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ABUNDANCE AND VIABILITY OF STRIPED BASS EGGS SPAWNED IN THE ROANOKE RIVER, NORTH CAROLINA IN 1991

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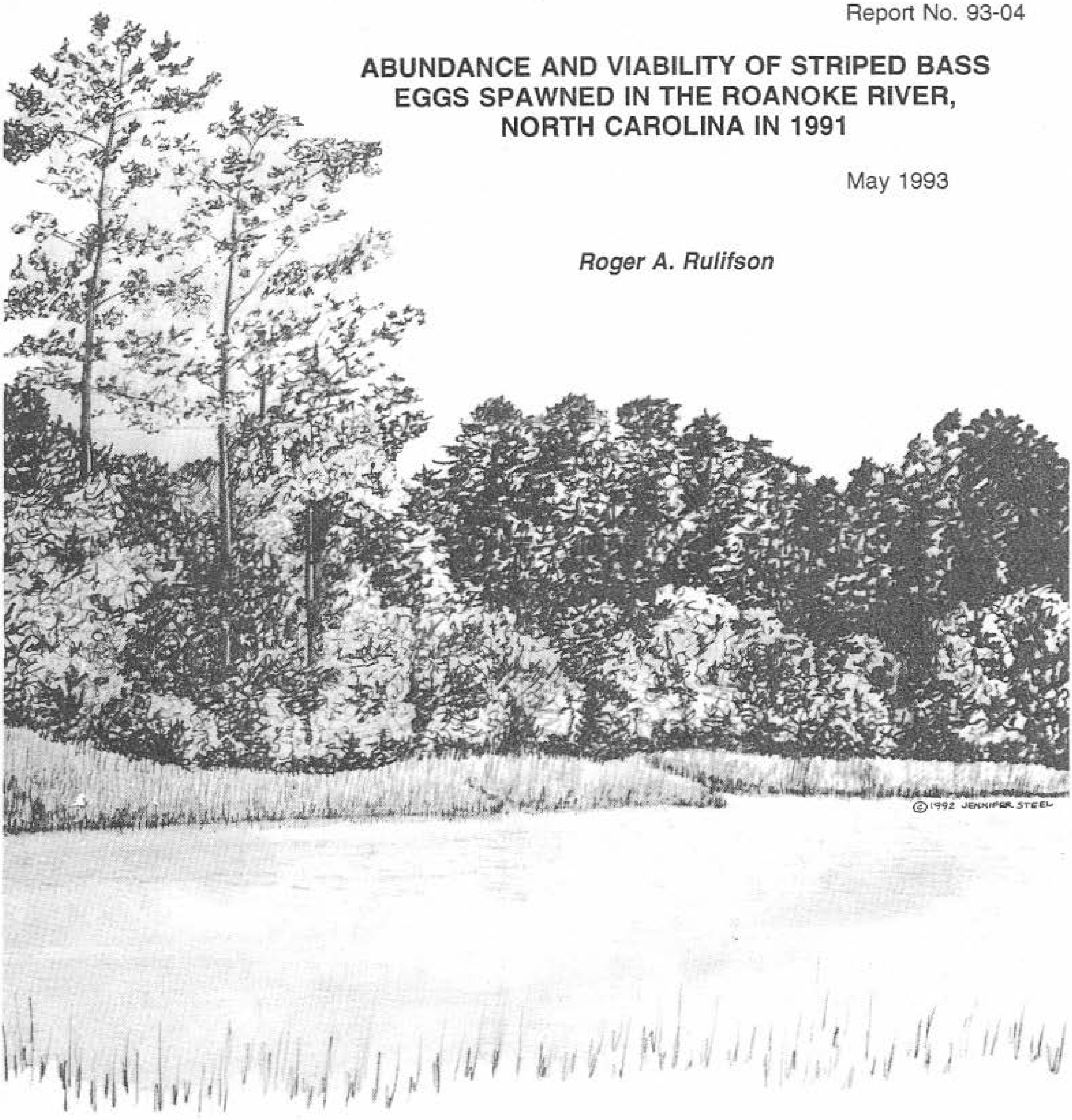
Roger A. Rulifson



ALBEMARLE-PAMLICO ESTUARINE STUDY

NC Department of
Environment, Health,
and Natural Resources

Environmental
Protection Agency
National Estuary Program

ABUNDANCE AND VIABILITY OF STRIPED BASS EGGS SPAWNED IN THE ROANOKE RIVER, NORTH CAROLINA, IN 1991

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EXECUTIVE SUMMARY

Striped bass spawning activity in the Roanoke River, North Carolina, was documented in 1991 by sampling for eggs at Barnhill's Landing (River Mile 117), which is just downstream of the spawning grounds between the towns of Halifax (RM 120) and Weldon (RM 130). Egg sampling was conducted every four hours near the surface and bottom from 15 April to 14 June. Water quality and changes in instream flow caused by water releases from Roanoke Rapids Reservoir at RM 137 also were monitored every four hours. Results were compared to similar studies funded by the Albemarle-Pamlico Estuarine Study during the springs of 1988, 1989, and 1990. Objectives were: 1) to continue the uninterrupted egg study data base of W.W. Hassler beginning in 1959; 2) to identify potential sources of bias in Hassler's egg production estimates; and 3) relate striped bass spawning activity to operation of the Roanoke Rapids hydroelectric dam upstream.

EGG PRODUCTION. The estimated number of striped bass eggs spawned in the Roanoke River in 1991 was 1.835 billion $\pm$65.787 million from a total of 10,467 eggs collected in surface nets. Spawning prior to 15 April, or after 14 June, was not monitored. The 1991 estimate is the highest observed at Barnhill's Landing since 1975. Estimated egg viability for the season was 55.4%, with no seasonal trend in viability evident. Most eggs drifting past Barnhill's Landing were less than 10 hours old.

SPAWNING EVENT MILESTONES. A 57-day spawning window was observed in 1991. The continuous spawning period of 41 days was longer than in 1988 (27 days) and 1989 (23 days), but shorter than 1990 (50 days). Eggs first appeared on 17 April. Seasonal egg production was 50% completed by 13 May, 75% completed by 15 May, and 90% completed by 25 May. The last eggs were collected on 12 June. Three spawning peaks were observed: 8-9 May (20% of total eggs), 11-12 May (17%), and 14 May (19%).

USING RIVER VOLUME TO ESTIMATE EGG PRODUCTION. Hassler's daily egg production estimates were made by a mathematical formula that used the average cross-sectional area of the river and average number of eggs collected every three hours in surface waters within five minutes. Daily egg production estimates also were calculated substituting river volume for cross-sectional area so that the two methods could be compared. Substituting river volume for cross-sectional area may be valuable only when major spawning activity occurs during high instream flow periods. Under these conditions, Hassler's method may underestimate the number of eggs produced. To perform this substitution requires additional measurements of environmental conditions, and several assumptions about the nature of these variables. Since an unquantifiable number of eggs is transported to the floodplain under flooding conditions, either method will underestimate egg production during the flooding event.

EFFECTS OF SAMPLING LOCATION. Since 1959, four sampling locations were used in the Hassler studies: Palmyra (RM 78.5), Halifax (RM 121), Barnhill's Landing (RM 117), and Johnson's Landing (RM 118). Results of the 1991 Barnhill's Landing study and a

concurrent study at Jacob's Landing (RM 102) indicate that annual egg production estimates will be statistically similar within a 20-mile reach downstream of the spawning grounds, but egg viability estimates will be different at each sampling location. Sampling too close to, or too far away from, the spawning grounds will overestimate egg viability. The best location to estimate overall egg viability is the Barnhill's Landing area.

WATER TEMPERATURES AND SPAWNING. Water temperatures on the spawning grounds can be lowered by naturally-occurring cold fronts, but also by man-caused water releases from Roanoke Rapids Reservoir. Major spawning activity begins after water temperatures reach 18°C. Early season water releases from the reservoir can delay spawning. Cold fronts or water releases occurring after spawning is initiated can cause spawning to cease if water temperatures drop below 18°C for prolonged periods; spawning activity resumes after the river returns to at least 18°C. The resulting pattern of springtime water temperatures dictates the period of peak spawning. The second week in May is the usual expectation of peak spawning activity, but the peak can be earlier or as late as Memorial Day.

WATER QUALITY AND EGG VIABILITY. Egg viability observed at Barnhill's Landing does not appear to be a function of environmental conditions in general, so other factors may be involved in influencing egg viability. Water quality farther downstream may play an important role in hatching success and larval survival.

MANAGEMENT IMPLICATIONS. Striped bass spawning activity can be manipulated by water releases from Roanoke Rapids Reservoir upstream. The spawning window is much longer than is currently considered by the power company, the U.S. Army Corps of Engineers, and the North Carolina Wildlife Resources Commission for management purposes. No information is available concerning which spawning period(s) make the greatest contribution to successful hatching and subsequent recruitment of young-of-year. Therefore, instream flow should be managed to mimic the historical flows as much as possible over the longest period of time possible (first of April to end of June). This management action includes providing adequate instream flows during the pre-spawning season (late March through April) to prevent downstream water temperatures from warming too quickly, and to provide attracting flows for the spawning population. Also, adequate and relatively stable flows should be maintained after the peak spawn, since spawning continues through mid-June. Moderate seasonal flows are associated with the highest juvenile abundance indices in Albemarle Sound. Moderate flow regime guidelines recommended by the Roanoke River Water Flow Committee, and implemented by the Corps and power company during the 1988-1991 study, should continue to be used.

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INTRODUCTION

Striped bass (*Morone saxatilis*) inhabiting Albemarle Sound and its tributaries support important recreational and commercial fisheries in coastal North Carolina (Johnson et al. 1986, USDOI and USDOC 1986). The major spawning area for Albemarle Sound striped bass is located in the Roanoke River, which discharges through several channels into the western end of Albemarle Sound (Figure 1). Since the mid-1970s, these fisheries have suffered due to reduced numbers of harvestable adults. Population decline may be caused by a number of factors such as reduced egg viability (Hassler et al. 1981), poor survival of eggs and larvae due to less than optimal stream flow (Hassler reports, Rulifson reports), poor food availability for larvae (Rulifson et al. 1992a, 1992b), poor survival of juveniles on the nursery grounds of the western Sound, and intense fishing pressure (Rulifson and Manooch 1991).

Studies on egg abundance and viability have been conducted each year since the mid-1950s by Dr. W.W. Hassler and co-workers from North Carolina State University in Raleigh. These daily records have been an extremely important source of information for reconstructing the historical spawning record in relation to exploitation, changes in fishing regulations, and man-induced changes in the flow regime and water quality for the Roanoke River watershed. Funds provided by the Albemarle-Pamlico Estuarine Study (APES) to East Carolina University in the spring of 1988 allowed the continuation of the study. This manuscript follows information obtained during the 1988-1990 spawning seasons (Rulifson 1989, 1990, 1992a), and summarizes the results of the 1991 striped bass spawning season.

The manner in which water is released from dams in this watershed, and the subsequent physiological and behavioral effects on spawning striped bass, has been scrutinized closely at various times since initiation of John H. Kerr Reservoir construction in 1950. This concern was one of the reasons for forming a Steering Committee for Roanoke River Studies in 1955. The Committee was composed of state, federal, and private agencies and interests whose objective was to conduct a comprehensive study of the river in order to minimize multiple use conflicts (Hassler and Taylor 1986). The findings of the Committee were discussed in detail by Fish (1959). The cooperative Roanoke-Albemarle Striped Bass Studies were initiated in 1955 as part of the Steering Committee studies. Original support for these efforts was provided by the National Council for Stream Improvement, Weyerhaeuser Company, and Albemarle Paper Manufacturing Company. Weyerhaeuser Company continued its support of the studies after 1958 when the Steering Committee studies were terminated; cooperative field work was resumed in 1975 with the U.S. Fish and Wildlife Service (FWS) and North Carolina Division of Marine Fisheries (NCDMF) under the auspices of the Anadromous Fish Conservation Act (PL 89-304).

In the mid-1980s, water quality and watershed management of the lower Roanoke River basin were again key issues for several reasons: the initiation of the Albemarle-Pamlico Estuarine Study; the controversy over interbasin transfer of water for municipal use by the City of Virginia Beach; the establishment of the Roanoke National Wildlife Refuge within the floodplain of the lower Roanoke River; relicensing of Roanoke and Gaston Dams (license expiration in year 2001); and the continued decline of the Roanoke/Albemarle striped bass stock. These events all had the common concern of how the flow regime is managed by the system of reservoirs located in the Piedmont region of the watershed, especially during the spring spawning season.

In 1988, an *ad hoc* group was formed to investigate the modification of Roanoke River instream flow below Roanoke Rapids Dam for striped bass and other downstream resources. The Roanoke River Water Flow Committee (Flow Committee) was comprised of 20 representatives of State and Federal agencies and university scientists. The purpose of the Committee was to gather information on all resources of the lower watershed and recommend a flow regime that was beneficial to the downstream resources and their users. Striped bass as a resource received the most attention because of its great social and economic importance to this region, and because of the extensive data base established by Dr. Hassler. Detailed descriptions of the Flow Committee findings were presented elsewhere (Manooch and Rulifson 1989; Rulifson and Manooch 1990a, 1991).

Also in 1988, a North Carolina Striped Bass Study was authorized by the U.S. Congress in the reauthorization of the Atlantic Striped Bass Conservation Act (P.L. 100-589) to conduct a study of factors affecting the decline of striped bass in the Albemarle Sound and Roanoke River basin. In 1989, a North Carolina Striped Bass Study Management Board was formed to undertake these studies, develop management recommendations, and submit the study results and recommendations to Congress and the States of North Carolina and Virginia (North Carolina Striped Bass Study Management Board 1991). Findings of substantial habitat degradation, especially water quality, led to recommendations of a moratorium on any additional wastewater discharges or consumptive water withdrawal until a basin-wide comprehensive water study can be completed (USFWS 1992).

At the present time, the manner in which waters are released from Roanoke Rapids Dam is governed by a tri-party agreement involving the U.S. Army Corps of Engineers (Corps), Virginia Power (VEPCO), and the North Carolina Wildlife Resources Commission (NCWRC). Provisions for minimum flows from the reservoir were established by the Memorandum of Understanding (MOU) signed in 1971. In the original agreement, no guidelines were given for maximum flows or for the manner in which the average daily discharge is derived. For example, under present guidelines the dam operator can double or cut in half the rate of discharge through the turbines every hour to optimize on-demand hydropower generation. A discharge of 5,000 cfs (cubic feet per second) can increase to 10,000 cfs in an hour, and then to 20,000 cfs after two hours. These sudden changes in the flow regime result in dramatic changes in water temperature and water depth on the spawning grounds within a several-hour period. The effects of reservoir discharge on striped bass spawning activity have been documented (Rulifson and Manooch 1990b, Zincone and Rulifson 1991). In 1989, the Corps agreed to a four-year trial period of modified flows from 1 April to 15 June as per the recommendations of the Flow Committee (Manooch and Rulifson 1989), after which the effects of the modified flow regime on striped bass and other natural resources downstream would be assessed.

The study described herein was undertaken with several objectives: 1) to continue the data base established by Dr. Hassler; 2) to identify potential sources of bias in Hassler's methodology in estimating egg production and viability; and 3) to determine the relationship between intensity of striped bass spawning (as measured by egg production) and water releases from the Roanoke Rapids Reservoir. Results of the 1991 study are compared with those obtained in the first three years of the study. Management implications and recommendations are presented.

STUDY SITE DESCRIPTION

The Roanoke River is a major coastal floodplain river originating in the Appalachian Ridge in Virginia and discharging into the western end of Albemarle Sound in North Carolina (Figure 1). The watershed encompasses 9,666 square miles (25,033 km^2), making it the largest basin of any North Carolina estuary (Giese et al. 1985). Waters descend 2,900 feet from the origin to the estuary, a distance of 410 miles.

Instream flow of the Roanoke River is highly regulated by a number of reservoirs upstream: in Virginia, Smith Mountain Lake, Philpott Lake, Leesville Lake, John H. Kerr Reservoir, and Lake Gaston; and Lake Gaston and Roanoke Rapids Lake in North Carolina. Of these, the Roanoke Rapids Reservoir located at River Mile (RM) 137 exerts direct influence on instream flow of the lower river; approximately 87% of the flow to the coastal watershed is provided by its discharge (Giese et al. 1985). Average annual discharge of the river at Weldon, North Carolina (USGS gage), is 8,120 ±8,622 cfs (1912-1990, Rulifson et al. 1992b). The watershed itself contributes approximately 50% of the freshwater input to Albemarle Sound, and therefore has a major impact on the coastal zone of northeastern North Carolina.

The primary spawning ground for Albemarle striped bass is located in the Roanoke River between Halifax (RM 120) and Weldon (RM 130), North Carolina. The historical spawning grounds farther upstream were blocked by construction of the Roanoke Rapids Dam (RM 137) in 1955 (McCoy 1959). Spawning activity begins in April and is completed by mid-June (Hassler et al. 1981). Once spawned, the fertilized eggs develop to the hatching stage as they are transported downstream by currents. After hatching, the larvae are transported through the distributaries of the delta into the historical nursery grounds of western Albemarle Sound (Rulifson et al. 1992a).

METHODS

The field station in 1991 was located at Barnhill's Landing (RM 117), the site of W.W. Hassler's sampling efforts during the period from 1975 to 1981 and the 1989 and 1990 egg studies (Rulifson 1990, 1992a). This area is located (Appendix Table A-2) approximately three miles below the historical spawning grounds and about 12 river miles upstream of the Pollock's Ferry site used in the 1988 (Rulifson 1989) study (Figure 2). Sampling was initiated on 15 April and was terminated on 14 June 1991.

Procedures for field sampling and sample workup were similar to those used by W.W. Hassler to ensure compatibility of the data sets. Many of the tables and figures presented in my study are similar to Hassler's for purposes of comparison.

Sampling for striped bass eggs was conducted six times daily at four-hour intervals (0200, 0600, 1000, 1400, 1800, and 2200 hours) by trailing paired 10-inch diameter nets constructed of 500-um nitex mesh (6:1 tail-to-mouth ratio) from a small aluminum boat anchored in mid-stream. A solid sample jar attached to the tail of each net was used to retain collected eggs. Two sample efforts of five-minute duration were made: the first sample six inches below the surface (Hassler's method), and the second sample near the bottom. This procedure allowed comparisons of egg density at the surface with the abundance of eggs near the bottom . A flowmeter with slow speed propeller was attached to the bongo frame to estimate the theoretical volume of water filtered. This methodology produced two estimates of egg production: 1) an estimate of egg density per unit of water filtered; and 2) an estimate of total eggs in the cross-sectional area of the river (Hassler's method). The cross-sectional area of the river at the sampling site was determined for the range of water levels encountered during the study. River stage, air and water temperatures, dissolved oxygen, conductivity, pH, total dissolved solids, and water velocity were recorded for each sample. Instruments used to measure environmental parameters were calibrated periodically according to U.S. Environmental Protection Agency (USEPA) standard methods. Secchi visibility depth was recorded for all samples taken during daylight hours.

The unpreserved samples were returned to the field station for immediate examination. Eggs collected by both nets were enumerated and averaged for each surface tow and each bottom tow. For each sample, all eggs were examined to determine viability and stage of development. Egg viability was determined as described by Hassler et al. (1981): each was examined to determine the status of the embryo (development), yolk and oil globules (intact), perivitelline space (cloudy or clear), and whether the chorion was broken or intact. Viable eggs were staged under a dissecting microscope using the criteria established by Bonn et al. (1976). Stage 1 included eggs less than 10 hours old. Stage 2 eggs were those 10 to 18 hours old. Stage 3 eggs were 20 to 28 hours old, and Stage 4 eggs were 30 to 38 hours old. Stage 5 were eggs 40 hours and older, and newly-hatched larvae. Stage of development was based on an assumed water temperature of 17°C since this is the only published photographic and written description available. Eggs spawned at water temperatures greater than this value will develop faster and hatch earlier (Shannon 1970).

Data were entered into the mainframe computer at East Carolina University and analyzed using the Statistical Analysis System, Version 5 (SAS 1985). The estimated number of striped bass eggs passing the sampling station was calculated on a daily basis using the equation developed by Hassler:

(1) $$N = 514.29\,XY,$$

where N = the estimated number of striped bass eggs spawned during the 24-hour period; X = the mean number of striped bass eggs collected per surface sample during the 24-hour period (12 samples maximum); and Y = the cross-sectional area of the river in square feet for mean river stage during the 24-hour period. The constant 514.29 was derived from the number of five-minute intervals in a 24-hour period (288) multiplied by the relationship of 1.0 ft^2 of river area to the mouth opening of the 10-inch diameter egg net (0.56 ft^2, equaling a ratio of 1:1.785714). Only surface samples were used in the daily egg production estimates so that data were comparable to Hassler's database.

Statistical analysis of the egg count data was performed using the SAS UNIVARIATE procedure to determine distribution of the data. Normal probability plots indicated that transformation of the count data was required; natural log transformation reduced skewness and kurtosis better than square root transformation.

In 1991, a concurrent egg study was conducted downstream at Jacob's Landing (RM 102) just upstream of the Highway 258 bridge to provide information about the possible effect of sampling location on egg production estimates and egg viability. Methods were identical to those described for Barnhill's Landing. Results were described in detail previously (Rulifson 1992b); however, a brief summary of the results is presented in this report.

RESULTS

About 95% of the possible samples (1,382 of 1,448) were examined in 1991. The remainder were not collected because of inclement weather or equipment failure.

Egg Production and Viability for 1991

The estimated number of striped bass eggs produced in 1991 was 1,837,208,211 (n=61, S.D. 65,787,080) from a total of 10,467 eggs collected in surface nets. Samples were first taken on 15 April; the first eggs appeared in Barnhill samples on 17 April (Table 1). Whether spawning occurred earlier than 15 April is unknown. Considering only the data obtained for the sampling period, spawning activity in 1991 appeared to start later than that observed in 1988 (12 April) and 1989 (16 April), and but earlier than 1990 (24 April). Spawning activity continued through 12 June 1991 for a 57-day spawning window; sampling was terminated on 14 June so any spawning in late June was not monitored. This late spawning activity was prolonged compared to 1988 (2 June) and 1989 (9 June), but similar to 1990 (12 June). In 1991, there were 41 consecutive days of spawning activity, a longer period than that observed in 1988 (27 days) and 1989 (23 days), but shorter than 1990 (50 days).

During the 1991 spawning season, there were three major and several minor spawning events. The three major events occurred near mid-May: 8-9 May, 11-12 May, and 14 May (Figure 3). Approximately 50% of the yearly egg production estimate was reached by 13 May, 75% of the total by 15 May, and 90% of the total by 25 May (Table 1, Figure 4).

The egg viability estimate for 1991 was 55.36%, the third highest estimate obtained at Barnhill's Landing and the sixth highest since 1974 (Table 2). No seasonal trend in egg viability was evident (Table 3, Figure 5), and vertically there was <1% difference in surface and bottom viability estimates.

Relationships between surface egg viability and various environmental parameters were determined using several statistical procedures. Striped bass eggs were collected in surface nets of 191 trips. Egg viability data from those trips were not normally distributed (Kolmogorov-D statistic, SAS 1985). Data were transformed using an arcsin square root function, then subjected to a correlation analysis to determine those environmental variables significantly related (alpha 0.05) to egg viability. Appropriate environmental variables and egg viability were subjected to a weighted least squares analysis, with the analysis weighted by the number of eggs in the sample. Results indicated that none of the environmental variables explained much of the variability in viability of eggs collected at the surface or by oblique tows. For surface egg viability, surface water velocity and dissolved oxygen were significant contributors to a linear model (df=2, 189; F=17.45; P=0.0001; R^2=0.16; Mallow's statistic=4.11). Variability in oblique egg viability was partially explained by an inverse relationship with dissolved oxygen and river stage (df=2, 206; F=14.88; P=0.0001; R^2=0.13; Mallow's statistic=3.61). Poor predictability of viability based on environmental factors was expected since water quality and instream flow were quite stable during the major egg production period.

A total of 9,593 eggs was examined throughout the season to determine stage of development; nearly all examined were in the early developmental stages. Approximately 62% of the eggs were less than 10 hours old. An additional 38% were 10-18 hours old, and only nine eggs (0.09%) were 20-28 hours into their development. No post-hatch striped bass larvae were observed in the samples.

Water temperatures were quite warm throughout the spring spawning activity (Figure 6) caused by the record-breaking hot weather prevailing at the time (Figure 7). One striped bass egg was collected from a single sample at the Scotland Neck bridge (NC Hwy. 258) while training the field crew prior to 15 April. At that time, the water temperature was 17°C. During the actual sampling season, water temperatures ranged from 12.0 to 26.0° C during the study. As in years previous, the major spawning activity was initiated after water temperatures reached 18°C (Figure 6). Approximately 94% of all eggs were collected in waters between 18°C and 21.9°C (Table 4). Daily water temperatures averaged above 18°C after 25 April. Environmental data suggest that river temperature was stabilized by reservoir discharge while daily air temperatures exhibited typical diurnal variability. The correlation coefficient for the water temperature-air temperature relationship was 0.59 (n=358; P=0.0001). No trend in egg viability related to water temperature was evident.

Surface water velocities ranged from a high of 123 cm/second on 17 April to a low of 49 cm/second on 11 June corresponding to changes in river depth at Barnhill's Landing (Figure 9). A high positive correlation coefficient of 0.88 (n=347; P=0.0001) between river stage and water velocity was evident. The moderate instream flow conditions that prevailed during the major period of spawning activity resulted in 92% of the eggs collected at surface water velocities of 60-79 cm second (Table 5). An additional 3.8% of the eggs were collected at velocities of 40-59 cm/second, and less than one percent of the eggs were caught in velocities of 100 cm/second or greater.

Seasonal changes in the water release schedule at Roanoke Rapids Dam influenced changes in surface water velocities and surface water temperatures. Heavy basinwide spring rains in March 1991 (3.4 inches above normal) resulted in high inflow to Kerr Reservoir, and increased water releases downstream. Reduced inflow to Kerr Reservoir in early April allowed the Corps to reduce flows downstream beginning 20 April, 20 days after the Negotiated Flow Regime of the Flow Committee should have been implemented. The Negotiated Flow Regime provides a step-down flow range from 1 April to 15 June designed to more closely represent the historial river flow prior to impoundment (Kerr Reservoir construction was initiated in 1950). The Corps of Engineers was able to provide an appropriate water release schedule to allow Virginia Power Company to maintain water releases from Roanoke Rapids Reservoir within the Flow Committee guidelines beginning 21 April (Figure 8). The moderated instream flow resulted in downstream water temperatures reaching 18°C early in April and remaining at or above this temperature during May and June (Figure 7).

Initially, the depth of secchi disk visibility was low concordant with high reservoir discharge. Lowest values (30 cm) were obtained on 15 April, after which visibility increased to 70-80 cm (Figure 10). Low values indicated increased turbidity, a result of changing water level in the river. Although low visibility values corresponded with river fluctuation events, the overall correlation coefficients indicated a significant inverse relationship between secchi visibility and river stage (n=288, r=-0.29), and secchi and water velocity (n=228, r=-0.27).

Conductivity of Roanoke River waters flowing past Barnhill's Landing was low throughout the study, ranging between 7 and 10 mS (Figure 11).

Egg distribution patterns in samples indicated a diurnal spawning pattern. Egg abundance was lowest in afternoon and evening samples, and highest between 0200 and 1000 hours (Table 6). Pinpointing the exact upstream location of major spawning activity is difficult. However, a general estimation can be made using the stage of egg development and water velocity. Nearly 62% of the eggs were <10 hours old (assuming a water temperature of 17°C), and an additional 38% were 10-18 hours old. About 92% of the eggs were collected in water velocities of 60-80 cm/second. The mean water velocity for most of the spawning activity was approximately 70 cm/second (2.3 ft/second). Thus, major spawning occurred from about RM 132 near Weldon to just upstream of Barnhill's Landing, perhaps RM 119.

Dissolved oxygen levels in Roanoke River waters remained above 7.0 mg/L for most of April and May, but in general exhibited a decreasing trend during the season to a level between 6.0 and 7.0 mg/L in June (Figure 12). Most (96%) of the eggs were collected at dissolved oxygen levels of 7.0-8.9 mg/L (Table 7).

The pH of Roanoke River waters remained above 7.0 for most of the study (Figure 13). Nearly 85% of the eggs were collected in waters of 7.74 pH or higher, and more than 33% were collected at pH values 8.0 and greater (Table 8).

Vertical Heterogeneity

During each sampling trip, paired-net egg samples were taken both at the surface and near the bottom for five-minute periods so that differences in the vertical distribution of eggs could be quantified. Egg production for each trip was calculated by using the ratio of the opening of the egg net to the estimated cross-sectional area of the river multiplied by the average number of eggs caught in either the surface nets or bottom-towed nets in five minutes.

Sample replications (net A, net B) were tested to determine normality of the data and ascertain whether both samples collected similar numbers of eggs. A total of 22,108 eggs was collected in all nets: 10,467 eggs in surface tows, and 11,641 in oblique tows. Surface net A collected 5,250 eggs (n=346; mean=15.17; S.D.=38.45), and surface net B collected 5,217 eggs (n=346; mean=15.08; S.D.=41.36). The seasonal difference between surface net collections was only 33 eggs. A similar pattern was observed for bottom tows. Net A collected 6,055 eggs (n=345; mean=17.55; S.D.=49.30) compared to 5,586 eggs for net B (n=345; mean=16.19; S.D.=39.69). The seasonal difference between paired bottom collections was 469 eggs.

No significant diffferences were observed between replicate surface samples, or between bottom replicate samples. The actual difference in numbers of eggs between the paired surface nets A and B was subjected to the UNIVARIATE procedure; results indicated non-normal distribution of the data. Data transformation reduced kurtosis of the data from 37.3 (raw data) to 1.4 (log values). A similar procedure was used for bottom sample data. Differences in the log-catches of the two surface nets were not significant (n=346; S=122176; P>|Z|=0.31); a similar result was obtained for bottom catches (n=345; S=119098; P>|Z|=0.97).

Differences between paired observations of surface and bottom egg collections were not significant. Results using log-transformed data indicated that egg collections of bottom net A and surface net A were similar (n=345, 346; S=-120545; P>|Z|=0.65); the same result was observed for the B nets (n=345, 346; S=123220; P>|Z|=0.13). Overall, the average numbers of eggs in bottom nets and surface nets were statistically similar (n=345, 346; S=121846; P>|Z|=0.34).

Estimating Egg Production on a Per Trip Basis

The original Hassler method of estimating daily egg production (Equation 1 above) produced a point value but no estimate of data variability. The trip method of calculating egg production was performed by estimating the number of eggs in the river at the time the sample was collected, then averaging the expanded numbers over the 24-hour period to estimate daily production. The result of this method is a daily egg production estimate and an estimate of variability for the number.

Egg production estimates on a per trip basis were calculated for surface samples, oblique samples, and all samples combined, then compared statistically to those values obtained using the Hassler (daily) averaging method. Table 9 lists the estimated egg abundance (in a five-minute period) for the six sampling periods each day. Table 10 presents the estimated daily egg production for surface, oblique, and all samples calculated by the Hassler and trip methods. As expected, results of analyses (UNIVARIATE) using the paired daily egg production estimates in Table 10 were not significantly different. However, in this instance we are particularly concerned with whether the yearly egg production estimates are significantly different from one another. The daily egg production estimates were analyzed using NPAR1WAY. Results indicated that the yearly egg production estimates for 1991, calculated by the Hassler and trip methods, using surface, oblique, and combined egg data, were not significantly different (Table 11).

Estimating Egg Production by Volume

Estimates of striped bass daily egg production can be calculated substituting volume for cross-sectional area of the river, and knowing the water velocity at the time of sample collection. The equation is

$$\text{(2)} \quad \text{Daily egg production} = \text{sample eggs} \times \frac{(\text{river discharge} \times 24 \text{ hrs} \times 60 \text{ min} \times 60 \text{ sec})}{(\text{water velocity} \times 0.9) \times \text{net area} \times 300 \text{ sec}}$$

where

river discharge = ft^3/sec, recorded upstream several hours previous to sample collection;
average water velocity = ft/sec x 0.9 (to correct for surface measurement); and
net area = 0.56 ft^2.

