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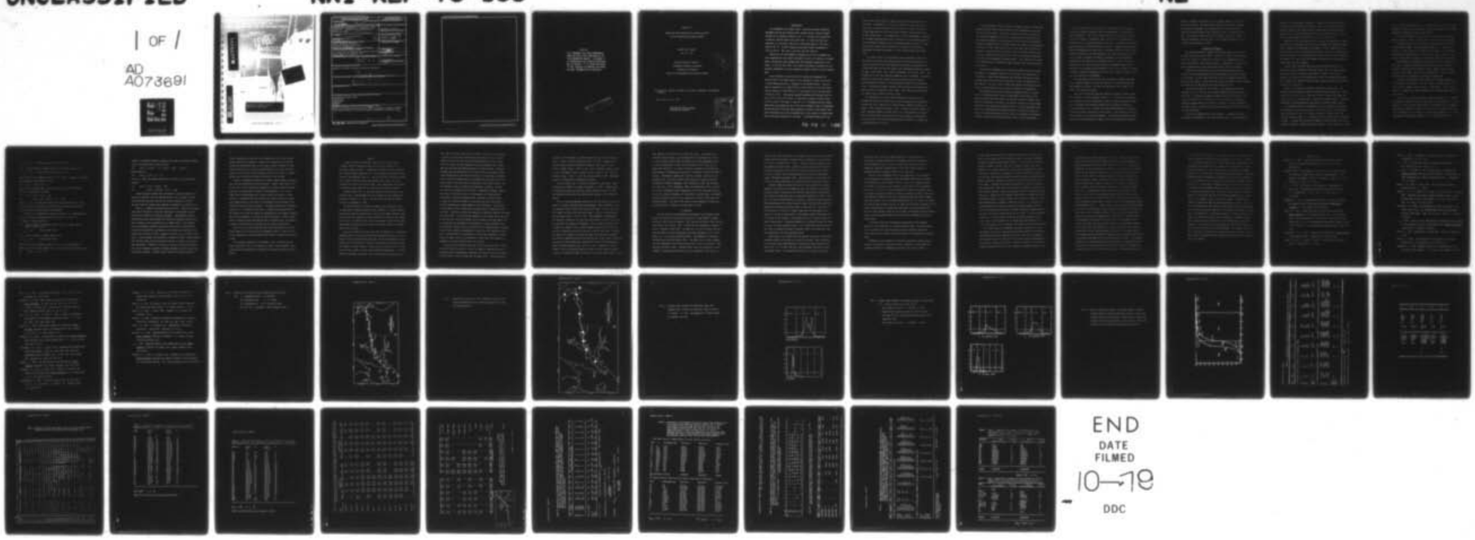

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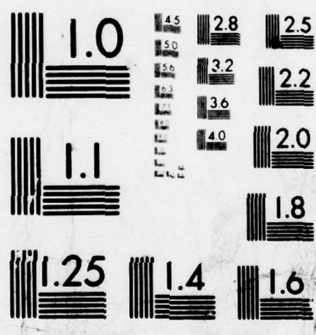

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This report contains Results of an intensive two-year (1971-72) study which attempts to adequately sample and analyze production of stiped bass eggs in the Chesapeake & Delaware Canal.

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APPENDIX II

PRODUCTION AND DISTRIBUTION OF STRIPED BASS EGGS IN THE CHESAPEAKE AND DELAWARE CANAL[1/]

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INTRODUCTION

The Chesapeake and Delaware Canal, a man-made waterway connecting Chesapeake Bay and the Delaware River, extends nearly 14 miles through the head of the Delmarva Peninsula (Fig. 1). The Canal was constructed in 1829 as a private barge canal with locks. In 1927, the Canal was converted to a sea-level anal with a controlling depth of 12 ft and a width of 90 ft. In 1954, Congress authorized further enlargement to 35 ft by 450 ft. This work is now more than 90% complete.

Concern for the environmental consequences of Canal enlargement was first expressed for the possible detrimental effects of disposal of dredged spoil, particularly spoil dredged from the Chesapeake approaches to the Canal. It was not until 1970 that concern was publicly expressed for the possible consequences of purely hydraulic changes effected by Canal enlargement.

A net difference in mean tide level between the Chesapeake and Delaware ends of the Canal results in net transport of water to the east, in effect making the Canal a tributary of the Delaware River. This net flow is estimated to be 1,000 ft^3/sec (= 283.2 m^3/sec) in the 27-ft Canal and may increase to 2,700 ft^3/sec (= 7.64.6 m^3/sec) in the 35-foot Canal; a ratio of 1:2.70. The average eastward maximum tidal velocity, 88.4 cm/sec (1.8 kt) in the 27-ft Canal, is expected to increase to 108.8 cm/sec (2.2 kt) in the 35-ft Canal; a ratio of 1:1.23. Discharge from the Susquehanna River, accounting for 46% of the total freshwater input to Chesapeake Bay and for 90% of the input above Annapolis, results in the nearly freshwater conditions seen in the Chesapeake Bay in the vicinity of Turkey Point and in the western portions of the Canal. The Delaware River end of the

Canal almost always exhibits a higher salinity than the western end of the Canal. Enlargement of the Canal is expected to intensify the tendency for a two-layered system of water flow in the Canal, an eastward flowing upper layer of fresh water and a westward flowing deeper layer of more saline water. The maximum effect of Canal enlargement on salinity of the upper Chesapeake Bay waters is expected to occur during periods of lowest freshwater discharge, with an estimated maximum increase of 3 ppt above Pooles Island and an increase not exceeding 0.2 ppt below the Chesapeake Bay Bridge (Pritchard, In: Anon.,1970;Pritchard and Cronin, 1971).

The present study of the production and distribution of fish eggs and larvae in the Canal and adjacent waters was largely prompted by the recent discovery that the Canal exhibited the highest concentrations of striped bass eggs that had been found in the Chesapeake Bay Region (Cronin, In: Anon., 1970; Dovel, 1971; Dovel and Edmunds, 1971; Hollis, 1967). The striped bass is the most important commercial fish in Maryland. The annual commercial catch of this species along the Atlantic coast is nearly 9 million pounds with nearly 3.5 million pounds accounted for by Maryland alone. Maryland and Virginia together take two-thirds of the annual commercial catch of striped bass (Koo, 1970). These figures do not include the valuable sport fishery for this species.

The Chesapeake Bay is the primary spawning and nursery area for striped bass along the Atlantic Coast, and the production of striped bass exceeds that of all other sites in North America combined (Vladykov and Wallace, 1952; Mansueti and Hollis, 1963). Mansueti and Hollis (1963) list known spawning grounds of striped bass in the Chesapeake Bay and noted that the Potomac River and the head of the Bay together constituted 85% (by surface area) of the total spawning grounds available to striped bass in Maryland waters of the Bay.

Dovel and Edmunds (1971) document the apparent change in striped bass spawning grounds from the lower reaches of the Susquehanna River to the Elk River and the Canal. They review available historical information on striped bass spawning in the lower Susquehanna and conclude that the once probably important spawning grounds of this species were destroyed through the combined effects of hydroelectric dam construction (especially 4 dams built on the lower 54 miles of the river from 1904 to 1928) and pollution, especially from coal mining. Dovel and Edmunds conclude that the Canal, converted to sea-level in 1927, was an acceptable alternative to the destroyed Susquehanna spawning grounds. This conclusion was based on the high catches of striped bass eggs obtained in the western portions of the Canal.

Concern over enlargement of the Canal has stemmed directly from this knowledge of the apparent importance of this area to the production of striped bass. While Canal enlargement and resultant increases in water transport and velocities might be expected to affect the production of this species - as well as that of other fish species utilizing this area - it was not known whether effects would be beneficial or detrimental.

The destruction of the once important spawning grounds of striped bass in the Delaware River estuary is documented by Chittenden (1971), Murawski (1969), and Raney (1952), and has been related to domestic and industrial pollution. The Canal is in effect a tributary of the Delaware River and it was feared that hydraulic effects of Canal enlargement might result in a significantly increased advection of striped bass eggs and larvae into the Delaware River estuary, where an unfavorable distribution of higher salinities and pollutants might result in their destruction.

These concerns led to the multi-institutional Canal investigations, a three-year program designed to study the environmental consequences of Canal enlargement. Part of this study consisted of an intensive two-year (1971-1972) attempt to adequately sample and analyze the production and distribution of fish eggs and larvae in the Canal. Our goals were to determine the species of fishes utilizing the area as a spawning and/or nursery ground; determination of actual areas of spawning within the system; determination of production and distribution of fish eggs and larvae with respect to season, geography, and physical parameters of the environment; assessment of the importance of production within the area to the total production of the several species within the Chesapeake region; and to integrate this knowledge with hydrographic results in an attempt to achieve a scheme for optimal management of the area; and to predict effects on fish eggs and larvae by the enlargement.

The eggs and/or larvae of more than 20 species of fishes were taken in our sampling efforts, but only the results for striped bass eggs have been completely analyzed. We limit the discussion in this paper to the results for striped bass eggs.

This work has been made possible through the support (Contract DACW-61-71-C-0062) of the Philadelphia District, U. S. Army Corps of Engineers. The Chesapeake Biological Laboratory, Natural Resources Institute, University of Maryland, has provided working space and material assistance. We are indebted to Drs. L. Eugene Cronin and Raymond Morgan for material assistance, advice, information, and criticism. John Wilson and Jim Rasin have provided much aid and encouragement. Preliminary hydrographic information has been provided by Mr. Thomas Hill of the Experimental Waterways

Station, Vicksburg, Mississippi, and Mr. Bernard Gardner of the Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Maryland. We gratefully acknowledge the cooperation of the various assistants connected with this project whose persistence made its completion possible: Carla Barrett, Melvin Beaven, John Cooper, George Gray, Thomas Johnson, Ruth Wilson, and Peter Zeni. We are deeply grateful to Mr. W. L. Dovel who initiated this study.

METHODS AND MATERIALS

The methods employed in taking and processing samples were similar to those described by Dovel (1964). In 1971, the transect extended about 75 km (46 mi)(Fig. 1) from near the mouth of the Susquehanna River to the Delaware River. Twenty-eight stations, corresponding in most cases to fixed navigation buoys, were distributed evenly along this transect.

