Red Tide

Ecological Observations on a Locally Limited Red Tide Bloom

1955

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ECOLOGICAL OBSERVATIONS ON A LOCALLY LIMITED RED TIDE BLOOM[1]

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ABSTRACT

In order to study the assumed importance of the passes in generating Red Tide outbreaks, the hydrographical tidal conditions were studied in the Boca Grande Pass. The results confirmed previous ones and indicated the two-layer character of this estuary. In the deeper water no *Gymnodinium brevis* was found. The heavier concentration was observed during all tidal phases on the side of Gasparilla Island, suggesting that they must have originated somewhere "behind Gasparilla Island" and not in the area of the highest total phosphorus. As a second, simultaneous part of the study, an effort was made to find the areas from which the *G. brevis* in this case originated. In two separate spots (Stations 12 and 20) actual, locally limited Red Tide kills were observed. An optimum salinity for the *G. brevis* appeared to exist between 32 and 33 parts per thousand. A diurnal vertical migration of *G. brevis* was observed.

INTRODUCTION

The research vessel, M/V PHYSALIA, carried out hydrographic and other Red Tide investigations off the west coast of Florida in November and December 1954. From these studies several independent results have come out. This report is a preliminary one on a special study made during the above period.

In the Preliminary Report (54-19) on the Red Tide studies from January to June 1954, submitted by the Marine Laboratory to the Florida State Board of Conservation, it was stated on the basis of previous observations that. (page 14) "the initial outbreak is usually observed as dying fish in the passes. Since the net flow in the passes is outwards, it is most probable that the origin of Red Tide must be inside the barrier islands . . . The most important passes, as to the first observation of Red Tide, seem to be Boca Grande Pass, Captiva Pass, and Gasparilla Pass."

In order to study the presumed importance of the passes in the origin of the Red Tide, an importance doubted by some Red Tide workers, attention was first given to hydrographic tidal conditions in the Boca Grande Pass itself. The main goal of this part of the study was to find out in which type of water the heaviest concentration of

[1] Contribution No. 152 from the Marine Laboratory, University of Miami.

Gymnodinium brevis was to be found. A second simultaneous study was made to find the areas from which *G. brevis* immediately originated.

This study was made possible by the fortunate occurrence of a locally limited Red Tide bloom in the area concerned. Thus it was possible to perform observations under the actual conditions of an initial Red Tide outbreak.

I. Hydrographic Conditions in the Boca Grande Pass in Relation to *Gymnodinium brevis*

Observations. The stations A-G (Figure 1) were occupied three times on December 1, 1954, once during the maximum ebb, once during the slack after ebb, and once during maximum flood. The location of the stations was the following:

A: 26° 42′ 32″ N., 82° 15′ 27″ W.
B: 26° 42′ 38″ N., 82° 15′ 33″ W.
C: 26° 42′ 54″ N., 82° 15′ 39″ W.
D: 26° 42′ 38″ N., 82° 14′ 50″ W.
E: 26° 42′ 58″ N., 82° 15′ 03″ W.
F: 26° 43′ 19″ N., 82° 15′ 15″ W.
G: 26° 43′ 39″ N., 82° 15′ 27″ W.

Observations, during the maximum ebb, were performed between 0730 and 0940, during the slack after ebb between 1215 and 1317, and during maximum flood between 1700 and 1812. The darkness and the shallow water made it impossible to occupy station G for a third time.

The day of observation was almost cloudless with less than 1/10 of the sky, above the land, covered with cumulus clouds during the noon hours, which later flattened into altocumulus and finally disappeared after sunset. When the observations were started at 0730, the air (65.0° F) was 3.6° F cooler than the sea surface (68.6° F). At 0945 both showed the same temperature, 68.3° F. At 1317 it was observed that the air (73.6° F) was 3.8° F warmer than the sea surface (69.8° F), while around the time of sunset, about 1800, both showed the same temperature, 69.5° F. During the morning hours the winds were from 30° to 60°, 8-10 knots, during the noon hours they were from 30° to 35°, 3-4 knots and during the later afternoon hours from 300° to 310°, increasing from 9 to 13 knots. Thus the wind observations mainly indicated the effect of land and sea breeze. The sea was, during the morning and noon hours, practic-

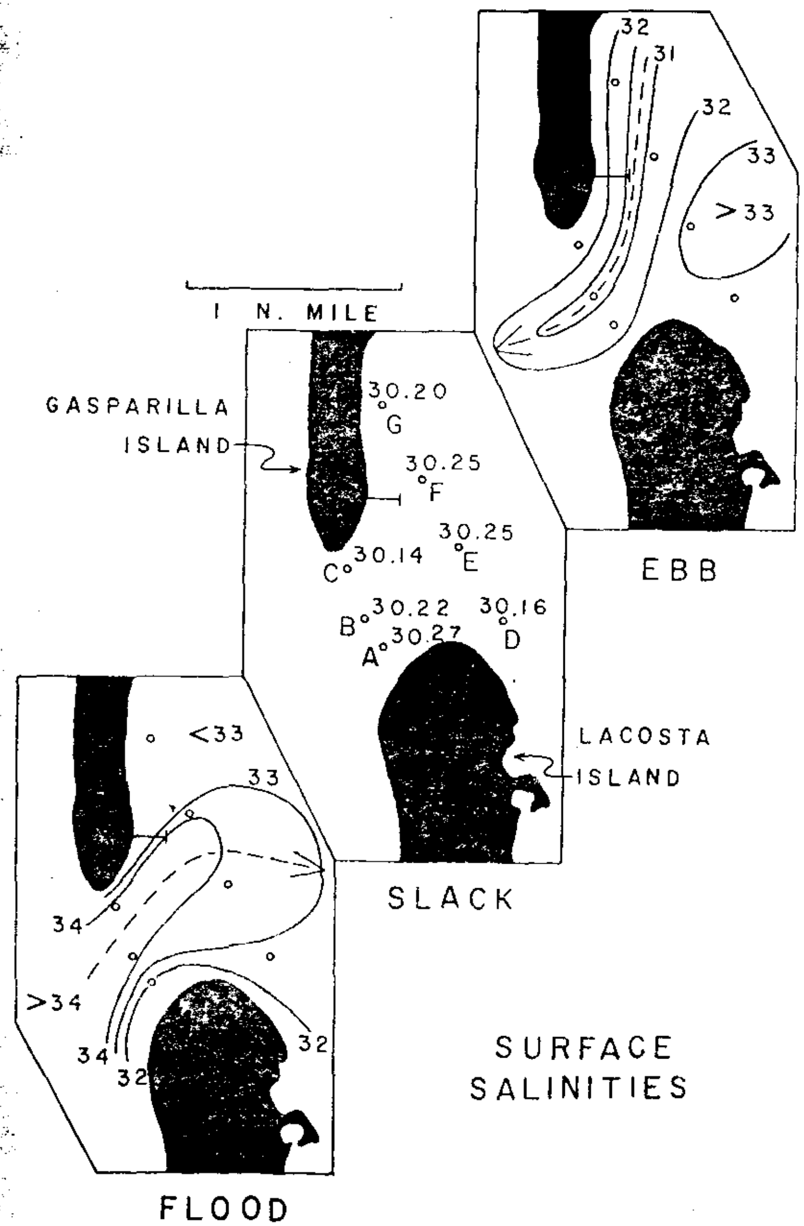


FIGURE 1. Surface salinities around Boca Grande Pass during maximum ebb, during slack after ebb, and during maximum flood.

ally smooth (0-1) but during the later afternoon hours slight wave action (1) was observed. Hence conditions were ideal for the study.

