OCEANOGRAPHY IN THE TONGUE OF THE OCEAN.

John C. Armstrong
American Museum of Natural History

October 1953

THE AMERICAN MUSEUM OF NATURAL HISTORY
Department of Fishes and Aquatic Biology
New York City

Oceanography in the Tongue of the Ocean,

Bahamas, B. W. I.

A report on oceanographic observations in the Tongue of the Ocean between Fresh Creek, Andros and the western end of New Providence.

John C. Armstrong
October 1953

INTRODUCTION

Under contract Nonr-04501, a survey of the Tongue of the Ocean in the Bahamas between Fresh Creek, Andros and the western end of New Providence was undertaken.

During the latter part of June, July and the early part of August 1950, the auxiliary ketch Mother Goose II was engaged upon this work. Sixteen dredge and twenty-seven hydrographic stations were occupied in depths to 1850 meters. Sixty-two plankton samples in depths to 1540 meters were obtained. Photographs of the bottom (figs. 9-25) were obtained in depths to 2200 meters and cores were taken in depths to 2034 meters. In addition to the forty-one soundings obtained in the course of the photography and coring operations, twenty-seven soundings were made to depths of 1070 meters with only the lead on the wire.

METHODS and EQUIPMENT

A 12,000 foot length of 1/8" diameter aircraft cable was carried on a drum belt driven from the main engine.

The metering wheel had been cut to a circumference of 1/4 fathom by simply turning it up in a lathe until a marked piece of wire just fit around a groove when held by hand. The final calibration was made by comparing the meter wheel values, corrected for wire angle but not for

the stretch of the cable, with those obtained from the unprotected reversing thermometers. The values read from the wheel were found to be too low by 12 per cent ± 3 per cent. It is considered that, after correction, the depth values obtained by vertical lowerings may be relied upon to ± 5 per cent.

Surface temperatures were obtained by dipping up a sample of water in a canvass bucket and measuring the temperature at once in the shade. Sub-surface temperatures and salinities were obtained by Nansen bottles and reversing thermometers.

Soundings were made with 200 pound lead weight at the end of the wire.

Bottom photographs were obtained with a Ewing deep-sea camera. This device operated satisfactorily nineteen times and failed to produce a usable negative fifteen times. A small coring device was attached to the trigger. This functioned well and usually brought up a good core, except, of course, from rocky bottom.

A reduced scale model of the large Ewing coring machine was used to obtain longer cores. This device did not operate consistently; a week's work only yielded five cores.

Plankton was collected with a series of six half-meter nets and two Clarke-bumpus plankton samples.

Positions were fixed by taking bearing on shore

objects wherever possible. Two bearings were considered sufficient for plankton stations, otherwise three cross-bearings were taken when possible and these stations placed in the center of the resulting triangle. When a distance from land was too great to obtain clear bearings, dead reckoning was kept from the last known position until returning at the end of the day's work bearings were again obtained. As steady wind and sea condisions are the rule during summer in this area it was possible to avoid working the outer stations during unsettled weather. The difference between the final dead reckoning position and that found by bearings was pro-rated along the ship's course for the day. These differences were not used to estimate current as they were obviously largely caused by leeway. In order to prevent error in these calculations from the effect of the many movable masses of iron and steel in our equipment upon the magnetic compass, the latter was frequently checked against the sun's azimuth.

The charts for the final plottings were prepared from aerial photographs by the radial line method.

TEMPERATURE and SALINITY

Fig. 3 shows a temperature profile constructed from a series of stations extending across the Tongue of the Ocean. As shown in table 1, no temperature observations

are available between the surface and about 100 meters. We had relied upon our bathythermograph here; its malfunctioning leaves a most serious gap in the data. The bottom profile shown here and in fig. 4 was constructed from our wire soundings off Fresh Creek and has not been extended to the New Providence coast as time did not permit taking soundings off that shore.

The salinity profile from the same stations is shown in fig. 4.

The temperature-salinity diagram (fig. 5) for these stations combined with all other available data, shows that for temperatures below 16° found at a depth of 500 meters, the T S curve appears to be identical with that shown by Islin (1936) for the Sargasso Sea. Between 16° and 18°, the Tongue of the Ocean water is slightly, but probably not significantly less saline. Water warmer than 18°, found above about 300 meter, shows very little correlation between temperature and salinity.

Smith (1940) showed that warm, high salinity water is produced over at least part of the Bahama Banks. We found such water (29.0° and 37.82°/oo) at sta. 36 on the bank south of the western end of New Providence. Sta. 34, two miles south of Goulding Cay and about an equal distance to leeward of the bank, shows a surface salinity of 36.54°/oo, one salinity maximum of 37.06°/oo at 51 meters and another less pronounced maximum of 36.66°/oo at

205 meters. At sta. 38, a little over four miles to leeward of the banks, the 51 meter observation of 36.59°/oo is only 0.04°/oo more saline than the surface and 0.06°/oo than that at 102 meters. At sta. 41, about seven miles to leeward, this upper salinity maximum is absent, the 51 meter salinity is 0.05°/oo less than that at the surface and 0.06°/oo less than that at 102 meters. The bottle containing the surface salinity sample for sta. 42 was unfortunately broken during shipment to Woods Hole for analysis. However, the 51 meter salinity, 36.53°/oo is equal to that at the surface at sta. 41 while the surface at sta. 28 is 36.45°/oo. It seems quite probable that the 51 meter depth would also show a slight salinity maximum at sta. 42. At sta. 25, the 51 meter observation is lacking. At sta. 33, the 51 meter observation is 0.28°/oo more than the surface and 0.19°/oo more than at 102 meters. Further inshore, the surface salinity is slightly higher than at 50 or 100 meters.

The deeper salinity maximum previously noted at sta. 34 at 205 meters was found at every station where salinity observations were made at about 200 meters.

Unfortunately, although much time and effort were expended in taking bathythermograph slides, after our return we were told that the instrument, which had been lent to us by the Woods Hole Oceanographic Institute, was defective and the slides were of no value.

Because of this failure of our bathythermograph, these salinity observations cannot unfortunately be directly correlated with details of the temperature distribution in the same depths zone.

Several bathythermograph observations made by the "Atlantis" on June 13, 15 and 16, 1945 at 24°57' N lat. and 77°35' W long., a position between the banks and our sta. 38, were kindly made available to us by the Woods Hole Oceanographic Institute. Most of these traces, (fig. 6) show temperature inversions at about 200 feet which are probably correlated with the 51 meter salinity maximum. Temperature irregularities at 600 feet may correspond to the salinity maximum at the 200 meter observations. As might be expected from the week development of this feature at the eastern stations of our salinity section, these temperature irregularities are not as marked as those at about 200 feet. The depth of all these features varied from trace to trace. As the depth of the mixed layer was well defined on a large proportion of the tracer and the variations in its thickness appeared clearly related to the depth of the upper temperature inversions, this feature was selected for analysis.

Starting from an arbitrary epoch, the observations were listed by tidal hours for the principal lunar semidiurnal tide, M_2. The longest series was that of ten observations on June 15. The series for June 16 and June 13

each includes some observations made during the tidal interval covered by the June 15 series. The depth of the mixed layer on June 15 was plotted against the tidal hour and interpolated values read off this graph for the depth at the time, in tidal hours, of the observations made during this tidal interval on the 13th and 16th. In this manner it was estimated that the average depth of the mixed layer was 14 feet greater on June 13 and 35 feet less on June 16. Accordingly so as to eliminate, so far as possible, long term or non-tidal fluctuations, 14 feet were subtracted from all the June 13 observations and 35 feet added to all those made on June 16. These data were then assembled and averaged for each tidal hour. The means were then smoothed by a running two term average. The results shown in fig. 7 clearly indicate a tidal periodicity. The amplitude is of course reduced by the smoothing process. Before smoothing but after correction for the difference between the average depth on the various days, the amplitude was about 70 feet.

