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PHOSPHORUS CONTENT OF WATERS ALONG THE WEST COAST OF FLORIDA

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PHOSPHORUS CONTENT OF WATERS ALONG THE WEST COAST OF FLORIDA

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ABSTRACT

The distribution of inorganic and total phosphorus in the waters along the west coast of Florida is reported for a period of more than 16 months. Some upwelling to subsurface levels is evident but no hydrographic feature occurs which could account for the high values of phosphorus found during the "red tide" of 1946-1947. There is no evidence that either leaching from the bottom of the Gulf or outflow from local rivers contributes large quantities of phosphorus to the Gulf waters. However, values of total phosphorus comparable to those of the red tide were found in blooms of *Trichodesmium* floating on the surface over water of very low phosphorus content.

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PHOSPHORUS CONTENT OF WATERS ALONG THE WEST COAST OF FLORIDA

Mass mortality of fish along the west coast of Florida during 1946 and 1947, caused by an intense water bloom of Gymnodinium brevis Davis in the form of a "red tide", stimulated an active interest in the causes of such plankton blooms (Galtsoff, 1948; Gunter, et al, 1947; Gunter, Smith, and Williams, 1947; Smith, 1949). In 1948 the Fish and Wildlife Service established a laboratory at Sarasota, Fla., dedicated to the study of the ecology of the local plankton, particularly the causes of plankton blooms.

Of the many hypotheses offered to explain the red tide, the one most generally accepted was that unusual enrichment of the coastal waters occurred, resulting in abnormal growth of plankton in general, and of G. brevis in particular.

Ketchum and Keen (1948) analyzed a number of surface samples from the red tide of 1947. Their analyses showed total phosphorus values ranging from about 5 µg-at/L[1/] in water of light amber color to more than 20 µg-at/L in water of deep amber color. As Ketchum and Keen pointed out, the total phosphorus content of waters containing dense Gymnodinium populations was from 2-1/2 to 10 times the maximum to be expected in the sea. To find such concentrations of phosphorus in subtropical surface waters was very unusual. They offered two possible explanations for these high values in surface samples: either a surface swarming of organisms which had absorbed all the phosphorus in the water column, or an enormous contamination or fertilization of the coastal waters. They tended to rule out terrigenous contamination because the quantities of phosphorus necessary would be unreasonably great.

In red tide samples, the total phosphorus was high but the inorganic phosphorus was generally low. At least some of the water in which the red tide occurred contained no measurable amount of inorganic phosphorus (Gunter, et al, 1947; Smith, 1949).

Enrichment of the Gulf waters with phosphorus by way of river drainage from phosphate mines in the interior was early suspected as a contributing cause of the red tide, but the importance of this contamination was later minimized as the red tide spread in extent, and as early historical records of occurrences of noxious red water along the Florida west coast came to light (Smith, 1949).

The program of the red tide laboratory at Sarasota included a hydrographic and biological survey of certain waters along the west coast of Florida. A series of river, coastal, and offshore stations were established and were occupied at regular intervals. Water samples were analyzed for salinity, oxygen, pH, inorganic and total phosphorus. Quantitative plankton samples were also taken.

1/ µg-at/L (microgram atom per liter) = micrograms per liter divided by the gram-atomic weight.

2/ W.W. Anderson was in charge of the Red Tide Investigations during the planning stages and directed the surveys during the first year of operations.

This paper presents the data on phosphorus and its possible bearing on the incidence of the destructive red tide.

METHODS

The locationsof stations are shown in figure 1. Station 1 is at Fort Myers at mid-channel on the Caloosahatchee River. Station 2 is at Punta Gorda in the mouth of the Peace River. At these two stations collections were made from the highway bridges crossing the rivers. Station 3 is in Charlotte Harbor into which the Peace River flows. Stations 4 to 8 are in the open Gulf in a line extending 120 miles westward from Boca Grande Pass, the entrance to Charlotte Harbor.

The original program of survey included only Stations 1 to 8. After 16 months, in August 1950, the program was revised. Stations 1, 2, 7, and 8 were discontinued as a regular part of the survey and Stations 9 to 13 were established. Stations 9 and 11 are on the 10-fathom line; Stations 10 and 12 are on the 20-fathom line. Station 13 is at the mouth of Big Pass, Sarasota Bay. In the revised program, there are three stations on the 10-fathom line and three stations on the 20-fathom line. The data included in this report are principally from the original 16-month study but some values from the newly established stations are also included.

Observations were made at intervals from the surface to the bottom at all stations except the river and Charlotte Harbor stations, where one sampling usually at a depth of about one meter was considered adequate because of the shallow depth and thorough mixing of the water column.

Inorganic phosphate determinations were made according to the conventional Deniges method as described by Robinson and Thompson (1948). Comparisons were made visually against appropriate series of standards and against blanks made up at the same time. Total phosphorus was determined by the method described by Harvey (1948), except that comparisons were made by visual colorimetry as in the case of the inorganic determinations. Organic phosphorus is reported as the difference between the inorganic and the total.

No high degree of accuracy is claimed for the analyses of the river water, especially at Station 2 (Peace River). Concentrations there were frequently so high that dilutions with salt solutions were necessary. Furthermore, yellowish or greenish tints often developed in the samples so that addition of dyestuffs to the standards was necessary in order to effect a match in color.

In an effort to clarify the water, some river samples were centrifuged. It was found that not only the total, but also the inorganic phosphorus was less in these samples, indicating that some of the inorganic phosphorus occurs in particulate form. This condition is not peculiar to these waters, as

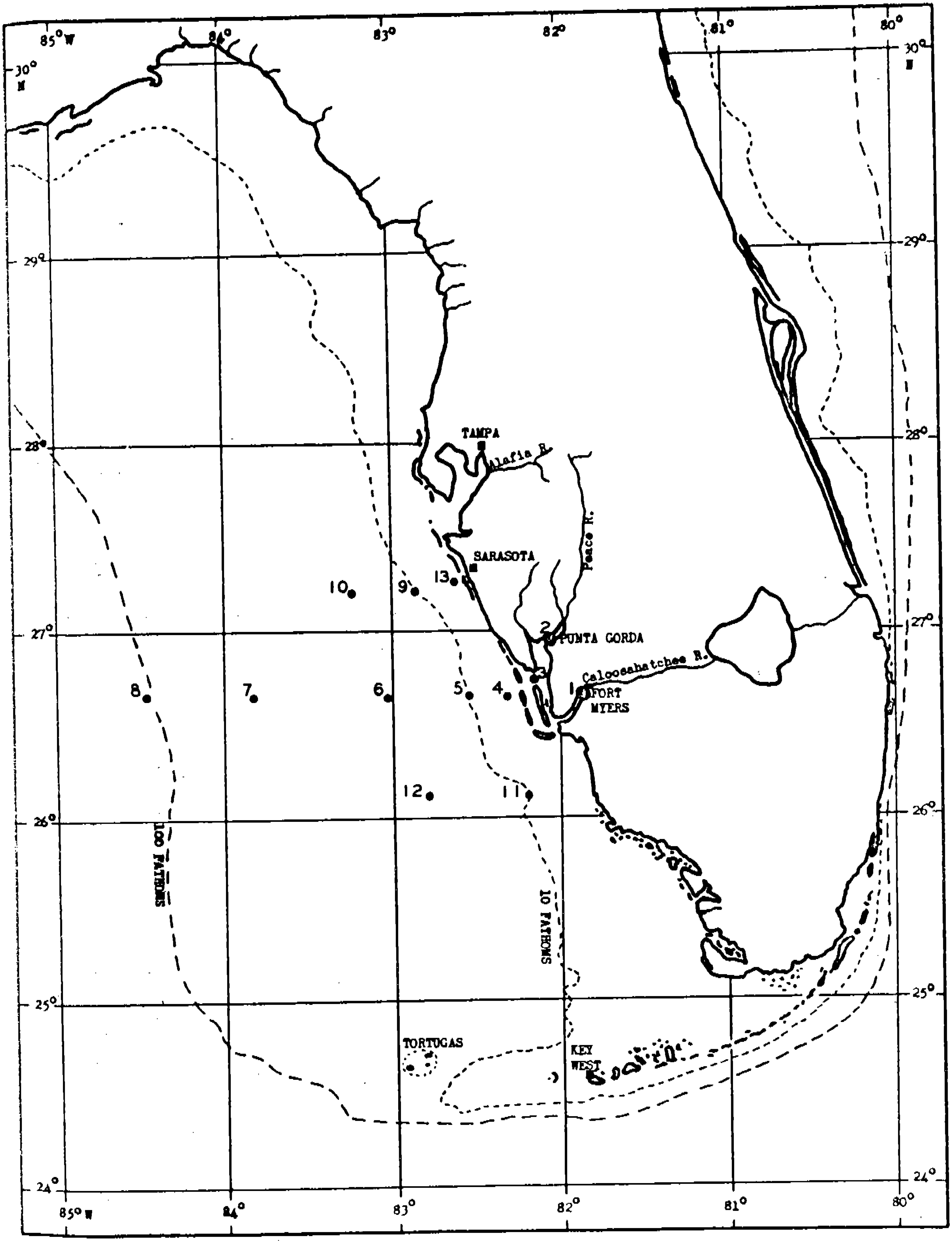

Fig. 1.--Chart showing location of stations

Armstrong and Harvey (1950) reported the same condition in the English Channel. Cooper (1948) suggested that the particulate inorganic phosphorus in the Channel is ferric phosphate.

RESULTS

Influence of Rivers

One of the purposes of the investigation was to determine whether the outflow of the Peace River causes any enrichment of the local Gulf waters. The concentrations of phosphorus at a depth of about one meter at the two river stations (Stations 1 and 2), Charlotte Harbor (Station 3) and the three Gulf stations closest inshore (Stations 4-6) for the 16 surveys are shown graphically in figure 2. The mean phosphorus values at a depth of about one meter for the 16 months of observations at all stations in the first series are shown in table 1. Figures 3 to 5 present graphically the individual data and means for surface values (about 1 meter) for stations 3 to 8 (Charlotte Harbor to a distance of 120 miles offshore).

Table 1.--Mean phosphorus values at surface (approximately 1 meter) for 16-month period (µg-at/L).

Station Number	Location	Inorganic	Organic	Total
1	Caloosahatchee River	1.21	1.42	2.63
2	Peace River	8.43	3.57	12.00
3	Charlotte Harbor	0.54	0.66	1.20
4	3 miles offshore	0.25	0.46	0.71
5	14 miles offshore	0.08	0.24	0.32
6	43 miles offshore	0.07	0.18	0.25
7	84 miles offshore	0.06	0.10	0.16
8	120 miles offshore	0.05	0.11	0.16

It will be noted that the concentrations in the Peace River are extremely high as compared with those in the Caloosahatchee River, Charlotte Harbor or in the open Gulf. This river drains an area of phosphatic rock, phosphate mines and processing plants which no doubt accounts for the high values. The concentrations in the Caloosahatchee River which is one of the drainage channels for Lake Okeechobee and surrounding agricultural area are only about one-fifth as great as in the Peace River.

