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This method is very effective for small specimens (less than 12 mm). Because the volume of the solution in the petri dish is so great in comparison to the volume of the specimens, it is not necessary to rinse the preservative from the larvae before the clearing process. The concentrations of the clearing and staining solutions are not critical, but should be kept at low levels to reduce the possibility of damage to the specimens.

LITERATURE CITED

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Earth and Planetary Sciences

MEASUREMENT OF WIND-DRIVEN CURRENTS IN A LAGOON

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Knowledge of the circulation processes and patterns of lagoonal waters is of major importance if their overall biological and physical characteristics are to be more completely understood. In addition, such circulation processes and patterns must be considered in the development of pollution controls.

The Indian River actually is a lagoon since it is separated from the ocean by a narrow strip of land; it is moderately saline and has a limited number of inlets. There is visible movement of these waters; however, no evidence of defined circulation processes or patterns has been found reported in the literature.

The Melbourne-Eau Gallie area of the Indian River lagoonal system is reported to be free of tidal influence (Intracoastal Waterway map 845-SC). The large surface area of the lagoon suggests the possibility of a wind driven circulation. If such circulation does occur, definite patterns should result under specific wind conditions.

Experimental Procedure—The area studied was a section of the Indian River lagoon just south of the Melbourne Causeway (Fig. 1; Chart 845-SC; C & G D S). The lagoon averages 8 ft deep in this area. A spoil island is located 500 yd east of Marker 6 and extends 150 to 200 yd in the 155°-335° direction which is parallel to the channel of the Intracoastal Waterway. The lagoon is almost two miles wide in this area and the channel and Marker 6 are about one mile from either shore. The causeway has small relief bridges at both ends and is open for

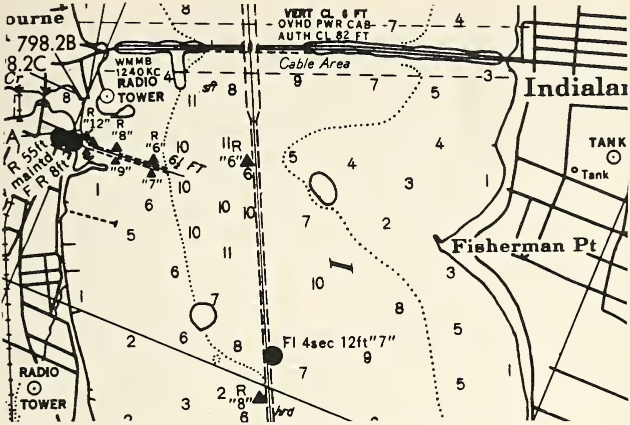

Fig. 1. Area of study, from Intracoastal Waterway Chart 845-SC.

300 yd on either side of the channel. Current crosses were released at Intracoastal Waterway Marker 6 and at the Melbourne Marina sign. The sites are 850 and 1150 yd respectively south of the causeway.

Landmarks and permanent in-water marks used as reference points were the WMMB radio tower, the Melbourne water tank on the east shore, Marker 6, Marker 7, the Melbourne Marina sign, and a radio tower one mile west of Marker 7. Sightings on these points resulted in at least three usable bearings to locate the cross removal points.

Current velocity measurements were made using aluminum crosses. Each of the four wings is 4 in high and 18 in long. They were suspended at selected depths using a measured length of line; a 1-qt plastic bottle half filled with water served as a float.

A boat which was anchored as close to the marker stanchion as possible served as a release platform. The crosses were placed in the water at depths of 0, 2, 4, and 6 ft, and were released approximately 1 min apart to avoid tangling the lines. Care was taken to allow the crosses to settle to the preselected depth before release.

The time was recorded as each float was released. The crosses were allowed to remain in the water as long as the weather and surface conditions permitted but never less than 1 hr. After the crosses had been in the water for a sufficient period, the boat was moved to the new location of the float and anchored. The time was noted, the float and cross were removed from the water, and bearings were taken on preestablished landmarks or in-water marks with a hand bearing compass.