The main sections between stations A and C consisted of the following observations:

- *Gymnodinium brevis* count; surface and bottom (Figure 11).
- Salinities, surface and bottom, also mid-depth at Station C (Figure 2).
- Surface temperatures (Figure 3).
- Vertical distribution of temperature, by bathythermograph (Figure 3).
- Densities, computed from the salinities and temperatures for the depths with salinity observations (Figure 4).
- Vertical distribution of current speeds, measured by means of the Von Arx current meter, for several depths (Figure 8).
- Total phosphorus, surface and bottom (Figure 9).
- NO_3-N, surface only (Figure 10).
- NO_2-N, surface only.
- P_H, surface only.
- Wind, direction and speed.
- Air temperature.
- Wet bulb temperature.
- Cloudiness, type and cover.
- Visibility.
- Sea.

The auxiliary sections, between stations D and G, consisted of the following observations:

- Salinities, surface and bottom (Figure 5).
- Surface temperatures (Figure 6).
- Vertical distribution of temperature, by bathythermograph (Figure 6).
- Densities, computed from the salinities and temperatures for the depths with salinity observations (Figure 7).
- Wind, direction and speed.
- Air temperature.
- Wet bulb temperature.
- Cloudiness, type and cover.
- Visibility.
- Sea.

The limited time available for observations made additional observations impossible. For the same reason it was necessary to limit

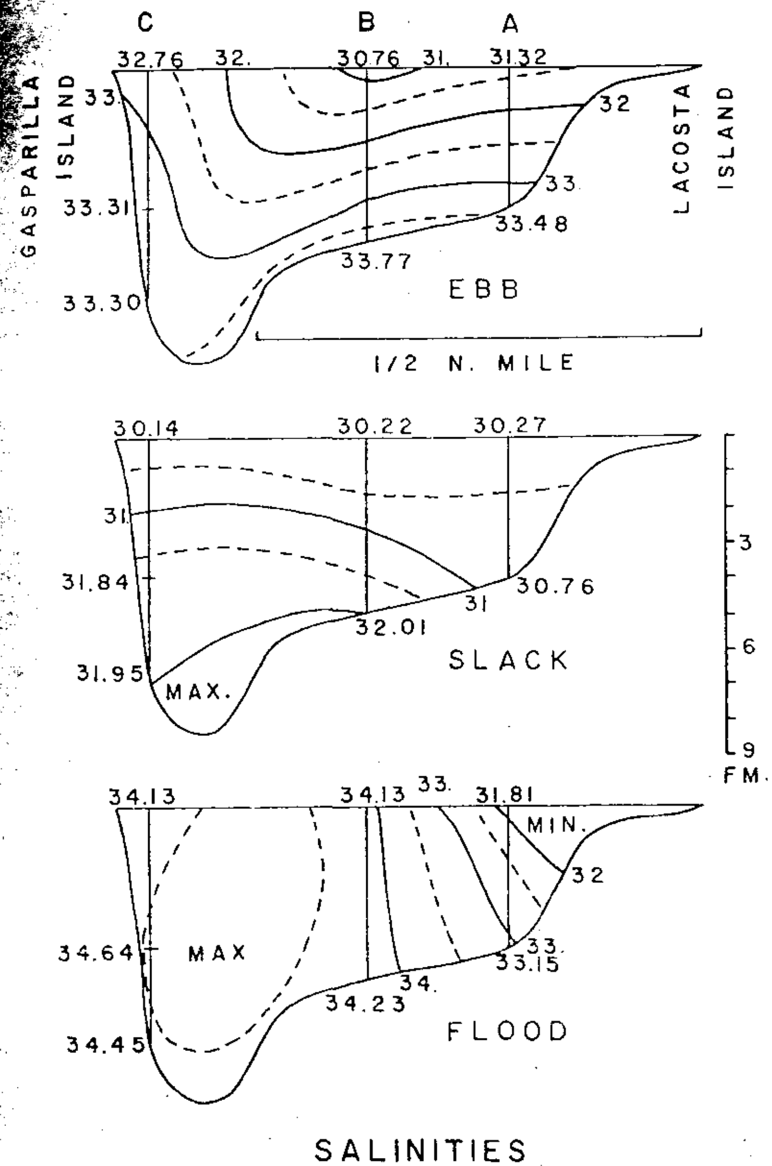


FIGURE 2. Transverse salinity sections across Boca Grande Pass.

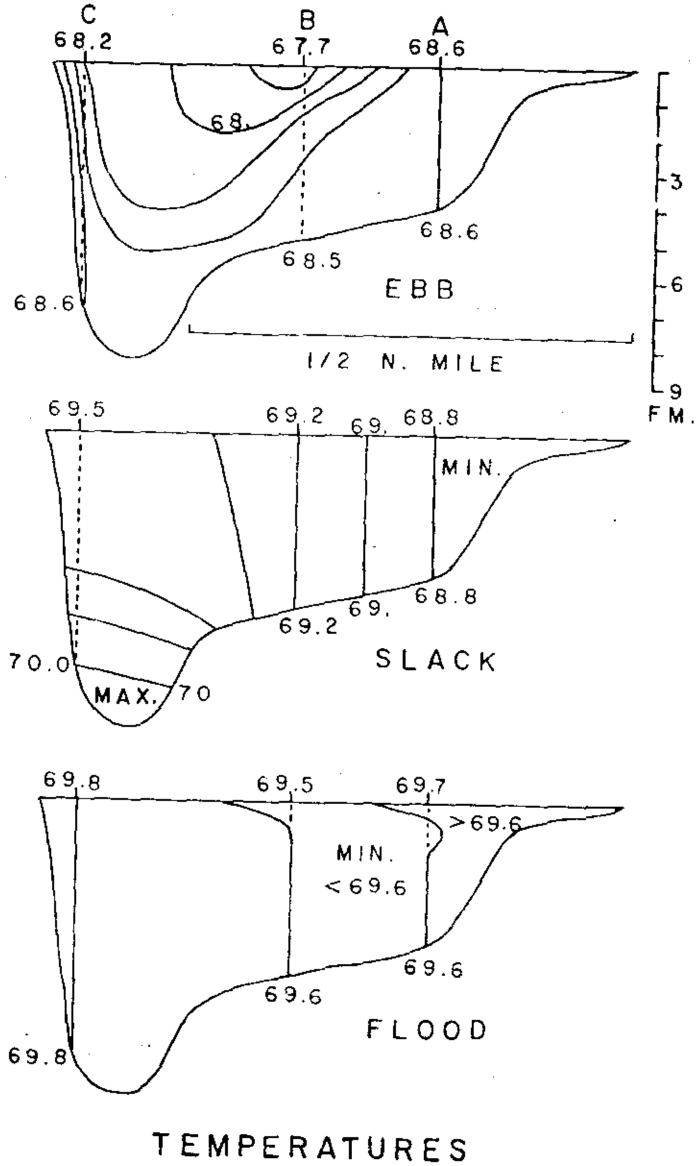
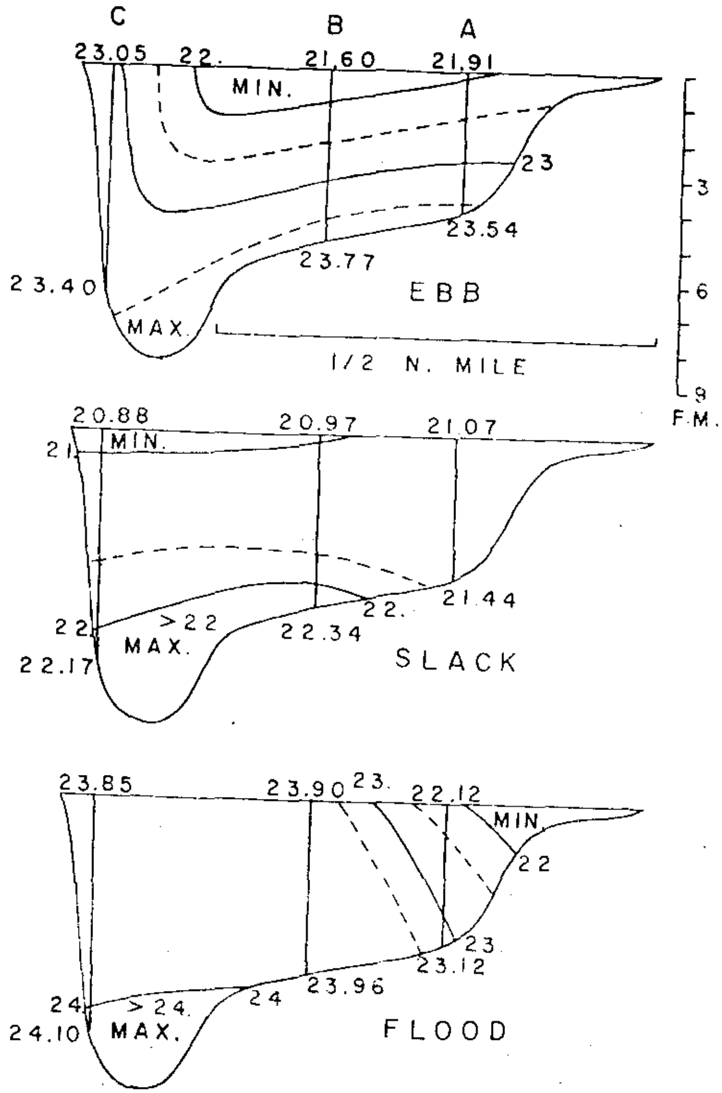