Sampling gear consisted of 24-in (61-cm) diameter plankton mesh (0.41 by 0.76-mm aperture when dry and unstretched) conical nets affixed to iron hoops. The nets were towed with 17-ft Boston Whalers powered by 60-hp Johnson engines. During sampling, the boat was headed into the current, the engine set at 1500 rpm, and the nets fished for 5 min.

Two nets were fished at each station. The surface net, hereafter referred to as the 'top' net, was fished immediately below the surface of the water. The deep net, hereafter referred to as the 'bottom' net, was fished with about 22.9 m of wire out (= 75 ft of wire out) yielding an estimated sampling depth of 4.57-6.10 m (15-20 ft), or about mid-depth in the Canal channel. Both nets were fished synchronously, with all tows taken in about mid-channel.

Each net was supplied with a TSK flowmeter. Calibration of these flowmeters was performed at the known velocity-flume at the Chesapeake Bay

Institute, The Johns Hopkins University. Despite the standradized method of making tows, flowmeter data (taken with each haul) indicated considerable variability in the amount of water filtered per tow around the mean value of 94.52 $\pm$ 2.54 m^3/tow (based on 165 tows, April 23 to May 1, 1971), with an extreme range of 70-130 m^3/tow (94.52 m^3 = 3337.5 ft^3).

Sampling in 1971 was initiated on 31 March and the transect was sampled every other day throughout April and May and somewhat less frequently thereafter. Sampling was terminated on 8 December. We have completed analysis of the results of the 1971 sampling year based on data from 49 sampling days and 1,236 samples, but we present only the results based on the 27 sampling days (April 15 - June 13) and 747 samples taken during the time period when striped bass eggs were captured.

In 1972, most hauls were made with the so-called double net, consisting of two nets identical to the nets used in 1971, but yoked together with a 25-in (63.5 cm) distance from center to center. This net was fished in the same way as the bottom net in 1971, but increased drag apparently resulted in a somewhat shallower towing depth, measured on one occasion as 13-15 ft (4.0-4.6 m).

Figure 2 illustrates the modified station plan used in 1972. Our sampling effort occupied two days each week from March through June. Hydrographic data (Table 5) at 1 (0.3m) and 20 (6.1m) ft depths were taken once each week at all 11 stations with a Martek Water Quality Monitor. Measured parameters included temperature, conductivity, dissolved oxygen, and pH.

All sampling effort was concentrated into one 30 h period each week. Four transects at the 8 inner stations (solid symbols, Fig. 2) were taken with the double net over a 24 h period commencing at 1200 h with a new transect beginning every 6 h. The Delaware River stations were not occupied at night. A second boat occupied two stations (usually #5 and C1) at two-h intervals beginning at 1800 h and ending at 0600 h Hauls made by the second boat were with a second double net. A final transect, at all 11 stations, commenced at 1200 h on the second day. During this transect, the methods employed were identical to those used in 1971.

The results presented in this paper are based on the 10 sampling periods, April 11 - June 15, during which striped bass eggs were taken.

Techniques used in processing samples were identical to those described by Dovel (1964). The concentrated samples, 1 - 4 quarts (1 - 4 liters) each, were fixed in 10% formalin and returned to the laboratory for sorting and identification. All fish eggs, larvae, juveniles, and adults removed from each sample were processed, identified, and counted.

Non-parametric and enumeration statistics are used exclusively in this study. Standard statistical texts have been used as reference material, especially Dixon and Massey (1957), Downie and Heath (1959), Sokal and Rohlf (1969), and Tate and Clelland (1957). Much of the data was processed on the University of Maryland UNIVAC 1108.

At times, weather and/or debris conditions precluded occupation of all stations in the transect. For this reason, a capture index (CI (i)) was devised to express catch in terms of catch/effort. Actual catch/effort was compared to a model distribution that assumed equal catch for equal effort.

In the case of capture information along the transect, i.e., comparing catches at different stations summed over some time-period T (=< ETI, where ETI is the effective time interval, the inclusive set of sampling days from the first day of capture to the last day of capture of the object of interest), if S = number of stations along transect, c(i) = capture (number of individuals taken) at i^{th} station summed over T

$$C = \sum_{i=1}^{S} c(i) \quad = \text{total capture over S stations over T}$$

e(i) = effort (number of samples taken) at i^{th} station summed over T

$$E = \sum_{i=1}^{S} e(i) \quad = \text{total effort over S stations over T,}$$

then if ce(i) is the expected capture at i^{th} station, assuming a rectangular distribution of catch/effort, we have:

(1) $ce(i) = [e(i) / E]^* \ C$

from which the capture index, CI(i), for the catch at the i^{th} station over T is constructed as follows:

(2) $CI(i) = [c(i) / ce(i)] * 100$

(3) $= [(c(i) * E) / (e(i) * C)] * 100.$

Values of CI(i) less than 100 indicate that fewer individuals were taken at the i^{th} station than would be expected from the model whereas values of CI(i) greater than 100 indicate the converse.

Similarly for information on capture over time, i.e., comparing total catches on different sampling days over some time T (=< ETI), if

D = number of sampling days in T

c(i) = capture (number of individuals taken) on day i, summed over all samples taken on day i

$$C = \sum_{i=1}^{D} c(i) \quad = \text{total capture over T}$$

e(i) = effort (number of samples taken)on day i

$$E = \sum_{i=1}^{D} e(i) \quad = \text{total effort over T,}$$

then if ce(i) is the expected capture on day i, if an equal number of samples were taken on all sampling days, the rectangular model predicts that:

(4) $ce(i) = (1 / D) * C.$

However, if differing numbers of samples were taken on different sampling days, a correction must be made such that

(5) $ce(i) = [(1/D) * C] + [(e(i) - (E/D) * (C/E)]$

which reduces to

(6) $ce(i) = [e(i) / E * C]$

as in (1). Thus, the capture index, CI(i), for day i is calculated as follows,

(7) $CI(i) = [c(i) / ce(i)] * 100$

(8) $= [c(i) * E)/(e(i) * C)] * 100.$

Separate capture indices were calculated for top net captures, for bottom net captures, and for combined captures (top + bottom) for each station and for each date over the ETI and over portions of the ETI. Top and bottom net captures were compared via Kendall's tau (Tables 3, 4).

There are a number of problems with this method. Ideally, the capture index should account for tow-to-tow differences in the amount of water filtered (as indicated by flowmeter readings). Unfortunately failures involving both gear and personnel have made this impossible because flowmeter readings are not available for all samples taken. The extremely great correspondence between catch/effort calculated as catch/m^3 water filtered and catch/effort calculated as CI(i) shown for a portion of the striped bass egg data in Table 1 suggests that this is not a crucial difficulty. We have assumed the differences in amounts of water filtered between tows from day-to-day and from station-to-station to average out over any long time-period. Captures of the eggs or larvae of any species found in the area are extremely variable and highly dependent upon the actual dates and stations sampled. An ideal capture index would combine capture vs.

effort information for both time and geography into one scheme, perhaps through some form of weighting. Because the variation from station-to-station and from date-to-date is quite high in terms of numbers of individuals taken (but not in terms of rank-abundance, see below) and since efforts in 1971 did not involve replicate tows, we have chosen to present capture data in terms of the index formulated in this section.

There is an important difficulty in simply summing capture information over any long time-period and then computing a capture index based solely on this sum, in that variation in abundance at a given station from sampling date to sampling date is masked by this procedure. If it can be shown that the rank-abundance of a given station with respect to other stations is concordant from date-to-date, the capture index is an acceptable simplification if the goal is to determine relative abundance from station-to-station along the transect. The highly significant concordance (Tables 1, 6, 7) exhibited by the sets of striped bass egg capture data, and indeed for all sets of capture data generated by this program, indicates that the rank-abundance at a given station with respect to other stations tends to remain the same from sampling date to sampling date, and provides a powerful justification for analysis via the capture index method.

While it can be easily shown that the actual distribution of catch/effort differs in all cases from the rectangular model, we know of no way to test differences in capture indices from station to station or from date to date.

The strongest advantage of this method is that it allows easy and rapid visualization (Fig. 3) of periods or areas of peak abundance, those localities or time-periods that resulted in the largest captures per unit effort.

RESULTS

A total of 60,030 striped bass eggs (23,329 in top net hauls = 38.86%; 36,701 in bottom net hauls = 61.14%) was taken in 1971. Raw data is given in Table 2. Comparison of captures in top and bottom nets revealed highly significant ($p < .01$) agreement with respect to time (Table 3) and geography (Table 4). The effective time interval was April 15 to June 13, but five consecutive sampling days, April 23 to May 1, accounted for 76.63% of the total catch. Water temperature and salinity or conductivity data taken in 1971 and 1972 is presented in Table 5.

Capture indices (Fig. 3) show peak captures in the Chesapeake and Delaware Canal. Rank-abundance data for striped bass egg captures are presented in Tables 1, 6, and 7. The data sets, both raw and pooled, are highly concordant ($p < .005$).

The concentrations of striped bass eggs, up to 36 eggs/m^3, are to our knowledge the highest reported values (Table 8A). A total of 83,918 striped bass eggs was obtained from a total of 445 samples taken in 1972. The effective time interval in 1972, was April 10 to June 15, but samples taken on May 1-2 yielded 54.94% of the total number of striped bass eggs taken despite the fact that only 18.9% of the total effort was expended during these two days.