The possibility that the salinity features of the upper 250 meters as shown in fig. 4 may be subject to vertical tidal movements of some 20 meters makes a more detailed analysis of our data. If the actual salinity distribution even approaches the complexity of the temperature distribution shown by the 'Atlantis' BT traces, then it is obvious that such a movement could account for a

considerable part of the differences between stations in the upper 250 meters.

The following general picture may, I believe, be safely drawn from these data:

1) The water in the Tongue of the Ocean below about 300 meters is unmodified central Atlantic water.

2) There is a salinity maximum at about 200 meters which may be as $0.40^{o}/oo$ higher than that at the surface.

3) There is a salinity maximum at about 50 meters separated from that at 200 meters by water of lower salinity.

4) Below 300 meter the isopleth are so nearly horizontal that a gradient current could not be reliably computed.

5) The depth of the mixed layer and probably of the layers of salinity maxima are subject to vertical tidal fluctuations which may have an amptitude of some 20 meters

CURRENTS

The vessel's centerboard could not be lowered without raising sail as, in the absence of any lateral pressure, her movements could cause an excessive pounding upon the centerboard logs. Consequently the leeway made in the prevelent SE wind made it impossible to form any accurate quantitative estimate of the surface current from the drift of the vessel.

Nevertheless under no circumstances was the vessel ever set to the south along the Andros coast and the existence of a northerly drift along this coast, probably strongest within a mile of shore, was quite apparent even though its velocity could not be estimated.

Photographs of the bottom near Fresh Creek showed bare rock to a depth of 230 meters and bare gravel to 450 meters.

This last station is a little over 0.3 mile to seaward of the reef so it seems very probable that this current is deep enough to keep the bottom swept clean to that depth.

This current together with the fact that neither our salinity stations near North West Light nor Smith's (1940) observations show extremely high salinity water over the eastern edge of the banks make it seem likely that the high salinity water shown on the salinity profile has either been carried northward or spread across the Tongue of the Ocean from the bank to the eastward.

BOTTOM SURVEYS

The shallow shelf extending nearly a mile off shore from Fresh Creek has a moderately well developed coral reef on its seaward margin. This shelf and its reef have been described by Newell (1951).

Beyond the reef, the depth increases very abruptly. When sailing along the edge of the shelf, it was not uncommon to see the greenish color of shallow water on one side of the vessel and the marine blue of deep water on the other even though her beam was only twelve and a half feet.

The seaward edge of the shelf is generally about 25 to 30 meters deep, the base of the steep cliff is at about 150 to 200 meters. Only three times was it possible to find bottom between 30 and 150 meters, once the sounding lead struck at 130 and again at 137 meters and the Ewing camera struck what appears to be a rocky ledge at 132 meters (fig. 9). A few samples of a limestone rock containing fossils were torn off the base of the cliff with the dredge. These were turned over to Dr. Newell for study.

Photographs of the bottom beyond the cliff (figs. 10-14) show bare rock down to 230 meters. A photograph (fig. 15) taken at 383 meters shows some sand and gravel which appears to lie as a covering over the rock. At 450 meters, (fig. 16) a photograph shows bare gravel. This gravel appeared in dredge samples and was found to consist almost entirely of dead segments of <u>Halimeda</u>. This genus of coralline algae is common in shallow water throughout the warm seas. The dredged material had, however, very much larger and coarser fronds than any now living along the Andros coast and according to Dr. Harold J. Humm, the calcification appears

to be considerably heavier than that of living material. Dredge and core samples showed that this exposed gravel was limited to a narrow zone just beyond the exposed rock from 400 to 500 meters deep.

At greater depths, this gravel becomes overlayed and mixed with a fine calcareous mud and finally disappears altogether from our samples between 500 and 600 meters. From 500 meters to 2200 meters the calcareous mud becomes increasingly fine.

The bottom fauna was extraordinarily scarce. Never in years of dredging experience have I seen so few organisms of any kind brought up after long drags over the bottom. Also when one considers that the very clear waters of the Tongue cannot produce anything but a very slow deposit of sediment in the deeper water, any tracks or markings of organic activity must persist for a long time. The paucity of such trails and tracks on all photographs except fig. 19 taken in 561 meters therefore confirms this impression of an almost barren bottom.

PLANKTON

While in the field it appeared that the amount of plankton collected at various depths was subject to systematic variations. Careful analysis of this by measuring the displacement volume and reducing to cc per hour towed does not substantiate this impression.(table 7). Reports on the results of systematic studies on the various groups of organisms obtained will appear at a later date.

REFERENCES

Drew, G. Harold
1914. On the precipitation of calcium carbonate in the sea by marine bacteria. Carnegie Inst. Washington Papers Tortugas Lab., Vol. 5, pp.7-45.

Islen, C. O'D.
1936. A study of the circulation of the western North Atlantic. Papers in Physical Oceanography and Meterolcgy. Vol. 4, No. 4, pp. 1-101.

Newell, N., J. Rigby, A. Whiteman and J. Bradley
1951. Shoal-water geology and environments eastern Andros Island, Bahamas. Bull. Am. Mus. Nat. Hist., Vol. 97, pp. 1-29.

Smith, C. L.
1940. The Great Bahama Bank. Journ. Marine Research, Vol. 3, pp. 147-189.

List of Figures

TABLE I

Temperature and Salinity Observations

Sta.	Date	Depth	Water temp.	Salinity	Air temp.	Wind	Sea	Swell	Weather	Clouds
6	6/16	0	27.3	--	28.1	SE light	1	1	clear	70
8	6/17	0	27.3	--	27.1	calm	0	1	clear	50
		0	27.2	--	27.0					
		0	28.05	--	28.2					
		0	27.75	--	28.1					
9	6/17	0	27.90	--	27.0	SE light	0	1	clear	5
10	6/18	0	27.85	--	27.6	" "	0	1	"	20
11	6/18	0	28.25	--	28.2	" "	0	1	"	15
12	6/24	0	27.95	--	--	" "	1	1	"	05
15	6/27	0	28.1	--	29.1	SE gentle	1	1	"	70
21	7/6	300	18.22	36.47	--	SE light	1	1	"	05
		399	17.06	36.32						
		446	16.62	36.25						
		598	--	35.97						
		699	12.05	35.58						
22	7/6	371	17.65	36.41	--	SE light	1	1	clear	10
		474	16.49	36.23						
		574	14.82	35.99						
		777	9.64	35.28						
		978	6.86	35.09						
23	7/6	0	27.7	36.45	--	SE light	1	1	clear	50
		102	--*	36.35						

*off scale

Sta.	Date	Depth	Water temp.	Sa-linity	Air temp.	Wind	Sea	Swell	Weather	Clouds
23 (cont.)	7/6	185	23.28	36.89						
		267	18.86	36.55						
24	7/6	0	27.7	--	--	SE light	1	1	clear	40
25	7/7	1156	4.89	35.03	--	" "	1	1	"	15
		1255	4.62	35.00						
		1454	4.25	34.97						
		1651	3.98	34.98						
		1851	3.81	34.97						
26	7/7	0	28.2	36.44	--	SE light	1	1	clear	25
		102	--	36.78						
		205	20.69	36.64						
		307	18.17	36.46						
		410	17.28	36.35						
		512	15.66	36.09						
		614	13.11	35.71						
		717	10.95	35.41						
		819	9.30	35.25						
27	7/7	0	28.1	--	--	SE light	1	1	clear	05
28	7/8	0	28.15	36.45	29.7	SE mod.	mod.	0	clear	05
		49	--	36.47						
		99	24.91	36.60						
		198	21.91	36.74						
		289	18.57	36.50						
		386	17.57	36.35						
		413	17.35	36.38						