The effects of the outflow from the Peace River on Charlotte Harbor are difficult to assess from the present data. The fluctuations in con-

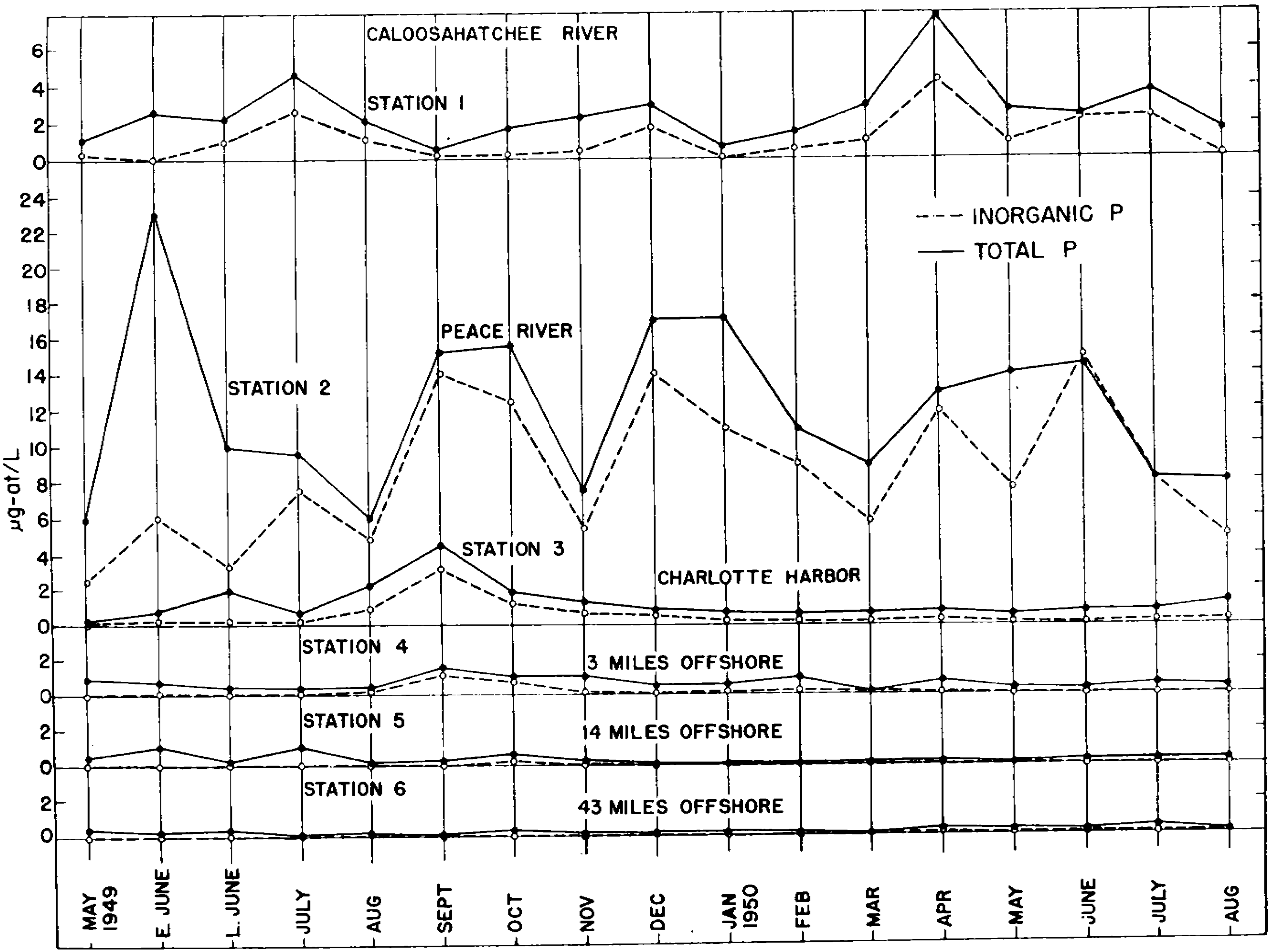

Fig. 2--Inorganic and total phosphorus at the surface (approximately 1 meter) at Stations 1 to 6 for the 16-month survey. Solid line represents total phosphorus; broken line represents inorganic phosphorus. Units in µg-at/L.

centrations at the Peace River Station are not reflected in the concentration in Charlotte Harbor with one exception. However, the values in the Harbor were about twice that for Station 4, in the ship channel about three miles offshore.

The next point to examine is whether outflow from Charlotte Harbor has any effect upon the inshore Gulf water. It will be noted that there is a decreasing amount of phosphorus in the surface layer from Charlotte Harbor to Station 8 (table 1 and figs. 3 to 5).

The question arises whether this is due to distance from Charlotte Harbor or is simply a gradient which is characteristic of the entire coast. Although many more stations along the coast would be necessary to answer this adequately, a few stations recently established give more information about the areas to the north and south of Charlotte Harbor.

For a comparison with Station 4, a station was established at the mouth of Sarasota Bay, Station 13. This station was occupied twice in January 1951. A comparison of values is shown in table 2. It will be noted that the quantities of phosphorus were very similar at the two stations at this time. This comparison suggests that conditions at Station 4 are not peculiar to that area. However, the results are inconclusive since the values obtained at Station 4 during that month were considerably below the average for that station. Whether more normal values at Station 4 are associated with higher values at Station 13 is not known.

Table 2.--Concentration of phosphorus at surface (approximately 1 meter) at inshore stations (µg-at/L).

Station number	Date	Inorganic	Organic	Total
4	Jan. 15,1951	0.20	0.10	0.30
13	Jan. 15,1951	0.10	0.25	0.35
13	Jan. 19,1951	0.10	0.20	0.30

Station 5, fourteen miles offshore and Station 6, forty-three miles offshore would not be expected to show any effect of out flow of water from Charlotte Harbor because of the distances involved. A comparison of concentrations in other latitudes but at similar distances from land substantiates this. In table 3 mean values for Stations 9 and 10, north of the original line, and for Stations 11 and 12, south of the original line are compared with mean values for Stations 5 and 6 in the original line of stations. It is obvious from this comparison that the values found in the original line of stations are not peculiar to that latitude.

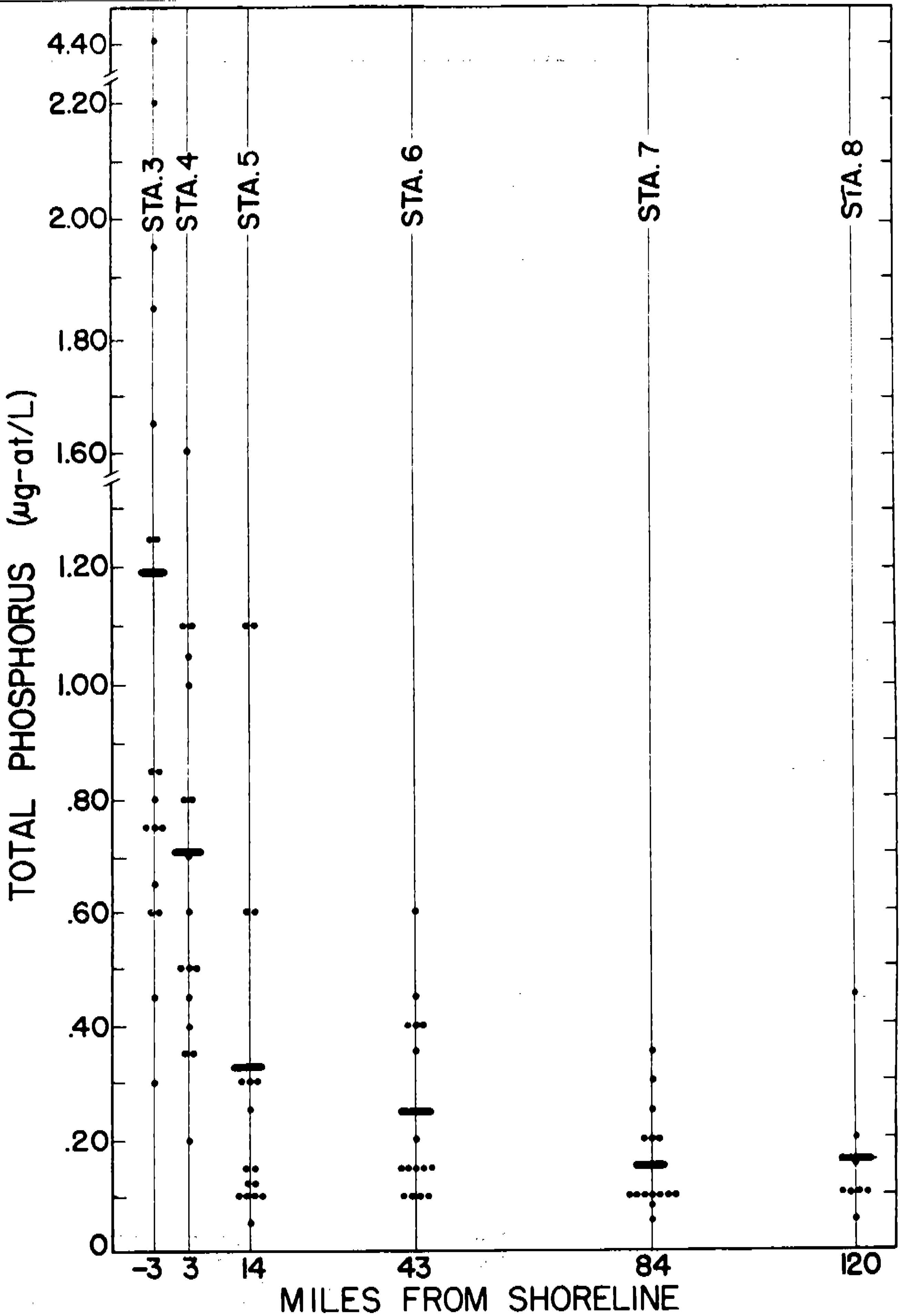

Fig. 3.--Total phosphorus at surface at Stations 3 to 8 for 17 surveys, May 1949 to August 1950. Dots represent individual observations. Bars pass through mean values for each station.

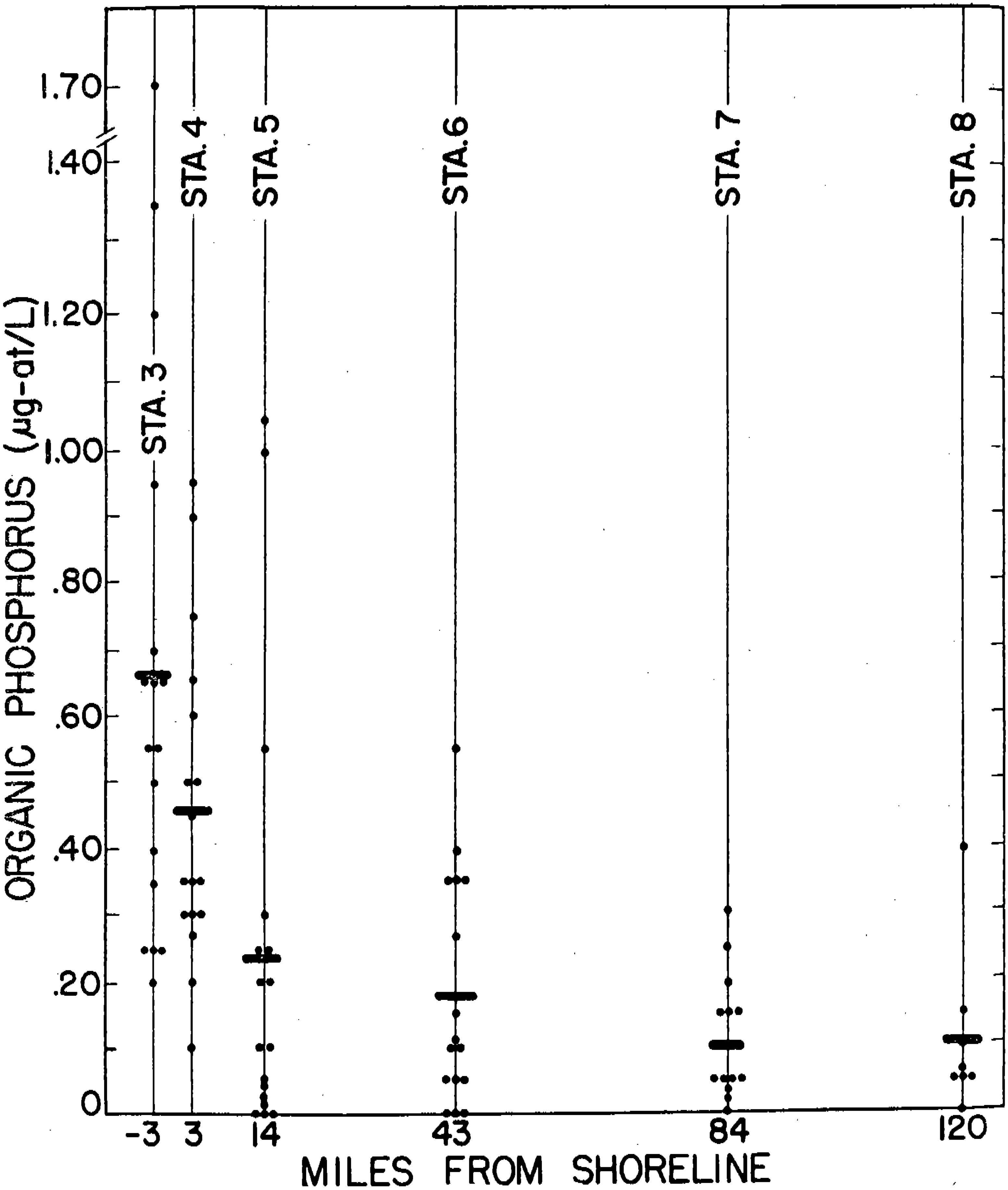

Fig. 4--Inorganic phosphorus at surface at Stations 3 to 8 for 17 surveys, May 1949 to August 1950. Dots represent individual observations. Bars pass through mean values for each station.

