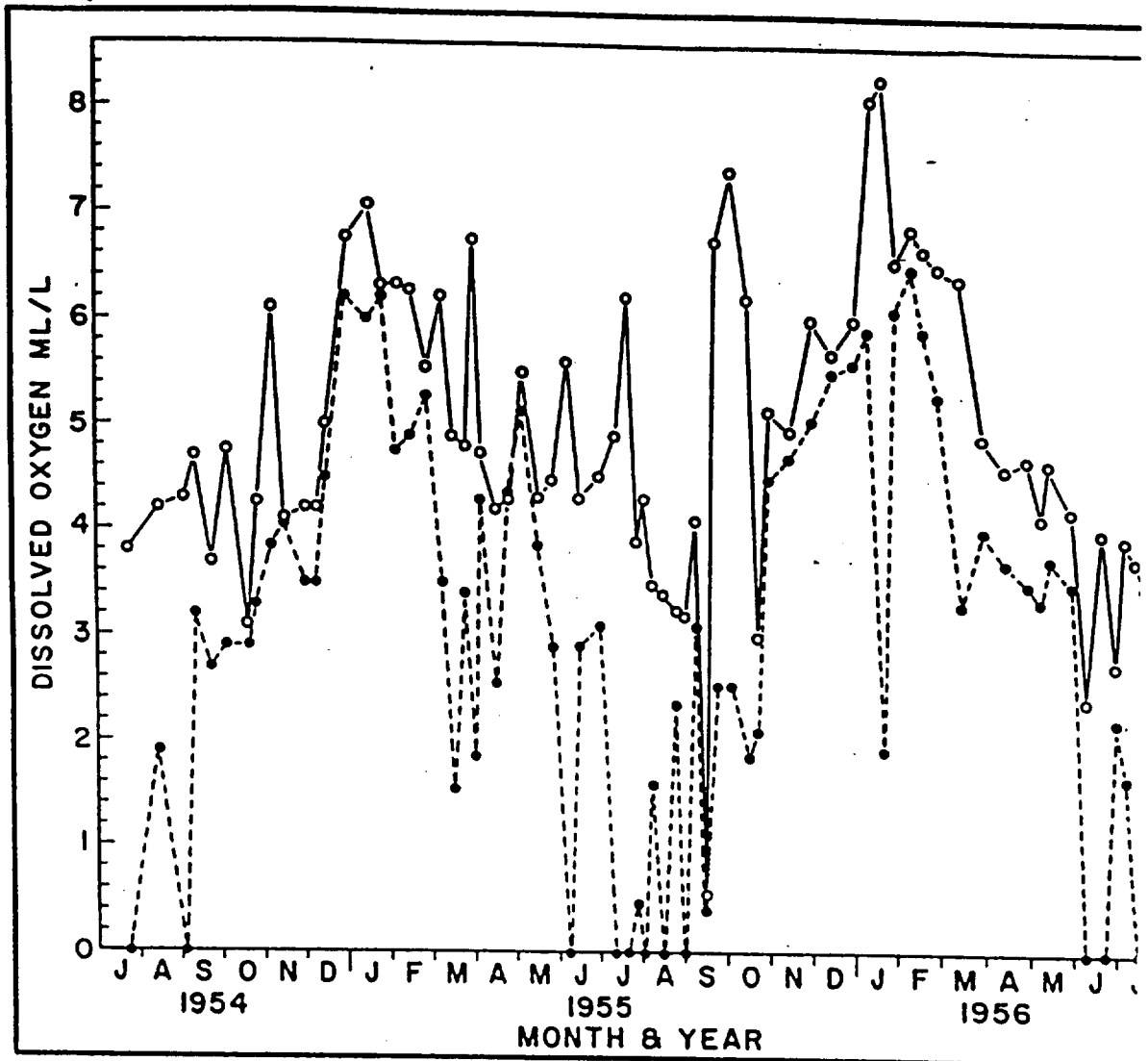


FIGURE 6. Dissolved oxygen. Surface (solid line) and bottom (12 meters) concentrations (dotted line) three miles off Fish Springs, Salton Sea.

shown in Table 5 with data from a station approximately one mile of shore above a depth of seven meters. The data show the high concentrations at mid-day, and the diurnal range when water temperatures were 15 to 16 degrees C.