Sta.	Date	Depth	Water temp.	Sa- linity	Air temp.	Wind	Sea	Swell	Weather	Clouds
28 (cont.)	7/8	516	--	36.10						
		578	13.32	35.77						
		620	12.83	35.66						
		827	9.13	35.22						
		929	7.30	35.11						
31	7/9	0	28.15	36.43	29.1	SE light	1	0	clear	10
		53	--	36.30						
		104	--	36.59						
		157	23.83	36.83						
		208	21.98	36.74						
		415	17.28	36.36						
		417	17.16	36.44						
		518	15.58	36.08						
		622	13.00	35.71						
32	7/9	247	19.76	36.63	--	SE light	1	0	rain	80
		311	18.57	36.49						
		377	17.75	36.44						
33	7/9	0	28.30	36.50	27.60	SE light	1	0	rain	80
		51	--	36.78						
		102	--	36.59						
		154	23.71	36.88						
		205	21.60	36.74						
		256	19.40	36.56						
		307	18.37	36.46						
		358	17.95	36.44						

Sta.	Date	Depth	Water temp.	Sa-linity	Air temp.	Wind	Sea	Swell	Weather	Clouds
33 (cont.)	7/9	410	17.30	36.34						
		518	15.41	36.04						
		620	13.06	35.72						
		724	10.66	35.38						
		827	8.95	35.20						
		1033	6.16	35.04						
34A	7/10	1143	5.02	35.01	--	SE mod.	mod.	1	clear	50
		1343	4.43	34.98						
		1553	4.12	34.97						
		1757	3.90	34.98						
34	7/11	0	28.40	36.54	28.65	E mod.	mod.	1	clear	25
		51	--	37.06						
		102	24.37	36.61						
		205	20.76	36.66						
		307	18.47	36.49						
		408	17.29	36.33						
		410	--	36.38						
35	7/11	0	28.35	--	28.95	ESE mod.	mod.	1	clear	10
		307	18.59	36.52						
		410	17.38	36.36						
		512	15.72	36.09						
		717	10.52	35.33						
36	7/12	0	29.0	37.82	28.2	ESE light	1	1	clear	15
37	7/12	0	28.4	36.55	28.25	"	1	1	"	15

Sta.	Date	Depth	Water temp.	Sa-linity	Air temp.	Wind	Sea	Swell	Weather	Clouds
38	7/12	0	28.35	36.55	28.65	EN light	1	1	clear	15
		51	--	36.59						
		102	25.07	36.53						
		205	21.34	36.67						
		922	6.93	36.88						
		1127	5.01	35.02						
39	7/12	1229	4.61	35.02	--	SE mod.	mod.	1	clear	60
		1434	4.39	34.97						
40/1	7/13	0	28.10	--	28.9	SE mod.	mod.	1	clear	15
40/2		0	28.42	--	28.6					
40/3		0	28.22	--	28.2					
41	7/13	0	28.19	36.53	28.1	SE light	1	1	clear	05
		51	--	36.48						
		102	24.84	36.64						
		205	21.55	36.72						
		307	18.43	36.56						
		410	17.28	36.36						
		512	15.29	36.03						
		614	12.99	35.71						
		819	8.87	35.18						
42	7/14	0	27.95	--	26.8	S light	1	1	clear	85
		51	--	36.53						
		102	--	36.49						
		205	23.44	36.90						
		307	19.01	36.56						

Sta.	Date	Depth	Water temp.	Sa-linity	Air temp.	Wind	Sea	Swell	Weather	Clouds
42 (cont.)	7/14	410	17.26	36.36						
		512	15.36	36.04						
		717	10.86	35.41						
		922	7.56	35.11						
44	7/15	0	28.18	36.55	28.2	SE light	1	2	clear	20
45	7/16	0	28.12	36.54	28.7	ESE mod.	rough	1	clear	30
*63/3	8/10	0	29.3	36.35	29.6	NE fresh		0	clear	
63/4		0	29.6	36.25	27.1	to mod.		0	clear	
63/5		0	30.3	36.55	28.2	NE light		0	clear	
63/6		0	30.7	36.25	29.15	to mod.		0	clear	
63/7		0	30.5	36.64	28.95	NE light		0	clear	
63/8		0	30.7	37.15	27.9	to mod.		0	clear	

Sta.	Position	time
*63/3	1 mile E of North West Light	1115
63/4	abeam North West Light	1145
63/5	7 miles W of North West Light	1400
63/6	14 miles W of North West Light	1600
	20 miles W of North West Light	1715
63/7	25 miles W of North West Light	1807
63/8	33 miles W of North West Light	1940

TABLE 2

Depth of Mixed Layer from 'Atlantis' BT data.

$24^{\circ}57'$ N lat; $77^{\circ}35'$ W long; 1945

June depth feet	13 M_2 phase angle	June depth feet	15 M_2 phase angle	June depth feet	16 M_2 phase angle
200	8	160	1	100	167
200	20	205	20	110	193
180	54	200	39	160	267
190	77	170	183	150	300
180	290	170	216	160	326
200	321	180	233	150	300
200	338	190	283	160	326
200	352	180	307	150	348
		180	333		

TABLE 3

Wire Soundings
All bearings in degrees magnetic
(also see core and camera stations for additional soundings)

Sta.	S*	Bearings High Cay	Light House	Goat Cay	Wire out fath.	Wire angle	corr. depth meters	Date	Wind	Sea	Weath.	Clouds
20	1	141	235	297	6	0	12.8	7/5	SE mod.		clear	
	2	144	232	295	8	0	16.4					
	3	143	232	--	10	0	20.0					
	4	142	230	--	15	0	31.0					
	5	143	228	283	103	0	210.0					
	6	144	240	294	67	0	137.0					
	7	143	238	292	16	0	33.0					
	8	146	239	286	125	0	256.0					
	9	146	235	282	185	0	379.0					
	10	--	235	282	219	0	448.0					
	11	--	235	280	267	0	547.0					
	12	--	234	276	318	18°	618.0					
	13	--	228	266	367	27°	669.0					
	14	--	228	262	423	29°	755.0					
	15	154	230	262	462	27°	843.0					
	16	154	226	258	476	4°	973.0					
	17	158	232	260	522	3°	1070.0					
		Light House	Goat Cay	School House								
30	1	239	296	267	12	0	24.0	7/9	SE light	1	clear	20
	2	238	292	263	63	0	130.0					
	3	236	289	262	110	0	225.0					

*Sounding

TABLE 4

Deep Water Camera Stations

Sta.	Date	Exp. No.	Bearings degrees magnetic		Wire out fath.	Corr. Depth met.	Wind	Sea	Swell	Weather	Clouds
			Light House	Goat Cay							
53	7/27						SE light	1	0	clear	0
		1	230	276	314	648		part of negative clouded			
		2	224	261	470	962		shutter did not trip			
		3	212	241	485	993		good negative			
54	7/28						SE light	1	0	clear	5
		1	234	270	373	764		camera did not trigger			
		2	219	252	516	1057		film did not rewind - no core - core catcher failed			
		3	217	240	652	1335		negative partly cloudy - core catcher failed			
		4	212	232	660	1351		good negative and core			
		5	205	225	486	995		camera went off in mid water - core catcher failed			
		6	202	225	442	905		camera did not trigger - core catcher failed			
		7	176	188	262	536		good negative and core			

Sta.	Date	Exp. No.	Bearings degrees magnetic			Wire out fath.	Corr. Depth met.	Wind	Sea	Swell	Weather	Clouds
55	7/29							ExS light	1	0	clear	10
		1	3 1/8 miles NE Fresh Creek			854	1748		good negative and core			
		2	7 miles NE Fresh Creek			1079	2209		good negative and core			
		3	Light House	Goat Cay					good core - film winder failed. Operations stopped to take camera ashore for repair.			
			223	239		828	1675					
56	7/30		Light House	Goat Cay	School House			SE light	1	0	clear	10
		1	234	296	266	8	16		fair to good negatives were obtained from all exposures, rewind mechanism continued to give trouble. Exposures uneven because of poor synchronization.			
		2	220	265	245	385	778					
		3	218	264	242	346	710					
		4	233	289	262	112	229					
		5	240	285	268	91	190					
		6	247	294	269	64	132					
		7	238	295	266	8	16					