Most hauls taken in 1972 were made with the double net. Our modified sampling design in 1972 was directed toward two specific goals: (1) estimation of error associated with net hauls, and (2) determination of variability over short periods of time (6 h) of abundance at a given station with respect to other stations. Results from the outside (left) or A-net and the inside (right) or B-net were determined independently. An extraordinary, presumably systematic, error was immediately detected in the data (and in fact was detected in the field) in that the A-net captures in nearly all cases were significantly larger than the B-net captures, despite the fact that the nets were yoked together with only a 25-in (63.5 cm) center-to-center separation, and that different nets (fabric portion) were used from sampling period to sampling period. Flowmeter readings taken simultaneously in the A and B nets were identical while visual observation in the field (with the net at the surface) indicated that the net was fishing exactly as intended with the plane of the net mouths normal to the direction of travel and to the plane of depth. We are completely unable to explain the difference in catches. We were thus unable to accomplish our first goal. Remarkably inclement weather, with heavy rain and fog as well as large amounts of floating debris (including on occasion telephone poles), resulted in aborted efforts at night on a sufficient number of occasions such that blank values in our data preclude full accomplishment of our second goal. The analysis of catch data for 1972 follows much the same course as analysis of 1971 catch data. Analysis of double-net captures is limited to material recovered from A-net hauls. As the A-net was identical to the single bottom net used in 1971 and 1972, and as the double net was fished in the same manner and at essentially the same depth as the bottom net, we have combined the A- and bottom-net captures for each station for each sampling period, yielding a pooled data estimate of abundance by station for a 30-h period for each week. An indication of the agreement in catch/effort expressed as concentration of eggs as well as an indication of short-term (6-h) changes in abundance at a given station is given in Table 8B.

A total of 59,159 striped bass eggs (47,790 from A-net hauls = 80.78%; 11,369 from bottom net hauls = 19.22%) was taken in combined data for A + bottom-net hauls (corresponding remarkably well with the fact that roughly 4/5 hauls made in 1972 were made with the double net). Top- and bottom-net captures in 1972 resulted in 15,298 striped bass eggs (3,929 in top-net hauls = 25.68%; 11,369 in bottom-net hauls = 74.32%). Comparisons of captures revealed highly significant agreement with respect to time (top vs. bottom, $tau_{10} = +.933$, $p < .01$; top vs. A+bottom, $tau_{10} = +.782$, $p < .01$) and geography (top vs. bottom, $tau_{11} = +.782$, $p < .01$; top vs. A+bottom, $tau_{11} = +.709$, $p < .01$) for all hauls made in 1972. Subsequent analysis is restricted to A+bottom-net captures.

Capture indices (Fig. 4) reveal peak captures in the Canal. Rank-abundance data (Table 9) is highly concordant ($p < .005$). Concentrations of striped bass eggs estimated from catches obtained on May 1-2, 1972, are comparable with values taken during peak captures in 1971 (Table 8A and 8B).

There is striking agrrement between the 1971 and 1972 data sets with respect to catches over both time and geography. This similarity is seen in comparing capture indices for the two years (Figs. 3 and 4; Table 10). With respect to both catch over time ($tau_{10} = +.600$, $p =<.02$) and catch over geography ($tau_{11} = +.891$, $p <.01$) this agreement is significant. The agreement between the two data sets with respect to time is less than the agreement with respect to geography. This is shown in Table 10 and is especially evident in Fig. 5 which compares catch data for each year plotted as cumulative percent of the total catch for each year. Although the sequence of captures of striped bass eggs (and therefore presumably the course of spawning activity) was much the same in both years (Table 10B), the period of peak spawning was significantly later in 1972 (Kolmogorov-Smirnov Maximum Difference $D_{10} = 58.74$, $p <.01$). Inspection of the raw (Tables 2 and 9) and capture index data (Figs. 3 and 4) shows that peak captures of striped bass eggs in 1971 were in the last week of April, whereas peak captures in 1972 were in the first week of May. Temperature data have been plotted on Fig. 5, and although data are available only for May 1, 1971, our data indicate that the median 20-ft depth temperature value of 18.8°C obtained May 1, 1971, was not obtained in 1972 until fully 3 weeks later on May 22. In fishes (and other vertebrates) the timing and effectiveness of breeding are affected by a multitude of biotic and abiotic factors: photoperiod, temperature, salinity, currents and tides, food abundance, etc., and all of them to some extent are seasonally related. Experimental evidence (Baggerman, 1957; Harrington, 1959b, and reviews by Atz, 1957; Hoar, 1955; Harrington, 1959a; and Schwassmann, 1971) has indicated that in temperate fishes photoperiod is the most important directive cue in the timing of breeding, but that within a certain range the pinpoint timing of spawning activity can be advanced or retarded by differing temperature regimes. Our data on the period of peak spawning of striped bass in 1971 and 1972 is entirely in accord with this idea.

DISCUSSION

The life history and environmental requirements for successful reproduction of striped bass have been discussed by a large number of authors (Albrecht, 1964; Dovel and Edmunds, 1971; Mansueti and Hollis, 1963; Mansueti, 1958; Raney, 1952; Talbot, 1966). Striped bass are anadromous, spawning in fresh or virtually fresh water. The eggs are cast into the water, probably near the surface, and are semibuoyant and large (averaging 3.4 mm in diameter, 2.4 - 3.9 mm after water-hardening). Egg diameters are inversely correlated with salinity (Bason, 1971). Hatching occurs 2-3 days (depending upon temperature) after fertilization (48 h at 18.3 C) (Mansueti, 1958; Mansueti and Hollis, 1963). Albrecht (1964) notes the importance of water currents in maintaining striped bass eggs in suspension, notes very low survival rates when eggs settle to the bottom, and states that the minimum current velocity required to maintain eggs in suspension is on the order of 1 ft/sec (= 30.48 cm/sec = .59 kt). Average current conditions in the Chesapeake and Delaware Canal (reported as mean eastward tidal velocity) have been calculated as 56.4 cm/sec in the 27-ft Canal and 69.5 cm/sec in the 35-ft Canal, with average maximum tidal velocities considerably larger (Pritchard and Cronin, 1971). These velocities are more than sufficient to ensure maintenance of striped bass eggs in the water column.

Albrecht (1964) has shown that waters of low salinity may be advantageous to the survival of striped bass eggs, and obtained the greatest hatching success at salinities of 0.948 ppt (chloride), with good hatches and survival in fresh water and in water with salinities to 4.595 - 4.740 ppt, but found a marked decrease in survival in waters of higher salinity. Bottom salinities in the Canal during the period of high river-runoff were reported by Pritchard and Cronin (1971) to vary from 0.11 - 0.27 ppt in the Elk River, to 0.33 ppt at Summit Bridge near the mid-length of the Canal, to 1.45 ppt at Reedy Point at the Delaware mouth of the Canal, and to 2.93 ppt in the channel of the Delaware River at a point 5 miles seaward of Reedy Point. Salinities observed by us during 1971 and 1972 (Table 5) agree well with Pritchard's data. All of these values are well within the range of tolerance reported by Albrecht (1964) for striped bass eggs, and conditions in the Canal approach optima.

There seems to be no doubt that the greatest portion of striped bass spawning activity in the area is located in the Canal. This is based on the consistent high concentrations of striped bass eggs obtained in the Canal (Figs. 3, 4) in 1971 and 1972, and corroborates the data of Dovel and Edmunds (1971). The repeated peak captures of eggs at the western end of the Canal (from about Summit Bridge to the Canal entrance at Sandy Point), limited observations of spawning activity and captures of non-water-hardened eggs, as well as limited input from the results of commercial fishermen, strongly point to this area as the location of maximum striped bass spawning effort in the Canal area.

That the lower Susquehanna River is not important to the production of this species was discussed by Dovel and Edmunds (1971) and is strongly corroborated by our data (Tables 2 and 9). In fact no striped bass eggs were taken at stations S2 and S1 adjacent to the mouth of the Susquehanna River (Fig. 1) in 1971. It can be shown that at these two stations, where no striped bass eggs were taken in 40 hauls (assuming an average of 94.52 m^3/haul) during the period of time that striped bass eggs were taken elsewhere along the transect, that the maximum concentration (at 95% limits) of striped bass eggs at these stations was one (1) egg/1,253 m^3 or one (1) egg/44, 243 ft^3. Actual concentrations of striped bass eggs taken in the Canal during the period of peak spawning (Table 8) were as high as 36 eggs/m^3 and were commonly found to be 10-20 eggs/m^3 over miles of the Canal (including both top and bottom hauls).

Chittenden (1971) has discussed the destruction of the spawning grounds of the striped bass in the lower Delaware River. His work suggests that the striped bass eggs and perhaps the samll juveniles reported by Bason (1971) and Smith (1971) had their origin in the Chesapeake and Delaware Canal.

Although we have attempted to review the literature recording concentrations of striped bass eggs from natural conditions, we have found considerable difficulty in comparing our results with those of others.

In many cases other authors have reported the presence of striped bass eggs in their samples but have provided no means to determine abundance in terms of numbers caught/volume filtered. In cases where such information is present, the nets used were of different shape, size, mesh aperture, etc., making comparisons between efforts approximate at best. The greatest difficulty in comparing our results with those of others is the fact that most previous efforts have been in rivers and the nets were fixed in position, filtering by means of the river current rather than being towed. Estimates have often been presented in terms of numbers of eggs captured/unit time, which in the absence of adequate information on river-current velocity, makes any meaningful attempt at comparison nearly impossible. Reports we have examined include those of Rathjen and Miller (1957:Hudson River), Tresselt (1950, 1952: 4 rivers in Virginia), McCoy (1959:Roanoke River), Humphries (1966:Tar River, N. C.), Erkilla et al. (1950:Sacramento-San Joaquin), Scruggs (1957:Santee-Cooper), May and Fuller (1962:Congaree and Wateree), Murawski (1969:lower Delaware River), and Bason (1971:lower Delaware River and the Canal). We are particularly surprised by the small number of striped bass eggs reported by Bason. In all cases, the concentrations of striped bass eggs observed by us in the Canal remain, to our knowledge, the highest that have been reported.