As representative of the concentrations of dissolved oxygen in the deeper water of the Sea, Figure 6 shows values obtained at approximately weekly intervals during 1955, and bi-monthly during 1956 about

TABLE 5  
Dissolved Oxygen, February 17, 1955, Salton Sea

Depth	Concentration in ml/L		
	6:45 AM	12 Midnight	5:30 PM
Surface.....	6.2	8.1	6.2

three miles east of Fish Springs in the deepest part of the Sea (about 12 meters). Surface concentrations ranged from 8.3 ml/L at mid-day (on January 16, 1956) to 0.55 (at dawn on September 16, 1955). Bottom values ranged from winter highs of 6.2 (January 4, 1955) and 6.5 ml/L (February 14, 1956) to the zero recorded on several occasions in summer.

In general, during winter there were high concentrations of oxygen throughout the water column. However, as early as January 1956 and during March and April 1955 there were times when concentrations were low at the bottom. In early June of both 1955 and 1956 the bottom became anoxic, but the condition did not last long (Figure 6). In July 1955, however, only one of six determinations showed any oxygen present, and that one (on July 27) showed only 0.46 ml/L. When oxygen was absent at the bottom there was no wind and the surface of the Sea became so smooth it mirrored the surrounding hills. One such windless period occurred in mid-July of 1955. Samples taken at 9:30 AM on July 12, at noon on July 18, and at 6 AM and 6 PM on July 19 contained no oxygen at depths below nine meters (Table 6).

In contrast, records for mid-September and mid-October illustrate the effect of mixing by wind during the 12-hour period between samplings (Table 7). Surface to bottom differences in concentrations of dissolved oxygen, pH, and temperature disappeared during the mixing.

TABLE 6  
Morning and Evening Concentrations of Dissolved Oxygen, Temperature, and pH, July 19, 1955, Salton Sea

Depth in Meters	6 AM			6 PM		
	Dissolved O <sub>2</sub> in mg/L	Temp. in Degrees C	pH	Dissolved O <sub>2</sub> in mg/L	Temp. in Degrees C	pH
0	7.4	30.6	8.69	9.3	31.4	8.73
7	6.4	29.4	8.55	5.6	30.3	8.58
9	0	28.0	8.34	0	-----	8.37
11	0	27.4	8.34	0	27.5	8.26

TABLE 7  
Morning and Evening Concentration of Dissolved Oxygen, Temperature, and pH, Mid-September and Mid-October 1955, Salton Sea

Depth in Meters	Dissolved O <sub>2</sub> in mg/L	Temp. in Degrees C	pH	Dissolved O <sub>2</sub> in mg/L	Temp. in Degrees C	pH
		September 15, 5 PM			September 16, 5:45 AM	
0	10.1	32.7	8.74	0.8	30.4	8.28
5	3.4	31.8	8.56	0.7	30.4	8.26
11	0.5	31.6	8.52	0.6	30.6	8.3
	October 18, 4 PM			October 19, 6 AM		
0	8.9	25.5	8.7	3.1	25.0	8.48
5	3.7	25.6	8.52	3.1	25.2	8.48
11	2.6	25.6	8.48	3.1	25.3	8.44

During 1956, the bottom anoxia again appeared in June, and was absent in early July. Then by July 16, after a windless period, oxygen was absent below 8 meters, and there was a three-degree difference in temperature between surface and bottom (Table 8). On July 18, two days later and after a day with strong south wind, thorough mixing was indicated by the similarity of surface and bottom temperatures, the presence of oxygen at the bottom again, the small difference in pH, etc. (Table 9).

During the mixing that followed a period of oxygen depletion at the bottom, oxygen concentrations at the surface sometimes would be lowered temporarily below the minimum needed to maintain many forms of life in the Sea. At such times, there sometimes would be a fish "kill," evidenced by dead fish floating on the surface and washed ashore on the beaches. The depletion of oxygen was reflected by the disappearance of a bottom-dwelling worm (*Neanthes*) from the mud at depths below about nine meters during summer. It seems that only the water below nine meters became anoxic; primarily in the central (deepest) part of the Sea, which is approximately the area below the -260-foot contour in Figure 2. Regions near shore that were shallower than nine meters, seemed to be affected only for brief periods in the early morning, when the situation was comparable to that in the surface waters above the deeper parts of the Sea, as shown in Table 7.