FIGURE 3. Transverse temperature sections across Boca Grande Pass.

the number of stations of the main section, A-C, to three. Later when plotting the different sections, it became evident that four stations with more depths would have covered the situation better than three, although it is believed that the short mean distance between stations A, B, and C, being only slightly above 300 yards, is rather unique in marine studies. Due to the limited number of stations, in some cases apparent minor inconsistencies can be observed in the patterns of representations of single elements, since sections were drawn independently and strictly following the method of interpolation. No attempt was made to adjust the different sections to each other which would easily have eliminated the apparent inconsistencies.

Hydrographic (Tidal) Conditions. In connection with another study of this author (The Marine Laboratory, 1954) performed on the tidal influences on the hydrography of the Boca Grande Channel, it was shown that in the whole Channel the salinities are practically always lower at the surface than at the bottom, which indicates that a strong hydrographic influence of the two-layer estuary must have extended at least some four miles off the Pass. The salinity sections between the Gasparilla and Lacosta Islands (Figure 2) show the same quite clearly for the ebb tide. However, at the maximum flood, the two-layer character of the Pass is almost destroyed by the flood waters which fill a good portion of the Pass. The same is roughly seen also from the temperature sections (Figure 3) which are, however, partly masked by the diurnal heating and cooling effects. Finally, the density sections (Figure 4) mainly verify the greater significance of salinity compared to temperature. In particular, it is seen clearly that the ebbing, less dense water is imbedded between more saline waters along the shorelines.

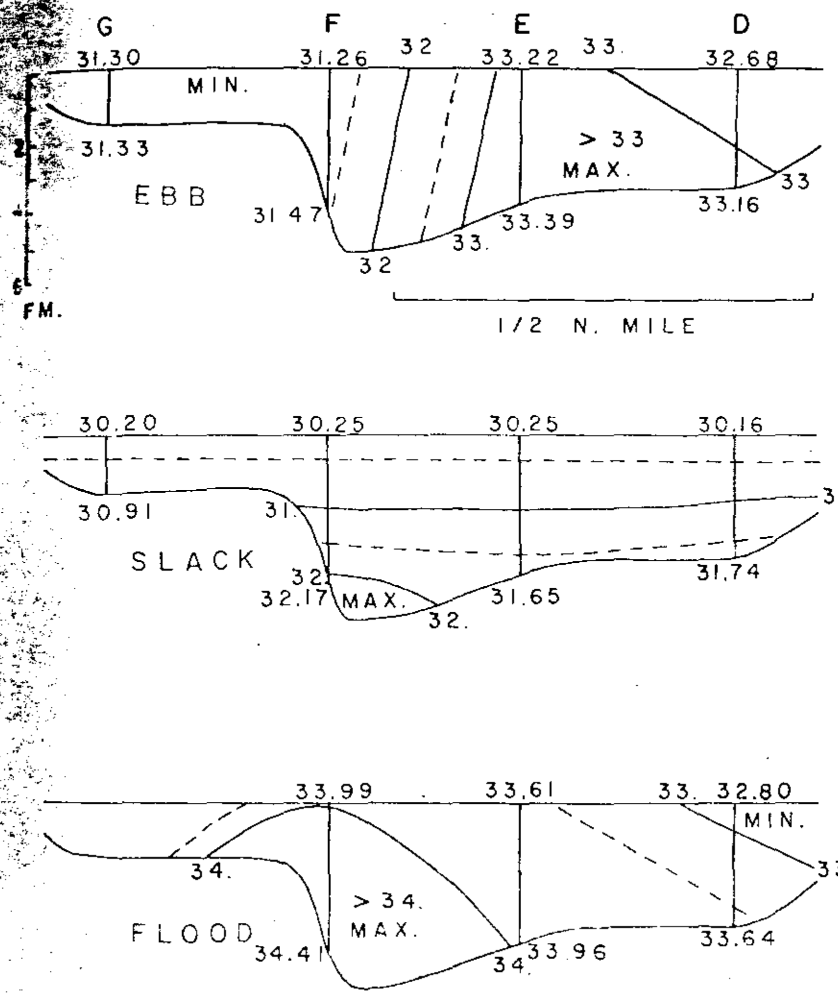
The auxiliary sections D-G, inside the Boca Grande Pass (Figures 5, 6, and 7), show corresponding conditions. The surface salinities are shown also as Figure 1, which clearly shows how the ebbing waters are in this case originated east of the Gasparilla Island and not directly east of the Pass. After having left the Pass, the ebbing waters take a westerly direction following the course of the Boca Grande Channel, but the flooding waters probably come from the region south of the Pass. These waters after having penetrated the Pass, follow an easterly or, possibly, an eastsoutheasterly course. Thus this mechanism indicates how the coastal water patches may be formed in the narrow pass by the flood current completely cutting off each ebbing water movement.



σ_T

FIGURE 4. Transverse density (σt) sections across Boca Grande Pass.