The foremost question prompting this study, whether or not Canal enlargement will lead to significantly greater advection of striped bass eggs and larvae from the spawning site in the Canal into the Delaware River estuary, and if so, what will be the effect upon the production of this species, cannot be definitively answered at present. Our evidence strongly suggests that most of the striped bass spawning activity in the area occurs in the western portion of the Canal, centered around stations C1 and C2, and there can be no doubt (based on the strong agreement between the results for 1971 and 1972 (Table 10) as well as the remarkable consistency of the data within each sampling year (Tables 1, 6, 7, and 9)) that by far the greatest concentrations of striped bass eggs are in the Canal. We will show in a subsequent paper that this is also true for young striped bass larvae. We need to know the probable direction and speed of advection of a parcel of water in the vicinity of Chesapeake City, Maryland, during the critical time period of late April through early June. If predictions indicate that striped bass eggs in this parcel of water will, on the average, quickly find their way into the Delaware River estuary, we need to know the likelihood of their survival. Since preliminary results seem to indicate that, on the average, eggs spawned near Chesapeake City will quickly (near or soon after the time of hatching) be carried into the Delaware system, and that the prognosis for their survival there is not favorable, we need to know the extent of this drain allowable for successful reproduction of striped bass. Balanced against the hydrographic predictions is the fact that in both sampling years catches of striped bass eggs and small larvae were consistently highest in the Canal, which may suggest that in fact in these two years the eggs hatched and the small larvae remained in the Canal. We have no direct way of separating from estimates of residence time in the Canal the effects of continued recruitment due to continued spawning activity. The evidence provided by the continued consistent peak captures of striped bass larvae in the Canal is partly blunted by the fact that captures of striped bass larvae were at most 1/15 - 1/20 of the captures of striped bass eggs, and to our minds is inconclusive. We certainly feel that continued monitoring of striped bass egg and larvae populations in the area is indicated.

In summary, there seems to be little doubt that construction of the Chesapeake and Delaware Canal has benefited the production of striped bass in Chesapeake Bay. The Canal probably has provided a favorable alternative to the historical and destroyed spawning grounds in the lower Susquehanna River (although our information on the one-time importance of the Susquehanna River to striped bass production is extremely limited). The Canal is a sufficiently favorable area that this manmade channel may be one of the more important spawning and nursery areas for this species. As a spawning and nursery area, the Canal is highly atypical, perhaps unique, in that within the same circumscribed geographic area, striped bass eggs are spawned, hatch, and the early growth of larvae occurs. Typically, striped bass eggs are spawned upstream in a river. The eggs are carried seaward by the current and early growth of the larvae occurs in low salinity estuarine conditions at the mouth of the river. Our data make it not impossible to envision the Canal as a large, artificial but successful, hatchery and nursery for this species. A number of authors have commented upon the adaptability of the striped bass successfully spawning in low energy areas of Chesapeake Bay tributaries as well as in high gradient areas such as the Roanoke Rapids. The apparent success of the striped bass in utilizing the entirely artificial waterway of the C and D Canal to our minds strongly underscores the notion of the adaptability of this species.

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Fig. 1. Location of fish egg and larvae sampling stations in 1971.

Key: S = Susquehanna River E = Elk River

NE = Northeast River C = C & D Canal

CB = Chesapeake Bay PPI = Pea Patch Island

C27, R10, etc., correspond to fixed navigation buoys.

Johnson and Koo - Fig. 1.

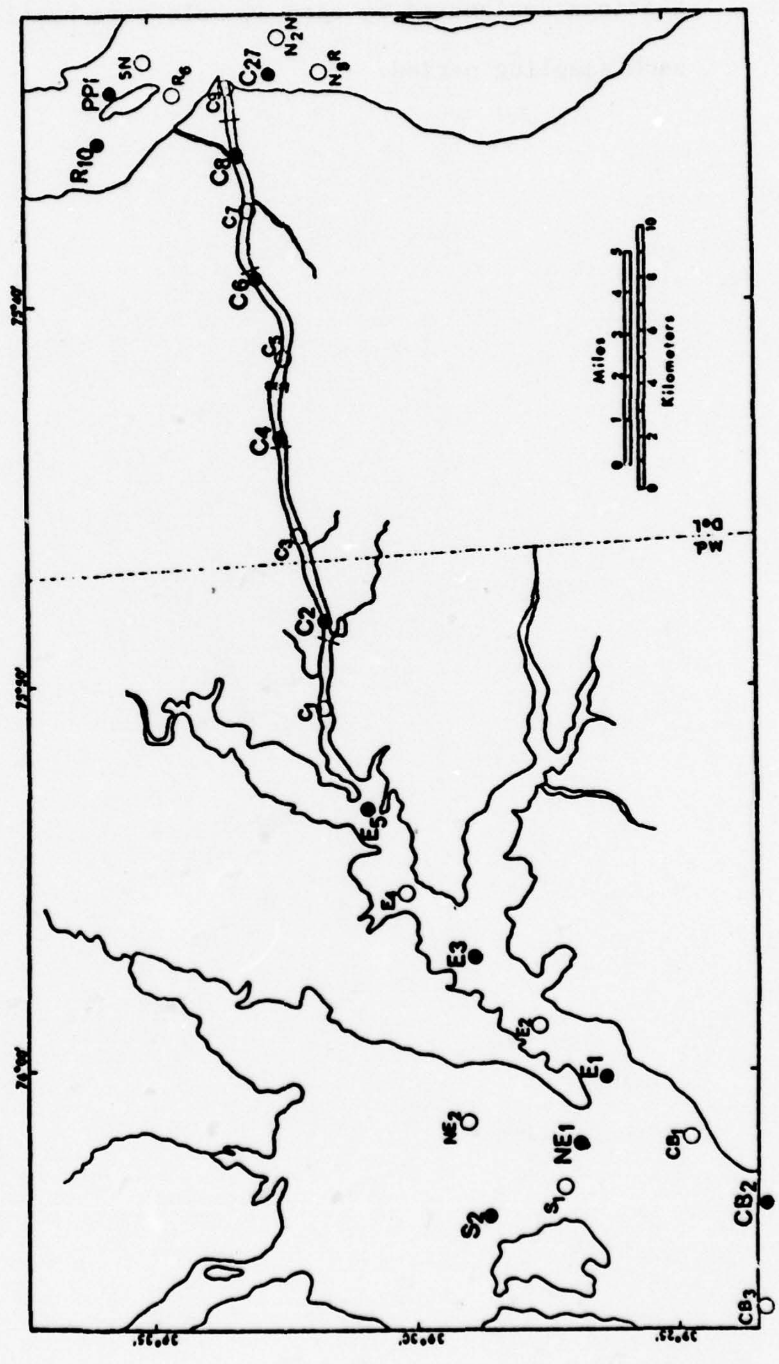


Fig. 2. Location of fish egg and larvae sampling stations in 1972. Stations designated by open symbols were sampled only once each sampling period.

Johnson and Koo - Fig. 2.

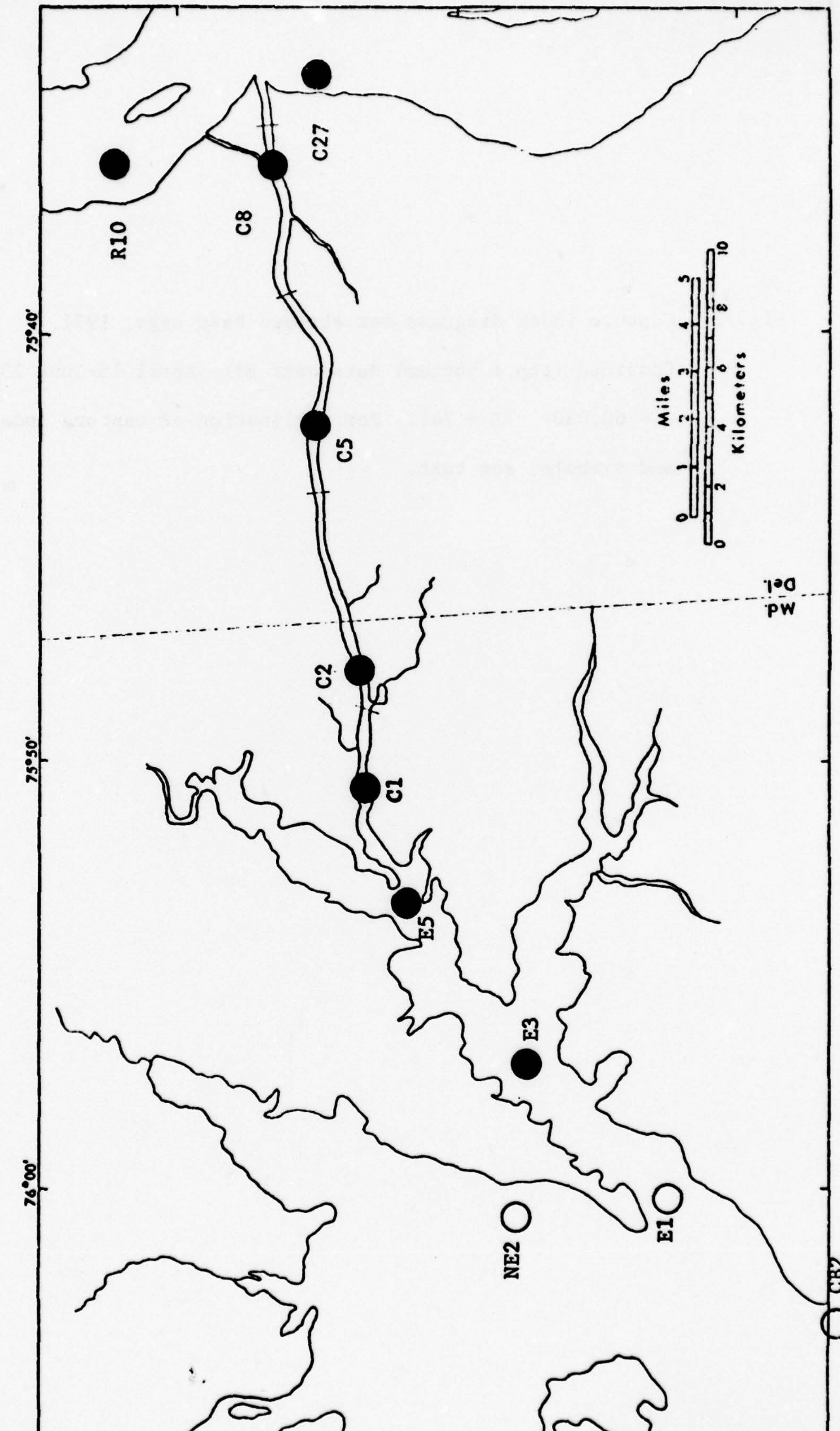
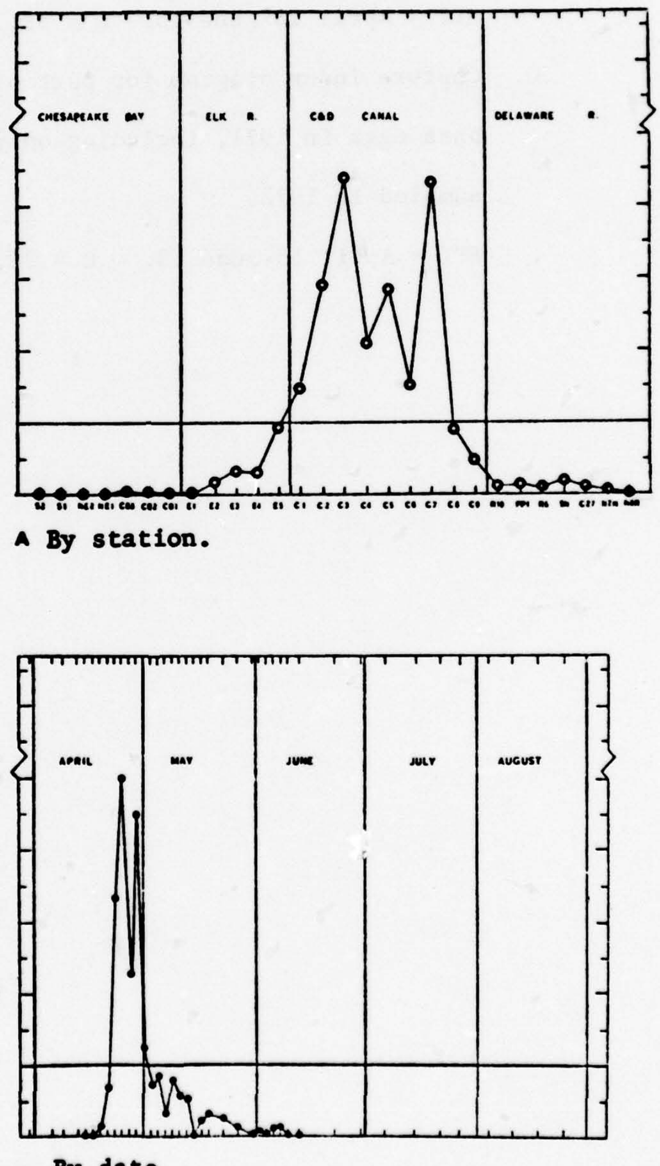