A data set of hourly instream flow records from the USGS gage was merged with the egg collection data so that each trip had seven possible values of flow: the actual flow measured at the time and date of the trip (FLOW), flow recorded one hour previous to the trip (FLOWL1), and so on through flow recorded six hours previous to an egg collection trip (FLOWL6).

Correlation analysis was used to determine which record of flow had the highest linear correlation with water velocity measured at the surface during sampling, and river stage at Barnhill's Landing. In 1991, water velocity was highly correlated with discharge, ranging from a low Pearson r value of 0.908 for FLOW, to 0.912 for FLOWL5; the value for river stage and FLOWL5 was r=0.970. Thus, instream flow measured five hours previous to sample collection was used in volumetric egg production estimates.

In 1991, the Hassler estimate of yearly egg production by cross-sectional area (1.837 ±0.062 billion eggs) was not significantly different (Table 11) from the Hassler estimate by volume (2.082 ±0.071 billion). Table 12 provides a daily comparison of both egg production estimates. The two estimates are never the same except in cases where no eggs were collected over the 24-hour period. Table 12 also lists the mean daily values of river characteristics used in estimating egg production by cross-section and by volume. Yearly egg production estimates calculated by the trip method (Table 12) were statistically similar (Table 11) to the Hassler method estimates.

Differences in Egg Production by Location

Statistical analyses were conducted on natural log-transformed data to ascertain how sampling location relative to striped bass spawning activity might influence the yearly egg production and egg viability estimates. Table 13 compares the results of egg monitoring at Barnhill's Landing to results of a similar study at Jacob's Landing 15 river miles downstream. Note that the total number of eggs counted at each location was similar; the yearly egg production estimates were not significantly different. This phenomenon is interesting considering that the number of days of continuous spawning activity downstream was 10 days longer than upstream, and the egg viability estimate was nearly 70% compared to the upstream estimate of 55%. It seems reasonable to suspect that some unknown amount of spawning activity was occurring between the two sampling locations. This hypothesis is supported by the presence of eggs <10 hours in development, while most viable eggs examined at the Jacob's Landing site downstream were over 10 hours old (Table 13).

To interpret the Jacob's Landing egg production estimate, several assumptions were required. It was necessary to assume that any relationships between egg production estimates for Barnhill's Landing (RM 117) and Jacob's Landing (RM 102) represented some constant mean process. Egg production estimates for each location were reduced to the smallest units so that each unit could be accounted for in the analyses. For example, the instantaneous egg production estimate at Barnhill's Landing was made up of all the dead eggs in the sample, plus four live-egg categories: Stages 1-4 (Table 14). The various units contributing to the Jacob's Landing instantaneous egg production estimate were unknown. Also, the egg transport time between the two sites was not known, so three separate analyses were performed using travel times of 4, 8 and 12 hours.

Regression analyses used the Jacob's Landing instantaneous egg production estimate

(LJIPROD) as the dependent variable. Stage 1 eggs collected at Jacob's Landing (LJST1) were assumed to originate from spawning activity between the two sites. The remainder of the Jacob's egg production estimate was assumed to be made up of eggs spawned above Barnhill's Landing: Stage 1 eggs (LBST1), Stage 2 eggs (LBST2), Stage 3 eggs (LBST3), Stage 4 eggs (LBST4), and dead eggs (LBDPROD). Dead eggs collected at Jacob's Landing originated from upstream of Barnhill's Landing and between the two sites. Since there was no way to estimate the number of dead eggs from each location, the dead eggs collected at Jacob's (LJDPROD) were assumed to originate from spawning activity downstream of Barnhill's Landing.

Initial regression analyses used the full data set. Approximately one-half of the records could not be used because of zero eggs collected at one or both stations. Visual examination of plots of residual vs. predicted values identified outliers in the data set. In all cases these outliers were caused by very low (less than 10) eggs in Jacob's Landing samples, or no eggs collected at Barnhill's Landing. These observations were removed from the data set, and the data set was reanalyzed.

The resultant full regression analyses accounted for 88% of the variability in the Jacob's Landing egg production estimates (Table 15). Interestingly, the full models of all three analyses for the 4, 8, and 12-hour travel times indicated that egg production between the two sites is not significant, and dead eggs at Barnhill's Landing do not contribute significantly to the Jacob's estimated egg production. Also, the number of Stage 3 eggs (20-28 hours old) found at Barnhill's Landing are few and do not contribute to an overall egg production rate at Jacob's Landing (Table 15). The 8-hour egg transport time resulted in an intercept closest to zero; significant contributors to the model included Barnhill Stage 1 and Stage 2 eggs along with dead eggs produced between the two sampling sites. For a 4-hour egg travel time, significant contributors to the analysis included Barnhill Stage 2 eggs and dead egg production between the two sites. However, the Durbin-Watson statistic to determine autocorrelation of the data was close to the 0.05 significance level (P=0.067), suggesting that the 4-hour lag time may be inappropriate. Results of the 12-hour egg transport analysis were similar to those of the 8-hour egg transport model (Table 15). A reduced model using only Jacob's Stage 1 eggs and the Barnhill total instantaneous egg production estimate was not a good predictor of Jacob's egg production estimates.

Since Stage 1 eggs collected at Jacob's Landing did not contribute significantly to any of the full analyses, the Jacob's egg production estimates were adjusted by subtracting the Jacob's Stage 1 eggs. Results of the Jacob's adjusted instantaneous egg production estimates indicated that both the 8-hour and 12-hour models were similar (Table 16). The few Stage 3 eggs from upstream did not contribute significantly to downstream egg production estimates. The 12-hour model indicated that dead eggs from upstream were important contributors to the downstream estimate, but upstream dead eggs were not significant in the 8-hour model.

Examination of the residuals indicated the possibility of other variables (e.g., water temperature) not accounted for in the full model. These additional variables remain to be investigated.

From the results of these analyses, it is evident that sampling location five to 20 miles downstream of the major spawning grounds will not significantly change the yearly egg production estimate, but will influence the egg viability estimate.

DISCUSSION

Substituting Volume for River Cross-section

Estimating yearly egg production by incorporating the volume of the river and the volume of water filtered through the net in a five minute period requires additional measurements of environmental conditions, and several assumptions about the nature of the variables in question. In order for the results of cross-sectional and volume calculations to be similar, water velocity must have a highly-correlated linear relationship with river volume as measured by the USGS gage upstream, and with the estimate of cross-sectional area. In 1990 and 1991, these correlations were highly related ($r>0.95$) and so the seasonal egg production estimates were not significantly different. However, this relationship may not hold for striped bass spawning activity under high flow conditions. For example, in 1989 the major spawning activity occurred during an extended period of high stable discharge from Roanoke Rapids Dam. River stage and cross-sectional area estimates were highly correlated with reservoir discharge ($r>0.95$), but the correlation of water velocity to discharge was lower ($r=0.89$) than in 1990 and 1991. Several possible explanations may explain this change in relationship. High flows tend to produce roiling of surface waters, making water velocity estimates more difficult. However, the primary problem may be due to a non-linear relationship between water velocity and discharge due to the configuration of the stream banks. From the Barnhill's Landing area extending upstream, the river bank resembles a series of steps where waters have cut into the banks. As the water level rises, water velocity increases until waters flood the next highest cut, thus extending the effective channel width and reducing water velocity. This phenomenon is minimal at low and moderate instream flow rates, but is quite noticeable at high discharge rates. Therefore, we should expect an underestimation of yearly egg production in years of high river flow. The 1989 estimate of nearly 638 million eggs, recalculated using volume, produced a value of approximately 1.16 billion. Thus, it is possible that the Hassler egg production estimates in years of high reservoir discharge were underestimated. It must be emphasized that this large difference should occur only if peak striped bass spawning activity occurs during rates of high instream flow when estimates of cross-sectional area and water velocity are more difficult.

Effects of Sampling Location

Results of the statistical analyses indicate that downstream instantaneous egg production estimates closely match egg production estimates farther upstream, but the viability estimates are probably a function of sampling location. Results of the 1988-1990 egg studies also suggested the possibility of this bias. A high viability estimate of 89% was recorded in 1988 at Pollock's Ferry (RM 105), and low values were recorded at Barnhill's Landing (RM 117) of 42% in 1989 and 58% in 1990. Additional evidence was noted in Hassler's data (Table 2). In 1959 and 1960, the average egg viability at Palmyra (RM 78.5) was nearly 93%, but in both years data for only a portion of the season were obtained. During the years that Hassler sampled upstream at Halifax (RM 121) near the spawning grounds (1961-1974), egg viability averaged 88.53% (S.D. 5.77, n=14). In 1975, egg viability dropped to about 56%, which also happened to coincide with a change in sampling location downstream at RM 117. For the seven years of data collection at Barnhill's Landing, egg viability averaged 51% (S.D. 11.75). In 1982, Hassler moved operations one mile upstream to Johnson's Landing and from 1982-1987, the average egg viability was 49% (S.D. 20.22, n=6).

Sampling too close to, or too far away from, the spawning grounds may overestimate the yearly egg viability estimate. Biologically, this rationale is sound. Sampling too close to the spawning grounds may not allow adequate time for eggs to physically show evidence of nonviability: e.g., cloudiness, broken membranes, nonfertilization. Sampling too far downstream may provide too much time between egg release and egg collection in nets, thus allowing nonviable eggs to be removed from the water column by bursting, predation, sinking, or transport to floodplain areas. The bulk of those eggs remaining within the water column should be viable. Following this line of reasoning, the sampling location providing the best estimate of egg viability should be somewhere between Hamilton and Palmyra (i.e., Johnson's Landing or Barnhill's Landing).

Two egg studies of a similar nature conducted at different locations in 1981, 1982, and 1983 provide additional support of the hypothesis. Hassler conducted his 1981 egg study at Barnhill's Landing (Hassler, Luempert and Mabry 1982) and at Johnson's Landing in 1982 and 1983 (Hassler and Taylor 1984). The NCWRC monitored egg production at Johnson's Landing in 1981 (Kornegay 1981), and at Pollock's Ferry in 1982 (Kornegay 1983) and 1983 (Kornegay and Mullis 1984). This comparison was reported by Rulifson (1990); the text of that comparison is presented below.

The methods and equipment used in the NCWRC studies were different than that used by Hassler; an understanding of data collection is necessary prior to comparing the two data sets. Hassler's methodology and gear were explained previously. Kornegay (1981) collected eggs with two 0.5-m diameter 505-µm mesh plankton nets. One net was mounted on each side of the boat in a push net frame described by Tarplee et al. (1979). Sampling frequency was initially three times a day; maximum frequency was every four hours during peak spawning activity. The nets were pushed through the water facing upstream at a speed such that the boat remained stationary or advanced slightly in relationship to the shore. Effort was six minutes initially, but was reduced to three minutes when spawning activity was greatest. The numbers of eggs collected were converted to numbers per 100 cubic meters of water filtered. Determination of egg viability was similar to the Hassler method. The same field procedures were used in 1982 and 1983 (Kornegay and Mullis 1984).

In 1981, Hassler (Hassler, Luempert and Mabry 1982) sampled from 29 April to 29 May and reported an egg viability of 73.7% (Table 1). Kornegay's efforts one mile downstream began on 21 April and ended 15 May, resulting in an egg viability estimate of 69%. These two egg viability estimates were within five percent and so appeared similar. The similarity was not so striking when daily viability estimates were examined. With one exception, daily egg viability estimates for Johnson's Landing in 1981 were consistently higher than for the downstream Barnhill's Landing site. These results supported the egg viability bias hypothesis described above. However, the daily egg production data were very similar and showed peak spawning activity around 29 April and again around 9-15 May. Coincidentally, spawning activity peaks in 1981 occurred just after sudden changes in river flow: a 4,000 cfs increase on 22-24 April and a similar decrease on 7-8 May. Minor spawning peaks in mid and late May of 1981 exhibited this similar pattern.

In 1982, Hassler (Hassler and Taylor 1984) sampled at Johnson's Landing from 3 May to 2 June; spawning activity had started prior to sampling efforts. Hassler's egg viability estimate for 1982 was 71.93% (Table 1). Thirteen miles downstream at Pollock's Ferry, Kornegay (1983) sampled from 20 April to 14 May and obtained an egg viability estimate of 76.47%, a value within five percent of the Hassler estimate. Again, the lower value obtained at Johnson's Landing and the higher value estimated downstream at Pollock's Ferry supported the sampling location bias hypothesis.

The 1982 egg viability estimates calculated on a daily basis indicated a high degree of similarity between the two stations. Even though the sites were 13 miles apart, egg transport time may be as short as 7.6 hours assuming a uniform water velocity of 2.5 feet/sec (75 cm/sec). Thus, egg viability estimates calculated on a daily, rather than per sample, basis may not be adequate to determine egg viability differences between the two sites. Both daily egg production estimates for 1982 revealed similar patterns in spawning activity: peak spawning occurred approximately 9-11 May just after river flow dropped from 11,600 cfs to about 6,300 cfs on 7-8 May. Kornegay (1983) attributed the spawning peak to increases in water temperature to 18.4°C.

In 1983, Hassler (Hassler and Taylor 1984) sampled at Johnson's Landing from 6 May to 12 June and estimated the overall egg viability as 33.29% (Table 2). Kornegay and Mullis (1984) sampled at Pollock's Ferry from 24 April to 31 May and reported egg viability at 40.48%. Again, the higher egg viability estimate downstream supported the sampling location bias hypothesis.

Trends in daily egg viability data for 1983 were obscured because of extensive spring flooding, although higher daily egg viability later in the season seemed to coincide with lower river flow. Flow models developed by the Corps show that the lower watershed will flood under prolonged periods of 8,000 cfs river flow or more (M. Grimes, Wilmington District, Corps of Engineers, personal communication).

Similar to the 1981 and 1982 spawning seasons, peaks in the 1983 striped bass spawning activity coincided with changes in river flow. During the latter half of April and early May, instream flow approached 26,000 cfs, then dropped to about 20,000 cfs on 7 May. The first, though minor, spawning peak was observed on 9 May. A second, slightly larger, spawning peak occurred on 15-17 May during a rather stable period of river flow. A third, larger peak on 24-26 May coincided with dropping water levels initiated on 25 May. The major peak spawn, which occurred on 30 May, coincided with lowest water levels of the season established two days earlier.

Comparisons Among Years 1988-1991

The four years of striped bass spawning studies conducted for the Albemarle-Pamlico Estuarine Study documents the predictability of striped bass spawning activity. Although the actual timing of peak spawning activity is variable from year to year, the sequence of spawning events related to water temperature and river flow is similar among years. Table 17 summarizes the major aspects of spawning in the lower Roanoke River watershed.

The number of spring days used by striped bass for spawning (the spawning window) is longer than generally acknowledged by state fishery agencies, the Corps, and Virginia Power Company. In my studies, egg sampling was initiated each year in mid-April, and eggs first appeared in samples within one week. Hassler's egg sampling schedule was variable each year (Table 2), depending on the movement of adults upstream from Albemarle Sound. This sampling design resulted in 14 years in which Hassler collected eggs on the first day of sampling (Manooch and Rulifson 1989, Appendix Table B-8). Also, Hassler's reports indicated that egg sampling was terminated after five consecutive days of no eggs in the samples, but the data for 10 of those years ended with no "zero catches", indicating that spawning activity was still occurring at termination of sampling. This assumption is reasonable considering that spawning activity occurred through 12 June in 1990 and 1991. Hassler's studies, combined with results from 1988-1991, indicate that striped bass spawning encompasses at least 50 days, with additional sporadic spawning by a few individuals prior to mid-April and after mid-June.

Major spawning activity is initiated after water temperatures reach 18°C, but limited spawning activity occurs at water temperatures as low as 14°C. Most eggs are collected between 18°C and 21.9°C. The exception to this trend appears to be in those years in which water temperatures increase rapidly while the spawning run of adult striped bass is still far downstream. When water temperatures increase gradually, major spawning activity occurs within days after reaching 18°C.

Water temperatures on the spawning grounds can be lowered by naturally-occurring cold fronts but also by man-caused water releases from Roanoke Rapids Dam, thus affecting spawning activity. Water temperatures may reach 18°C early in the season, and spawning activity may commence, but passing cold fronts or reservoir releases of cold water may rapidly lower spawning grounds water temperatures below 18°C, causing cessation of spawning. This same phenomenon has been documented for striped bass spawning in the Annapolis River, Nova Scotia; rapid temperature drops to 15-16°C caused spawning to cease (Williams 1978).

The resulting pattern of springtime water temperatures directly affects the period of peak spawning. The third week in May is the usual expectation of peak spawning activity; however, the peak can be as early as the second week in May (1988, 1991) or as late as Memorial Day weekend (1989). In 1988, water temperatures were warm earlier in the season due to low flow conditions in late March and early April. In 1989, flooding conditions caused water temperatures to increase late in the season.

Water quality near the spawning grounds is not a problem for egg viability, but may play an important role farther downstream. Most eggs appeared in river waters with pH values of 7.0 or higher (Table 17). Roanoke River waters become more acidic farther downstream, especially during periods of flooding, caused by flushing and/or draining of backwater sloughs and floodplain areas. The 1988 Pollock's Ferry data collected at RM 105 indicate how pH values decrease in downstream areas. Acidic waters cause egg and larval mortality; the presence of high levels of aluminum characteristic of North Carolina coastal streams seems to hasten death (Dorton 1991). Dissolved oxygen levels are adequate downstream of the spawning grounds, but may be a problem farther downstream when swamp waters high in organic matter are flushed into the system. Most eggs are collected in waters of dissolved oxygen content between 7.0 and 8.9 mg/L; however, in 1988 most eggs collected at Pollock's Ferry were in waters between 5.0 and 7.9 mg/L (Table 17). Low dissolved oxygen values during spawning have been documented for the lower river, delta, and western Albemarle Sound (Rulifson et al 1992a).

Egg viability observed at Barnhill's Landing does not appear to be a function of environmental conditions in general, so other factors may be involved in influencing observed egg viabilities. One possibility concerns whether females are producing less viable eggs due to poor environmental quality as the eggs are forming in the ovaries. This hypothesis is known as "habitat squeeze", first proposed by Coutant (1985) for Tennessee reservoirs. Sampling in Albemarle Sound during summer indicates that most areas of the Sound exceed the preferred tolerance levels of striped bass. A second possibility is that hourly shifts in egg viability reflect the age structure of the spawning population. Considerable controversy exists about whether first-time spawning females can produce eggs of the same quality as females weighing 10 pounds or more. If viability is correlated with fish age, then lower egg viability would suggest younger females participating in the spawning act; higher viability would suggest older females releasing eggs. NCRWC personnel believe that younger females come upstream earlier to spawn, followed by older females later in the season (K. Nelson, personal communication). If egg viability was related to the age distribution of the spawning population, then a seasonal progression of lower to higher egg viability should be observed. No such trend was apparent in the 1988-1991 studies.

Although "rock fights" -- the spawning act -- are observed throughout the day, most egg deposition occurs in the evening. This aspect is reflected in the sampling times at which most eggs are collected at Barnhill"s Landing: 0200-1000 (Table 17). Eggs spawned in rock fights observed just downstream of the Weldon landing near dusk, and transported at an average rate of 70 cm/second (2.3 feet/second, or 1.5 miles/hour) should appear at Barnhill's Landing within eight hours (i.e., 0200-0600 hours). Eggs spawned upstream of Weldon at the same time would arrive at the collection site later (e.g., 1000), and would be 10-18 hours old in development.

Management Implications

Striped bass spawning activity in the lower Roanoke River can be manipulated by water releases from Roanoke Rapids Reservoir upstream. The spawning window is much longer than is currently considered by VEPCO, the Corps, and the NCWRC for management purposes. However, there is little evidence to ascertain which period(s) of the spawning season makes the greatest contribution to successful hatching and subsequent recruitment of young-of-year striped bass to the year class forming in Albemarle Sound. YOY recruitment may be: (1) from the relatively few numbers of surviving eggs spawned throughout the season; (2) from the tremendous number of eggs released during the peak spawn period; or (3) from the progeny of only several females spawned at a fortuitous time (i.e., "optimal conditions") in the season. Since what constitutes "optimal conditions" is not known, the Roanoke River instream flow should be managed to mimic the historical river flows as much as possible over the longest period of time possible (first of April to end of June). Moderate flows result in the highest juvenile abundance indices in Albemarle Sound (Hassler et al. 1981, Rulifson and Manooch 1990b). This management action includes providing adequate instream flows during the pre-spawning season (late March through April) to prevent downstream water temperatures from warming too quickly and to provide attracting flows for the spawning population. Also, adequate flows should be maintained after the peak spawn, since spawning continues through mid-June. Typically in late May and June, hydroelectric activity by the power company to meet peak electrical demands results in downstream flows fluctuating between 2,000 and 20,000 cfs within hours. Moderated hydroelectric activities are recommended to provide a more stable environment downstream. Moderate flow regime guidelines as recommended by the Roanoke River Water Flow Committee, and implemented by the Corps and VEPCO during the study period (1988-1991), should continue to be used.

SUMMARY AND CONCLUSIONS

1. The estimated number of striped bass eggs produced in the Roanoke River for 1991 was 1.837 billion ±65.787 million from a total of 10,467 eggs collected in surface nets during the period 15 April to 14 June. Spawning prior to 15 April, and after 14 June, was undetermined.

2. A 57-day spawning window was observed in 1991; the 41-day continuous spawning window was longer than in 1988 (27 days) and 1989 (23 days), but shorter than 1990 (50 days).

3. Eggs first appeared in surface samples on 17 April. Seasonal egg production was 50% complete by 13 May, 75% complete by 15 May, and 90% complete by 25 May. The last eggs were collected on 12 June.

4. Three spawning peaks, all early in the season, were observed in 1991: 8-9 May (20% of total egg production), 11-12 May (17%), and 14 May (19%).

5. Major egg deposition occurred after water temperatures reached 18°C, a phenomenon observed in 1988, 1989, and 1990.

6. Egg viability for 1991 was 55.4%. The difference between egg viability of surface and bottom samples was less than one percent.

7. No seasonal trend in egg viability was evident; only a small portion of data variability was explained by dissolved oxygen and water velocity (R^2=0.16). Poor predictability of viability based on environmental factors was expected since water quality and instream flow were quite stable during the major egg production period.

8. Most eggs (62%) passing Barnhill's Landing were less than 10 hours old. An additional 38% were 10-18 hours old, and only nine eggs were 20-28 hours in development.

9. The estimation of annual egg viability is probably influenced by location in the river at which the sampling was conducted. Sample location does not significantly change the annual egg production estimate.

10. About 94% of all eggs were collected at water temperatures 18.0-21.9°C. The range of temperatures during the study was 12.0-26.0°C.

11. Most eggs (92%) were collected at surface water velocities of 60-79 cm/second. Water velocities ranged from 49 cm/second to 123 cm/second, with a seasonal mean of 74 cm/second.

12. Changes in secchi disk visibility coincided with changes in river level, ranging from 30 cm to 85 cm.

13. Most eggs (96%) were collected at dissolved oxygen levels between 7.0 and 8.9 mg/L; a seasonal decrease in dissolved oxygen was observed, from a high of 10.0 mg/L in April to a low of 5.2 mg/L in June.

14. Most eggs (85%) were caught in waters of pH 7.74 or greater.

15. In 1991, there were no significant differences in the number of eggs collected in surface or bottom samples.

16. In 1991, the daily estimates of egg production calculated by the Hassler (daily averaging) method and by the trip method were not statistically different. The trip method produces a daily egg estimate with an estimate of data variability; the Hassler daily estimate is a single point value with no estimate of variability.

17. In 1991, the daily egg production estimates calculated by cross-sectional area of the river, and by volume, were not significantly different. However, in some years (e.g., 1990) the cross-sectional area calculations (Hassler's method) may underestimate the number of eggs in the river during high flow years if major spawning activity occurs during high flows.

18. From the results of the independent studies conducted by Hassler and the NCWRC in 1981, 1982, and 1983, and the 1988-1991 egg studies by Rulifson, it is clear that spawning activity of Roanoke River striped bass is affected by reservoir discharge. The relationship of egg viability to successful juvenile recruitment to the year class is unclear.

19. The value of the annual egg studies is the documentation of striped bass spawning activity relative to changing environmental conditions, especially human-related activities such as hydroelectric generation upstream. The annual studies should be regarded as an important relative index of striped bass activity among years, and daily activity within the season and should be continued to provide critical data for renewal of the dam licences by the Federal Energy Regulatory Commission.

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REFERENCES

Bonn, E.W., W.M. Bailey, J.D. Bayless, K.E. Erickson, and R.E. Stevens. 1976. Guidelines for striped bass culture. American Fisheries Society, Bethesda, Maryland, USA.

Coutant, C.C. 1985. Striped bass, temperature, and dissolved oxygen: a speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 11:31-61.

Dorton, P.F. 1991. Aluminum and acid pH effects on larval striped bass (*Morone saxatilis*) epithelium determined by scanning electron microscopy. M.S. Thesis, East Carolina University, Greenville, NC. 56 p.

Fish, F.F. 1959. Report of the steering committee for Roanoke River studies, 1955-58. U.S. Public Health Service, Raleigh, NC. 279 p.

Giese, G.L., H.B. Wilder, and G.G. Parker, Jr. 1985. Hydrology of major estuaries and sounds in North Carolina. Reston, VA: U.S. Geological Survey, Water Supply Paper No. 2221.

Hassler, W.W., B.B. Brandt, J.T. Brown, and P.R. Cheek. 1961. Status of the striped bass in the Roanoke River, North Carolina, for 1960. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 38 p. + Appendices.

Hassler, W.W., W.L. Trent, and W.E. Gray. 1963. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1963. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 43 p. + Appendices.

Hassler, W.W., W.L. Trent, and B.M. Florence. 1965. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1964. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 45 p. + Appendices.

Hassler, W.W., W.L. Trent, and B.M. Florence. 1966. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1965. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 53 p. + Appendices.

Hassler, W.W., W.T. Hogarth, and H.L. Liner, III. 1967. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1966. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 53 p. + Appendices.

Hassler, W.W., W.T. Hogarth, H.L. Liner, III and H.S. Millsaps. 1968. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1967. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 72 p. + Appendices.

Hassler, W.W., W.T. Hogarth, C.R. Stroud, Jr., and H.S. Millsaps. 1969. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1968. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 71 p. + Appendices.

Hassler, W.W., and W.T. Hogarth. 1970. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, and the spawning of striped bass in the Tar River, North Carolina. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 64 p. + Appendices.

Hassler, W.W., W.T. Hogarth, and C.S. Manooch. 1971. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1970. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 82 p. + Appendices.

Hassler, W.W., W.T. Hogarth, C.S. Manooch, and N.L. Hill. 1973. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1972. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 75 p. + Appendices.

Hassler, W.W., and N.L. Hill. 1975. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1973. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 64 p. + Appendices.

Hassler, W.W., and N.L. Hill. 1976. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1974. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 80 p. + Appendices.

Hassler, W.W., and N.L. Hill. 1976. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1975. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 87 p. + Appendices.

Hassler, W.W., and N.L. Hill. 1978. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1976. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 117 p. + Appendices.

Hassler, W.W., and N.L. Hill. 1979. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1977. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 118 p. + Appendices.

Hassler, W.W., and N.L. Hill. 1980. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1979. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 82 p.

Hassler, W.W., N.L. Hill, and J.T. Brown. 1981. The status and abundance of striped bass in the Roanoke River and Albemarle Sound, North Carolina 1956-1980. North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Special Scientific Report No. 38.

Hassler, W.W., L.G. Luempert, and J.W. Mabry. 1982. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1981. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report, 55 p. + Appendices.

Hassler, W.W., and S.D. Taylor. 1984. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1982 and 1983. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 67 p. + Appendices.

Hassler, W.W., and S.D. Taylor. 1986. The status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1985. Department of Zoology, North Carolina State University, Raleigh, Mimeo Report. 47 p. + Appendices.

Johnson, J.C., P. Fricke, M. Hepburn, J. Sabella, W. Still, and C.R. Hayes. 1986. Recreational fishing in the sounds of North Carolina: a socioeconomic analysis. Volume I. UNC Sea Grant Publication UNC-SG-86-12.

Kornegay, J.W. 1981. Investigations into the possible causes of the decline of Albemarle Sound striped bass. Final Report for 1 April to 30 September 1981, Jobs 2 and 3. North Carolina Wildlife Resources Commission, Raleigh. 16 p.

Kornegay, J.W. 1983. Coastal fisheries investigations. Study VIII: Investigations into the decline in egg viability and juvenile survival of Albemarle Sound striped bass (*Morone saxatilis*), Jobs 1-4. Federal Aid in Fish Restoration Project F-22, Final Report for period 1 April 1982 - 1 January 1983. North Carolina Wildlife Resources Commission, Raleigh. 13 p.

Kornegay, J.W. and A.W. Mullis. 1984. Investigations into the decline in egg viability and juvenile survival of Albemarle Sound striped bass (*Morone saxatilis*). Final Report on Project F-22, Study VIII. North Carolina Wildlife Resources Commission, Raleigh. 13 p.

Manooch, C.S., III and R.A. Rulifson (eds.). 1989. Roanoke River Water Flow Committee Report: A recommended water flow regime for the Roanoke River, North Carolina, to benefit anadromous striped bass and other below-dam resources and users. NOAA Technical Memorandum NMFS-SEFC-216, 224 p.

McCoy, E.G. 1959. Quantitative sampling of striped bass, *Roccus saxatilis* (Walbaum), eggs in the Roanoke River, North Carolina. M.S. Thesis, North Carolina State University, Raleigh, NC, 136 p.

North Carolina Striped Bass Study Management Board. 1991. Report on the Albemarle Sound-Roanoke River stock of striped bass. U.S. Fish and Wildlife Service, Atlanta GA. 56 p. + Appendices.

Rulifson, R.A. 1989. Abundance and viability of striped bass eggs spawned in the Roanoke River, North Carolina, in 1988. Albemarle-Pamlico Estuarine Study, Raleigh, NC, Project No. APES 90-03. 76 p.

Rulifson, R.A. 1990. Abundance and viability of striped bass eggs spawned in the Roanoke River, North Carolina, in 1989. Albemarle-Pamlico Estuarine Study, Raleigh, NC, Report No. APES Project 90-11. 96 p.

Rulifson, R.A. 1992a. Abundance and viability of striped bass eggs spawned in the Roanoke River, North Carolina, in 1990. Albemarle-Pamlico Estuarine Study, Raleigh, NC, Report No. APES 92-23, 87 p.

Rulifson, R.A. 1992b. Striped bass egg abundance and viability at Scotland Neck, Roanoke River, North Carolina, for 1991. North Carolina Wildlife Resources Commission, Raleigh, Completion Report for Project F-27, Study 2. 48 p. + 2 appendices.

Rulifson, R.A., and C.S. Manooch, III. 1990a. Roanoke River Water Flow Committee report for 1988 and 1989. NOAA Technical Memorandum NMFS-SEFC-256, 209 p.

Rulifson, R.A., and C.S. Manooch, III. 1990b. Recruitment of juvenile striped bass in the Roanoke River, North Carolina, as related to reservoir discharge. North American Journal of Fisheries Management 10:397-407.

Rulifson, R.A., and C.S. Manooch, III. 1991. Roanoke River Water Flow Committee report for 1990. NOAA Technical Memorandum NMFS-SEFC-291, 433 p.

Rulifson, R.A., J.E. Cooper, D.W. Stanley, M.E. Shepherd, S.F. Wood, and D.D. Daniel. 1992a. Food and feeding of young striped bass in Roanoke River and western Albemarle Sound, North Carolina, 1984-1991. North Carolina Wildlife Resources Commission, Raleigh, Completion Report for Project F-27.

