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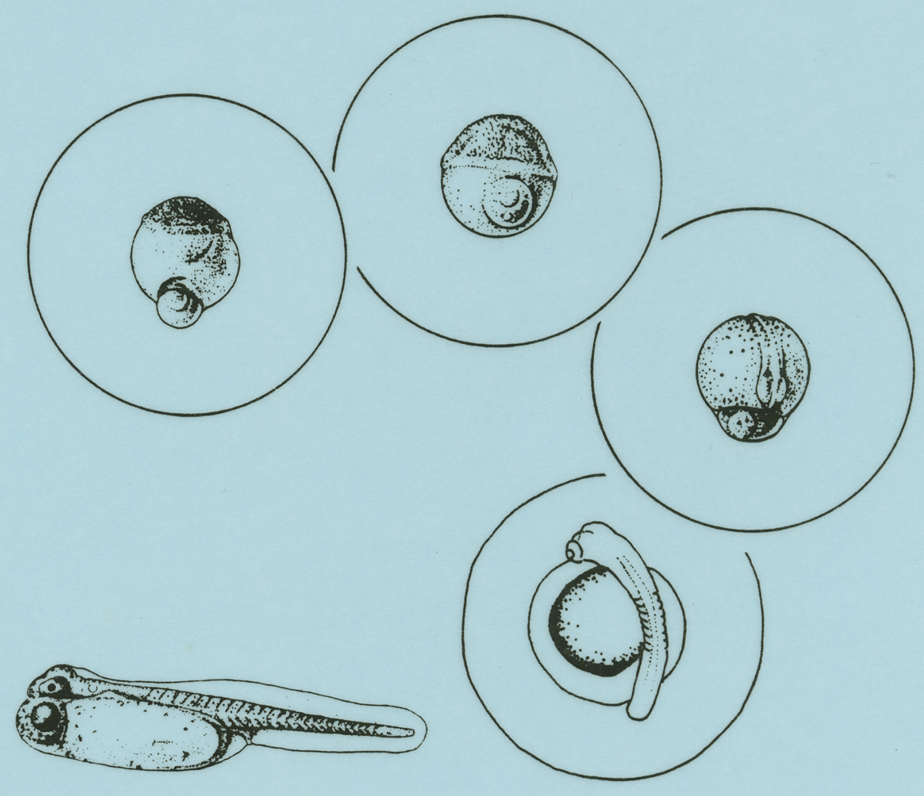
STRIPED BASS EGG ABUNDANCE and VIABILITY at SCOTLAND NECK, ROANOKE RIVER, NORTH CAROLINA, FOR 1991

Completion Report for Project F-27: Striped Bass Investigations, Study 2
to North Carolina Wildlife Resources Commission



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STRIPED BASS EGG ABUNDANCE AND VIABILITY AT SCOTLAND NECK, ROANOKE RIVER, NORTH CAROLINA, FOR 1991

Completion Report for Project F-27, Study 2
Striped Bass Investigations

For

North Carolina Wildlife Resources Commission
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EXECUTIVE SUMMARY

From 15 April to 14 June 1991, annual production and viability estimates of striped bass, *Morone saxatilis*, eggs spawned in the Roanoke River, North Carolina, were determined by sampling downstream of the spawning grounds near the town of Scotland Neck, North Carolina, at a site known as Jacob's Landing (River Mile 102). Results were compared to concurrent sampling conducted upstream at Barnhill's Landing (River Mile 117), a site closer to the historical spawning grounds. Comparisons of the data sets at the two locations provided information on the effects of reservoir discharge on striped bass spawning activity, and possible effects of sampling location on resultant egg production and viability estimates. At each site, samples were taken by trailing paired nets at the surface from a small boat for five minutes every four hours for 60 days. Data collected at Barnhill's Landing represent the official egg production and viability estimates each year, so results of the Scotland Neck study are presented in context to the Barnhill's Landing estimates.

1991 Egg Production Estimates. Barnhill's Landing data resulted in a 1991 egg production estimate of 1.837 billion eggs, the fifth largest observed since 1959. The egg viability estimate was 55.36%, the sixth highest since 1974. Within the Barnhill study sampling period, a 57-day spawning window covered the period from 17 April to 12 June, with a 41-day period of continuous spawning activity. Approximately 50% of the yearly egg production was reached by 13 May, 75% by 15 May, and 90% by 25 May. Three major spawning peaks were observed at Barnhill's Landing: 8-9 May (20% of total egg production), 11-12 May (17%), and 14 May (19%).

Estimates from Downstream Samples. A similar egg production estimate resulted from sampling downstream at Jacob's Landing, but the egg viability estimate was 15% higher (69.5%). The 51-day spawning window downstream was slightly later (25 April-14 June), and continuous spawning was observed for the entire 51-day period. Eggs collected at Jacob's Landing were older in stage of development than those collected upstream, although the presence of eggs in early stages of development indicated some spawning activity between RM 102 and RM 117. Results of statistical analyses indicated that egg transport time was approximately eight hours between the two sites, and that spawning between the two sites is minor. About 88% of the variability in the Jacob's instantaneous egg production estimate was explained by several factors: the number of Stage 1 (0-8 hours old) and Stage 2 (10-18 hours) eggs recorded upstream 8 hours earlier, and the number of dead eggs in the Jacob's samples. Factors not contributing significantly to the Jacob's egg production model were the Stage 1 eggs spawned between the two sites, and the number of Stage 3 eggs (20-28 hours) and dead eggs recorded upstream 8 hours earlier.

Environmental Conditions. Major spawning activity occurred after water temperatures reached 18°C; spawning continued into June even though water temperatures became quite warm from the record-setting weather. Instream flow was moderate and stable for the period of major

spawning activity. Dissolved oxygen levels of river waters declined seasonally; concentrations less than 5.0 mg/L were noted at Jacob's Landing. Water became slightly more acidic between RM 117 and RM 103.

Conclusions and Recommendations. Striped bass spawning activity in the lower Roanoke River can be determined effectively by monitoring egg abundance downstream of the spawning grounds. Decreasing water temperatures can stop or slow spawning activity, especially if the water temperature drops below 18°C. Since reservoir releases from upstream can alter water quality, especially river temperature, reservoir release schedules can impact spawning activity downstream. Reservoir releases also change the instream flow velocity, which in turn alters the travel time of developing striped bass eggs downstream. Roanoke striped bass continue to spawn into mid-June even though river temperatures exceed optimal conditions for egg survival. Low level spawning activity may occur earlier than mid-April. Monitoring egg production too close to, or too far downstream of, the spawning grounds will overestimate egg viability. Consistency in sampling locations most likely provides the best relative estimates of egg production and viability. Manipulation of river flow can be used to regulate spawning activity of striped bass in the lower Roanoke River. Annual egg studies provide daily information on spawning activity in relation to reservoir releases and water quality, and can be used to update and revise creel survey schedules. Daily egg production estimates can be compared to those young-of-year striped bass captured in the Albemarle juvenile trawl survey to determine the relative mortality rates of the spawning cohorts. Recommendations include continuing the egg production studies on an annual basis to detect changes in spawning activity related to environmental and man-induced alterations in Roanoke River water quality. The information of the annual studies will be needed as documentation for hydroelectric relicensing efforts presently underway in the lower watershed.

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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 1987). 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. 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 food availability for larvae (Rulifson et al. 1986, 1988, 1992), and poor survival of juveniles on the nursery grounds of the western Sound.

Annual studies of egg abundance and viability have been conducted since the mid-1950s by Dr. W.W. Hassler and co-workers from North Carolina State University in Raleigh. The information gathered by these researchers spans nearly 30 years and is well-known as one of the best data bases on striped bass spawning activity in North America. These daily records have been an extremely important source of information for reconstructing historical spawning records in relation to exploitation, changes in fishing regulations, and man-induced changes in the flow regime and water quality of the Roanoke River watershed. Dr. Hassler stopped actively pursuing his studies in 1987; since that time the egg studies have been continued by Rulifson and colleagues at East Carolina University.

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 construction and closure of John H. Kerr Reservoir in 1952. This concern was one of the reasons for forming a Steering Committee for Roanoke River Studies in 1955. The Steering 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). Committee findings 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 their 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 and North Carolina Division of Marine Fisheries 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: initiation of the Albemarle-Pamlico Estuarine Study; litigation concerning the interbasin transfer of Roanoke River water for municipal use by the City of Virginia Beach; efforts by the Federal government to establish a national wildlife refuge within the floodplain of the lower Roanoke River; hydroelectric relicensing activities in Virginia and North Carolina; and continued decline of the Roanoke-Albemarle striped bass stock. These events all had the common problem of how instream flow of the Roanoke River is managed by the system of reservoirs located in the Piedmont region of the watershed.

In 1988, an *ad hoc* group was formed to investigate the effects of instream flow management below Roanoke Rapids Dam on striped bass and other downstream resources. The Roanoke River Water Flow Committee was comprised of 20 representatives of State and Federal agencies and university scientists. The purpose of the Flow 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 by Manooch and Rulifson (1989) and Rulifson and Manooch (1990a, 1991); one of the findings was the correlation of instream flow of the Roanoke River and subsequent number of young of year striped bass caught in the annual Albemarle Sound juvenile survey (Rulifson and Manooch 1990b, Rulifson et al. 1991).

At the present time, the manner in which waters are released from Roanoke Rapids Reservoir is governed by a tri-party agreement involving the U.S. Army Corps of Engineers (Corps), Virginia Power Company, 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, but 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 operator of the dam can double or cut in half the rate of discharge through the turbines every two hours to optimize on-demand hydropower generation. A discharge of 5,000 cfs (cubic feet per second) can increase to 10,000 cfs within two hours, and then to 20,000 cfs within three hours. These sudden changes in the flow regime result in dramatic changes in water depth on the spawning grounds within a several-hour period. Although these sudden and dramatic changes in instream flow are well-known, no studies had been conducted to determine how spawning is affected by this surge of water until 1988 with the initiation of the Rulifson striped bass egg studies. Results of these studies (Rulifson 1989, 1990, 1991) clearly demonstrate how reservoir discharge from Roanoke Rapids Dam reduces water temperature downstream, which in turn affects striped bass spawning activity.

One observation from the results of the 1988-1990 egg studies was the possibility that annual egg production and egg viability estimates might vary as a function of the location (i.e., river mile) at which samples are collected. My hypothesis was that sampling too close downstream of the primary spawning grounds may underestimate production (missing those spawning fish farther downstream) and overestimate viability; eggs that are destined for mortality may not have time to manifest the visible characteristics. Alternatively, sampling too far downstream may result in an underestimate of egg production (those eggs lost in the floodplain, consumed, or disintegrated) and overestimate viability (only those that are viable have been transported downstream to the point of sampling).

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; 3) to determine the relationship between intensity of striped bass spawning (as measured by egg production) and water releases from the Roanoke Rapids Reservoir; and 4) to compare estimates of egg viability, egg production, and stage of development with a concurrent study conducted 15 river miles upstream.

STUDY SITE DESCRIPTION

The Roanoke River is a major coastal floodplain river originating on the eastern slopes of 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.

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 is most important to the lower River and Albemarle Sound; approximately 87% of the flow to the coastal watershed is provided by its discharge (Giese et al. 1985). Average (1912-1990) annual River discharge at Roanoke Rapids, North Carolina (USGS gage), is 8,120 $\pm$ 8,622 cfs (Rulifson et al. 1992). The watershed itself contributes approximately 50% of the freshwater input to Albemarle Sound.

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. 1992).

METHODS

Two sampling sites were used in the 1991 spring sampling season. The first field station was located at Barnhill's Landing (RM 117) in Halifax County, the site of W.W. Hassler's sampling efforts during the period from 1975 to 1981. This area is located approximately three miles below the historical spawning grounds (Figure 2). The second field station was located at the edge of a field in Northampton County known as Jacob's Landing at approximately RM 102. Samples were first collected on 15 April; the study was terminated on 14 June.

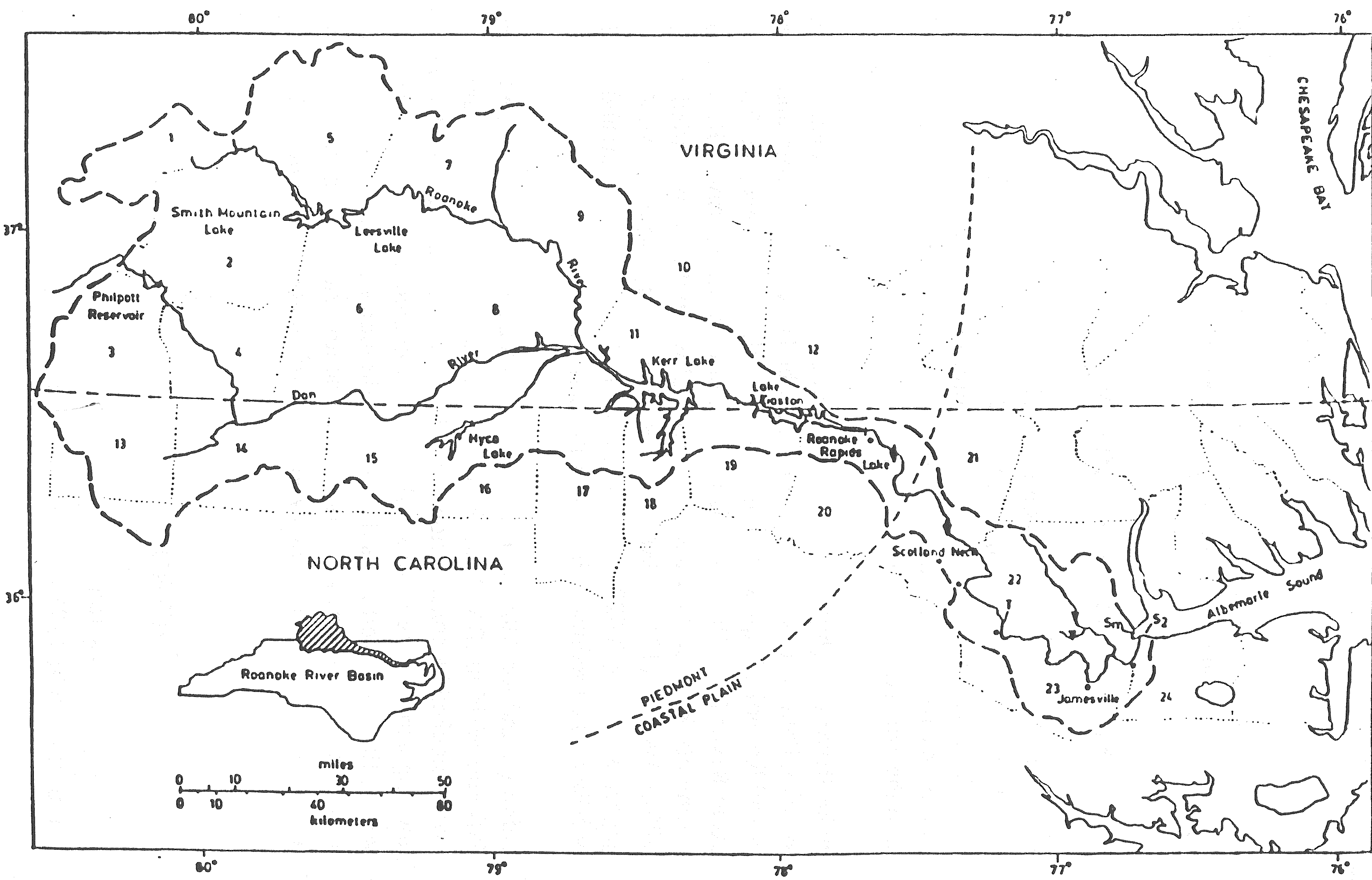


Figure 1. Drainage area of the Roanoke River Basin. Dashed line indicated approximate location of the Fall Line; diamonds=locations of USGS water quality and gaging stations; inverted triangle=USGS water quality station; T=upstream limit of tidal influence; S2=mean upstream intrusion limit of saltwater front (200 mg/L chloride); Sm=maximum upstream intrusion of saltwater front (Giese et al. 1979. Counties containing Roanoke watershed are enumerated and listed in Appendix Table A-1.

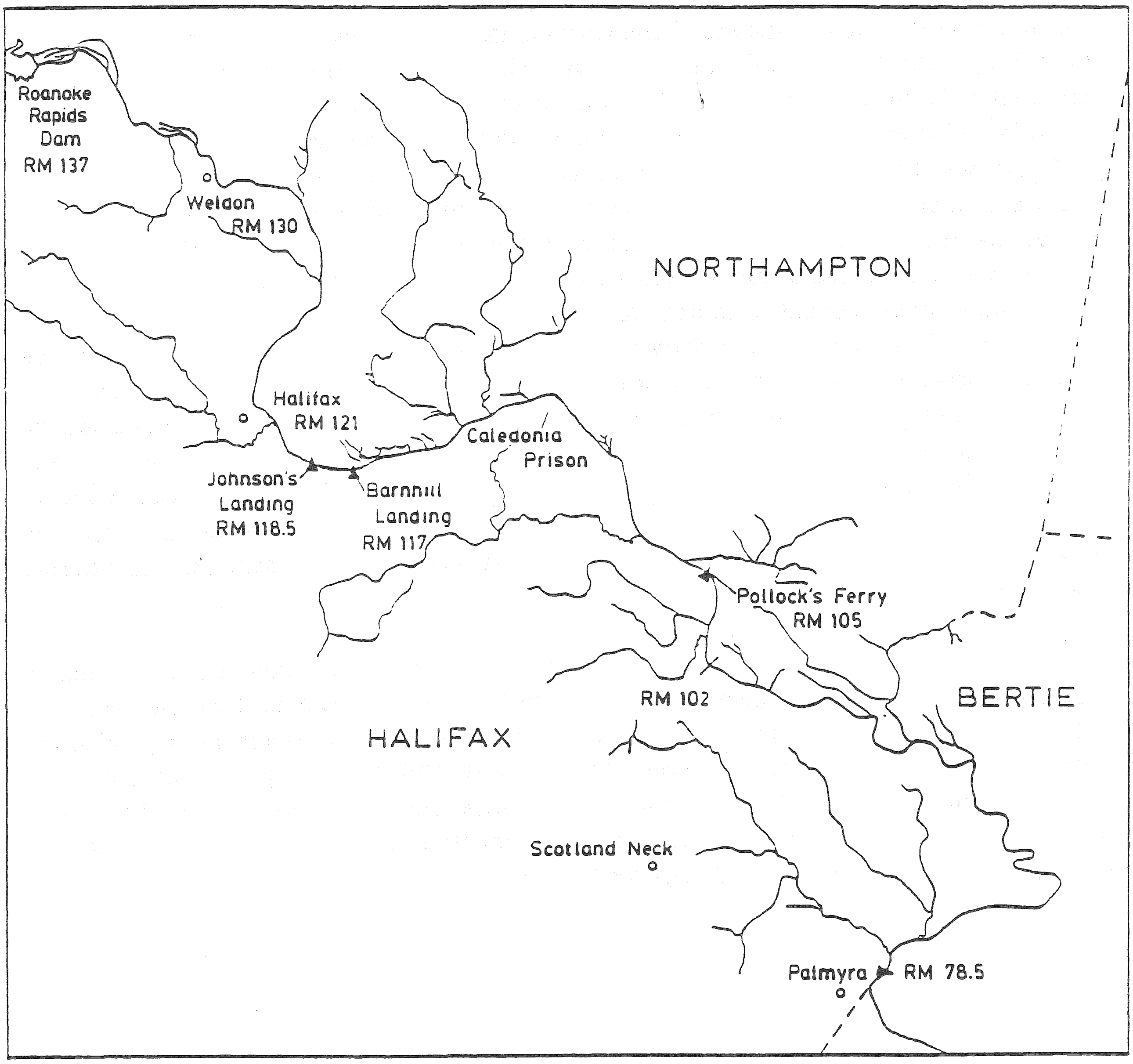


Figure 2. Roanoke River watershed downstream of Roanoke Rapids Reservoir showing the historical sampling stations for striped bass eggs: Palmyra (1959-60), Halifax (1961-74), Barnhill's Landing (1975-81, 1989-91), Johnson's Landing (1982-87), Pollock's Ferry (1988), and Jacob's Landing (1991).

At both sites, procedures for field sampling and sample workup were those used by Hassler to ensure compatibility to the historical record. Egg collection methods were similar to those described in Hassler's annual reports. Samples were taken 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-µm nitex mesh (6:1 length-to-mouth ratio) from a small aluminum boat anchored in mid-stream. A solid cup attached to the tail of each net was used to retain collected eggs. Two tows of five-minute duration were made: the first tow six inches below the surface (Hassler's method), and the second tow near the bottom. The two sets of samples allowed comparisons of egg density at the surface with the abundance of eggs at the bottom. A flowmeter with slow speed propeller was attached to the bongo frame so that the theoretical volume of water filtered could be estimated. 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 temperature, dissolved oxygen, conductivity, pH, total dissolved solids, and water velocity were recorded for each sample. Instruments used to record environmental parameters were calibrated periodically between the two sites according to USEPA standard methods. Secchi visibility depth was recorded for all samples taken during daylight hours.