Fig. 3. Capture index diagrams for striped bass eggs, 1971. Combined (top + bottom) data over ETI: April 15-June 13. C = 60,030 E = 747. For explanation of capture index and symbols, see text.

Johnson and Koo - Fig. 3.



A By station.

B By date.

Fig. 4. Capture index diagrams for striped bass eggs, 1971 and 1972.

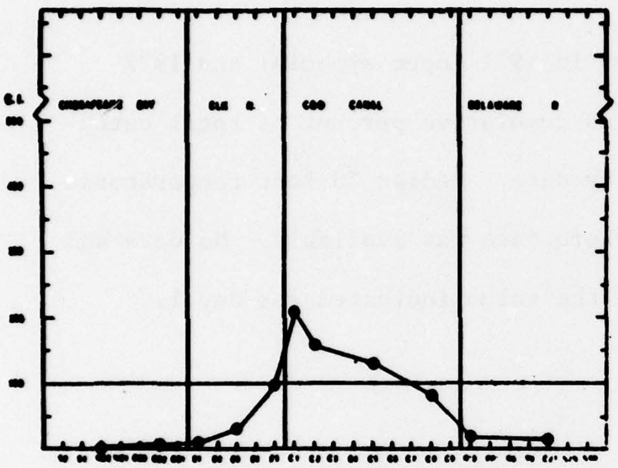
A, B. Catch of striped bass eggs in 1972.

ETI = April 10-June 15. C = 59,159 E = 288

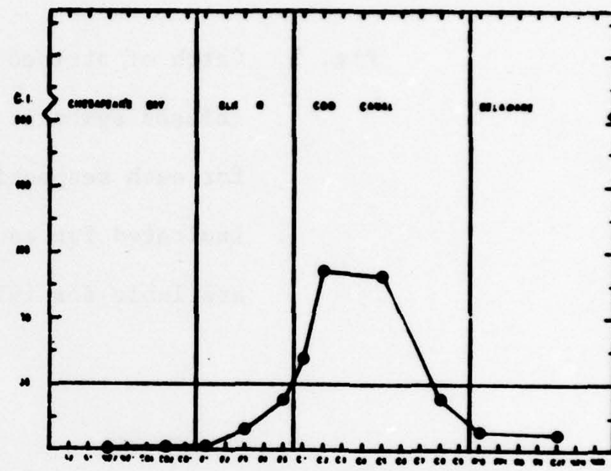
C. Capture index diagram for part of catch of striped bass eggs in 1971, including only those stations also sampled in 1972.

ETI = April 15-June 13. C = 28,062 E = 327

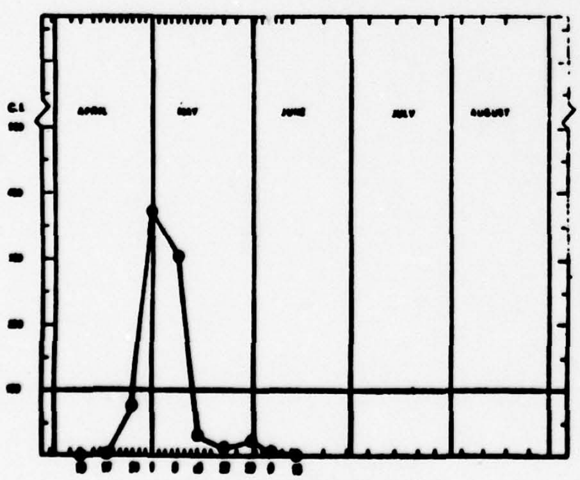
Johnson and Koo - Fig. 4.



A By station, 1972.



C By station, 1971.



B By date, 1972.

Fig. 5. Catch of striped bass eggs in 1971 (open symbols) and 1972 (closed symbols) plotted as cumulative percent of total catch for each respective year by date. Median 20-foot temperatures indicated for each date where data was available. No data was available for 1971 except the value indicated for May 1.

Johnson and Koo - Fig. 5

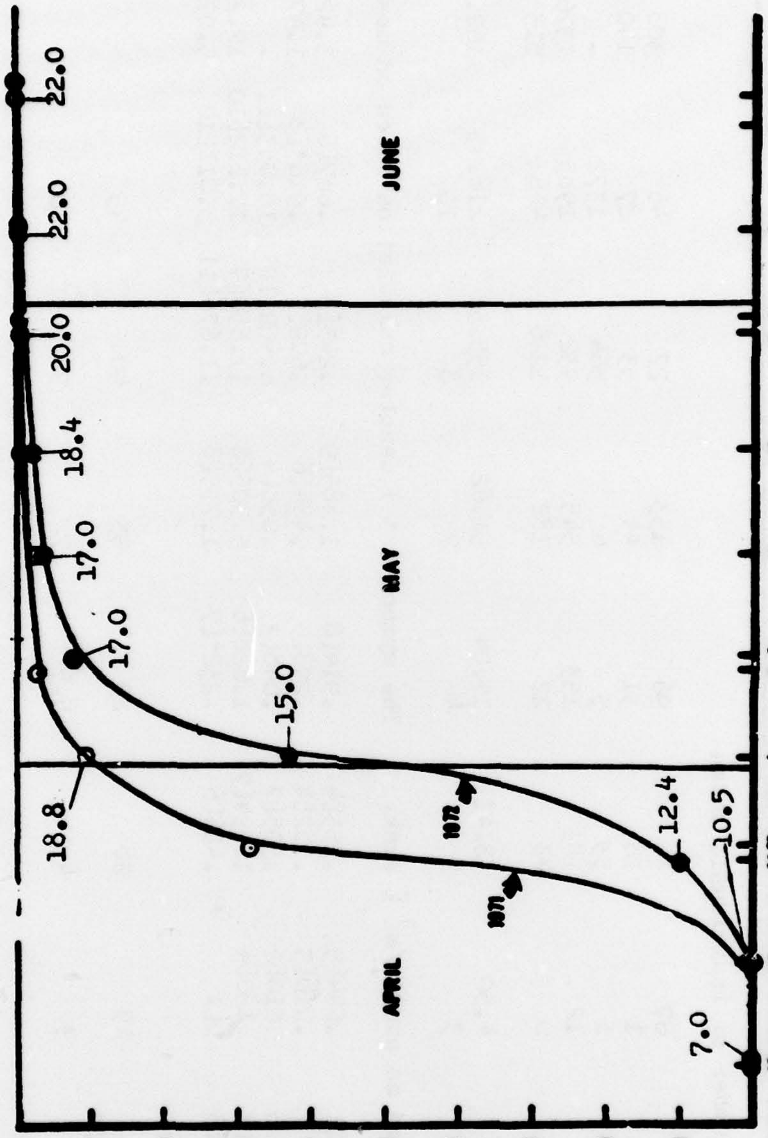


Table 1. Rank-abundance by station of capture of striped bass eggs, 1971. Bottom net hauls only. Dates included: April 23 - May 1.