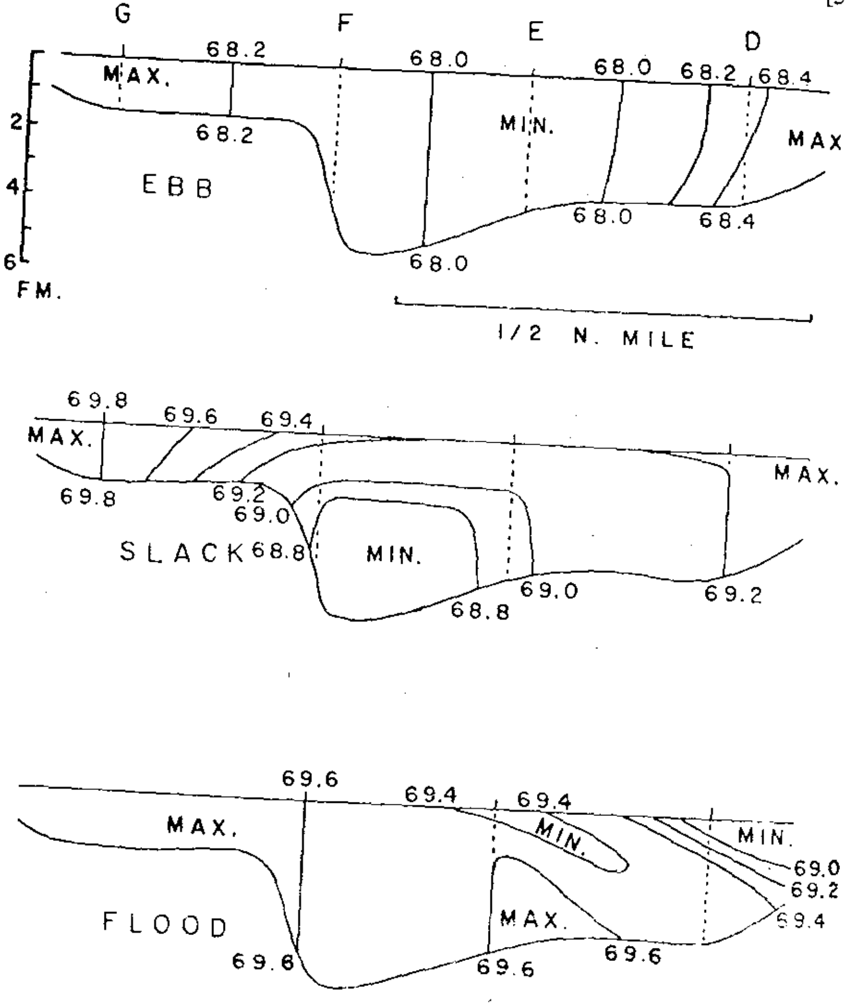
The current observations (Figure 8) show that the ebb current actually takes a path rather close to the northern edge of the Boca



SALINITIES

FIGURE 5. Transverse salinity sections inside Boca Grande Pass.

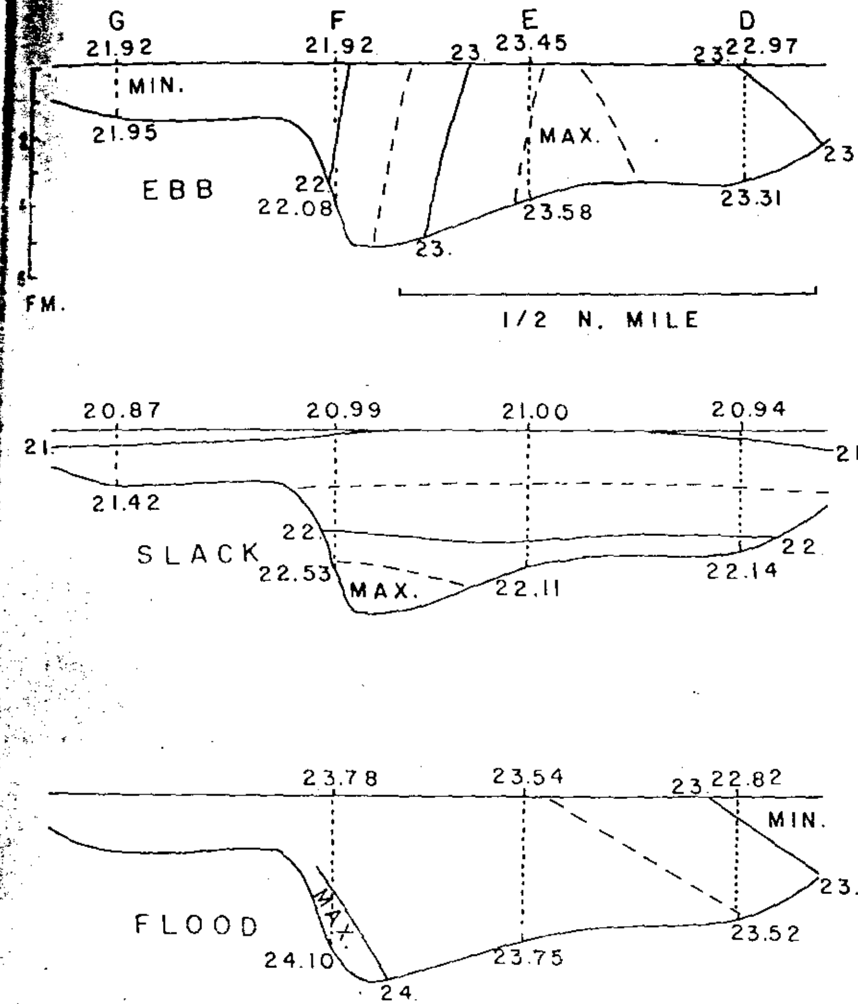
Grande Pass, while the flood current stays in the middle portion of the Pass. The current measurements were made by means of a Von Arx current meter which gives only the speeds (in knots) but not direction. In the rather shallow Boca Grande Pass the direction



TEMPERATURES

FIGURE 6. Transverse temperature sections inside Boca Grande Pass.

of current is apparently always determined mainly by the topography of the Pass, and could always be estimated from the direction of the fin. In this connection, it is necessary to observe that an additional station between B and C would have been very useful for the deter-



σ_T

FIGURE 7. Transverse density (σt) sections inside Boca Grande Pass.

mination of the northern limit of the strong flood current (Figure 8) and, similarly, of the exact location of the salinity borders of the ebb and flood currents (Figures 1 and 2). Due to this lack of the additional station, some inconsistency may be seen between the Figures

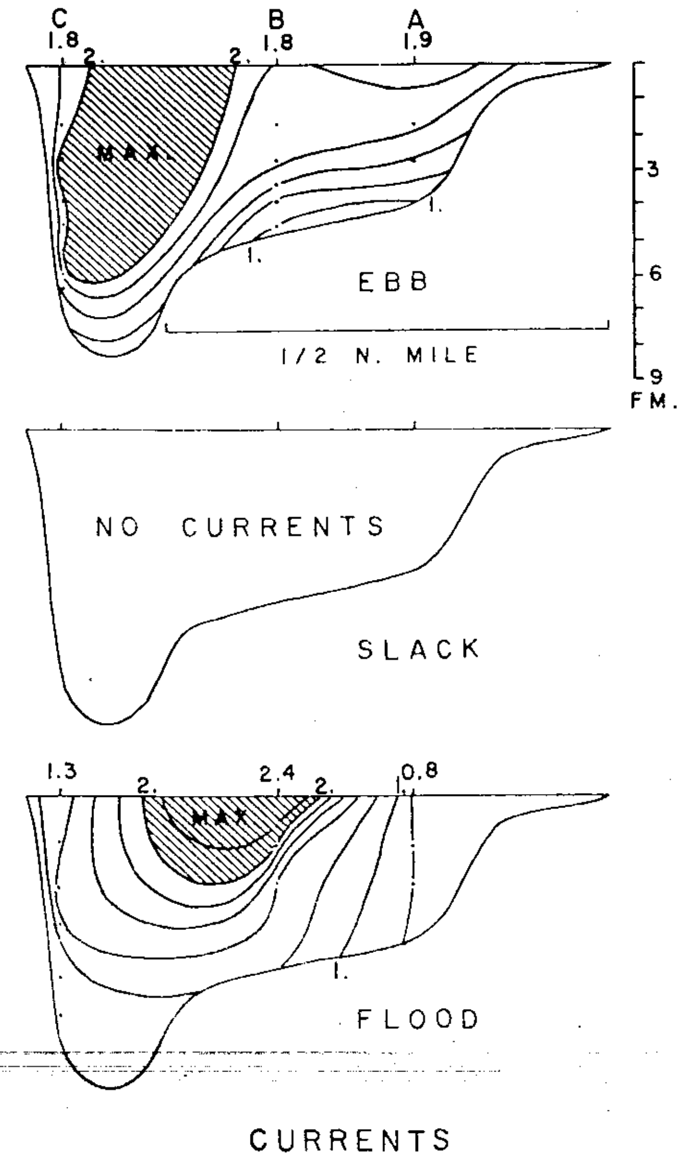


FIGURE 8. Transverse sections of current speed across Boca Grande Pass. The speeds are given in knots.

