*vetulus*, 85-165 mm, and *I. isolepis*, 95-155 mm, were commonly captured. *Isopsetta isolepis*, 4-7 mm, were captured with 0.5-m plankton net. No later stages were taken. Richardson (1973) took this species (12-22 mm) off Oregon close to shore. Entry into the estuary probably occurs as metamorphosed juveniles.

Several types of sampling equipment should be utilized in future studies to capture early stages near bottom, on tide flats, in embayments, and during darkness. This preliminary investigation indicated little spawning occurred in this west coast estuary; most species captured were spawned in the ocean, or were anadromous species that spawned upstream and drifted into the estuary. Results of this investigation and bottom trawling by other researchers indicated this estuary is utilized primarily as a nursery grounds by the post-larval and juvenile stages of several species.

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# A NOTE ON: "VELOCITY AND TRANSPORT OF THE ANTILLES CURRENT NORTHEAST OF THE BAHAMA ISLANDS"

Interest of fishery scientists in the Antilles Current east of the Bahama Islands stems from a generally accepted hypothesis that it served as a conveyor of larvae of large pelagic fishes northward into the Gulf Stream system. Larvae of billfishes (Istiophoridae) were captured in plankton tows east of the Bahamas during the first MARMAP Operational Test Phase (OPT-I) cruise in July-August 1972.[1] These captures clearly

[1]Richards, W. J., J. W. Jossi, and T. W. McKenney. Interim report on the distribution and abundance of tuna and billfish larvae collected during MARMAP Operational Test Phase cruises I and II, 1972-1973. MARMAP Contrib. 16. Unpubl. manuscr., 15 p.

show that adult billfishes had been in the area shortly before the sampling occurred, but the implication of the transport of the larvae northward by the Antilles Current is not so clear. We have reason to doubt the existence of the strong, steady, broad surface flow to the northwest which has been assumed to be characteristic of the Antilles Current east of the northern Bahamas.

In a recent analysis of six occupations of Standard Section A-7 (Figure 1) by U.S. Coast Guard cutters, Ingham (1975) did not find a strong, steady, broad surface flow attributed to the Antilles Current (Wüst 1924; Boisvert 1967). In a study of directly measured values of the transport of the Gulf Stream between the Florida Straits and Cape Hatteras, Knauss (1969) noted that the transport increases at a rate of about 7%/100 km, from $33 \times 10^6$ m³/s in the Florida Straits, to $63 \times 10^6$ m³/s off Cape Hatteras. Increases of this magnitude were also evident in earlier transport measurements for the Florida Straits (Wüst 1924; Montgomery 1941) and Cape Hatteras (Iselin 1936). Exactly how this increase takes place has not been determined. Wüst (1924) and Iselin (1936) felt that the Antilles Current makes a significant addition ($12 \times 10^6$ m³/s) to the Gulf Stream just north of the Bahama Islands, but Stommel (1965) felt that this value for the contribution of the Antilles Current was questionable. It should be noted that Wüst's (1924) transport to the northwest was approximately balanced by two countercurrents on each side of the current moving to the southeast.

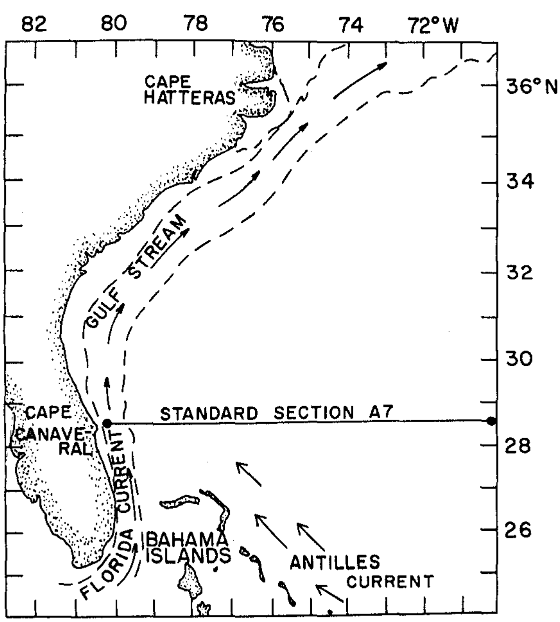


FIGURE 1.—Position of Coast Guard Standard Section A-7 in relationship to surrounding currents and land masses.