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 using Hassler's criteria (Hassler et al. 1981): each egg was examined to determine the status of the embryo, yolk and oil globules, and perivitelline space. Eggs were staged under a dissecting microscope using the criteria of Bonn et al. (1976). Stage 1 eggs were those 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 was newly-hatched larvae. Stage of development was based on an assumed water temperature of 17°C; 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 (SAS Institute 1985). The estimated number of striped bass eggs passing the sampling station was calculated on a daily basis using the Hassler equation

$$N = 514.29\,XY,$$

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 square feet of river area to the mouth opening of the 10-inch diameter egg net (0.56 square feet, 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.

Natural log-transformed data were used in statistical analyses. Normal probability plots indicated that transformation of the count data was required; natural log transformation reduced skewness and kurtosis better than square root transformation. Multiple regression techniques were used to determine the relationships between egg production estimates at the two sampling sites. The Durbin Watson statistic was used to investigate first-order autocorrelation of the variables. However, multicollinearity (correlation among the independent variables) was not investigated.

RESULTS

Approximately 94% of the scheduled 1,440 samples were collected: 1,348 at Barnhill's Landing and 1,354 at Jacob's Landing. The remaining samples could not be collected due to unfavorable weather or were lost.

Egg Production

The number of eggs collected at each site was not statistically different. A total of 22,108 eggs was counted at Barnhill's Landing: 10,467 in surface samples and 11,641 in bottom samples. At Jacob's Landing, surface samples collected 10,644 eggs and bottom samples contained 12,878 eggs for a total of 23,522 eggs at the downstream site.

From surface samples collected at Barnhill's Landing, the 1991 egg production estimate was 1.837 billion (± 301 million) from a total of 10,467 eggs. The 1991 estimate is the fifth largest observed since 1959, and the second largest value obtained at Barnhill's Landing (Table 1). At Jacob's Landing, the estimate was 2.068 billion (± 68 million) from a total of 10,644 eggs collected in surface samples.

Estimates of egg production also varied with depth at which the samples were taken. Bottom samples at Barnhill's Landing resulted in an estimate approximately 200 million eggs greater than surface samples; this represents a 10% difference in estimates. Downstream the discrepancy was larger; the bottom sample estimate was 431 million eggs greater than the surface estimate, for a 17% difference (Table 2).

Spawning Activity

The estimated seasonal spawning window and the number of consecutive spawning days was slightly different at the two sites. For Barnhill's Landing, the first egg was collected on 17

Table 1. 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	1,837,088,715	55.36	Barnhill's Landing
	15 Apr-14 Jun	2,068,304,334	69.51	Jacob's Landing (RM 102)

Table 2. 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	1,348	1,364
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	1,837,088,715	2,068,304,334
bottom	2,051,430,565	2,499,322,372
average of combined samples	1,944,122,846	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 2 (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

April and the last egg was caught on 12 June, for a 57-day spawning window. A slightly later 51-day window was observed at Jacob's Landing, ranging from 25 April to 14 June. The number of days for continuous spawning activity was 41 at Barnhill's Landing and 51 (the full spawning window) at Jacob's Landing (Table 2).

As expected, milestones depicting spawning activity were similar for both sites. Approximately 50% of the yearly egg production estimate was reached by 13 May upstream (14 May downstream), 75% of the total by 15 May (18 May downstream), and 90% of the total by 25 May (26 May downstream) (Figure 3).

Three major spawning peaks were observed at both locations, a pattern common to that observed in Hassler's data. At Barnhill's Landing, these dates were 8-9 May, 11-12 May, and 14 May (Figure 4).

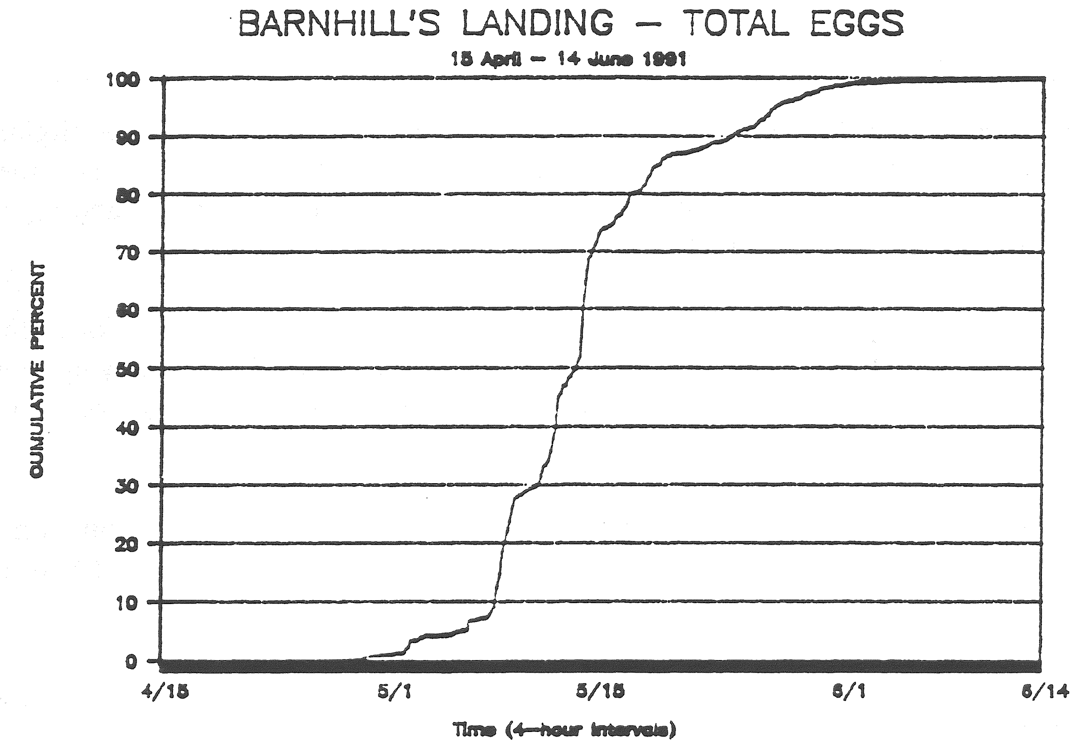
Egg Viability

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 1). No seasonal trend in egg viability was evident in the data (Figure 5). However, the estimates were substantially different between the two sites. The average surface egg viability was 55% at Barnhill's Landing, but nearly 70% at Jacob's Landing. Vertically, there was less than one percent difference between surface and bottom viability estimates for Barnhill's Landing. Downstream, about 2% more of bottom-caught eggs were viable compared to those collected at the surface (Table 2).

Egg Development

As expected, eggs collected downstream at Jacob's Landing were older in stage of development than those caught at Barnhill's Landing. Approximately 62% of the 9,593 eggs examined at Barnhill's Landing were less than 10 hours old. An additional 37% were 10-18 hours old, and only nine eggs (0.09%) were 20-28 hours into their development. At Jacob's Landing, about 68% the 16,621 eggs examined were 20-28 hours old, and nearly 3% were 30 hours or more into development. A small percentage of the samples (0.05%) were newly-hatched striped bass larvae (Table 2).

Even though the major portion of Jacob's Landing eggs were well developed, about 26% of the eggs were 10-18 hours old, and nearly 3% were less than 10 hours in development. These results suggest that striped bass spawning activity must have occurred between RM 117 and RM 102 since the eggs must be transported for several hours to reach the downstream site. Field crew at both sites noted "rock fights", or acts of spawning, during the study.



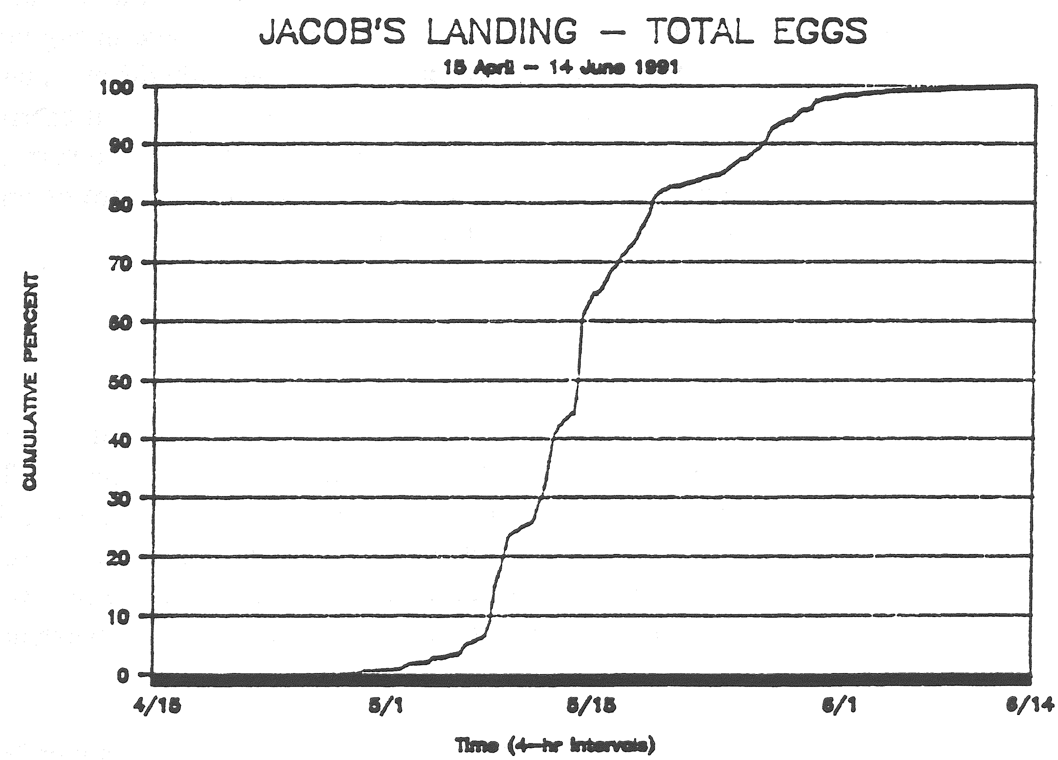
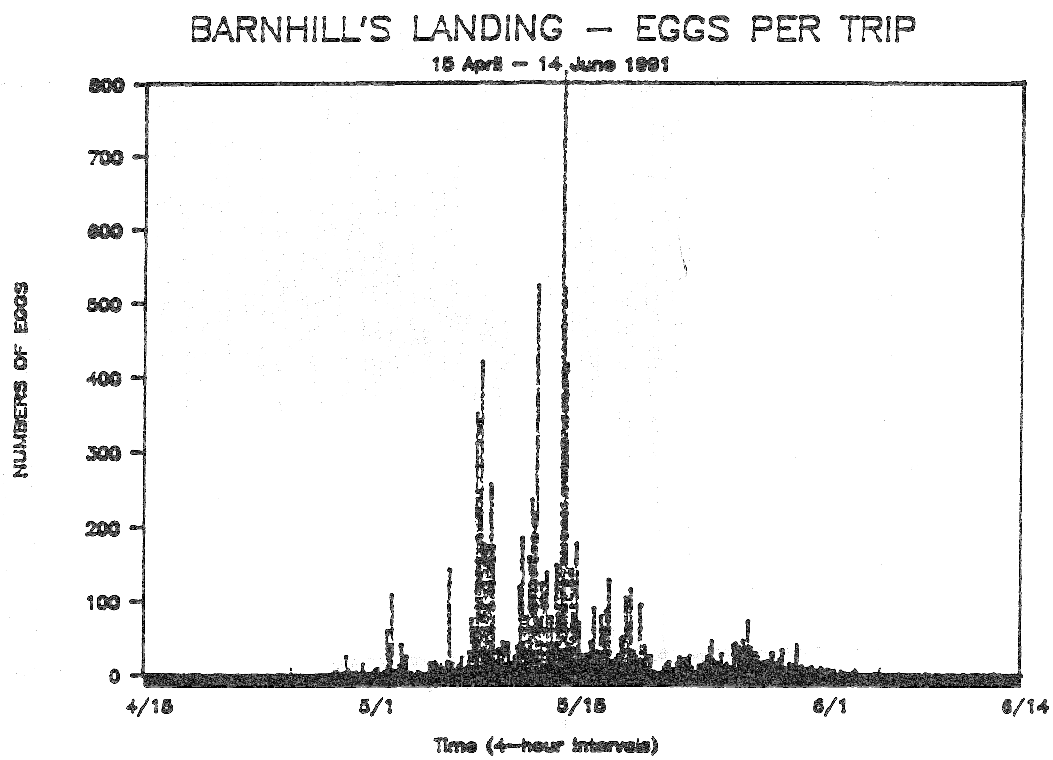


Figure 3. Estimated production of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing and at Jacob's Landing, NC, in 1991, presented as percentage of total production.



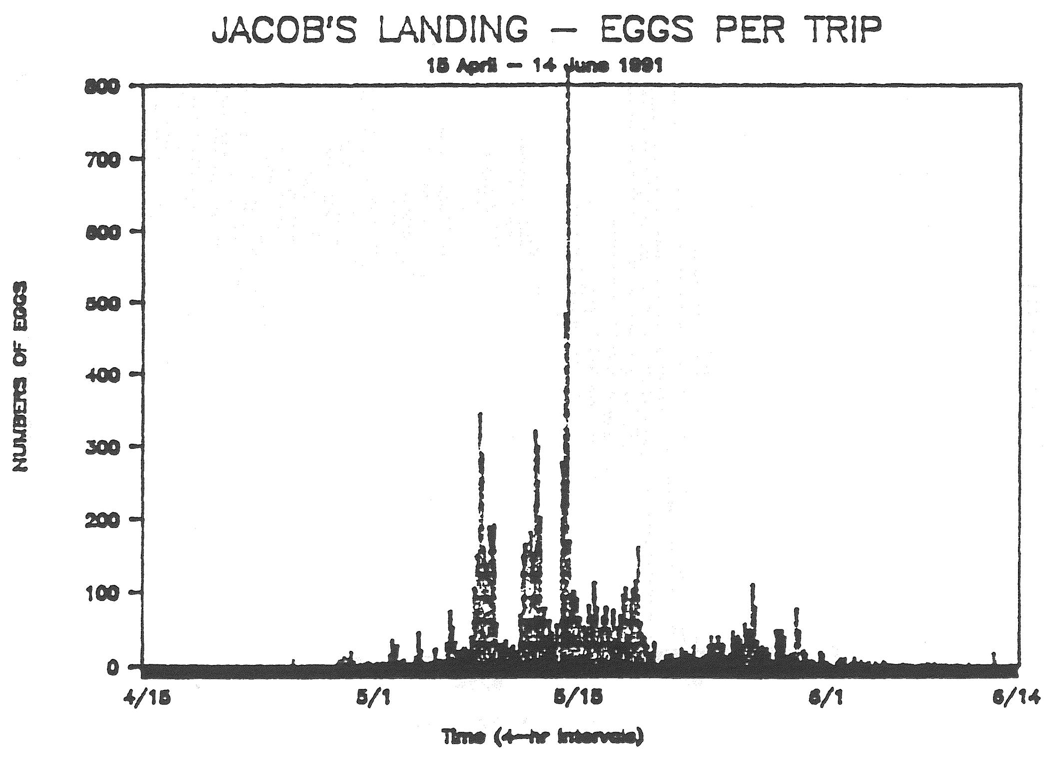
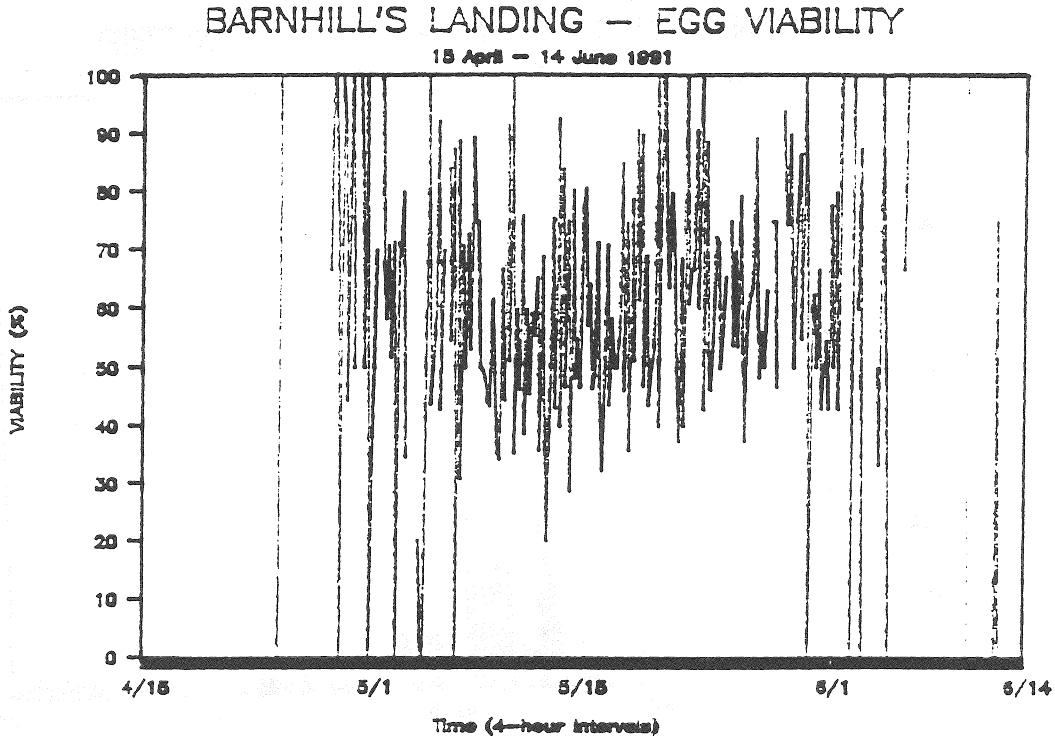


Figure 4. Number of striped bass eggs collected in surface nets during each trip at Barnhills' Landing and Jacob's Landing, NC, in 1991.



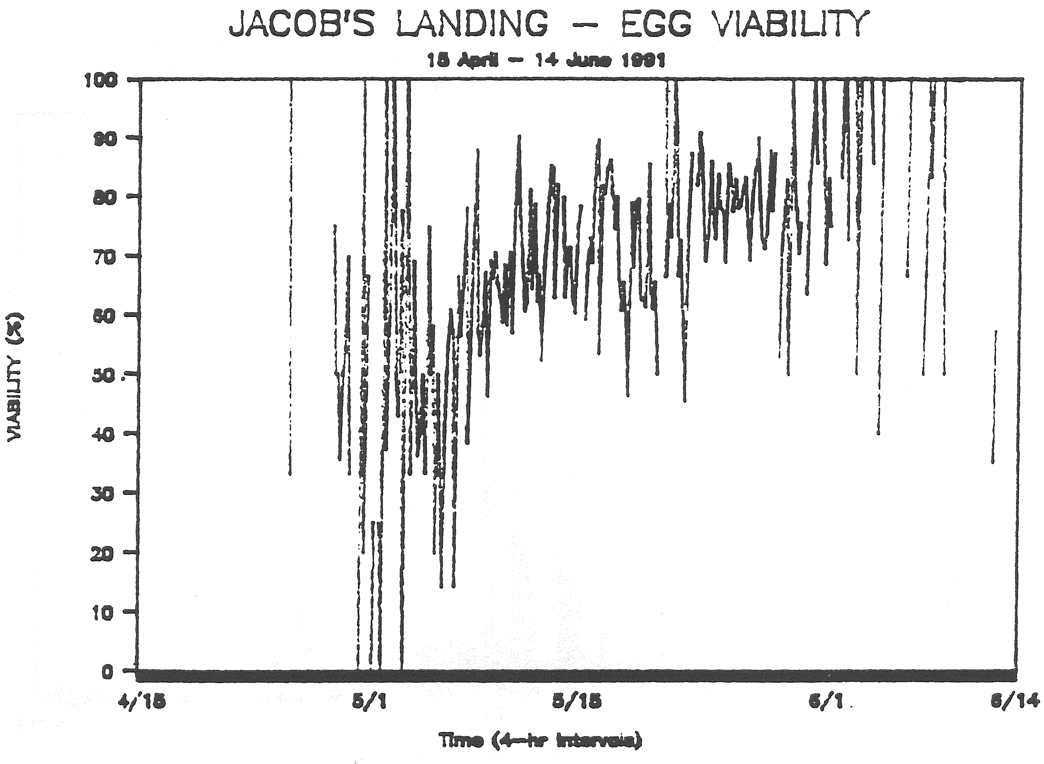


Figure 5. Daily viability estimates of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing and Jacob's Landing, NC, in 1991.