2 and 8. These apparent inconsistencies are brought about by interpolation and are most probably not real.

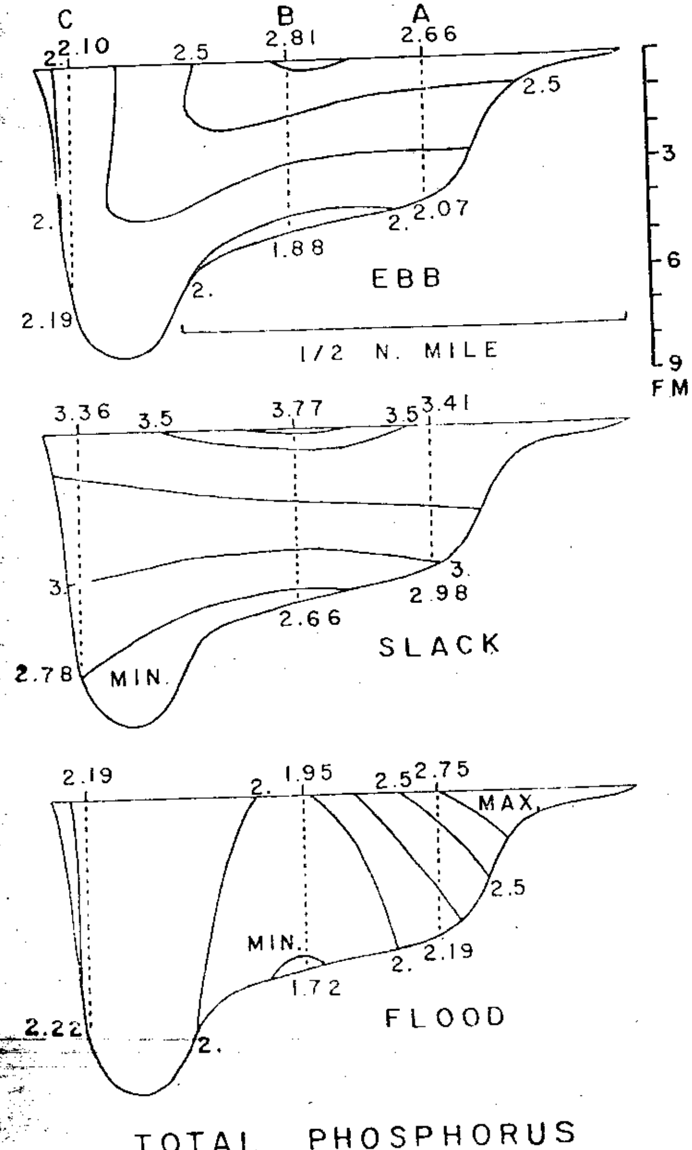


FIGURE 9. Transverse sections of total phosphorus across Boca Grande Pass. The concentrations are given in μga/L.

The distribution of total phosphorus concentration is shown as Figure 9 in μga/L. Generally it has been assumed that the total phosphorus in this area indicates the existing, or the hypothetically possible highest, concentration of *Gymnodinium brevis*. It is seen again here that the higher total phosphorus is found in the ebbing water while the lower concentrations are encountered in the flood current. However, when these distributions are compared with Figure 11, which shows the *G. brevis* concentrations (in a logarithmic scale), it becomes evident that the origin of the latter must have been somewhere "behind the Gasparilla Island" and not simply in the area of the highest total phosphorus.

Probable distributions of the NO_3-N are shown in Figure 10, which is based upon surface observations only and which seems to indicate the existence of littoral effects. The NO_2-N distribution was the following at the surface:

	A	B	C
Maximum ebb	.19	.20	.17
Slack after ebb	.18	.15	.20
Maximum flood	.18	.16	.17

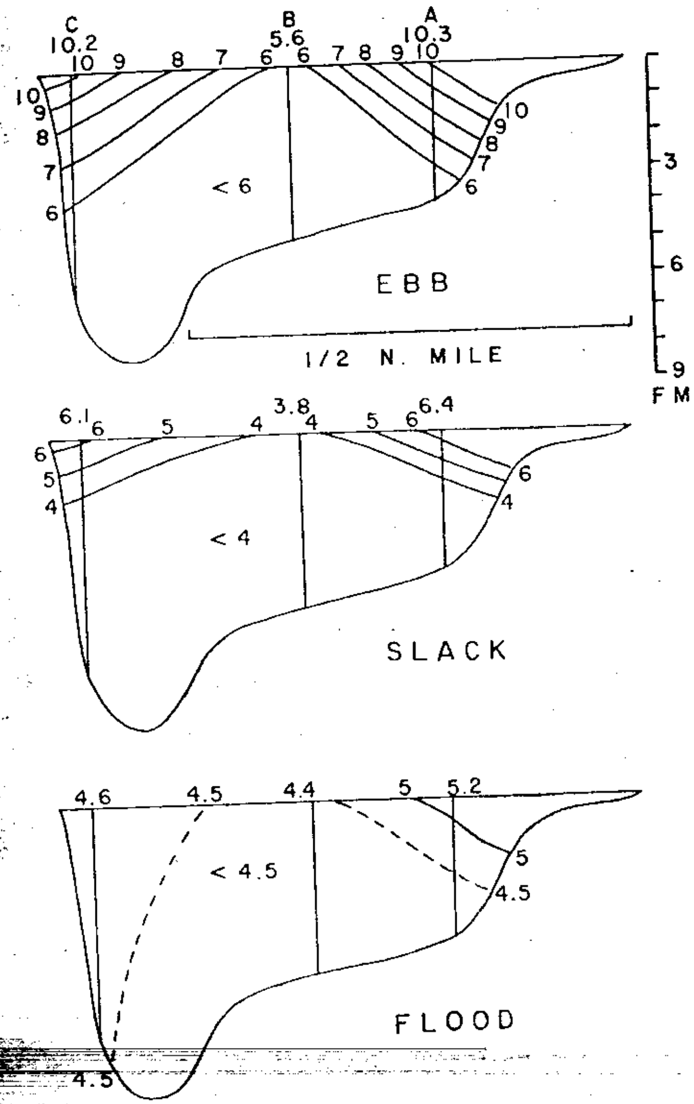
And finally the p_H varied in the following way at the surface

	A	B	C
Maximum ebb	8.4	8.4	8.4
Slack after ebb	8.3	8.3	8.3
Maximum flood	8.5	8.5	8.6

GYMNODINIUM BREVIS. The *Gymnodinium brevis* concentrations (Figure 11) are given in a logarithmic scale showing the number of individuals per liter. From the schematic drawings it can be seen (i) that in the deeper water no *G. brevis* were found during the period of observation covering one daylight day; (ii) that during all tidal phases the heavier concentration was observed adjacent to Gasparilla Island; and (iii) that at the maximum ebb current a heavy concentration was seen only at station C, but later at the slack after ebb, it also appeared at station B. The flood current again pushed the heavy concentration more or less against the southern shoreline of Gasparilla Island, station C.