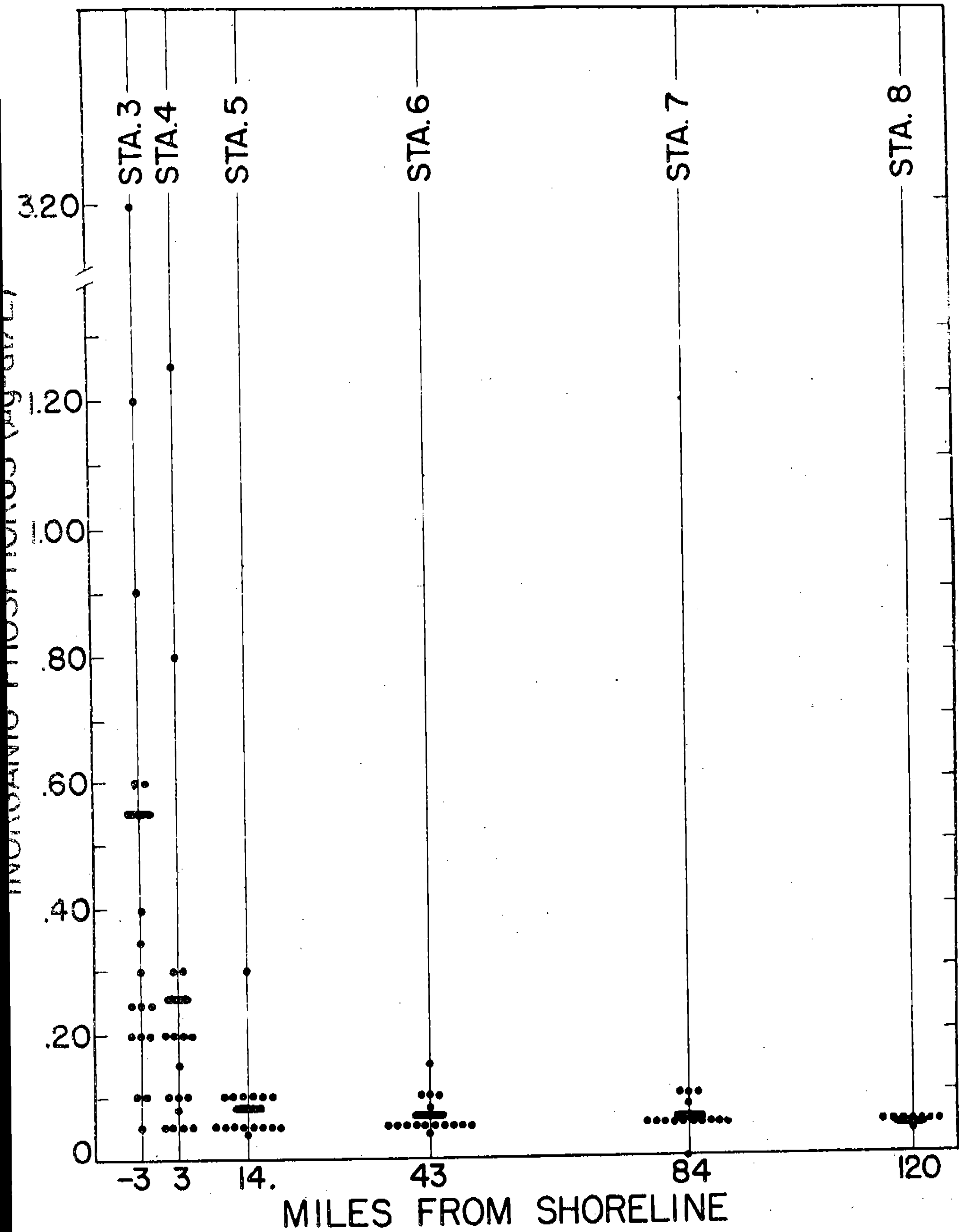

Fig. 5--Organic phosphorus at surface at Stations 3 to 8 for 17 surveys, May 1949 to August 1950. Dots represent individual observations. Bars pass through mean values for each station.

It seems reasonable to conclude that outflow of phosphate-rich water from the Peace River does not ordinarily enrich the Gulf waters to any appreciable degree.

There is evidence, however, that under conditions of unusual rainfall some effect of outflow from Charlotte Harbor is noticeable, at least close inshore. From figure 2 it can be seen that the only case in which a rise in phosphorus in the ship channel (Station 4) was accompanied by a rise in Charlotte Harbor (Station 3) was during the September 1949 survey.

These observations were made from August 20 to September 1 following a month of unusual rainfall. Associated with these high values of phosphorus were very low values of salinity. This was the only period in which there was any appreciable freshening of the water in Charlotte Harbor or in the ship channel.

Table 3.--Concentration of phosphorus at surface (approximately 1 meter) at stations on 10- and 20-fathom lines. Values, in µg-at/L, are means for five cruises during the period Sept. 20, 1950 to Jan. 19, 1951.

Station number	No. of samples	Inorganic mean	Inorganic range	Organic mean	Organic range	Total mean	Total range
		On 10-fathom line					
5	5	0.10	0.05-0.15	0.15	0.05-0.25	0.25	0.20-0.30
9	5	0.14	0.10-0.30	0.12	0.05-0.20	0.26	0.20-0.35
11	5	0.11	0.05-0.15	0.07	0.00-0.15	0.18	0.15-0.20
		On 20-fathom line					
6	4	0.14	0.05-0.30	0.10	0.00-0.15	0.24	0.20-0.30
10	5	0.10	0.05-0.15	0.10	0.00-0.20	0.20	0.10-0.35
12	5	0.08	0.05-0.10	0.11	0.00-0.20	0.19	0.10-0.30

During the hurricane of August 1949 a slime dam containing phosphate sludge at one of the mines broke, releasing large quantities of phosphate which drained into the Peace River. This probably accounts for the high phosphorus values found in the Peace River during the September and October surveys and in Charlotte Harbor in the September survey. The high value at Station 4 in this survey is probably related to this also as the salinity was low there at that time indicating an unusual flow of water out of the Pass. The relatively high phosphorus values at Station 4 in the following months (October to November) may possibly be related to this also. However, relatively high values in Charlotte Harbor at other times (June and early August 1949, for instance) were not accompanied by unusual values at Station 4 in the ship channel. Only in late August 1949 (September survey) is there a clear case of high concentration in Charlotte Harbor affecting the phosphorus concentration three miles offshore.

The concentration of organic phosphorus usually exceeded the concentration of inorganic phosphorus except in the Peace River. In this body of water the inorganic phosphorus usually exceeded the organic and represented on the average 70 percent of the total (table 1). No doubt this condition was due to the release of phosphate from the deposits inland. Some time may have to elapse before the plankton can incorporate this inorganic material into the biomass. Perhaps the phosphorus requirements of the phytoplankton are more than fulfilled and some other element becomes the limiting factor for growth. Such a condition might leave a large excess of inorganic phosphorus.

At the Caloosahatchee River station the mean value for organic phosphorus exceeded that for inorganic phosphorus (table 1) but there were some instances when the reverse condition obtained (table 4). The unusually high values of total phosphorus occurring in July 1949 and April 1950 were due to high values of inorganic phosphorus.

In Charlotte Harbor the concentration of organic phosphorus usually exceeded that of inorganic but there were several times when the values for inorganic were greater, notably after the hurricane of August 1949 when large quantities of phosphate were brought down the Peace River.

At the channel station in the Gulf, three miles offshore, Station 4, the concentration of organic phosphorus exceeded that of inorganic at all times except after the storms of August 1949. From the latter part of August until October inorganic phosphorus exceeded organic at this station, which is further evidence that the high values were due to excessive amounts of inorganic phosphorus carried down the Peace River.

At Station 5, fourteen miles offshore, the effects of the outflow from Charlotte Harbor after the 1949 storms were not evident. At this station and at all stations further from shore the organic phosphorus usually exceeded the inorganic.

Phosphorus in the Open Gulf

Station data

The data for individual stations are presented in table 5. At Station 5, fourteen miles offshore, the concentration of inorganic phosphorus was always relatively low. The high values of total phosphorus observed at certain times were due to increased amounts of organic phosphorus.

TABLE 4.--Integral mean concentrations of total phosphorus in water columns, in µg-at/L.

Station number	1949 May	Early June	Late June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1950 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
5-----	0.91	1.24	0.27	0.44	0.10	0.18	0.51	0.26	0.10	0.10	0.12	0.14	0.20	0.10	0.22	0.28	0.16
6-----	0.23	0.31	0.48	0.17		0.12	0.28	0.18	0.16	0.18	0.10	0.12	0.18	0.13	0.11	0.30	0.14
7-----	0.44	0.23	0.18	0.16		0.16	0.45	0.16	0.10	0.10		0.09	0.23	0.25	0.11	0.21	0.22
8-----	0.57					0.59	0.59	0.36	0.42					0.35	0.62		0.55

Table 5.--Station data

Station 1. Caloosahatchee River

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
1	May 9, 1949	1	0.50	0.70	1.20
2	June 10, 1949	1	0.15	2.55	2.70
3	June 27, 1949	1	1.10	1.20	2.30
4	July 14, 1949	1	2.75	2.05	4.80
5	Aug. 4, 1949	1	1.20	1.00	2.20
6	Aug. 25, 1949	1	0.35	0.30	0.65
7	Oct. 6, 1949	1	0.35	1.45	1.80
8	Nov. 3, 1949	1	0.45	1.75	2.20
9	Dec. 1, 1949	1	1.80	1.20	3.00
10	Jan. 5, 1950	1	0.20	0.60	0.80
11	Feb. 9, 1950	1	0.60	0.90	1.50
12	Mar. 2, 1950	1	1.15	1.85	3.00
13	Mar. 30, 195-	1	4.40	3.60	8.00
14	Apr. 27, 1950	1	0.90	1.85	2.75
15	June 8, 1950	1	2.20	0.20	2.40
16	July 11, 1950	1	2.40	1.40	3.80
17	Aug. 21, 1950	1	0.15	1.45	1.60

Table 5.--Station data (continued)

Station 2. Peace River

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
1	May 10, 1949	0	2.50	3.50	6.00
2	June 6, 1949	2	6.00	17.00	23.00
3	June 27, 1949	2	3.20	6.97	10.17
4	July 14, 1949	2	7.50	2.10	9.60
5	Aug. 4, 1949	2	4.80	1.20	6.00
6	Aug. 25, 1949	2	14.00	1.20	15.20
7	Oct. 6, 1949	2	12.50	3.00	15.50
8	Nov. 3, 1949	2	5.40	2.10	7.50
9	Dec. 1, 1949	2	14.00	3.00	17.00
10	Jan. 5, 1950	2	11.00	6.00	17.00
11	Feb. 9, 1950	2	9.00	2.00	11.00
12	Mar. 2, 1950	2	5.75	3.25	9.00
13	Mar. 30, 1950	2	12.00	1.00	13.00
14	Apr. 27, 1950	2	12.00	1.00	13.00
15	June 8, 1950	2	15.00	0.00	15.00
16	July 11, 1950	2	8.00	0.10	8.10
17	Aug. 21, 1950	0	5.00	2.00	7.00

Table 5.--Station data (continued)