Rulifson, R.A., J.E. Cooper, D.W. Stanley, M.E. Shepherd, S.F. Wood, and D.D. Daniel. 1992b. Food and feeding of young striped bass in Roanoke River and western Albemarle Sound, North Carolina, 1990-1991. North Carolina Wildlife Resources Commission, Raleigh, and North Carolina Striped Bass Study Management Board, Completion Report for Projects 90-2 and 91-2, 62 p.

SAS Institute. 1985. SAS User's Guide: Statistics, Version 5 Edition. SAS Institute, Inc., Cary, NC 584 p.

Shannon, E.H. 1970. Effect of temperature changes upon developing striped bass eggs and fry. Proceedings of the 23rd Annual Conference of Southeastern Fish and Game Commissioners 1969:265-274.

Tarplee, W.H., W.T. Bryson, and R.G. Sherfinski. 1979. Portable pushnet apparatus for sampling ichthyoplankton. Progressive Fish Culturist 41:213-215.

USDOI and USDOC (U.S. Department of the Interior and U.S. Department of Commerce). 1986. Emergency striped bass research study. 1985 Annual Report. Washington, District of Columbia, USA.

USFWS (U.S. Fish and Wildlife Service). 1992. Report to the Congress for the North Carolina Striped Bass Study, Albemarle Sound and Roanoke River Basin. U.S. Fish and Wildlife Service in consultation with the National Oceanic and Atmospheric Administration, Washington, D.C., 8 p.

Williams, R.R.G. 1978. Spawning of the striped bass, *Morone saxatilis* (Walbaum), in the Annapolis River, Nova Scotia. M.Sc. Thesis, Acadia University, Wolfville, Nova Scotia.

Zincone, L.H., Jr., and R.A. Rulifson. 1991. Instream flow and striped bass recruitment in the lower Roanoke River, North Carolina. Rivers 2:125-137.

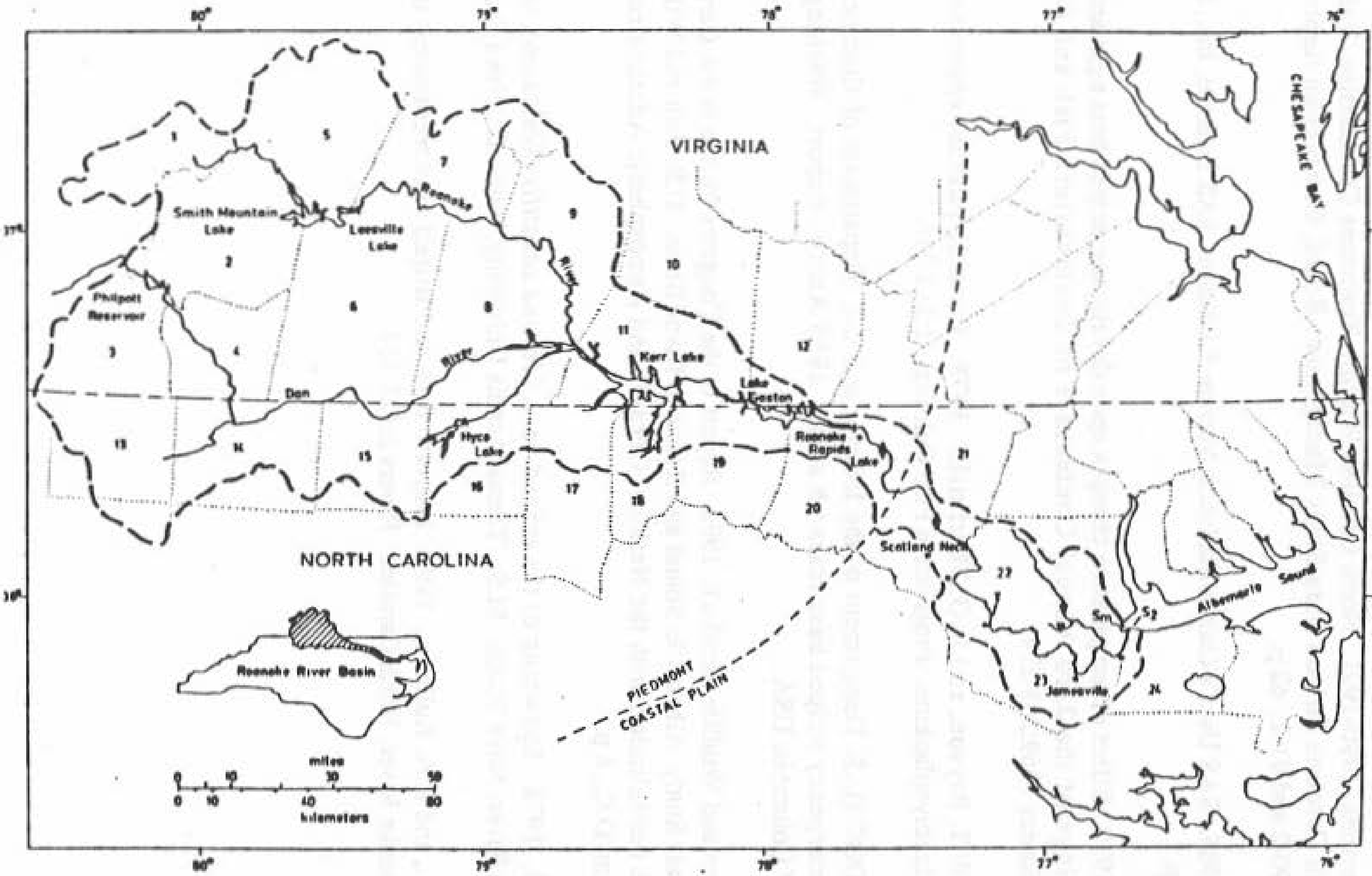

Figure 1. Drainage area of the Roanoke River Basin. Dashed line indicated approximate location of the Fall Line; diamonds=locations of USGS water quality and gaging stations; inverted triangle=USGS water quality station; T=upstream limit of tidal influence; S2=mean upstream intrusion limit of saltwater front (200 mg/L chloride); Sm=maximum upstream intrusion of saltwater front (Giese et al. 1985). Counties containing Roanoke watershed are enumerated and listed in Appendix Table A-1.

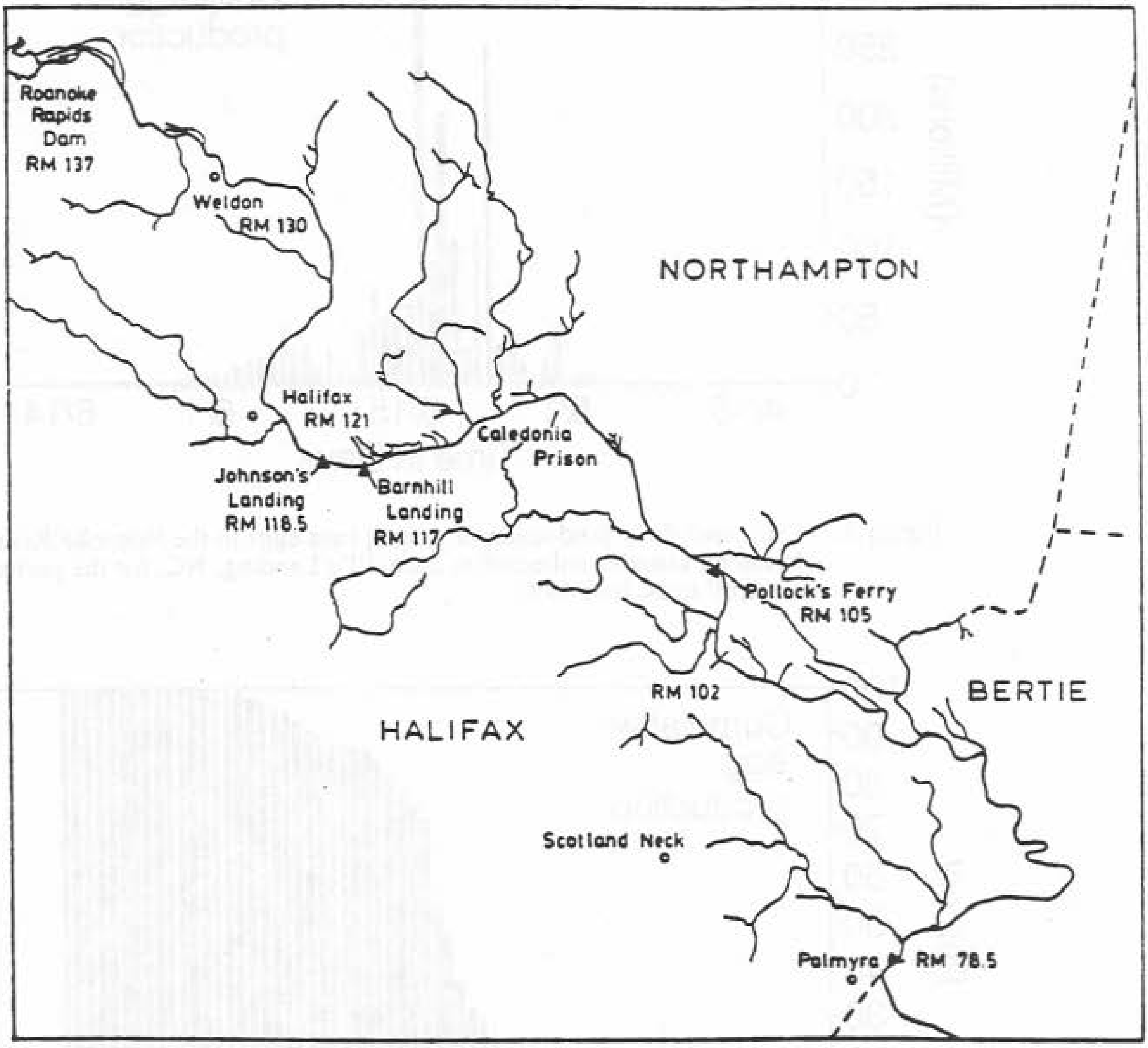

Figure 2. Roanoke River watershed downstream of Roanoke Rapids Reservoir showing the historical sampling stations for striped bass eggs: Palmyra (1959-60), Halifax (1961-74), Barnhill's Landing (1975-81, 1989-1991), Johnson's Landing (1982-87), and Pollock's Ferry (1988).

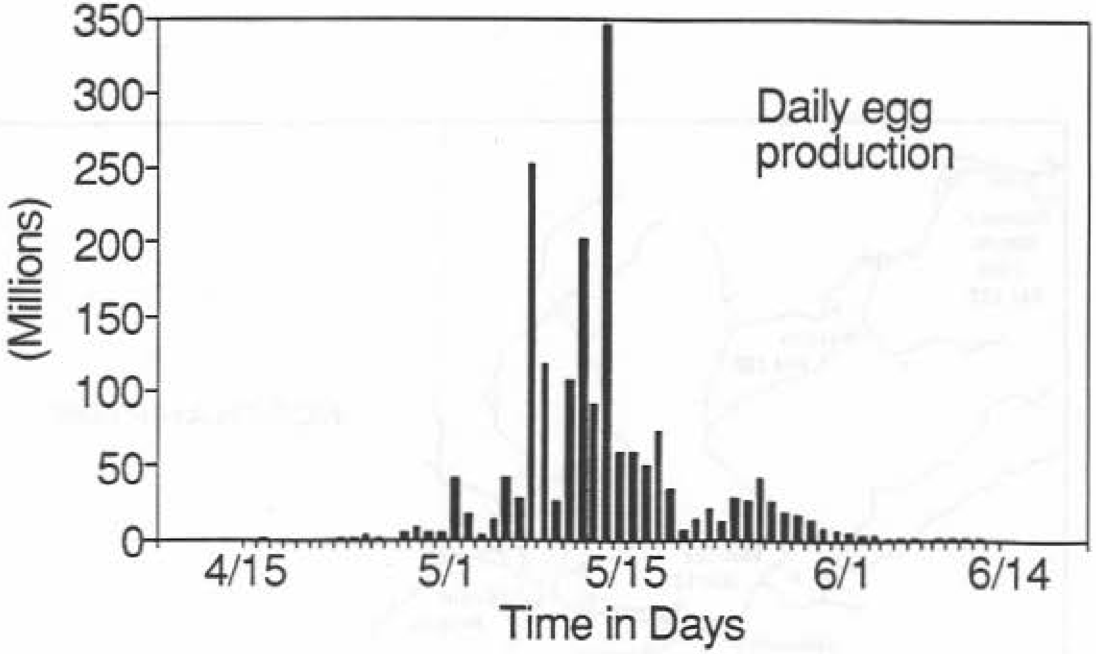

Figure 3. Estimated daily production of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing, NC, for the period 15 April to 14 June 1991.

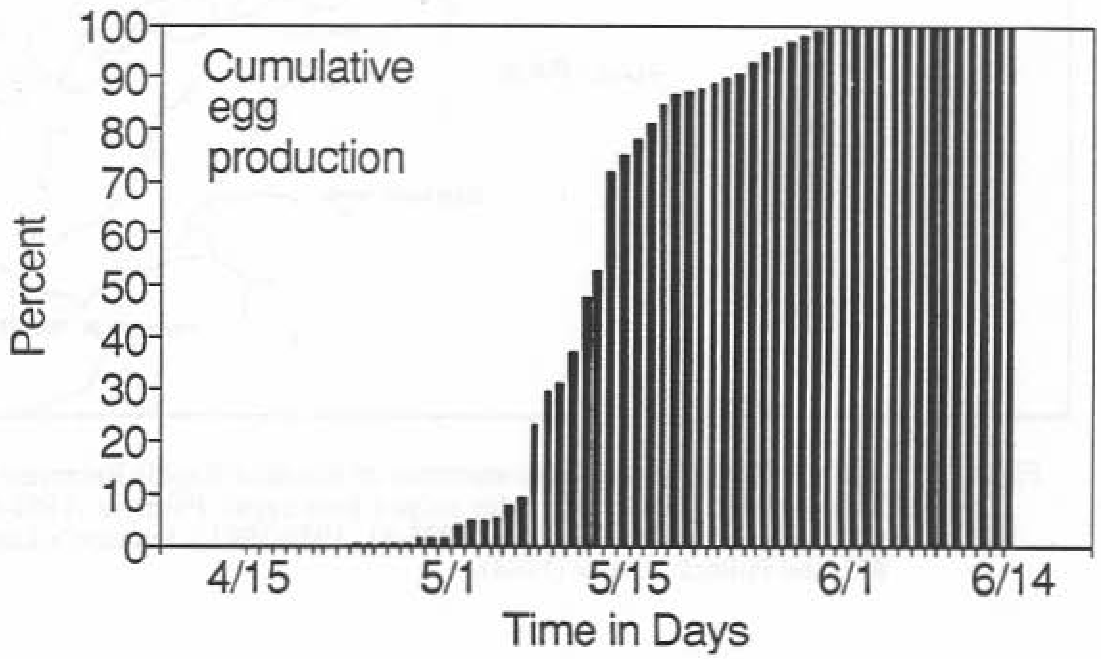

Figure 4. Estimated production of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing, NC, in 1991, presented as percentage of total production.

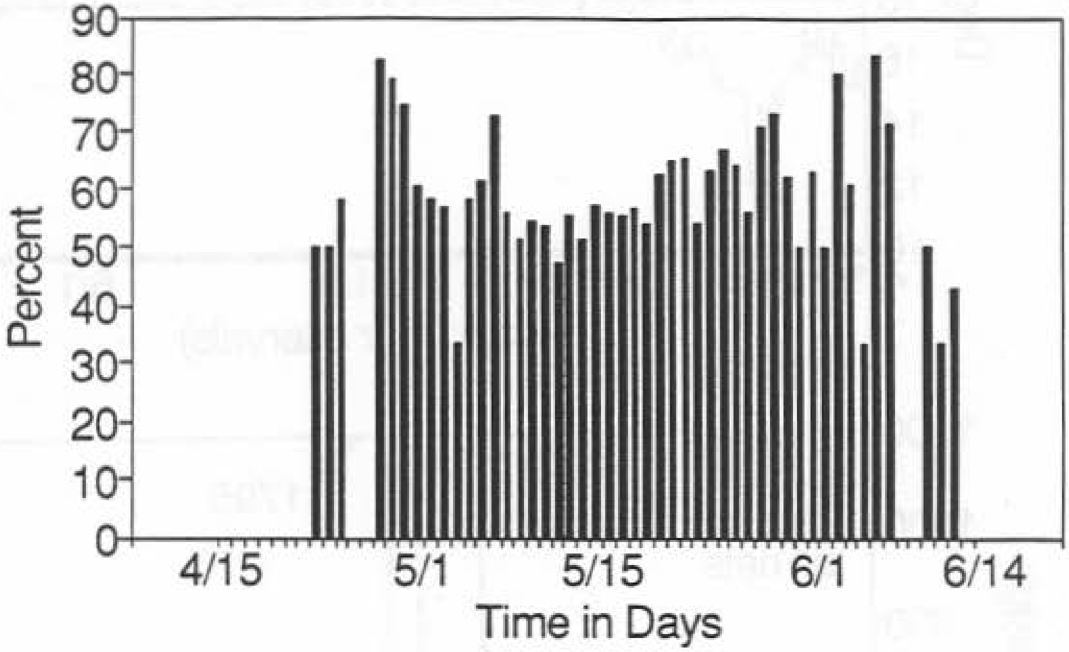

Figure 5. Daily viability estimates of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing, NC, in 1991.

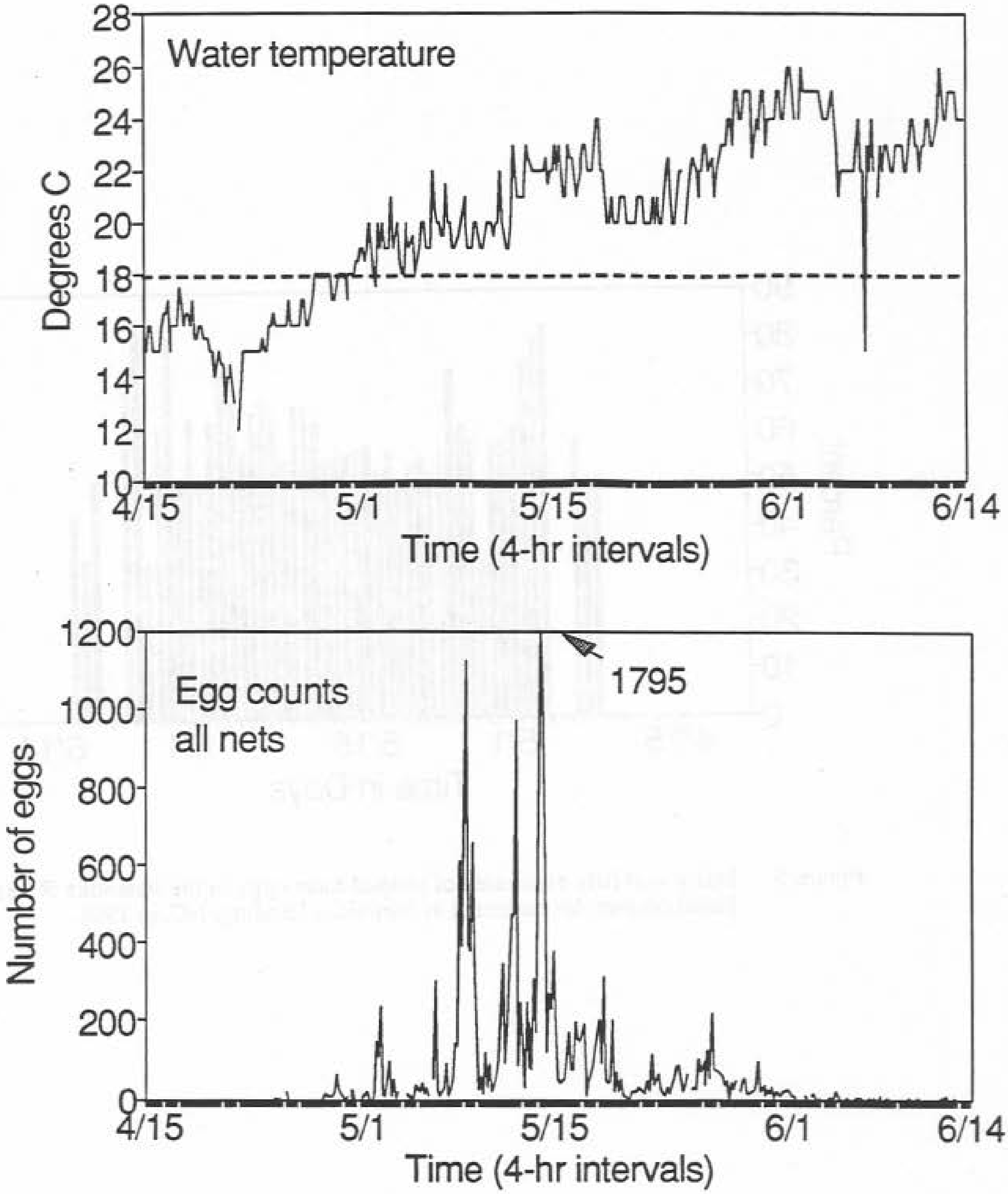

Figure 6. Number of striped bass eggs collected in all nets during each trip, and corresponding water temperatures (°C) at Barnhill's Landing, NC, for the period 15 April to 14 June 1991.

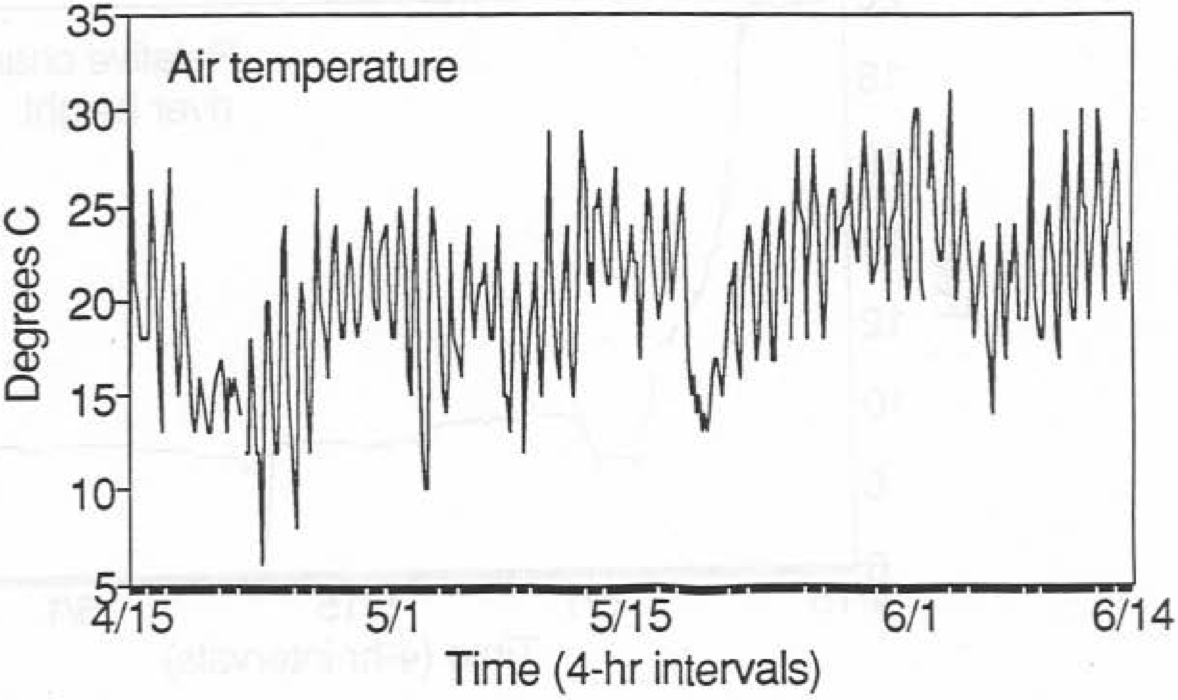

Figure 7. Air temperature (°C) measured at Barnhill's Landing, NC, for the period 15 April to 14 June 1991.

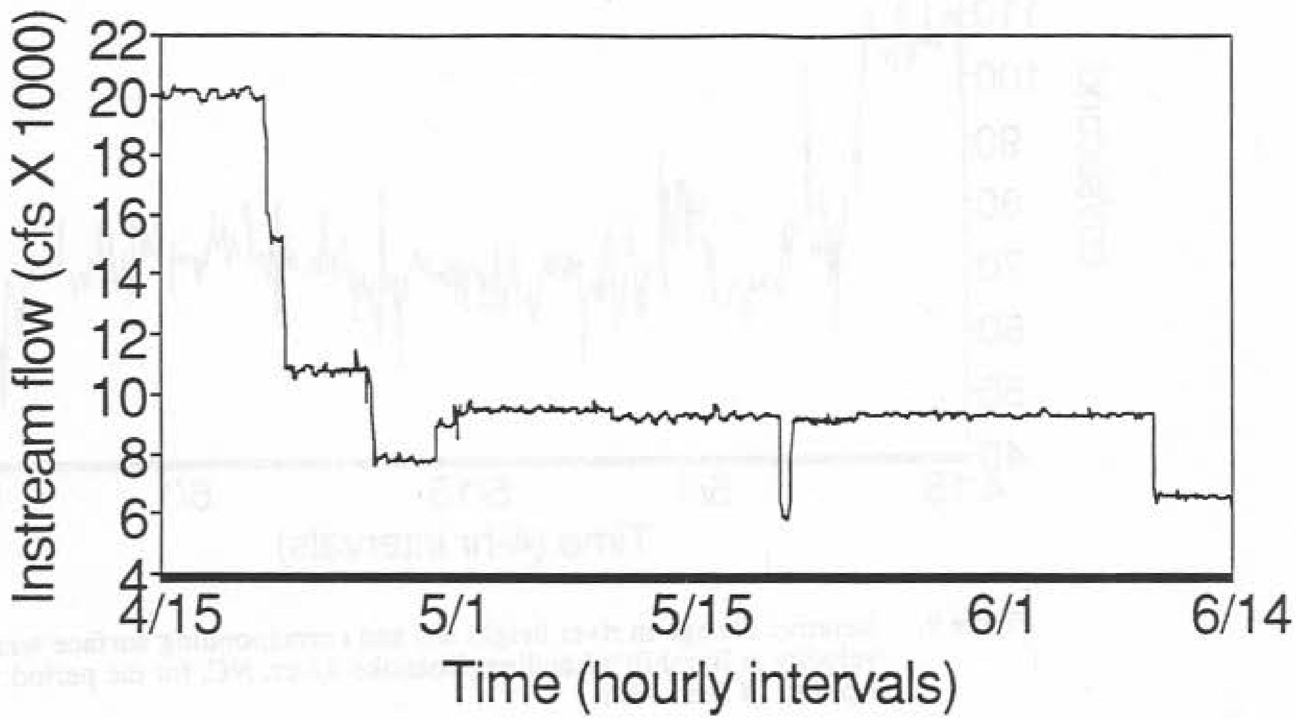

Figure 8. Hourly record of Roanoke River instream flow (cfs) downstream of the Roanoke Rapids Reservoir (USGS data), April-June 1991.

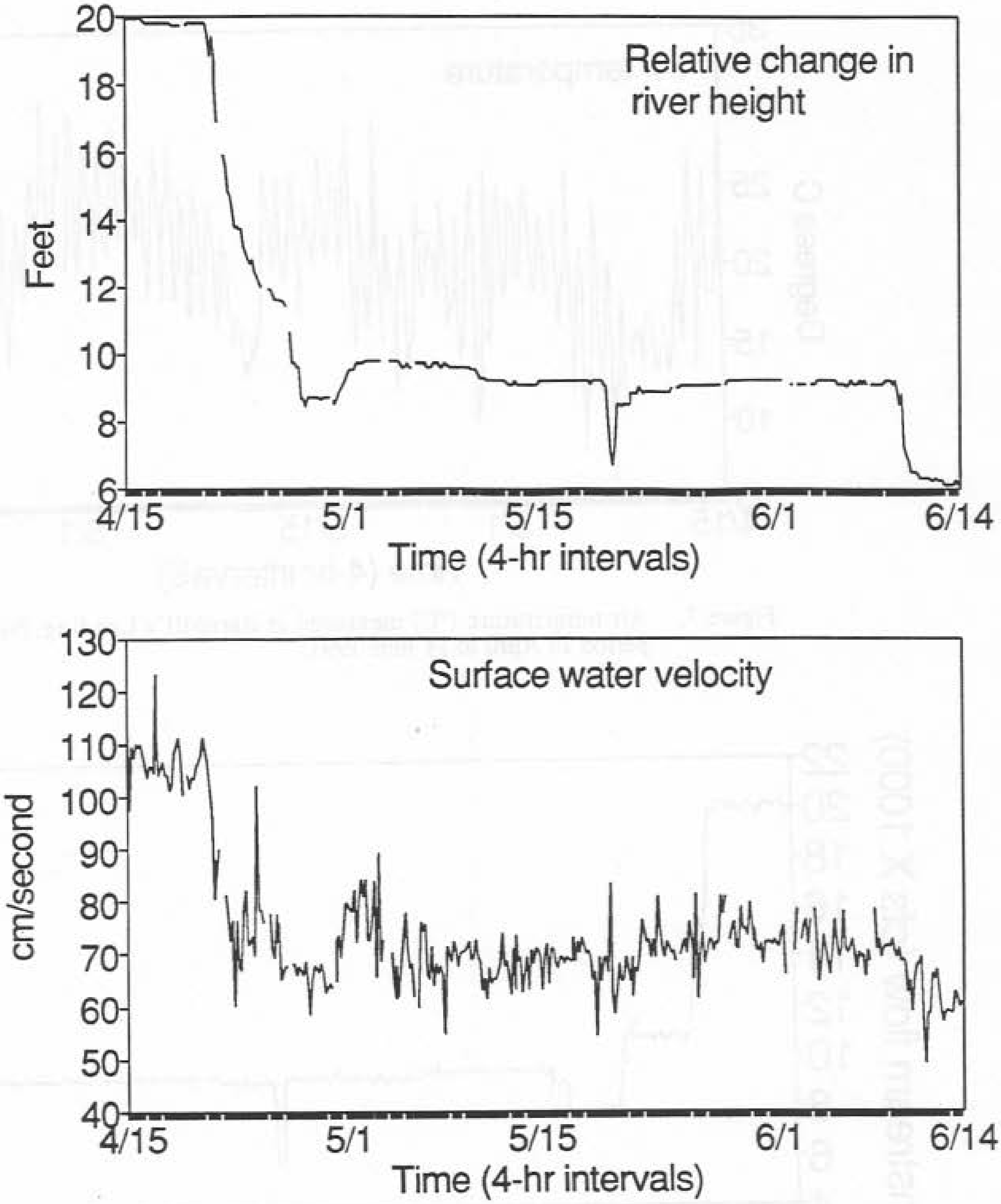

Figure 9. Relative change in river height (ft) and corresponding surface water velocity at Barnhill's Landing, Roanoke River, NC, for the period 15 April to 14 June 1991.