Egg Production Analyses

Statistical analyses were conducted on natural log-transformed data to ascertain how the two egg production estimates could be similar at the two locations when upstream eggs had an overall 42% mortality rate. Several assumptions were required in order to perform the analyses. It was necessary to assume that any relationships between egg production estimates for Barnhill's Landing and Jacob's Landing 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 3). 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 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 4). 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 was 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 4). 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

Table 3. 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 4. 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 3.

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		

inappropriate. Results of the 12-hour egg transport analysis were similar to those of the 8-hour egg transport model (Table 4). 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 5). 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 another variable (e.g., water temperature) not accounted for in the full model. These additional variables remain to be investigated.

Environmental Conditions and Egg Abundance

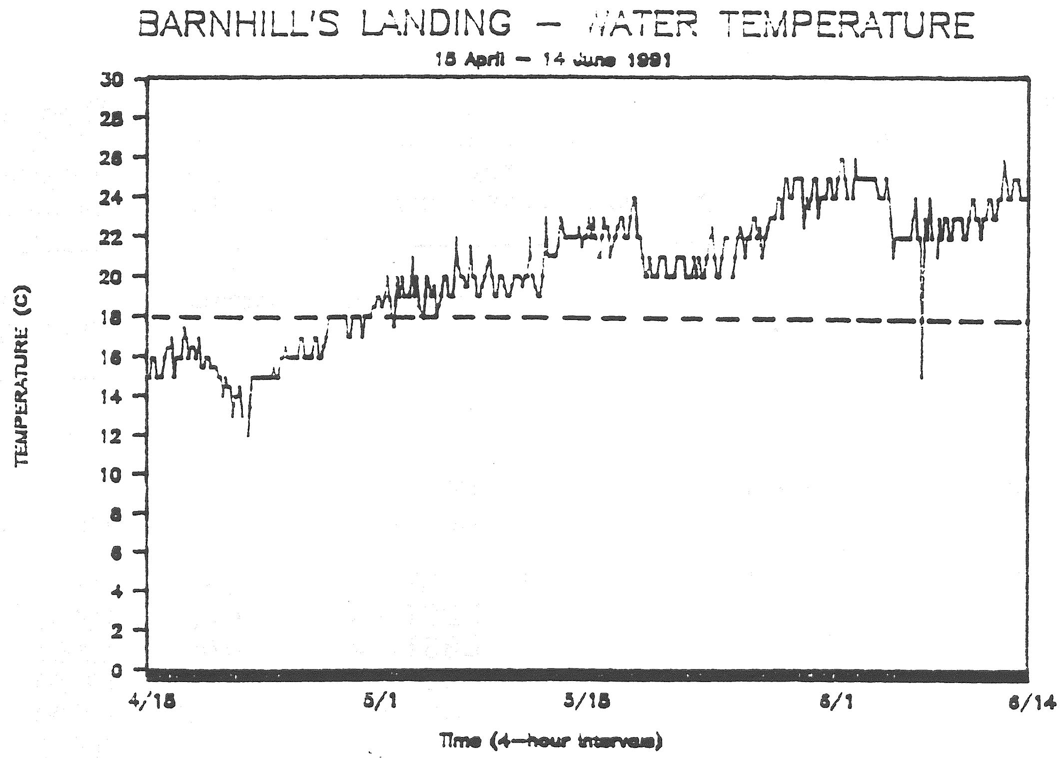
Water temperatures were quite warm throughout the spring spawning activity (Figure 6), caused by the record-breaking hot weather prevailing at the time (Figure 7). One striped bass egg was collected from a single sample at the Scotland Neck Bridge (NC Hwy. 258) while training the field crew prior to 15 April. At that time, the water temperature was 17° C. As in previous years, major spawning activity was observed (indicated by presence of eggs in the River, Figure 4) after water temperatures reached 18° C. At both sites, approximately 70% of the eggs were collected at water temperatures ranging from 20.0-23.9° C. No trend in viability as a function of water temperature was observed.

Surface water velocities were slightly faster at Barnhill's Landing compared to Jacob's Landing (Figure 8), caused by the smaller cross-sectional area of the river at RM 117, but at both locations most eggs were collected within a similar range of velocities . 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 60.0-79.9 cm/second (Table 2). An additional 3.8% of the eggs were collected at velocities of 40.0-59.9 cm/second, and less than one percent of the eggs were caught in water velocities of 100 cm/second or greater. At Jacob's Landing, 96% of the eggs were collected at velocities of 60.0-79.9 cm/second. An additional 3% were caught in velocities of 80.0-99.0 cm/second; less than one percent were collected at the lowest water velocities of 40.0-59.9 cm/second.

Seasonal changes in surface water velocity can be attributed to the water release schedule at Roanoke Rapids Dam and the subsequent change in river height downstream (Figure 9). Heavy spring rains in March 1991 (3.4 inches above normal) resulted in high inflow to Kerr Reservoir,

Table 5. 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 3.

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		



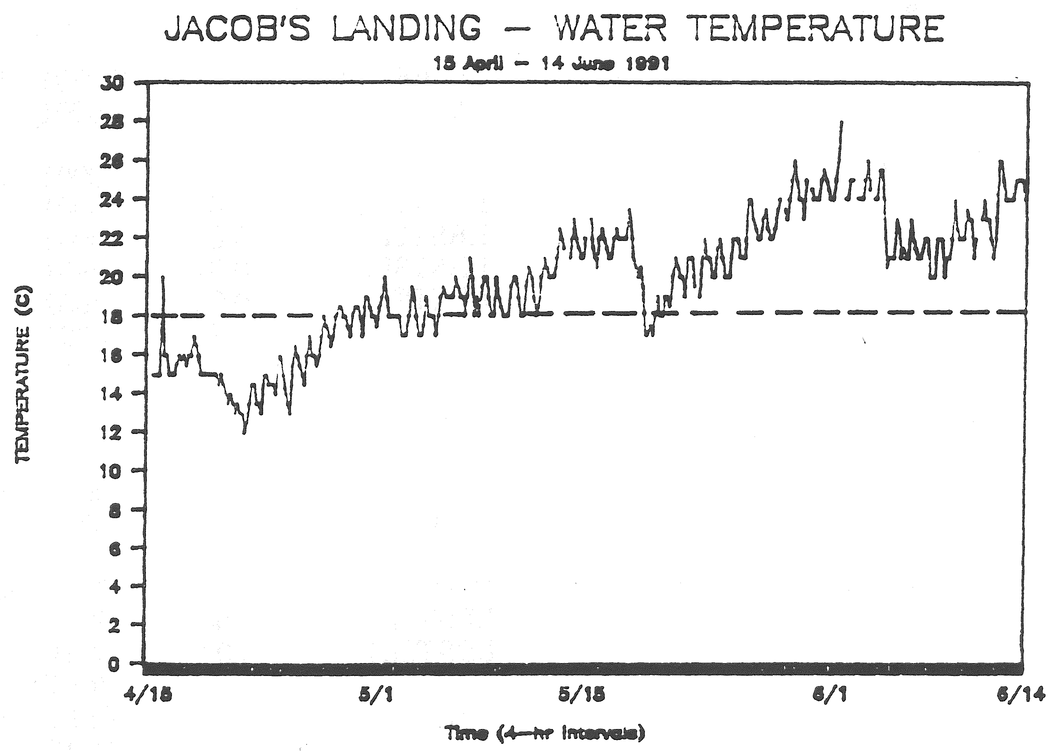
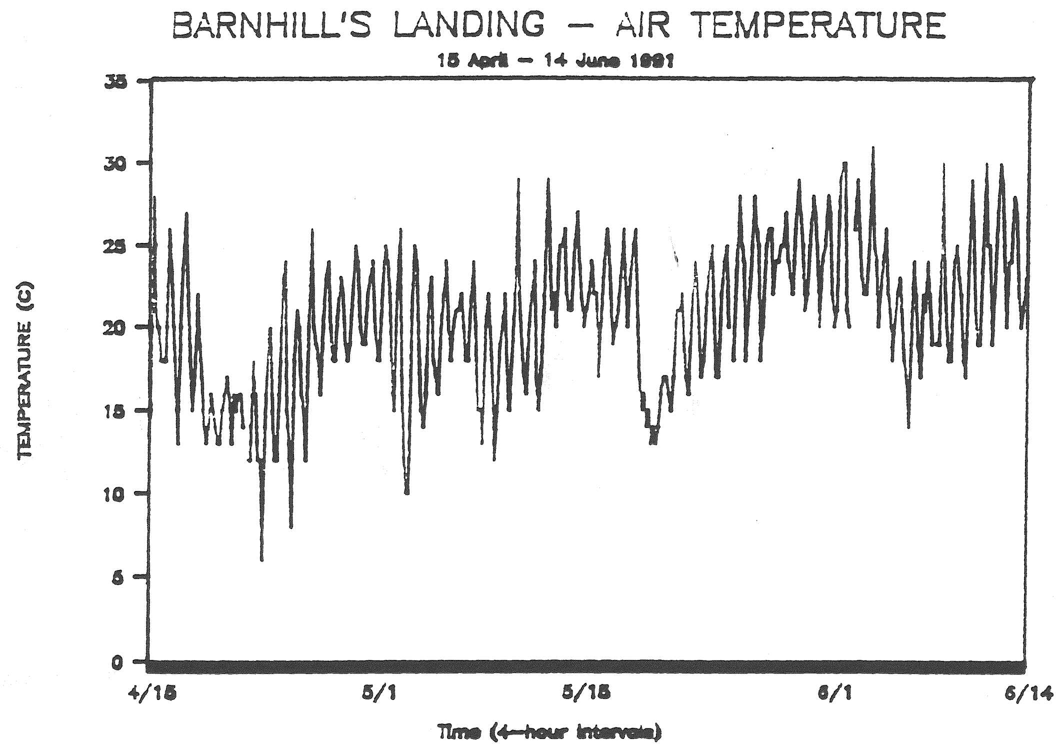


Figure 6. Water temperatures (°C) of the Roanoke River measured at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.



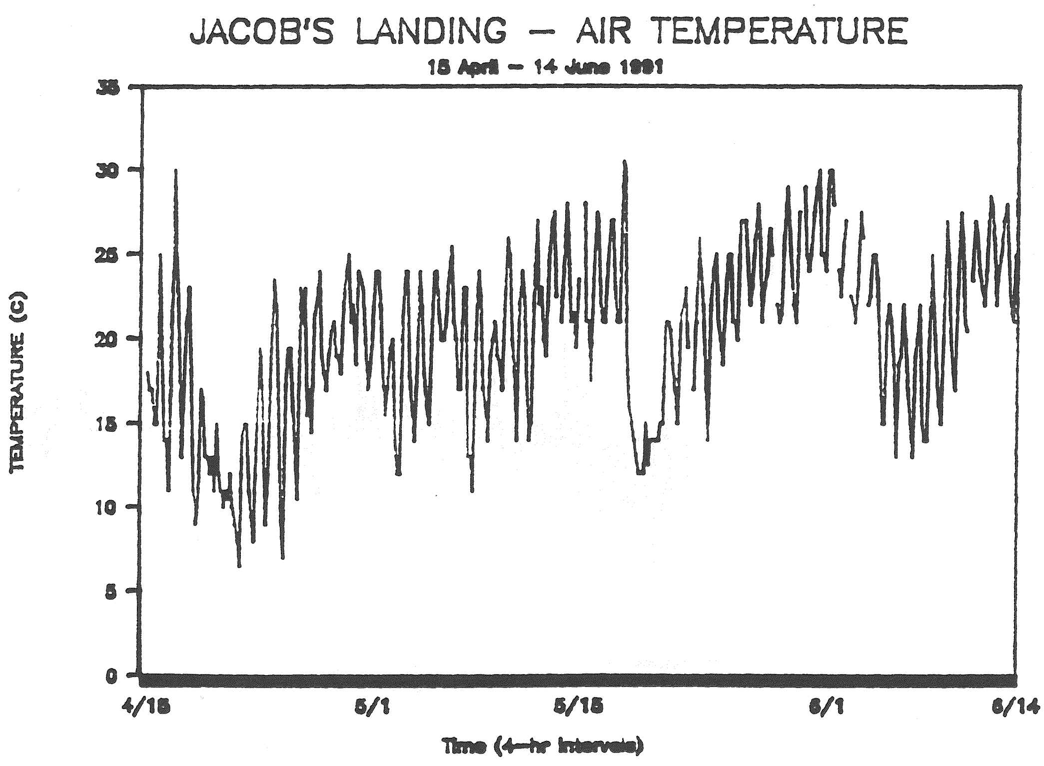
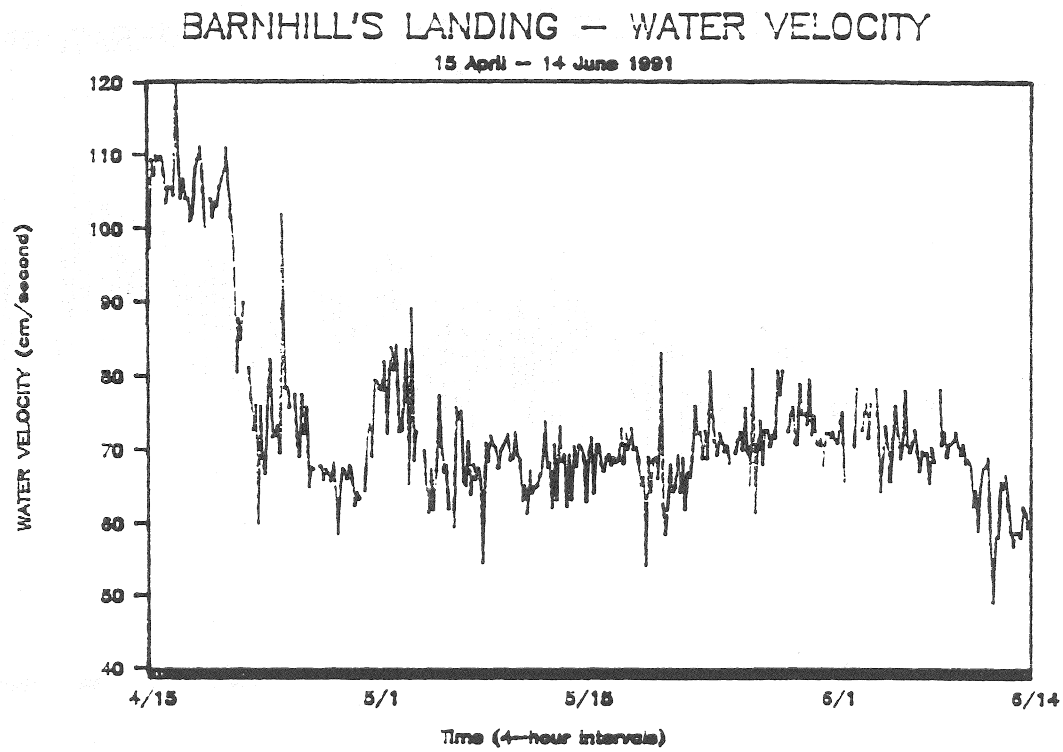


Figure 7. Air temperature (°C) measured at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.



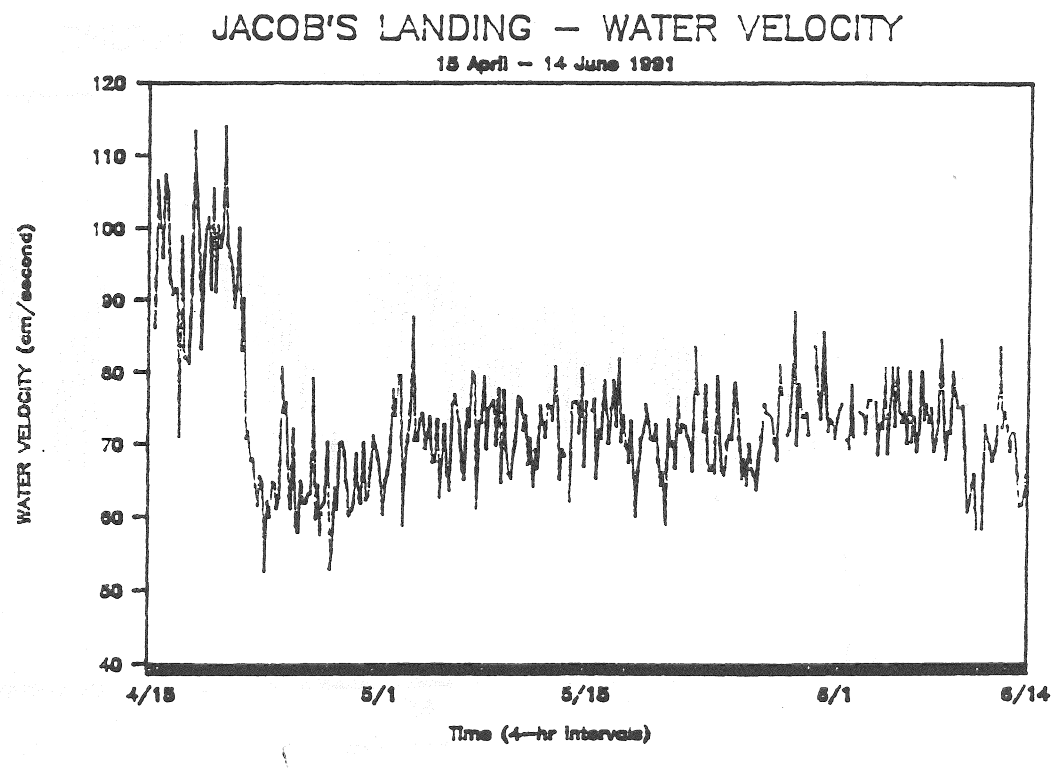
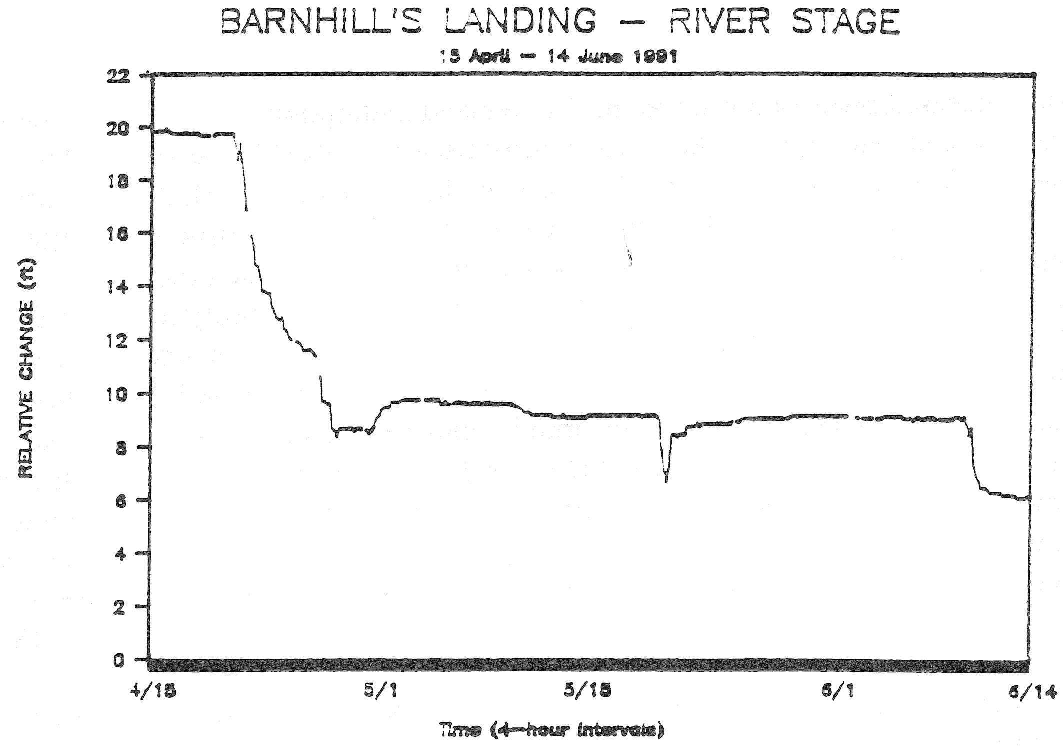


Figure 8. Surface water velocity (cm/second) of the Roanoke River measured at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.