Station 3. Charlotte Harbor

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
1	May 10, 1949	0	0.10		
		2	0.10	0.20	0.30
2	June 7, 1949	1	0.25	0.55	0.80
3	June 20, 1949	0	0.25	1.70	1.95
4	July 11, 1949	0	0.20	0.55	0.75
5	Aug. 1, 1949	2	0.90	1.35	2.20
6	Aug. 30, 1949	1	3.20	1.20	4.10
7	Oct. 10, 1949	0	1.20	0.65	1.85
8	Nov. 7, 1949	0	0.60	0.65	1.25
9	Dec. 5, 1949	0	0.60	0.25	0.85
10	Jan. 9, 1950	2	0.40	0.25	0.65
11	Feb. 13, 1950	0	0.35	0.25	0.60
12	Mar. 6, 1950	0	0.20	0.40	0.60
13	Apr. 3, 1950	0	0.25	0.50	0.75
14	May 1, 1950	0	0.10	0.35	0.45
15	June 12, 1950	0	0.05	0.70	0.75
16	July 12, 1950	0	0.20	0.65	0.85
17	Aug. 22, 1950	0	0.30	0.95	1.25

Table 5.--Station data (continued)

Station 4. Three Miles Offshore

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
1	May 10, 1949	0	0.05	0.95	1.00
		7	0.05	0.15	0.20
2	June 7, 1949	0	0.15	0.65	0.80
		7	0.05	0.50	0.55
3	June 20, 1949	0	0.05	0.45	0.50
		7	0.05	0.45	0.50
4	July 11, 1949	0	0.05	0.35	0.40
		7	0.10	0.50	0.60
5	Aug. 2, 1949	0	0.30	0.20	0.50
		7	0.15	0.25	0.40
6	Aug. 30, 1949	0	1.25	0.35	1.60
		7	0.30	0.50	0.80
7	Oct. 10, 1949	0	0.80	0.30	1.10
		7	0.60	0.30	0.90
8	Nov. 7, 1949	0	0.20	0.90	1.10
		7	0.30	0.50	0.80
9	Dec. 5, 1949	0	0.20	0.30	0.50
		6	0.10	0.20	0.30
10	Jan. 10, 1950	0	0.20	0.50	0.70
		7	0.35	0.45	0.80
11	Feb. 14, 1950	0	0.30	0.75	1.05
		7	0.35	0.70	1.05
12	Mar. 7, 1950	0	0.10	0.10	0.20
		7	0.10	0.20	0.30
13	Apr. 4, 1950	0	0.20	0.60	0.80
		7	0.30	0.82	1.12
14	May 2, 1950	0	0.08	0.27	0.35
		7	0.08	0.32	0.40
15	June 13, 1950	0	0.05	0.30	0.35
		7	0.10	0.50	0.60
16	July 12, 1950	0	0.10	0.50	0.60
		7	0.15	0.55	0.70
17	Aug. 22, 1950	0	0.10	0.35	0.45
		7	0.10	0.65	0.75

Table 5.--Station data (continued)

Station 5. 14 miles offshore

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
1	May 11, 1949	0	0.05	0.55	0.60
		10	0.05	1.05	1.10
		16	0.05	0.85	0.90
2	June 8, 1949	0	0.10	1.00	1.10
		10	0.10	1.20	1.30
		17	0.10	1.20	1.30
3	June 21, 1949	0	0.05	0.25	0.30
		10	0.05	0.15	0.20
		17	0.05	0.25	0.30
4	July 12, 1949	0	0.05	1.05	1.10
		10	1.10	0.10	0.20
		17	0.10	0.10	0.20
5	Aug. 2, 1949	0	0.10	0.00	0.10
		10	0.00	0.10	0.10
		16	0.05	0.05	0.10
6	Aug. 31, 1949	0	0.05	0.20	0.25
		10	0.05	0.10	0.15
		16	0.10	0.05	0.15
7	Oct. 11, 1949	0	0.30	0.30	0.60
		10	0.10	0.30	0.40
		16	0.25	0.50	0.75
8	Nov. 8, 1949	0	0.10	0.20	0.30
		10	0.10	0.15	0.25
		16	0.15	0.10	0.25
9	Dec. 6, 1949	0	0.10	0.00	0.10
		10	0.10	0.00	0.10
		16	0.10	0.00	0.10
10	Jan. 10, 1950	0	0.10	0.00	0.10
		10	0.10	0.00	0.10
		16	0.10	0.00	0.10
11	Feb. 14, 1950	0	0.10	0.02	0.12
		10	0.10	0.04	0.14
		17	0.10	0.02	0.12

Table 5.--Station data (continued)

Station 5. 14 miles offshore (continued)

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
12	Mar. 7, 1950	0	0.08	0.04	0.12
		10	0.08	0.07	0.15
		17	0.08	0.07	0.15
13	Apr. 4, 1950	0	0.05	0.05	0.10
		10	0.05	0.20	0.25
		17	0.05	0.20	0.25
14	May 2, 1950	0	0.04	0.01	0.05
		10	0.04	0.06	0.10
		16	0.05	0.10	0.15
15	June 13, 195-	0	0.05	0.10	0.15
		10	0.05	0.25	0.30
		17	0.08	0.07	0.15
16	July 13, 1950	0	0.05	0.25	0.30
		10	0.05	0.20	0.25
		17	0.05	0.25	0.30
17	Aug. 22, 1950	0	0.05	0.10	0.15
		8	0.05	0.10	0.15
		16	0.10	0.10	0.20
18	Sept. 22, 1950	0	0.15	0.05	0.20
		10	0.15	0.00	0.15
		16	0.20	0.15	0.35
22	Oct. 25, 1950	0	0.10	0.20	0.30
		10	0.10	0.10	0.20
		17	0.15	0.20	0.35
25	Nov. 15, 1950	0	0.05	0.25	0.30
		10	0.10	0.20	0.30
		17	0.25	0.00	0.25
28	Dec. 13, 1950	0	0.15	0.10	0.25
		10	0.15	0.05	0.20
		17	0.10	0.15	0.25
33	Jan. 17, 1951	0	0.05	0.15	0.20
		10	0.05	0.20	0.25
		18	0.10	0.20	0.30

Table 5.--Station data (continued)

Station 6. 43 miles offshore

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
1	May 11, 1949	0	0.05	0.55	0.60
		10	0.05	0.05	0.10
		20	0.05	0.15	0.20
		31	0.05	0.15	0.20
2	June 8, 1949	0	0.05	0.35	0.40
		10	0.05	0.40	0.45
		20	0.05	0.10	0.15
		35	0.10	0.25	0.35
3	June 21, 1949	0	0.05	0.40	0.45
		10	0.05	0.30	0.35
		20	0.05	0.70	0.75
		35	0.05	0.15	0.20
4	July 12, 1949	0	0.05	0.15	0.20
		10	0.05	0.10	0.15
		20	0.15	0.00	0.15
		35	0.10	0.10	0.20
6	Aug. 31, 1949	0	0.05	0.10	0.15
		10	0.05	0.05	0.10
		20	0.05	0.05	0.10
		36	0.10	0.05	0.15
7	Oct. 11, 1949	0	0.05	0.35	0.40
		10	0.05	0.30	0.35
		20	0.05	0.10	0.15
		34	0.10	0.20	0.30
8	Nov. 8, 1949	0	0.10	0.00	0.10
		10	0.10	0.00	0.10
		20	0.10	0.05	0.15
		36	0.35	0.05	0.40
9	Dec. 7, 1949	0	0.10	0.05	0.15
		10	0.10	0.05	0.15
		20	0.10	0.05	0.15
		35	0.15	0.10	0.25
10	Jan. 10, 1950	0	0.15	0.00	0.15
		10	0.05	0.05	0.10
		20	0.10	0.05	0.15
		34	0.15	0.15	0.30
11	Feb. 15, 1950	0	0.10	0.00	0.10
		10	0.10	0.00	0.10
		20	0.10	0.00	0.10
		36	0.10	0.00	0.10

Table 5.--Station data (continued)

Station 6. 43 Miles offshore (continued)

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
12	Mar. 7, 1950	0	0.05	0.05	0.10
		10	0.05	0.07	0.12
		20	0.05	0.07	0.12
		37	0.05	0.07	0.12
13	Apr. 4, 1950	0	0.08	0.27	0.35
		10	0.05	0.15	0,20
		20	0.08	0.04	0.12
		35	0.08	0.07	0.15
14	May 2, 1950	0	0.04	0.11	0.15
		10	0.04	0.06	0.10
		20	0.04	0.06	0.10
		36	0.05	0.15	0.20
15	June 13, 1950	0	0.05	0.10	0.15
		10	0.05	0.05	0.10
		20	0.05	0.05	0.10
		36	0.08	0.02	0.10
16	July 13, 1950	0	0.05	0.35	0.40
		10	0.05	0.25	0.30
		20	0.05	0.25	0.30
		37	0.20	0.05	0.25
17	Aug. 23, 1950	0	0.05	0.05	0.10
		10	0.05	0.05	0.10
		20	0.05	0.15	0.20
		35	0.10	0.00	0.10
18	Sept. 22, 1950	0	0.30	0.00	0.35
		10	0.35	0.00	0.35
		20	0.30	0.05	0.35
		36	0.30	0.00	0.20
22	Oct. 25, 1950	0	0.10	0.10	0.20
		10	0.10	0.05	0.15
		20	0.10	0.05	0.15
		36	0.15	0.00	0.15
28	Dec. 13, 1950	0	0.10	0.15	0.25
		10	0.10	0.10	0.20
		20	0.10	0.10	0.20
		35	0.10	0.10	0.20
33	Jan. 17, 1951	0	0.05	0.15	0.20
		10	0.05	0.10	0.15
		20	0.05	0.10	0.15
		36	0.10	0.00	0.10

Table 5.--Station data (continued)

Station 7. 34 miles offshore

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
1	May 12, 1949	0	0.00	0.20	0.20
		10	0.00	0.15	0.15
		20	0.05	0.30	0.35
		30	0.05	0.55	0.60
		50	0.05	0.45	0.50
		71	0.25	0.25	0.50
2	June 9, 1949	0	0.05	0.15	0.20
		10	0.05	0.10	0.15
		20	0.05	0.25	0.30
		30	0.05	0.10	0.15
		50	0.05	0.25	0.30
		73	0.10	0.15	0.25
3	June 22, 1949	0	0.05	0.05	0.10
		10	0.05	0.10	0.15
		20	0.05	0.10	0.15
		30	0.05	0.15	0.20
		50	0.10	0.05	0.15
		73	0.15	0.15	0.30
4	July 13, 1949	0	0.05	0.30	0.35
		10	0.05	0.15	0.20
		20	0.05	0.10	0.15
		30	0.05	0.05	0.10
		50	0.05	0.10	0.15
		72	0.15	0.00	0.15
6	Sept. 1, 1949	0	0.05	0.05	0.10
		10	0.10	0.00	0.10
		20	0.10	0.00	0.10
		30	0.10	0.00	0.10
		50	0.10	0.05	0.15
		73	0.35	0.10	0.45
7	Oct. 12, 1959	0	0.05	0.25	0.30
		10	0.05	0.30	0.35
		20	0.05	0.20	0.25
		30	0.05	0.30	0.30
		40	0.10	0.10	0.20
		50	0.15	0.40	0.55
		74	0.80	0.10	0.90
8	Nov. 9, 1949	0	0.05	0.15	0.20
		10	0.10	0.10	0.20
		20	0.10	0.00	0.10
		30	0.05	0.05	0.10
		50	0.05	0.05	0.10
		72	0.20	0.20	0.40
9	Dec. 7, 1949	0	0.05	0.00	0.05
		10	0.05	0.00	0.05
		20	0.10	0.00	0.10
		30	0.10	0.00	0.10
		50	0.10	0.00	0.10
		72	0.15	0.03	0.18

Table 5.--Station data (continued)

Station 7. 84 miles offshore (continued)