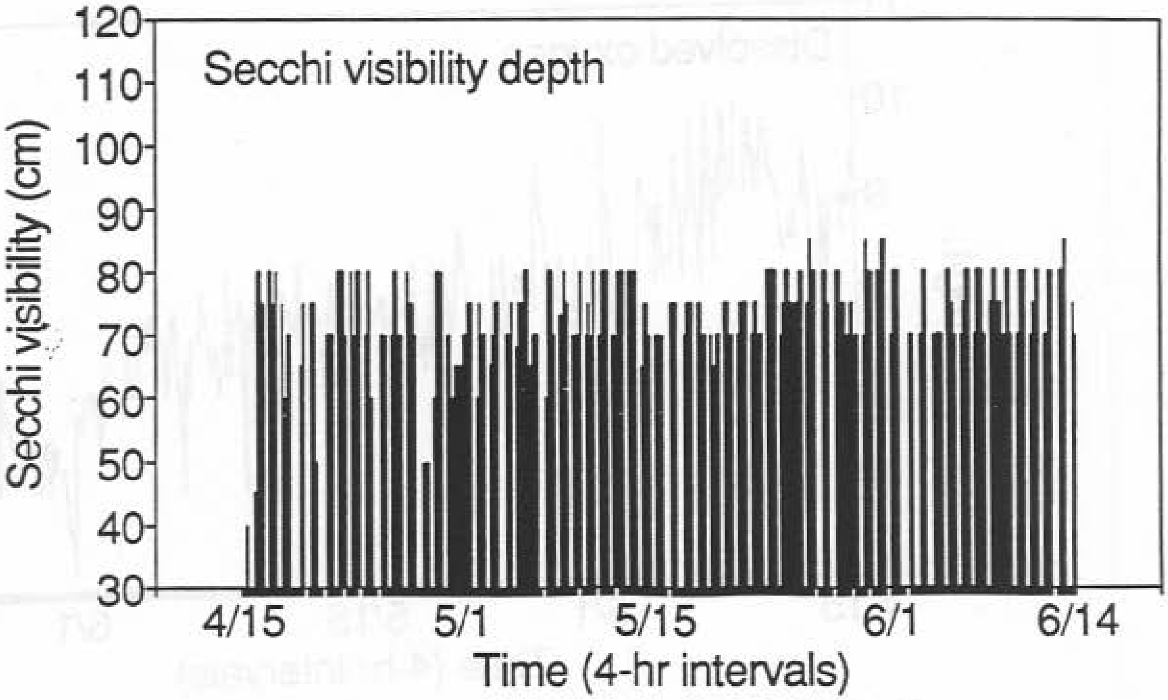

Figure 10. Depth (cm) of secchi disk visibility in the Roanoke River at Barnhill's Landing, NC, for the period 15 April to 14 June 1991. Unfilled bars indicate no information available.

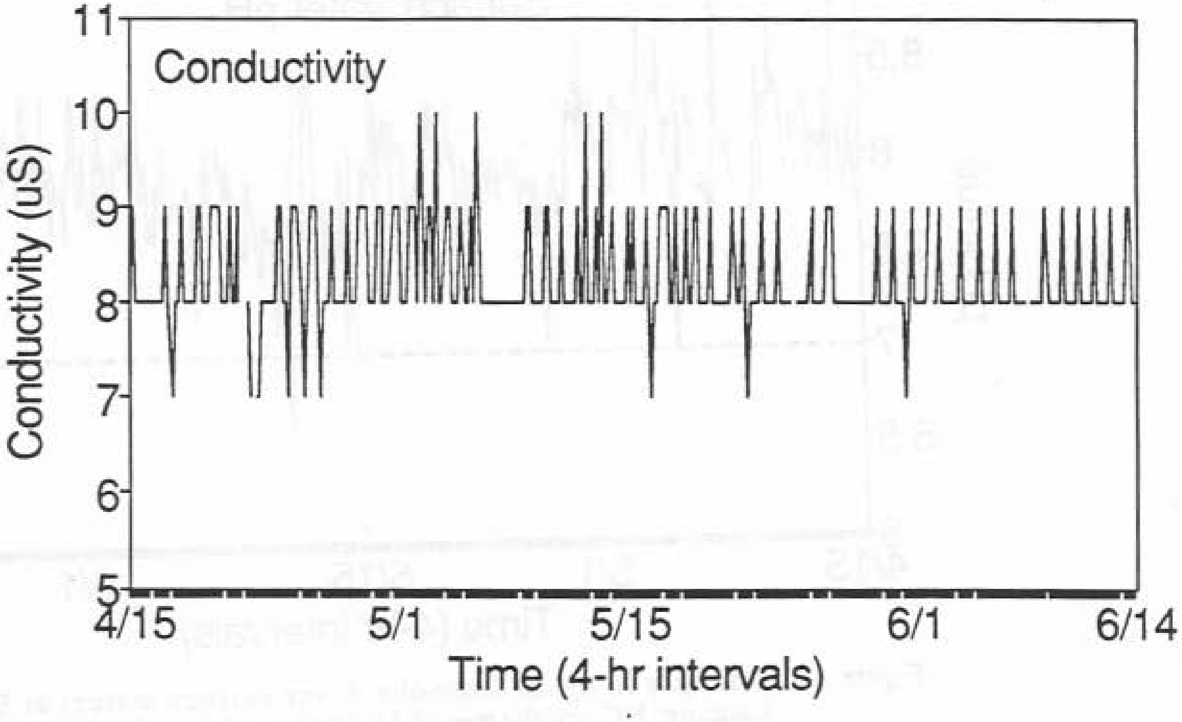

Figure 11. Changes in conductivity (µS) of Roanoke River waters at Barnhill's Landing, NC, for the period 15 April to 14 June 1991.

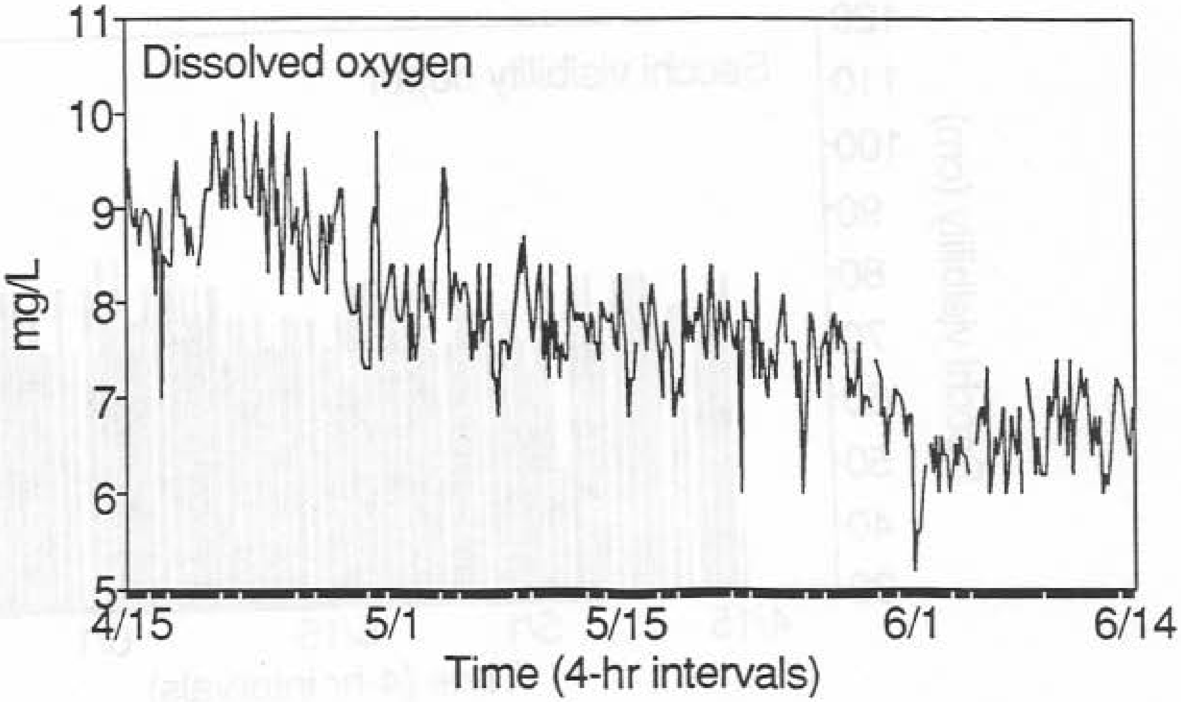

Figure 12. Changes in dissolved oxygen (mg/L) of Roanoke River waters at Barnhill's Landing, NC, for the period 15 April to 14 June 1991.

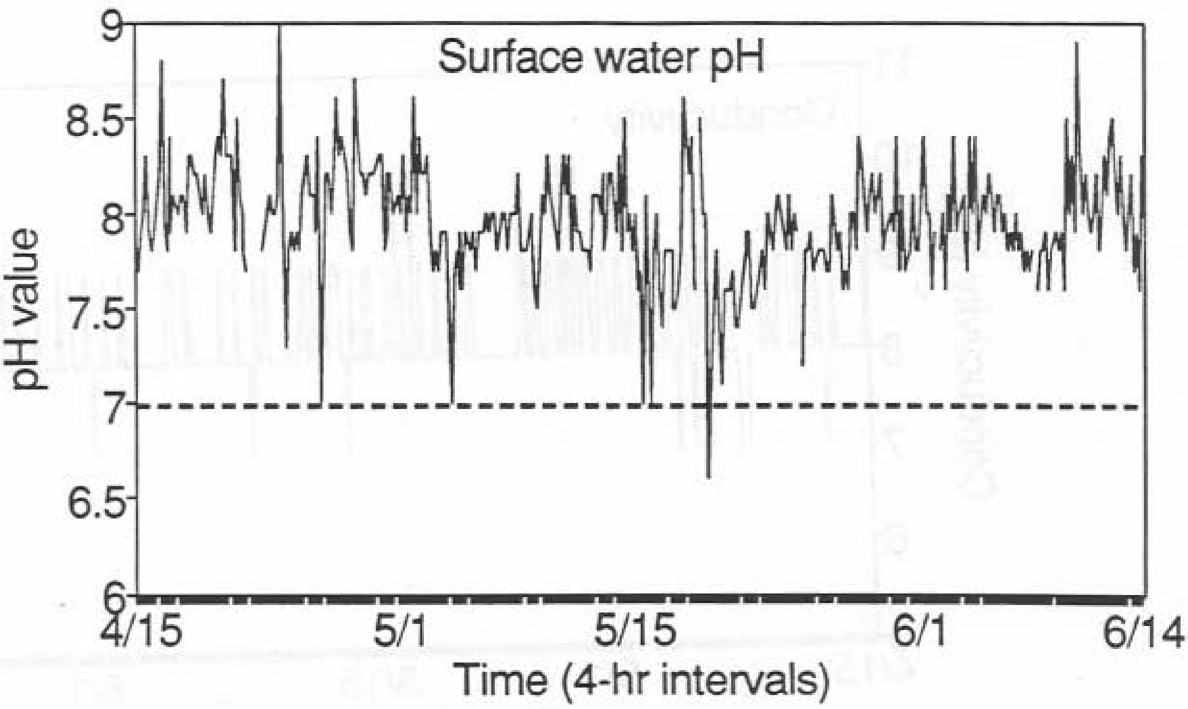

Figure 13. Changes in pH of Roanoke River surface waters at Barnhill's Landing, NC, for the period 15 April to 14 June 1991.

Table 1. Striped bass daily egg production in the Roanoke River, NC, 1991, estimated by the Hassler method and by river discharge five hours previous to sample collection.

Date	Number samples	River flow (cfs)	Mean eggs/ net	Estimated eggs/day (Hassler)	% of total (Hassler)	Cumulative percent (Hassler)	Estimated eggs/day (Volume)	% of total (Volume)	Cumulative percent (Volume)
910415	10	20,055	0	0	0.0	0.0	0	0.0	0.0
910416	12	20,139	0	0	0.0	0.0	0	0.0	0.0
910417	12	20,004	0	349,644	0.0	0.0	266,415	0.0	0.0
910418	12	20,052	0	0	0.0	0.0	0	0.0	0.0
910419	10	20,083	0	0	0.0	0.0	0	0.0	0.0
910420	12	20,020	0	0	0.0	0.0	0	0.0	0.0
910421	12	15,836	0	0	0.0	0.0	0	0.0	0.0
910422	10	11,297	0	0	0.0	0.0	0	0.0	0.0
910423	12	10,825	0	476,091	0.0	0.0	425,162	0.0	0.0
910424	12	10,791	0	886,916	0.0	0.1	792,839	0.0	0.1
910425	10	10,808	1	3,039,676	0.2	0.3	3,042,206	0.1	0.2
910426	10	10,860	0	247,741	0.0	0.3	271,327	0.0	0.2
910427	12	8,085	0	0	0.0	0.3	0	0.0	0.2
910428	12	7,810	2	3,777,979	0.2	0.5	3,993,722	0.2	0.4
910429	12	7,771	4	8,742,234	0.5	1.0	9,177,152	0.4	0.9
910430	10	8,181	2	4,765,173	0.3	1.2	4,753,955	0.2	1.1
910501	12	9,165	2	4,924,741	0.3	1.5	4,746,864	0.2	1.3
910502	12	9,511	20	42,272,152	2.3	3.8	41,299,676	2.0	3.3
910503	10	9,500	8	16,686,391	0.9	4.7	16,783,198	0.8	4.1
910504	10	9,511	1	2,600,477	0.1	4.8	3,053,943	0.1	4.3
910505	12	9,462	7	14,099,135	0.8	5.6	15,767,393	0.8	5.0
910506	10	9,494	19	40,636,743	2.2	7.8	44,507,797	2.1	7.2
910507	12	9,511	13	28,376,626	1.5	9.4	32,707,375	1.6	8.7
910508	12	9,483	118	252,225,065	13.7	23.1	290,064,227	13.9	22.7
910509	12	9,511	56	118,391,049	6.4	29.5	130,578,718	6.3	28.9
910510	12	9,402	13	26,382,648	1.4	31.0	29,834,214	1.4	30.4
910511	12	9,250	52	107,006,692	5.8	36.8	128,512,164	6.2	36.5
910512	12	9,239	98	202,652,419	11.0	47.8	233,208,626	11.2	47.7
910513	12	9,239	45	91,284,628	5.0	52.8	105,307,107	5.1	52.8
910514	12	9,272	168	344,834,188	18.8	71.6	395,191,853	19.0	71.8
910515	12	9,293	29	59,300,326	3.2	74.8	68,247,098	3.3	75.1
910516	12	9,293	29	58,865,042	3.2	78.0	67,004,766	3.2	78.3
910517	12	9,277	24	50,259,042	2.7	80.7	56,132,930	2.7	81.0

Table 1. Continued.

Date	Number samples	River flow (cfs)	Mean eggs/ net	Estimated eggs/day (Hassler)	% of total (Hassler)	Cumulative percent (Hassler)	Estimated eggs/day (Volume)	% of total (Volume)	Cumulative percent (Volume)
910518	12	9,271	35	73,051,127	4.0	84.7	82,063,464	3.9	84.9
910519	12	9,293	17	34,377,001	1.9	86.6	41,227,980	2.0	86.9
910520	12	7,081	4	6,503,436	0.4	86.9	6,597,644	0.3	87.2
910521	12	9,174	7	12,704,913	0.7	87.6	15,795,023	0.8	88.0
910522	12	9,180	10	19,901,131	1.1	88.7	22,392,820	1.1	89.0
910523	12	9,110	6	12,090,546	0.7	89.4	13,050,179	0.6	89.7
910524	12	9,244	14	28,081,642	1.5	90.9	31,864,449	1.5	91.2
910525	10	9,298	12	25,317,723	1.4	92.3	27,914,144	1.3	92.5
910526	12	9,347	20	40,970,399	2.2	94.5	46,222,310	2.2	94.8
910527	10	9,315	12	24,377,387	1.3	95.8	27,048,083	1.3	96.1
910528	10	9,320	9	19,082,707	1.0	96.9	19,521,860	0.9	97.0
910529	12	9,272	8	16,179,281	0.9	97.7	16,992,567	0.8	97.8
910530	12	9,315	7	14,113,840	0.8	98.5	15,070,058	0.7	98.5
910531	12	9,304	4	7,229,040	0.4	98.9	7,939,350	0.4	98.9
910601	10	9,315	3	6,196,320	0.3	99.2	6,805,535	0.3	99.3
910602	8	9,255	2	4,097,040	0.2	99.5	4,418,486	0.2	99.5
910603	10	9,298	1	2,048,520	0.1	99.6	2,140,231	0.1	99.6
910604	12	9,331	2	3,089,700	0.2	99.7	3,522,916	0.2	99.7
910605	12	9,309	0	514,950	0.0	99.8	556,507	0.0	99.8
910606	12	9,298	1	1,024,260	0.1	99.8	1,151,233	0.1	99.8
910607	12	9,320	1	1,198,260	0.1	99.9	1,372,851	0.1	99.9
910608	10	9,336	0	0	0.0	99.9	0	0.0	99.9
910609	12	9,336	0	171,650	0.0	99.9	190,826	0.0	99.9
910610	12	7,425	0	613,608	0.0	99.9	661,019	0.0	99.9
910611	12	6,691	0	367,777	0.0	100.0	464,619	0.0	99.9
910612	12	6,655	1	823,137	0.0	100.0	1,076,238	0.1	100.0
910613	12	6,618	0	0	0.0	100.0	0	0.0	100.0
910614	6	6,573	0	0	0.0	100.0	0	0.0	100.0
1991 egg production estimate:				1,837,208,211 ± 61,787,080			2,081,731,118 ± 70,953,356		

Table 2. Estimated number of striped bass eggs spawned in the Roanoke River, NC, and the corresponding egg viability, 1959-1987 (Hassler reports), 1988-1990 (Rulifson reports), and 1991 (this study).

Year	Sampling period	Estimated number of eggs	Egg viability (%)	Site of egg collection
1959		300,000,000	92.88	Palmyra (RM 78.5)
1960	23 Apr-8 Jun	740,000,000	92.88	Palmyra
1961		2,065,232,519	79.74	Halifax (RM 121)
1962		1,088,076,294	86.22	Halifax
1963	18 Apr-8 Jun	918,652,436	79.94	Halifax
1964	24 Apr-27 May	1,285,351,276	95.77	Halifax
1965	21 Apr-28 May	823,522,540	95.91	Halifax
1966	26 Apr-31 May	1,821,385,754	94.51	Halifax
1967	21 Apr-11 Jun	1,333,312,869	96.20	Halifax
1968	24 Apr-4 Jun	1,483,102,338	86.20	Halifax
1969	27 Apr-6 Jun	3,229,715,526	89.86	Halifax
1970	30 Apr-1 Jun	1,464,841,490	89.23	Halifax
1971		2,833,119,620	80.81	Halifax
1972	2 May-28 May	4,932,000,707	90.51	Halifax
1973	29 Apr-3 Jun	1,501,498,887	87.21	Halifax
1974	1 May-2 Jun	2,163,239,468	87.31	Halifax
1975	7 May-2 Jun	2,193,008,096	55.69	Barnhill's (RM 117)
1976	1 May-30 May	1,496,768,659	50.73	Barnhill's Landing
1977	29 Apr-31 May	1,775,957,318	52.72	Barnhill's Landing
1978		1,691,227,585	37.72	Barnhill's Landing
1979	10 May-11 Jun	1,613,382,382	43.62	Barnhill's Landing
1980	1 May-1 Jun	870,322,832	43.39	Barnhill's Landing
1981	29 Apr-29 May	344,364,065	73.70	Barnhill's Landing
1982	3 May-2 Jun	1,698,888,853	71.93	Johnson's (RM 118)
1983	6 May-12 Jun	1,352,611,202	33.29	Johnson's Landing
1984	9 May-9 Jun	703,879,559	22.73	Johnson's Landing
1985	23 Apr-23 May	600,562,645	72.21	Johnson's Landing
1986		2,279,071,483	51.10	Johnson's Landing
1987		1,382,496,006	42.87	Johnson's Landing
1988	10 Apr-7 Jun	2,082,130,728	89.00	Pollock's Ferry (RM 105)
1989	16 Apr-15 Jun	637,919,162	41.80	Barnhill's Landing
1990	16 Apr-15 Jun	964,791,625	58.00	Barnhill's Landing
1991	15 Apr-14 Jun	1,837,208,211	55.36	Barnhill's Landing
	15 Apr-14 Jun	2,068,304,334	69.51	Jacob's Landing (RM 102)

Table 3. Striped bass daily egg viability at Barnhill's Landing, Roanoke River, NC, 1991.

Date	Number of samples	Number non-viable eggs	Number viable eggs	Percentage viable eggs
910415	10	0	0	.
910416	12	0	0	.
910417	12	1	0	0.00
910418	12	0	0	.
910419	10	0	0	.
910420	12	0	0	.
910421	12	0	0	.
910422	10	0	0	.
910423	12	1	1	50.00
910424	12	2	2	50.00
910425	10	5	7	58.33
910426	10	1	0	0.00
910427	12	0	0	.
910428	12	4	19	82.61
910429	12	11	42	79.25
910430	10	6	18	75.00
910501	12	11	17	60.71
910502	12	98	137	58.30
910503	10	33	44	57.14
910504	10	8	4	33.33
910505	12	33	46	58.23
910506	10	73	116	61.38
910507	12	43	116	72.96
910508	12	621	796	56.18
910509	12	323	343	51.50
910510	12	68	82	54.67
910511	12	286	334	53.87
910512	12	622	557	47.24
910513	12	238	296	55.43
910514	12	981	1,039	51.44
910515	12	147	198	57.39
910516	12	150	192	56.14
910517	12	130	162	55.48
910518	12	182	243	57.18
910519	12	92	108	54.00
910520	12	16	27	62.79
910521	12	27	51	65.38
910522	12	41	78	65.55
910523	12	33	39	54.17
910524	12	61	106	63.47
910525	10	41	83	66.94
910526	12	86	154	64.17
910527	10	52	67	56.30

Table 3. Continued.

Date	Number of samples	Number non-viable eggs	Number viable eggs	Percentage viable eggs
910528	10	27	66	70.97
910529	12	25	69	73.40
910530	12	31	51	62.20
910531	12	21	21	50.00
910601	10	11	19	63.33
910602	8	8	8	50.00
910603	10	2	8	80.00
910604	12	7	11	61.11
910605	12	2	1	33.33
910606	12	1	5	83.33
910607	12	2	5	71.43
910608	10	0	0	.
910609	12	0	1	0.00
910610	12	2	2	50.00
910611	12	2	1	33.33
910612	12	4	3	42.86
910613	12	0	0	.
910614	6	0	0	.

Table 4. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991, relative to water temperature.

Temperature range (C)	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	.	.	.	.
12.0-13.9	0	0	0.00	0.000
14.0-15.9	1	1	50.00	0.019
16.0-17.9	69	96	58.18	1.576
18.0-19.9	918	1,428	60.87	22.413
20.0-21.9	1,861	1,874	50.17	35.684
22.0-23.9	1,647	2,081	55.82	35.617
24.0-25.9	170	309	64.51	4.576
>=26.0	6	6	50.00	0.115
	=====	=====		=======
	4,672	5,795		100.000

Table 5. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991, relative to surface water velocity.

Water velocities (cs/second)	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	.	.	.	.
40.0-59.9	94	308	76.62	3.841
60.0-79.9	4,410	5,254	54.37	92.328
80.0-99.9	165	233	58.54	3.802
100.0-119.9	3	0	0.00	0.029
120.0-139.9	0	0	0.00	0.000
	=====	=====		=======
	4,672	5,795		100.000

Table 6. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991, relative to time of day.

Time of collection	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
0200	1,169	1,188	50.40	22.518
0600	629	1,563	71.30	20.942
1000	1,428	1,092	43.33	24.076
1400	398	595	59.92	9.487
1800	687	662	49.07	12.888
2200	361	695	65.81	10.089
	=====	=====		=======
	4,672	5,795		100.000

Table 7. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991, relative to dissolved oxygen.

Dissolved oxygen values	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	43	46	51.69	0.850
5.0-5.9	5	8	61.54	0.124
6.0-6.9	92	213	69.84	2.914
7.0-7.9	3,188	3,908	55.07	67.794
8.0-8.9	1,329	1,597	54.58	27.955
9.0-9.9	15	23	60.53	0.363
10.0-10.9	0	0	0.00	0.000
	=====	=====		=======
	4,672	5,795		100.000

Table 8. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991, relative to pH.

Range of pH values	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	3	30	90.91	0.315
6.50-6.74	4	9	69.23	0.124
6.75-6.99	0	0		0.000
7.00-7.24	65	114	63.69	1.710
7.25-7.49	26	73	73.74	0.946
7.50-7.74	497	753	60.24	11.942
7.75-7.99	2,786	2,620	48.46	51.648
8.0 OR MORE	1,291	2,196	62.98	33.314
	=====	=====		=======
	4,672	5,795		100.000

Table 9. Raw data and egg production estimates by trip for striped bass eggs samples taken at Barnhill's Landing, Roanoke River, North Carolina, in 1991. Combined production is the average of surface and oblique samples.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
910415	600	0	0	0	0	19.9	8,203	0	0	0
	1000	0	0	0	0	19.9	8,203	0	0	0
	1400	0	0	0	0	19.9	8,203	0	0	0
	1800	0	0	0	0	19.9	8,203	0	0	0
	2200	0	0	0	0	19.9	8,203	0	0	0
910416	200	0	0	0	0	19.9	8,203	0	0	0
	600	0	0	0	0	20.0	8,248	0	0	0
	1000	0	0	0	0	19.9	8,203	0	0	0
	1400	0	0	0	0	19.8	8,158	0	0	0
	1800	0	0	0	0	19.8	8,158	0	0	0
	2200	0	0	0	0	19.8	8,158	0	0	0
910417	200	0	0	0	0	19.8	8,158	0	0	0
	600	0	0	0	0	19.8	8,158	0	0	0
	1000	0	0	0	1	19.8	8,158	0	7,284	3,642
	1400	0	0	0	0	19.8	8,158	0	0	0
	1800	0	0	0	0	19.8	8,158	0	0	0
	2200	1	0	0	0	19.8	8,158	7,284	0	3,642
910418	200	0	0	0	0	19.8	8,158	0	0	0
	600	0	0	0	0	19.8	8,158	0	0	0
	1000	0	0	0	1	19.8	8,158	0	7,284	3,642
	1400	0	0	0	0	19.7	8,113	0	0	0
	1800	0	0	0	0	19.7	8,113	0	0	0
	2200	0	0	0	0	19.7	8,113	0	0	0

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
910419	200	0	0	0	0	19.7	8,113	0	0	0
	600	0	0	0	0	19.7	8,113	0	0	0
	1000	.	.	.	.	.	.	.	.	.
	1400	0	0	0	0	19.7	8,113	0	0	0
	1800	0	0	0	0	19.8	8,158	0	0	0
	2200	0	0	0	0	19.8	8,158	0	0	0
910420	200	0	0	0	0	19.8	8,158	0	0	0
	600	0	0	0	0	19.8	8,158	0	0	0
	1000	0	0	0	0	19.8	8,158	0	0	0
	1400	0	0	0	0	19.8	8,158	0	0	0
	1800	0	0	0	0	19.8	8,158	0	0	0
	2200	0	0	0	0	19.8	8,158	0	0	0
910421	200	0	0	0	0	19.4	7,979	0	0	0
	600	0	0	0	0	18.8	7,709	0	0	0
	1000	0	0	0	0	19.4	7,979	0	0	0
	1400	0	0	0	0	18.7	7,665	0	0	0
	1800	0	0	0	0	18.0	7,350	0	0	0
	2200	0	0	0	0	16.9	6,875	0	0	0
910422	200	.	.	.	.	.	.	.	.	.
	600	0	0	0	0	15.9	6,475	0	0	0
	1000	0	0	0	0	15.6	6,357	0	0	0
	1400	0	0	0	0	14.8	6,042	0	0	0
	1800	0	0	0	0	14.7	6,003	0	0	0
	2200	0	0	0	0	14.3	5,848	0	0	0
910423	200	0	0	0	0	13.8	5,656	0	0	0
	600	0	0	0	0	13.8	5,656	0	0	0

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1000	0	0	0	0	13.7	5,618	0	0	0
	1400	0	0	0	0	13.7	5,618	0	0	0
	1800	0	0	0	0	13.2	5,428	0	0	0
	2200	1	1	0	0	13.0	5,352	9,557	0	4,778
910424	200	0	0	1	0	12.8	5,278	0	4,713	2,356
	600	0	0	0	0	12.7	5,241	0	0	0
	1000	0	0	1	1	12.8	5,278	0	9,425	4,713
	1400	2	0	0	0	12.4	5,131	9,162	0	4,581
	1800	2	0	2	2	12.3	5,094	9,096	18,192	13,644
	2200	0	0	0	0	12.1	5,020	0	0	0
910425	200	0	1	2	0	12.0	4,983	4,449	8,898	6,674
	600	.	.	.	.	.	.	.	.	.
	1000	6	4	6	7	11.9	4,947	44,170	57,421	50,795
	1400	0	0	0	0	11.9	4,947	0	0	0
	1800	1	0	0	1	11.8	4,911	4,385	4,385	4,385
	2200	0	0	0	0	11.6	4,839	0	0	0
910426	200	0	1	0	1	11.6	4,839	4,320	4,320	4,320
	600	0	0	0	0	11.6	4,839	0	0	0
	1000	0	0	0	0	11.6	4,839	0	0	0
	1400	0	0	0	0	11.5	4,803	0	0	0
	1800	0	0	0	1	11.4	4,767	0	4,256	2,128
	2200	.	.	.	.	.	.	.	.	.
910427	200	0	0	0	0	10.6	4,485	0	0	0
	600	0	0	0	0	9.7	4,181	0	0	0
	1000	0	0	0	0	9.7	4,181	0	0	0
	1400	0	0	0	0	9.6	4,148	0	0	0

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1800	0	0	0	0	9.6	4,148	0	0	0
	2200	0	0	0	0	8.7	3,854	0	0	0
910428	200	0	0	1	0	8.6	3,822	0	3,412	1,706
	600	1	2	3	4	8.4	3,758	10,066	23,486	16,776
	1000	1	5	4	5	8.7	3,854	20,647	30,970	25,809
	1400	5	2	1	4	8.7	3,854	24,088	17,206	20,647
	1800	3	2	2	3	8.7	3,854	17,206	17,206	17,206
	2200	1	1	1	5	8.7	3,854	6,882	20,647	13,765
910429	200	4	2	6	5	8.7	3,854	20,647	37,853	29,250
	600	12	14	24	12	8.7	3,854	89,470	123,882	106,676
	1000	3	6	8	8	8.6	3,822	30,712	54,600	42,656
	1400	4	1	1	7	8.7	3,854	17,206	27,529	22,368
	1800	1	0	0	0	8.7	3,854	3,441	0	1,721
	2200	4	2	2	0	8.7	3,854	20,647	6,882	13,765
910430	200	.	.	.	.	.	.	.	.	.
	600	0	2	1	3	8.6	3,822	6,825	13,650	10,237
	1000	9	6	6	4	8.5	3,790	50,758	33,838	42,298
	1400	2	2	0	1	8.6	3,822	13,650	3,412	8,531
	1800	0	1	1	0	8.8	3,886	3,470	3,470	3,470
	2200	2	0	0	0	9.1	3,983	7,113	0	3,556
910501	200	2	1	3	1	9.2	4,016	10,757	14,343	12,550
	600	5	3	3	2	9.4	4,082	29,157	18,223	23,690
	1000	6	4	4	5	9.5	4,115	36,740	33,066	34,903
	1400	0	0	0	0	9.5	4,115	0	0	0
	1800	0	1	0	0	9.5	4,115	3,674	0	1,837
	2200	3	3	0	2	9.7	4,181	22,397	7,466	14,931

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
910502	200	27	35	39	48	9.7	4,181	231,432	324,751	278,091
	600	31	10	39	29	9.7	4,181	153,043	253,828	203,436
	1000	59	51	67	62	9.7	4,181	410,604	481,527	446,066
	1400	1	6	6	2	9.8	4,214	26,336	30,098	28,217
	1800	1	0	2	6	9.8	4,214	3,762	30,098	16,930
	2200	8	6	18	25	9.8	4,214	52,671	161,776	107,224
910503	200	19	23	31	26	9.8	4,214	158,014	214,447	186,230
	600	3	2	4	1	9.8	4,214	18,811	18,811	18,811
	1000	17	9	17	12	9.8	4,214	97,818	109,105	103,461
	1400	0	0	0	5	9.8	4,214	0	18,811	9,406
	1800	2	2	10	5	9.8	4,214	15,049	56,433	35,741
	2200	.	.	.	.	.	.	.	.	.
910504	200	.	.	.	.	.	.	.	.	.
	600	2	3	4	6	9.8	4,214	18,811	37,622	28,217
	1000	0	1	5	5	9.8	4,214	3,762	37,622	20,692
	1400	2	0	1	1	9.8	4,214	7,524	7,524	7,524
	1800	0	2	5	3	9.8	4,214	7,524	30,098	18,811
	2200	1	1	2	1	9.8	4,214	7,524	11,287	9,406
910505	200	6	10	12	7	9.8	4,214	60,196	71,482	65,839
	600	4	4	10	5	9.6	4,148	29,627	55,551	42,589
	1000	8	10	14	9	9.6	4,148	66,661	85,178	75,920
	1400	7	6	0	3	9.7	4,181	48,526	11,198	29,862
	1800	8	6	10	9	9.6	4,148	51,847	70,364	61,106
	2200	8	2	1	1	9.6	4,148	37,034	7,407	22,220
910506	200	.	.	.	.	.	.	.	.	.
	600	16	3	20	13	9.7	4,181	70,923	123,181	97,052