The bearings were plotted on a map of the area to identify the removal point, identified as the point of bearing crossings, or as the center of the triangle formed when the three bearings were plotted. The distance and direction the cross had traveled from the release point to the removal point was then recorded. The speed of the cross was calculated using its travel time from release to pick-up.

Wind data were obtained from the Federal Aviation Agency's Flight Service Station at the Melbourne Municipal Airport, which is approximately three miles from the study area. Data were taken from instruments which recorded wind speed and direction every hour on the hour. The instruments are located on a 20 ft tower. Wind and current directions are both expressed as moving toward a compass heading in order to show their interrelationships more clearly. The readings of wind speed and direction were added vectorially to obtain averages of these quantities for the 24 hr period between current measurements.

Measurements of current speed and direction were conducted on a daily basis from March 22 to April 8 between 8 a.m. and 10 a.m. The wind data recorded with each current profile represent the wind speeds and directions for the 24 hr prior to the current measurement. In order to avoid contributing to the distortion of a shifting wind pattern, consecutive groupings of direction and speed were averaged, permitting an association of directional changes in the prevailing winds during the experimental period with the behavior of the surface water current in the area of study.

The hand bearing compass was graduated in 2° increments. When the water was calm, the instrument could be read accurately to less than ±1°. However, when the water was choppy the readings were somewhat less accurate. By actual experience, accuracy to within ±2° could be obtained routinely even when the water was choppy.

The surface float exerts a drag on the subsurface cross that may produce a slight deviation from the actual value of current speed and direction. However, it is considered small compared to the uncertainty associated with the margin of error in determining the location of release and pick-up points.

Bearings were taken to fix the position of the Melbourne Marina sign since it was not located on the original chart. The sign was located approximately 300 yd south of Marker 6 on a bearing of 165°.

RESULTS—The fig. 2 through 9 show the results in graphic form. The graphs are in parallel projection to show the direction of the current as a function of depth. The wind data depicts the development in time of the wind direction. The wind strength is not shown in these figures.

A. *Surface Currents*: The variation of wind direction and surface current velocity as a function of time for the period of March 27 to March 29 is shown in Fig. 2. During the 48 hr period, the overall surface current change was clockwise from 314° to 355°. The greatest change, from 314° to 347°, occurred in the first 24 hr. The concurrent wind shift was also clockwise from 270° to 100° with an average speed of 6 kn. During the second 24 hr, the surface current shifted from 347° to 355° while the wind swung between 50° and 100° at an average speed of 4.2 kn.

The surface current speed on the 27th, 28th and 29th was 0.24, 0.12 and 0.19 kn. During the 11 hr after the current measurement of the 27th, the average wind direction was 308°. This wind direction tended to maintain the surface current