TABLE 8  
Temperature, pH, and Concentration of Dissolved Oxygen, Ammonia,  
and Sulfide, July 16, 1956, Salton Sea

Depth in Meters	Temp. in Degrees C	pH	Dissolved O <sub>2</sub> in mg/L	NH <sub>3</sub> -N (μg-at/L)	Sulfide-S (μg-at/L)
0.....	30.0	8.51	5.4	10	0.35
6.....	29.0	8.42	4.3	11	0.7
8.....	28.4	8.35	0.5	22	1
9.....	--	8.19	0	35	15
10.....	27.2	8.16	0	40	38
11.....	--	8.08	0	48	64
12.....	27.0	8.02	0	36	85

TABLE 9  
Temperature, pH, and Concentration of Dissolved Oxygen, Ammonia,  
and Sulfide, July 18, 1956, Salton Sea

Depth in Meters	Temp. in Degrees C	pH	Dissolved O <sub>2</sub> in mg/L	NH <sub>3</sub> -N (μg-at/L)	Sulfide-S (μg-at/L)
0	29.5	8.50	5.0	17	0.1
6	29	8.49	4.5	15	0.1
8	29	8.47	4.4	12	0.1
10	29	8.42	3.7	14	0.1
12	29	8.40	3.4	17	0.1

HYDROGEN ION CONCENTRATION

Field determinations, made with a Beckman Model G portable pH meter, showed the pH ranged from 8.3 to 8.6 in winter and from 8.5 to 8.8 in summer. The Salton Sea contains a different ratio of carbonate to bicarbonate than the oceans, and the pH is higher. As in the oceans, photosynthetic uptake of carbon from the buffer system causes a diurnal cycle of pH. An example (Table 10) of the diurnal range of pH near shore and one mile offshore on April 12, 1955 illustrates the daily trend during the time of year when water temperatures were below 20 degrees C (18.6-19.4 degrees C).

Data from the same locations on July 19, 1955 (Table 11) illustrate the pH values during the hottest part of the year, on a day when surface temperatures were 31.4 degrees C. at dawn and 31.6 at sunset. Data for vertical distribution of pH and the diurnal range observed in the deeper part of the Sea on the same date (July 19, 1955) appear in Table 6. Tables 7 and 8 also include data for pH values in deeper water.

OXIDATION AND REDUCTION POTENTIAL OF BOTTOM MUD

The redox potential of the bottom, taken with a platinum electrode in a Beckman Model G portable pH meter, was -560 mV at 12 meters three miles offshore on August 11, 1955, a day without oxygen in the bottom water. The pH was 7.5. During anoxic periods in 1956, the redox potentials of the mud were -474 mV on June 6, -480 mV on June 22, and -450 mV on July 16. The pH of the mud on these occasions was 7.4 to 7.5.

SULFIDE

A thick layer of settled plankton accumulated on the bottom in summer. On the surface of this bottom layer, the sulfur bacterium (or blue-

TABLE 10  
Diurnal pH, April 12, 1955, Salton Sea

Time	pH Near Shore		pH One Mile Offshore	
	Surface	3 Meters	Surface	7 Meters
6 a.m.	8.32	8.39	8.41	8.39
12 Midnight	8.5	8.4	8.56	8.51
6 p.m.	8.62	8.6	8.58	8.51
12 Midnight	8.47	8.47	8.45	8.4

TABLE 11  
Diurnal pH, July 19, 1955, Salton Sea

Time	pH Near Shore		pH One Mile Offshore	
	Surface	3 Meters	Surface	7 Meters
6 a.m.	8.67	8.63	8.62	8.52

green alga) *Beggiatoa* was noted in September and October 1955. The combination of sulfur bacteria and periods of bottom anoxia during the summer and fall led to the belief that high concentrations of sulfide might occur when oxygen was absent. A method of determining sulfide in sea water was obtained from Dr. N. W. Rakestraw, Scripps Institution of Oceanography. It was a modification of the colorimetric technique (American Public Health Assoc., 1955) which utilizes para-aminodimethyl-anilin and ferric chloride to produce methylene blue in the presence of sulfide ion.

Beginning in January 1956 and continuing through June, determinations were made on a by-monthly basis. Six samples were analyzed during July. The average value of 12 bottom samples (from a depth of 12 meters), taken from January through May, was 0.25  $\mu\text{g-at/L}$  (microgram-atoms per liter), with a range from 0.0 to 0.5. On June 6, the first day of oxygen depletion at the bottom, the concentrations of sulfide rose to 1.5  $\mu\text{g-at/L}$  at the bottom, and on June 22 it was 50  $\mu\text{g-at/L}$ . On both July 2 and 9, concentrations were low: 0.5  $\mu\text{g-at/L}$ . On July 16, the bottom concentration of sulfide rose to 85  $\mu\text{g-at/L}$ . The values for the last three determinations, made on July 18, 24, and 30, respectively, were 0.1, 1.0, and 0.6  $\mu\text{g-at/L}$ . In contrast to high values and great variation at the bottom, the average sulfide concentration in surface samples during January through July 1956 was 0.3  $\mu\text{g-at/L}$ , with a range from 0.0 to 0.6  $\mu\text{g-at/L}$ . Data on vertical distribution of sulfide on July 16 and 18 have been included in Tables 8 and 9.