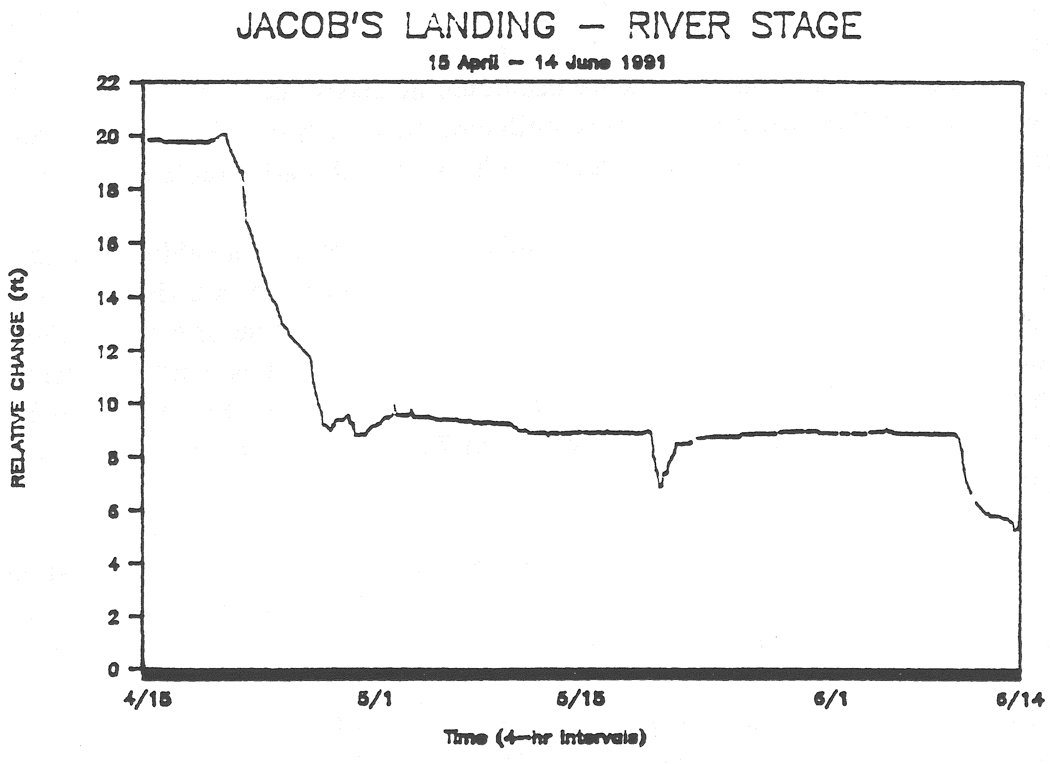


Figure 9. Relative change in river stage (ft) of the Roanoke River at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.

and increased releases downstream. On-demand hydropower generation at the Roanoke Rapids facility was evident from the Corps hourly flow records (Figure 10). Reduced inflow to Kerr Reservoir in early April was finally observed beginning 20 April, 20 days after the Negotiated Flow Regime recommended by the Roanoke River Water Flow Committee (Manooch and Rulifson 1989) 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 historical River flow prior to impoundment (Kerr Reservoir construction was started 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 on 21 April (Figure 11). The moderated instream flow resulted in downstream water temperatures reaching 18° C early in the season and remaining at or above this temperature at Barnhill's Landing during May and June (Figure 6). A three-day precipitation event in May combined with a brief and sudden reduction in water release from the reservoir (Figure 12) caused water temperatures at Jacob's Landing to dip briefly below 18°C (Figure 6).

Levels of dissolved oxygen in the lower Roanoke River remained above 7.0 mg/L for most of April and May, but fell to between 6.0 and 7.0 mg/L at both locations in June (Figure 13). At Barnhill's Landing, 95% of the eggs were collected in waters containing 7.0-8.9 mg/L of dissolved oxygen. Less than one percent of striped bass eggs were collected in waters with dissolved oxygen levels less than 7.0 or greater than 8.9 mg/L (Table 2). At Jacob's Landing, approximately 69% of all eggs were collected at dissolved oxygen levels of 7.0-8.9 mg/L; however about 23% of the eggs were collected in waters of 9.0-9.9 mg/L, and less than one percent were caught at dissolved oxygen levels of 4.0-4.9 mg/L (Table 2).

Waters flowing downstream past Jacob's Landing were noticeably more acidic and variable in pH than when flowing past Barnhill's Landing farther upstream (Figure 14). The three-day precipitation event in late May, combined with reduced volume of water in the River, caused a reduction in pH at Jacob's Landing. Upstream, 85% of the eggs were collected at pH values of 7.75 or greater: nearly 33% were collected at pH values 8.0 and higher (Table 2). Downstream, 90% of the eggs were collected at pH values of 7.5-7.99; only 4% were collected at a pH of 8.0 or greater.

Secchi disk visibility was less variable upstream compared to the downstream site (Figure 15). The large decrease in River height following a reduction in water release from Roanoke Rapids Reservoir was reflected in a brief decrease in secchi disk visibility at Jacob's Landing.

Conductivity of Roanoke River waters flowing past Barnhill's Landing was low throughout the study, usually varying between 7 and 10 mmhos (Figure 16). The conductivity of waters passing Jacob's Landing was more variable in early April and again in late May and early June. Possible causes of the conductivity decrease are unclear.

Egg distribution patterns compared to sampling time reflected the time of travel downstream from the spawning grounds. For the entire spawning season, egg collection was greatest

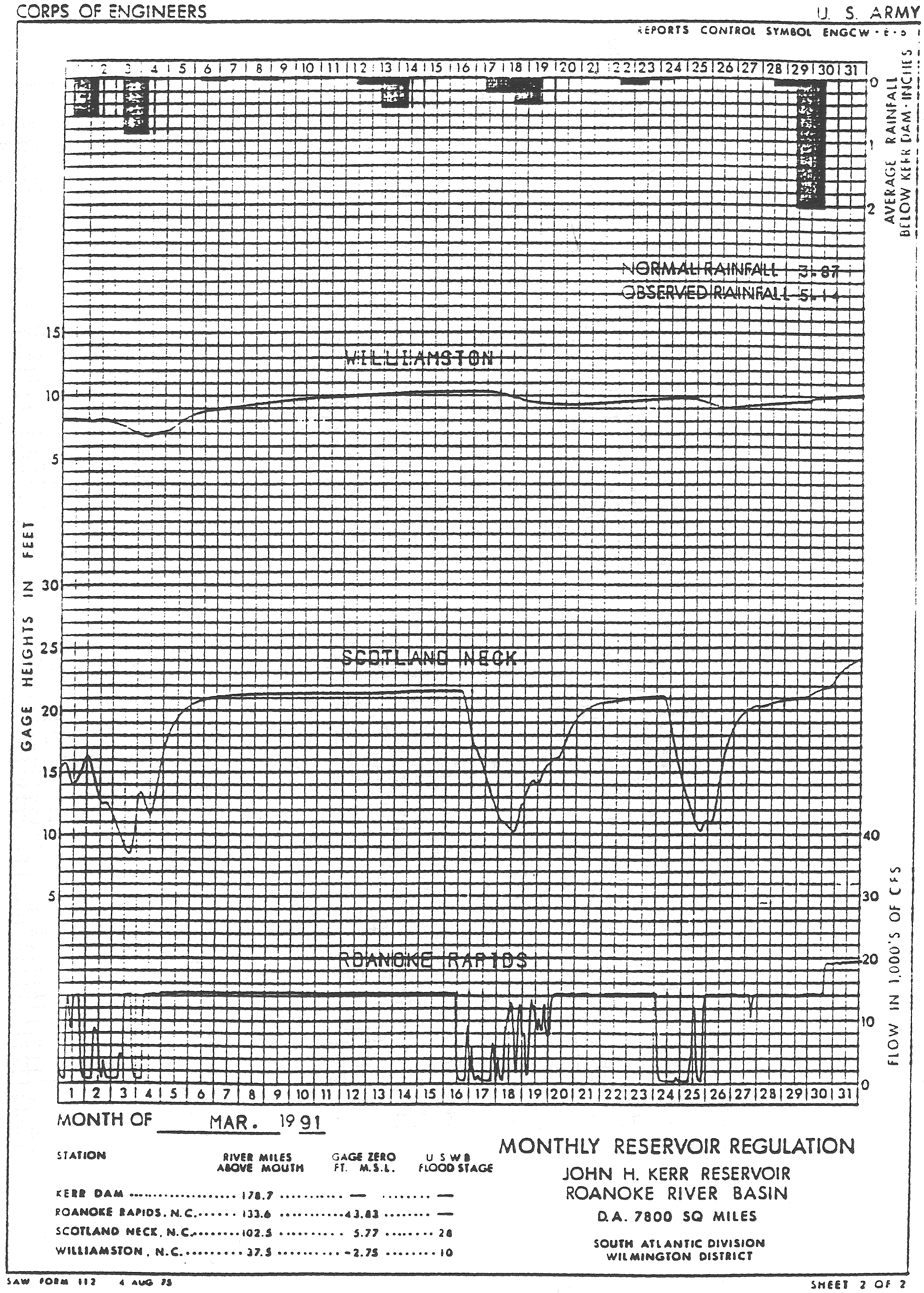


Figure 10. Instream flow (cfs) of the Roanoke River at the Roanoke Rapids Dam, and river stage (ft) at Scotland Neck and Williamston, NC, for March 1991; precipitation (in) to the watershed below the dam is depicted at the top (U.S. Army Corps of Engineers).

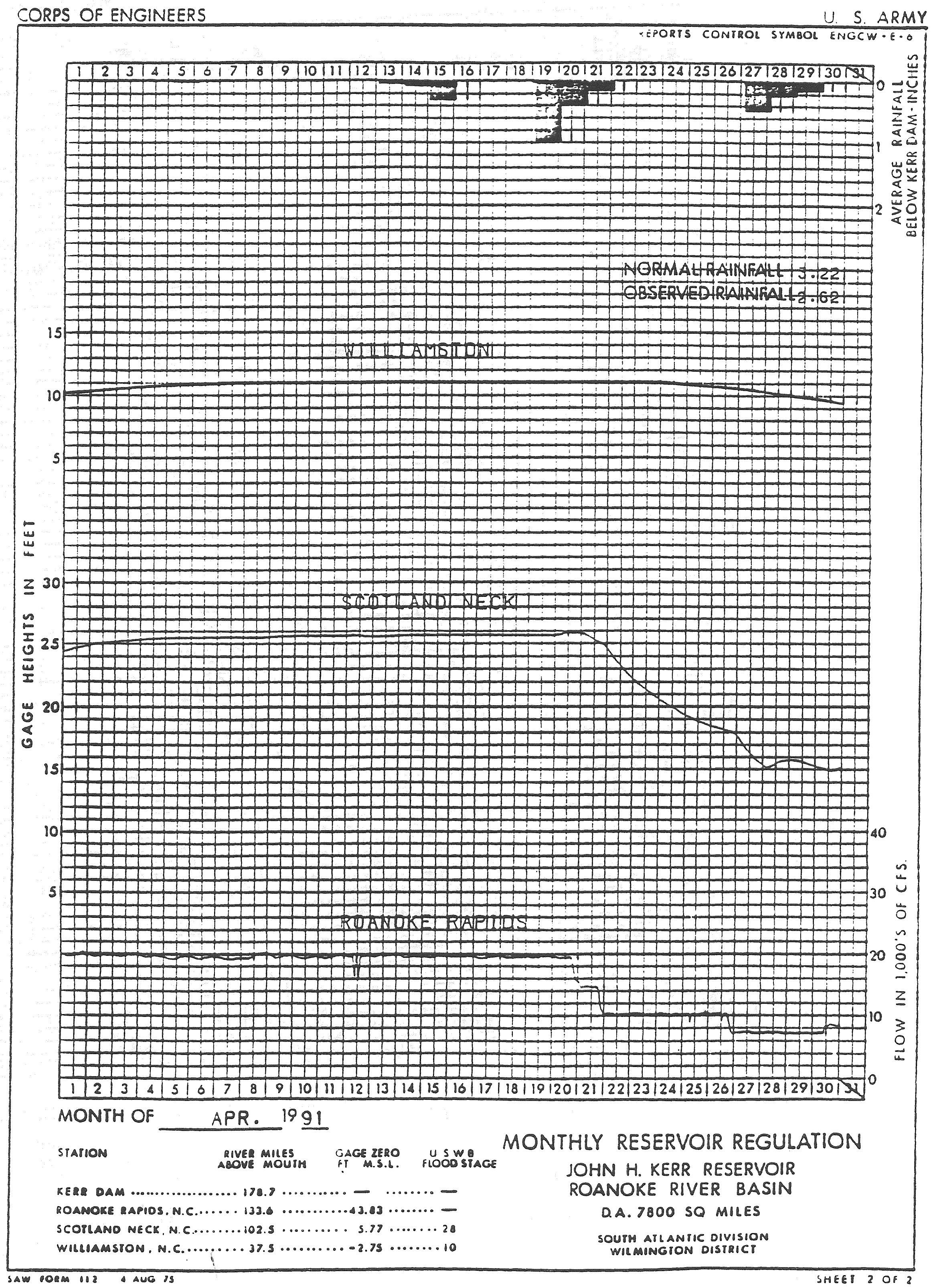


Figure 11. Instream flow (cfs) of the Roanoke River at the Roanoke Rapids Dam, and river stage (ft) at Scotland Neck and Williamston, NC, for April 1991; precipitation (in) to the watershed below the dam is depicted at the top (U.S. Army Corps of Engineers).

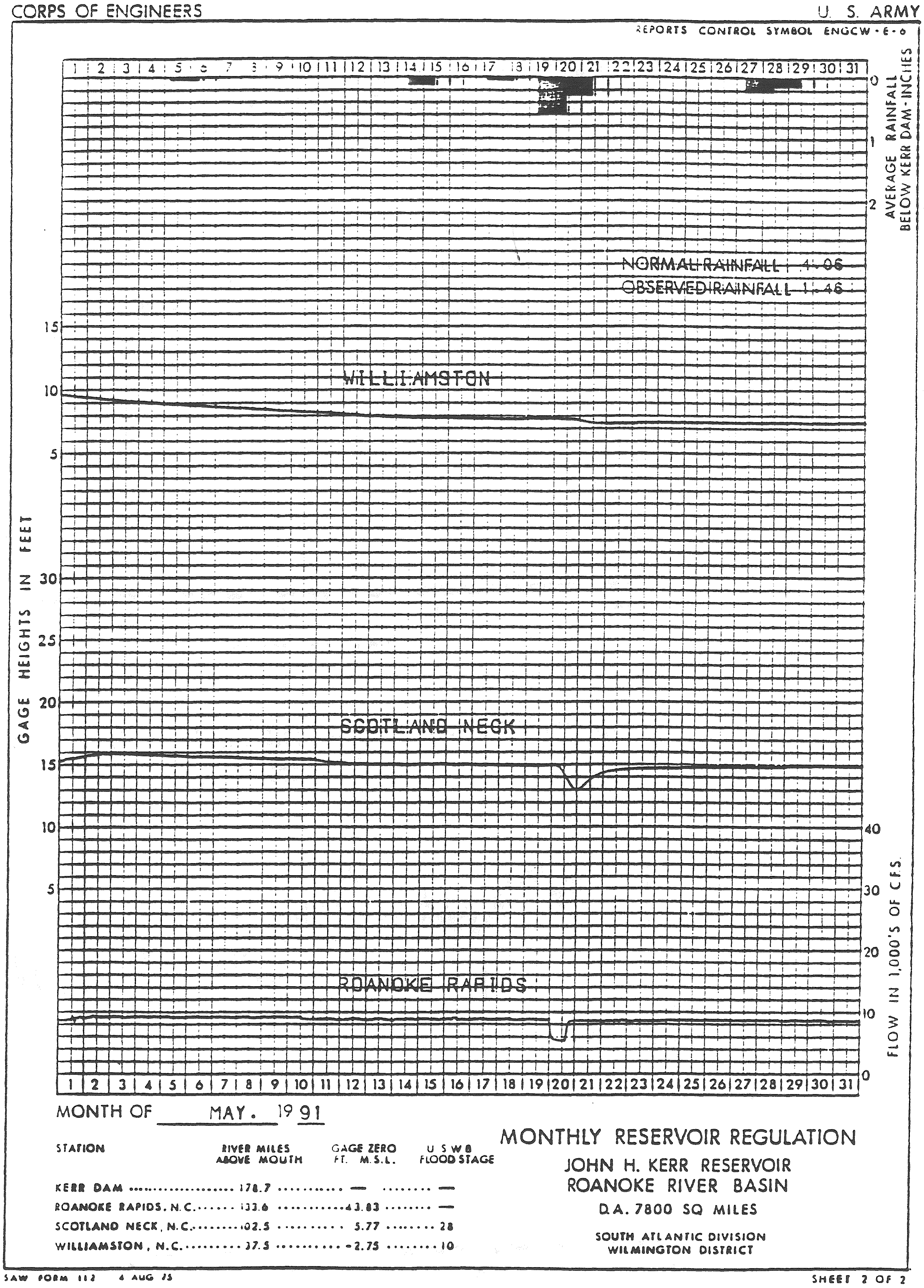


Figure 12. Instream flow (cfs) of the Roanoke River at the Roanoke Rapids Dam, and river stage (ft) at Scotland Neck and Williamston, NC, for May 1991; precipitation (in) to the watershed below the dam is depicted at the top (U.S. Army Corps of Engineers).

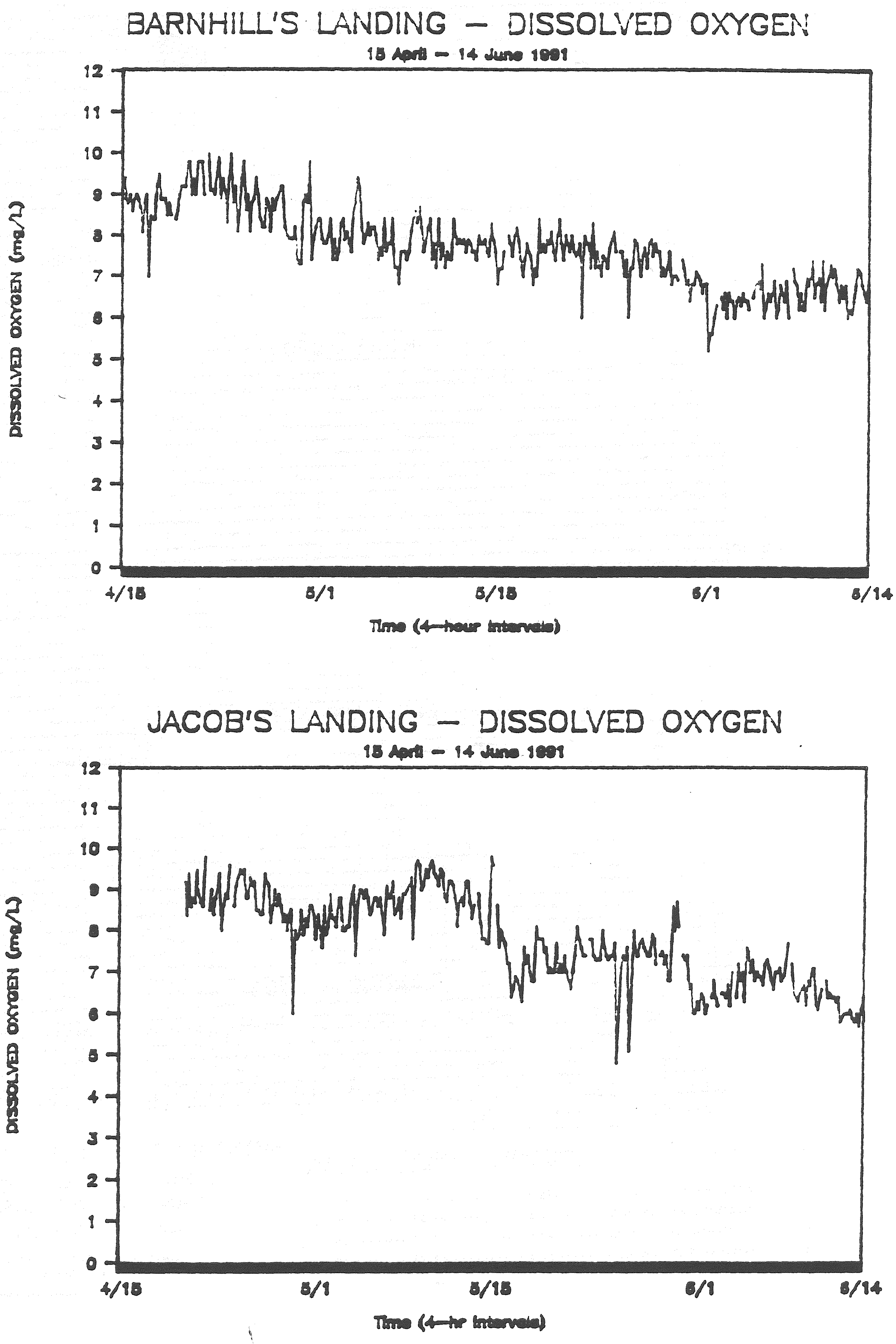
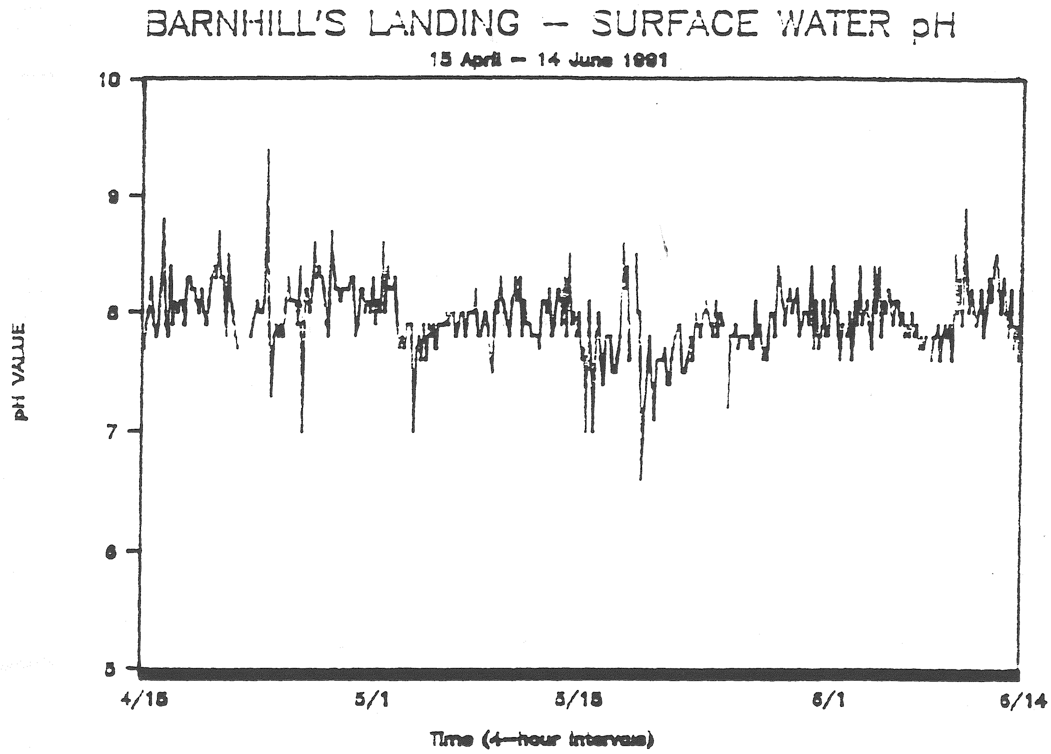


Figure 13. Changes in dissolved oxygen (mg/L) of Roanoke River waters at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.