Sta.	Date	Exp. No.	Bearings degrees magnetic Light House	Goat Cay	School House	Wire out fath.	Corr. Depth met.	Wind	Sea Swell Weather Clouds
57	7/30							SE light	1 0 clear --
		1	236	290	260	106	218		good exposure - no core
		2	238	286	262	164	336		camera did not trigger - contacts repaired no core
		3	233	290	260	81	166		good exposure - a few freshly broken pebbles in core tube
		4	244	294	267	187	382		good exposure - a few <u>Halimeda</u> fronds in core tube
		5	242	288	263	220	450		good exposure - a few <u>Halimeda</u> fronds in core tube
		6	246	294	269	135	276		good exposure - no core
58	7/31							SE light	1 0 clear 5
		1	200	284		81	166		good exposure - no core
		2	206	274		245	501		good exposure - no core
		3	198	265		225	461		camera did not trigger - no core
		4	195	252		274	561		good exposure and core
		5	210	260		292	598		good exposure and core
		6	205	260		290	594		flash bulb failed - good core
		7	226	267		356	730		syncr. failed - contact bent
		8	231	281		213	437		insulator leaked

TABLE 5

CORE STATIONS

Sta.	Date	Sample No.	Core tag no.	Bearings degrees magnetic: Light House	Bearings degrees magnetic: Goat Cay	Wire out fath.	Wire angle	Corr. depth meters	Wind	Sea	Swell	Weath.	Clds.
59	8/1	1	0175	245	280	413	0	852	0	0	0	clear	5°/o
60	8/2	1	0056	208	231	561	0	1148	SE light	1	0	"	15°/o
		2	0009	210	230	610	0	1249					
61	8/3	1	0066	5 1/2 miles NE of Fresh Creek		993	0	2034	SE light	1	0	"	20°/o
62	8/4	1	0025	6 1/2 miles N of Fresh Creek		993	0	2034	SE light	1	0	"	10°/o

TABLE 6

DREDGE STATIONS

Sta.	Date	Bearings	Depth	Wind	Sea	Swell	Weath.	Clouds	Bottom
16	6/28	start High Cay 161 Light House 232 finish High Cay 158 Light House 225	600-700	SE light	1	1	clear	15	sand
17	6/28	start High Cay 156 Light House 244 finish High Cay 165 Nassau Radio 72	500-600	SW light	1	1	clear	90	sand
18	6/28	start High Cay 176 Nassau Radio 32 finish High Cay 208 Nassau Radio 32	300	SSW light	1	2	clear	80	dredge empty
19	6/28	1/2 mile 186 off High Cay	510	SW light	1	1	clear	80	fine sand rock sample obtain.
48	7/19	High Cay 158 Goat Cay 280 Light House 254	620	SE light	mod.	1	clear	20	fine sand
49	7/21	Light House 258 Goat Cay 300 School House 276 High Cay 140	266-290	E	1	1	clear	90	sand
50	7/22	1/4 mile NE Sunken Rock, Fresh Creek	200-250	SE light	1	1	clear	10	rock
52	7/22	Light House 198 Goat Cay 260 School House 234	140	SE light	1	1	clear	15	rock and sand 5 hauls at this station

TABLE 7

Plankton Stations 1/2 meter nets

Station	Date	Sample No.	Bearings degrees magnetic		Time out	Time in	Wire out fathoms	Wire angle	corrected depth met.	cc/hr.	note: 'W' in cc/hr. column indicates sargassum weed
6	6/16		High Cay	Light House							
		1	160	228	whole string of nets	towed at depth 1230 - 1430	65	30	115	W	Air temp. 28.1
		2	160	228			90	30	159	W	Surface temp.27.3
		3	160	228			140	30	249	2.1	Wind SE light
		4	160	228			240	30	426	1.0	Sea 1
		5	160	228			340	30	603	2.9	Swell 1
		6	160	228			440	30	781	2.8	Weather clear Clouds 70
10	6/18		High Cay	Light House							
		1	164	234	1005	1150	--	--	932	4.5	Air temp. 27.6
		2	164	234	1010	1145	--	--	830	3.4	Surface temp.28.8
		3	164	234	1015	1140	--	--	728	6.0	Wind SE light
		4	164	234	1022	1135	--	--	625	5.0	Sea 0
		5	164	234	1028	1130	--	--	523	W	Swell 1
		6	164	234	1035	1120	--	--	421		Weather clear Clouds 20

Station	Date	Sample No.	Bearings degrees magnetic: High Cay	Light House	Time out	Time in	Wire out fathoms	Wire angle	corrected depth met.	cc/hr.	note: 'W' in cc/hr. column indicates sargassum weed.
11	6/18										
		1	221	168	1250	1511	180	38	291	4.1	Air Temp. 28.2
		2	221	168	1245	1525	280	38	454	2.9	Surface temp.28.3
		3	221	168	1242	1540	380	38	613	1.6	Wind SE light
		4	221	168	1235	1549	480	38	774	2.9	Sea 0
		5	221	168	1231	1557	571	38	922	3.3	Swell 1
		6	221	168	1235	1631	680	38	1097	4.1	Weather clear Clouds 15
15	6/27	1	5 miles		whole string of nets towed at depth 935-1135		650	40	1024	4.1	Air temp. 29.2
		2	E N E of				700	40	1095	4.6	Surface temp.28.1
		3	Fresh				750	40	1178	3.5	Wind SE gentle
		4	Creek				800	40	1249	W	Sea 1
		5					850	40	1331	4.4	Swell 1
		6					900	40	1414	W	Weather clear Clouds 70
44	7/15	1	6 miles		1247	1600	376	50	494-591	2.6	Air temp. 28.2
		2	N E of		1240	1606	498	50	684-781	1.8	Surface temp.28.2
		3	Fresh		1234	1615	620	50	876-973	3.4	Wind SE light
		4	Creek		1227	1620	742	50	1070-1165	2.4	Sea 1
		5			1221	1626	864	50	1260-1335	1.5	Swell 2
		6			1215	1631	986	50	1450-1547	1.6	Weather clear Clouds 20
		Whole string of nets raised 50 fathoms during tow.									

Station	Date	Sample No.	Bearings degrees magnetic		Time out	Time in	Wire out fathoms	Wire angle	corrected depth met.	cc/hr.	note: 'W' in cc/hr. column indicates sargassum weed
45	7/16		High Cay	Light House							
		7	164	261	1521	1626	0	45	0	1.4	Air temp. 28.7
		8	164	261	1517	1628	39	45	57	19.6	Surface temp. 28.1
		9	164	261	1515	1631	78	45	113	5.1	Wind ESE moderate
		10	164	261	1510	1635	156	45	225	2.3	Sea rough
		11	164	261	1506	1639	234	45	338	3.3	Swell 2
		12	164	261	1500	1634	310	45	450	3.7	Weather clear Clouds 30
46	7/17		High Cay	School House							
		5	160	249	Whole string of nets towed at depth 1215-1430		218	45	315	1.6	Wind SE moderate
		6	160	249			141	45	205	1.6	Sea moderate
		7	160	249			70	45	102	2.6	Swell 1
		8	160	249			35	45	51	5.6	Weather clear
		9	160	249			0	45	0	W	