The geostrophic velocities and volume transports (Table 1) obtained by Ingham (1975) indicate that the previous estimate (Wüst 1924) of the transport of the Antilles Current is too large and that a better estimate of the mean northward transport is on the order of $8.6 \times 10^6$ m³/s. The difference in reference levels between Ingham (1,000 decibars) and Wüst (800 decibars) does not account for this discrepancy since Wüst's shallower reference level would result in less transport than Ingham, not more. In the six transects measured by Ingham only one showed a net transport large enough to account for the above mentioned increase in the Gulf Stream. In addition, the net transport through the section was highly variable, showing values of 3.4 and $6.4 \times 10^6$ m³/s southward in two of the transects. Ingham (1975) suggested that some mechanism other than the Antilles Current may account for the increase in the Gulf Stream and that the contribution of local wind-driven (Ekman) transport be considered as a possibility, since the mean direction of the winds in the vicinity would produce a northward or northwestward drift.

In order to determine this northward transport contribution by locally wind-driven currents, quarterly averages (January-March, April-June, etc.) of Ekman transport values for 1946-73 were obtained from the Pacific Environmental Group, National Marine Fisheries Service, NOAA for three locations northeast of the Bahama Islands, along lat. 27°N at long. 78°W, 75°W, and 72°W (Figure 1). These values were calculated from the mean monthly atmospheric pressure field using the method described by Bakun (1973) to determine the mean monthly wind stress on the ocean surface and the resulting Ekman transport. The quarterly mean meridional Ekman transports, per unit length, for each position were averaged to give a mean transport value for a hypothetical

TABLE 1.—Transports across Coast Guard Standard Section A-7 as reported by Ingham (1975).

| Date of transect | Transport ($10^6$ m³/s) and direction |
|---|---|
| 29-30 Jan. 1967 | 16.0 North |
| 26-28 June 1967 | 30.4 North |
| 24-25 June 1968 | 3.4 South |
| 9-11 Dec. 1969 | 3.9 North |
| 29 Sept.- 1 Oct. 1970 | 6.4 South |
| 17-19 Nov. 1970 | 11.4 North |

transect along lat. 27°N. This value was then multiplied by the length of the transect to give a net quarterly meridional transport through the transect. The hypothetical transect extends eastward from the Bahama Islands, 668 km, to the same longitude as the eastern end of Standard Section A-7 (about long. 70°12′W). Thus it crosses the same portion of the Antilles Current as that cut by Standard Section A-7, but about 180 km upstream of it. Therefore, meridional Ekman transports computed for the transect along lat. 27°N can be compared with measured geostrophic transports through A-7. Although the effects of lateral boundaries were not considered, the piling up of water against the Bahama Banks would result in a southeastward geostrophic flow, further substantiating the result of this report.

The results of these computations, for this hypothetical transect, show a large range of net quarterly meridional Ekman transport values, from $60\times10^3$ m$^3$/s northward to $20\times10^3$ m$^3$/s southward with an overall mean of net transports, over 28 yr, of $15\pm2\times10^3$ m$^3$/s northward (the range gives the limits of the 95% confidence level) and an SD of $11\times10^3$ m$^3$/s. When the 28 yr of net meridional transports were averaged by quarters, there was the appearance of distinct seasonality, with the lowest average value in the first quarter (January-March) amounting to $7\pm4\times10^3$ m$^3$/s northward with an SD of $12\times10^3$ m$^3$/s. The transport increased in the second (April-June) and third (July-September) quarters to $15\pm3$ and $17\pm2\times10^3$ m$^3$/s northward with respective SD's of 9 and $6\times10^3$ m$^3$/s. The fourth quarter (October-December) had the highest value of $23\pm4\times10^3$ m$^3$/s northward, with an SD of $12\times10^3$ m$^3$/s. These values for the Ekman transport are three orders of magnitude too small to account for the transport increase in the Gulf Stream. Thus locally induced Ekman drift can be ruled out as a significant contributor.

There still is a possibility that an Antilles Current could account for the observed increase in transport of the Gulf Stream. If a strong, narrow band of the current hugged the eastern edge of the Bahama Banks and joined the Gulf Stream before it crossed Standard Section A-7 (Figure 1), it would have escaped detection in Ingham's (1975) analysis. The existence of such an intense current would contradict Knauss' (1969) observation that the transport increase in the Gulf Stream takes place gradually from the Florida Straits to Cape Hatteras, with no large increase in transport ($>2\times10^6$ m$^3$/s) south of lat. 32°N and the suggestion by Worthington (in press) and Sturges (1968) that the increase in transport of the Gulf Stream takes place over its entire length and at all levels. Nevertheless a study in preparation by R. Yager (pers. commun.) using direct transport measurements appears to show a narrow (80 km), intense ($12\times10^6$ m$^3$/s) current to the northwest hugging the east side of the Bahama Banks.