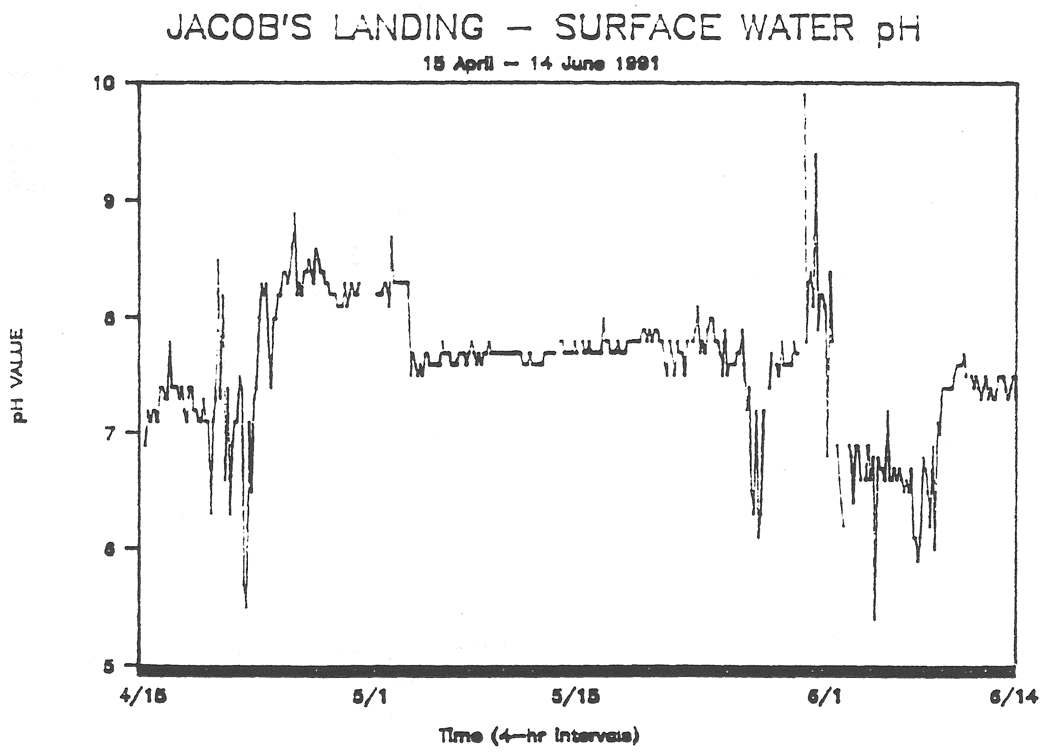
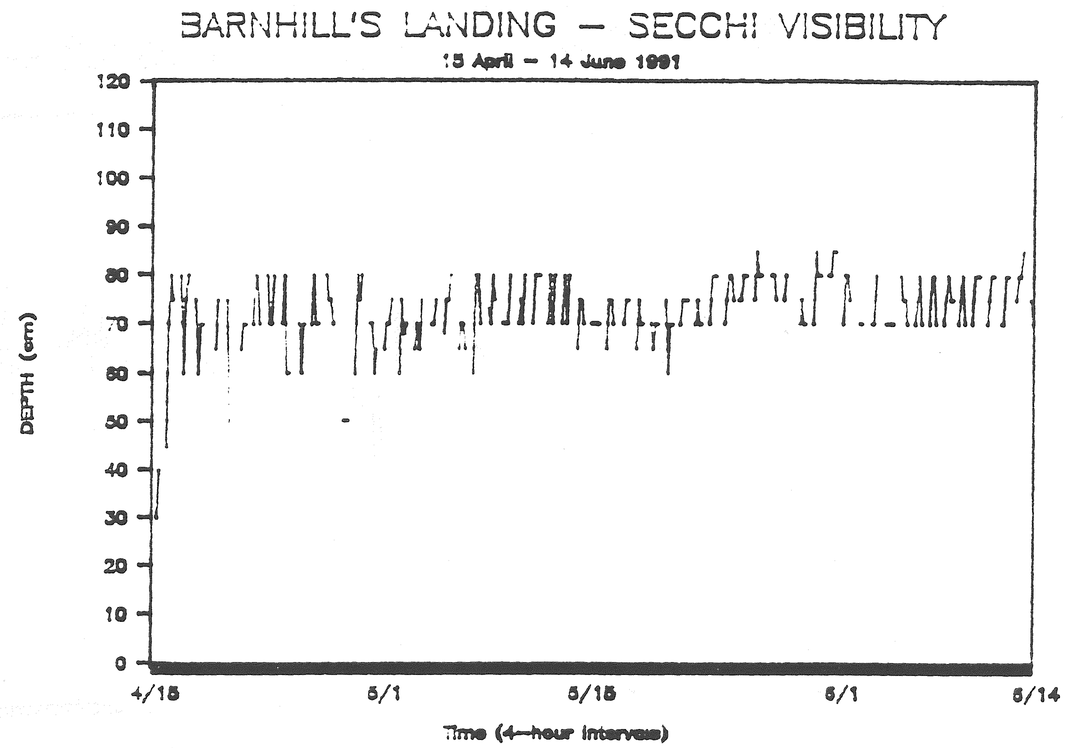


Figure 14. Changes in pH of Roanoke River waters at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.



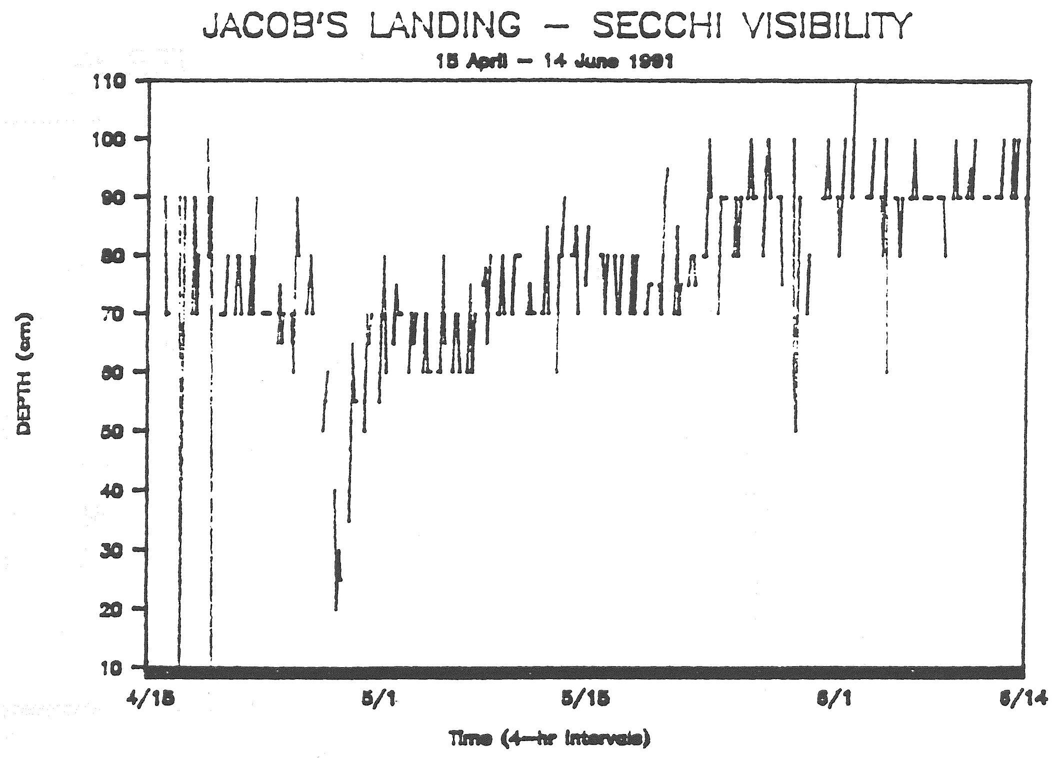
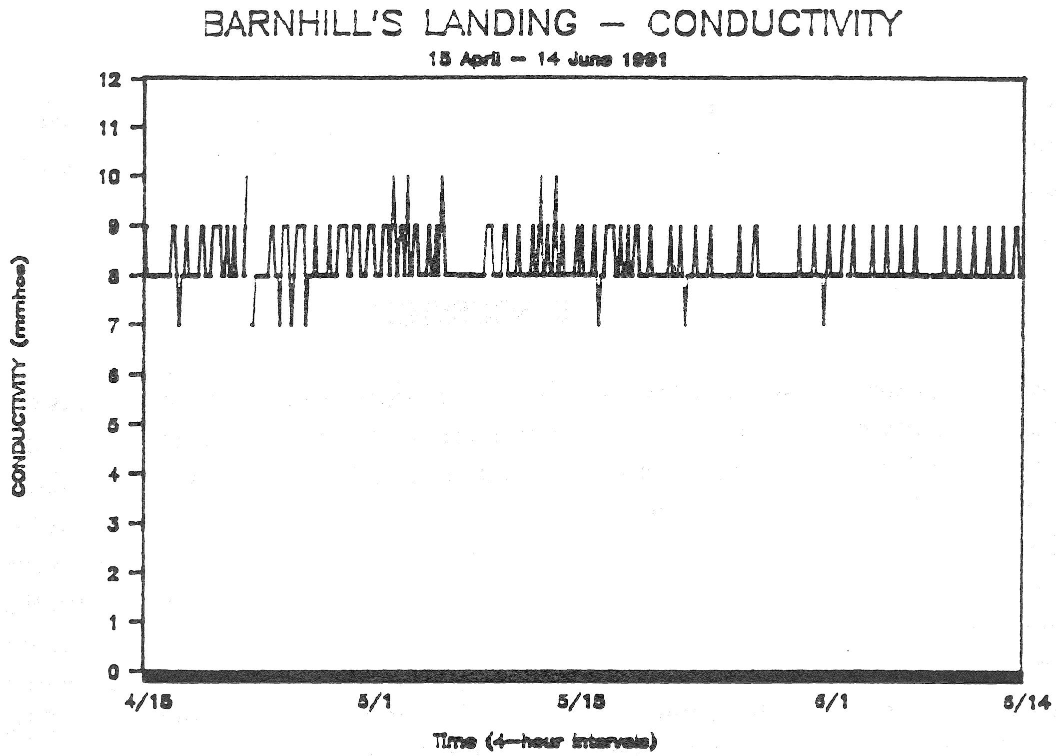


Figure 15. Depth (cm) of secchi disk visibility in the Roanoke River at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.



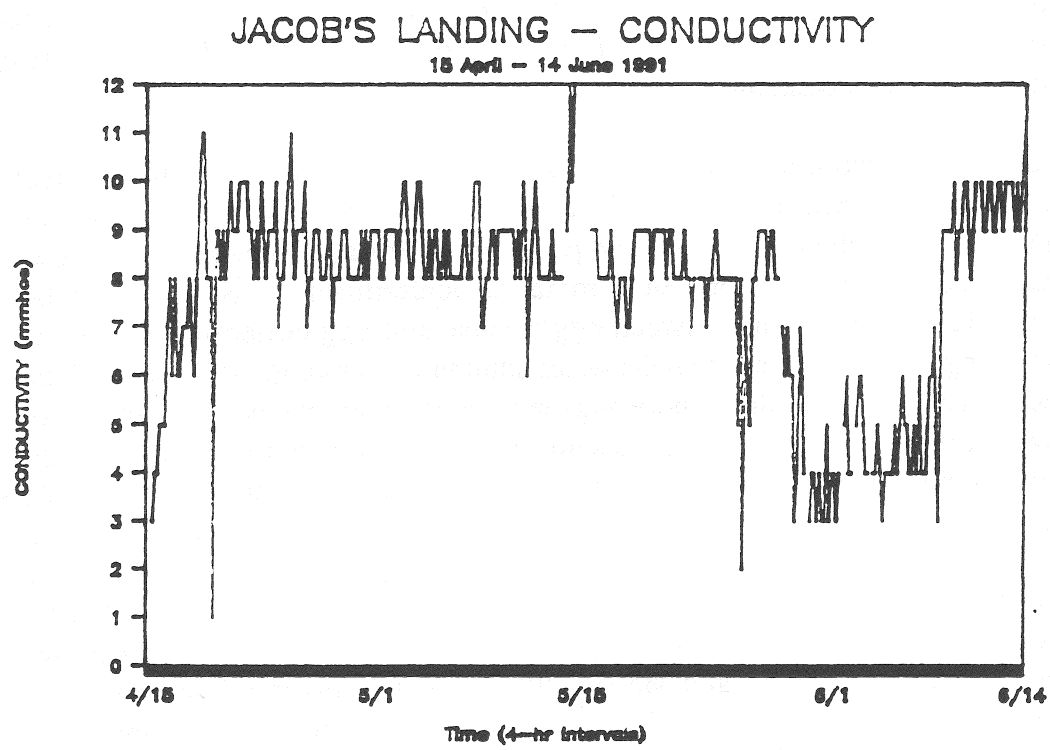


Figure 16. Conductivity (mmhos) of the Roanoke River at Barnhill's Landing and Jacob's Landing, NC, for the period 15 April to 14 June 1991.

upstream from 0200 to 1000 hours, and downstream at 1000 and 1400 hours. Assuming an average water velocity of 70 cm/second, the travel time for eggs between the two sites should have been between eight and nine hours.

DISCUSSION

Results of the statistical analyses indicate that downstream instantaneous egg production estimates closely match egg production estimates farther upstream, but the viability estimates may be 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 1). 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 51.08 (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 only 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 an indirect test 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 1982), 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.

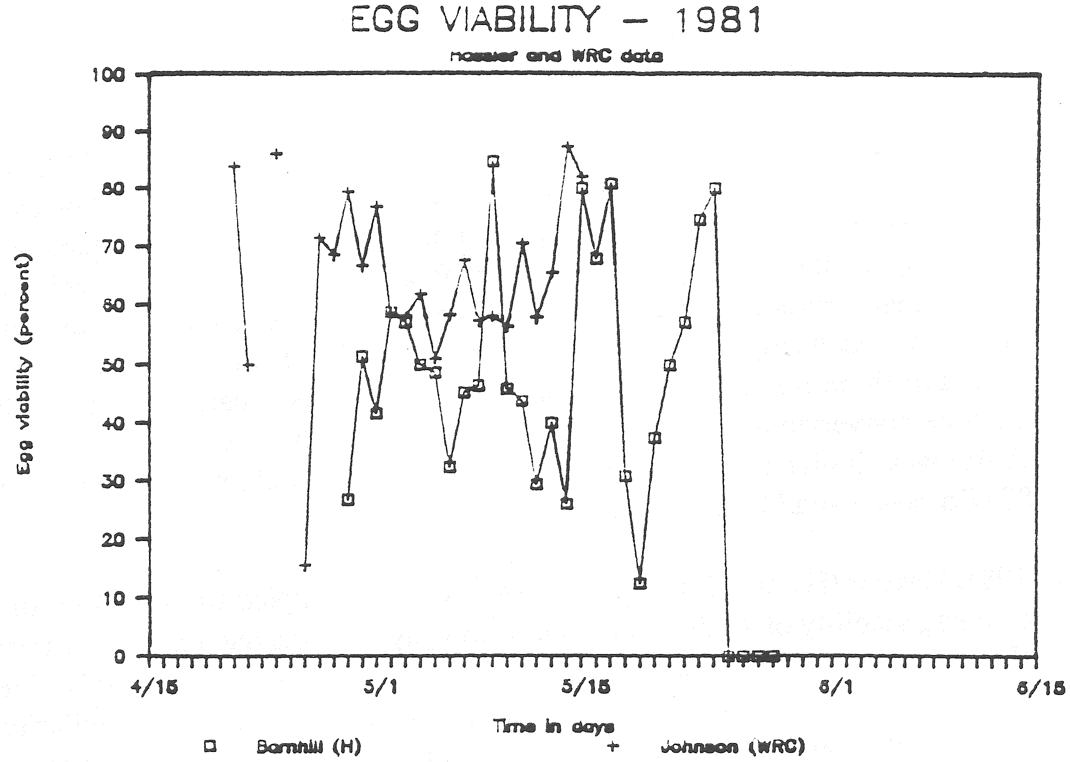
The methods and equipment used in the NCWRC studies were different than that used by Hassler; an understanding of data collection is necessary prior to comparing the two data sets.

Hassler's methodology and gear were explained previously. Kornegay (1982) 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 68.97%. These two egg viability estimates were within five percent and so appeared similar. The similarity was not so striking when daily viability estimates were plotted (Figure 17). With one exception, daily egg viability estimates for Johnson's Landing 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 (Figure 17). Coincidentally, these spawning activity peaks 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 (Figure 18). Minor spawning peaks in mid and late May 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.

However, visual inspection of the 1982 daily viability estimates indicated a high degree of similarity between the two stations (Figure 19). 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 reveal similar patterns in spawning activity: peak spawning occurred approximately 9-11 May (Figure 19) just after river flow dropped from 11,600 cfs to about 6,300 cfs on 7-8 May (Figure 20). Kornegay (1983) attributed the spawning peak to increases in water temperature to 18.4°C.