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
10	Jan. 11, 1950	0	0.10	0.00	0.10
		10	0.05	0.05	0.10
		20	0.05	0.05	0.10
		30	0.05	0.05	0.10
		50	0.05	0.00	0.05
		73	0.20	0.00	0.20
12	Mar. 8, 1950	0	0.05	0.03	0.08
		10	0.08	0.00	0.08
		20	0.08	0.00	0.08
		30	0.05	0.03	0.08
		50	0.05	0.05	0.10
		73	0.10	0.01	0.11
13	Apr. 5, 1950	0	0.08	0.02	0.10
		10	0.05	0.00	0.05
		20	0.05	0.00	0.05
		30	0.10	0.00	0.10
		50	0.15	0.15	0.30
		72	0.50	0.10	0.60
14	May 3, 1950	0	0.10	0.15	0.25
		10	0.04	0.11	0.15
		20	0.05	0.10	0.15
		30	0.10	0.20	0.30
		50	0.04	0.11	0.15
		75	0.10	0.45	0.55
15	June 14, 1950	0	0.05	0.05	0.10
		10	0.05	0.05	0.10
		20	0.05	0.05	0.10
		30	0.05	0.05	0.10
		50	0.05	0.05	0.10
		75	0.15	0.00	0.15
16	July 13, 1950	0	0.05	0.05	0.10
		10	0.05	0.15	0.20
		20	0.05	0.15	0.20
		30	0.05	0.10	0.15
		50	0.05	0.10	0.15
		73	0.40	0.05	0.45
17	Aug. 23, 1950	0	0.10	0.00	0.10
		10	0.05	0.15	0.20
		20	0.05	0.05	0.10
		30	0.05	0.05	0.10
		50	0.05	0.05	0.10
		73	0.50	0.25	0.75

Table 5.--Station data (continued)

Station 8. 120 miles offshore

Survey No.	Date	Depth (Meters)	Phosphorus (μg-at/L) Inorganic	Organic	Total
1	May 12, 1949	0	0.05	0.15	0.20
		10	0.05	0.10	0.15
		20	0.05	0.15	0.20
		30	0.05	0.20	0.25
		50	0.05	0.15	0.20
		75	0.05	0.55	0.60
		100	0.40	0.10	0.50
		150	1.10	0.00	1.10
		170	1.10	0.00	1.10
6	Sept. 1, 1949	0	0.05	0.10	0.15
		10	0.05	0.05	0.10
		20	0.05	0.05	0.10
		30	0.10	0.00	0.10
		50	0.05	0.10	0.15
		75	0.10	0.05	0.15
		100	0.75	0.05	0.80
		150	1.10	0.10	1.20
		182	1.20	0.00	1.20
7	Oct. 12, 1949	0	0.05	0.05	0.10
		10	0.05	0.05	0.10
		20	0.05	0.00	0.05
		30	0.05	0.15	0.20
		50	0.10	0.10	0.20
		75	0.15	0.25	0.40
		100	0.60	0.00	0.60
		150	0.80	0.30	1.10
		183	1.10	0.15	1.25
8	Nov. 9, 1949	0	0.05	0.00	0.05
		10	0.05	0.10	0.15
		20	0.05	0.00	0.05
		30	0.05	0.00	0.05
		50	0.10	0.05	0.15
		75	0.15	0.05	0.20
		100	0.30	0.00	0.30
		150	0.50	0.25	0.75
		182	0.70	0.10	0.80

Table 5.--Station data (Continued)

Station 8. 120 miles offshore (continued)

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
9	Dec. 8, 1949	0	0.05	0.05	0.10
		10	0.05	0.05	0.10
		20	0.05	0.10	0.15
		30	0.05	0.05	0.10
		50	0.05	0.05	0.10
		75	0.05	0.05	0.10
		100	0.20	0.20	0.40
		150	0.80	0.00	0.80
		182	1.20	0.00	1.20
14	May 4, 1950	0	0.04	0.06	0.10
		10	0.04	0.11	0.15
		20	0.04	0.11	0.15
		30	0.04	0.16	0.20
		50	0.04	0.16	0.20
		75	0.04	0.11	0.15
		100	0.04	0.11	0.15
		150	0.35	0.30	0.65
		182	1.00	0.00	1.00
15	June 14, 1950	0	0.05	0.40	0.45
		10	0.05	0.10	0.15
		20	0.05	0.15	0.20
		30	0.05	0.15	0.20
		50	0.20	0.10	0.30
		75	0.30	0.15	0.45
		100	0.70	0.45	1.00
		150	0.75	0.00	0.75
		180	1.15	0.00	1.15
17	Aug. 24, 1950	0	0.05	0.05	1.10
		10	0.10	0.00	0.10
		20	0.10	0.05	0.15
		30	0.20	0.00	0.20
		50	0.15	0.10	0.25
		75	0.40	0.00	0.40
		100	0.60	0.05	0.65
		150	0.70	0.00	0.70
		182	1.40	0.20	1.60

Table 5.--Station data (continued)

Station 9

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
18	Sept. 20, 1950	0	0.30	0.05	0.35
		10	0.30	0.00	0.30
		17	0.30	0.10	0.40
22	Oct. 26, 1950	0	0.10	0.10	0.20
		10	0.10	0.15	0.25
		17	0.10	0.05	0.15
25	Nov. 16, 1950	0	0.10	0.15	0.25
		10	0.05	0.05	0.10
		17	0.05	0.10	0.15
28	Dec. 15, 1950	0	0.10	0.20	0.30
		10	0.10	0.15	0.25
		17	0.10	0.15	0.25
33	Jan. 19, 1951	0	0.10	0.10	0.20
		8	0.05	0.10	0.15
		15	0.10	0.15	0.25

Table 5.--Station data (continued)

Station 10

Survey No.	Date	Depth (Meters)	(Phosphorus (µg-at/L) Inorganic	Organic	Total
18	Sept. 20, 1950	0	0.15	0.20	0.35
		10	0.20	0.00	0.20
		20	0.15	0.05	0.20
		36	0.40	0.05	0.45
22	Oct. 26, 1950	0	0.10	0.00	0.10
		10	0.10	0.00	0.10
		20	0.10	0.00	0.10
		36	0.20	0.10	0.30
25	Nov. 16, 1950	0	0.15	0.15	0.30
		10	0.05	0.20	0.25
		20	0.05	0.20	0.25
		36	0.15	0.10	0.25
28	Dec. 15, 1950	0	0.05	0.10	0.15
		10	0.05	0.10	0.15
		20	0.05	0.15	0.20
		37	0.10	0.35	0.45
33	Jan. 19, 1951	0	0.05	0.05	0.10
		10	0.05	0.05	0.10
		20	0.05	0.10	0.15
		35	0.05	0.10	0.15

Table 5.--Station data (continued)

Station 11

Survey No.	Date	Depth (Meters)	Phosphours (µg-at/L) Inorganic	Organic	Total
18	Sept. 21, 1950	0	0.15	0.05	0.20
		10	0.15	0.25	0.40
		18	0.10	0.20	0.30
22	Oct. 24, 1950	0	0.10	0.05	0.15
		10	0.10	0.05	0.15
		17	0.15	0.05	0.20
25	Nov. 14, 1950	0	0.15	0.00	0.15
		10	0.05	0.10	0.15
		17	0.10	0.10	0.20
28	Dec. 14, 1950	0	0.10	0.10	0.20
		10	0.10	0.10	0.20
		17	0.10	0.10	0.20
33	Jan. 18, 1951	0	0.05	0.15	0.20
		10	0.05	0.05	0.10
		17	0.05	0.15	0.20

Table 5.--Station data (continued)

Station 12

Survey No.	Date	Depth (Meters)	Phosphorus (µg-at/L) Inorganic	Organic	Total
18	Sept. 21, 1950	0	0.10	0.05	0.15
		10	0.10	0.25	0.35
		20	0.10	0.10	0.20
		36	0.20	0.25	0.45
22	Oct. 24, 1950	0	0.10	0.00	0.10
		10	0.10	0.00	0.10
		20	0.10	0.00	0.10
		37	0.25	0.05	0.30
25	Nov. 15, 1950	0	0.05	0.17	0.20
		10	0.05	0.10	0.15
		20	0.05	0.07	0.10
		37	0.05	0.05	0.10
28	Dec. 14, 1950	0	0.10	0.20	0.30
		10	0.10	0.25	0.35
		20	0.10	0.05	0.15
		35	0.10	0.15	0.25
33	Jan. 18, 1951	0	0.05	0.10	0.15
		10	0.05	0.15	0.20
		20	0.05	0.10	0.15
		33	0.10	0.10	0.20

Observations at this station extended only to 17 meters, as the depth of bottom was only 10 fathoms. On practically every cruise the concentration of inorganic phosphorus was essentially the same from surface to bottom. For more than half the months, the total phosphorus was also essentially the same from surface to bottom but in many cases the vertical distribution was very irregular with higher values either at the surface, at 10 meters, or at 17 meters.

At Station 6 on the 20-fathom line forty-three miles from shore, there was still a very uniform distribution of inorganic phosphorus with depth throughout the year. Except in one case values were less than 0.1 µg-at/L down to 20 meters. Below this depth there was, in about half the cases a slight increase in inorganic phosphorus toward the bottom. The amount of organic phosphorus varied considerably from month to month and showed no consistent change with depth.

At Station 7, eighty-four miles from shore on the 40-fathom line, the inorganic phosphorus concentration showed a remarkable uniformity through the 16 months of study. The concentration was always less than 0.10 µg-at/L from the surface to 50 meters and always showed an increase between 50 and 75 meters. The amount of increase toward the bottom varied considerably but the average value for 75 meters was 0.27 µg-at/L while for the 50-meter level it was 0.07 µg-at/L.

Judging from the phosphorus distribution one would conclude that the euphotic zone at this station did not extend below 50 meters. Not only did the inorganic phosphorus tend to increase below this level but the amount of organic phosphorus decreased except in four cases.

The sharp increases which occurred toward the bottom at certain times, as in August 1950, probably are the result of an upwelling of deeper water from farther offshore. The sections of phosphorus distribution (figs. 6 and 7) show this as does a study of the isotherms (unpublished).

At Station 8, which is located on the 100-fathom line 120 miles from the shore, observations extended well into the thermocline and below the euphotic zone. This station was occupied only eight times during the 16-month period because of weather conditions but sufficient information was obtained from these trips to make some definite conclusions.

The concentration of inorganic phosphorus in the surface water at this station was always extremely low, less than 0.1 µg-at/L. This layer of phosphate-poor water extended to 80 meters at all seasons of the year except in the summer. During June and August the observations show an increase in inorganic phosphorus with depth beginning at about 40 meters. During May 1950 the phosphate depleted water extended to 100 meters. Between this layer of phosphate-poor water and the bottom there was a rapid increase in concentration to a value that was usually between 1.1 and 1.2 µg-at/L. However, in November 1949 the concentration near the bottom was only 0.7 µg-at/L and in August 1950 it was 1.4 µg-at/L.