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1000	66	77	68	90	9.7	4,181	533,786	589,777	561,781
	1400	13	3	3	9	9.7	4,181	59,724	44,793	52,259
	1800	2	0	0	5	9.7	4,181	7,466	18,664	13,065
	2200	2	7	9	1	9.7	4,181	33,595	37,328	35,461
910507	200	9	4	10	9	9.6	4,148	48,144	70,364	59,254
	600	16	8	19	46	9.6	4,148	88,881	240,720	164,801
	1000	1	1	5	5	9.6	4,148	7,407	37,034	22,220
	1400	8	3	2	11	9.7	4,181	41,060	48,526	44,793
	1800	15	17	11	8	9.7	4,181	119,449	70,923	95,186
	2200	47	30	21	44	9.7	4,181	287,423	242,630	265,026
910508	200	37	26	49	24	9.6	4,148	233,314	270,348	251,831
	600	173	180	170	89	9.6	4,148	1,307,297	959,179	1,133,238
	1000	119	105	57	107	9.7	4,181	836,140	612,174	724,157
	1400	179	243	453	253	9.6	4,148	1,562,832	2,614,595	2,088,713
	1800	83	95	120	98	9.6	4,148	659,204	807,340	733,272
	2200	117	60	101	103	9.6	4,148	655,500	755,492	705,496
910509	200	83	92	120	101	9.6	4,148	648,094	818,450	733,272
	600	144	114	223	181	9.6	4,148	955,475	1,496,170	1,225,823
	1000	78	97	70	73	9.6	4,148	648,094	529,585	588,839
	1400	16	1	7	5	9.6	4,148	62,958	44,441	53,699
	1800	13	22	17	8	9.6	4,148	129,619	92,585	111,102
	2200	2	4	1	9	9.6	4,148	22,220	37,034	29,627
910510	200	26	19	36	41	9.6	4,148	166,653	285,161	225,907
	600	5	7	8	11	9.5	4,115	44,088	69,806	56,947
	1000	25	18	28	23	9.5	4,115	157,983	187,375	172,679
	1400	6	2	1	10	9.5	4,115	29,392	40,414	34,903

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1800	5	12	10	8	9.4	4,082	61,959	65,604	63,781
	2200	15	10	9	27	9.3	4,049	90,382	130,150	110,266
910511	200	21	18	31	27	9.3	4,049	140,995	209,686	175,340
	600	78	43	60	43	9.3	4,049	437,447	372,373	404,910
	1000	79	107	76	81	9.2	4,016	666,959	562,971	614,965
	1400	20	15	34	20	9.2	4,016	125,503	193,633	159,568
	1800	38	41	57	47	9.2	4,016	283,278	372,924	328,101
	2200	81	79	94	88	9.2	4,016	573,728	652,616	613,172
910512	200	131	107	121	117	9.2	4,016	853,421	853,421	853,421
	600	98	113	157	104	9.2	4,016	756,604	935,895	846,250
	1000	224	301	209	235	9.2	4,016	1,882,547	1,592,097	1,737,322
	1400	26	48	8	3	9.2	4,016	265,349	39,444	152,397
	1800	53	73	51	69	9.2	4,016	451,811	430,296	441,054
	2200	3	2	8	19	9.1	3,983	17,782	96,024	56,903
910513	200	57	83	48	59	9.1	3,983	497,900	380,538	439,219
	600	26	15	8	31	9.1	3,983	145,814	138,701	142,257
	1000	42	37	58	60	9.1	3,983	280,958	419,659	350,308
	1400	18	24	25	10	9.2	4,016	150,604	125,503	138,053
	1800	61	89	75	82	9.1	3,983	533,464	558,359	545,912
	2200	19	63	58	29	9.1	3,983	291,627	309,409	300,518
910514	200	389	427	526	453	9.1	3,983	2,902,045	3,481,743	3,191,894
	600	316	204	315	198	9.1	3,983	1,849,343	1,824,448	1,836,895
	1000	154	264	138	114	9.1	3,983	1,486,587	896,220	1,191,403
	1400	23	18	36	43	9.1	3,983	145,814	280,958	213,386
	1800	64	79	59	68	9.1	3,983	508,569	451,666	480,118
	2200	41	41	71	77	9.1	3,983	291,627	526,351	408,989

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
910515	200	97	81	109	90	9.1	3,983	633,044	707,729	670,387
	600	26	45	38	71	9.2	4,016	254,592	390,853	322,722
	1000	14	12	24	7	9.2	4,016	93,231	111,160	102,195
	1400	12	2	13	14	9.2	4,016	50,201	96,817	73,509
	1800	16	12	13	5	9.2	4,016	100,402	64,544	82,473
	2200	16	12	11	17	9.2	4,016	100,402	100,402	100,402
910516	200	19	26	23	38	9.2	4,016	161,361	218,734	190,048
	600	50	41	30	47	9.2	4,016	326,308	276,107	301,207
	1000	15	18	23	17	9.2	4,016	118,331	143,432	130,882
	1400	12	19	26	20	9.2	4,016	111,160	164,947	138,053
	1800	34	46	68	47	9.2	4,016	286,864	412,367	349,616
	2200	20	42	47	43	9.2	4,016	222,320	322,722	272,521
910517	200	49	38	33	28	9.2	4,016	311,965	218,734	265,349
	600	63	67	38	26	9.2	4,016	466,154	229,491	347,823
	1000	10	8	18	14	9.2	4,016	64,544	114,746	89,645
	1400	5	3	2	2	9.2	4,016	28,686	14,343	21,515
	1800	10	12	11	14	9.2	4,016	78,888	89,645	84,266
	2200	16	11	23	17	9.2	4,016	96,817	143,432	120,124
910518	200	21	29	17	18	9.2	4,016	179,290	125,503	152,397
	600	39	13	44	37	9.2	4,016	186,462	290,450	238,456
	1000	65	41	43	52	9.2	4,016	380,095	340,651	360,373
	1400	33	34	12	15	9.2	4,016	240,249	96,817	168,533
	1800	73	44	86	109	9.2	4,016	419,539	699,232	559,385
	2200	9	24	10	10	9.1	3,983	117,362	71,129	94,245
910519	200	14	12	10	8	9.2	4,016	93,231	64,544	78,888
	600	18	2	13	13	9.2	4,016	71,716	93,231	82,473

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1000	50	46	48	59	9.2	4,016	344,237	383,681	363,959
	1400	5	8	7	2	9.2	4,016	46,615	32,272	39,444
	1800	21	18	8	23	9.2	4,016	139,846	111,160	125,503
	2200	1	5	5	6	9.1	3,983	21,339	39,121	30,230
910520	200	17	9	14	12	9.0	3,950	91,703	91,703	91,703
	600	1	3	3	3	7.9	3,598	12,850	19,275	16,062
	1000	1	4	3	4	7.1	3,346	14,937	20,911	17,924
	1400	0	3	2	0	6.7	3,081	8,252	5,502	6,877
	1800	1	0	1	1	7.3	3,409	3,044	6,087	4,565
	2200	3	1	12	5	8.5	3,790	13,535	57,525	35,530
910521	200	4	7	3	5	8.5	3,790	37,222	27,071	32,146
	600	10	5	4	1	8.4	3,758	50,328	16,776	33,552
	1000	10	8	9	4	8.5	3,790	60,909	43,990	52,450
	1400	5	5	3	4	8.5	3,790	33,838	23,687	28,763
	1800	4	4	3	2	8.5	3,790	27,071	16,919	21,995
	2200	9	7	3	8	8.8	3,886	55,516	38,167	46,841
910522	200	11	14	10	12	8.8	3,886	86,743	76,334	81,539
	600	9	3	2	8	8.8	3,886	41,637	34,697	38,167
	1000	14	9	36	54	8.8	3,886	79,804	312,276	196,040
	1400	14	7	8	11	9.0	3,950	74,068	67,014	70,541
	1800	17	10	21	14	8.8	3,886	93,683	121,441	107,562
	2200	9	2	12	2	8.9	3,918	38,482	48,977	43,730
910523	200	3	2	4	6	8.9	3,918	17,492	34,984	26,238
	600	1	0	4	7	8.9	3,918	3,498	38,482	20,990
	1000	8	6	7	11	8.9	3,918	48,977	62,971	55,974
	1400	8	1	5	2	8.9	3,918	31,486	24,489	27,987

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1800	13	4	12	11	8.9	3,918	59,473	80,463	69,968
	2200	12	14	19	12	8.9	3,918	90,958	108,450	99,704
910524	200	21	17	25	20	8.9	3,918	132,939	157,428	145,183
	600	19	28	17	23	8.9	3,918	164,424	139,936	152,180
	1000	9	12	17	14	8.9	3,918	73,466	108,450	90,958
	1400	9	5	3	4	8.9	3,918	48,977	24,489	36,733
	1800	10	8	9	12	8.9	3,918	62,971	73,466	68,219
	2200	11	18	15	20	9.0	3,950	102,285	123,447	112,866
910525	200	.	.	.	.	.	.	.	.	.
	600	11	5	1	7	9.0	3,950	56,433	28,216	42,325
	1000	7	6	9	8	9.0	3,950	45,852	59,960	52,906
	1400	4	6	11	5	9.1	3,983	35,564	56,903	46,234
	1800	18	23	37	23	9.1	3,983	145,814	213,386	179,600
	2200	23	21	18	7	9.1	3,983	156,483	88,911	122,697
910526	200	19	21	31	26	9.1	3,983	142,257	202,716	172,487
	600	3	5	4	24	9.1	3,983	28,451	99,580	64,016
	1000	16	32	29	50	9.1	3,983	170,709	280,958	225,833
	1400	19	13	5	18	9.1	3,983	113,806	81,798	97,802
	1800	34	40	78	64	9.1	3,983	263,176	505,013	384,094
	2200	12	26	10	30	9.1	3,983	135,144	142,257	138,701
910527	200	16	12	21	26	9.1	3,983	99,580	167,152	133,366
	600	19	12	20	14	9.1	3,983	110,249	120,919	115,584
	1000	11	14	17	19	9.1	3,983	88,911	128,031	108,471
	1400	7	9	10	11	9.1	3,983	56,903	74,685	65,794
	1800	8	11	18	11	9.1	3,983	67,572	103,136	85,354
	2200	.	.	.	.	9.1	3,983	.	.	.

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
910528	200	13	7	13	8	9.1	3,983	71,129	74,685	72,907
	600	3	1	12	9	9.1	3,983	14,226	74,685	44,455
	1000	23	7	8	8	9.1	3,983	106,693	56,903	81,798
	1400	.	.	.	.	.	.	.	.	.
	1800	8	9	.	.	9.1	3,983	60,459	.	60,459
	2200	11	11	18	8	9.2	4,016	78,888	93,231	86,059
910529	200	22	13	7	15	9.2	4,016	125,503	78,888	102,195
	600	6	4	2	3	9.2	4,016	35,858	17,929	26,894
	1000	3	3	6	4	9.2	4,016	21,515	35,858	28,686
	1400	13	3	3	4	9.2	4,016	57,373	25,101	41,237
	1800	8	4	4	3	9.2	4,016	43,030	25,101	34,065
	2200	11	4	9	12	9.2	4,016	53,787	75,302	64,544
910530	200	19	23	26	29	9.2	4,016	150,604	197,219	173,911
	600	4	2	6	5	9.2	4,016	21,515	39,444	30,479
	1000	7	7	10	11	9.2	4,016	50,201	75,302	62,752
	1400	0	2	1	5	9.2	4,016	7,172	21,515	14,343
	1800	4	6	9	10	9.2	4,016	35,858	68,130	51,994
	2200	5	3	4	2	9.2	4,016	28,686	21,515	25,101
910531	200	7	5	9	12	9.2	4,016	43,030	75,302	59,166
	600	2	1	1	1	9.2	4,016	10,757	7,172	8,965
	1000	4	3	6	5	9.2	4,016	25,101	39,444	32,272
	1400	2	0	3	2	9.2	4,016	7,172	17,929	12,550
	1800	6	5	7	4	9.2	4,016	39,444	39,444	39,444
	2200	4	3	8	5	9.2	4,016	25,101	46,615	35,858
910601	200	2	7	9	9	9.2	4,016	32,272	64,544	48,408
	600	5	3	4	6	9.2	4,016	28,686	35,858	32,272

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1000	5	0	2	5	9.2	4,016	17,929	25,101	21,515
	1400	6	1	1	1	9.2	4,016	25,101	7,172	16,136
	1800	1	0	2	1	9.2	4,016	3,586	10,757	7,172
	2200	.	.	.	.	.	.	.	.	.
910602	200	4	2	2	3	9.1	3,983	21,339	17,782	19,560
	600	.	.	.	.	.	.	.	.	.
	1000	1	2	3	3	9.1	3,983	10,669	21,339	16,004
	1400	0	2	3	1	9.1	3,983	7,113	14,226	10,669
	1800	.	.	.	.	.	.	.	.	.
	2200	1	4	1	2	9.1	3,983	17,782	10,669	14,226
910603	200	6	2	1	4	9.1	3,983	28,451	17,782	23,117
	600	0	1	1	1	9.1	3,983	3,556	7,113	5,335
	1000	0	0	1	0	9.1	3,983	0	3,556	1,778
	1400	1	0	5	0	9.1	3,983	3,556	17,782	10,669
	1800	.	.	.	.	.	.	.	.	.
	2200	0	0	0	0	9.1	3,983	0	0	0
910604	200	0	0	0	0	9.1	3,983	0	0	0
	600	0	2	1	1	9.1	3,983	7,113	7,113	7,113
	1000	3	0	0	2	9.2	4,016	10,757	7,172	8,965
	1400	1	0	2	0	9.2	4,016	3,586	7,172	5,379
	1800	7	3	5	6	9.2	4,016	35,858	39,444	37,651
	2200	2	0	0	0	9.2	4,016	7,172	0	3,586
910605	200	1	0	0	0	9.2	4,016	3,586	0	1,793
	600	0	0	1	1	9.2	4,016	0	7,172	3,586
	1000	1	0	2	0	9.2	4,016	3,586	7,172	5,379
	1400	0	0	0	0	9.2	4,016	0	0	0

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
	1800	1	0	1	0	9.1	3,983	3,556	3,556	3,556
	2200	0	0	1	1	9.1	3,983	0	7,113	3,556
910606	200	2	1	2	1	9.1	3,983	10,669	10,669	10,669
	600	0	2	1	1	9.1	3,983	7,113	7,113	7,113
	1000	0	0	2	1	9.0	3,950	0	10,581	5,291
	1400	1	0	0	1	9.1	3,983	3,556	3,556	3,556
	1800	0	0	1	0	9.2	4,016	0	3,586	1,793
	2200	0	0	1	0	9.1	3,983	0	3,556	1,778
910607	200	0	1	1	2	9.1	3,983	3,556	10,669	7,113
	600	0	0	0	1	9.1	3,983	0	3,556	1,778
	1000	0	2	2	2	9.2	4,016	7,172	14,343	10,757
	1400	0	0	0	0	9.1	3,983	0	0	0
	1800	0	0	1	1	9.2	4,016	0	7,172	3,586
	2200	3	1	2	1	9.1	3,983	14,226	10,669	12,447
910608	200	.	.	.	.	.	.	.	.	.
	600	0	0	0	0	9.1	3,983	0	0	0
	1000	0	0	1	3	9.1	3,983	0	14,226	7,113
	1400	0	0	1	0	9.1	3,983	0	3,556	1,778
	1800	0	0	0	0	9.1	3,983	0	0	0
	2200	0	0	0	0	9.1	3,983	0	0	0
910609	200	0	0	0	0	9.1	3,983	0	0	0
	600	0	1	0	0	9.2	4,016	3,586	0	1,793
	1000	0	0	0	0	9.2	4,016	0	0	0
	1400	0	0	0	0	9.2	4,016	0	0	0
	1800	0	0	0	0	9.1	3,983	0	0	0
	2200	0	0	2	1	9.2	4,016	0	10,757	5,379

Table 9. Continued.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
910610	200	0	0	0	0	8.9	3,918	0	0	0
	600	0	0	0	0	8.5	3,790	0	0	0
	1000	1	1	0	0	8.8	3,886	6,939	0	3,470
	1400	1	1	1	0	7.3	3,409	6,087	3,044	4,565
	1800	0	0	0	0	7.0	3,314	0	0	0
	2200	0	0	0	0	6.8	3,159	0	0	0
910611	200	1	0	0	0	6.5	2,925	2,612	0	1,306
	600	0	0	1	0	6.5	2,925	0	2,612	1,306
	1000	0	0	0	0	6.5	2,925	0	0	0
	1400	1	0	0	0	6.4	2,848	2,542	0	1,271
	1800	0	0	0	0	6.3	2,770	0	0	0
	2200	1	0	1	0	6.3	2,770	2,473	2,473	2,473
910612	200	0	0	1	0	6.3	2,770	0	2,473	1,236
	600	0	0	0	0	6.3	2,770	0	0	0
	1000	1	0	2	1	6.3	2,770	2,473	7,419	4,946
	1400	3	1	0	1	6.2	2,692	9,614	2,403	6,009
	1800	1	1	0	5	6.2	2,692	4,807	12,017	8,412
	2200	0	0	0	1	6.3	2,770	0	2,473	1,236
910613	200	0	0	0	0	6.2	2,692	0	0	0
	600	0	0	0	0	6.2	2,692	0	0	0
	1000	0	0	3	1	6.2	2,692	0	9,614	4,807
	1400	0	0	0	0	6.1	2,614	0	0	0
	1800	0	0	0	0	6.1	2,614	0	0	0
	2200	0	0	0	0	6.1	2,614	0	0	0
910614	200	0	0	0	0	6.1	2,614	0	0	0
	600	0	0	0	0	6.2	2,692	0	0	0
	1000	0	0	0	0	6.1	2,614	0	0	0

Table 10. Daily egg production of striped bass at Barnhill's Landing, Roanoke River, North Carolina, in 1991 estimated by two methods and two depths.

Date	No. of samples	Total eggs surface only (trip method)	Total eggs oblique only (trip method)	Total eggs all depths (trip method)	Total eggs surface only (Hassler)	Total eggs oblique only (Hassler)	Total eggs all depths (Hassler)
910415	20	0	0	0	0	0	0
910416	24	0	0	0	0	0	0
910417	24	349,644	349,644	349,644	349,644	349,644	349,644
910418	24	0	349,644	174,822	0	348,682	174,341
910419	20	0	0	0	0	0	0
910420	24	0	0	0	0	0	0
910421	24	0	0	0	0	0	0
910422	20	0	0	0	0	0	0
910423	24	458,738	0	229,369	476,091	0	238,046
910424	24	876,376	1,551,832	1,214,104	886,916	1,552,103	1,219,509
910425	20	3,053,031	4,072,565	3,562,798	3,039,676	4,052,901	3,546,289
910426	20	248,855	493,996	371,425	247,741	495,481	371,611
910427	24	0	0	0	0	0	0
910428	24	3,786,692	5,420,578	4,603,635	3,777,979	5,420,578	4,599,278
910429	24	8,742,004	12,035,916	10,388,960	8,742,234	12,041,190	10,391,712
910430	20	4,712,594	3,131,774	3,922,184	4,765,173	3,176,782	3,970,977
910501	24	4,930,858	3,508,739	4,219,799	4,924,741	3,517,672	4,221,207
910502	24	42,137,087	61,540,246	51,838,666	42,272,152	61,699,354	51,985,753
910503	20	16,686,391	24,054,408	20,370,399	16,686,391	24,054,408	20,370,399
910504	20	2,600,477	7,151,310	4,875,893	2,600,477	7,151,310	4,875,893
910505	24	14,106,902	14,456,803	14,281,853	14,099,135	14,456,075	14,277,605
910506	20	40,636,743	46,872,010	43,754,376	40,636,743	46,872,010	43,754,376
910507	24	28,433,731	34,089,760	31,261,746	28,376,626	34,087,645	31,232,135
910508	24	252,207,910	288,920,528	270,564,219	252,225,065	289,070,929	270,647,997
910509	24	118,391,049	144,877,936	131,634,493	118,391,049	144,877,936	131,634,493
910510	24	26,422,129	37,368,787	31,895,458	26,382,648	37,287,476	31,835,062
910511	24	106,940,691	113,482,666	110,211,678	107,006,692	113,565,166	110,285,929
910512	24	202,922,437	189,466,056	196,194,246	202,652,419	189,245,389	195,948,904
910513	24	91,218,357	92,744,877	91,981,617	91,284,628	92,823,133	92,053,880
910514	24	344,834,188	358,149,567	351,491,878	344,834,188	358,149,567	351,491,878

Table 10. Continued.

Date	No. of samples	Total eggs surface only (trip method)	Total eggs oblique only (trip method)	Total eggs all depths (trip method)	Total eggs surface only (Hassler)	Total eggs oblique only (Hassler)	Total eggs all depths (Hassler)
910515	24	59,130,420	70,632,850	64,881,635	59,300,326	70,816,622	65,058,474
910516	24	58,865,042	73,839,482	66,352,262	58,865,042	73,839,482	66,352,262
910517	24	50,259,042	38,899,121	44,579,081	50,259,042	38,899,121	44,579,081
910518	24	73,104,472	77,942,162	75,523,317	73,051,127	77,863,907	75,457,517
910519	24	34,415,541	34,752,731	34,584,136	34,377,001	34,720,771	34,548,886
910520	24	6,927,486	9,648,265	8,287,875	6,503,436	9,074,561	7,788,998
910521	24	12,714,530	7,997,330	10,355,930	12,704,913	7,981,292	10,343,102
910522	24	19,892,189	31,715,759	25,803,974	19,901,131	31,774,915	25,838,023
910523	24	12,090,546	16,792,426	14,441,486	12,090,546	16,792,426	14,441,486
910524	24	28,083,247	30,106,592	29,094,920	28,081,642	30,099,484	29,090,563
910525	20	25,352,579	25,769,051	25,560,815	25,317,723	25,726,074	25,521,898
910526	24	40,970,399	62,991,988	51,981,193	40,970,399	62,991,988	51,981,193
910527	20	24,377,387	34,210,283	29,293,835	24,377,387	34,210,283	29,293,835
910528	18	19,088,460	21,564,450	19,911,252	19,082,707	21,544,992	20,177,056
910529	24	16,179,281	12,392,640	14,285,960	16,179,281	12,392,640	14,285,960
910530	24	14,113,840	20,310,161	17,212,001	14,113,840	20,310,161	17,212,001
910531	24	7,229,040	10,843,560	9,036,300	7,229,040	10,843,560	9,036,300
910601	20	6,196,320	8,261,760	7,229,040	6,196,320	8,261,760	7,229,040
910602	16	4,097,040	4,609,170	4,353,105	4,097,040	4,609,170	4,353,105
910603	20	2,048,520	2,663,076	2,355,798	2,048,520	2,663,076	2,355,798
910604	24	3,095,340	2,923,220	3,009,280	3,089,700	2,918,050	3,003,875
910605	24	514,950	1,200,610	857,780	514,950	1,201,550	858,250
910606	24	1,024,260	1,874,990	1,449,625	1,024,260	1,877,810	1,451,035
910607	24	1,197,790	2,227,690	1,712,740	1,198,260	2,225,340	1,711,800
910608	20	0	1,024,260	512,130	0	1,024,260	512,130
910609	24	172,120	516,360	344,240	171,650	514,950	343,300
910610	24	625,291	146,097	385,694	613,608	153,402	383,505
910611	24	366,110	244,073	305,092	367,777	245,185	306,481
910612	24	810,911	1,285,721	1,048,316	823,137	1,293,501	1,058,319

Table 10. Continued.

Date	No. of samples	Total eggs surface only (trip method)	Total eggs oblique only (trip method)	Total eggs all depths (trip method)	Total eggs surface only (Hassler)	Total eggs oblique only (Hassler)	Total eggs all depths (Hassler)
910613	24	0	461,472	230,736	0	454,804	227,402
910614	12	0	0	0	0	0	0
Total eggs:		1,837,639,036	2,051,936,992	1,944,372,811	1,837,208,211	2,051,620,568	1,944,277,596
S.D.		± 61,792,545	± 65,745,038	± 63,678,774	± 61,787,080	± 65,754,219	± 63,679,706

Table 11. Results of statistical analyses (NPAR1WAY, SAS 1985) on log-transformed data testing whether significant differences exist in the 1991 yearly egg production estimates calculated by the Hassler method and trip method using cross-sectional area of the river or discharge from the dam five hours previous, and surface and oblique sampling techniques. Significance tests with 2 df = Kruskal-Wallis with chi-square statistic; 1 df = Wilcoxon signed-rank with Z statistic.

Class	Comparison	n	df	Statistic	P>statistic
River cross-section only					
Hassler	Surface, Oblique, All	61	2	0.26	0.8770
Trip	Surface, Oblique, All	61	2	0.27	0.8755
All samples	Hassler, Trip	61	1	0.00	0.9980
Oblique	Hassler, Trip	61	1	0.00	0.9980
Surface	Hassler, Trip	61	1	0.00	0.9898
Cross-section vs volume (surface samples only)					
Hassler	Xsect, Volume	61	1	-0.0437	0.9652
Trip	Xsect, Volume	61	1	0.0103	0.9918
Volume	Hassler, Trip	61	1	0.1977	0.8433
Xsect	Hassler, Trip	61	1	0.1566	0.8755

Table 12. Striped bass spawning in the Roanoke River, NC, estimated from surface samples by the Hassler and trip methods, and by cross-sectional area (Hassler) and river discharge five hours previous, 1991.

Date	Number of samples	Mean river stage	Mean surface velocity	Mean X-section (sq.ft.)	Mean river discharge	Mean eggs/ day	Mean volume filtered (cfs)	Daily eggs- by trip X-sect.	Daily eggs- by trip Flow15	Daily eggs - Hassler X-sect.	Daily eggs - Hassler Flow15
910415	20	19.9	3.5	8,203	20,055	0	593	0	0	0	0
910416	24	19.9	3.5	8,188	20,139	0	590	0	0	0	0
910417	24	19.8	3.6	8,158	20,004	0	601	349,644	280,733	349,644	266,415
910418	24	19.7	3.5	8,136	20,052	0	584	0	0	0	0
910419	20	19.7	3.4	8,131	20,083	0	570	0	0	0	0
910420	24	19.8	3.5	8,158	20,020	0	588	0	0	0	0
910421	24	18.5	3.0	7,593	15,836	0	498	0	0	0	0
910422	20	15.1	2.4	6,145	11,297	0	405	0	0	0	0
910423	24	13.5	2.4	5,554	10,825	0	407	458,738	432,721	476,091	425,162
910424	24	12.5	2.6	5,174	10,791	0	436	876,376	705,096	886,916	792,839
910425	20	11.8	2.4	4,925	10,808	1	409	3,053,031	2,949,890	3,039,676	3,042,206
910426	20	11.5	2.3	4,817	10,860	0	384	248,855	262,064	247,741	271,327
910427	24	9.6	2.2	4,166	8,085	0	369	0	0	0	0
910428	24	8.6	2.1	3,833	7,810	2	360	3,786,692	4,096,235	3,777,979	3,993,722
910429	24	8.7	2.1	3,849	7,771	4	359	8,742,004	9,053,264	8,742,234	9,177,152
910430	20	8.7	2.4	3,861	8,181	2	396	4,712,594	4,589,164	4,765,173	4,753,955
910501	24	9.5	2.6	4,104	9,165	2	433	4,930,858	4,689,638	4,924,741	4,746,864
910502	24	9.7	2.6	4,197	9,511	20	433	42,137,087	39,079,500	42,272,152	41,299,676
910503	20	9.8	2.5	4,214	9,500	8	418	16,686,391	15,345,593	16,686,391	16,783,198
910504	20	9.8	2.1	4,214	9,511	1	359	2,600,477	3,001,748	2,600,477	3,053,943
910505	24	9.6	2.3	4,164	9,462	7	379	14,106,902	15,887,918	14,099,135	15,767,393
910506	20	9.7	2.3	4,181	9,494	19	387	40,636,743	42,815,923	40,636,743	44,507,797
910507	24	9.6	2.2	4,164	9,511	13	370	28,433,731	32,449,272	28,376,626	32,707,375
910508	24	9.6	2.2	4,153	9,483	118	371	252,207,910	298,989,699	252,225,065	290,064,227
910509	24	9.6	2.3	4,148	9,511	56	388	118,391,049	132,622,304	118,391,049	130,578,718
910510	24	9.5	2.3	4,104	9,402	13	378	26,422,129	29,781,761	26,382,648	29,834,214

Table 12. Continued.

Date	Number of samples	Mean river stage	Mean surface velocity	Mean X-section (sq.ft.)	Mean river discharge	Mean eggs/ day	Mean volume filtered (cfs)	Daily eggs- by trip X-sect.	Daily eggs- by trip Flow15	Daily eggs - Hassler X-sect.	Daily eggs - Hassler Flow15
910511	24	9.2	2.1	4,027	9,250	52	357	106,940,691	128,028,619	107,006,692	128,512,164
910512	24	9.2	2.2	4,011	9,239	98	374	202,922,437	224,205,849	202,652,419	233,208,626
910513	24	9.1	2.2	3,989	9,239	45	375	91,218,357	104,468,886	91,284,628	105,307,107
910514	24	9.1	2.3	3,983	9,272	168	379	344,834,188	396,253,553	344,834,188	395,191,853
910515	24	9.2	2.2	4,011	9,293	29	376	59,130,420	68,656,539	59,300,326	68,247,098
910516	24	9.2	2.3	4,016	9,293	29	379	58,865,042	66,851,918	58,865,042	67,004,766
910517	24	9.2	2.3	4,016	9,277	24	386	50,259,042	56,512,309	50,259,042	56,132,930
910518	24	9.2	2.3	4,011	9,271	35	384	73,104,472	81,980,151	73,051,127	82,063,464
910519	24	9.2	2.1	4,011	9,293	17	361	34,415,541	40,470,730	34,377,001	41,227,980
910520	24	7.7	2.2	3,529	7,081	4	369	6,927,486	7,763,489	6,503,436	6,597,644
910521	24	8.5	2.2	3,801	9,174	7	362	12,714,530	15,835,787	12,704,913	15,795,023
910522	24	8.8	2.3	3,902	9,180	10	390	19,892,189	22,396,011	19,901,131	22,392,820
910523	24	8.9	2.4	3,918	9,110	6	402	12,090,546	13,149,964	12,090,546	13,050,179
910524	24	8.9	2.3	3,924	9,244	14	388	28,083,247	31,771,866	28,081,642	31,864,449
910525	20	9.1	2.4	3,970	9,298	12	397	25,352,579	27,722,731	25,317,723	27,914,144
910526	24	9.1	2.3	3,983	9,347	20	388	40,970,399	45,654,715	40,970,399	46,222,310
910527	22	9.1	2.3	3,983	9,315	12	393	24,377,387	27,069,730	24,377,387	27,048,083
910528	20	9.1	2.5	3,990	9,320	9	426	19,088,460	19,448,728	19,082,707	19,521,860
910529	24	9.2	2.4	4,016	9,272	8	410	16,179,281	16,758,331	16,179,281	16,992,567
910530	24	9.2	2.4	4,016	9,315	7	405	14,113,840	15,205,814	14,113,840	15,070,058
910531	24	9.2	2.3	4,016	9,304	4	394	7,229,040	7,906,567	7,229,040	7,939,350
910601	20	9.2	2.3	4,016	9,315	3	394	6,196,320	6,726,519	6,196,320	6,805,535
910602	16	9.1	2.4	3,983	9,255	2	402	4,097,040	4,484,298	4,097,040	4,418,486
910603	20	9.1	2.5	3,983	9,298	1	417	2,048,520	2,148,570	2,048,520	2,140,231
910604	24	9.2	2.3	4,005	9,331	2	381	3,095,340	3,506,112	3,089,700	3,522,916
910605	24	9.2	2.4	4,005	9,309	0	401	514,950	569,640	514,950	556,507
910606	24	9.1	2.3	3,983	9,298	1	388	1,024,260	1,142,441	1,024,260	1,151,233
910607	24	9.1	2.3	3,994	9,320	1	380	1,197,790	1,373,954	1,198,260	1,372,851

Table 12. Continued.