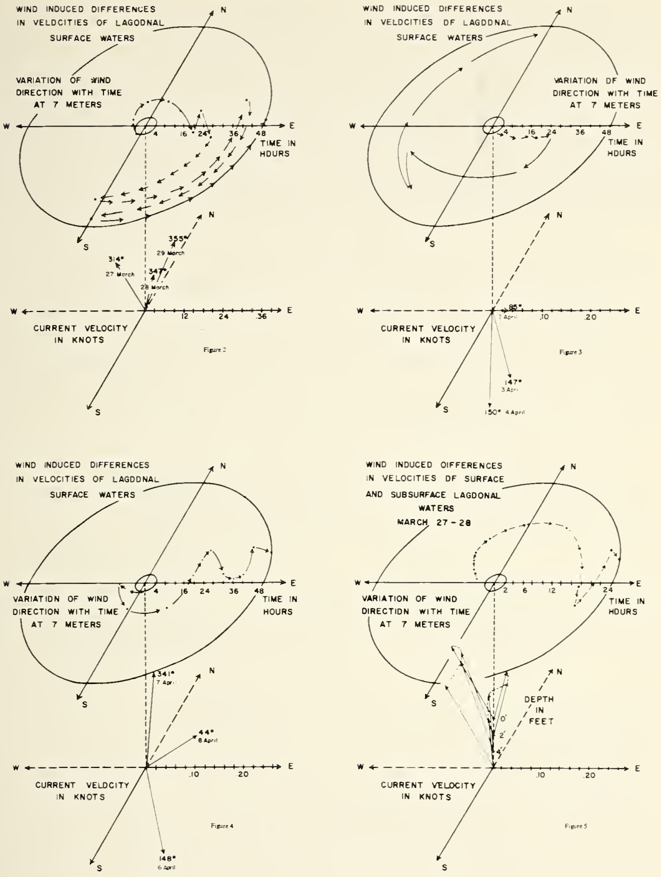

Fig. 2, 3, 4, 5. Wind direction and current velocity data.

direction and probably contributed to its speed of 0.24 kn. During the next 13 hr of the period, the wind direction shifted to 76°. The current follows this change in direction slightly, and decreases in strength. The wind component probably slowed the surface water current and aids in accounting for the loss of speed noted on the 28th.

The increase of surface current speed from 0.12 to 0.19 kn, which occurred between the 28th and 29th probably resulted from a small angular difference between the directions of the wind and the surface current for an extended time (60° and 355° respectively). This small angular difference produced a force in the same direction as the current, tending to increase its speed.

The changes of current speed and direction from April 2 to April 4 are shown in Fig. 3. Surface current direction changed from 85° to 159° in a clockwise direction while the speed increased from 0.04 to 0.24 kn during the 48 hr period.

The greatest change in current direction occurred during the first 24 hr of the period. The directional shift (85° to 147°) and the speed increase (0.04 to 0.24 kn)

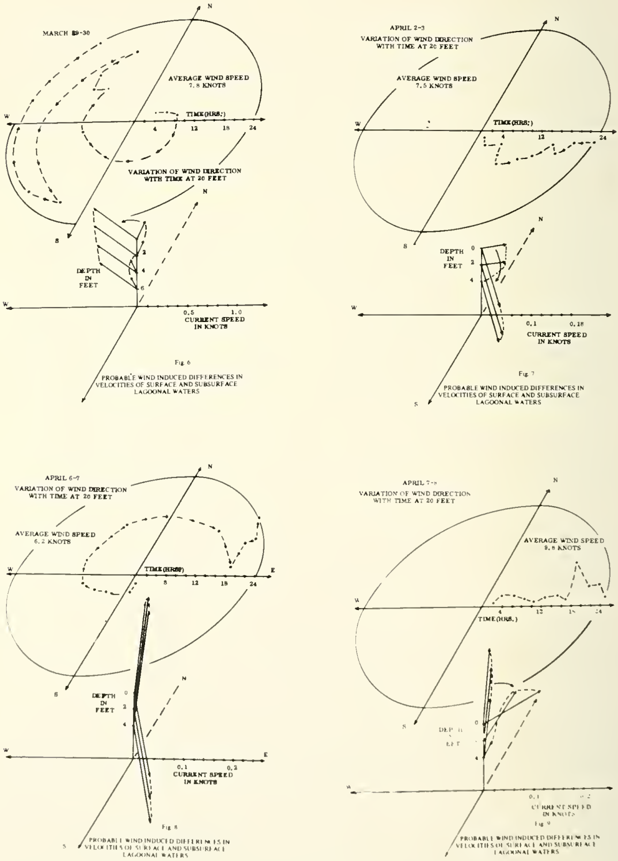

Fig. 6, 7, 8, 9. Wind direction and current velocity data.

of the surface current during these 24 hr correlates well with the predominant wind pattern (130° and 7.5 kn).

The slow shift of the wind pattern from 180° to 360° during the 24 hr from April 3-4 was followed by a further shift in the current direction (147° to 159°) and slight increase in speed (0.17 to 0.24 kn) of the surface current.

Figure 4 depicts the clockwise shift of the surface current, and the predominant winds from April 7-8. The winds during the first 24 hr rotated from 150° to 70°, and were accompanied by a surface current change from 148° to 341°. The current subsequently shifted from 341° to 44° under the influence of a wind moving toward 70° for the next 24 hr.