#### AMMONIA, NITRATE, AND PHOSPHATE

Ammonia was determined by direct Nesslerization after precipitating interfering ions by the Witting-Buch technique (Wirth and Robinson, 1933); nitrate by the diphenylbenzidine method (Atkins, 1932); and

TABLE 12  
Concentration of Ammonia, Nitrate, and Phosphate at Four Locations, Salton Sea

Station Number	Depth in Meters		Concentration in $\mu\text{g-at/L}$		
			Ammonia	Nitrate	Phosphate
1.....	0	Average Range	5.35 0.2-13.5	0.85 0.2-1.9	0.47 0.33-1.0
	6	Average Range	5.9 0.2-18.3	0.8 0.2-1.7	0.61 0.32-1.95
	12	Average Range	9.5 0.4-40.0	0.78 0.2-1.85	0.45 0.3-0.85
2.....	0	Average Range	5.5 0.1-12.3	0.91 0.4-2.0	0.47 0.3-0.6
	3	Average Range	5.9 0.2-13.8	0.99 0.4-2.2	0.51 0.2-0.85
3.....	0	Average Range	4.8 0.1-10.0	0.93 0.4-1.4	0.71 0.45-1.1
4.....	0	Average	12.3	7.63	1.1

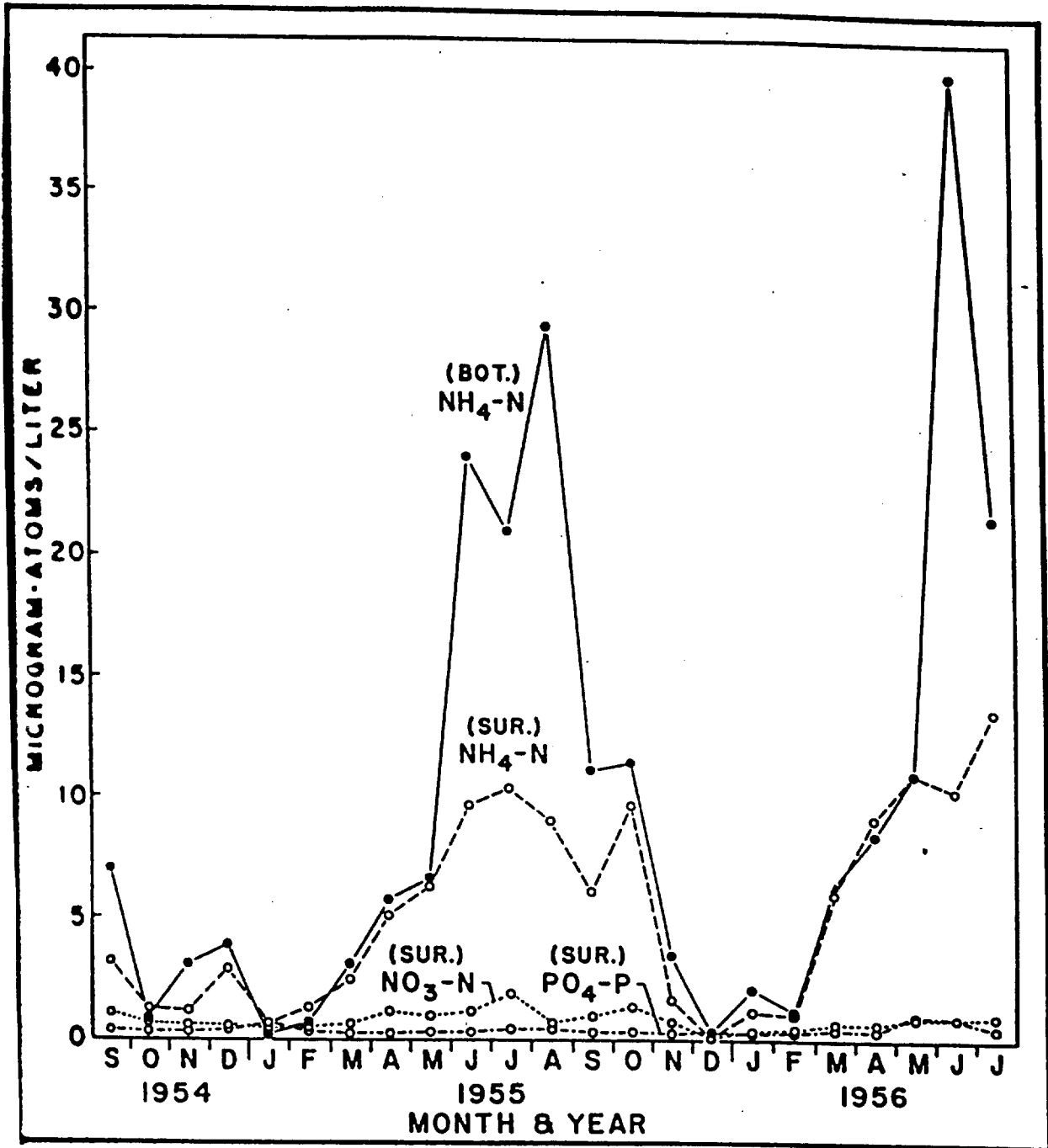


FIGURE 7. Ammonia-N, Nitrate-N, and Phosphate-P three miles off Fish Springs, Salton Sea.

phosphate by the molybdate-stannous chloride method (Wooster and Rakestraw, 1951). Only ammonia was in sufficient quantity to show significant seasonal trends. Concentrations of nitrate and phosphate, although high in the water entering the Sea, were so low in the main body of the Sea that not much reliance can be placed on the absolute values obtained with the colorimetric methods used for analysis. Results of the nitrate test, especially, are of doubtful value.

Table 12 summarizes data obtained at four stations. Those from Stations 1 and 2 are based on weekly samplings during a two-year period (September 1954 to July 1956). Station 1, representative of the deepest

(see Figure 2). Station 2, representative of conditions near shore, was about 100 meters off Fish Springs. Data from the other two stations are based on monthly sampling during a one-year period (May 1955 to May 1956). Station 3 was on the south shore (depth about 1.5 meters), a location relatively little influenced by stream discharge into the Sea. Station 4 was off Mullet Island (depth about 1.5 meters), where the effects of freshwater discharge were noticeable. Only surface samples were taken at Stations 2 and 3.