II. The Origin Spots of *Gymnodinium brevis* Found in the Boca Grande Pass

Sampling for GYMNODINIUM BREVIS *around Gasparilla Island.* In addition to the surface and bottom water samples for *Gymnodinium brevis* counts, referred to above, samples were taken in a longitudinal



NO_3-N

FIGURE 10. Transverse sections of NO_3-N across Boca Grande Pass. The concentrations are given in μga/L.

section west-southwest of Boca Grande Pass (Figure 12) and in shallow areas around Gasparilla Island (Figures 13 and 14). The

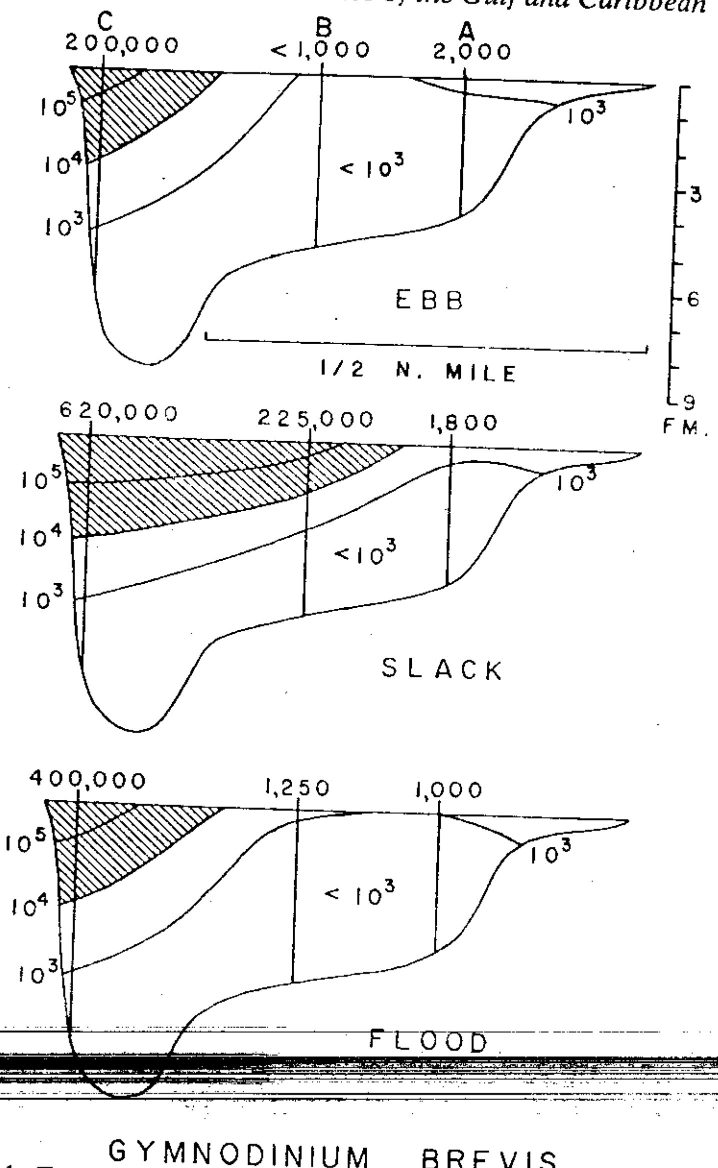


FIGURE 11. Transverse sections of *Gymnodinium brevis* concentration in Boca Grande Pass. The concentrations, in a logarithmic scale, are given as the number of cells per liter.

G. brevis counts were performed immediately after the sampling. At stations 12 and 20 actual fish kills were observed with *G. brevis*

concentration of over 10 million per liter, rather syrupy water, and with dying or dead fish. It is worthwhile mentioning that these observations, together with other facts previously reported here led to the establishment of a field laboratory on Gasparilla Island by The Marine Laboratory.

The Patchy Character of Offshore Concentration of GYMNODINIUM BREVIS. Red Tide biologists are aware of the fact that *Gymnodinium brevis* shows a patchy character in its concentration offshore. This fact was referred to in a previous report (Hela, 1955). The author also observed, in November 1954, a *G. brevis* concentration of 500,000 individuals per liter some 35 nautical miles west-southwest off Tampa Bay without any noticeable concentrations in adjacent

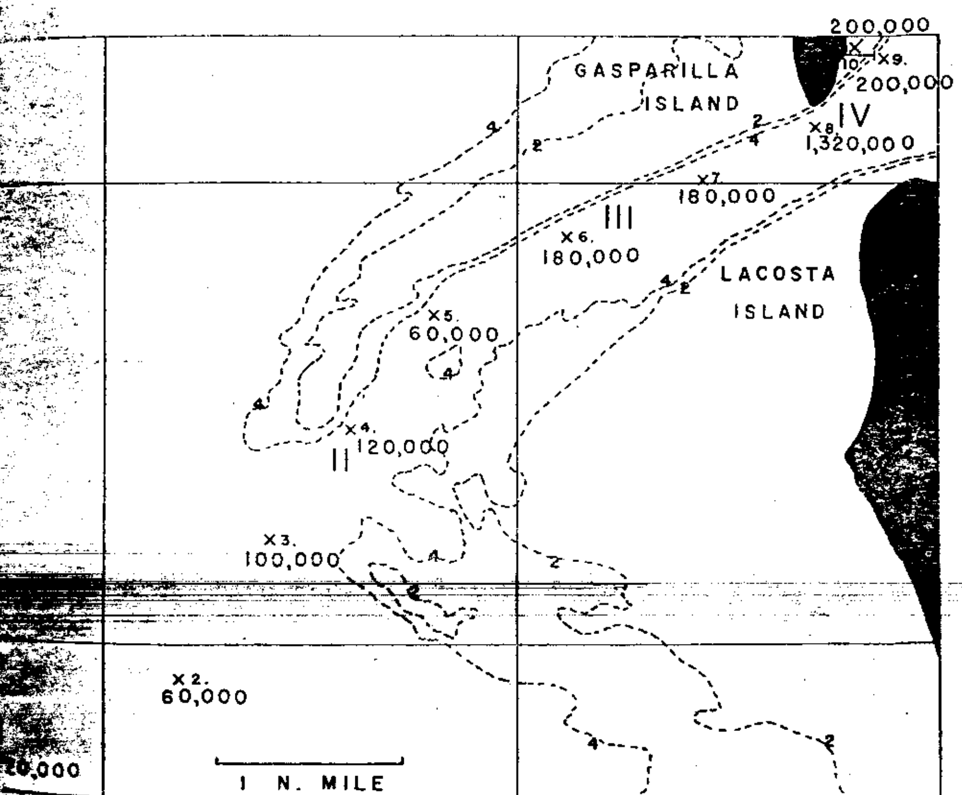


FIGURE 12. Longitudinal *Gymnodinium brevis* stations in Boca Grande Channel. The concentrations are given as the number of cells per liter.