TABLE 8

Clarke-Bumpus Plankton Sampler - oblique hauls

Sta.	Date	Sample No.	Bearings		Time out	Time in	Wire out fath.	Wire angle	Corr. Depth met.	Revolution sampler meter	Wind	Sea	Swell	Weather	Clou
7	7/16		High Cay	Light House							SE light	1	1	rain	85
		1	156	214	1515	1600	10	30	0-18	2678					
		2	156	214	1510	1605	20	30	18-35	2573					
43	7/14	1	10 miles		1320	1410	50	15	0-54	3323	SE	1	1	clear	85
		2	NE off		1445	1450	50	32	0-48	4818					
		3	Fresh Creek		1445	540	100	32	48-95	5402					
45	7/16		High Cay	Light House							ESE	rough	2	clear	30
		1	160	250	1030	1130	25	30	0-46	5911					
					1030	1130	50	30	46-88	6230					

Sta.	Date	Sample No.	Bearings High Cay	Bearings Light House	Time out	Time in	Wire out fath.	Wire angle	Corr. depth met.	Revolution sampler meter	Wind	Sea	Swell	Weather	Clouds
46	7/17										SE mod.	mod.	1	clear	--
		1	159	260	946	1045	10	30	0-18	6279					
		2			946	1045	21	30	18-36	5421					
		3			1118	1220	30	20	38-57	3709					
		4			1118	1220	40	20	57-79	3259					
47	7/17										SE mod.	mod.	-	clear	--
		1	171	239	1600	1700	10	30	0-18	4149					
		2			1600	1700	20	30	18-36	3859					
		3			1720	1815	30	30	36-53	3122					

Fig. 1

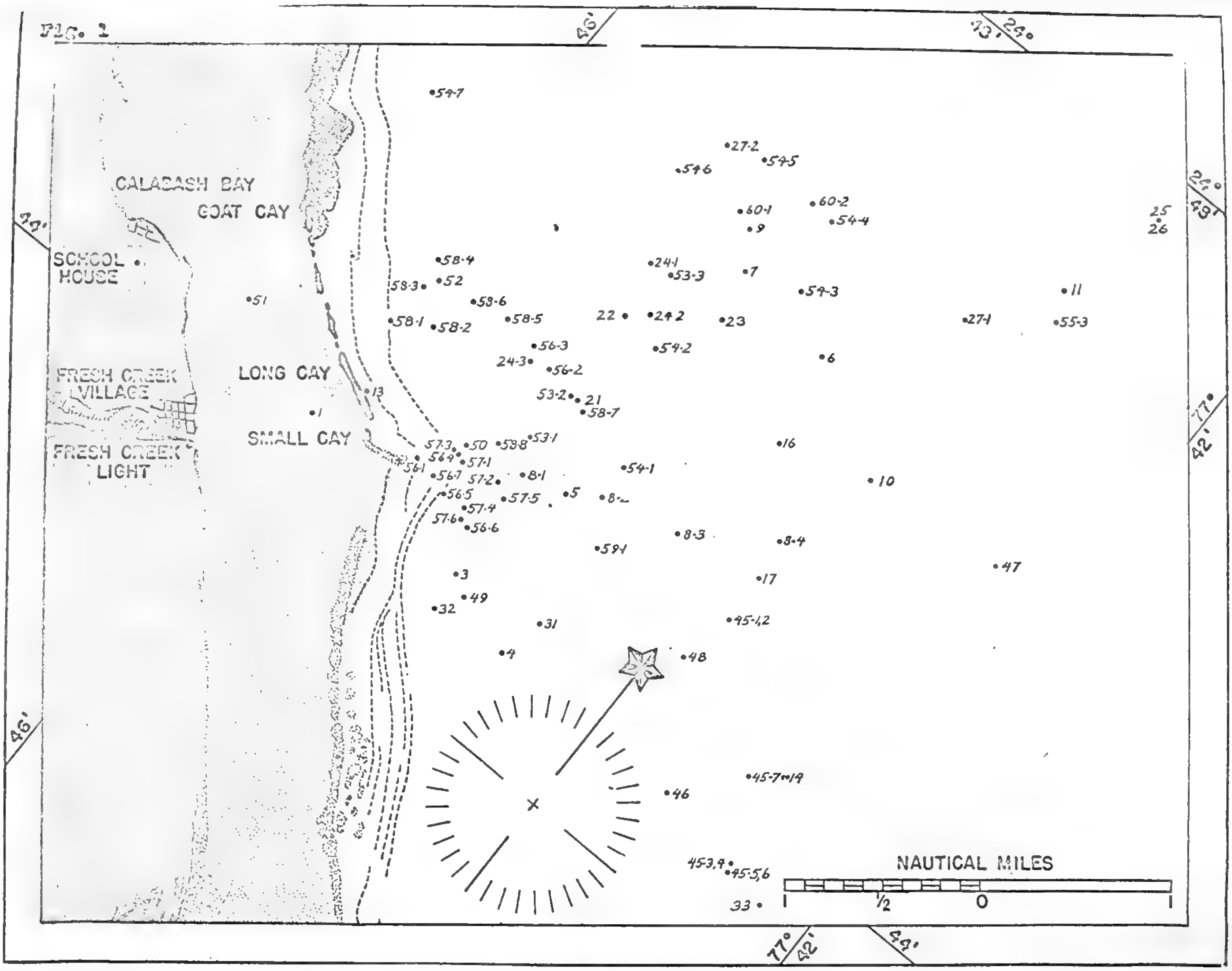
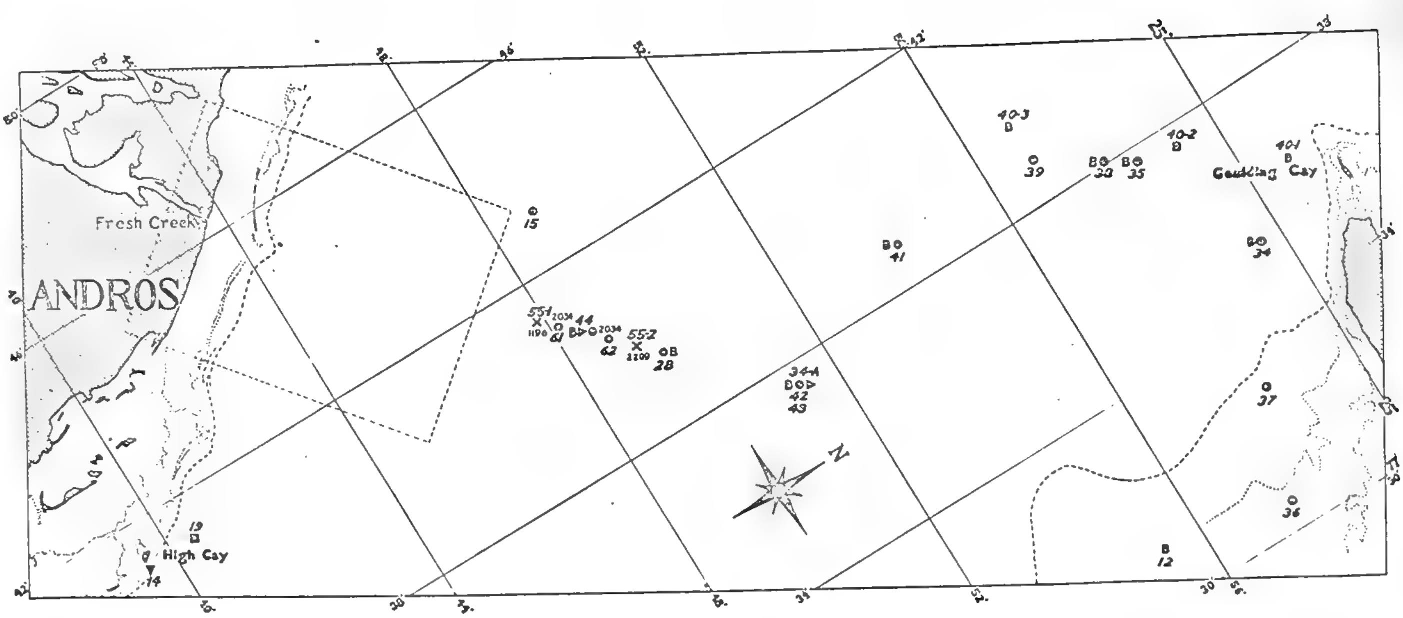


Fig. 2 Location of stations not on fig. 1

Plankton; ☐ Dredge; B Bathythermograph; • Hydrographic station;

Deep-sea camera; ○ Core; Small number - sounding in meters.