Date	Number of samples	Mean river stage	Mean surface velocity	Mean X-section (sq.ft.)	Mean river discharge	Mean eggs/ day	Mean volume filtered (cfs)	Daily eggs- by trip X-sect.	Daily eggs- by trip Flowl5	Daily eggs - Hassler X-sect.	Daily eggs - Hassler Flowl5
910608	20	9.1	2.4	3,983	9,336	0	399	0	0	0	0
910609	24	9.2	2.3	4,005	9,336	0	391	172,120	187,915	171,650	190,826
910610	24	7.9	2.1	3,579	7,425	0	359	625,291	588,057	613,608	661,019
910611	24	6.4	2.1	2,860	6,691	0	346	366,110	489,141	367,777	464,619
910612	24	6.3	2.1	2,744	6,655	1	346	810,911	1,031,121	823,137	1,076,238
910613	24	6.1	1.9	2,653	6,618	0	326	0	0	0	0
910614	12	6.1	2.0	2,640	6,573	0	334	0	0	0	0
Total egg production estimate for the season:								1,837,639,036	2,077,392,576	1,837,208,211	2,081,731,118
Standard deviation:								± 61,792,545	± 71,195,920	± 61,787,080	± 70,953,356

Table 13. Summary of striped bass spawning activity in the Roanoke River observed at Barnhill's Landing (River Mile 117) and Jacob's Landing (RM 102) from 15 April to 14 June 1991.

Activity	Barnhill's Landing	Jacob's Landing
Total number of samples examined	1,382	1,386
Total number of eggs collected:		
surface	10,467	10,644
bottom	11,641	12,878
total	22,108	23,522
Egg production estimate (Hassler method):		
surface	1,837,208,211	2,068,304,334
bottom	2,051,620,568	2,499,322,372
average of combined samples	1,944,277,596	2,283,054,389
Egg viability estimate (%):		
surface	55.36	69.51
bottom	56.32	71.84
average of combined samples	55.87	70.78
Date of first egg:	17 April	25 April
Date of last egg:	12 June	14 June
Days within spawning window:	57	51
Number of days of continuous spawning	41	51
Dates of peak spawning activity and percent of total eggs collected:		
first peak	8-9 May (20%)	8-9 May (17%)
second peak	11-12 May (17%)	11-12 May (15%)
third peak	14 May (19%)	14 May (20%)
Date at which egg production was:		
50% complete	13 May	14 May
75% complete	15 May	18 May
90% complete	25 May	26 May
Percent of all viable eggs (17° C criteria):		
less than 10 hours	62.29	2.92
10 to 18 hours	37.61	26.05
20 to 28 hours	0.09	68.30
30 hours and older	0.00	2.68
newly-hatched larvae	0.00	0.05

Table 13 (continued).

Activity	Barnhill's Landing	Jacob's Landing
Egg collection water temperatures (C):		
most eggs	20-23.9 (71%)	20-23.9 (70%)
minimum temperature	14-15.9 (<1%)	14-15.9 (<1%)
maximum temperature	26.0+ (<1%)	26.0+ (<1%)
Surface water pH:		
most eggs	7.75+ (85%)	7.5-7.99 (90%)
minimum pH	6.5-6.74 (<1%)	5.75-5.99 (<1%)
maximum pH	8.0+ (33%)	8.0+ (4%)
Dissolved oxygen (mg/L):		
most eggs	7-8.9 (95%)	7-8.9 (69%)
minimum DO	5-5.9 (<1%)	4-4.9 (<1%)
Surface water velocity (cm/second):		
most eggs	60-79.9 (92%)	60-79.9 (96%)
minimum velocity	40-59.9 (4%)	40-59.9 (<1%)
maximum velocity	100-119.9 (<1%)	80-99.9 (3%)
Time of collection (percent of total eggs caught):		
0200	22.5	11.3
0600	20.9	16.7
1000	24.1	21.6
1400	9.5	24.6
1800	12.9	14.6
2200	10.1	11.2

Table 14. Description of variables used in the Jacob's Landing instantaneous egg production analyses.

Variable name	Variable description
Barnhill's Landing:	
BIPROD	instantaneous egg production estimate
BDPROD	number of dead eggs in BIPROD
BST1	number of live Stage 1 eggs (0-8 hours) in BIPROD
BST2	number of live Stage 2 eggs (10-18 hours) in BIPROD
BST3	number of live Stage 3 eggs (20-28 hours) in BIPROD
BST4	number of live Stage 4 eggs (30+ hours) in BIPROD
Jacob's Landing:	
JIPROD	instantaneous egg production estimate
JDPROD	number of dead eggs in JIPROD
JST1	number of live Stage 1 eggs (0-8 hours) in JIPROD
Variable name additions:	
L	prefix indicating natural log transformed data of the variable
L4	suffix indicating data record 4 hours earlier than the matching record downstream
L8	suffix indicating data record 8 hours earlier than the matching record downstream
L12	suffix indicating data record 12 hours earlier than the matching record downstream

Table 15. Results of regression analyses (PROC REG, SAS Institute 1985) predicting instantaneous egg production estimates at Jacob's Landing (RM 102) based on egg production estimates from Barnhill's Landing (RM 117) four, eight, and 12 hours earlier. Variable definitions in Table 14.

Dependent variable	DF	F	P	R^2	Independent variables	Parameter estimate	P>T	Durbin Watson	P
Four-hour egg transport:									
LJIPROD	2,167	61.583	0.0001	0.42	INTERCEPT	11.059	0.0001	1.173	0.435
					LJST1	-0.023	0.0246		
					LBIPROD4	0.379	0.0001		
LJIPROD	6,152	186.837	0.0001	0.88	INTERCEPT	3.765	0.0001	1.759	0.067
					LJST1	-0.004	0.3639		
					LBST1L4	0.025	0.0728		
					LBST2L4	0.035	0.0001		
					LBST3L4	-0.016	0.2903		
					LBDPROD4	0.013	0.2354		
					LJDPROD	0.784	0.0001		
Eight-hour egg transport:									
LJIPROD	2,167	159.685	0.0001	0.66	INTERCEPT	6.317	0.0001	1.675	0.219
					LJST1	-0.009	0.2457		
					LBIPROD8	0.653	0.0001		
LJIPROD	6,149	180.004	0.0001	0.88	INTERCEPT	3.665	0.0001	1.597	0.215
					LJST1	-0.006	0.2471		
					LBST1L8	0.062	0.0001		
					LBST2L8	0.030	0.0001		
					LBST3L8	-0.016	0.2180		
					LBDPROD8	0.007	0.5077		
					LJDPROD	0.763	0.0001		
12-hour egg transport:									
LJIPROD	2,168	26.857	0.0001	0.24	INTERCEPT	14.100	0.0001	0.872	0.603
					LJST1	-0.022	0.0602		
					LBIPROD12	0.200	0.0001		
LJIPROD	6,150	157.471	0.0001	0.86	INTERCEPT	3.728	0.0001	1.634	0.238
					LJST1	-0.006	0.2367		
					LBST1L12	0.035	0.0054		
					LBST2L12	0.030	0.0001		
					LBST3L12	0.001	0.9655		
					LBDPROD12	0.007	0.5074		
					LJDPROD	0.786	0.0001		

Table 16. Results of regression analyses (PROC REG, SAS Institute 1985) predicting adjusted instantaneous egg production estimates at Jacob's Landing (RM 102) (by subtracting Jacob's stage 1 eggs) based on egg production estimates from Barnhill's Landing (RM 117) four, eight, and 12 hours earlier. Variable definitions in Table 14.

Dependent variable	DF	F	P	R^2	Independent variables	Parameter estimate	P>T	Durbin Watson	P
Four-hour egg transport:									
LAJIPROD	1,170	120.668	0.0001	0.42	INTERCEPT	10.394	0.0001	1.197	0.440
					LBIPROD4	0.408	0.0001		
LAJIPROD	5,153	40.619	0.0001	0.57	INTERCEPT	10.533	0.0001	1.570	0.317
					LBST1L4	0.082	0.0001		
					LBST2L4	0.057	0.0001		
					LBST3L4	0.035	0.2250		
					LBDPROD4	0.042	0.0300		
					LJDPROD	0.261	0.0001		
Eight-hour egg transport:									
LAJIPROD	1,170	294.383	0.0001	0.63	INTERCEPT	5.661	0.0001	1.916	0.136
					LBIPROD8	0.685	0.0001		
LAJIPROD	5,152	233.102	0.0001	0.88	INTERCEPT	3.082	0.0001	1.601	0.174
					LBST1L8	0.065	0.0001		
					LBST2L8	0.033	0.0001		
					LBST3L8	-0.014	0.2931		
					LBDPROD8	0.001	0.3668		
					LJDPROD	0.787	0.0001		
12-hour egg transport:									
LAJIPROD	1,170	36.635	0.0001	0.18	INTERCEPT	13.832	0.0001	0.895	0.590
					LBIPROD12	0.205	0.0001		
LAJIPROD	5,150	192.209	0.0001	0.86	INTERCEPT	3.178	0.0001	1.557	0.224
					LBST1L12	0.042	0.0034		
					LBST2L12	0.033	0.0001		
					LBST3L12	-0.004	0.7650		
					LBDPROD12	0.025	0.0211		
					LJDPROD	0.789	0.0001		

Table 17. Summary of striped bass spawning activity in the Roanoke River observed at Pollock's Ferry (RM 105) in 1988, and Barnhill's Landing (RM 117), 1989-1991.

Activity	1988	1989	1990	1991
Number of samples examined:				
surface	625	688	698	692
bottom	624	678	696	690
total	1,249	1,366	1,394	1,382
Number of eggs collected:				
surface	20,144	4,722	5,309	10,467
bottom	21,575	5,107	6,630	11,641
total	41,719	9,829	11,939	22,108
Hassler egg production estimate:				
surface	2.082 billion	0.638 billion	0.965 billion	1.837 billion
bottom	2.277 billion	0.720 billion	1.261 billion	2.052 billion
average of combined samples	2.178 billion	0.677 billion	1.114 billion	1.944 billion
Egg viability estimate:	89.0%	41.8%	58.5%	55.4%
Date of first egg:	12 Apr	16 Apr	24 Apr	17 Apr
Date of last egg:	2 Jun	9 Jun	12 Jun	12 Jun
Days within spawning window:	52	55	50	57
Number of days of continuous spawning:	27	23	50	41
Major spawning activity and percent of total eggs collected:				
first peak	11-12 May (38%)	23-24 May (27%)	2-3 May (7%)	8-9 May (20%)
second peak	15-16 May (22%)	26-27 May (33%)	7 May (15%)	11-12 May (17%)
third peak	20 May (13%)	31 May-1 Jun (26%)	10 May (20%)	14 May (19%)
fourth peak	23-24 May (13%)			

Table 17. Continued.

Activity	1988	1989	1990	1991
Date at which egg production was:				
50% complete	15 May	26 May	10 May	13 May
75% complete	20 May	27 May	14 May	15 May
90% complete	24 May	31 May	20 May	25 May
Percent of all staged viable eggs (17° C criteria):				
less than 10 hours	<1	77	71	62
10 to 18 hours	13	5	29	38
20 to 28 hours	72	19	<1	<1
30 hours and older	14	<1	<1	0
newly-hatched larvae	0	0	0	0
Percent of all eggs collected at water temperature (°C):				
12-13.9	<1	0	0	0
14-15.9	<1	<1	0	<1
16-17.9	2	3	<1	2
18-19.9	43	40	48	22
20-21.9	36	48	48	36
22-23.9	16	8	3	36
24-25.9	4	<1	0	5
26 +	0	0	0	<1
Percent of all eggs collected at surface water pH:				
5.50-5.74	0	0	0	0
6.00-6.24	<1	0	0	0
6.25-6.49	2	0	0	0
6.50-6.74	2	<1	0	<1
6.75-6.99	4	1	1	2
7.00-7.24	67	1	12	2
7.25-7.49	8	3	24	<1
7.50-7.74	14	6	52	12
7.75-7.99	<1	38	6	52
8.0 +	0	47	3	33
not recorded	3	3	1	<1

Table 17. Continued.

Activity	1988	1989	1990	1991
Percent of all eggs collected at surface dissolved oxygen (mg/L):				
5-5.9	6	0	0	<1
6-6.9	53	0	3	3
7-7.9	32	28	47	68
8-8.9	8	72	46	28
9-9.9	<1	<1	3	<1
10-10.9	<1	0	0	0
not recorded	<1	<1	<1	<1
Percent of all eggs collected at surface water velocity (cm/second):				
40-59.9	0	7	2	4
60-79.9	30	22	66	92
80-99.9	69	9	26	4
100-119.9	<1	58	7	<1
120-139.9	0	5	0	0
not recorded	<1	<1	0	0
Percent of all eggs collected at time:				
0200	5	18	28	23
0600	15	28	42	21
1000	18	22	12	24
1400	19	11	6	9
1800	27	6	4	13
2200	16	15	7	10

APPENDIX

Table A-1. List of Counties Enumerated in Figure 1.

Virginia	North Carolina
1. Roanoke	13. Stokes
2. Franklin	14. Rockingham
3. Patrick	15. Caswell
4. Henry	16. Person
5. Bedford	17. Granville
6. Pittsylvania	18. Vance
7. Campbell	19. Warren
8. Halifax	20. Halifax
9. Charlotte	21. Northampton
10. Lunenburg	22. Bertie
11. Mecklenburg	23. Martin
12. Brunswick	24. Washington

Table A-2. Location of the historical sampling locations used by W.W. Hassler and co-workers (1959-1987) and Rulifson (1988-present).

Location	River mile	Latitude	Longitude
Halifax	120	77°35'5"E	36°20'6"N
Johnson's Landing	118.5	77°18'23"E	36°33'20"N
Barnhill's Landing	117	77°18'23"E	36°32'15"N
Pollock' Ferry	105	77°24'30"E	36°15'30"N
Jacobs Landing	102	77°22'30"E	36°14'57"N
Palmyra	78.5	77°19'30"E	36°4'32"N

Table A-3. Hourly sample grid for the 1991 striped bass egg study at Barnhill's Landing, Roanoke River, NC.

Day	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
0	910415	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
1	910416	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
2	910417	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
3	910418	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
4	910419	.	4	.	.	.	4	.	.	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
5	910420	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
6	910421	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
7	910422	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
8	910423	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
9	910424	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
10	910425	.	4	.	.	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
11	910426	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	20
12	910427	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
13	910428	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
14	910429	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
15	910430	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
16	910501	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
17	910502	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
18	910503	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	20
19	910504	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
20	910505	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
21	910506	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
22	910507	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
23	910508	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
24	910509	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
25	910510	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
26	910511	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
27	910512	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
28	910513	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
29	910514	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24

Table A-3. Continued

Day	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
30	910515	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
31	910516	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
32	910517	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
33	910518	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
34	910519	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
35	910520	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
36	910521	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
37	910522	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
38	910523	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
39	910524	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
40	910525	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
41	910526	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
42	910527	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	20
43	910528	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	.	2	.	.	.	4	.	.	18
44	910529	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
45	910530	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
46	910531	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
47	910601	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	20
48	910602	.	4	.	.	.	.	.	.	.	4	.	.	.	4	.	.	.	.	.	.	.	4	.	.	16
49	910603	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	.	4	.	.	20
50	910604	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
51	910605	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
52	910606	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
53	910607	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
54	910608	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
55	910609	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
56	910610	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
57	910611	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
58	910612	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
59	910613	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
60	910614	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12

Table A-4. Water quality data collected at Barnhill's Landing, Roanoke River, North Carolina, from 15 April to 14 June 1991.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
1	910415	600	13.5	15.0	7.8	9.2	2.0	.	113.5	19.9	8203.2	6818	7361
2	910415	1000	15.5	15.0	7.7	9.4	4.0	.	97.4	19.9	8203.2	6226	6082
3	910415	1400	28.0	15.0	7.9	8.9	4.0	30.0	109.4	19.9	8203.2	2472	7113
4	910415	1800	21.0	16.0	8.0	8.8	4.0	40.0	107.2	19.9	8203.2	6115	6364
5	910415	2200	20.0	16.0	8.3	9.0	4.0	.	110.0	19.9	8203.2	7410	7044
6	910416	200	18.0	15.0	7.9	8.6	3.0	.	109.4	19.9	8203.2	6780	6890
7	910416	600	18.0	15.0	7.8	8.9	4.0	45.0	110.0	20.0	8248.1	7180	7477
8	910416	1000	18.0	15.0	7.9	9.0	4.0	70.0	107.8	19.9	8203.2	6630	6577
9	910416	1400	26.0	16.0	8.2	8.9	4.0	80.0	103.6	19.8	8158.3	7585	7058
10	910416	1800	24.0	16.5	8.8	8.7	4.0	75.0	105.6	19.8	8158.3	7001	6874
11	910416	2200	20.0	16.5	7.9	8.1	4.0	.	105.6	19.8	8158.3	7074	8156
12	910417	200	16.0	17.0	7.8	8.8	4.0	.	104.6	19.8	8158.3	6827	6925
13	910417	600	13.0	15.0	8.4	9.0	4.0	80.0	123.3	19.8	8158.3	7554	6741
14	910417	1000	20.0	16.0	7.9	7.0	4.0	60.0	111.1	19.8	8158.3	7429	5633
15	910417	1400	24.0	16.0	8.1	8.5	3.0	75.0	104.1	19.8	8158.3	7038	6814
16	910417	1800	27.0	16.0	8.0	8.4	4.0	80.0	106.7	19.8	8158.3	7287	7484
17	910417	2200	22.0	17.5	8.1	8.4	4.0	.	104.1	19.8	8158.3	6637	7726
18	910418	200	18.0	17.0	8.1	9.2	4.0	.	104.1	19.8	8158.3	7117	6800
19	910418	600	15.0	16.0	7.9	9.5	4.0	75.0	101.1	19.8	8158.3	6799	6506
20	910418	1000	17.0	16.5	8.3	8.9	4.0	60.0	102.1	19.8	8158.3	6962	6332
21	910418	1400	22.0	16.5	8.3	8.9	4.0	70.0	108.3	19.7	8113.4	7098	6774
22	910418	1800	19.0	16.0	8.2	8.9	4.0	70.0	109.4	19.7	8113.4	7492	7079
23	910418	2200	17.0	17.0	8.2	8.5	4.0	.	111.1	19.7	8113.4	7273	6985
24	910419	200	14.0	15.5	8.1	8.8	4.0	.	107.8	19.7	8113.4	6852	6910
25	910419	600	13.0	15.5	8.0	8.5	5.0	.	100.2	19.7	8113.4	7276	6905
26	910419	1000	14.0	16.0	8.2	.	4.0	.	.	.	.	.	.
27	910419	1400	16.0	16.0	8.0	8.4	4.0	65.0	104.1	19.7	8113.4	6854	6901
28	910419	1800	15.0	15.5	7.9	8.6	4.0	75.0	101.6	19.8	8158.3	6512	6978
29	910419	2200	14.0	15.5	8.1	9.0	4.0	.	103.6	19.8	8158.3	6844	6962
30	910420	200	13.0	15.5	8.3	9.2	5.0	.	103.1	19.8	8158.3	6903	6512

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
31	910420	600	13.0	15.0	8.4	9.2	5.0	.	105.6	19.8	8158.3	6988	6844
32	910420	1000	15.0	15.0	8.3	9.2	5.0	75.0	106.7	19.8	8158.3	6826	6673
33	910420	1400	16.0	14.0	8.7	9.8	4.0	50.0	107.8	19.8	8158.3	6794	7120
34	910420	1800	17.0	15.0	8.3	9.8	4.0	.	111.1	19.8	8158.3	6946	6833
35	910420	2200	16.0	14.5	8.3	9.0	4.0	.	106.1	19.8	8158.3	6943	6931
36	910421	200	13.0	14.5	7.8	9.4	5.0	.	101.6	19.4	7978.7	6647	6865
37	910421	600	16.0	13.0	8.5	9.0	4.0	.	97.4	18.8	7709.3	7520	6011
38	910421	1000	15.0	14.0	8.1	9.8	4.0	65.0	80.5	19.4	7978.7	5351	5407
39	910421	1400	16.0	14.0	8.0	9.8	5.0	70.0	87.8	18.7	7664.5	6523	6210
40	910421	1800	16.0	14.5	7.8	9.8	4.0	70.0	85.0	18.0	7350.3	5723	4812
41	910421	2200	14.0	13.0	7.7	9.0	.	.	90.0	16.9	6875.4	6036	5851
42	910422	200	.	.	.	.	.	.	.	.	.	.	.
43	910422	600	12.0	12.0	7.7	10.0	.	70.0	81.1	15.9	6475.2	5047	5093
44	910422	1000	12.0	13.5	.	9.1	.	80.0	77.0	15.6	6356.8	3866	5451
45	910422	1400	18.0	15.0	.	9.1	.	80.0	72.8	14.8	6042.2	4825	4608
46	910422	1800	16.0	15.0	7.8	9.0	3.0	70.0	76.2	14.7	6003.4	4775	4381
47	910422	2200	12.0	15.0	7.9	9.5	3.0	.	60.1	14.3	5848.0	4614	4440
48	910423	200	12.0	15.0	8.0	9.9	4.0	.	76.2	13.8	5655.6	4916	4278
49	910423	600	6.0	15.0	8.1	8.9	4.0	80.0	67.7	13.8	5655.6	4546	4923
50	910423	1000	14.0	15.0	8.0	9.4	4.0	70.0	66.9	13.7	5617.6	4798	4834
51	910423	1400	20.0	15.0	8.0	9.1	.	70.0	78.4	13.7	5617.6	5207	5068
52	910423	1800	20.0	15.0	8.1	8.3	.	80.0	82.4	13.2	5427.8	5133	4408
53	910423	2200	15.0	15.0	9.4	9.4	4.0	.	71.8	13.0	5351.9	5886	5494
54	910424	200	12.0	15.5	7.9	10.0	5.0	.	72.1	12.8	5278.1	5252	5210
55	910424	600	12.0	15.0	7.3	8.8	.	70.0	73.3	12.7	5241.3	5295	4965
56	910424	1000	17.0	15.0	7.8	9.2	.	80.0	69.7	12.8	5278.1	3458	5063
57	910424	1400	23.0	16.0	7.9	8.1	.	60.0	102.1	12.4	5130.6	5192	4740
58	910424	1800	24.0	16.0	7.8	8.5	.	60.0	78.4	12.3	5093.7	4880	4364
59	910424	2200	15.0	16.5	7.9	9.4	.	.	78.4	12.1	5020.0	5151	4981
60	910425	200	13.0	16.0	7.8	9.8	.	.	75.9	12.0	4983.1	4099	4918
61	910425	600	8.0	16.0	8.1	8.6	.	.	.	.	.	.	.
62	910425	1000	18.0	16.0	8.3	9.0	.	70.0	77.6	11.9	4947.0	4697	5026
63	910425	1400	21.0	16.0	8.1	8.1	.	60.0	70.9	11.9	4947.0	5225	4722

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
64	910425	1800	20.0	16.0	8.1	8.8	.	70.0	69.3	11.8	4910.9	5190	4991
65	910425	2200	16.0	17.0	8.1	8.9	.	.	77.6	11.6	4838.8	5207	4826
66	910426	200	15.0	17.0	7.9	9.4	.	.	72.3	11.6	4838.8	5445	5235
67	910426	600	12.0	16.0	8.4	9.0	.	70.0	75.9	11.6	4838.8	5500	4962
68	910426	1000	20.0	16.0	7.0	8.4	.	80.0	65.0	11.6	4838.8	4388	3592
69	910426	1400	26.0	16.0	8.2	8.2	.	70.0	67.7	11.5	4802.7	5148	4152
70	910426	1800	20.0	16.0	8.2	8.2	.	70.0	67.5	11.4	4766.6	4965	4679
71	910426	2200	19.0	17.0	8.0	8.9	.	.	.	.	.	.	.
72	910427	200	18.0	17.0	8.2	8.8	.	.	67.9	10.6	4485.2	5209	5167
73	910427	600	16.0	16.0	8.6	8.1	.	80.0	67.9	9.7	4180.7	4364	1248
74	910427	1000	20.0	16.0	8.3	8.9	.	75.0	66.1	9.7	4180.7	4574	4239
75	910427	1400	23.0	16.5	8.4	8.6	.	75.0	67.5	9.6	4147.8	4507	4323
76	910427	1800	24.0	17.0	8.3	8.9	.	70.0	66.9	9.6	4147.8	4429	4392
77	910427	2200	20.0	18.0	8.2	9.0	.	.	65.8	8.7	3854.1	4230	4138
78	910428	200	18.0	18.0	7.9	9.2	.	.	68.4	8.6	3822.0	4312	4235
79	910428	600	18.0	18.0	7.8	9.2	.	.	64.8	8.4	3757.8	4591	4373
80	910428	1000	21.0	18.0	8.7	8.2	.	50.0	58.6	8.7	3854.1	3935	4574
81	910428	1400	23.0	18.0	8.4	8.0	.	50.0	65.3	8.7	3854.1	4209	5127
82	910428	1800	22.0	18.0	8.2	7.9	.	50.0	67.5	8.7	3854.1	4302	4043
83	910428	2200	19.0	18.0	8.2	7.9	.	.	67.1	8.7	3854.1	4590	4306
84	910429	200	18.0	18.0	8.1	7.9	.	.	66.3	8.7	3854.1	5185	4440
85	910429	600	19.0	17.0	8.2	8.2	.	60.0	67.9	8.7	3854.1	4504	4470
86	910429	1000	22.0	17.0	8.2	7.4	.	80.0	66.3	8.6	3822.0	1652	3375
87	910429	1400	25.0	18.0	8.2	7.3	.	75.0	62.6	8.7	3854.1	4125	3483
88	910429	1800	24.0	18.0	8.3	7.3	.	80.0	64.3	8.7	3854.1	4420	4035
89	910429	2200	20.0	18.0	8.3	8.8	.	.	63.5	8.7	3854.1	4773	4562
90	910430	200	19.0	18.0	7.8	9.0	.	.	.	.	.	.	.
91	910430	600	19.0	17.0	7.9	8.8	.	70.0	64.6	8.6	3822.0	5205	4253
92	910430	1000	22.0	18.0	8.2	9.8	.	70.0	72.6	8.5	3789.9	4681	4371
93	910430	1400	23.0	18.0	8.2	7.4	.	60.0	73.6	8.6	3822.0	4646	4328
94	910430	1800	24.0	18.0	8.0	7.9	.	65.0	69.3	8.8	3886.1	4210	4320
95	910430	2200	20.0	18.5	8.1	8.2	.	.	79.6	9.1	3983.2	5009	5067
96	910501	200	18.0	18.5	8.0	8.4	.	.	79.3	9.2	4016.1	4877	4673

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
97	910501	600	18.0	19.0	8.3	8.4	.	65.0	78.4	9.4	4082.0	5309	5186
98	910501	1000	22.0	19.0	7.9	7.9	.	70.0	78.1	9.5	4114.9	5123	5032
99	910501	1400	25.0	18.5	8.1	7.8	.	70.0	82.1	9.5	4114.9	5023	4923
100	910501	1800	24.0	19.0	8.0	7.8	.	75.0	72.3	9.5	4114.9	4692	4667
101	910501	2200	22.0	20.0	8.6	8.0	.	.	80.5	9.7	4180.7	5492	4656
102	910502	200	16.0	19.0	8.0	8.4	.	.	84.0	9.7	4180.7	5842	5821
103	910502	600	15.0	18.0	8.4	7.4	.	60.0	80.8	9.7	4180.7	5474	5379
104	910502	1000	22.0	17.5	8.2	7.9	.	75.0	84.3	9.7	4180.7	4622	4652
105	910502	1400	26.0	20.0	8.2	7.4	.	68.0	72.6	9.8	4213.7	5234	3434
106	910502	1800	17.0	19.0	8.3	7.6	.	70.0	72.8	9.8	4213.7	.	4895
107	910502	2200	12.0	20.0	7.9	8.3	.	.	76.8	9.8	4213.7	4957	4930
108	910503	200	10.0	19.0	7.7	8.4	.	.	83.7	9.8	4213.7	5123	4820
109	910503	600	10.0	19.0	7.8	7.9	.	65.0	65.4	9.8	4213.7	4693	4715
110	910503	1000	21.0	19.0	7.7	8.1	.	70.0	89.3	9.8	4213.7	5156	4463
111	910503	1400	25.0	21.0	7.9	7.8	.	65.0	68.6	9.8	4213.7	4946	4884
112	910503	1800	24.0	19.0	7.9	7.6	.	75.0	72.6	9.8	4213.7	5301	5309
113	910503	2200	19.0	20.0	7.9	8.6	.	.	.	.	.	.	.
114	910504	200	15.0	18.5	7.0	8.8	.	.	.	.	.	.	.
115	910504	600	14.0	18.0	7.7	9.4	.	.	69.9	9.8	4213.7	4475	5041
116	910504	1000	16.0	18.0	7.8	9.2	.	70.0	64.6	9.8	4213.7	4621	4699
117	910504	1400	22.0	20.0	7.6	8.2	.	70.0	61.5	9.8	4213.7	5016	5048
118	910504	1800	23.0	19.5	7.9	7.8	.	75.0	67.5	9.8	4213.7	4820	4642
119	910504	2200	18.0	19.0	7.6	8.0	.	.	61.8	9.8	4213.7	4381	4862
120	910505	200	17.0	19.5	7.9	8.3	.	.	67.3	9.8	4213.7	4832	3521
121	910505	600	16.0	18.0	7.8	8.0	.	68.0	77.6	9.6	4147.8	5265	6352
122	910505	1000	20.0	18.5	7.9	8.2	.	75.0	70.9	9.6	4147.8	4915	5012
123	910505	1400	22.0	19.0	7.7	8.2	.	75.0	67.1	9.7	4180.7	4910	4862
124	910505	1800	24.0	20.0	7.9	8.0	.	80.0	67.9	9.6	4147.8	4446	5077
125	910505	2200	20.0	20.0	7.9	7.4	.	.	62.0	9.6	4147.8	4315	4700
126	910506	200	18.0	19.0	7.9	7.7	.	.	.	.	.	.	.
127	910506	600	20.0	19.0	8.0	7.5	.	65.0	59.6	9.7	4180.7	4400	5252
128	910506	1000	21.0	19.0	7.9	8.4	.	70.0	75.9	9.7	4180.7	4856	4701