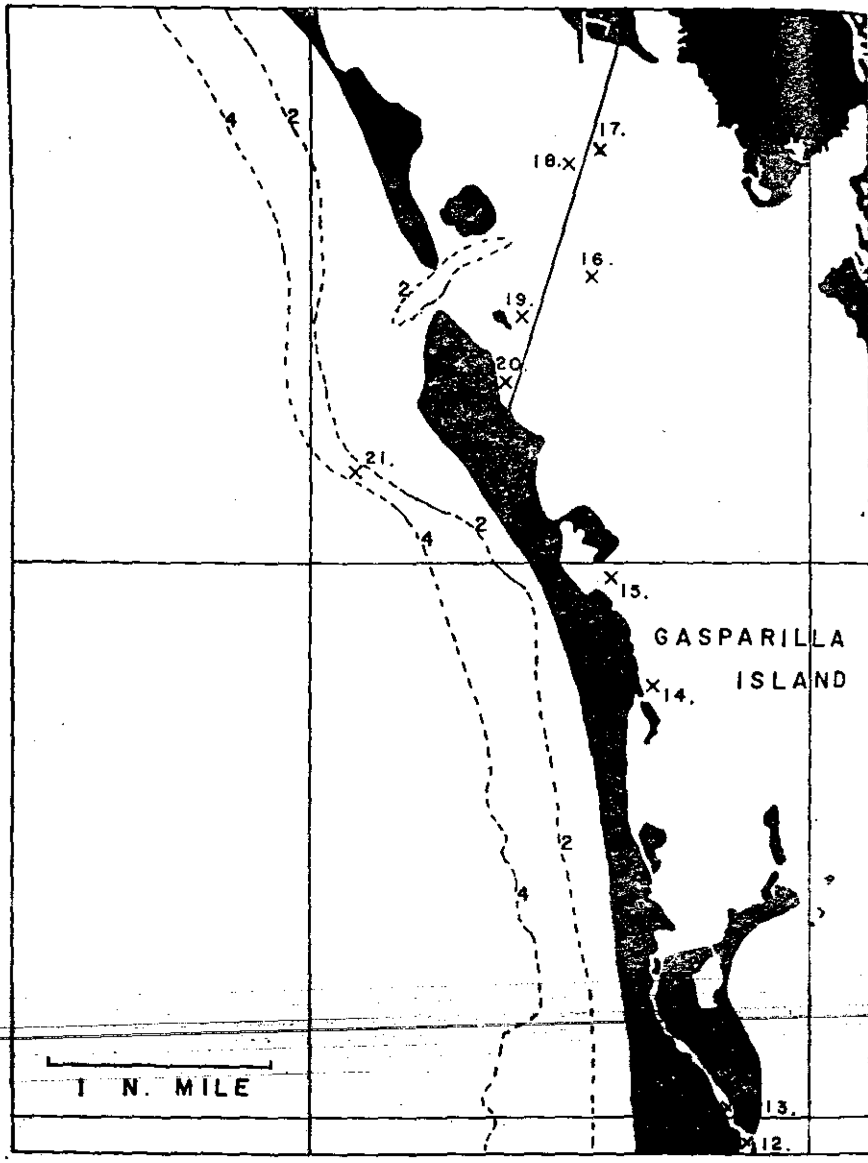


FIGURE 13. *Gymnodinium brevis* stations around Gasparilla Island.

waters. A later effort to find this high concentration, for purpose of another sampling, was not successful.

The patchy character of the offshore concentration of *G. brevis* can be understood, at least partly, when it is remembered that every ebb current takes a new patch of coastal water to the open Gulf. Also off Boca Grande Pass, as shown in Figure 12, the *G. brevis* concentration varied rather rapidly from station to station during a period of sampling of about 40 minutes. In this section, successive patches of coastal water may perhaps be indicated by *G. brevis* con-
centrations. They are shown in the Figure by the Roman letters, I-IV.

The Optimum Salinity for GYMNODINIUM BREVIS. The *Gymnodin-*
ium brevis samples taken around the Gasparilla Island with salinity
determinations make it once more possible to plot the *G. brevis* counts
against the salinity (Figure 15) in an attempt to find optimum salinity
for *G. brevis* in natural waters. It is seen rather clearly from this
logarithmic representation that maximum concentrations appear
around 32 to 33 parts per thousand. This is not necessarily an opti-
mum condition. It is at least possible, however, that the data show that
a local Red Tide bloom occurs only where all the other factors, such
as radiation, shallowness, exposure, etc., are or have been favorable
for the bloom and where the salinity is about, say, 31 to 34 parts per
thousand.

Vertical Migration of GYMNODINIUM BREVIS. In Figure 16 all the
counts on *Gymnodinium brevis* samples, taken at surface during the
period of study around the Gasparilla Island, are plotted against the
time. The location of the sampling stations can be seen from Figures
13 and 14. The schematic curve through the dots is drawn to empha-
size the possible diurnal character in the surface concentration of *G.*
brevis. It is evident that the *G. brevis* seems to leave the surface dur-
ing the night and rise during the day. It is emphasized that even the
syrupy character of the surface water at the very shallow stations 12
and 20, at which the highest *G. brevis* concentrations were found,
simply disappeared rapidly around sunset without any observable ex-
ternal cause, such as an advective water movement, other than the
disappearing daylight. Efforts have been made to connect the above
changes in the concentration also with tidal or other advective causes,
but the above changes seem to be mainly phototactic. Therefore, an-
other study is planned to observe in a suitable spot the actual vertical
migration of *G. brevis*.

That vertical migration in marine Dinoflagellates in the above

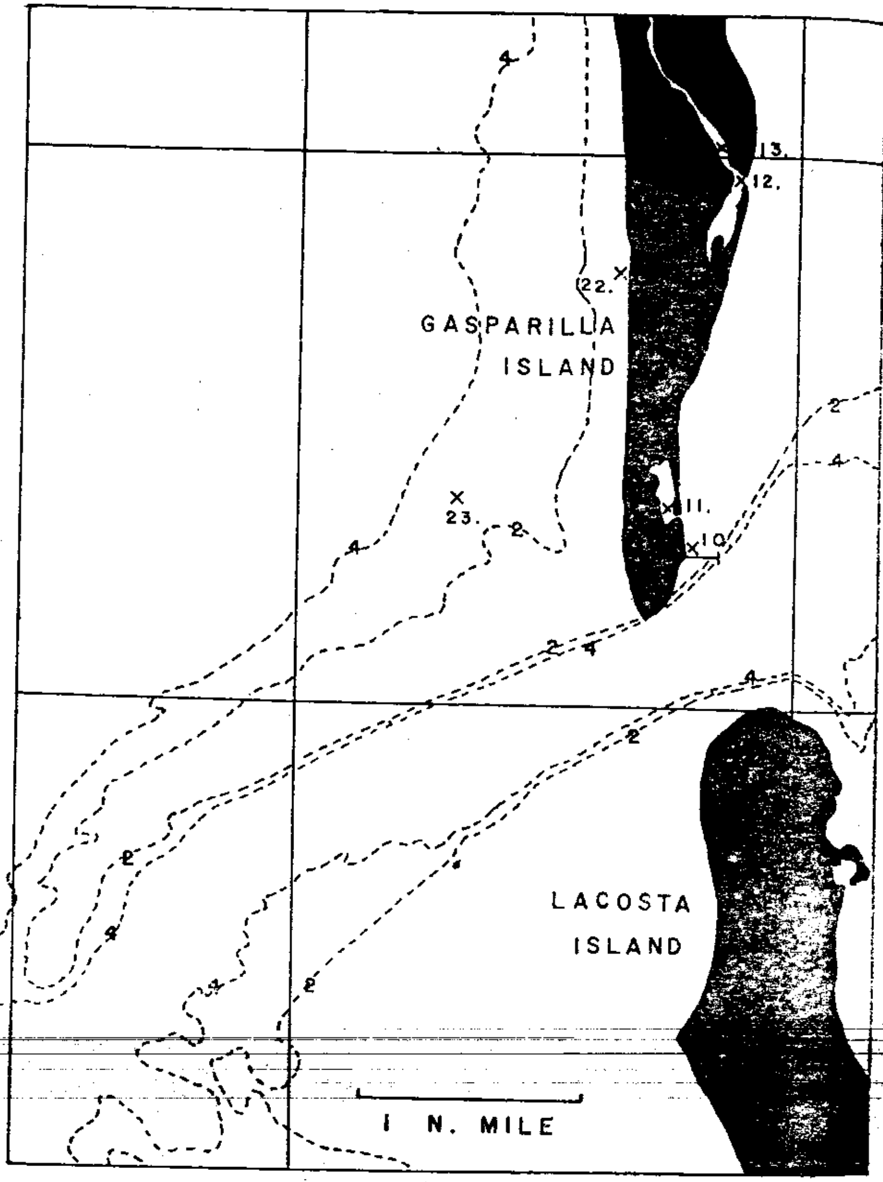


FIGURE 14. *Gymnodinium brevis* stations around Gasparilla Island.