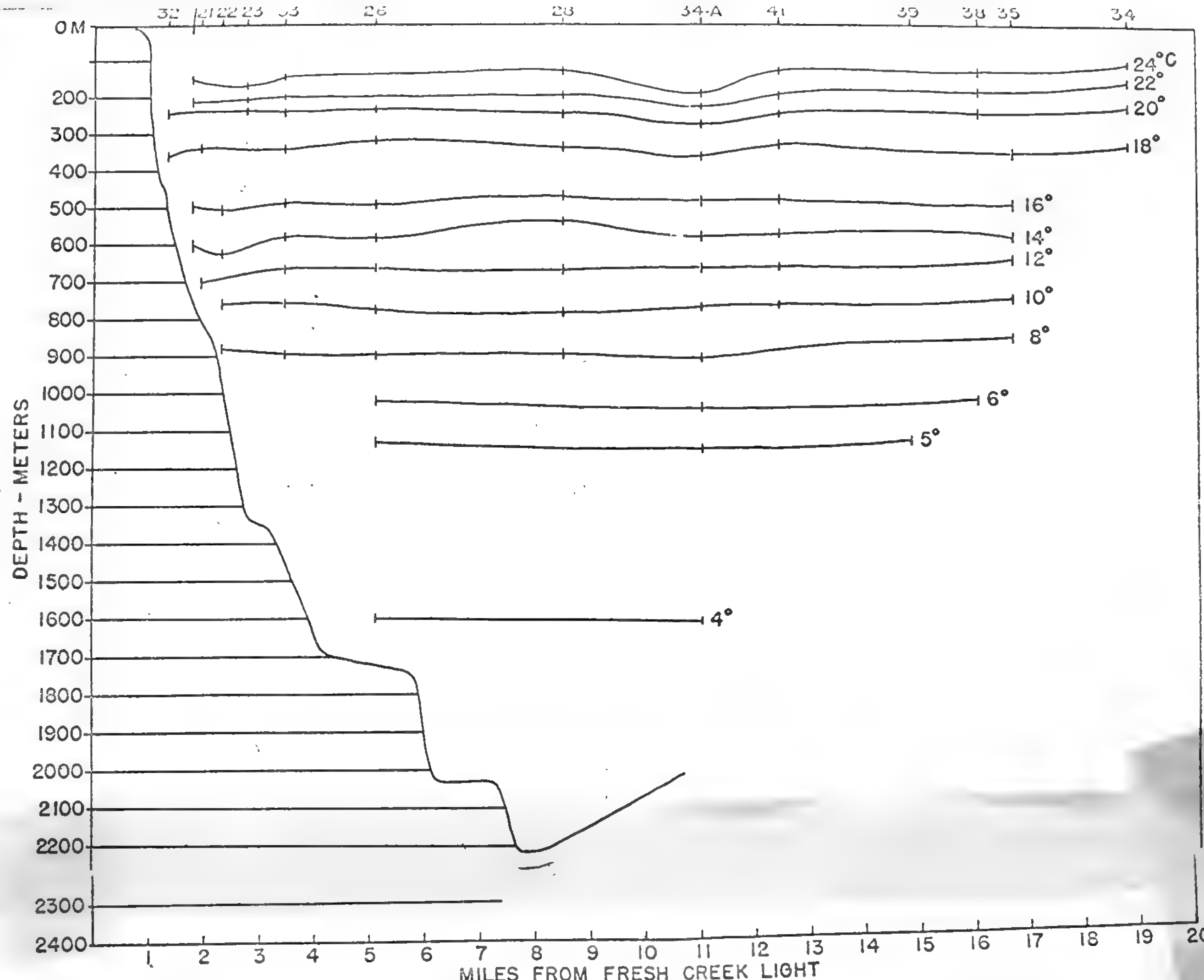

DEPTH - METERS
MILES FROM FRESH CREEK LIGHT
24°C
4°

FIG. 4

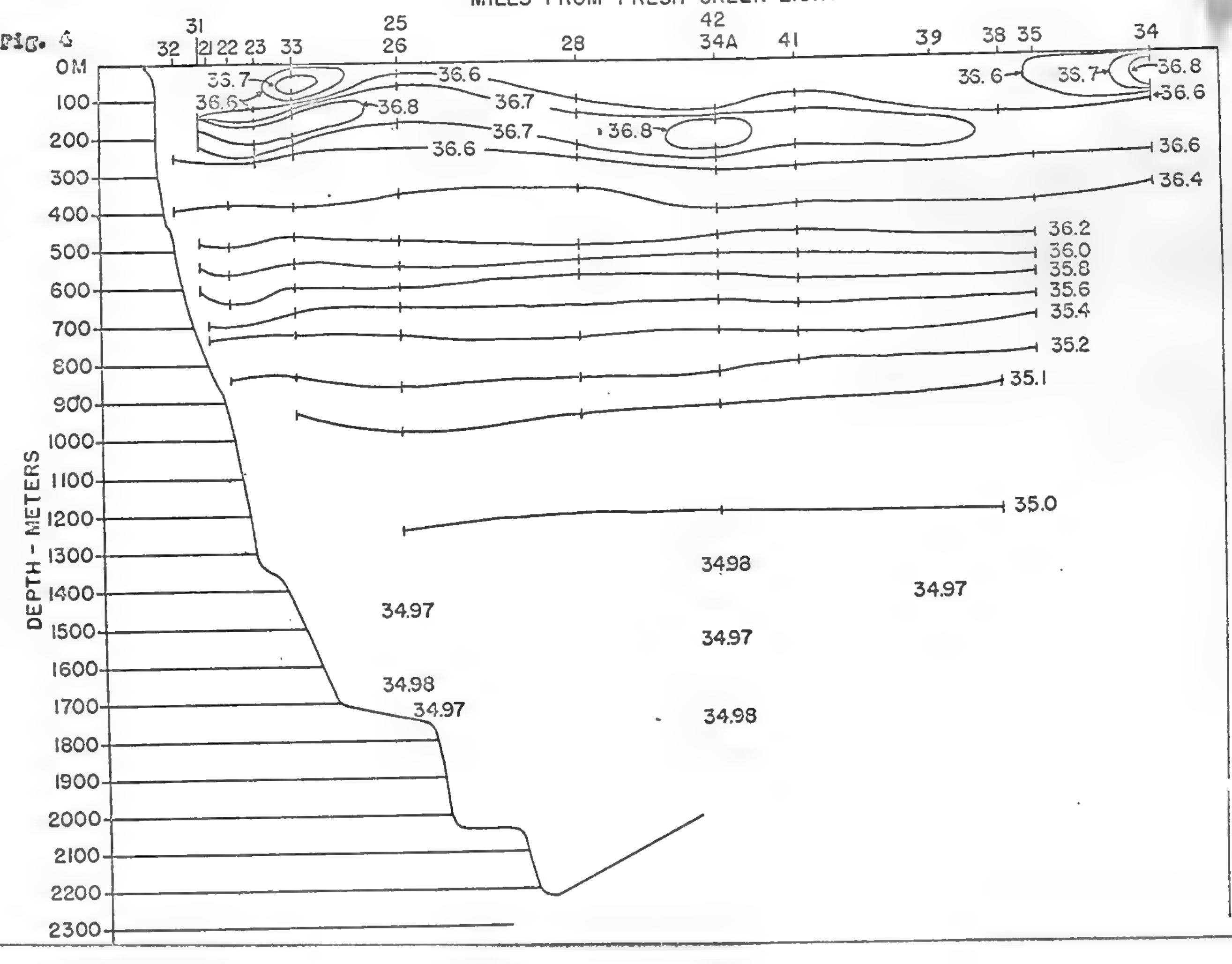

DEPTH - METERS
36.8
35.0
34.97
34.98

Fig. 5

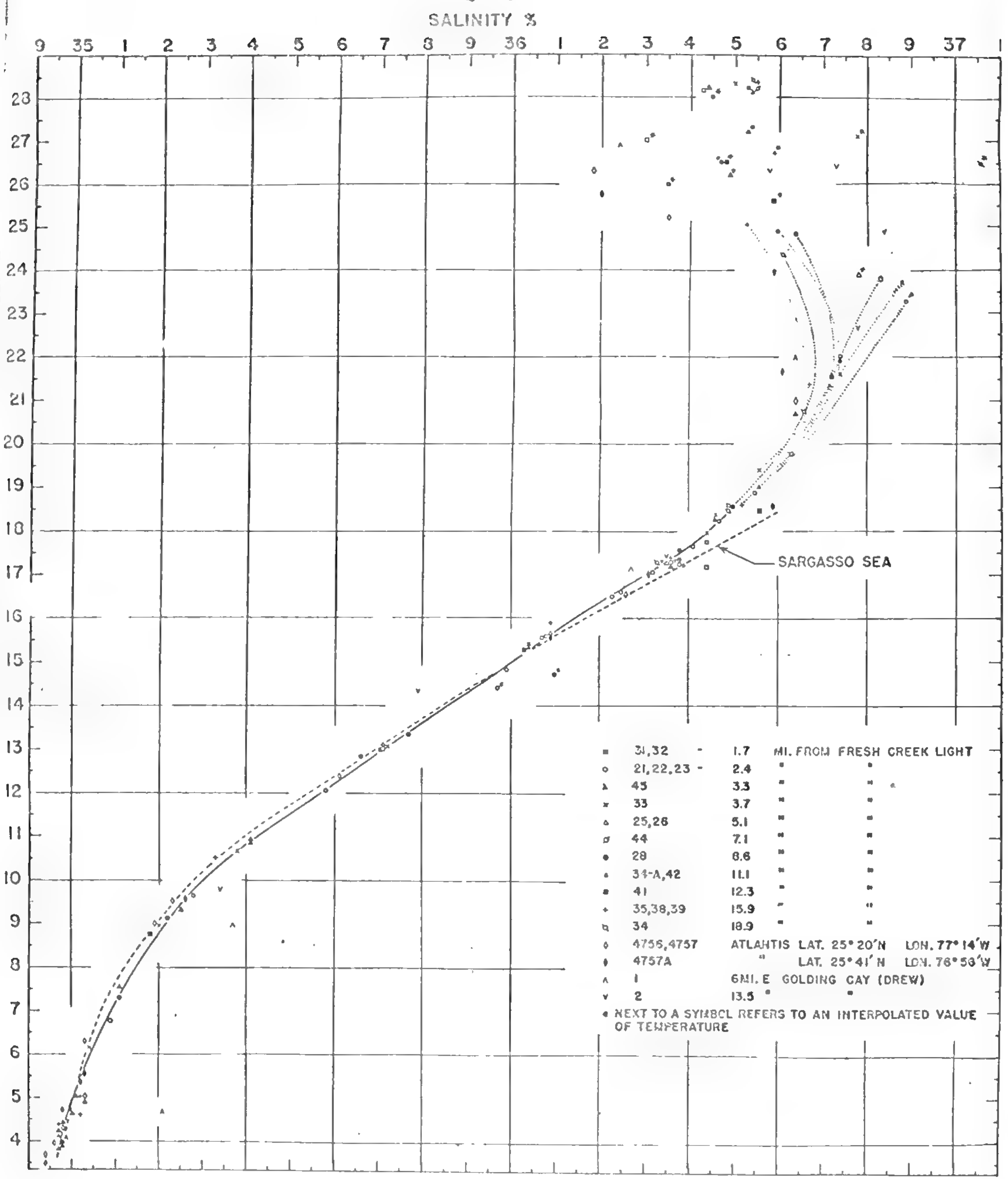


Fig. 6