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
129	910506	1400	21.0	22.0	8.0	7.6	.	70.0	74.3	9.7	4180.7	4818	5414
130	910506	1800	22.0	20.5	8.0	7.8	.	65.0	75.4	9.7	4180.7	4385	4929
131	910506	2200	20.0	20.0	7.8	7.8	.	.	65.8	9.7	4180.7	4410	4494
132	910507	200	18.0	20.0	7.9	8.4	.	.	65.3	9.6	4147.8	4880	4623
133	910507	600	18.0	19.5	8.0	7.2	.	60.0	71.4	9.6	4147.8	4900	5003
134	910507	1000	21.5	19.5	8.0	7.2	.	80.0	64.1	9.6	4147.8	5491	1788
135	910507	1400	24.0	21.5	7.8	6.8	.	80.0	68.2	9.7	4180.7	5732	4849
136	910507	1800	20.0	20.0	8.0	7.6	.	70.0	66.1	9.7	4180.7	4395	4193
137	910507	2200	15.0	20.0	8.0	7.6	.	.	67.7	9.7	4180.7	4628	3504
138	910508	200	15.0	19.0	8.0	7.6	.	.	66.1	9.6	4147.8	4314	4951
139	910508	600	13.0	19.0	8.2	7.4	.	73.0	54.7	9.6	4147.8	4569	3103
140	910508	1000	20.0	19.5	7.8	7.6	.	70.0	71.1	9.7	4180.7	4632	4489
141	910508	1400	22.0	20.0	7.8	8.1	.	80.0	68.6	9.6	4147.8	4733	4625
142	910508	1800	20.0	20.5	7.9	8.4	.	75.0	72.1	9.6	4147.8	4735	4875
143	910508	2200	17.0	21.0	8.0	8.6	.	.	70.9	9.6	4147.8	4951	4620
144	910509	200	12.0	20.0	7.9	8.3	.	.	70.4	9.6	4147.8	4461	4752
145	910509	600	15.0	19.0	7.6	8.7	.	70.0	67.7	9.6	4147.8	4931	4701
146	910509	1000	19.0	19.0	7.5	8.2	.	70.0	69.9	9.6	4147.8	4695	4580
147	910509	1400	20.0	20.0	8.1	7.6	.	70.0	70.6	9.6	4147.8	4645	4977
148	910509	1800	22.0	20.0	8.0	7.8	.	80.0	71.4	9.6	4147.8	4522	4572
149	910509	2200	18.0	19.5	8.3	8.2	.	.	72.3	9.6	4147.8	4383	4400
150	910510	200	15.0	19.0	8.1	8.4	.	.	68.8	9.6	4147.8	4533	4620
151	910510	600	18.0	19.0	8.0	7.4	.	70.0	69.0	9.5	4114.9	4475	3958
152	910510	1000	21.0	19.5	7.9	7.8	.	75.0	72.6	9.5	4114.9	4828	5049
153	910510	1400	29.0	20.0	7.8	7.2	.	70.0	69.5	9.5	4114.9	4859	5175
154	910510	1800	22.0	20.0	8.1	8.4	.	80.0	68.6	9.4	4082.0	4793	4787
155	910510	2200	19.0	20.0	8.3	7.4	.	.	63.1	9.3	4049.1	4591	4352
156	910511	200	17.0	19.5	8.1	7.8	.	.	65.3	9.3	4049.1	4436	4662
157	910511	600	16.0	20.0	8.3	7.2	.	70.0	61.5	9.3	4049.1	4588	4250
158	910511	1000	20.0	20.0	7.8	7.6	.	80.0	67.3	9.2	4016.1	4985	4599
159	910511	1400	22.0	22.0	8.1	7.4	.	80.0	64.3	9.2	4016.1	4254	4165
160	910511	1800	24.0	20.0	7.9	7.4	.	80.0	65.0	9.2	4016.1	4324	4465

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
161	910511	2200	17.0	19.5	7.9	8.4	.	.	65.3	9.2	4016.1	3940	3516
162	910512	200	15.0	19.0	7.8	8.0	.	.	66.5	9.2	4016.1	4278	4730
163	910512	600	17.0	19.0	7.8	7.8	.	70.0	67.9	9.2	4016.1	4426	4612
164	910512	1000	21.0	20.0	7.8	7.9	.	80.0	74.0	9.2	4016.1	4409	4836
165	910512	1400	29.0	23.0	7.7	7.8	.	70.0	67.7	9.2	4016.1	4727	4346
166	910512	1800	26.0	21.0	8.1	7.9	.	80.0	68.4	9.2	4016.1	4688	5010
167	910512	2200	21.0	21.0	8.1	7.6	.	.	62.2	9.1	3983.2	4056	4418
168	910513	200	22.0	21.0	8.0	7.9	.	.	70.9	9.1	3983.2	5109	5090
169	910513	600	20.0	21.0	8.2	7.8	.	70.0	63.3	9.1	3983.2	4545	3741
170	910513	1000	25.0	21.5	7.8	7.6	.	80.0	73.3	9.1	3983.2	4756	4777
171	910513	1400	25.0	23.0	7.9	7.6	.	70.0	68.6	9.2	4016.1	4600	4290
172	910513	1800	26.0	22.5	8.2	7.4	.	80.0	69.5	9.1	3983.2	4855	4593
173	910513	2200	22.0	22.0	8.2	8.0	.	.	62.4	9.1	3983.2	3726	3778
174	910514	200	21.0	22.0	7.9	7.8	.	.	69.5	9.1	3983.2	4779	4717
175	910514	600	21.0	22.0	8.3	7.8	.	65.0	63.3	9.1	3983.2	4724	4149
176	910514	1000	25.0	22.0	7.8	7.9	.	75.0	70.6	9.1	3983.2	4541	4583
177	910514	1400	27.0	22.0	8.5	7.6	.	75.0	67.9	9.1	3983.2	4637	5344
178	910514	1800	24.0	22.0	7.9	7.5	.	70.0	70.9	9.1	3983.2	4913	5012
179	910514	2200	22.0	22.5	8.0	8.3	.	.	70.4	9.1	3983.2	4844	4960
180	910515	200	20.0	21.5	7.8	7.9	.	.	69.3	9.1	3983.2	4651	4721
181	910515	600	21.0	22.0	8.0	7.6	.	70.0	63.1	9.2	4016.1	4603	4137
182	910515	1000	22.0	22.0	7.6	6.8	.	70.0	69.7	9.2	4016.1	4293	3734
183	910515	1400	24.0	23.0	7.7	7.2	.	70.0	71.8	9.2	4016.1	4122	4234
184	910515	1800	22.0	22.0	7.0	7.2	.	70.0	64.3	9.2	4016.1	3196	3689
185	910515	2200	22.0	23.0	8.1	7.6	.	.	70.9	9.2	4016.1	3551	4682
186	910516	200	17.0	22.0	7.6	.	.	.	70.9	9.2	4016.1	4417	4633
187	910516	600	20.0	21.0	7.0	8.0	.	65.0	68.2	9.2	4016.1	4012	4044
188	910516	1000	23.0	21.0	7.8	7.8	.	75.0	67.3	9.2	4016.1	4422	4188
189	910516	1400	26.0	23.0	8.0	7.5	.	75.0	69.0	9.2	4016.1	4222	4157
190	910516	1800	25.0	22.5	7.6	8.0	.	70.0	69.5	9.2	4016.1	4582	5656
191	910516	2200	22.0	22.5	7.4	8.2	.	.	68.2	9.2	4016.1	4968	4476
192	910517	200	19.0	21.0	7.8	7.9	.	.	69.0	9.2	4016.1	4410	4101

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
193	910517	600	20.0	21.5	7.8	7.4	.	.	68.6	9.2	4016.1	5069	4031
194	910517	1000	21.0	22.0	7.8	7.0	.	70.0	68.8	9.2	4016.1	4703	4245
195	910517	1400	23.0	22.5	7.5	7.4	.	75.0	73.1	9.2	4016.1	5039	4265
196	910517	1800	26.0	23.0	7.5	7.8	.	75.0	68.4	9.2	4016.1	4727	3541
197	910517	2200	23.0	23.0	7.6	7.6	.	.	72.3	9.2	4016.1	5853	5024
198	910518	200	20.0	22.0	7.8	7.5	.	.	70.2	9.2	4016.1	4121	4213
199	910518	600	23.0	22.0	8.6	6.8	.	65.0	73.1	9.2	4016.1	4636	4652
200	910518	1000	25.0	23.0	8.2	7.2	.	75.0	70.2	9.2	4016.1	4709	5038
201	910518	1400	26.0	24.0	8.4	7.0	.	70.0	70.4	9.2	4016.1	4156	4471
202	910518	1800	22.0	24.0	7.6	8.4	.	70.0	69.0	9.2	4016.1	4917	4890
203	910518	2200	17.0	22.0	.	7.6	.	.	65.3	9.1	3983.2	4873	4343
204	910519	200	15.0	22.0	8.5	7.8	.	.	66.5	9.2	4016.1	4412	4127
205	910519	600	16.0	21.0	8.0	7.6	.	70.0	54.3	9.2	4016.1	3866	4295
206	910519	1000	14.0	20.0	8.0	7.9	.	65.0	69.3	9.2	4016.1	5152	4902
207	910519	1400	15.0	20.0	6.6	7.8	.	70.0	64.5	9.2	4016.1	4830	3415
208	910519	1800	13.0	21.0	7.1	8.1	.	70.0	68.8	9.2	4016.1	4934	4830
209	910519	2200	14.0	20.0	7.5	7.6	.	.	69.3	9.1	3983.2	4966	4716
210	910520	200	13.0	20.0	7.8	7.4	.	.	66.3	9.0	3950.3	4212	4159
211	910520	600	14.0	20.0	7.4	8.0	.	75.0	83.3	7.9	3598.0	3701	3522
212	910520	1000	16.0	21.0	7.1	8.4	.	60.0	62.6	7.1	3345.8	3641	3586
213	910520	1400	17.0	21.0	7.6	7.8	.	70.0	58.6	6.7	3080.9	3709	3455
214	910520	1800	17.0	21.0	7.6	7.4	.	70.0	62.9	7.3	3408.9	4407	3836
215	910520	2200	16.0	20.0	7.6	8.0	.	.	68.2	8.5	3789.9	4557	1141
216	910521	200	15.0	20.0	7.7	7.8	.	.	64.5	8.5	3789.9	8331	5374
217	910521	600	17.0	20.0	7.4	7.6	.	70.0	65.0	8.4	3757.8	5384	4480
218	910521	1000	21.0	20.0	7.4	8.0	.	75.0	69.5	8.5	3789.9	4753	4582
219	910521	1400	21.0	21.0	7.7	7.6	.	75.0	64.5	8.5	3789.9	4793	4612
220	910521	1800	22.0	21.0	7.8	7.5	.	75.0	69.0	8.5	3789.9	4411	4213
221	910521	2200	19.0	21.0	7.9	7.6	.	.	62.0	8.8	3886.1	4152	4301
222	910522	200	17.0	21.0	7.9	7.8	.	.	67.1	8.8	3886.1	4310	4126
223	910522	600	16.0	20.0	7.5	6.0	.	70.0	66.5	8.8	3886.1	5161	4248
224	910522	1000	21.0	20.0	7.5	8.0	.	75.0	70.2	8.8	3886.1	4704	4443

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
225	910522	1400	24.0	20.0	7.6	7.8	.	70.0	76.2	9.0	3950.3	4776	5082
226	910522	1800	23.0	21.0	7.8	7.8	.	70.0	72.3	8.8	3886.1	4773	4834
227	910522	2200	20.0	20.0	7.6	7.2	.	.	72.6	8.9	3918.2	4279	4538
228	910523	200	17.0	21.0	8.0	8.3	.	.	69.0	8.9	3918.2	4021	4317
229	910523	600	18.0	20.0	7.9	7.2	.	70.0	72.8	8.9	3918.2	4808	4678
230	910523	1000	22.0	20.0	7.8	7.6	.	80.0	69.0	8.9	3918.2	4834	4795
231	910523	1400	24.0	21.0	8.0	7.2	.	80.0	80.8	8.9	3918.2	5137	4884
232	910523	1800	25.0	22.0	8.1	7.0	.	80.0	74.6	8.9	3918.2	5180	4654
233	910523	2200	21.0	22.5	8.0	7.5	.	.	71.4	8.9	3918.2	4682	4455
234	910524	200	17.0	21.0	7.9	7.4	.	.	69.5	8.9	3918.2	4312	4452
235	910524	600	17.0	20.0	7.8	7.2	.	70.0	72.3	8.9	3918.2	4760	4393
236	910524	1000	22.0	20.0	8.1	7.7	.	75.0	71.1	8.9	3918.2	4303	4526
237	910524	1400	24.0	21.0	7.8	7.9	.	80.0	69.9	8.9	3918.2	4608	4189
238	910524	1800	25.0	22.0	8.0	8.1	.	80.0	70.6	8.9	3918.2	4231	4306
239	910524	2200	20.0	22.0	7.9	7.6	.	75.0	68.4	9.0	3950.3	5263	5270
240	910525	200	.	.	.	.	.	.	.	.	.	.	.
241	910525	600	18.0	20.0	7.2	7.6	.	75.0	69.7	9.0	3950.3	4964	4629
242	910525	1000	23.0	21.0	7.8	7.6	.	75.0	71.4	9.0	3950.3	4636	4654
243	910525	1400	28.0	22.0	7.8	7.0	.	80.0	72.6	9.1	3983.2	5209	4555
244	910525	1800	25.0	22.5	7.9	7.4	.	80.0	70.2	9.1	3983.2	4257	4915
245	910525	2200	24.0	22.0	7.7	6.0	.	.	75.9	9.1	3983.2	5450	5080
246	910526	200	18.0	21.0	7.8	7.2	.	.	69.9	9.1	3983.2	4215	4371
247	910526	600	21.0	22.0	7.8	7.2	.	75.0	65.3	9.1	3983.2	5709	5330
248	910526	1000	23.0	22.0	7.8	7.9	.	85.0	81.1	9.1	3983.2	5440	5165
249	910526	1400	28.0	23.0	7.8	7.8	.	80.0	61.5	9.1	3983.2	4890	4691
250	910526	1800	26.0	23.0	7.7	7.4	.	80.0	70.8	9.1	3983.2	5255	4954
251	910526	2200	25.0	22.0	7.7	7.0	.	.	74.1	9.1	3983.2	4927	4389
252	910527	200	18.0	22.5	8.1	7.5	.	.	68.0	9.1	3983.2	4402	4521
253	910527	600	20.0	21.0	7.8	7.7	.	.	72.8	9.1	3983.2	4121	4571
254	910527	1000	25.0	22.0	7.9	7.2	.	80.0	72.8	9.1	3983.2	5107	4921
255	910527	1400	26.0	22.5	7.6	7.8	.	80.0	70.6	9.1	3983.2	4823	4562
256	910527	1800	26.0	23.0	7.7	7.9	.	75.0	72.1	9.1	3983.2	5102	4701

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
257	910527	2200	22.0	23.0	7.6	7.5	.	.	71.8	9.1	3983.2	4720	4522
258	910528	200	24.0	23.0	8.0	7.8	.	.	80.8	9.1	3983.2	4907	4618
259	910528	600	24.0	24.0	8.0	7.6	.	75.0	77.6	9.1	3983.2	3830	4697
260	910528	1000	25.0	24.0	7.8	7.6	.	80.0	80.8	9.1	3983.2	4577	4275
261	910528	1400	25.0	23.0	8.4	7.0	.	.	.	.	.	.	.
262	910528	1800	27.0	25.0	8.3	7.2	.	75.0	72.6	9.1	3983.2	5855	.
263	910528	2200	24.0	25.0	8.1	7.0	.	.	74.9	9.2	4016.1	5202	4781
264	910529	200	23.0	24.0	7.9	7.2	.	.	75.9	9.2	4016.1	4214	4376
265	910529	600	22.0	24.0	8.1	7.6	.	70.0	71.1	9.2	4016.1	4792	4478
266	910529	1000	26.0	25.0	8.2	6.8	.	75.0	70.9	9.2	4016.1	3815	4436
267	910529	1400	29.0	25.0	8.0	7.0	.	70.0	79.0	9.2	4016.1	5102	5238
268	910529	1800	27.0	25.0	8.1	7.0	.	70.0	74.9	9.2	4016.1	5021	5387
269	910529	2200	25.0	25.0	8.2	6.9	.	.	74.8	9.2	4016.1	4999	4965
270	910530	200	21.0	22.5	7.8	.	.	.	73.6	9.2	4016.1	4678	4765
271	910530	600	22.0	24.0	7.9	7.4	.	70.0	79.6	9.2	4016.1	4962	4522
272	910530	1000	25.0	23.5	8.0	7.2	.	85.0	72.1	9.2	4016.1	5053	4715
273	910530	1400	28.0	24.0	8.0	6.8	.	80.0	74.6	9.2	4016.1	5269	4885
274	910530	1800	27.0	25.0	7.9	6.9	.	80.0	70.9	9.2	4016.1	5234	4967
275	910530	2200	24.0	25.0	8.4	6.4	.	.	70.6	9.2	4016.1	5211	3633
276	910531	200	20.0	23.0	7.7	6.8	.	.	71.6	9.2	4016.1	4856	4623
277	910531	600	24.0	24.0	8.1	6.8	.	80.0	67.9	9.2	4016.1	4860	4869
278	910531	1000	25.0	24.0	7.7	7.1	.	80.0	72.3	9.2	4016.1	5120	4856
279	910531	1400	28.0	24.0	7.8	7.0	.	85.0	72.3	9.2	4016.1	4963	4712
280	910531	1800	27.0	25.0	8.1	6.9	.	85.0	71.8	9.2	4016.1	4766	4681
281	910531	2200	22.0	25.0	7.8	6.6	.	.	72.6	9.2	4016.1	4867	4511
282	910601	200	20.0	24.0	7.8	6.8	.	.	71.6	9.2	4016.1	4901	4706
283	910601	600	21.0	24.0	8.1	6.8	.	70.0	71.1	9.2	4016.1	4788	4623
284	910601	1000	29.0	25.0	8.4	5.2	.	80.0	73.9	9.2	4016.1	4452	5028
285	910601	1400	30.0	26.0	8.0	5.6	.	80.0	75.1	9.2	4016.1	4974	4688
286	910601	1800	30.0	26.0	8.0	5.6	.	75.0	65.8	9.2	4016.1	5395	3640
287	910601	2200	21.0	25.0	7.6	6.0	.	.	.	.	.	.	.
288	910602	200	20.0	24.0	7.9	6.3	.	.	69.9	9.1	3983.2	4930	4461

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
289	910602	600	.	.	.	.	.	.	.	.	.	.	.
290	910602	1000	26.0	24.0	7.8	6.5	.	70.0	70.6	9.1	3983.2	5113	5140
291	910602	1400	29.0	26.0	8.0	6.2	.	70.0	78.4	9.1	3983.2	5046	5055
292	910602	1800	26.0	25.0	7.6	6.6	.	.	.	.	.	.	.
293	910602	2200	23.0	25.0	8.1	6.0	.	.	72.8	9.1	3983.2	4069	5067
294	910603	200	22.0	25.0	7.9	6.6	.	.	75.1	9.1	3983.2	5253	4700
295	910603	600	22.0	25.0	8.4	6.4	.	70.0	76.5	9.1	3983.2	4814	4559
296	910603	1000	25.0	25.0	7.9	6.4	.	70.0	71.8	9.1	3983.2	4716	4654
297	910603	1400	31.0	25.0	8.0	6.0	.	80.0	76.5	9.1	3983.2	4475	5286
298	910603	1800	25.0	25.0	8.1	6.4	.	.	.	.	.	.	.
299	910603	2200	24.0	25.0	7.9	6.5	.	.	78.4	9.1	3983.2	4796	4876
300	910604	200	20.0	24.5	7.7	6.3	.	.	72.1	9.1	3983.2	4861	4678
301	910604	600	22.0	24.0	8.4	6.6	.	70.0	64.5	9.1	3983.2	5512	5171
302	910604	1000	24.0	24.0	8.0	6.4	.	70.0	68.6	9.2	4016.1	5053	4503
303	910604	1400	26.0	24.0	8.4	6.4	.	70.0	73.3	9.2	4016.1	4867	4964
304	910604	1800	22.0	25.0	7.8	6.2	.	70.0	70.9	9.2	4016.1	4491	4732
305	910604	2200	21.0	24.0	8.1	.	.	.	65.8	9.2	4016.1	4449	3977
306	910605	200	18.0	23.0	8.0	6.5	.	.	70.6	9.2	4016.1	4407	4601
307	910605	600	20.0	21.0	8.2	6.8	.	80.0	76.2	9.2	4016.1	4330	4027
308	910605	1000	22.0	22.0	8.1	6.9	.	75.0	72.3	9.2	4016.1	4401	4665
309	910605	1400	23.0	22.0	7.9	6.7	.	75.0	69.0	9.2	4016.1	4512	4233
310	910605	1800	21.0	22.0	8.1	7.3	.	70.0	70.6	9.1	3983.2	4221	4577
311	910605	2200	18.0	22.0	8.1	6.0	.	.	78.1	9.1	3983.2	4240	4518
312	910606	200	17.0	22.0	7.9	6.2	.	.	70.9	9.1	3983.2	4458	4123
313	910606	600	14.0	22.0	8.0	6.6	.	70.0	69.9	9.1	3983.2	5108	5192
314	910606	1000	19.0	22.0	7.8	6.4	.	75.0	71.1	9.0	3950.3	5151	5045
315	910606	1400	24.0	23.0	7.9	6.6	.	80.0	72.8	9.1	3983.2	5398	4612
316	910606	1800	22.0	24.0	7.8	6.9	.	70.0	69.9	9.2	4016.1	5144	4952
317	910606	2200	19.0	22.0	8.0	6.0	.	.	67.3	9.1	3983.2	4590	4094
318	910607	200	17.0	22.0	7.8	6.2	.	.	69.9	9.1	3983.2	4122	4212
319	910607	600	22.0	15.0	7.9	6.8	.	70.0	69.5	9.1	3983.2	4468	3955
320	910607	1000	21.0	23.0	7.7	6.6	.	80.0	69.7	9.2	4016.1	5309	4684

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
321	910607	1400	24.0	22.0	7.8	6.4	.	80.0	65.6	9.1	3983.2	4755	5184
322	910607	1800	22.0	24.0	7.7	6.9	.	70.0	70.4	9.2	4016.1	4826	4627
323	910607	2200	19.0	22.0	7.8	6.0	.	.	68.6	9.1	3983.2	4729	4313
324	910608	200	.	.	.	.	.	.	.	.	.	.	.
325	910608	600	19.0	21.0	7.6	7.2	.	70.0	78.4	9.1	3983.2	4447	5523
326	910608	1000	19.0	23.0	7.8	6.9	.	75.0	70.9	9.1	3983.2	4853	4569
327	910608	1400	30.0	22.0	7.8	6.8	.	80.0	72.6	9.1	3983.2	4399	4412
328	910608	1800	23.0	23.0	7.9	6.2	.	75.0	69.3	9.1	3983.2	4475	4560
329	910608	2200	20.0	23.0	7.6	6.6	.	75.0	70.9	9.1	3983.2	4475	4560
330	910609	200	18.0	22.0	7.8	6.2	.	.	71.1	9.1	3983.2	4487	4326
331	910609	600	18.0	22.0	7.9	6.2	.	70.0	71.4	9.2	4016.1	4655	4578
332	910609	1000	24.0	23.0	7.8	7.0	.	75.0	72.6	9.2	4016.1	5061	4931
333	910609	1400	25.0	23.0	7.9	6.8	.	80.0	70.6	9.2	4016.1	4688	4258
334	910609	1800	23.0	23.0	7.6	7.0	.	70.0	69.5	9.1	3983.2	4033	3968
335	910609	2200	22.0	23.0	8.5	7.4	.	.	70.9	9.2	4016.1	4665	4668
336	910610	200	18.0	22.0	8.0	6.5	.	.	68.4	8.9	3918.2	4718	4424
337	910610	600	17.0	22.0	8.3	6.8	.	70.0	68.8	8.5	3789.9	4428	4312
338	910610	1000	24.0	23.0	7.9	7.0	.	80.0	67.9	8.8	3886.1	4233	3915
339	910610	1400	29.0	24.0	8.9	6.4	.	80.0	62.4	7.3	3408.9	4011	4659
340	910610	1800	26.0	24.0	8.3	7.4	.	80.0	64.6	7.0	3314.3	4016	4197
341	910610	2200	21.0	23.0	8.0	6.2	.	.	59.1	6.8	3158.7	3777	3767
342	910611	200	19.0	23.0	8.2	6.8	.	.	65.0	6.5	2925.3	3423	3366
343	910611	600	19.0	22.0	8.0	7.0	.	70.0	67.7	6.5	2925.3	4386	4233
344	910611	1000	24.0	23.0	7.9	7.3	.	75.0	67.9	6.5	2925.3	4003	3861
345	910611	1400	30.0	23.0	8.0	7.0	.	80.0	69.0	6.4	2847.5	4392	4055
346	910611	1800	25.0	24.0	8.2	7.2	.	80.0	57.3	6.3	2769.7	4101	4287
347	910611	2200	25.0	24.0	7.8	6.8	.	.	49.1	6.3	2769.7	4325	4518
348	910612	200	19.0	23.0	8.0	6.4	.	.	58.3	6.3	2769.7	3866	3601
349	910612	600	22.0	23.0	8.3	6.8	.	70.0	58.3	6.3	2769.7	4518	3641
350	910612	1000	26.0	24.0	8.1	6.5	.	70.0	65.8	6.3	2769.7	4050	4084
351	910612	1400	30.0	24.0	8.4	6.8	.	80.0	65.0	6.2	2691.9	3880	3710
352	910612	1800	29.0	26.0	8.5	6.0	.	80.0	66.7	6.2	2691.9	4271	4248

Table A-4. Continued.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	TDS	SECCHI	WVEL	RSTAGE	XSECT	SREVS	OREVS
353	910612	2200	25.0	25.0	8.2	6.2	.	.	62.8	6.3	2769.7	4005	4200
354	910613	200	20.0	24.0	8.0	6.1	.	.	59.1	6.2	2691.9	4117	4375
355	910613	600	24.0	24.0	8.3	6.4	.	75.0	57.0	6.2	2691.9	4002	3965
356	910613	1000	24.0	25.0	8.0	6.8	.	80.0	58.9	6.2	2691.9	4012	4007
357	910613	1400	28.0	25.0	7.8	7.2	.	80.0	58.8	6.1	2614.1	4021	3871
358	910613	1800	27.0	25.0	8.2	7.1	.	85.0	58.3	6.1	2614.1	3987	3655
359	910613	2200	22.0	24.0	7.7	6.8	.	.	62.4	6.1	2614.1	4184	4275
360	910614	200	20.0	24.0	7.9	6.6	.	.	61.7	6.1	2614.1	4099	4233
361	910614	600	21.0	24.0	7.6	6.4	.	75.0	59.6	6.2	2691.9	4204	4007
362	910614	1000	23.0	24.0	8.3	6.9	.	70.0	60.4	6.1	2614.1	4112	4055

Table A-5. Striped bass egg enumeration, viability, and stage of development collected at Barnhill's Landing, Roanoke River, North Carolina, from 15 April to 14 June 1991.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
1	910415	600	0	0	0	0	.	.	.	.	.	.	.	.	.
2	910415	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
3	910415	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
4	910415	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
5	910415	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
6	910416	200	0	0	0	0	.	.	.	.	.	.	.	.	.
7	910416	600	0	0	0	0	.	.	.	.	.	.	.	.	.
8	910416	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
9	910416	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
10	910416	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
11	910416	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
12	910417	200	0	0	0	0	.	.	.	.	.	.	.	.	.
13	910417	600	0	0	0	0	.	.	.	.	.	.	.	.	.
14	910417	1000	0	0	0	1	0	0	0	0	.	.	.	.	.
15	910417	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
16	910417	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
17	910417	2200	1	0	0	0	0	0	0	0	.	.	.	.	.
18	910418	200	0	0	0	0	.	.	.	.	.	.	.	.	.
19	910418	600	0	0	0	0	.	.	.	.	.	.	.	.	.
20	910418	1000	0	0	0	1	0	0	0	0	.	.	.	.	.
21	910418	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
22	910418	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
23	910418	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
24	910419	200	0	0	0	0	.	.	.	.	.	.	.	.	.
25	910419	600	0	0	0	0	.	.	.	.	.	.	.	.	.
26	910419	1000	.	.	.	.	.	.	.	.	.	.	.	.	.
27	910419	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
28	910419	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
29	910419	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
30	910420	200	0	0	0	0	.	.	.	.	.	.	.	.	.