A measure of the significance of Ekman transport in moving the larvae of pelagic fishes northward to the Gulf Stream can be obtained by deriving a rough estimate of the average speed of neutrally buoyant objects in the wind-driven layer. For this the average northward transport is divided by the area of the cross-section through which the flow is occurring (depth of layer × length of section). Using the familiar empirical relationship,

$$D = \frac{7.6W}{\sqrt{\sin\phi}} \quad \text{(Defant 1961 Vol. I:422)},$$

where $D$ is the depth of the wind-influenced layer, $W$ is the wind speed (here the median wind speed, 5.5 m/s shown for lat. 25°-30°N, long. 70°-75°W in the U.S. Naval Oceanographic Office atlas 1963), and $\phi$ is the latitude, we obtain an estimate of the average depth of the wind-influenced layer to be about 60 m. From the depth (60 m), the length of the section (668 km), and the net transport computed earlier ($15\pm2\times10^3$ m$^3$/s), we obtain an estimate of the average northward velocity of larvae to be 0.04 cm/s. It is apparent that this velocity, which translates to 0.03 km/day, is considerably smaller than the geostrophic velocities through lat. 28°35′N reported by Ingham (1975) which generally ranged from 5 to 40 cm/s either northward or southward.

The vertical distribution of ichthyoplankton could have a considerable effect on their transport by wind-driven currents; however, their vertical distribution is not well known. If, in order to obtain a maximum possible velocity, we assume that the larvae remain in the upper meter or so of the wind-driven layer instead of spending time at various depths throughout it, then their wind-driven drift speed would be considerably greater than the 0.04 cm/s average. Using the relationship

$$V_0 = \frac{\lambda W}{\sqrt{\sin\phi}} \quad \text{(Defant 1961 Vol. I:418)},$$

which relates surface current speed ($V_0$) to wind speed ($W$) in terms of latitude ($\phi$) and an empirical constant ($\lambda \doteq 10^{-2}$), we obtain an estimate of average wind-driven surface current velocity of 5.7 cm/s northward.

In light of the velocity estimates, it is apparent that locally wind-driven currents are significant for the northward transport of pelagic larvae east of the northern Bahamas only if the larvae spend most of their time near the sea surface. If, instead, they are scattered throughout the upper layer or undergo diurnal vertical migration, their northward progress will be much slower.

Another possible pathway of larval transport which should be considered, however, is the nearshore band of strong flow mentioned by R. Yager (pers. commun.). If such a band exists as a regular, steady feature of the current field east of the Bahama Banks, then it would be particularly informative to conduct seasonal ichthyoplankton surveys on a scale appropriate to determine the relative abundance of pelagic larvae in and near the current band.

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## SALINITY ACCLIMATION IN THE SOFT-SHELL CLAM, *MYA ARENARIA*

A steady increase in sewage pollution followed by the closing of many productive shellfish growing areas has seriously affected the harvesting of the soft-shell clam, *Mya arenaria,* in the State of Maine. In areas where a large percentage of the population derives its income from harvesting soft-shell clams, these closings have caused severe economic hardships. Beginning in the mid-1950's the Maine Department of Marine Resources (then Maine Department of Sea and Shore Fisheries) accelerated research on clam depuration in an attempt to salvage moderately polluted clams of 70-700 most probable number of *Escherichia coli* bacteria per 100 g. Based upon the design and development of a pilot process (Goggins et al. 1964) five commercial depuration plants have been established. The first of these (Seafair, Inc.[1]), in Phippsburg, Maine, utilized clams dug from Parker Head, Maine. During routine operation of this plant, it was apparent that exposure of clams to certain salinity and temperature conditions increased the time required for depuration.

Former investigators have revealed that pumping activity and associated shell and ciliary movements are affected when bivalves other than soft-shell clams are immersed in water of a different salinity from that to which they are accustomed (Wells et al. 1940; Medcof 1944; Loosanoff[2]). In this paper, salinities lower than

[1]Reference to a commercial enterprise does not imply endorsement by the National Marine Fisheries Service, NOAA.

[2]Loosanoff, V. L. 1952. Behavior of oysters in water of low salinities. Conv. Address Proc. Natl. Shellfish. Assoc., Atlantic City.