Date	CB1	E1	E2	E3	E4	E5	C1	C2	C3	C4
A. Raw data: given as number of individuals taken										
23	6	5	67	36	96	153	27	46	308	608
25	1	0	1	18	31	44	53	87	140	236
27	0	11	1	53	5	6	564	1372	-	624
29	10	7	12	183	153	545	932	1985	1376	1226
1	1	10	0	43	22	182	1226	446	513	174
CI(i)	1.00	1.83	4.50	18.48	17.04	51.62	155.51	218.45	162.19	159.17
Rank	1	2	3	5	4	7	8	10		9
B. Catch/effort expressed as number/m^3 [rank. The symbol (•) denotes calculation based on mean value of 94.52										
23	.055[2	.048[1	.644[5	.353[4	.914[8	1.485[9	.245[3	.667[6	3.422	5.961[10
25	.007[2	0[1	.010[3	.182[4	.298[5	.484[6	.609[7	.916•[8	1.474•	2.484•[10
27	0[1	.104[5	.010[2	.505[7	.048[3	.058[4	6.409[10	18.053[11	-	6.000[9
29	.118[3	.069[1	.120[4	1.794[7	1.628[6	5.505[8	11.650[9	17.112[10	17.200	18.299[11
1	.010[2	.093[3	0[1	.426[6	.232•[7	1.733[8	11.676[11	5.011[10	5.079	1.933[9
Sum of Ranks	10	11	15	28	29	35	40	45		49
Rank of Sum	1	2	3	4	5.5	7	9	10		11

Concordance of catch/effort data: $\chi^2_{10} = 32.436$, $p < .005$

Agreement between CI(i) and catch/effort: $tau_{11} = + .800$ $p << .01$

Table 1 (continued)

C5	C6	C7	C8	C9
793	1392	1869	20	63
1405	1375	3444	493	218
358	15	160	-	24
-	-	72	90	6
12	26	33	13	40
178.22	194.88	309.58 11	42.75	19.48 6
m^3 water filtered/tow (no flowmeter data available).				
9.554	16.186	26.700[11	.256	.716[7
14.789*	14.474*	36.253*[11	15.716*	2.290*[9
4.115	.268	2.290[8	-	.312[6
-	-	1.180[5	1.324	.079[2
.138	.310	.333[4	.135	.417[5
		39		29
		8		5.5

Table 2. Capture of striped bass eggs in 1971, raw data. Top and bottom captures (in that order) given for each sampling day.

Date	No. Spec.	S2	S1	HB2	HB1	CB3	CB2	CB1	E1	E2	E3	E4	E5	C1	C2	C3	C4	C5	C6	C7	C8	C9	R10	PP1	R6	SB	C27	[illegible]	[illegible]
April																													
13	6	-	-	-	0	-	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	-	-	-	-	-	-	-
	11	-	-	-	0	-	0	0	0	0	0	0	9	0	0	2	0	0	0	0	0	0	-	-	-	-	-	-	-
17	17	0	-	-	0	0	0	0	0	1	0	5	0	0	0	0	0	1	0	0	0	0	6	-	-	6	0	-	0
	56	0	-	-	0	0	0	0	0	5	0	2	1	0	2	0	0	0	10	1	1	0	20	-	-	11	2	-	1
19	233	0	0	0	0	0	0	0	0	2	0	6	32	40	40	10	6	0	0	4	1	2	9	39	0	27	0	10	0
	676	0	0	0	0	0	0	0	2	1	0	33	106	95	32	1	0	0	1	1	0	0	64	55	30	37	1	6	1
21	921	0	0	0	0	0	0	0	0	1	1	1	91	119	377	227	-	47	30	10	9	0	9	9	4	-	4	-	-
	1391	0	0	0	0	1	0	0	0	51	81	147	309	398	360	131	82	22	6	2	2	2	-	-	0	0	1	-	-
23	3667	-	0	-	0	-	-	0	0	1	0	1	1	0	2	108	142	633	850	1703	156	30	-	-	-	-	-	-	-
	5409	-	0	-	0	-	-	6	5	67	36	96	153	27	46	308	608	793	1392	1869	20	63	-	-	-	-	-	-	-
25	3496	-	-	-	-	-	-	0	0	0	0	1	0	10	14	62	157	696	357	1211	791	199	-	-	-	-	-	-	-
	8546	-	-	-	-	-	-	1	0	1	18	31	44	53	87	140	236	1405	1375	3644	1493	218	-	-	-	-	-	-	-
27	5364	0	0	0	0	0	0	0	0	3	3	0	25	26	2386	1372	762	256	215	151	55	41	12	26	-	-	35	-	0
	3262	6	0	0	0	7	1	0	11	1	53	5	6	564	1372	-	624	358	15	160	-	26	10	3	-	-	48	-	0
29	3564	-	-	0	-	-	-	0	0	0	9	12	83	213	1491	1634	1139	464	190	124	94	46	-	-	-	-	53	10	-
	6663	-	-	2	-	-	-	10	7	12	183	153	545	932	1985	1376	1226	-	-	72	90	6	-	-	-	-	64	0	-
May																													
1	1126	0	-	-	0	-	0	0	1	1	0	1	120	117	281	463	38	28	3	5	29	6	-	33	-	-	12	-	-
	2036	0	-	-	1	-	3	1	10	0	43	22	182	1226	446	513	174	12	26	33	13	40	-	97	-	-	16	-	-
3	306	-	-	-	0	-	-	-	0	3	46	13	25	52	0	26	38	2	3	3	3	-	-	-	-	-	-	-	-
	1365	-	-	-	0	-	-	-	0	86	151	98	299	196	131	-	185	77	74	35	35	-	-	-	-	-	-	-	-
5	290	0	-	0	0	-	-	-	2	0	4	-	10	127	0	94	-	0	62	21	-	-	-	-	-	-	-	-	-
	1676	0	-	0	0	-	-	-	0	0	0	-	31	163	17	713	99	350	175	78	18	12	-	-	-	-	-	-	-
7	473	0	0	0	0	0	0	0	1	0	0	0	0	0	26	68	279	32	22	11	6	-	2	6	-	-	6	-	-
	668	0	0	0	0	26	11	0	0	0	125	4	82	21	182	-	136	1	0	4	16	-	3	6	-	-	13	-	-
9	788	0	-	-	0	-	-	2	0	3	5	5	19	20	19	303	61	-	19	37	20	115	-	-	-	-	0	-	-
	1460	0	-	-	0	-	-	7	0	29	73	9	98	33	176	781	158	-	76	22	4	2	-	-	-	-	0	-	-
11	316	0	0	-	0	-	0	-	0	3	4	-	5	-	168	84	17	-	30	-	1	-	3	1	-	-	0	-	-
	1140	0	0	-	7	-	4	-	17	176	216	-	401	-	155	-	131	-	29	-	2	-	0	1	-	-	1	-	-
13	203	-	-	-	0	-	-	-	0	0	0	0	129	66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	379	-	-	-	0	-	-	-	0	16	11	107	83	160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	5	-	-	-	0	-	0	-	0	-	0	1	3	0	0	-	0	-	0	-	1	-	-	-	-	-	-	-	-
	9	-	-	-	0	-	0	-	0	-	0	0	0	9	0	-	-	-	0	-	0	-	-	-	-	-	-	-	-
17	43	-	-	-	-	-	-	-	-	-	32	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	67	-	-	-	-	-	-	-	16	7	-	22	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	253	0	-	-	0	-	0	-	0	-	11	-	90	-	73	-	33	-	0	-	5	-	0	0	-	-	5	-	-
	666	0	-	-	0	-	0	-	1	-	40	80	110	-	50	-	29	-	0	-	4	-	56	14	-	-	28	-	-
23	187	0	-	-	0	-	0	-	0	-	0	-	13	-	22	-	99	-	26	-	20	-	6	1	-	-	-	-	-
	290	0	-	-	0	-	0	-	1	-	0	-	33	-	72	-	92	-	67	-	9	-	15	-	-	-	1	-	-
27	33	0	-	-	1	-	0	-	0	-	0	-	14	-	2	-	14	-	0	-	-	-	0	0	-	-	0	-	-
	165	0	-	-	2	-	0	-	3	-	3	-	19	-	47	-	61	-	26	-	-	-	1	-	-	-	5	-	-
31	0	0	-	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	0	-	-	0	-	-
	2	0	-	-	2	-	0	-	0	-	-	-	0	-	-	-	-	-	0	-	0	-	0	0	-	-	0	-	-
June																													
2	13	-	-	-	-	-	-	-	-	-	-	0	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	25	0	-	-	0	-	0	-	1	-	0	0	1	4	2	-	4	-	1	-	2	-	3	2	-	-	3	-	-
	43	0	-	-	0	-	1	-	1	-	1	6	4	0	9	0	7	-	5	-	5	-	3	-	-	-	1	-	-
6	16	-	-	-	-	-	-	-	-	-	-	11	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	0	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	107	-	-	-	0	-	-	-	2	-	0	-	90	6	7	-	25	-	31	-	18	-	-	0	-	-	0	-	-
	36	-	-	-	2	-	-	-	1	-	0	-	0	4	7	-	0	-	0	-	0	-	-	1	-	-	1	-	-
10	0	-	-	-	-	-	-	-	-	-	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	0	-	-	-	-	-	-	-	-	-	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	1	-	-	-	0	-	-	-	0	-	1	-	0	-	0	-	0	-	0	-	0	-	-	-	-	-	-	-	-
	0	-	-	-	0	-	-	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	-	-	-	-	-	-	-
Totals:																													
Top	23329	0	0	0	1	0	0	2	5	18	116	66	777	813	4012	4511	2886	2167	1827	3200	1211	461	31	106	4	31	126	20	3
Bot	30701	0	0	2	14	32	28	31	91	430	1004	829	2631	3900	5076	3903	3034	3010	3275	5721	1712	367	174	177	38	40	102	6	2

Table 3. Comparison of capture, top net vs bottom net, by date.
Striped bass eggs: N = 60030. ETI: 15 April - 13 June, 1971.

Date	CI(i) Top	R	CI(i) Bottom	R
15	.38	3	.65	3
17	1.20	5	2.45	5
19	14.64	10	17.02	12
21	67.83	21	66.65	17
23	347.60	24	324.63	24
25	377.64	25	572.82	26
27	346.36	23	142.60	22
29	500.85	26	418.70	25
1	91.22	22	143.68	23
3	23.84	11	105.57	21
5	36.15	17	105.32	20
7	33.32	15	29.61	14
9	67.48	20	86.82	19
11	32.00	18	76.41	18
13	46.99	19	54.44	16
15	.74	4	.90	4
17	34.84	16	16.84	11
19	31.53	14	32.03	15
23	25.25	12	24.97	13
27	4.46	7	15.08	10
31	0	1	.20	2
2	10.53	8	3.02	6
4	2.70	6	3.09	7
6	11.34	9	6.03	9
8	27.55	13	3.29	8
13	.20	2	0	1

Tau = +.806 $p < .01$

June 10 (no striped bass eggs captured) omitted

Johnson and Koo - Table 4

Table 4. Comparison of capture, top net vs bottom net, by station, over ETI (April 15 - June 13, 1971). Striped bass eggs: N = 60030.