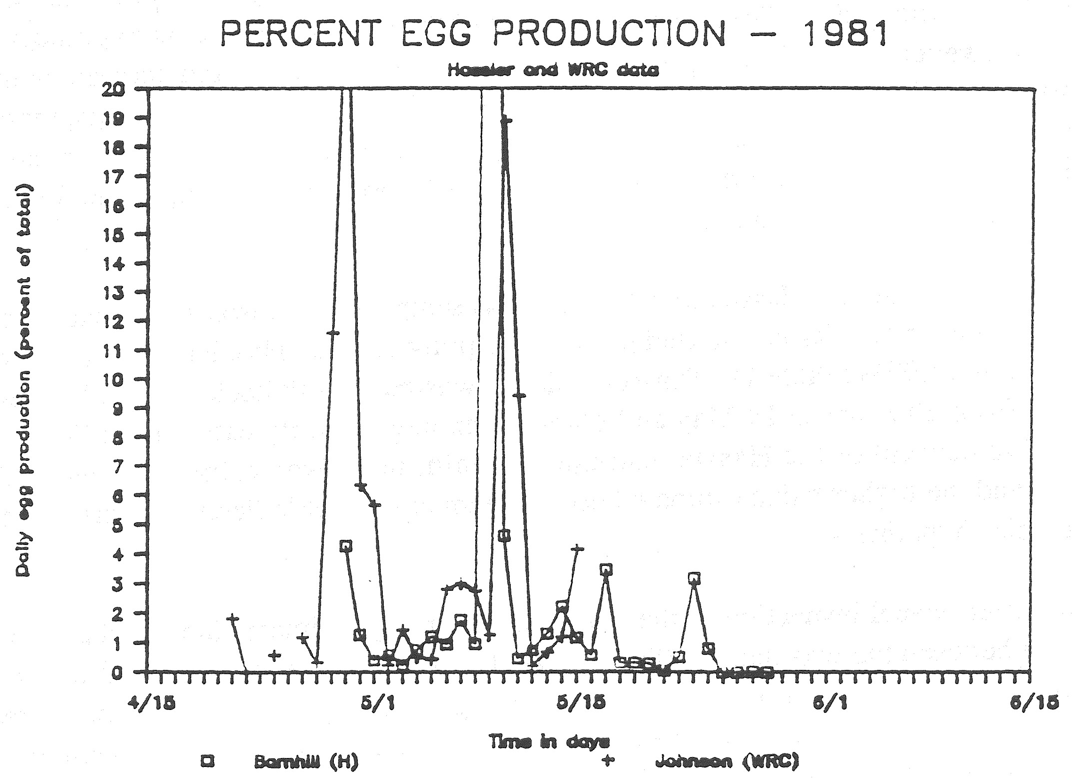


Figure 17. Daily estimates of striped bass egg production and viability in the Roanoke River by Hassler (Barnhill's Landing) and the Wildlife Resources Commmission (Johnson's Landing) for the 1981 spawning season (from Rulifson 1990).

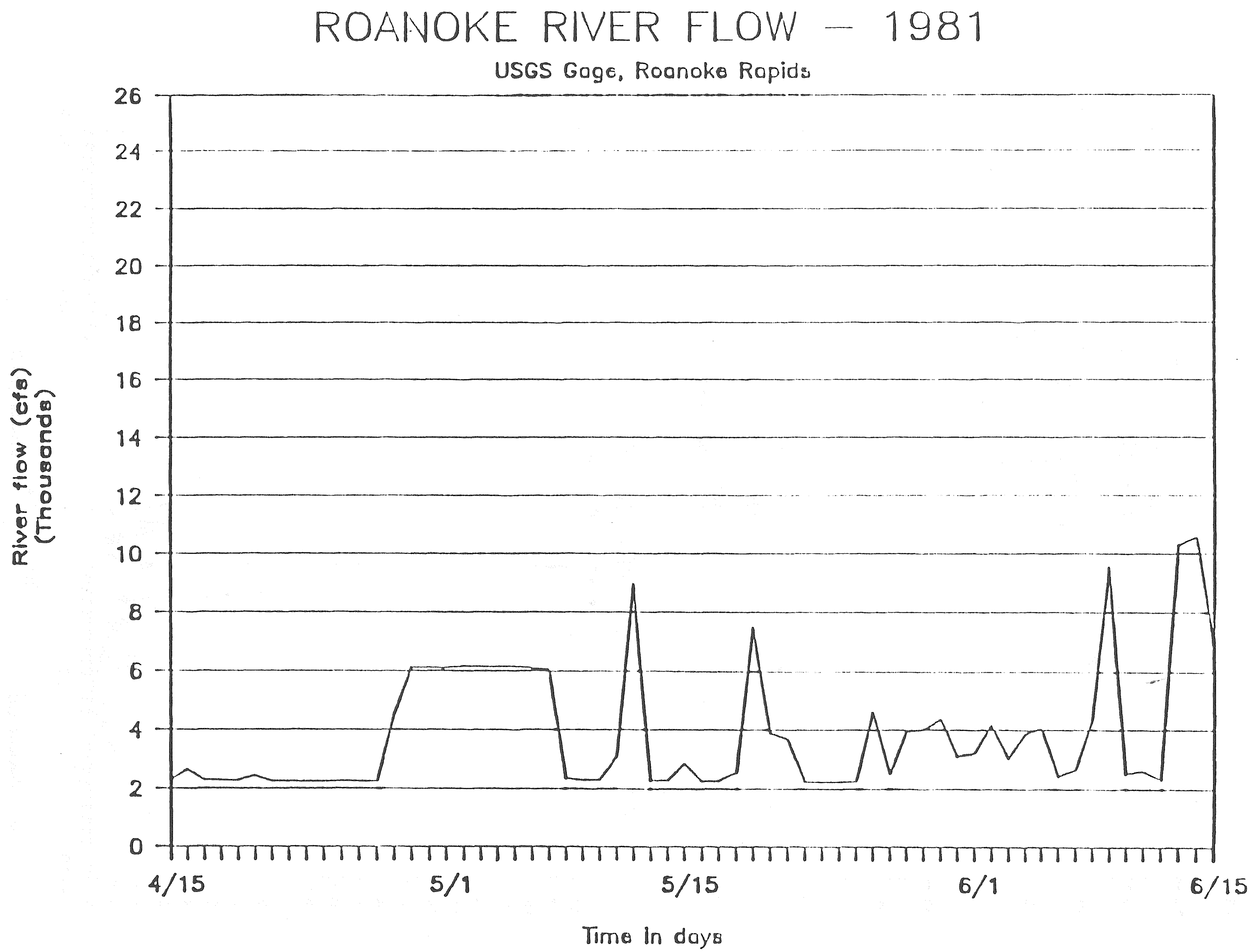
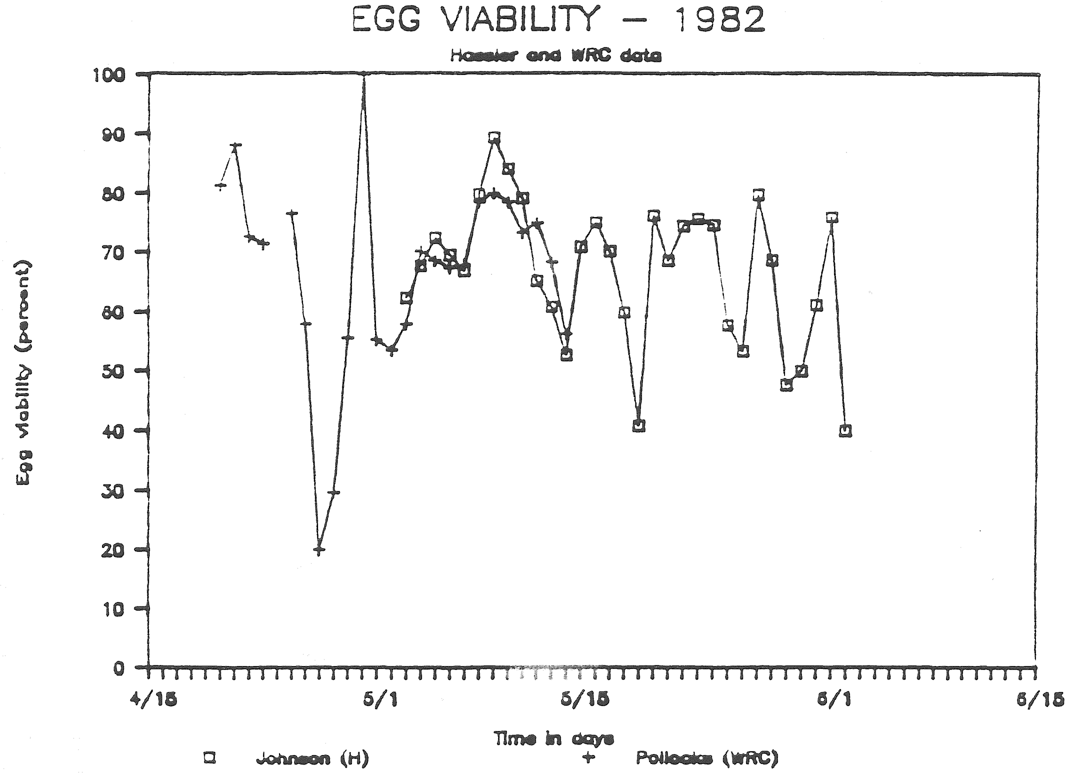


Figure 18. Average daily flow (cfs) of the Roanoke River for the period 15 April to 15 June 1981 (USGS data, from Rulifson 1990).



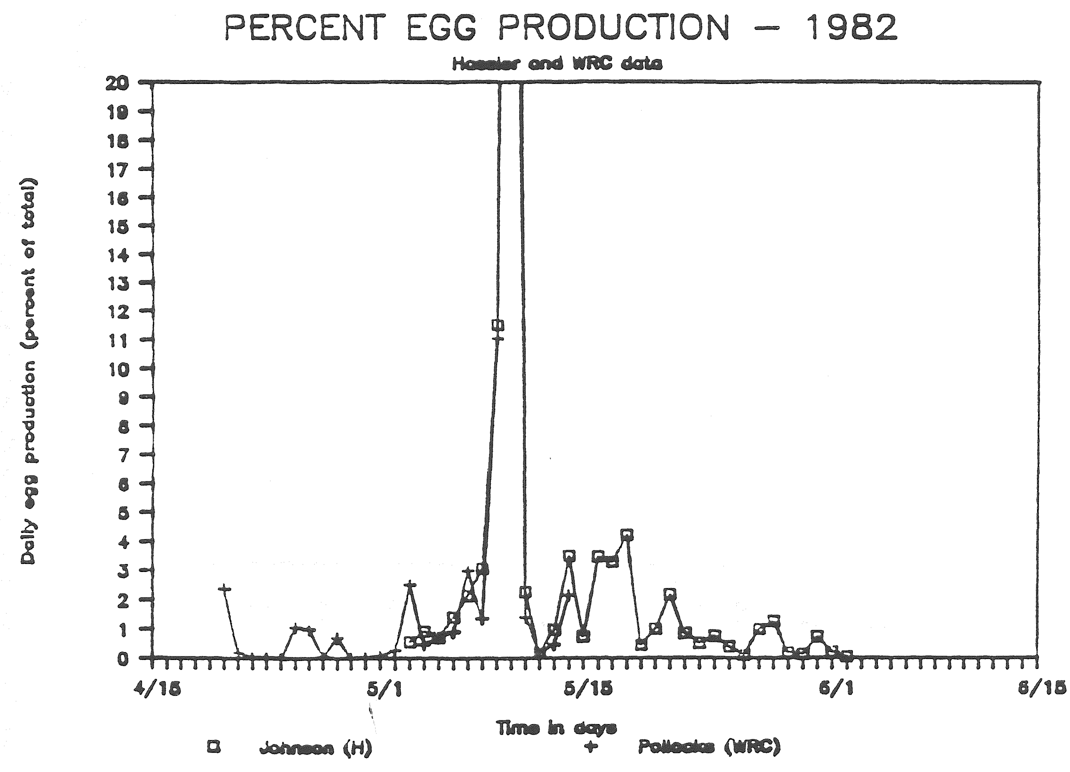


Figure 19. Daily estimates of striped bass egg production and viability in the Roanoke River by Hassler (Johnson's Landing) and the Wildlife Resources Commmission (Pollock's Ferry) for the 1982 spawning season (from Rulifson 1990).

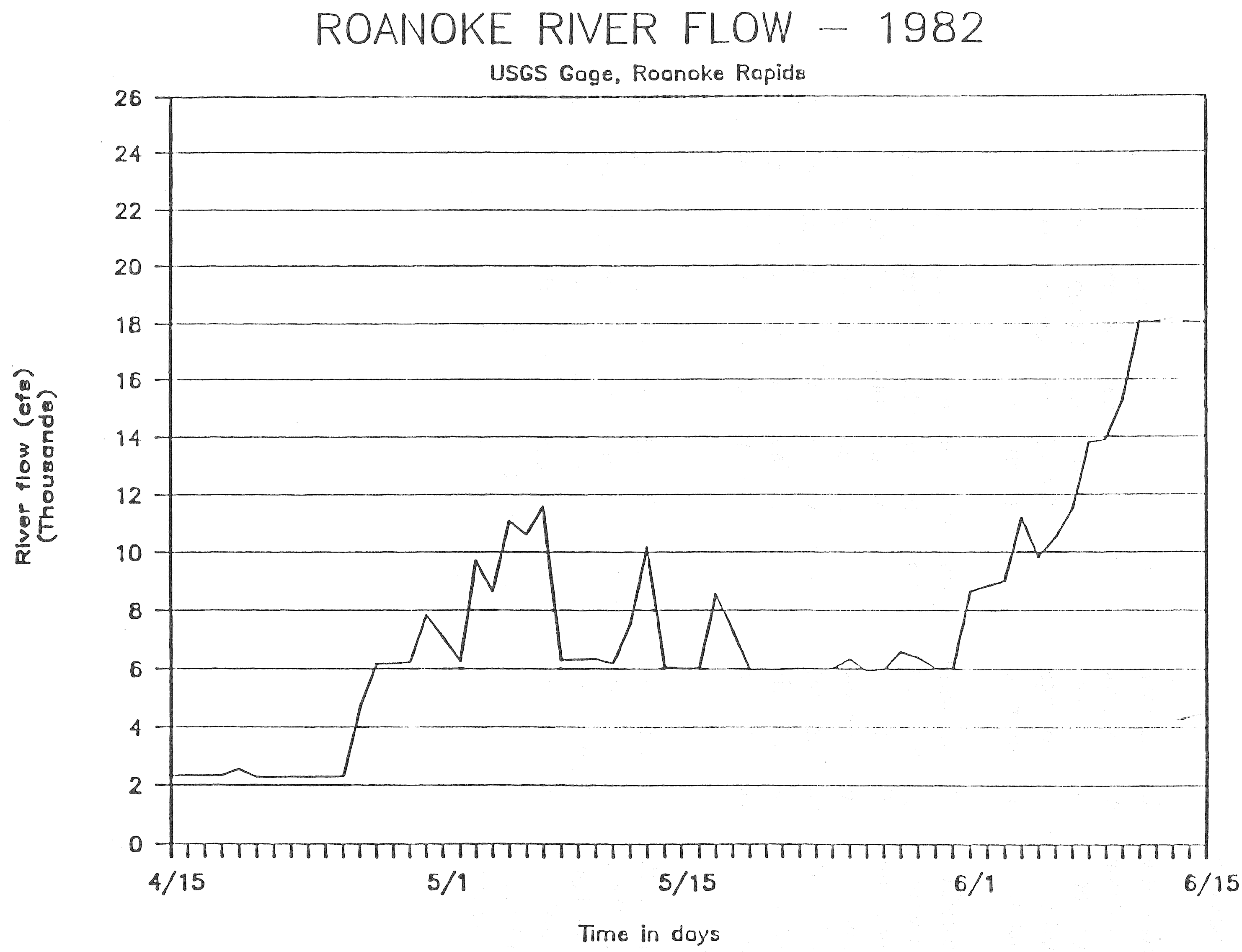


Figure 20. Average daily flow (cfs) of the Roanoke River for the period 15 April to 15 June 1982 (USGS data, from Rulifson 1990).

In 1983, Hassler (Hassler and Taylor 1984) sampled at Johnson's Landing from 6 May to 12 June and estimated egg viability as 33.29% (Table 1). 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 are obscured because of extensive flooding in the spring of 1983 (Figure 21), although higher daily egg viability later in the season seemed to coincide with lower river flow (Figure 22). Flow models by the U.S. Army Corps of Engineers indicate that the lower watershed floods 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 (Figure 22).

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. Completion of the USGS modeling of Roanoke River instream flow should provide additional information about how egg and larval production are related, and how environmental factors may influence juvenile striped bass recruitment.

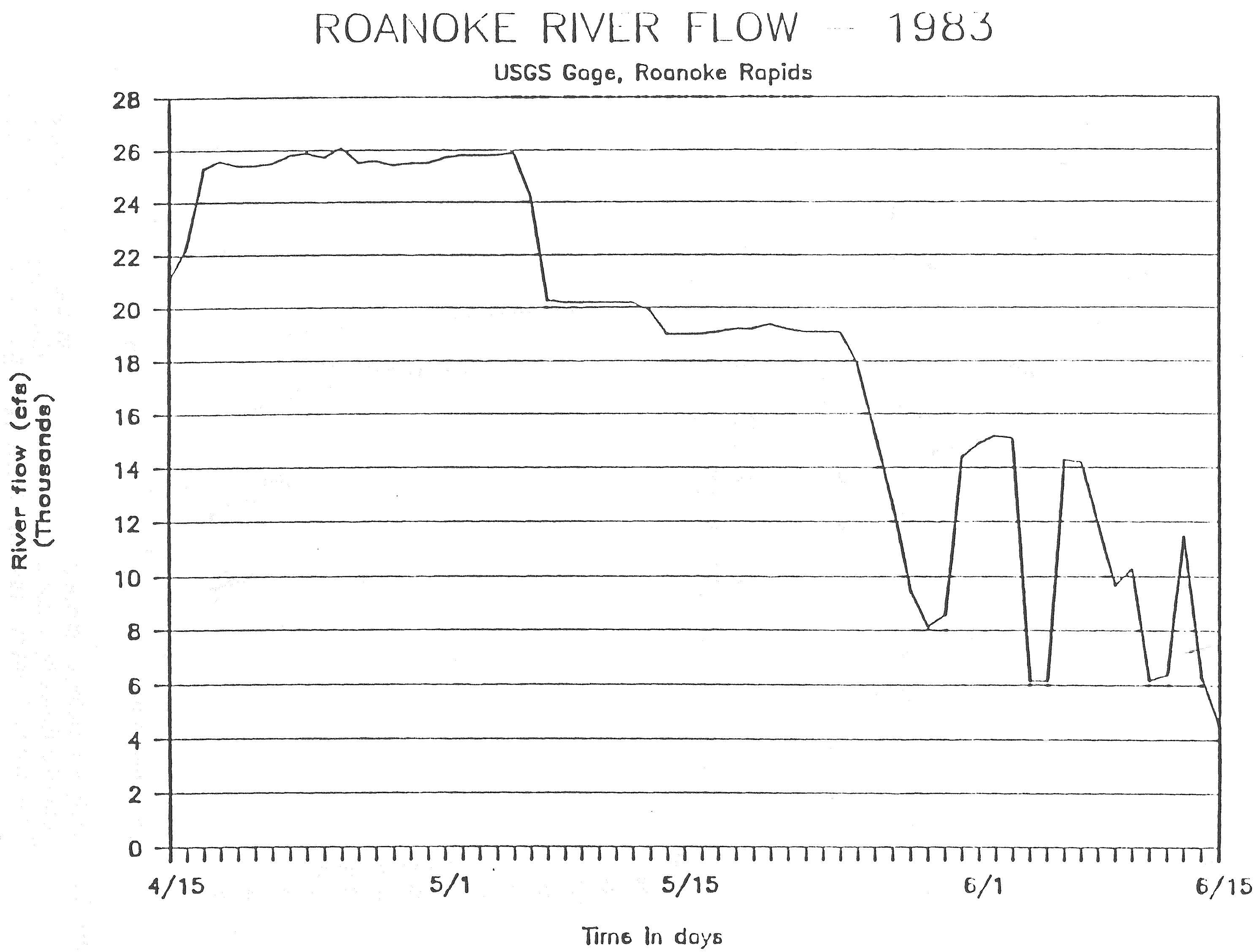
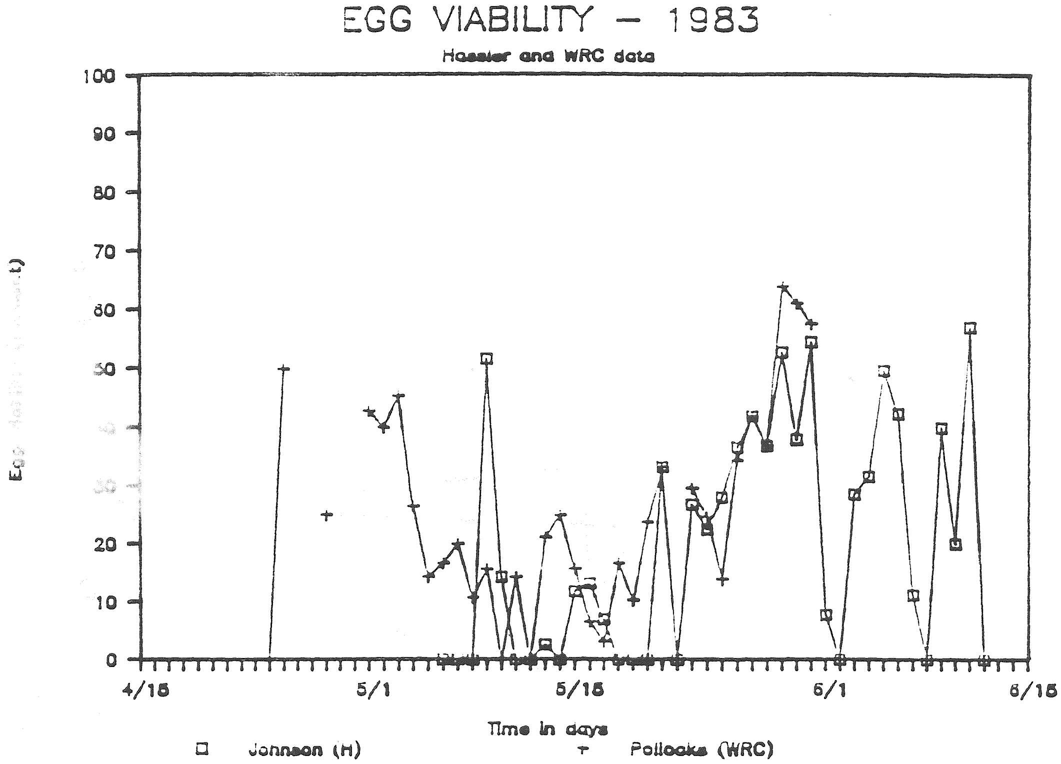


Figure 21. Average daily flow (cfs) of the Roanoke River for the period 15 April to 15 June 1983 (USGS data, from Rulifson 1990).