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
31	910420	600	0	0	0	0	.	.	.	.	.	.	.	.	.
32	910420	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
33	910420	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
34	910420	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
35	910420	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
36	910421	200	0	0	0	0	.	.	.	.	.	.	.	.	.
37	910421	600	0	0	0	0	.	.	.	.	.	.	.	.	.
38	910421	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
39	910421	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
40	910421	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
41	910421	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
42	910422	200	.	.	.	.	.	.	.	.	.	.	.	.	.
43	910422	600	0	0	0	0	.	.	.	.	.	.	.	.	.
44	910422	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
45	910422	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
46	910422	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
47	910422	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
48	910423	200	0	0	0	0	.	.	.	.	.	.	.	.	.
49	910423	600	0	0	0	0	.	.	.	.	.	.	.	.	.
50	910423	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
51	910423	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
52	910423	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
53	910423	2200	1	1	0	0	1	0	0	0	1	0	0	0	0
54	910424	200	0	0	1	0	0	0	0	0	.	.	.	.	.
55	910424	600	0	0	0	0	.	.	.	.	.	.	.	.	.
56	910424	1000	0	0	1	1	0	0	1	0	1	0	0	0	0
57	910424	1400	2	0	0	0	0	0	0	0	.	.	.	.	.
58	910424	1800	2	0	2	2	2	0	2	1	5	0	0	0	0
59	910424	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
60	910425	200	0	1	2	0	0	1	1	0	2	0	0	0	0
61	910425	600	.	.	.	.	.	.	.	.	.	.	.	.	.
62	910425	1000	6	4	6	7	5	0	4	5	14	0	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
63	910425	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
64	910425	1800	1	0	0	1	1	0	0	1	0	2	0	0	0
65	910425	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
66	910426	200	0	1	0	1	0	0	0	0	.	.	.	.	.
67	910426	600	0	0	0	0	.	.	.	.	.	.	.	.	.
68	910426	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
69	910426	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
70	910426	1800	0	0	0	1	0	0	0	0	.	.	.	.	.
71	910426	2200	.	.	.	.	.	.	.	.	.	.	.	.	.
72	910427	200	0	0	0	0	.	.	.	.	.	.	.	.	.
73	910427	600	0	0	0	0	.	.	.	.	.	.	.	.	.
74	910427	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
75	910427	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
76	910427	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
77	910427	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
78	910428	200	0	0	1	0	0	0	0	0	.	.	.	.	.
79	910428	600	1	2	3	4	1	1	1	3	6	0	0	0	0
80	910428	1000	1	5	4	5	1	5	3	5	14	0	0	0	0
81	910428	1400	5	2	1	4	5	2	1	3	11	0	0	0	0
82	910428	1800	3	2	2	3	3	1	2	2	8	0	0	0	0
83	910428	2200	1	1	1	5	0	0	1	4	0	5	0	0	0
84	910429	200	4	2	6	5	4	2	5	3	0	14	0	0	0
85	910429	600	12	14	24	12	11	13	21	9	0	54	0	0	0
86	910429	1000	3	6	8	8	1	3	6	6	16	0	0	0	0
87	910429	1400	4	1	1	7	3	1	1	5	0	10	0	0	0
88	910429	1800	1	0	0	0	1	0	0	0	0	1	0	0	0
89	910429	2200	4	2	2	0	1	2	1	0	2	2	0	0	0
90	910430	200	.	.	.	.	.	.	.	.	.	.	.	.	.
91	910430	600	0	2	1	3	0	2	0	2	4	0	0	0	0
92	910430	1000	9	6	6	4	8	5	5	3	0	21	0	0	0
93	910430	1400	2	2	0	1	1	1	0	1	0	3	0	0	0
94	910430	1800	0	1	1	0	0	1	0	0	0	1	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
95	910430	2200	2	0	0	0	0	0	0	0	.	.	.	.	.
96	910501	200	2	1	3	1	1	0	1	1	3	0	0	0	0
97	910501	600	5	3	3	2	3	1	0	1	4	1	0	0	0
98	910501	1000	6	4	4	5	4	3	2	3	7	5	0	0	0
99	910501	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
100	910501	1800	0	1	0	0	0	1	0	0	1	0	0	0	0
101	910501	2200	3	3	0	2	2	2	0	2	6	0	0	0	0
102	910502	200	27	35	39	48	20	16	12	30	77	1	0	0	0
103	910502	600	31	10	39	29	23	6	31	23	79	4	0	0	0
104	910502	1000	59	51	67	62	30	27	42	27	54	3	0	0	0
105	910502	1400	1	6	6	2	0	5	6	1	9	3	0	0	0
106	910502	1800	1	0	2	6	0	0	1	4	5	0	0	0	0
107	910502	2200	8	6	18	25	5	5	8	13	27	4	0	0	0
108	910503	200	19	23	31	26	12	17	19	16	58	6	0	0	0
109	910503	600	3	2	4	1	3	1	1	1	1	5	0	0	0
110	910503	1000	17	9	17	12	7	2	5	3	15	2	0	0	0
111	910503	1400	0	0	0	5	0	0	0	2	2	0	0	0	0
112	910503	1800	2	2	10	5	1	1	6	1	9	0	0	0	0
113	910503	2200	.	.	.	.	.	.	.	.	.	.	.	.	.
114	910504	200	.	.	.	.	.	.	.	.	.	.	.	.	.
115	910504	600	2	3	4	6	1	0	2	3	5	1	0	0	0
116	910504	1000	0	1	5	5	0	0	4	2	6	0	0	0	0
117	910504	1400	2	0	1	1	0	0	1	1	2	0	0	0	0
118	910504	1800	0	2	5	3	0	1	2	2	5	0	0	0	0
119	910504	2200	1	1	2	1	1	1	1	1	4	0	0	0	0
120	910505	200	6	10	12	7	1	6	8	4	19	0	0	0	0
121	910505	600	4	4	10	5	2	2	10	3	17	0	0	0	0
122	910505	1000	8	10	14	9	4	6	6	5	21	0	0	0	0
123	910505	1400	7	6	0	3	6	6	0	2	14	0	0	0	0
124	910505	1800	8	6	10	9	3	3	5	6	17	0	0	0	0
125	910505	2200	8	2	1	1	6	1	1	0	8	0	0	0	0
126	910506	200	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
127	910506	600	16	3	20	13	13	3	15	5	36	0	0	0	0
128	910506	1000	66	77	68	90	34	44	41	42	138	23	0	0	0
129	910506	1400	13	3	3	9	11	3	2	8	24	0	0	0	0
130	910506	1800	2	0	0	5	0	0	0	1	1	0	0	0	0
131	910506	2200	2	7	9	1	2	6	3	0	11	0	0	0	0
132	910507	200	9	4	10	9	3	1	4	6	14	0	0	0	0
133	910507	600	16	8	19	46	11	6	9	29	55	0	0	0	0
134	910507	1000	1	1	5	5	1	0	4	3	8	0	0	0	0
135	910507	1400	8	3	2	11	6	2	1	10	19	0	0	0	0
136	910507	1800	15	17	11	8	8	9	8	7	32	0	0	0	0
137	910507	2200	47	30	21	44	43	26	16	26	111	0	0	0	0
138	910508	200	37	26	49	24	29	18	32	17	96	0	0	0	0
139	910508	600	173	180	170	89	129	135	129	39	126	132	0	0	0
140	910508	1000	119	105	57	107	66	46	25	66	69	22	0	0	0
141	910508	1400	179	243	453	253	80	129	148	106	201	27	0	0	0
142	910508	1800	83	95	120	98	37	49	48	39	80	17	0	0	0
143	910508	2200	117	60	101	103	53	25	43	50	79	24	0	0	0
144	910509	200	83	92	120	101	29	47	58	44	70	17	0	0	0
145	910509	600	144	114	223	181	105	54	110	80	133	31	0	0	0
146	910509	1000	78	97	70	73	37	49	39	31	66	14	0	0	0
147	910509	1400	16	1	7	5	6	0	5	5	15	1	0	0	0
148	910509	1800	13	22	17	8	5	7	6	5	23	0	0	0	0
149	910509	2200	2	4	1	9	1	3	0	6	10	0	0	0	0
150	910510	200	26	19	36	41	12	8	19	18	48	9	0	0	0
151	910510	600	5	7	8	11	4	7	7	7	25	0	0	0	0
152	910510	1000	25	18	28	23	15	7	9	16	35	12	0	0	0
153	910510	1400	6	2	1	10	6	2	0	6	14	0	0	0	0
154	910510	1800	5	12	10	8	2	4	4	2	9	3	0	0	0
155	910510	2200	15	10	9	27	9	6	6	21	42	0	0	0	0
156	910511	200	21	18	31	27	10	8	12	12	34	8	0	0	0
157	910511	600	78	43	60	43	56	36	41	32	128	37	0	0	0
158	910511	1000	79	107	76	81	30	42	37	32	67	74	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
159	910511	1400	20	15	34	20	12	9	18	14	41	12	0	0	0
160	910511	1800	38	41	57	47	19	17	20	17	52	21	0	0	0
161	910511	2200	81	79	94	88	52	43	55	58	202	6	0	0	0
162	910512	200	131	107	121	117	78	54	71	66	130	19	0	0	0
163	910512	600	98	113	157	104	63	75	95	75	124	34	0	0	0
164	910512	1000	224	301	209	235	85	103	177	134	145	92	0	0	0
165	910512	1400	26	48	8	3	16	35	4	3	32	26	0	0	0
166	910512	1800	53	73	51	69	24	23	21	18	50	36	0	0	0
167	910512	2200	3	2	8	19	0	1	5	14	11	9	0	0	0
168	910513	200	57	83	48	59	28	35	26	30	103	16	0	0	0
169	910513	600	26	15	8	31	22	9	4	19	43	11	0	0	0
170	910513	1000	42	37	58	60	18	16	26	29	26	63	0	0	0
171	910513	1400	18	24	25	10	18	21	17	5	40	21	0	0	0
172	910513	1800	61	89	75	82	31	29	34	38	51	81	0	0	0
173	910513	2200	19	63	58	29	14	55	36	16	53	68	0	0	0
174	910514	200	389	427	526	453	206	175	275	251	114	312	0	0	0
175	910514	600	316	204	315	198	244	147	239	141	80	305	0	0	0
176	910514	1000	154	264	138	114	41	79	79	49	5	113	2	0	0
177	910514	1400	23	18	36	43	20	13	21	27	58	23	0	0	0
178	910514	1800	64	79	59	68	29	40	30	31	.	.	.	.	.
179	910514	2200	41	41	71	77	25	20	34	46	67	58	0	0	0
180	910515	200	97	81	109	90	43	40	42	36	103	58	0	0	0
181	910515	600	26	45	38	71	16	39	26	60	101	40	0	0	0
182	910515	1000	14	12	24	7	14	7	18	4	18	35	0	0	0
183	910515	1400	12	2	13	14	8	0	11	5	7	17	0	0	0
184	910515	1800	16	12	13	5	12	6	9	5	9	23	0	0	0
185	910515	2200	16	12	11	17	7	6	8	8	11	18	0	0	0
186	910516	200	19	26	23	38	11	11	10	18	19	31	0	0	0
187	910516	600	50	41	30	47	38	27	28	35	48	80	0	0	0
188	910516	1000	15	18	23	17	7	8	10	9	8	26	0	0	0
189	910516	1400	12	19	26	20	4	6	11	13	13	21	0	0	0
190	910516	1800	34	46	68	47	19	17	38	31	19	86	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
191	910516	2200	20	42	47	43	18	26	32	15	29	62	0	0	0
192	910517	200	49	38	33	28	21	17	20	16	43	31	0	0	0
193	910517	600	63	67	38	26	34	42	27	19	83	39	0	0	0
194	910517	1000	10	8	18	14	5	4	10	8	7	20	0	0	0
195	910517	1400	5	3	2	2	3	1	0	2	4	2	0	0	0
196	910517	1800	10	12	11	14	5	7	5	6	3	20	0	0	0
197	910517	2200	16	11	23	17	14	9	19	13	25	30	0	0	0
198	910518	200	21	29	17	18	11	12	10	9	24	18	0	0	0
199	910518	600	39	13	44	37	29	10	35	25	55	44	0	0	0
200	910518	1000	65	41	43	52	20	18	16	30	33	49	2	0	0
201	910518	1400	33	34	12	15	27	26	10	13	32	42	2	0	0
202	910518	1800	73	44	86	109	36	24	52	70	130	52	0	0	0
203	910518	2200	9	24	10	10	9	21	7	7	27	17	0	0	0
204	910519	200	14	12	10	8	8	8	5	4	15	10	0	0	0
205	910519	600	18	2	13	13	16	2	6	11	8	27	0	0	0
206	910519	1000	50	46	48	59	24	21	37	32	92	21	1	0	0
207	910519	1400	5	8	7	2	3	6	1	2	8	4	0	0	0
208	910519	1800	21	18	8	23	9	8	5	13	22	13	0	0	0
209	910519	2200	1	5	5	6	0	3	4	5	9	3	0	0	0
210	910520	200	17	9	14	12	9	5	6	4	17	7	0	0	0
211	910520	600	1	3	3	3	1	3	2	2	4	4	0	0	0
212	910520	1000	1	4	3	4	0	2	1	1	0	4	0	0	0
213	910520	1400	0	3	2	0	0	3	2	0	3	2	0	0	0
214	910520	1800	1	0	1	1	1	0	1	1	1	2	0	0	0
215	910520	2200	3	1	12	5	2	1	8	4	12	3	0	0	0
216	910521	200	4	7	3	5	3	4	2	2	7	4	0	0	0
217	910521	600	10	5	4	1	7	5	3	1	7	9	0	0	0
218	910521	1000	10	8	9	4	6	7	9	4	20	6	0	0	0
219	910521	1400	5	5	3	4	2	3	2	1	6	2	0	0	0
220	910521	1800	4	4	3	2	2	1	1	2	5	1	0	0	0
221	910521	2200	9	7	3	8	6	5	3	7	15	6	0	0	0
222	910522	200	11	14	10	12	5	5	6	4	13	7	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
223	910522	600	9	3	2	8	9	3	2	5	16	3	0	0	0
224	910522	1000	14	9	36	54	8	6	21	30	61	4	0	0	0
225	910522	1400	14	7	8	11	9	5	7	6	23	4	0	0	0
226	910522	1800	17	10	21	14	12	6	14	9	24	17	0	0	0
227	910522	2200	9	2	12	2	8	2	11	1	10	12	0	0	0
228	910523	200	3	2	4	6	2	1	2	3	6	2	0	0	0
229	910523	600	1	0	4	7	1	0	4	7	12	0	0	0	0
230	910523	1000	8	6	7	11	3	3	4	5	5	10	0	0	0
231	910523	1400	8	1	5	2	7	1	2	0	2	8	0	0	0
232	910523	1800	13	4	12	11	8	1	12	8	16	13	0	0	0
233	910523	2200	12	14	19	12	5	7	9	7	18	10	0	0	0
234	910524	200	21	17	25	20	11	10	14	9	32	12	0	0	0
235	910524	600	19	28	17	23	13	21	11	16	54	7	0	0	0
236	910524	1000	9	12	17	14	6	9	9	6	19	11	0	0	0
237	910524	1400	9	5	3	4	4	3	2	2	8	3	0	0	0
238	910524	1800	10	8	9	12	6	4	6	7	14	9	0	0	0
239	910524	2200	11	18	15	20	9	10	14	14	28	19	0	0	0
240	910525	200	.	.	.	.	.	.	.	.	.	.	.	.	.
241	910525	600	11	5	1	7	8	4	1	7	13	7	0	0	0
242	910525	1000	7	6	9	8	4	3	6	4	12	5	0	0	0
243	910525	1400	4	6	11	5	4	3	9	2	13	5	0	0	0
244	910525	1800	18	23	37	23	12	10	28	17	34	33	0	0	0
245	910525	2200	23	21	18	7	21	14	12	6	36	17	0	0	0
246	910526	200	19	21	31	26	10	12	18	18	41	17	0	0	0
247	910526	600	3	5	4	24	0	3	4	14	7	14	0	0	0
248	910526	1000	16	32	29	50	10	18	19	29	60	16	0	0	0
249	910526	1400	19	13	5	18	10	10	3	16	29	10	0	0	0
250	910526	1800	34	40	78	64	26	21	40	33	39	51	0	0	0
251	910526	2200	12	26	10	30	9	25	4	22	24	36	0	0	0
252	910527	200	16	12	21	26	9	9	12	14	32	12	0	0	0
253	910527	600	19	12	20	14	8	7	9	8	22	10	0	0	0
254	910527	1000	11	14	17	19	6	8	11	9	27	7	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
255	910527	1400	7	9	10	11	4	4	6	7	12	9	0	0	0
256	910527	1800	8	11	18	11	5	7	11	8	21	10	0	0	0
257	910527	2200	.	.	.	.	.	.	.	.	.	.	.	.	.
258	910528	200	13	7	13	8	9	6	6	5	5	21	0	0	0
259	910528	600	3	1	12	9	2	1	6	7	6	10	0	0	0
260	910528	1000	23	7	8	8	9	5	6	8	14	14	0	0	0
261	910528	1400	.	.	.	.	.	.	.	.	.	.	.	.	.
262	910528	1800	8	9	.	.	8	8	.	.	7	9	0	0	0
263	910528	2200	11	11	18	8	8	10	4	5	18	9	0	0	0
264	910529	200	22	13	7	15	17	9	7	9	27	15	0	0	0
265	910529	600	6	4	2	3	6	3	1	1	8	3	0	0	0
266	910529	1000	3	3	6	4	2	2	3	4	9	4	0	0	0
267	910529	1400	13	3	3	4	6	2	3	1	7	5	0	0	0
268	910529	1800	8	4	4	3	6	3	4	2	5	11	0	0	0
269	910529	2200	11	4	9	12	10	3	7	11	15	16	0	0	0
270	910530	200	19	23	26	29	11	12	17	14	33	21	0	0	0
271	910530	600	4	2	6	5	4	2	6	3	5	10	0	0	0
272	910530	1000	7	7	10	11	6	5	6	7	11	13	1	0	0
273	910530	1400	0	2	1	5	0	0	0	4	2	2	0	0	0
274	910530	1800	4	6	9	10	3	3	6	7	5	14	0	0	0
275	910530	2200	5	3	4	2	2	3	3	2	8	2	0	0	0
276	910531	200	7	5	9	12	3	3	6	7	12	7	0	0	0
277	910531	600	2	1	1	1	1	1	1	0	2	1	0	0	0
278	910531	1000	4	3	6	5	2	1	4	3	4	6	0	0	0
279	910531	1400	2	0	3	2	1	0	2	2	4	1	0	0	0
280	910531	1800	6	5	7	4	3	3	4	2	3	9	0	0	0
281	910531	2200	4	3	8	5	2	1	5	2	2	8	0	0	0
282	910601	200	2	7	9	9	2	5	5	4	6	10	0	0	0
283	910601	600	5	3	4	6	3	1	2	3	1	8	0	0	0
284	910601	1000	5	0	2	5	4	0	1	5	8	2	0	0	0
285	910601	1400	6	1	1	1	2	1	0	1	4	0	0	0	0
286	910601	1800	1	0	2	1	1	0	2	1	3	1	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
287	910601	2200	.	.	.	.	.	.	.	.	.	.	.	.	.
288	910602	200	4	2	2	3	2	1	2	1	4	2	0	0	0
289	910602	600	.	.	.	.	.	.	.	.	.	.	.	.	.
290	910602	1000	1	2	3	3	0	0	1	1	1	1	0	0	0
291	910602	1400	0	2	3	1	0	2	1	0	2	0	1	0	0
292	910602	1800	.	.	.	.	.	.	.	.	.	.	.	.	.
293	910602	2200	1	4	1	2	1	2	0	2	4	1	0	0	0
294	910603	200	6	2	1	4	5	2	0	3	7	3	0	0	0
295	910603	600	0	1	1	1	0	0	0	1	0	1	0	0	0
296	910603	1000	0	0	1	0	0	0	0	0	.	.	.	.	.
297	910603	1400	1	0	5	0	1	0	5	0	6	0	0	0	0
298	910603	1800	.	.	.	.	.	.	.	.	.	.	.	.	.
299	910603	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
300	910604	200	0	0	0	0	.	.	.	.	.	.	.	.	.
301	910604	600	0	2	1	1	0	1	1	1	1	2	0	0	0
302	910604	1000	3	0	0	2	1	0	0	1	2	0	0	0	0
303	910604	1400	1	0	2	0	1	0	1	0	1	1	0	0	0
304	910604	1800	7	3	5	6	4	3	4	5	2	14	0	0	0
305	910604	2200	2	0	0	0	1	0	0	0	1	0	0	0	0
306	910605	200	1	0	0	0	0	0	0	0	.	.	.	.	.
307	910605	600	0	0	1	1	0	0	0	1	0	1	0	0	0
308	910605	1000	1	0	2	0	1	0	1	0	2	0	0	0	0
309	910605	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
310	910605	1800	1	0	1	0	0	0	1	0	0	1	0	0	0
311	910605	2200	0	0	1	1	0	0	1	1	1	1	0	0	0
312	910606	200	2	1	2	1	1	1	0	1	0	3	0	0	0
313	910606	600	0	2	1	1	0	2	1	0	3	0	0	0	0
314	910606	1000	0	0	2	1	0	0	1	0	0	1	0	0	0
315	910606	1400	1	0	0	1	1	0	0	1	0	2	0	0	0
316	910606	1800	0	0	1	0	0	0	0	0	.	.	.	.	.
317	910606	2200	0	0	1	0	0	0	1	0	1	0	0	0	0
318	910607	200	0	1	1	2	0	1	0	1	0	2	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
319	910607	600	0	0	0	1	0	0	0	1	1	0	0	0	0
320	910607	1000	0	2	2	2	0	1	0	1	0	2	0	0	0
321	910607	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
322	910607	1800	0	0	1	1	0	0	1	1	0	2	0	0	0
323	910607	2200	3	1	2	1	2	1	2	1	4	2	0	0	0
324	910608	200	.	.	.	.	.	.	.	.	.	.	.	.	.
325	910608	600	0	0	0	0	.	.	.	.	.	.	.	.	.
326	910608	1000	0	0	1	3	0	0	0	1	0	1	0	0	0
327	910608	1400	0	0	1	0	0	0	1	0	0	1	0	0	0
328	910608	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
329	910608	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
330	910609	200	0	0	0	0	.	.	.	.	.	.	.	.	.
331	910609	600	0	1	0	0	0	1	0	0	0	1	0	0	0
332	910609	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
333	910609	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
334	910609	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
335	910609	2200	0	0	2	1	0	0	2	1	2	1	0	0	0
336	910610	200	0	0	0	0	.	.	.	.	.	.	.	.	.
337	910610	600	0	0	0	0	.	.	.	.	.	.	.	.	.
338	910610	1000	1	1	0	0	1	1	0	0	0	2	0	0	0
339	910610	1400	1	1	1	0	0	0	0	0	.	.	.	.	.
340	910610	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
341	910610	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
342	910611	200	1	0	0	0	0	0	0	0	.	.	.	.	.
343	910611	600	0	0	1	0	0	0	0	0	.	.	.	.	.
344	910611	1000	0	0	0	0	.	.	.	.	.	.	.	.	.
345	910611	1400	1	0	0	0	0	0	0	0	.	.	.	.	.
346	910611	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
347	910611	2200	1	0	1	0	1	0	1	0	1	1	0	0	0
348	910612	200	0	0	1	0	0	0	0	0	.	.	.	.	.
349	910612	600	0	0	0	0	.	.	.	.	.	.	.	.	.
350	910612	1000	1	0	2	1	0	0	0	1	1	0	0	0	0

Table A-5. Continued.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
351	910612	1400	3	1	0	1	2	1	0	0	2	1	0	0	0
352	910612	1800	1	1	0	5	0	0	0	3	2	1	0	0	0
353	910612	2200	0	0	0	1	0	0	0	1	1	0	0	0	0
354	910613	200	0	0	0	0	.	.	.	.	.	.	.	.	.
355	910613	600	0	0	0	0	.	.	.	.	.	.	.	.	.
356	910613	1000	0	0	3	1	0	0	1	0	0	1	0	0	0
357	910613	1400	0	0	0	0	.	.	.	.	.	.	.	.	.
358	910613	1800	0	0	0	0	.	.	.	.	.	.	.	.	.
359	910613	2200	0	0	0	0	.	.	.	.	.	.	.	.	.
360	910614	200	0	0	0	0	.	.	.	.	.	.	.	.	.
361	910614	600	0	0	0	0	.	.	.	.	.	.	.	.	.
362	910614	1000	0	0	0	0	.	.	.	.	.	.	.	.	.

Table A-6. Surface net egg collections, Barnhill's Landing, Roanoke River, North Carolina in 1991.

Day	Date	0200	0600	1000	1400	1800	2200	Total
0	910415	.	0	0	0	0	0	0
1	910416	0	0	0	0	0	0	0
2	910417	0	0	0	0	0	1	1
3	910418	0	0	0	0	0	0	0
4	910419	0	0	.	0	0	0	0
5	910420	0	0	0	0	0	0	0
6	910421	0	0	0	0	0	0	0
7	910422	.	0	0	0	0	0	0
8	910423	0	0	0	0	0	2	2
9	910424	0	0	0	2	2	0	4
10	910425	1	.	10	0	1	0	12
11	910426	1	0	0	0	0	.	1
12	910427	0	0	0	0	0	0	0
13	910428	0	3	6	7	5	2	23
14	910429	6	26	9	5	1	6	53
15	910430	.	2	15	4	1	2	24
16	910501	3	8	10	0	1	6	28
17	910502	62	41	110	7	1	14	235
18	910503	42	5	26	0	4	.	77
19	910504	.	5	1	2	2	2	12
20	910505	16	8	18	13	14	10	79
21	910506	.	19	143	16	2	9	189
22	910507	13	24	2	11	32	77	159
23	910508	63	353	224	422	178	177	1417
24	910509	175	258	175	17	35	6	666
25	910510	45	12	43	8	17	25	150
26	910511	39	121	186	35	79	160	620
27	910512	238	211	525	74	126	5	1179
28	910513	140	41	79	42	150	82	534
29	910514	816	520	418	41	143	82	2020
30	910515	178	71	26	14	28	28	345
31	910516	45	91	33	31	80	62	342
32	910517	87	130	18	8	22	27	292
33	910518	50	52	106	67	117	33	425
34	910519	26	20	96	13	39	6	200
35	910520	26	4	5	3	1	4	43
36	910521	11	15	18	10	8	16	78
37	910522	25	12	23	21	27	11	119
38	910523	5	1	14	9	17	26	72
39	910524	38	47	21	14	18	29	167
40	910525	.	16	13	10	41	44	124
41	910526	40	8	48	32	74	38	240
42	910527	28	31	25	16	19	.	119
43	910528	20	4	30	.	17	22	93
44	910529	35	10	6	16	12	15	94
45	910530	42	6	14	2	10	8	82

Table A-6. Continued.

Day	Date	0200	0600	1000	1400	1800	2200	Total
46	910531	12	3	7	2	11	7	42
47	910601	9	8	5	7	1	.	30
48	910602	6	.	3	2	.	5	16
49	910603	8	1	0	1	.	0	10
50	910604	0	2	3	1	10	2	18
51	910605	1	0	1	0	1	0	3
52	910606	3	2	0	1	0	0	6
53	910607	1	0	2	0	0	4	7
54	910608	.	0	0	0	0	0	0
55	910609	0	1	0	0	0	0	1
56	910610	0	0	2	2	0	0	4
57	910611	1	0	0	1	0	1	3
58	910612	0	0	1	4	2	0	7
59	910613	0	0	0	0	0	0	0
60	910614	0	0	0	.	.	.	0

Table A-7. Oblique net egg collections, Barnhill's Landing, Roanoke River, North Carolina in 1991.

Day	Date	0200	0600	1000	1400	1800	2200	Total
0	910415	.	0	0	0	0	0	0
1	910416	0	0	0	0	0	0	0
2	910417	0	0	1	0	0	0	1
3	910418	0	0	1	0	0	0	1
4	910419	0	0	.	0	0	0	0
5	910420	0	0	0	0	0	0	0
6	910421	0	0	0	0	0	0	0
7	910422	.	0	0	0	0	0	0
8	910423	0	0	0	0	0	0	0
9	910424	1	0	2	0	4	0	7
10	910425	2	.	13	0	1	0	16
11	910426	1	0	0	0	1	.	2
12	910427	0	0	0	0	0	0	0
13	910428	1	7	9	5	5	6	33
14	910429	11	36	16	8	0	2	73
15	910430	.	4	10	1	1	0	16
16	910501	4	5	9	0	0	2	20
17	910502	87	68	129	8	8	43	343
18	910503	57	5	29	5	15	.	111
19	910504	.	10	10	2	8	3	33
20	910505	19	15	23	3	19	2	81
21	910506	.	33	158	12	5	10	218
22	910507	19	65	10	13	19	65	191
23	910508	73	259	164	706	218	204	1624
24	910509	221	404	143	12	25	10	815
25	910510	77	19	51	11	18	36	212
26	910511	58	103	157	54	104	182	658
27	910512	238	261	444	11	120	27	1101
28	910513	107	39	118	35	157	87	543
29	910514	979	513	252	79	127	148	2098
30	910515	199	109	31	27	18	28	412
31	910516	61	77	40	46	115	90	429
32	910517	61	64	32	4	25	40	226
33	910518	35	81	95	27	195	20	453
34	910519	18	26	107	9	31	11	202
35	910520	26	6	7	2	2	17	60
36	910521	8	5	13	7	5	11	49
37	910522	22	10	90	19	35	14	190
38	910523	10	11	18	7	23	31	100
39	910524	45	40	31	7	21	35	179
40	910525	.	8	17	16	60	25	126
41	910526	57	28	79	23	142	40	369
42	910527	47	34	36	21	29	.	167
43	910528	21	21	16	.	.	26	84
44	910529	22	5	10	7	7	21	72
45	910530	55	11	21	6	19	6	118

Table A-7. Continued.

Day	Date	0200	0600	1000	1400	1800	2200	Total
46	910531	21	2	11	5	11	13	63
47	910601	18	10	7	2	3	.	40
48	910602	5	.	6	4	.	3	18
49	910603	5	2	1	5	.	0	13
50	910604	0	2	2	2	11	0	17
51	910605	0	2	2	0	1	2	7
52	910606	3	2	3	1	1	1	11
53	910607	3	1	4	0	2	3	13
54	910608	.	0	4	1	0	0	5
55	910609	0	0	0	0	0	3	3
56	910610	0	0	0	1	0	0	1
57	910611	0	1	0	0	0	1	2
58	910612	1	0	3	1	5	1	11
59	910613	0	0	4	0	0	0	4
60	910614	0	0	0	.	.	.	0

Table A-8. Number of eggs in all nets, Barnhill's Landing, Roanoke River, North Carolina in 1991.

Day	Date	0200	0600	1000	1400	1800	2200	Total
0	910415	.	0	0	0	0	0	0
1	910416	0	0	0	0	0	0	0
2	910417	0	0	1	0	0	1	2
3	910418	0	0	1	0	0	0	1
4	910419	0	0	.	0	0	0	0
5	910420	0	0	0	0	0	0	0
6	910421	0	0	0	0	0	0	0
7	910422	.	0	0	0	0	0	0
8	910423	0	0	0	0	0	2	2
9	910424	1	0	2	2	6	0	11
10	910425	3	.	23	0	2	0	28
11	910426	2	0	0	0	1	.	3
12	910427	0	0	0	0	0	0	0
13	910428	1	10	15	12	10	8	56
14	910429	17	62	25	13	1	8	126
15	910430	.	6	25	5	2	2	40
16	910501	7	13	19	0	1	8	48
17	910502	149	109	239	15	9	57	578
18	910503	99	10	55	5	19	.	188
19	910504	.	15	11	4	10	5	45
20	910505	35	23	41	16	33	12	160
21	910506	.	52	301	28	7	19	407
22	910507	32	89	12	24	51	142	350
23	910508	136	612	388	1128	396	381	3041
24	910509	396	662	318	29	60	16	1481
25	910510	122	31	94	19	35	61	362
26	910511	97	224	343	89	183	342	1278
27	910512	476	472	969	85	246	32	2280
28	910513	247	80	197	77	307	169	1077
29	910514	1795	1033	670	120	270	230	4118
30	910515	377	180	57	41	46	56	757
31	910516	106	168	73	77	195	152	771
32	910517	148	194	50	12	47	67	518
33	910518	85	133	201	94	312	53	878
34	910519	44	46	203	22	70	17	402
35	910520	52	10	12	5	3	21	103
36	910521	19	20	31	17	13	27	127
37	910522	47	22	113	40	62	25	309
38	910523	15	12	32	16	40	57	172
39	910524	83	87	52	21	39	64	346
40	910525	.	24	30	26	101	69	250
41	910526	97	36	127	55	216	78	609
42	910527	75	65	61	37	48	.	286
43	910528	41	25	46	.	17	48	177
44	910529	57	15	16	23	19	36	166
45	910530	97	17	35	8	29	14	200

Table A-8. Continued.

Day	Date	0200	0600	1000	1400	1800	2200	Total
46	910531	33	5	18	7	22	20	105
47	910601	27	18	12	9	4	.	70
48	910602	11	.	9	6	.	8	34
49	910603	13	3	1	6	.	0	23
50	910604	0	4	5	3	21	2	35
51	910605	1	2	3	0	2	2	10
52	910606	6	4	3	2	1	1	17
53	910607	4	1	6	0	2	7	20
54	910608	.	0	4	1	0	0	5
55	910609	0	1	0	0	0	3	4
56	910610	0	0	2	3	0	0	5
57	910611	1	1	0	1	0	2	5
58	910612	1	0	4	5	7	1	18
59	910613	0	0	4	0	0	0	4
60	910614	0	0	0	.	.	.	0

Table A-9. Normal and observed rainfall (inches) for the Roanoke River basin downstream of Kerr Reservoir (RM 178.7), and basinwide, for April-June 1982-1991 (U.S. Army Corps of Engineers data).

	Below Kerr Dam						Basinwide					
	Normal			Observed			Normal			Observed		
Year	Apr	May	Jun	Apr	May	Jun	Apr	May	Jun	Apr	May	Jun
1963	3.37	4.02	3.91	1.55	2.83	2.59						
1964	3.26	4.02	3.91	2.20	1.30	2.45						
1965	3.26	3.77	3.78	2.04	1.98	8.30						
1966	3.16	3.62	4.16	1.49	6.38	3.55						
1967	3.03	3.84	4.11	1.88	3.24	2.39						
1968	2.95	3.79	3.99	3.21	5.20	3.05						
1969	2.95	3.79	3.99	3.05	3.24	4.12						
1970	2.95	3.79	3.99	4.09	2.36	3.12						
1971	2.95	3.79	3.99	2.57	6.36	3.41						
1972	2.95	3.79	3.99	2.32	5.03	4.52						
1973	2.95	3.79	3.99	4.62	4.53	5.95						
1974	2.95	3.79	3.99	2.56	5.68	2.65						
1975	2.95	3.79	3.99	2.23	3.23	2.27						
1976	2.95	3.79	3.99	0.85	3.73	4.39						
1977	2.95	3.79	3.99	2.66	5.44	3.69						
1978	2.90	4.08	3.87	4.94	4.85	5.60						
1979	2.98	4.11	3.94	4.30	6.09	5.87						
1980	2.98	4.11	3.94	3.15	2.85	2.84						
1981	2.98	4.11	3.94	1.41	4.96	3.10						
1982	2.98	4.11	3.94	3.04	2.56	4.83						
1983	2.98	4.11	3.97	5.99[A]	3.99	2.48						
1984	2.98	4.11	3.97	4.59	6.83	2.49						
1985	3.13	4.19	3.88	1.13	3.03	3.32						
1986	3.13	4.19	3.88	1.40	1.98	0.32[B]						
1987	3.13	4.19	3.88	5.53	2.21	3.44						
1988	3.01	4.09	3.75	4.67	3.87	3.68						
1989	3.01	4.09	3.75	6.41	5.16	8.41	3.36	3.89	3.84	4.02	5.76	7.95
1990	3.22	4.06	3.87	3.37	5.83	2.34	3.40	3.87	3.83	3.51	7.55	1.76
1991	3.22	4.06	3.87	2.62	1.46	2.86	3.40	3.87	3.83	2.94	3.08	2.68

[A] Maximum observed April rainfall since 1952.

[B] Record low observed June rainfall.