Station	CI(i) Top	R	CI(i) Bottom	R
NE2	0	2.5	.34	1
NE1	.08	5	.67	3
CB3	0	2.5	6.43	8
CB2	0	2.5	2.01	4
CB1	.29	6	2.83	5
E1	.35	7	3.81	7
E2	1.94	8	28.78	14
E3	7.83	11	48.63	17
E4	7.16	10	43.87	16
E5	54.74	17	115.01	19
C1	65.87	18	196.46	22
C2	361.77	24	242.93	23
C3	522.08	26	398.65	25
C4	227.33	22	193.75	21
C5	292.60	23	275.85	24
C6	134.56	21	164.64	20
C7	408.81	25	442.46	26
C8	98.11	20	90.59	18
C9	74.70	19	33.54	15
R10	8.26	12	17.49	10
PPI	15.61	14	22.24	13
R6	3.24	9	19.10	12
N5	25.11	16	16.09	11
C27	14.58	[illegible]	12.20	9
N2N	16.20	15	3.02	6
N8R	0	2.5	.67	2

Tau = +.738 $p < .01$

S2,S1 (no striped bass eggs captured) omitted.

Table 58 Temperature (°C.) and salinity (in conductivity, millimhos/cm) data collected in 1972. Station positions shown in Figs. 1 and 2. Values given for 1 and 20' depths in that order.

Date	Temperature						Conductivity					
	NE2	E1	E5	C1	C5	C27	NE2	E1	E5	C1	C5	C27
March 27	-	6.1	6.2	-	6.1	6.5	-	0.6	0.6	-	0.7	0.9
	-	5.8	6.0	-	6.0	5.5	-	0.6	0.6	-	0.7	0.9
April 3	7.1	7.0	7.6	7.9	7.1	7.0	0.6	0.8	0.7	0.7	0.8	1.2
	-	7.0	7.5	7.2	7.5	7.0	-	0.7	0.7	0.7	0.8	1.2
April 10	6.9	5.9	7.0	7.0	7.5	7.0	0.6	0.6	0.8	0.8	0.8	2.3
	6.7	5.9	7.0	7.0	7.1	7.5	0.6	0.6	0.8	0.8	0.9	4.4
April 17	-	11.8	10.9	11.8	11.8	11.1	-	0.6	1.4	1.6	2.6	2.2
	-	10.0	10.9	10.5	9.5	10.5	-	0.6	1.4	1.7	2.7	2.1
April 24	11.8	12.0	12.6	12.0	12.2	12.0	0.6	0.6	0.8	0.8	1.0	0.6
	11.8	11.8	12.9	12.5	12.7	12.2	0.6	0.6	0.8	0.8	1.0	0.7
May 1	-	15.2	15.8	16.0	-	-	-	0.5	0.7	0.7	-	-
	-	14.0	15.0	15.0	-	-	-	0.5	0.7	0.7	-	-
May 8	18.0	17.9	18.4	17.9	17.5	17.0	0.6	0.6	0.6	0.6	0.6	0.7
	17.1	17.0	17.4	18.0	17.0	16.5	0.6	0.6	0.6	0.6	0.6	0.7
May 15	16.0	16.2	18.0	17.5	17.0	17.0	0.6	0.6	0.6	0.6	0.8	0.8
	15.5	15.5	18.0	17.0	17.0	17.0	0.6	0.6	0.6	0.6	0.6	0.3
May 22	19.2	18.5	19.0	19.0	-	-	0.6	0.6	0.7	0.7	-	-
	18.2	18.2	18.5	18.5	-	-	0.6	0.6	0.7	0.7	-	-
May 30	21.5	20.0	20.0	21.0	20.0	19.0	0.6	0.8	1.2	1.4	1.6	2.2
	21.0	20.0	20.0	20.0	19.0	19.0	0.6	0.8	1.2	1.2	1.6	3.2
June 6	22.5	22.0	21.5	21.0	21.0	21.5	0.6	0.6	0.8	0.8	0.8	0.6
	23.0	22.0	22.0	22.0	21.0	22.0	0.6	0.6	0.8	0.9	0.8	0.6
June 15	-	21.0	22.0	22.0	22.0	22.5	-	0.6	0.6	0.6	0.6	1.2
	-	21.0	22.0	22.0	22.0	21.5	-	0.6	0.6	0.6	0.6	1.2
June 28	-	-	18.0	19.0	20.0	20.8	-	-	0.5	0.6	0.6	0.6
	-	-	17.9	18.6	19.0	19.9	-	-	0.6	0.6	0.6	0.6

Johnson and Koo - Table 5

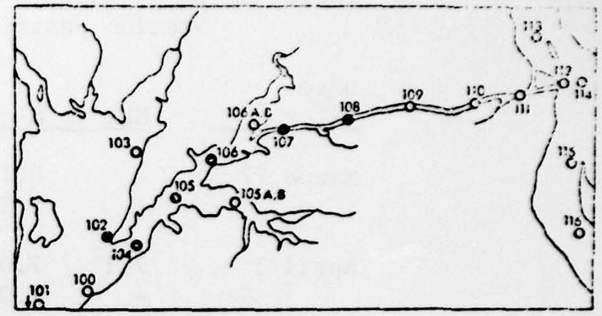


Table . Temperature (°C.) and salinity (ppt) data collected in 1971. Station positions shown in figure at right. Values for surface and bottom, in that order, given for each station.

Date	Temperature						Salinity					
	102	104	105	106	107	108	102	104	105	106	107	108
March 2	4.9	-	-	4.8	-	-	-	-	-	-	-	-
	4.8	-	-	4.9	-	-	-	-	-	-	-	-
April 1	7.6	8.9	-	-	-	6.6	0.5	0.5	-	-	-	1.4
	7.4	8.2	-	-	-	6.5	0.5	0.4	-	-	-	1.6
May 1	-	-	20.5	19.9	21.9	18.5	-	-	0.5	0.9	1.5	2.1
	-	-	18.8	18.3	20.2	17.5	-	-	0.4	1.4	1.6	2.1
June 22	-	-	29.3	30.2	27.0	26.3	0.9	0.9	1.2	1.7	1.7	2.1
	-	-	28.1	28.0	26.3	25.5	1.0	1.1	1.1	1.7	1.8	2.1
July 12-14	-	-	27.2	27.6	28.0	27.5	-	-	1.1	2.1	2.2	5.7
	-	-	27.0	27.2	27.5	27.5	-	-	1.0	3.9	4.4	5.4
Aug. 30-31	-	-	-	-	28.2	24.8	0.9	1.1	-	-	1.2	1.2
	-	-	-	-	26.9	24.6	1.1	1.4	-	-	1.3	1.3
Sept. 20-22	-	-	-	27.2	-	25.3	-	-	-	-	-	-
	-	-	-	27.1	-	26.4	-	-	-	-	-	-
Oct. 26-27	17.7	17.9	17.8	17.5	18.0	17.9	1.9	3.3	3.1	2.9	2.2	2.6
	18.0	18.2	17.9	17.8	17.8	18.0	4.7	6.8	5.6	3.3	4.4	2.7
Dec. 6 -7	2.3	3.4	4.5	3.8	4.6	4.6	0.3	1.1	1.4	1.1	1.1	1.2
	2.8	3.9	4.5	4.0	4.3	4.8	0.6	2.4	1.3	1.0	1.3	1.2

Table 6. Calculation of concordance for striped bass egg data, 1971. Ranks given in this table are based on raw data given in Table 2, and represent the rank of the combined (top + bottom) capture at a given station with respect to every other station sampled on that date. Dates include: April 23 - May 1. Some stations could not be indluded due to blank (no available sample) data values.

Date	Number Taken	CB1	E1	E2	E3	E4	E5	C1	C2	C3	C4	C5	C6	C7	C8	C9
		(rank-abundance by station)														
23	9136	14	15	10	12	9	7	13	11	5	4	3	2	1	6	8
25	12042	13.5	15	13.5	12	11	10	9	8	7	6	3	4	1	2	5
27	8466	15	12	14	9	13	11	5	1	2	3	4	7	6	10	8
29	12098	14	15	13	8	11	5	4	1	2	3	6	9	7	10	12
1	3822	14.5	13	14.5	7	12	4	1	3	2	5	9	11	10	8	6
Sum of ranks		71	70	65	48	56	37	32	24	18	21	25	33	25	36	39
$R(i)^2$		5041	4900	4225	2304	3136	1369	1024	576	324	441	625	1089	625	1296	1521
$D(i)$		31	30	25	8	16	3	8	16	22	19	15	7	15	4	1
$D(i)^2$		961	900	625	64	256	9	64	256	484	361	225	49	225	16	1

$m = 5 \quad n = 15$ Expected sum of ranks, $Re(i) = ((m*n*(n+1))/2)/n = 40$ $\quad D(i) = |Re(i) - R(i)|$

Concordance, $W_{m,n} = (12*\Sigma D(i)^2)/(m^2 * n * (n^2 - 1))$

$$= \frac{12\ (4496)}{25(15)(224)} = .642 \quad p < .01$$

Chisquare, $\chi^2_{(n-1)} = ((12 * \Sigma R(i)^2)/(m*n*(n+1))) - (3*m*(n+1))$

$$= \frac{12 * 23496}{5 * 15 * 16} - 3*5*16 = 44.96 \quad p << .01$$

Table 7. Calculation of concordance for pooled striped bass egg data, 1971. Data given in this table are based on combined (top + bottom) data summed within each zone for each date. Effort is the total number of hauls within each zone for each date. Data taken from Table 2. Dates included: April 23 - June 8. Stations included in zones: Chesapeake Bay (S2,S1,NE2,NE1, CB3, CB2,CB1); Elk River (E1,E2,E3,E4,E5); C&D Canal (C1,C2,C3,C4,C5, C6,C7,C8,C9); Delaware River (R10,PPI,R6,N5,C27,N2N,N8R).