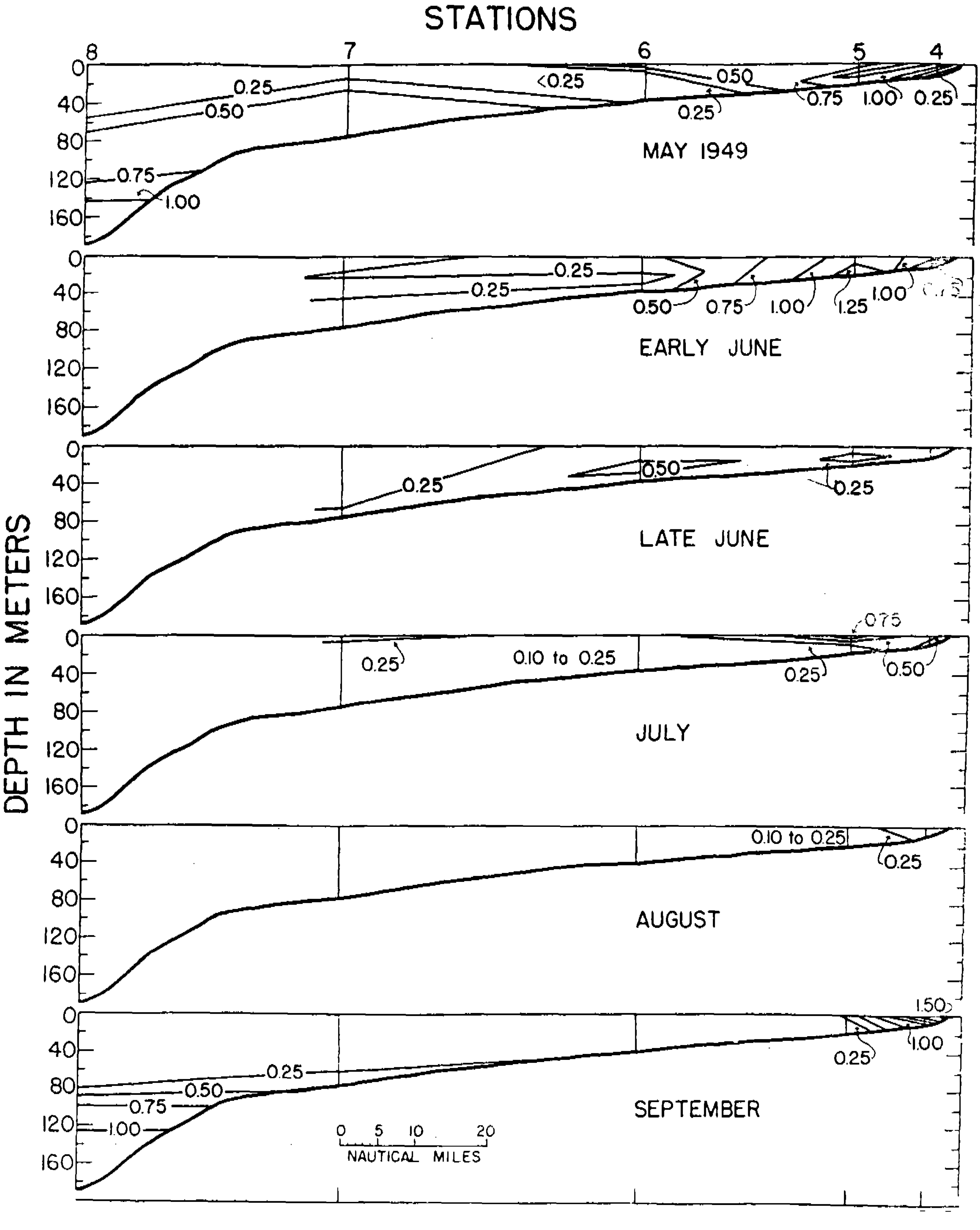

Fig. 6--Total phosphorus sections extending westward from Station 4, 3 miles from Boca Grande Pass, Charlotte Harbor, to Station 8, 120 miles offshore. Units in μg-at/L.

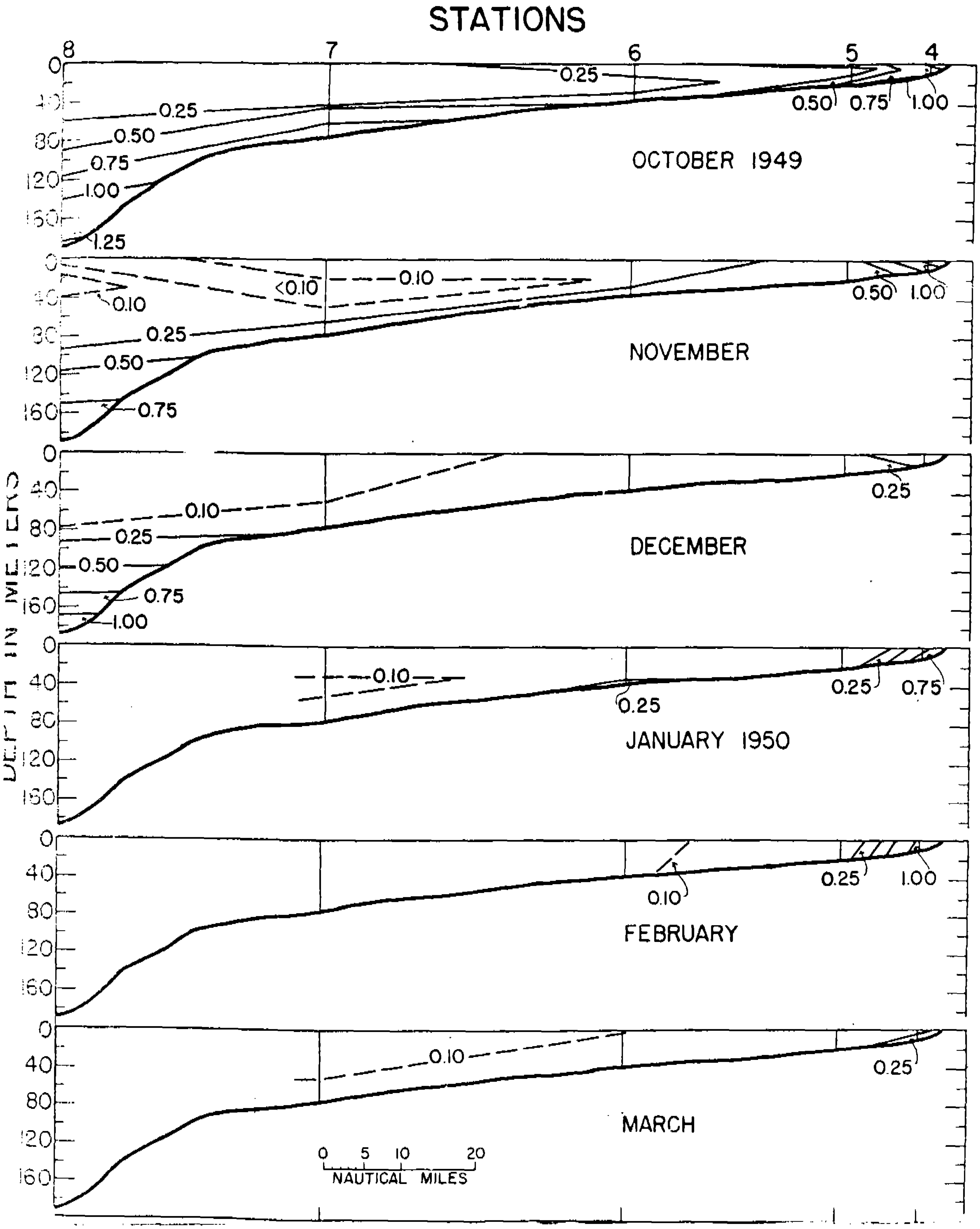

Fig. 6--Total phosphorus sections extending westward from Station 4, 3 miles from Boca Grande Pass, Charlotte Harbor, to Station 8, 120 miles offshore. Units in µg-at/L. (continued)

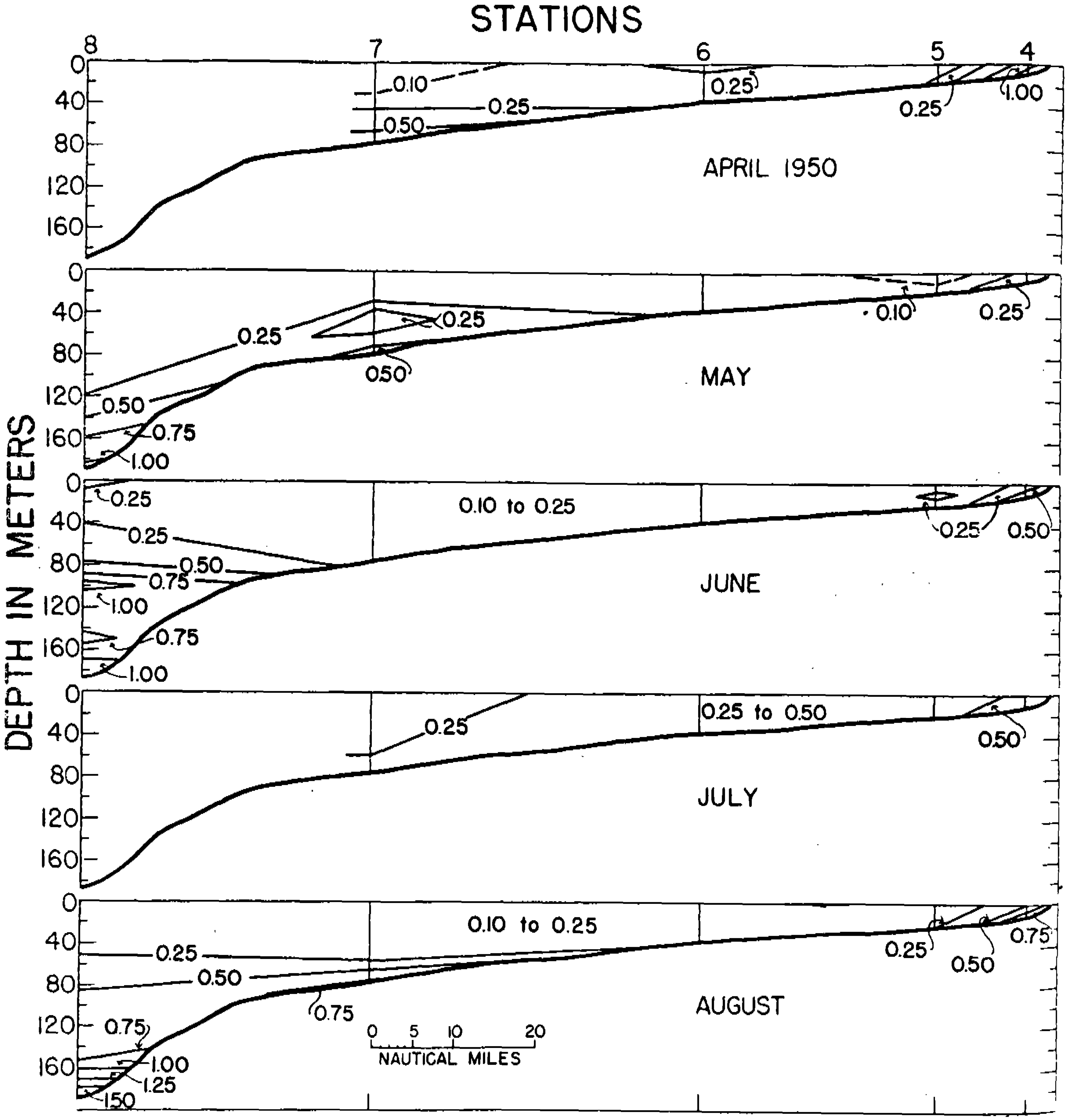

Fig. 6--Total phosphorus sections extending westward from Station 4, 3 miles from Boca Grande Pass, Charlotte Harbor, to Seation 8, 120 miles offshore. Units in µg-at/L. (continued)