B. *Velocity versus Depth Profiles*—Figures 5 to 9 show the effect of wind stress on current profiles, and how changes in the wind pattern modify current profiles during 24 hr periods.

Figure 5 shows the effect of a relatively high speed wind (9.8 kn) on a current profile that exhibited constant direction with depth. The current profile at 341° rotated clockwise when a wind with a 70° average direction blew 24 hr. This resulted in a 26° difference in direction of currents between the surface and 4-ft levels.

Rapidly shifting winds may also be associated with a directional difference in the currents of the surface and subsurface waters. The change in the current profile from March 27-28 (Fig. 5) was preceded by a shift of the wind pattern from 308° (11 hr) to 76° (13 hr). This shift in subsurface waters was generally 10° less than that of the surface waters.

The current profiles of March 28-29 suggest that at certain times, the wind speed may be so low that only the direction of the surface and near surface waters shift with the wind while the direction of the deeper water current remains relatively constant.

The changes in current velocity with depth are shown in Fig. 6 for March 29-30, which depicts the counterclockwise shift of the current profiles following a similar shift in wind direction. The variation of current direction with depth noted in the profile of the 29th, changed by the 30th, to a profile of constant direction with depth. This change was probably induced by winds at 335° and 309° at a 7 kn average for a total of 13 hr. Similar changes in current profiles were noted on March 25-26, and April 5-6. There was a general increase in current speed (0.17 to 0.67 kn) from March 29-30 which was also associated with this wind.

Figures 7 and 8 suggest the shift of a profile with no difference in direction between the surface and lower level waters. The clockwise rotation of the profile from April 2-3 was accompanied by a wind headed toward 130° (average direction) at a speed of 7.5 kn. The wind may have produced the constant directional change with depth because of its relatively high speed.

Summary—It is reasonably evident in the data presented that the overall circulation pattern in the study area of the lagoon is variable and depends primarily on the wind as its driving force. Current velocity data obtained from March 22 to April 8, 1972, were correlated with wind velocity data for the same period. This comparison showed that the movements of water in the lagoon were easily related to wind speed and direction. During the period of study, the wind changes generally progressed in a clockwise direction and similar current changes followed. At times, definite differences were noted in current direction of water at different depths; at other times, the current at all depths was aligned with the wind. Experimental data indicate that the difference of direction between the deeper water currents and the concurrent wind is related to wind velocity and duration. The observed current patterns are probably a superposition of drift currents and slope currents, while currents due to astronomical tides play a minor role. More data would be needed to make a definitive confirmation and to establish pertinent time constants.

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Biological Sciences

BEHAVIORAL RESPONSES TO VISUAL STIMULATION IN THE SCALLOP (*AEQUIPECTEN IRRADIANS*)[1]

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Abstract: *In a series of experiments, the scallop's shell closure responses to visual stimulation were studied. Recordings were made of the animal's responses to repeated offsets of illumination. The findings indicated that the responses declined in amplitude over a series of offsets. The decline in responding increased as the length of the interval between offsets decreased. It was found that the decline in responding could not be attributed to either an effector or receptor mechanism. It was therefore concluded that the decline was due to a central process. The investigation also revealed that the amplitude of the response to the first offset was found to depend upon both the duration and the intensity of the light.*

The scallop has long been noted for the two rather unusual characteristics: it has an impressive array of eyes and it is capable of active swimming. The animal's numerous eyes are located on the tips of short stalks found along both shell halves. Each eye contains a large lens and a mass of sense cell material. The sense cells form two distinct retinae, one in front of the other, but the two retinae do not appear to have any functional or anatomical connections between them (Barber, Evans and Land, 1967; Schoepfle and Young, 1936). Each gives rise to its own branch of the optic nerve and the two branches join several mm behind the eye. The branch arising from the proximal retina (nearest the back of the eye) responds when the eye is illuminated; the branch arising from the distal retina responds to

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