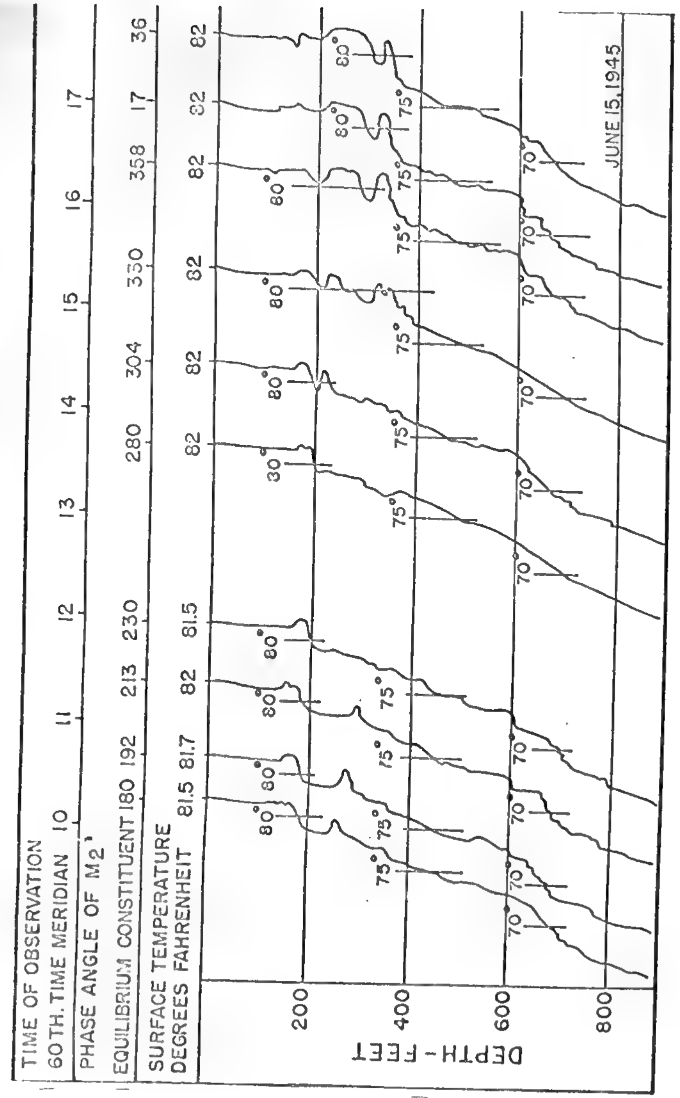
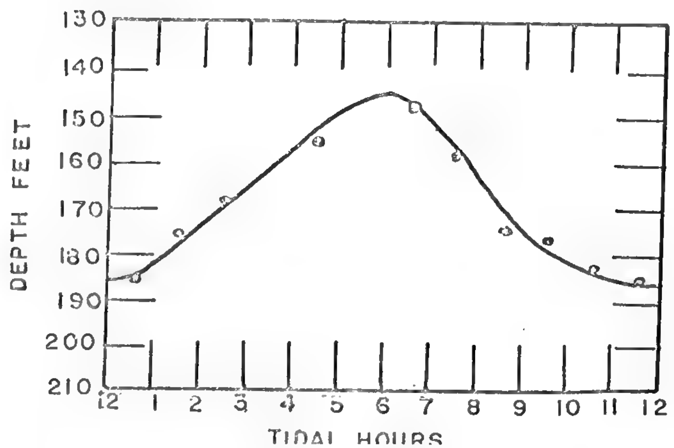
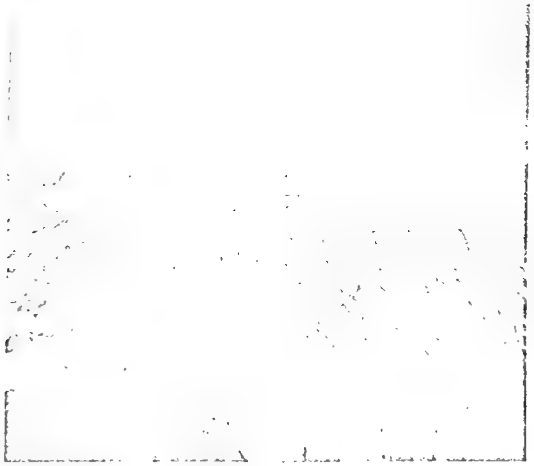
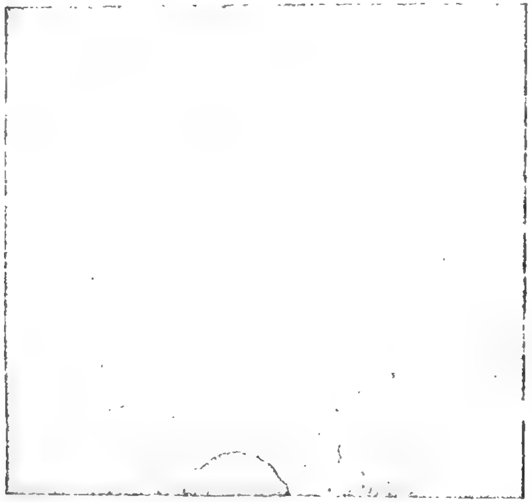
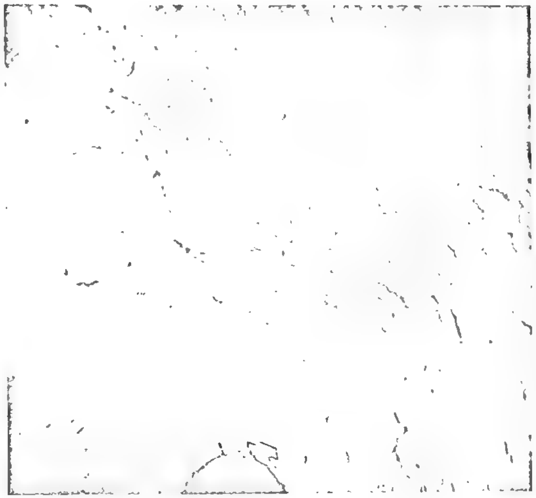
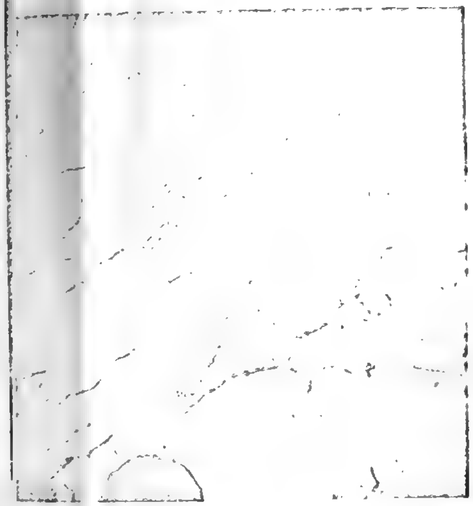