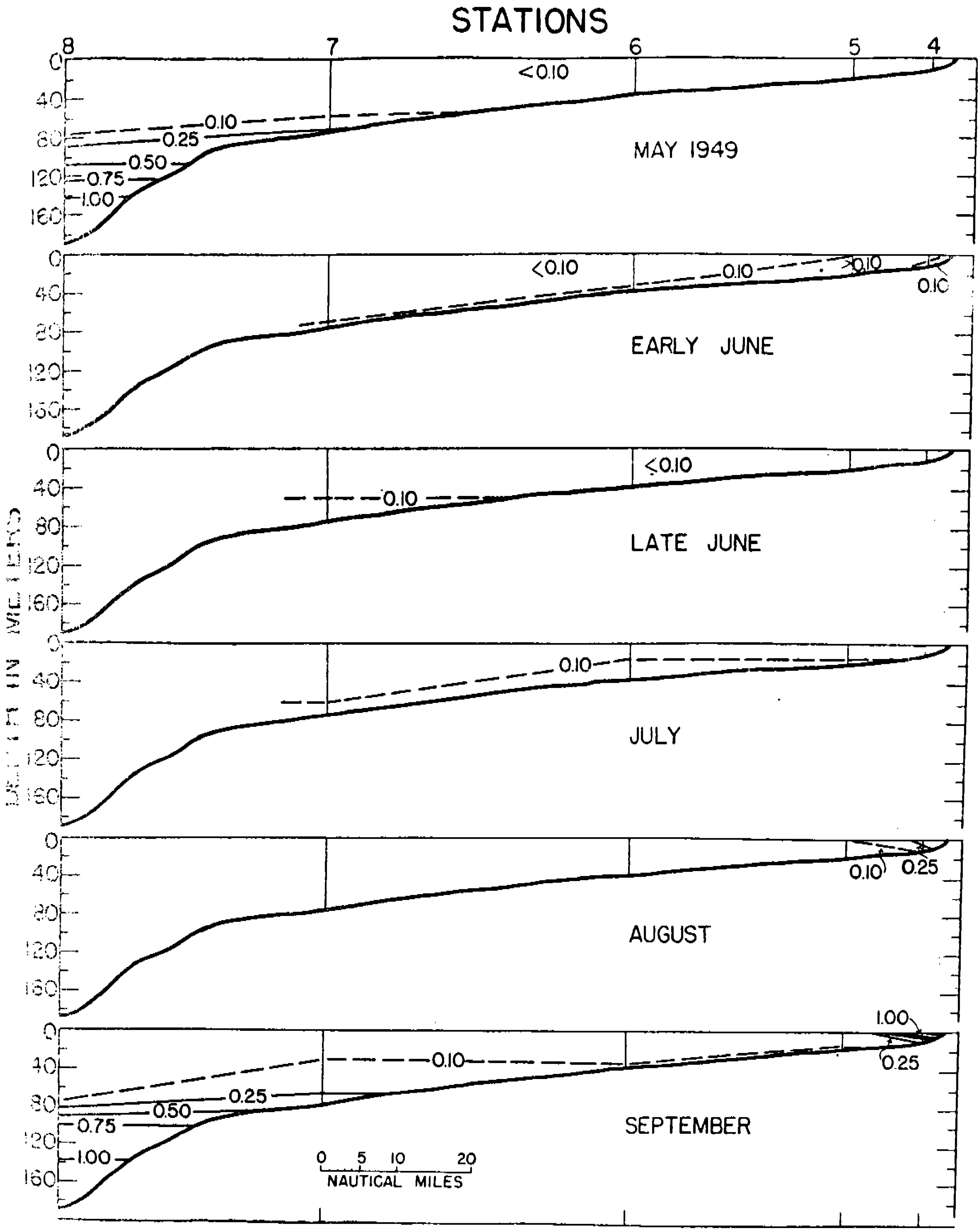

Fig. 7--Inorganic phosphorus sections extending westward from Station 4, 3 miles from Boca Grande Pass, Charlotte Harbor, to Station 8. 120 miles offshore. Units in μg-at/L.

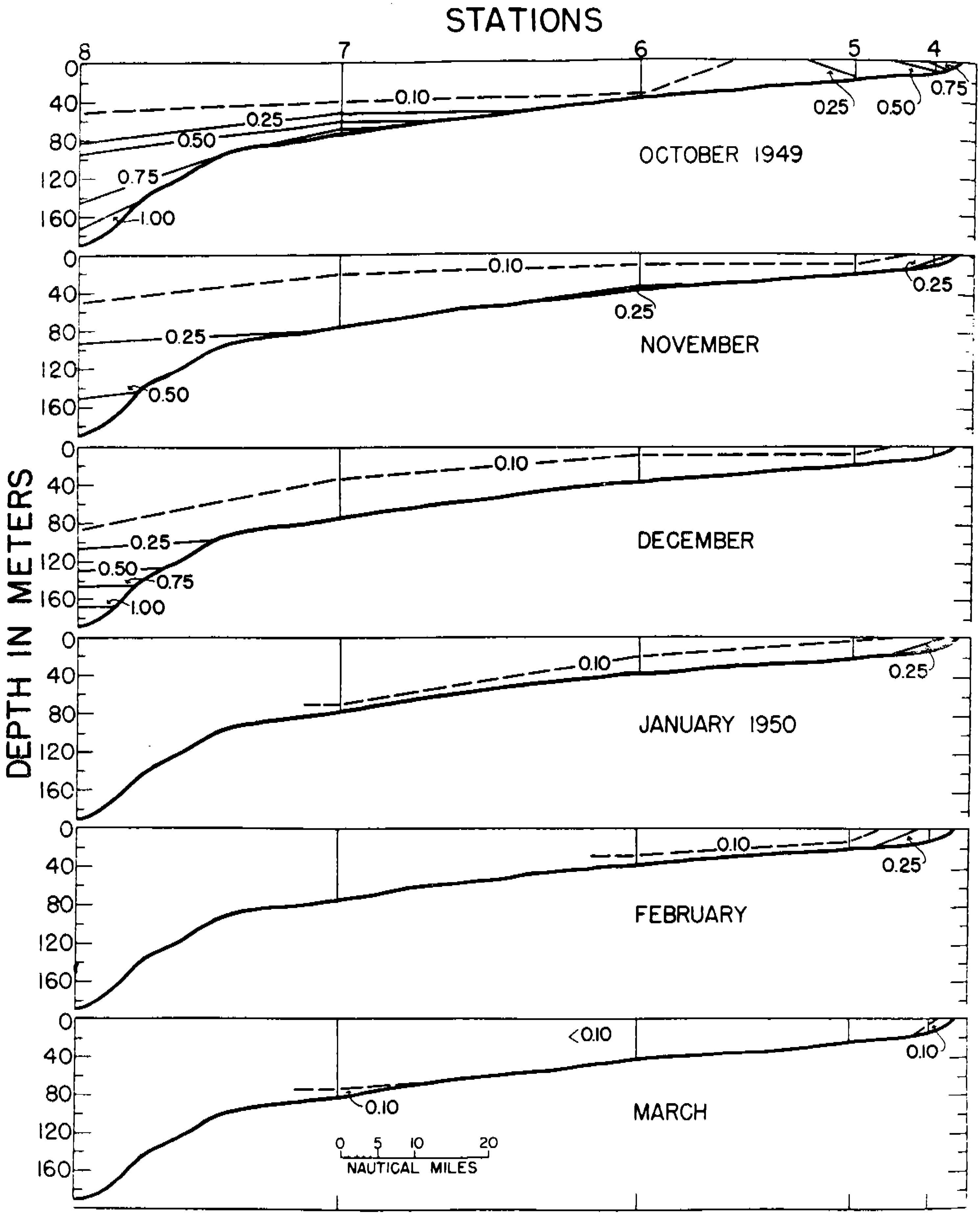

Fig. 7--Inorganic phosphorus sections extending westward from Station 4, 3 miles from Boca Grande Pass, Charlotte Harbor, to Station 8, 120 miles offshore. Units in μg-at/L. (continued)

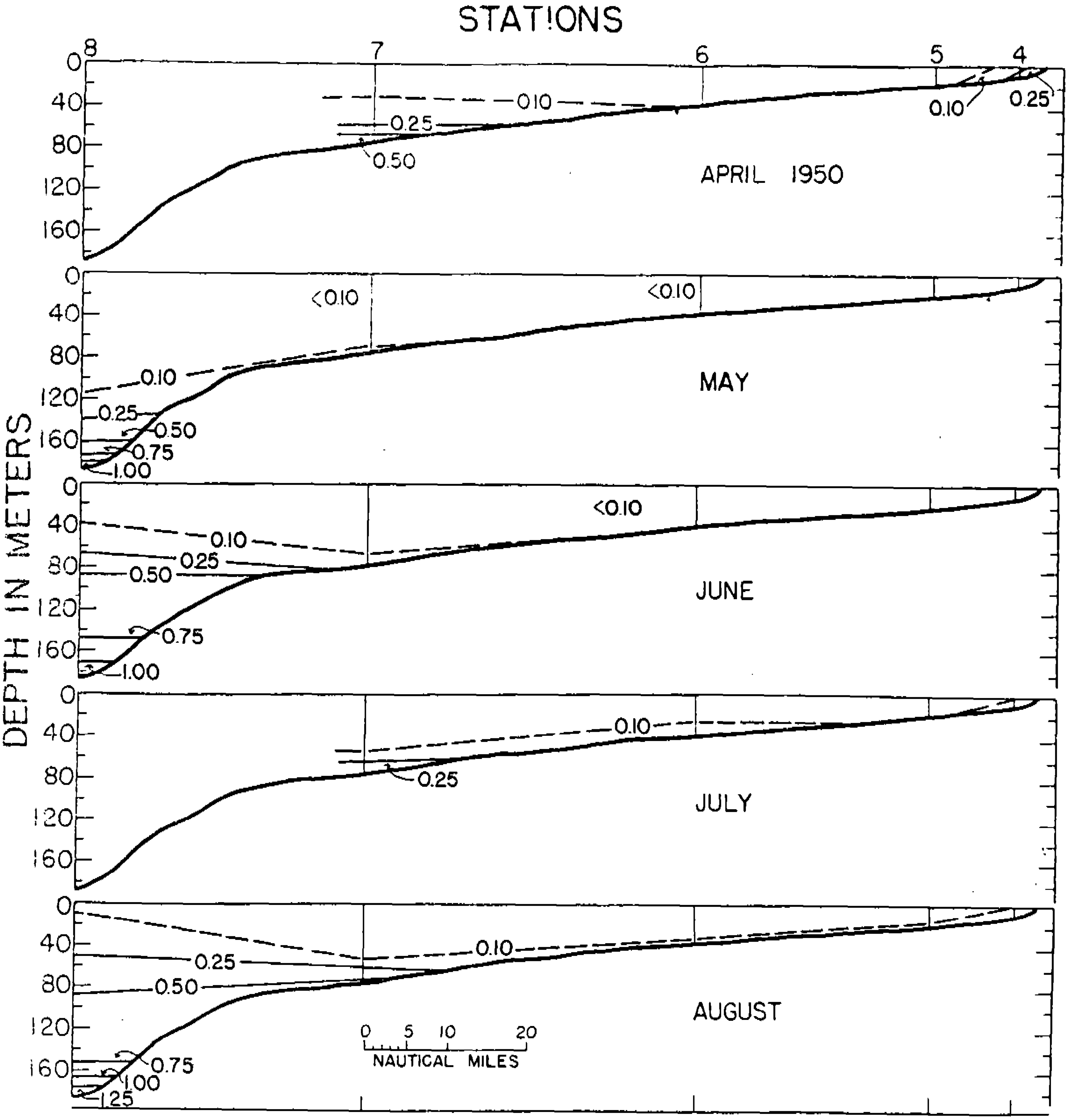

Fig. 7--Inorganic phosphorus sections extending westward from Station 4, 3 miles from Boca Grande Pass, Charlotte Harbor, to Station 8, 120 miles offshore. Units in µg-at/L. (continued)

The amount of organic phosphorus in the water at Station 8 was low at all levels and throughout the year. In only two cases was the concentration of organic phosphorus greater than 0.3 µg-at/L and usually it was not more than 0.1 or 0.2 µg-at/L.

The vertical distribution of organic phosphorus was very erratic. In June 1950 there was a relatively high value at the surface. In general there were extremely low values in the upper 80 meters, the layer in which the content of inorganic phosphorus was low. Higher values of organic phosphorus were occasionally found at this level and at greater depths. There was usually no organic phosphorus near the bottom at this station but in three instances a small amount was observed at the deepest level sampled, 183 meters.

Phosphorus Sections

The sections (figs. 6 and 7) show the phosphorus distribution along the original series of stations from month to month throughout the 16-month period of survey.

In the following discussion the phosphorus distribution will be related to the thermal structure of the water. The temperature data are not reported in this paper but some general aspects of the temperature distribution will be discussed as it relates to phosphorus.

The sections show two places of moderate phosphorus concentration: the inshore water, and the deep water at Station 8. The upper 50 meters from Station 5 outward was generally almost devoid of phosphorus, that is, values of total phosphorus were less than 0.25 µg-at/L.

In May 1949 when the summer thermal stratification of the water was just beginning, the phosphorus content of the upper layers was a little above normal. This condition remained throughout June and July as the thermal stratification became fully developed.

In early September the stratification of the water continued but wind stirring had extended to 20 meters. The phosphorus content was low from Station 5 outward and to a depth of 60 meters. The high values at Station 4 are discussed above.