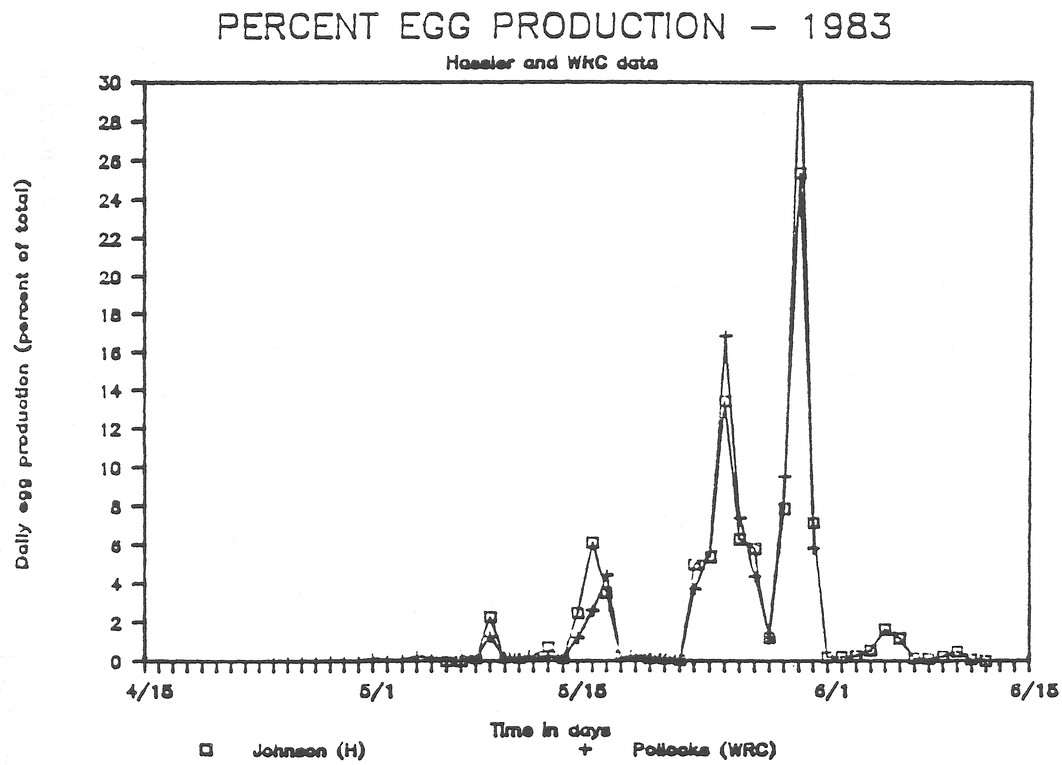


Figure 22. Daily estimates of striped bass egg production and viability in the Roanoke River by Hassler (Johnson's Landing) and the Wildlife Resources Commmission (Pollock's Ferry) for the 1983 spawning season (from Rulifson 1990).

CONCLUSIONS

Based on the results of this study, and on comparing results of similar concurrent studies by Hassler and NCWRC, the following conclusions can be made:

1. Striped bass spawning activity in the lower Roanoke River can be determined effectively by monitoring egg abundance downstream of the spawning grounds.

2. Decreasing water temperatures can slow or stop striped bass spawning activity in the Roanoke River, especially if the temperature drops below 18°C.

3. Reservoir releases from upstream can alter water quality, especially river temperature, which in turn affects spawning.

4. Reservoir releases from upstream change the instream flow velocity, which in turn alters the travel time of striped bass eggs downstream.

5. Roanoke striped bass continue to spawn into mid-June even though water temperatures rise above optimal conditions. Low-level spawning activity may occur earlier than mid-April.

6. In 1991, instantaneous egg production downstream was mostly a function of upstream spawning, with only minor spawning activity between the two sites.

7. Annual egg production estimates made from sampling locations just downstream of the major spawning grounds will reflect higher numbers of Stage 1 eggs than samples farther downstream; consequently, egg viability estimates reflect the high mortality rate in the initial stages of development.

8. Egg sampling sites too close to (e.g., Halifax), or too far downstream of (e.g., Palmyra), the spawning grounds will overestimate egg viability of all eggs spawned. In most years, the location best suited for overall egg viability is probably near River Mile 117 (Barnhill's Landing and Johnson's Landing).

9. Regardless of the location, consistency in sampling locations most likely provides the best relative estimates of egg production and viability.

MANAGEMENT IMPLICATIONS

Instream flow of the lower Roanoke River directly affects striped bass spawning activity through the relationship of reservoir releases and water temperature. Manipulation of river flow can therefore be used to regulate spawning activity. Completion of the USGS flow model for the Roanoke River may help clarify the relationships of egg production and viability to downstream survival of striped bass larvae and food supply (Study 1), and subsequent recruitment of juveniles to the year class forming in Albemarle Sound in late summer and fall. The annual egg studies provide daily information on the spawning activity of striped bass in relation to water quality and reservoir discharge, which can be used by state and federal personnel to update creel survey schedules. Recent (1991) age-at-maturity and fecundity schedules for this population may be used in conjunction with studies of egg production and population census of adults to estimate the relative importance of each year class to egg production.

RECOMMENDATIONS

1. Continue the egg studies each year to detect changes in striped bass spawning activity in relation to environmental and man-induced changes in Roanoke River water quality. This information will be needed as documentation during the upcoming hydroelectric relicensing procedures for Gaston and Roanoke Rapids reservoirs (the FERC licenses expire in year 2001).

2. Initiate studies to determine how the seasonal pattern in egg production and subsequent survivors of juveniles on the nursery grounds are related. This could be accomplished by back calculations of juvenile otoliths to determine spawning dates, and relating spawning date information to egg production.

ACKNOWLEDGMENTS

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APPENDIX A

BARNHILL'S LANDING INFORMATION

Table 1. Striped bass spawning in the Roanoke River, N.C. as estimate d from samples collected at Barnhill's Landing, 1991.

DATE	Number samples	Average river stage (ft)	Area of river cross-section (sq.ft)	Average eggs/net	Est. no. eggs/day	Percentage of total spawning	Cumulative percentage of spawning
910415	10	19.9	8,203	0.00	0	0.00	0.00
910416	12	19.9	8,188	0.00	0	0.00	0.00
910417	12	19.8	8,158	0.08	349,644	0.02	0.02
910418	12	19.7	8,136	0.00	0	0.00	0.02
910419	10	19.7	8,131	0.00	0	0.00	0.02
910420	12	19.8	8,158	0.00	0	0.00	0.02
910421	12	18.5	7,593	0.00	0	0.00	0.02
910422	10	15.1	6,145	0.00	0	0.00	0.02
910423	12	13.5	5,554	0.17	476,091	0.03	0.04
910424	12	12.5	5,174	0.33	886,916	0.05	0.09
910425	10	11.8	4,925	1.20	3,039,676	0.17	0.26
910426	10	11.5	4,817	0.10	247,741	0.01	0.27
910427	12	9.6	4,166	0.00	0	0.00	0.27
910428	12	8.6	3,833	1.92	3,777,979	0.21	0.48
910429	12	8.7	3,849	4.42	8,742,234	0.48	0.95
910430	10	8.7	3,861	2.40	4,765,173	0.26	1.21
910501	12	9.5	4,104	2.33	4,924,741	0.27	1.48
910502	12	9.7	4,197	19.58	42,272,152	2.30	3.78
910503	10	9.8	4,214	7.70	16,686,391	0.91	4.69
910504	10	9.8	4,214	1.20	2,600,477	0.14	4.83
910505	12	9.6	4,164	6.58	14,099,135	0.77	5.60
910506	10	9.7	4,181	18.90	40,636,743	2.21	7.81
910507	12	9.6	4,164	13.25	28,376,626	1.54	9.36
910508	12	9.6	4,153	118.08	252,225,065	13.73	23.09
910509	12	9.6	4,148	55.50	118,391,049	6.44	29.53
910510	12	9.5	4,104	12.50	26,382,648	1.44	30.97
910511	12	9.2	4,027	51.67	107,006,692	5.82	36.79
910512	12	9.2	4,011	98.25	202,652,419	11.03	47.82
910513	12	9.1	3,989	44.50	91,284,628	4.97	52.79
910514	12	9.1	3,983	168.33	344,834,188	18.77	71.56
910515	12	9.2	4,011	28.75	59,300,326	3.23	74.79
910516	12	9.2	4,016	28.50	58,865,042	3.20	77.99
910517	12	9.2	4,016	24.33	50,259,042	2.74	80.73
910518	12	9.2	4,011	35.42	73,051,127	3.98	84.71
910519	12	9.2	4,011	16.67	34,377,001	1.87	86.58
910520	12	7.7	3,529	3.58	6,503,436	0.35	86.93
910521	12	8.5	3,801	6.50	12,704,913	0.69	87.62
910522	12	8.8	3,902	9.92	19,901,131	1.08	88.71
910523	12	8.9	3,918	6.00	12,090,546	0.66	89.36
910524	12	8.9	3,924	13.92	28,081,642	1.53	90.89
910525	10	9.1	3,970	12.40	25,317,723	1.38	92.27
910526	12	9.1	3,983	20.00	40,970,399	2.23	94.50
910527	10	9.1	3,983	11.90	24,377,387	1.33	95.83
910528	10	9.1	3,990	9.30	19,082,707	1.04	96.87
910529	12	9.2	4,016	7.83	16,179,281	0.88	97.75
910530	12	9.2	4,016	6.83	14,113,840	0.77	98.52

Table 1. Striped bass spawning in the Roanoke River, N.C. as estimate d from samples collected at Barnhill's Landing, 1991.

DATE	Number samples	Average river stage (ft)	Area of river cross-section (sq.ft)	Average eggs/net	Est. no. eggs/day	Percentage of total spawning	Cumulative percentage of spawning
910531	12	9.2	4,016	3.50	7,229,040	0.39	98.91
910601	10	9.2	4,016	3.00	6,196,320	0.34	99.25
910602	8	9.1	3,983	2.00	4,097,040	0.22	99.47
910603	10	9.1	3,983	1.00	2,048,520	0.11	99.58
910604	12	9.2	4,005	1.50	3,089,700	0.17	99.75
910605	12	9.2	4,005	0.25	514,950	0.03	99.78
910606	12	9.1	3,983	0.50	1,024,260	0.06	99.83
910607	12	9.1	3,994	0.58	1,198,260	0.07	99.90
910608	10	9.1	3,983	0.00	0	0.00	99.90
910609	12	9.2	4,005	0.08	171,650	0.01	99.91
910610	12	7.9	3,579	0.33	613,608	0.03	99.94
910611	12	6.4	2,860	0.25	367,777	0.02	99.96
910612	14	6.3	2,736	0.50	703,641	0.04	100.00
910613	12	6.1	2,640	0.00	0	0.00	100.00
910614	4	6.1	2,653	0.00	0	0.00	100.00

Table 2. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991.

DATE	Number samples	Number non-viable eggs	Number viable eggs	Percentage viable eggs
910415	10	0	0	0.00
910416	12	0	0	0.00
910417	12	1	0	0.00
910418	12	0	0	0.00
910419	10	0	0	0.00
910420	12	0	0	0.00
910421	12	0	0	0.00
910422	10	0	0	0.00
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	0.00
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
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	0.00
910609	12	0	1	0.00
910610	12	2	2	50.00
910611	12	2	1	33.33
910612	14	4	3	42.86
910613	12	0	0	0.00
910614	4	0	0	0.00

Table 3. Estimated daily egg production for 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
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

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)
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	28	695,067	1,102,046	898,556	703,641	1,105,721	904,681
910613	24	0	461,472	230,736	0	452,581	226,290
910614	8	0	0	0	0	0	0
		===========	===========	===========	===========	===========	===========
		1837523192	2051753318	1944223052	1837088715	2051430565	1944122846

Table 4. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991, as a function of 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, as a function of 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, as a function of 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, as a function of 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	3,174	3,855	54.84	67.154
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
12.0 OR MORE	14	53	79.10	0.640
	=====	=====		=======
	4,672	5,795		100.000

Table 8. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1991, as a function of 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
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

Raw data and instantaneous egg production estimates

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	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
	200	0	0	0	0	19.9	8,203	0	0	0
	1000	0	0	0	0	19.9	8,203	0	0	0
	600	0	0	0	0	20.0	8,248	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	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
	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
910419	1000	.	.	.	.	.	.	.	.	.
	200	0	0	0	0	19.7	8,113	0	0	0
	600	0	0	0	0	19.7	8,113	0	0	0
	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

Raw data and instantaneous egg production estimates

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
910421	2200	0	0	0	0	16.9	6,875	0	0	0
	1800	0	0	0	0	18.0	7,350	0	0	0
	1400	0	0	0	0	18.7	7,665	0	0	0
	600	0	0	0	0	18.8	7,709	0	0	0
	200	0	0	0	0	19.4	7,979	0	0	0
	1000	0	0	0	0	19.4	7,979	0	0	0
910422	200	.	.	.	.	.	.	.	.	.
	2200	0	0	0	0	14.3	5,848	0	0	0
	1800	0	0	0	0	14.7	6,003	0	0	0
	1400	0	0	0	0	14.8	6,042	0	0	0
	1000	0	0	0	0	15.6	6,357	0	0	0
	600	0	0	0	0	15.9	6,475	0	0	0
910423	2200	1	1	0	0	13.0	5,352	9,557	0	4,778
	1800	0	0	0	0	13.2	5,428	0	0	0
	1000	0	0	0	0	13.7	5,618	0	0	0
	1400	0	0	0	0	13.7	5,618	0	0	0
	200	0	0	0	0	13.8	5,656	0	0	0
	600	0	0	0	0	13.8	5,656	0	0	0
910424	2200	0	0	0	0	12.1	5,020	0	0	0
	1800	2	0	2	2	12.3	5,094	9,096	18,192	13,644
	1400	2	0	0	0	12.4	5,131	9,162	0	4,581
	600	0	0	0	0	12.7	5,241	0	0	0
	200	0	0	1	0	12.8	5,278	0	4,713	2,356
	1000	0	0	1	1	12.8	5,278	0	9,425	4,713
910425	600	.	.	.	.	.	.	.	.	.
	2200	0	0	0	0	11.6	4,839	0	0	0
	1800	1	0	0	1	11.8	4,911	4,385	4,385	4,385
	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
	200	0	1	2	0	12.0	4,983	4,449	8,898	6,674
910426	2200	.	.	.	.	.	.	.	.	.
	1800	0	0	0	1	11.4	4,767	0	4,256	2,128
	1400	0	0	0	0	11.5	4,803	0	0	0
	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

Raw data and instantaneous egg production estimates

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
910427	2200	0	0	0	0	8.7	3,854	0	0	0
	1400	0	0	0	0	9.6	4,148	0	0	0
	1800	0	0	0	0	9.6	4,148	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
	200	0	0	0	0	10.6	4,485	0	0	0
910428	600	1	2	3	4	8.4	3,758	10,066	23,486	16,776
	200	0	0	1	0	8.6	3,822	0	3,412	1,706
	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	1000	3	6	8	8	8.6	3,822	30,712	54,600	42,656
	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
	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	.	.	.	.	.	.	.	.	.
	1000	9	6	6	4	8.5	3,790	50,758	33,838	42,298
	600	0	2	1	3	8.6	3,822	6,825	13,650	10,237
	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
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

Raw data and instantaneous egg production estimates

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
910503	2200	.	.	.	.	.	.	.	.	.
	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
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	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
	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
	1400	7	6	0	3	9.7	4,181	48,526	11,198	29,862
	200	6	10	12	7	9.8	4,214	60,196	71,482	65,839
910506	200	.	.	.	.	.	.	.	.	.
	600	16	3	20	13	9.7	4,181	70,923	123,181	97,052
	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
	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
	1000	119	105	57	107	9.7	4,181	836,140	612,174	724,157

Raw data and instantaneous egg production estimates

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
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	2200	15	10	9	27	9.3	4,049	90,382	130,150	110,266
	1800	5	12	10	8	9.4	4,082	61,959	65,604	63,781
	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
	200	26	19	36	41	9.6	4,148	166,653	285,161	225,907
910511	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
	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
910512	2200	3	2	8	19	9.1	3,983	17,782	96,024	56,903
	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
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
	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
	1400	18	24	25	10	9.2	4,016	150,604	125,503	138,053
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

Raw data and instantaneous egg production estimates

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	2200	9	24	10	10	9.1	3,983	117,362	71,129	94,245
	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
910519	2200	1	5	5	6	9.1	3,983	21,339	39,121	30,230
	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
	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
910520	1400	0	3	2	0	6.7	3,081	8,252	5,502	6,877
	1000	1	4	3	4	7.1	3,346	14,937	20,911	17,924
	1800	1	0	1	1	7.3	3,409	3,044	6,087	4,565
	600	1	3	3	3	7.9	3,598	12,850	19,275	16,062
	2200	3	1	12	5	8.5	3,790	13,535	57,525	35,530
	200	17	9	14	12	9.0	3,950	91,703	91,703	91,703

Raw data and instantaneous egg production estimates

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
910521	600	10	5	4	1	8.4	3,758	50,328	16,776	33,552
	200	4	7	3	5	8.5	3,790	37,222	27,071	32,146
	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
	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
	1400	14	7	8	11	9.0	3,950	74,068	67,014	70,541
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
	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

Raw data and instantaneous egg production estimates

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
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	.	.	.
910528	1400	.	.	.	.	.	.	.	.	.
	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
	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	2200	.	.	.	.	.	.	.	.	.
	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
	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

Raw data and instantaneous egg production estimates

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
910602	600	.	.	.	.	.	.	.	.	.
	1800	.	.	.	.	.	.	.	.	.
	200	4	2	2	3	9.1	3,983	21,339	17,782	19,560
	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
	2200	1	4	1	2	9.1	3,983	17,782	10,669	14,226
910603	1800	.	.	.	.	.	.	.	.	.
	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
	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	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
	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
910606	1000	0	0	2	1	9.0	3,950	0	10,581	5,291
	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
	1400	1	0	0	1	9.1	3,983	3,556	3,556	3,556
	2200	0	0	1	0	9.1	3,983	0	3,556	1,778
	1800	0	0	1	0	9.2	4,016	0	3,586	1,793
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
	1400	0	0	0	0	9.1	3,983	0	0	0
	2200	3	1	2	1	9.1	3,983	14,226	10,669	12,447
	1000	0	2	2	2	9.2	4,016	7,172	14,343	10,757
	1800	0	0	1	1	9.2	4,016	0	7,172	3,586

Raw data and instantaneous egg production estimates

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
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
	1800	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
	2200	0	0	2	1	9.2	4,016	0	10,757	5,379
910610	2200	0	0	0	0	6.8	3,159	0	0	0
	1800	0	0	0	0	7.0	3,314	0	0	0
	1400	1	1	1	0	7.3	3,409	6,087	3,044	4,565
	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
	200	0	0	0	0	8.9	3,918	0	0	0
910611	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
	1400	1	0	0	0	6.4	2,848	2,542	0	1,271
	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
910612	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
	200	0	0	0	0	6.2	2,692	0	0	0
	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
	2200	0	0	0	1	6.3	2,770	0	2,473	1,236

Raw data and instantaneous egg production estimates

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
910613	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
	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	3	1	6.2	2,692	0	9,614	4,807
910614	1000	0	0	0	0	6.1	2,614	0	0	0
	600	0	0	0	0	6.2	2,692	0	0	0

Table 10. List of Counties Enumerated in Figure 1.