Fig. 7





Figs. 9,10,11

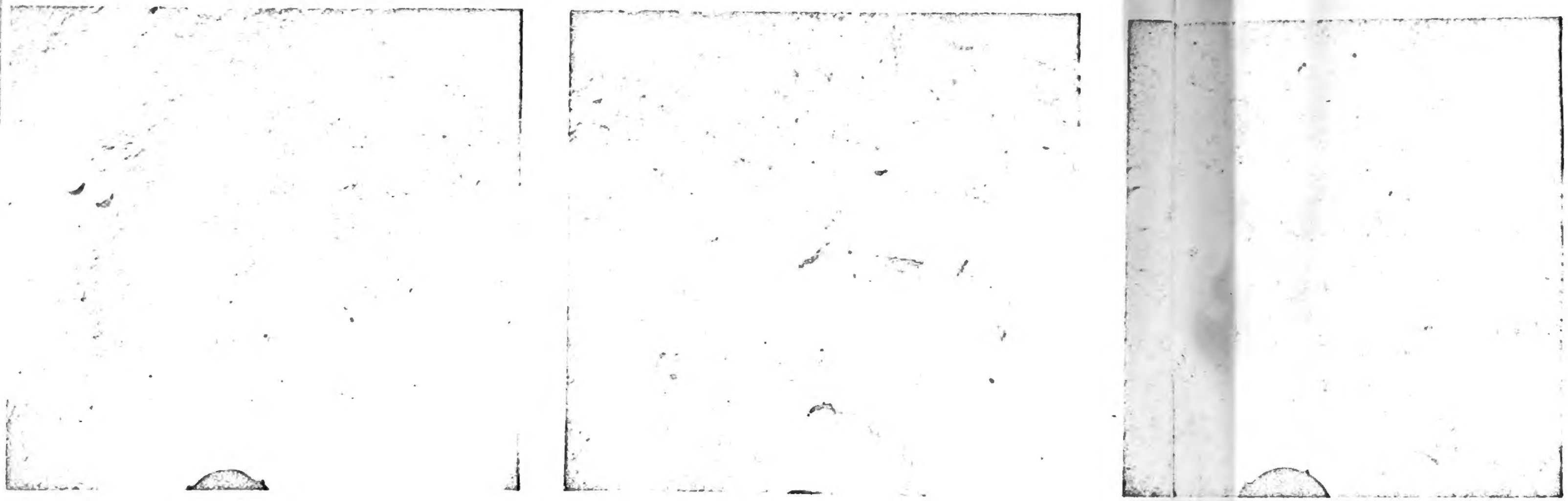




Figs. 12,13,14

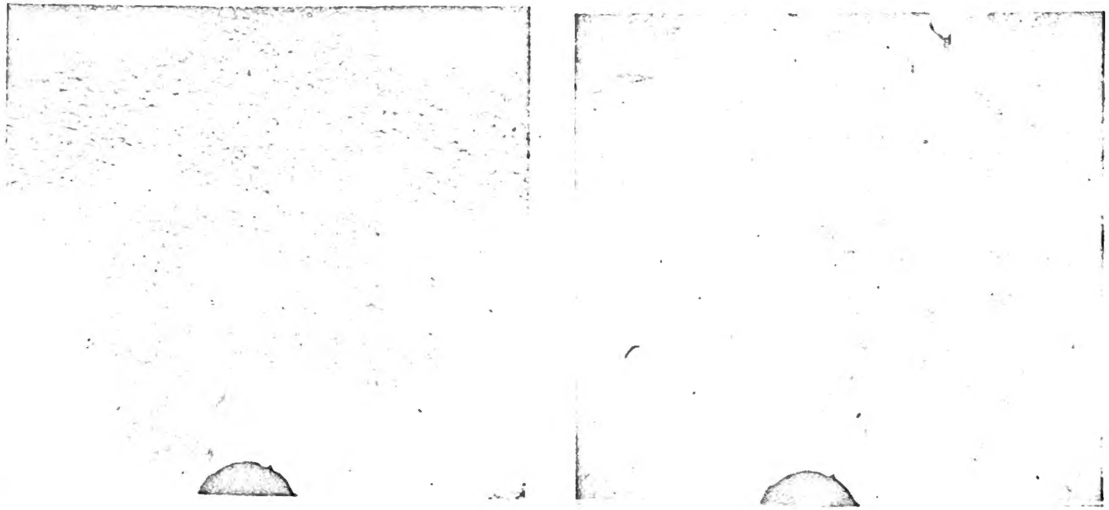


Figs. 15,16,17

Figs, 18,19,20



Figs. 21,22,23



Figs. 24,25