In October the thermal structure in the upper levels was about the same as in September except surface cooling had started and uniform temperatures extended to 30 meters. The phosphorus content was low at those levels as in September. In the deeper water, however, the isotherms indicated a movement of water along the bottom toward shore resulting in a displacement of water upward. This was reflected in higher phosphorus content below 60 meters at Station 7. There is indication that the effect of this movement extended as far as Station 6 where the value at the bottom was unusually high. It should be noted, however, that the mean concentration of total phosphorus in the water column at the 20-fathom line (Station 6) was only 0.28 µg-at/L (see table 4). Thus, this upwelling did not produce very high concentrations of phosphorus in the coastal waters.

In November with slightly colder weather and drop in surface temperature, convection extended to 50 meters at Station 8. The normally low concentrations of phosphorus in the upper layers occurred at the offshore stations to a depth of about 80 meters as in October. There was only a slight indication of upward movement of water at Station 7.

In December with a marked drop in surface temperature, convection extended to 75 meters below which there was a thermocline at Station 8. There was no indication of upwelling at this time. The total phosphorus content in the upper layers was low from Station 5 outward and to a depth of 80 meters.

From January through April 1950 no observations were made at Station 8 but Station 7 was occupied in all but one of these months. In January the surface temperature was unchanged over December and the wind-stirred layer extended to 50 meters at Station 7. However, the bottom temperature was slightly lower than in December indicating a movement of water to this point from another area.

In winter the inshore waters are colder than the offshore so that from a consideration of temperature alone one cannot arrive at the origin of the colder water at the bottom at Station 7. Either upwelling from offshore or a transport from inshore would lower the bottom temperature there. However, the inshore waters are less saline and an examination of the salinity records shows that the colder bottom water at Station 7 in January could not have originated inshore. It is interesting to note that the slight upwelling that occurred at this time was not reflected in unusual phosphorus values.

In February observations did not extend beyond Station 6 but in March all but Station 8 were visited. The thermal structure in March showed a further decrease in temperature at the surface. The bottom temperature was the same as in January but the low values extended up to 30 meters depth. The phosphorus content was very low at all offshore stations.

In April the surface water had the lowest surface temperature recorded during the first 16 months of the survey, and the wind-stirred layer at Station 7 extended to 50 meters. The bottom temperature showed a sharp decrease over the previous month. This time the drop in temperature at the bottom was accompanied by much higher phosphorus content. The phosphorus found was principally inorganic. In this case the evidence of upwelling was very definite. The temperature, salinity and phosphorus content all indicated a movement of water from a depth of 135 meters offshore. Again it should be noted that this upwelling did not result in high phosphorus values throughout the water column at the 20-fathom line. The mean concentration of total phosphorus at Station 6 was only 0.18 µg-at/L (see table 4).

In May when observations extended to Station 8 the surface waters were warming but the colder bottom water at 40 fathoms (Station 7) was maintained. The phosphorus content was high at the bottom, again similar to the water at 135 meters at Station 8. In this case, however, the high phosphorus was represented by organic phosphorus. Perhaps the upwelled water of the previous month had been maintained while the inorganic phosphorus was converted to organic.

In June considerable surface heating had taken place and a thermocline was developed at all stations. The phosphorus concentration was low at all depths at Stations 6 and 7 and in the upper layers at Station 8 except at the surface.

In July the surface temperature had continued to increase and the bottom temperature had also increased at Station 7. The phosphorus content of the water in the upper layers was higher than usual.

In August the temperature had reached its yearly maximum at the surface at the offshore stations while the bottom temperature at Station 7 was unchanged over July. At Station 8 the thermocline was well developed with a decrease in temperature to the bottom. The phosphorus content of the water in the upper 40 meters was low from Station 5 outward.

It can be concluded from this study of the phosphorus distribution to the 100-fathom line that, although upwelling does occur at certain times, it does not produce abnormally high concentrations of phosphorus in the coastal waters where the red tide occurred.

Another point brought out by this study is that the concentrations of inorganic phosphorus in the upper layers of the open Gulf are always extremely low.

At the surface at Stations 5, 6, 7 and 8 the concentration of inorganic phosphorus was almost always less than 0.1 µg-at/L. In fact, the values recorded are practically within the experimental error of the method of determination.

Any inorganic phosphorus that was brought to the photic zone, either by vertical or horizontal movement or run-off from land during the 16-month period of observation, in the entire area from the 10-fathom line outward, was quickly removed from the water by the phytoplankton. The concentration 0.05 to 0.1 µg-at/L probably represents the minimum value to which the phytoplankton can deplete the water.

In our observations there is nothing to indicate that the bottom of the Gulf is a source of phosphorus. If quantities of soluble phosphate were available on the bottom, the bottom water should show high values during periods of high thermal stratification and the entire water column should show an increase in phosphorus when the thermocline disappears and wind-stirring extends to the bottom. No increase was found in the deeper water except the expected increase below the euphotic zone and no increase in values was found during the months when the water "turned over" from surface to bottom. From November to April the convection zone extended from 30 to 50 meters depth yet during these months the phosphorus concentration of the water was less, rather than more, at stations inside the 40-fathom line. There seems to be no evidence of the bottom contributing phosphorus to the Gulf waters in any measurable degree.

Total phosphorus in column

Since Kalle (1937) and Armstrong and Harvey (1950) have used total phosphorus concentration in the water column as an indicator of water masses, it is interesting to study the changes in the total phosphorus in the body of water in the Gulf.

The integral mean concentrations of total phosphorus for the water columns at Stations 5 to 8 are shown in table 4. At Station 8, 120 miles offshore, there was an indication of a different water mass from November 1949 to May 1950. Although data were obtained for only three months of that period, the integral means were consistently about 65 percent of the values for the rest of the year.

At Station 7 where observations were more complete, 84 miles offshore, there was a greater and a more irregular variation in the integral mean concentration throughout the period of study and the fluctuations do not correspond to those found at Station 8. Either the water masses passing through the two regions were quite independent of each other or else the changes occurred at some particular level. Changes at particular levels would not be accurately reflected in the total phosphorus-integral means because of the redistribution of phosphorus by the vertical migrations of the zooplankton and the sinking of organic detritus.

At Stations 5 and 6 there was also a wide range in mean values from month to month although values were always comparatively low except in a few instances at Station 5, the station closest inshore of this series. It is impossible to explain these fluctuations in our present state of knowledge. They may be related to tidal and irregular along-shore currents. The tremendous migrations of Gulf shrimp and other fish no doubt are important in the redistribution of phosphorus in the water and may have to be taken into consideration in any attempt to explain the horizontal distribution.

PHOSPHORUS AND RED TIDE

The high values of total phosphorus found in the bloom of *Gymnodinium brevis* in 1947 have yet to be satisfactorily explained. Nowhere in the Gulf or in Charlotte Harbor at any time during this investigation were phosphorus concentrations found corresponding to the high values which occurred in the red tide of 1947 except in a scum of *Trichodesmium* which will be discussed below.

Neither the rivers, nor the bottom of the Gulf, nor the deep water of the Gulf can be held as a source of phosphorus sufficient to increase the concentration in the body of coastal water to the values which were found in the red tide samples.

Ketchum and Keen's (1948) suggestion that the high values may have been caused by a swarming of organisms to the surface after absorbing all the phosphorus in the water column is as plausible an explanation as any to date. Unfortunately no blooms of *Gymnodinium* occurred during this study so that this hypothesis could not be tested.

However, blooms of *Trichodesmium* are common along the Florida west coast and an opportunity was afforded to make an analysis of this material. This filamentous blue-green alga is always present in the plankton there and frequently occurs in bloom proportions. It grows in the water and on the surface. It was found in practically every plankton sample examined, whether surface or subsurface. (See also King, 1950.) Its propensity for floating on the surface is the feature which is of importance to the present problem. At times clumps of alga appearing as green flakes are spread over a wide area. At other times the growth is so abundant as to cover the surface of the sea with a scum so thick that it can be scooped up with the hand.

Since it accumulates at the surface it is driven by the wind. Sometimes it piles up in such abundance as to create a nuisance at bathing beaches. On April 12, 1949 a bloom was blown into Sarasota Bay and up onto the beach. The accumulated decomposing organic matter created such a nuisance that it was necessary for the city of Sarasota to haul it away in trucks.

The color of the blooms varies from light green through straw-colored to brownish-red. There is evidence to indicate that when brown the alga is moribund. On one occasion when a mass of straw-colored *Trichodesmium* was filtered, the filtrate contained a high concentration of red-blue pigments indicating that the cells were breaking down.

Phosphorus analyses of some of these blooms are presented in table 6. It is evident that heavy blooms occurred in water containing very little inorganic phosphorus. The analysis of the bloom of October 5, 1950 is particularly significant in this respect. This bloom was found as a thick straw-colored surface accumulation about 12 miles off Venice, Florida, in the area between Sarasota and Charlotte Harbor. A sample of this bloom collected with a bucket contained 10.20 µg-at/L of total phosphorus but a scarcely measurable amount of inorganic phosphorus. A portion of the sample was filtered and the filtrate showed the same low concentration of inorganic phosphorus. The quantity of total phosphorus found in this bloom was within the range reported for the red tide samples.

Throughout the present investigations there was never any evidence of sudden increases in inorganic or total phosphorus immediately preceding any of these blooms of *Trichodesmium*. It seems necessary to conclude that *Trichodesmium* is able to live in water of very low phosphate concentration and that by drifting about it can accumulate phosphorus from a large volume of water. The phosphorus content of the bloom itself, then, bears no direct relation either to the phosphorus content of the water in which it is growing or to that of the entire column of water underlying it.

Since *Trichodesmium* drifts about like so much Sargassum, it would be as inaccurate to include floating *Trichodesmium* in a sample of water for total phosphorus analysis as it would be to include a piece of floating Sargasso Weed. In neither case would the floating plants represent an integral part of the underlying water column as does the suspended plankton.

Table 6.--Analysis of *Trichodesmium* blooms.

Location	Date	Phosphorus inorganic	(µg-at/L) Total
Off Boca Grande Pass	Feb. 25, 1949	-	4.00
Off Stump Pass	June 12, 1950	0.05	1.75
Lido Beach	June 23, 1950	0.20	-
Off Venice:			
Unfiltered sample	Oct. 5, 1950	1/ 0.05	10.20
Filtrate		0.05	2.35

1/ Estimated

Trichodesmium can be concentrated by the winds and tide into long narrow bands several hundred yards wide and miles long. This much has been observed. If conditions suddenly became unfavorable for the survival of this organism a great mass of organic matter would suddenly become available to the biological cycle in the sea. The decomposition of this material would release large quantities of nutrients for the growth of other organisms. Blooms of other organisms would be expected under such conditions.

Since *Gymnodinium brevis* was not found during the period of these investigations and a red tide did not occur during that time, the relation of concentrations of *Trichodesmium* to red tide could not be ascertained. The results of analysis of *Trichodesmium* are presented here simply to focus attention on the occurrence of concentrations of phosphorus in living material floating on offshore waters of extremely low phosphorus content.

SUMMARY

1. The total, inorganic, and organic phosphorus content of the Peace River, Caloosahatchee River, Charlotte Harbor, and ten stations in the Gulf of Mexico off the west coast of Florida extending to 120 miles offshore is reported for a period covering more than sixteen months in 1949 and 1950.

2. The phosphorus-rich water of the Peace River does not normally increase the phosphorus content of local Gulf waters to any measurable degree.

3. In the surface water there is a gradual decrease in phosphorus content with increase in distance from shore out to a distance of about 85 miles.

4. At distances of 14 or more miles from the Florida west coast in the surface water the concentration of total phosphorus was usually below 0.25 µg-at/L; the concentration of inorganic phosphorus usually below 0.10 µg-at/L; and the amount of organic phosphorus usually exceeded the inorganic.

5. Larger quantities of phosphorus were found at depths below 50 meters and this was largely inorganic phosphorus.

6. An upwelling of deep water was found at certain times but this upwelling did not have any apparent effect on the phosphorus content of the water in the euphotic zone.

7. There was no evidence of the bottom sediments of the Gulf contributing any appreciable quantities of phosphorus to the Gulf water.

8. The integral mean concentrations of total phosphorus in the water column at each station varied widely from month to month indicating either complex movements of the water masses or a redistricution of phosphorus by biological agencies.

9. Blooms of Trichodesmium drifting with the wind were found to constitute a mechanism for the local accumulation of large quantities of phosphorus.

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