A. Raw data: given as capture(effort for each zone for each date.

Date	N	Chesapeake Bay	Elk River	C&D Canal	Delaware River
17	73	0(10	14(10	15(18	44(8
19	727	0(14	190(10	250(18	287(14
21	2512	1(14	770(10	1724(17	7(5
27	8606	8(14	107(10	8359(16	132(8
29	12227	12(4	1004(10	11084(16	118(4
1	3984	5(8	388(10	3433(18	158(4
7	1121	41(14	236(10	808(15	36(6
9	2176	9(6	241(10	1926(16	0(2
11	1456	11(8	822(8	617(9	6(6
19	699	8(6	357(7	222(8	113(6
23	485	0(6	55(6	407(8	23(4
27	198	3(6	41(6	148(6	6(5
4	68	1(6	14(8	39(10	14(5
8	223	2(6	113(6	106(10	2(6
$\sum$=	34537(511	101(122	4352(121	29138(185	946(83

B. Capture indices: given as CI(i)(rank for each zone for each date.

Date	Chesapeake Bay	Elk River	C&D Canal	Delaware River
17	0(1	88.22(3	52.51(2	346.58(4
19	0(1	146.36(3	106.99(2	157.91(4
21	.13(1	141.57(3	186.45(4	2.57(2
27	.32(1	5.97(2	291.39(4	9.20(3
29	.83(1	27.94(3	192.78(4	8.21(2
1	.63(1	38.96(2	191.49(4	39.66(3
7	11.76(1	94.74(3	216.24(4	24.09(2
9	2.34(2	37.66(3	188.09(4	0(1
11	2.93(2	218.77(4	145.96(3	2.13(1
19	5.14(1	196.71(4	107.04(3	72.64(2
23	0(1	45.36(3	251.75(4	28.45(2
27	5.81(1	79.38(3	286.53(4	13.94(2
4	7.11(1	74.63(2	166.32(4	119.41(3
8	4.19(1	236.47(4	133.09(3	4.19(2

$W_{14,4} = .622$ $p < .01$ $\chi^2_3 = 26.143$ $p < .005$

Johnson and Koo - Table 8 [Note values (based on average of 94.52) to be added (1) = .011 (2) = .105 (3) = .011
(4) = .232 (5) = .349 (6) = 1.052 (7) = .169. Part A must be completely retyped]

Table 8A. Calculated concentrations of striped bass eggs during period of peak capture, April 23 - May 1, 1971. Expressed as number of eggs / m^3 water filtered. This period accounted for 76.63% of the total catch of striped bass eggs in 1971. Given as results for top and bottom hauls, in that order, for each date.
Key: (-) no available sample (*)calculation based on mean value of 94.52 m^3 water filtered/ tow (no flowmeter data available)

Date	Number Taken	S2	S1	NE2	NE1	CB3	CB2	CB1	E1	E2	E3	E4	E5	C1	C2	C3	C4	C5	C6	C7	C8	C9	R10	PP1	C27	N2N
April 23	3647	-	0	-	0	-	-	0	0	.009	0	.009	.009	0	.025	1.161	1.392	6.549	9.341	21.833	1.902	.532	-	-	-	-
	3489	-	0	-	0	-	-	.055	.048	.644	.353	.914	1.485	.245	.667	3.422	5.961	9.554	16.186	26.700	.256	.716	-	-	-	-
25	3496	-	-	-	-	-	-	0	0	0	0	F [1]	0	F [2]	.184	.838	1.915	8.361	4.890	13.163	10.547	2.584	-	-	-	-
	8546	-	-	-	-	-	-	.007	0	.010	.182	.290	.484	.609	.916*	1.474*	2.484*	14.789*	14.474*	36.253*	15.716*	2.290*	-	-	-	-
27	5344	0	0	0	0	0	0	0	0	.028	.029	0	.225	.226	26.511	15.077	8.940	2.753	2.416	1.716	.611	.461	.130	.264	.376	-
	3262	0	0	0	0	.071	F [3]	0	.104	.010	.505	.048	.058	6.409	18.053	-	6.000	4.115	.268	2.290	-	.312	.084	.036	.676	-
29	5564	-	-	0	-	-	-	0	0	0	.085	.115	.755	1.919	15.531	16.845	11.277	4.017	2.065	1.319	.959	.426	-	-	.457	.118
	6663	-	-	.019	-	-	-	.118	.069	.120	1.794	1.628	5.505	11.650	17.112	17.200	18.299	-	-	1.180	1,324	.079	-	-	.598	0
May 1	1126	0	-	-	0	-	0	0	.009	.009	0	.010	1.196	1.045	3.345	4.475	.447	.350	.035	.059	.349	.083	-	F [5]	.128	-
	2858	0	-	-	.013	-	.029	.010	.093	0	.426	F [4]	1.733	11.676	5.011	5.079	1.933	.138	.310	.333	.135	.417	-	F	F	-

Table 8B. Calculated concentrations of striped bass eggs during period of peak capture, May 1 - 2, 1972. Expressed as number of eggs / m^3 water filtered. Data for A and bottom nets only.

Time	Net	NE2	CB2	E1	E3	E5	C1	C2	C5	C8	R10	C27
1200-1800	A	-	-	-	-	-	1.14	13.77	18.66	9.15	0.27	0.16
1800-2400	A	-	-	-	0.17	10.41	7.93	2.40	13.43	8.70	-	-
2400-0600	A	-	-	-	0.15	5.06	6.06	14.89	5.49	13.23	-	-
0600-1200	A	-	-	-	-	13.41	8.99	-	9.80	2.07	1.48	0.18
1200-1800	Bot	-	-	0.04	0.15	5.80	22.42	14.18	19.94	15.68	4.76	2.90

Johnson and Koo - Table 9

Table 9. **Rank-abundance by station of capture of striped bass eggs, 1972. A+bottom net hauls. Data summed over ETI: April 10 - June 15 but calculation of concordance based on data from April 17 - June 7 inclusive. These 7 sampling dates accounted for 99.998% of the striped bass eggs taken in 1972 and the 8 stations included accounted for 99.78% of the striped bass eggs taken on these 7 dates.**

Date	Number	NE2	CB2	E1	E3	E5	C1	C2	C5	C8	R10	C27
A. Raw data: given as capture(effort for each station for each date.												
10-11*	0(18	0(1	0(1	0(1	0(2	0(2	0(2	0(2	0(2	0(2	0(2	0(1
17-18	1(35	0(1	0(1	0(1	0(5	0(4	0(5	0(5	0(5	0(4	1(2	0(2
24-25	5675(36	-	-	7(1	278(5	1156(8	1208(6	1314(4	812(4	576(4	162(2	162(2
1-2	32011(42	0(1	0(1	4(1	46(3	5139(7	9579(9	5580(5	6310(5	4478(5	439(3	436(2
8-9	16911(27	-	-	89(1	1421(2	1673(4	6935(7	4712(7	1823(3	88(1	152(1	18(1
15-16	2328(35	0(1	9(1	11(1	156(4	290(4	671(4	828(4	218(4	76(4	55(4	14(4
22-23	867(36	-	-	0(1	251(6	237(6	139(5	115(5	107(5	2(4	5(2	11(2
30-31	1255(29	-	-	11(1	157(4	185(4	265(4	255(4	243(4	133(4	6(2	0(2
6	110(6	-	-	-	28(2	29(2	32(2	14(2	6(2	1(2	0(2	0(2
15	1(14	-	-	0(1	0(2	0(2	0(1	1(2	0(2	0(2	0(1	0(1
B. Ranks of resulting capture indices for selected stations for selected dates.												
24-25					1	4.5	6	8	7	4.5	2.5	2.5
1-2					1	4	6	7	8	5	2	3
8-9					7	4	8	6	5	2	3	1
15-16					3	6	7	8	5	4	2	1
22-23					8	7	6	5	4	1	2	3
30-31					4	5	8	7	6	3	2	1
6					6	7	8	5	4	3	1.5	1.5

***the single striped bass egg taken on April 10 was taken in a B net haul.**

$W_{7,8} = .635$ $p < .01$ $X^2_7 = 31.11$ $p < .005$

Table 10 . Part A. Comparison of captures of striped bass eggs in 1971 and 1972 by station. Data given are capture(effort by station summed over ETI (1971 data = combined top+ bottom; 1972 data = A+bottom).

Station	1971 Capture(Effort	Rank of CI(i)	1972 Capture(Effort	Rank of CI(i)
NE2	2(12	1	0(4	1
CB2	28(28	2	9(4	2
E1	96(47	3	122(9	3
E3	1180(46	6	2337(35	6
E5	3408(46	7	8709(43	8
C1	4721(40	9	18829(45	11
C2	9986(43	11	12819(40	10
C5	5185(23	10	9519(36	9
C8	2923(39	8	5354(32	7
R10	225(20	5	820(21	5
C27	308(29	4	641(19	4
Totals	28062(327		59159(288	

$Tau_{11} = +.891$ $p < .01$

Table 10. Part B. Comparison of striped bass egg captures in 1971 and 1972 by date. Data presented and collected as in part A. April 9 - June 15.(Dates in parentheses apply only to 1972)

Date	1971 Capture(Effort	Rank of CI(i)	1972 Capture(Effort	Rank of CI(i)
9	0(28	1		
10-11			0(18	1
17 (-18)	73(46	5	1(35	2
(24-) 25	12042(30	10	5675(36	8
1 (-2)	3984(40	9	32011(42	10
7	1121(45	8		
8-9			16911(27	9
15 (-16)	14(21	4	2328(35	7
(22-) 23	485(24	7	867(36	5
(30-) 31	2(23	3	1255(29	6
6	20(3	6	110(16	4
13	1(14	2		
15			1(14	3
Totals	17742(274		59159(288	

$Tau_{10} = +.600$ $p = .02$