In the main body of the Sea (Stations 1 and 2), the range of nitrate-N was nearly the same at all depths: the average was slightly higher at the surface and near shore. The range and average concentrations were highest offshore at the bottom. Concentrations of ammonia showed a marked seasonal trend in the main body of the Sea (Figure 7). At the bottom, the concentrations rose from a low ( $0.4 \mu\text{g-at/L}$ ) in winter to about  $10 \mu\text{g-at/L}$  by May and a maximum above  $20 \mu\text{g-at/L}$  during summer. Concentrations fell to  $10 \mu\text{g-at/L}$  in September and October, and then down to the winter low.

Station 3 (the south shore of the Sea) had slightly higher concentrations of phosphate and nitrate, and slightly lower concentrations of ammonia, than were found in the main body of the Sea. Station 4 (off Mullet Island, in line with the discharge from the Alamo River) had higher concentrations of nitrate and phosphate than any other station, and had the highest average concentration of ammonia, although the maximum there was exceeded at the bottom in deeper water (Station 1).

Concentration of ammonia, nitrate, and phosphate off Mullet Island depended on the quantity of water discharged into the Sea which varied seasonally according to irrigation practices in the Imperial Valley. The water "wasted" into the Sea had been used primarily for irrigation or for land leaching, and it carried with it fertilizer and salts from the land. In the waters of the New and the Alamo Rivers, near their points of discharge into the Sea, there have been averages of  $10 \mu\text{g-at}$  of ammonia-N,  $25 \mu\text{-at}$  of nitrate-N and five  $\mu\text{g-at}$  of phosphate-P per liter. The available nitrogen momentarily present at the surface of the main body of the Sea was low (average six  $\mu\text{g-at/L}$  at Station 1) and was largely in the form of ammonia. The concentration of available nitrogen entering the Sea was much greater ( $35 \mu\text{g-at/L}$ ) and largely in the form of nitrate. Most of the nitrogen and phosphate were not, of course, in the dissolved inorganic form, but were tied up in the organisms and in the organic mud of the bottom.