sense is possible as shown by Hasle (1950) who studied the problem in the inner and relatively shallow Oslo fjord. "The following dino-

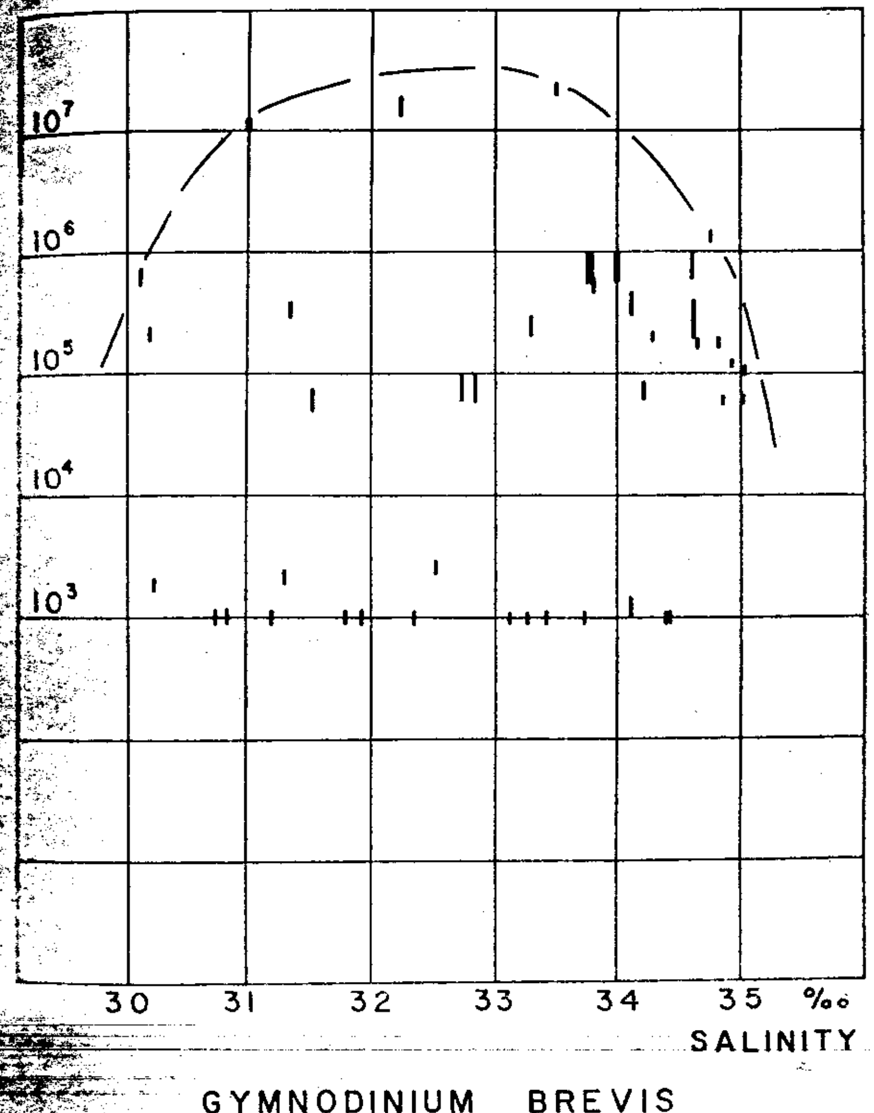
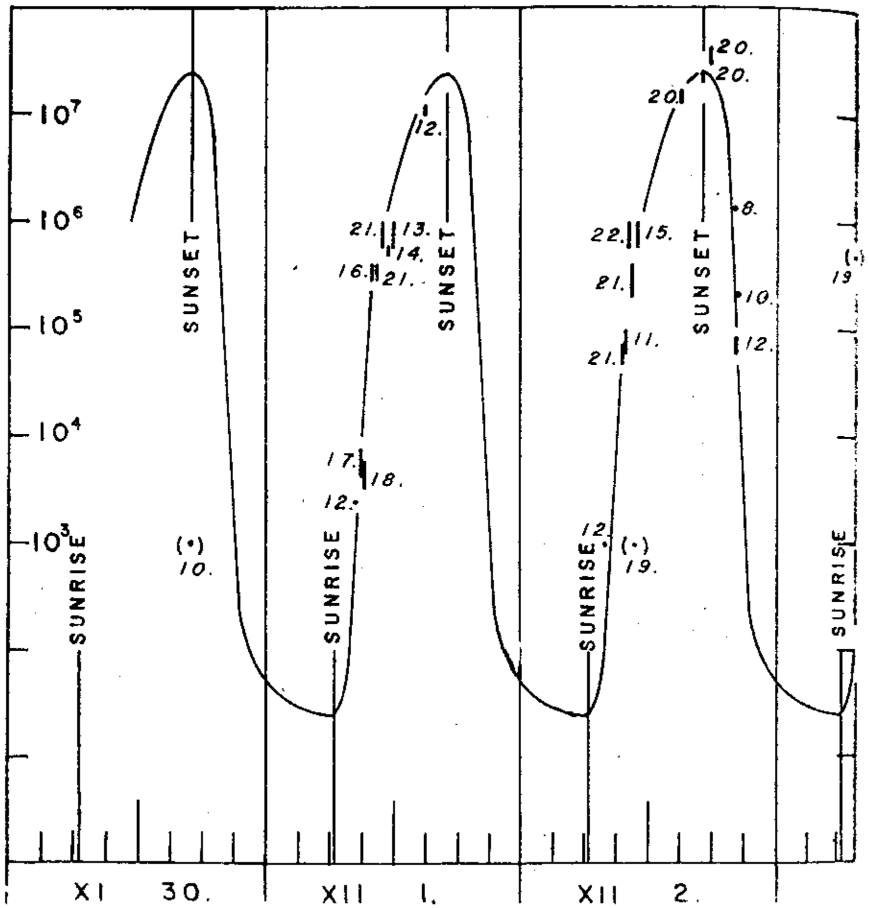


FIGURE 15. Concentrations of *Gymnodinium brevis* around Gasparilla Island plotted against salinity.

flagellates were studied: *Ceratium fusus* and *C. tripos, Gonyaulax polyedra* and *Prorocentrum micans* . . . Two distinct types are found. The two *Ceratium* species belong to one type: The population at the



GYMNODINIUM BREVIS

FIGURE 16. Concentrations of *Gymnodinium brevis* around Gasparilla Island plotted against time.

surface . . . seem to decrease as the light intensity increases, which means that the ceratia leave the surface during the day and rise at night. . . . *Gonyaulax polyedra* and *Prorocentrum micans* represent the second type. The curves for the population at the surface . . . and for the intensity of daylight follow much the same trend. These species leave the surface during the night and rise during the day. In *Prorocentrum micans* the maximum number at the surface was, however,

recorded from about 12.00 hr., while in *Gonyaulax polyedra* it occurred considerably later, between 16.00 and 18.00 hr., when maximum of daylight intensity had passed some time before."

When further studies have definitely verified the character of the vertical migration of *G. brevis,* as suggested above, the effects of radiation and of the shallowness of the sea area may be taken into consideration anew as vital ecological factors for the development of local Red Tide blooms.

REFERENCES

HASLE, GRETHE RYTTER
1950. Phototactic Vertical Migration in Marine Dinoflagellates. Oikos 2: (2): 162-175.

HELA, ILMO
1955. A Pattern of Coastal Circulation Inferred from Synoptic Salinity Data. Tech. Report, The Marine Laboratory, University of Miami, in press.

THE MARINE LABORATORY, UNIVERSITY OF MIAMI
1954. Red Tide Studies, January to June, 1954, Preliminary Report. Tech. Rept. 54-19. Mimeogr.