1-12	(Virginia)	13-24	(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 11. Location of the historical sampling locations used by W.W. Hassler and colleagues (1959-1987), and Rulifson (1988-1991).

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's Ferry	105	77°24'30"E	36°15'30"N
Jacob's Landing	103		
Palmyra	78.5	77°19'30"E	36°4'32"N

APPENDIX B

JACOB'S LANDING INFORMATION

Table 1. Striped bass spawning in the Roanoke River, N.C. as estimated from samples collected at Jacob's Landing, 1991.

DATE	Number samples	Average river stage (ft)	Area of river cross-section (sq.ft)	Average eggs/net	Est. no. eggs/day	Percentage of total spawning	Cumulative percentage of spawning
910415	4	19.9	8,295	0.00	0	0.00	0.00
910416	12	19.9	8,282	0.00	0	0.00	0.00
910417	10	19.8	8,256	0.00	0	0.00	0.00
910418	12	19.8	8,256	0.00	0	0.00	0.00
910419	12	19.8	8,256	0.00	0	0.00	0.00
910420	10	20.0	8,335	0.00	0	0.00	0.00
910421	12	19.4	8,111	0.00	0	0.00	0.00
910422	12	17.5	7,352	0.00	0	0.00	0.00
910423	12	15.3	6,526	0.00	0	0.00	0.00
910424	12	13.8	5,990	0.00	0	0.00	0.00
910425	12	12.7	5,584	1.00	2,871,915	0.14	0.14
910426	12	12.0	5,355	0.17	459,018	0.02	0.16
910427	12	10.3	4,746	0.08	203,385	0.01	0.17
910428	12	9.2	4,383	1.00	2,254,313	0.11	0.28
910429	12	9.4	4,450	4.58	10,490,198	0.51	0.79
910430	10	8.9	4,283	1.00	2,202,875	0.11	0.89
910501	12	9.2	4,394	1.00	2,260,030	0.11	1.00
910502	12	9.6	4,518	8.25	19,168,115	0.93	1.93
910503	12	9.6	4,523	2.25	5,234,090	0.25	2.18
910504	12	9.5	4,478	7.58	17,465,516	0.84	3.03
910505	12	9.4	4,461	4.17	9,560,437	0.46	3.49
910506	12	9.4	4,445	17.17	39,240,678	1.90	5.39
910507	12	9.4	4,445	9.42	21,525,227	1.04	6.43
910508	12	9.3	4,417	91.08	206,896,475	10.00	16.43
910509	12	9.3	4,411	65.08	147,650,396	7.14	23.57
910510	12	9.2	4,394	13.17	29,757,065	1.44	25.01
910511	12	9.0	4,311	40.42	89,608,307	4.33	29.34
910512	12	8.9	4,278	101.83	224,036,364	10.83	40.17
910513	12	8.9	4,272	25.75	56,577,489	2.74	42.91
910514	10	8.9	4,284	190.60	419,976,550	20.31	63.21
910515	10	9.0	4,311	35.90	79,594,040	3.85	67.06
910516	12	8.9	4,289	34.92	77,016,433	3.72	70.78
910517	12	8.9	4,283	28.17	62,047,660	3.00	73.78
910518	12	8.9	4,278	38.00	83,601,131	4.04	77.83
910519	12	8.9	4,289	43.58	96,132,684	4.65	82.47
910520	12	7.8	3,933	7.83	15,845,712	0.77	83.24
910521	12	7.9	3,943	5.58	11,322,472	0.55	83.79
910522	12	8.5	4,156	7.58	16,210,095	0.78	84.57
910523	10	8.8	4,245	6.90	15,062,392	0.73	85.30
910524	12	8.8	4,245	15.25	33,290,069	1.61	86.91
910525	12	8.8	4,245	12.58	27,468,855	1.33	88.24
910526	12	8.9	4,272	19.50	42,845,088	2.07	90.31
910527	12	8.9	4,278	27.25	59,950,811	2.90	93.21
910528	10	8.9	4,284	12.30	27,102,369	1.31	94.52
910529	12	9.0	4,311	12.75	28,268,078	1.37	95.89
910530	10	9.0	4,311	18.40	40,794,717	1.97	97.86

DATE	Number samples	Average river stage (ft)	Area of river cross-section (sq.ft)	Average eggs/net	Est. no. eggs/day	Percentage of total spawning	Cumulative percentage of spawning
910531	12	8.9	4,294	3.25	7,177,843	0.35	98.20
910601	10	8.9	4,278	2.60	5,720,077	0.28	98.48
910602	10	8.9	4,278	3.60	7,920,107	0.38	98.86
910603	10	8.9	4,278	2.90	6,380,086	0.31	99.17
910604	12	9.0	4,311	1.33	2,956,139	0.14	99.32
910605	12	9.0	4,305	1.08	2,398,789	0.12	99.43
910606	12	8.9	4,278	0.42	916,679	0.04	99.48
910607	12	8.9	4,278	0.50	1,100,015	0.05	99.53
910608	12	8.9	4,278	1.42	3,116,709	0.15	99.68
910609	12	8.9	4,278	0.67	1,466,687	0.07	99.75
910610	12	7.9	3,949	0.42	846,300	0.04	99.79
910611	10	6.3	3,416	0.30	527,118	0.03	99.82
910612	12	5.8	3,280	2.00	3,373,468	0.16	99.98
910613	12	5.7	3,232	0.08	138,514	0.01	99.99
910614	6	5.4	3,205	0.17	274,751	0.01	100.00

Table 2. Striped bass egg viability at Jacob's Landing, Roanoke River, NC, 1991.

DATE	Number samples	Number non-viable eggs	Number viable eggs	Percentage viable eggs
910415	4	0	0	0.00
910416	12	0	0	0.00
910417	10	0	0	0.00
910418	12	0	0	0.00
910419	12	0	0	0.00
910420	10	0	0	0.00
910421	12	0	0	0.00
910422	12	0	0	0.00
910423	12	0	0	0.00
910424	12	0	0	0.00
910425	12	6	6	50.00
910426	12	1	1	50.00
910427	12	0	1	0.00
910428	12	5	7	58.33
910429	12	26	29	52.73
910430	10	7	3	30.00
910501	12	8	4	33.33
910502	12	35	64	64.65
910503	12	12	15	55.56
910504	12	48	43	47.25
910505	12	24	26	52.00
910506	12	98	108	52.43
910507	12	45	68	60.18
910508	12	416	677	61.94
910509	12	292	489	62.61
910510	12	58	100	63.29
910511	12	152	333	68.66
910512	12	367	855	69.97
910513	12	71	238	77.02
910514	10	569	1,337	70.15
910515	10	114	245	68.25
910516	12	86	333	79.47
910517	12	64	274	81.07
910518	12	163	293	64.25
910519	12	143	380	72.66
910520	12	28	66	70.21
910521	12	10	57	85.07
910522	12	29	62	68.13
910523	10	13	56	81.16
910524	12	39	144	78.69
910525	12	32	119	78.81
910526	12	55	179	76.50
910527	12	56	271	82.87
910528	10	37	86	69.92
910529	12	37	116	75.82
910530	10	50	134	72.83
910531	12	5	34	87.18
910601	10	7	19	73.08
910602	10	4	32	88.89
910603	10	6	23	79.31
910604	12	4	12	75.00
910605	12	0	13	0.00
910606	12	1	4	80.00
910607	12	2	4	66.67
910608	12	2	15	88.24
910609	12	1	7	87.50
910610	12	0	5	0.00
910611	10	2	1	33.33
910612	12	14	10	41.67
910613	12	1	0	0.00
910614	6	0	1	0.00

Estimated daily egg production for 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	8	0	0	0	0	0	0
910416	24	0	0	0	0	0	0
910417	20	0	424,572	212,286	0	424,572	212,286
910418	24	0	0	0	0	0	0
910419	24	0	707,620	353,810	0	707,620	353,810
910420	20	0	0	0	0	0	0
910421	24	0	0	0	0	0	0
910422	24	0	0	0	0	0	0
910423	24	0	0	0	0	0	0
910424	24	0	0	0	0	0	0
910425	24	2,839,987	3,082,354	2,961,170	2,871,915	3,111,242	2,991,579
910426	24	457,521	227,260	342,391	459,018	229,509	344,264
910427	24	210,906	187,617	199,262	203,385	203,385	203,385
910428	24	2,285,865	3,232,566	2,759,215	2,254,313	3,193,610	2,723,962
910429	24	10,474,159	12,006,726	11,240,442	10,490,198	12,016,045	11,253,122
910430	20	2,208,567	881,719	1,545,143	2,202,875	881,150	1,542,013
910501	24	2,264,342	1,880,493	2,072,417	2,260,030	1,883,359	2,071,694
910502	24	19,194,781	19,447,563	19,321,172	19,168,115	19,361,733	19,264,924
910503	24	5,229,751	6,973,001	6,101,376	5,234,090	6,978,787	6,106,438
910504	24	17,465,516	20,152,518	18,809,017	17,465,516	20,152,518	18,809,017
910505	24	9,543,157	11,064,186	10,303,672	9,560,437	11,090,107	10,325,272
910506	24	39,240,678	28,573,310	33,906,994	39,240,678	28,573,310	33,906,994
910507	24	21,525,227	26,287,445	23,906,336	21,525,227	26,287,445	23,906,336
910508	24	206,693,798	227,644,224	217,169,011	206,896,475	227,907,919	217,402,197
910509	24	147,650,396	174,117,817	160,884,106	147,650,396	174,117,817	160,884,106
910510	24	29,755,637	30,261,119	30,008,378	29,757,065	30,322,073	30,039,569
910511	24	89,548,282	93,651,180	91,599,731	89,608,307	93,857,774	91,733,041
910512	24	224,036,364	328,904,449	276,470,407	224,036,364	328,904,449	276,470,407
910513	24	56,593,852	78,005,724	67,299,788	56,577,489	78,000,033	67,288,761
910514	20	419,479,342	443,664,303	431,571,823	419,976,550	444,214,441	432,095,495
910515	20	79,594,040	109,303,237	94,448,638	79,594,040	109,303,237	94,448,638
910516	24	76,968,530	106,079,298	91,523,914	77,016,433	106,058,430	91,537,431
910517	24	62,079,912	61,886,616	61,983,264	62,047,660	61,864,087	61,955,873
910518	24	83,601,131	121,368,309	102,484,720	83,601,131	121,368,309	102,484,720
910519	24	96,001,306	110,872,850	103,437,078	96,132,684	111,021,302	103,576,993
910520	24	16,337,245	20,249,603	18,293,424	15,845,712	19,385,712	17,615,712
910521	24	11,406,644	13,793,772	12,600,208	11,322,472	13,688,362	12,505,417
910522	24	16,205,381	17,460,326	16,832,853	16,210,095	17,457,025	16,833,560
910523	20	15,062,392	30,124,784	22,593,588	15,062,392	30,124,784	22,593,588
910524	24	33,290,069	45,478,236	39,384,152	33,290,069	45,478,236	39,384,152
910525	24	27,468,855	33,653,895	30,561,375	27,468,855	33,653,895	30,561,375
910526	24	42,867,854	60,817,690	51,842,772	42,845,088	60,788,758	51,816,923
910527	24	59,950,811	67,834,251	63,892,531	59,950,811	67,834,251	63,892,531
910528	18	27,144,031	40,830,743	30,784,325	27,102,369	40,763,726	33,174,083
910529	24	28,268,078	53,025,742	40,646,910	28,268,078	53,025,742	40,646,910
910530	20	40,794,717	37,025,640	38,910,179	40,794,717	37,025,640	38,910,179
910531	24	7,172,863	12,357,489	9,765,176	7,177,843	12,331,166	9,754,504

Estimated daily egg production for 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)
910601	20	5,720,077	5,940,080	5,830,079	5,720,077	5,940,080	5,830,079
910602	20	7,920,107	10,340,140	9,130,124	7,920,107	10,340,140	9,130,124
910603	20	6,380,086	5,720,077	6,050,082	6,380,086	5,720,077	6,050,082
910604	24	2,956,139	4,249,450	3,602,794	2,956,139	4,249,450	3,602,794
910605	24	2,409,007	3,882,817	3,145,912	2,398,789	3,874,967	3,136,878
910606	24	916,679	916,679	916,679	916,679	916,679	916,679
910607	24	1,100,015	733,343	916,679	1,100,015	733,343	916,679
910608	24	3,116,709	2,200,030	2,658,369	3,116,709	2,200,030	2,658,369
910609	24	1,466,687	3,116,709	2,291,698	1,466,687	3,116,709	2,291,698
910610	24	892,576	3,793,219	2,342,897	846,300	3,554,460	2,200,380
910611	20	548,969	182,990	365,979	527,118	175,706	351,412
910612	24	3,362,531	4,344,636	3,853,584	3,373,468	4,357,396	3,865,432
910613	24	138,743	277,485	208,114	138,514	277,028	207,771
910614	12	0	0	0	274,751	274,751	274,751
		============	============	============	============	============	============
		2067840308	2499237901	2280336042	2068304334	2499322372	2283054389

Table 4. Striped bass egg viability at Jacob's Landing, Roanoke River, NC, 1991, as a function of 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	0	1	0.00	0.009
16.0-17.9	117	187	61.51	2.856
18.0-19.9	822	1,585	65.85	22.614
20.0-21.9	1,296	2,936	69.38	39.759
22.0-23.9	905	2,330	72.02	30.393
24.0-25.9	87	346	79.91	4.068
>=26.0	18	14	43.75	0.301
	=====	=====		=======
	3,245	7,399		100.000

Table 5. Striped bass egg viability at Jacob's Landing, Roanoke River, NC, 1991, as a function of 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	16	31	65.96	0.442
60.0-79.9	3,130	7,128	69.49	96.374
80.0-99.9	99	240	70.80	3.185
100.0-119.9	0	0	0.00	0.000
	=====	=====		=======
	3,245	7,399		100.000

Table 6. Striped bass egg viability at Jacob's Landing, Roanoke River, NC, 1991, as a function of time of day.

Time of collection	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
0200	347	860	71.25	11.340
0600	500	1,274	71.82	16.667
1000	598	1,698	73.95	21.571
1400	866	1,757	66.98	24.643
1800	549	1,008	64.74	14.628
2200	385	802	67.57	11.152
	=====	=====		=======
	3,245	7,399		100.000

Table 7. Striped bass egg viability at Jacob's Landing, Roanoke River, NC, 1991, as a function of dissolved oxygen

Dissolved oxygen values	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	0	4	0.00	0.038
4.0-4.9	2	12	85.71	0.132
5.0-5.9	20	47	70.15	0.629
6.0-6.9	182	545	74.97	6.830
7.0-7.9	1,077	2,882	72.80	37.195
8.0-8.9	1,087	2,346	68.34	32.253
9.0-9.9	877	1,563	64.06	22.924
	=====	=====		=======
	3,245	7,399		100.000

Table 8. Striped bass egg viability at Jacob's Landing, Roanoke River, NC, 1991, as a function of pH.

Range of pH values	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	15	30	66.67	0.423
5.50-5.74	0	0	0.00	0.000
5.75-5.99	1	1	50.00	0.019
6.00-6.24	10	26	72.22	0.338
6.25-6.49	22	104	82.54	1.184
6.50-6.74	19	142	88.20	1.513
6.75-6.99	4	34	89.47	0.357
7.00-7.24	29	82	73.87	1.043
7.25-7.49	28	70	71.43	0.921
7.50-7.74	2,300	4,826	67.72	66.949
7.75-7.99	677	1,775	72.39	23.036
8.0 OR MORE	140	309	68.82	4.218
	=====	=====		=======
	3,245	7,399		100.000

Raw data and instantaneous egg production estimates

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	.	.	.	.	.	.	.	.	.
	1000	.	.	.	.	.	.	.	.	.
	1400	.	.	.	.	.	.	.	.	.
	1800	0	0	0	0	19.9	8,295	0	0	0
	2200	0	0	0	0	19.9	8,295	0	0	0
910416	1800	0	0	0	0	19.8	8,256	0	0	0
	2200	0	0	0	0	19.8	8,256	0	0	0
	200	0	0	0	0	19.9	8,295	0	0	0
	600	0	0	0	0	19.9	8,295	0	0	0
	1000	0	0	0	0	19.9	8,295	0	0	0
	1400	0	0	0	0	19.9	8,295	0	0	0
910417	200	.	.	.	.	19.8	8,256	.	.	.
	600	0	0	0	0	19.8	8,256	0	0	0
	1000	0	0	0	0	19.8	8,256	0	0	0
	1400	0	0	0	1	19.8	8,256	0	7,371	3,685
	1800	0	0	0	0	19.8	8,256	0	0	0
	2200	0	0	0	0	19.8	8,256	0	0	0
910418	200	0	0	0	0	19.8	8,256	0	0	0
	600	0	0	0	0	19.8	8,256	0	0	0
	1000	0	0	0	0	19.8	8,256	0	0	0
	1400	0	0	0	0	19.8	8,256	0	0	0
	1800	0	0	0	0	19.8	8,256	0	0	0
	2200	0	0	0	0	19.8	8,256	0	0	0
910419	200	0	0	0	0	19.8	8,256	0	0	0
	600	0	0	0	0	19.8	8,256	0	0	0
	1000	0	0	1	0	19.8	8,256	0	7,371	3,685
	1400	0	0	0	0	19.8	8,256	0	0	0
	1800	0	0	0	0	19.8	8,256	0	0	0
	2200	0	0	0	1	19.8	8,256	0	7,371	3,685
910420	200	.	.	.	.	19.9	8,295	.	.	.
	600	0	0	0	0	19.9	8,295	0	0	0
	1000	0	0	0	0	20.0	8,335	0	0	0
	1400	0	0	0	0	20.0	8,335	0	0	0
	1800	0	0	0	0	20.1	8,375	0	0	0
	2200	0	0	0	0	20.1	8,375	0	0	0

Raw data and instantaneous egg production estimates

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
910421	2200	0	0	0	0	18.9	7,900	0	0	0
	1800	0	0	0	0	19.1	7,979	0	0	0
	1400	0	0	0	0	19.3	8,057	0	0	0
	1000	0	0	0	0	19.5	8,137	0	0	0
	600	0	0	0	0	19.7	8,216	0	0	0
	200	0	0	0	0	20.1	8,375	0	0	0
910422	2200	0	0	0	0	16.3	6,899	0	0	0
	1800	0	0	0	0	16.6	7,012	0	0	0
	1400	0	0	0	0	16.8	7,088	0	0	0
	1000	0	0	0	0	17.8	7,471	0	0	0
	200	0	0	0	0	18.7	7,822	0	0	0
	600	0	0	0	0	18.7	7,822	0	0	0
910423	2200	0	0	0	0	14.6	6,268	0	0	0
	1800	0	0	0	0	14.8	6,341	0	0	0
	1400	0	0	0	0	15.1	6,452	0	0	0
	1000	0	0	0	0	15.5	6,600	0	0	0
	600	0	0	0	0	15.8	6,711	0	0	0
	200	0	0	0	0	16.0	6,786	0	0	0
910424	2200	0	0	0	0	13.3	5,798	0	0	0
	1800	0	0	0	0	13.6	5,905	0	0	0
	1400	0	0	0	0	13.8	5,977	0	0	0
	1000	0	0	0	0	13.9	6,013	0	0	0
	600	0	0	0	0	14.1	6,086	0	0	0
	200	0	0	0	0	14.3	6,158	0	0	0
910425	2200	0	0	0	2	12.4	5,478	0	9,782	4,891
	1800	8	1	4	0	12.5	5,513	44,303	19,690	31,997
	1400	2	1	4	2	12.6	5,549	14,863	29,725	22,294
	1000	0	0	0	1	12.8	5,620	0	5,017	2,509
	600	0	0	0	0	12.9	5,655	0	0	0
	200	0	0	0	0	13.0	5,691	0	0	0
910426	2200	1	0	0	0	11.8	5,268	4,703	0	2,352
	1800	0	0	1	0	11.9	5,303	0	4,735	2,367
	1400	0	0	0	0	12.0	5,338	0	0	0
	1000	0	0	0	0	12.1	5,373	0	0	0
	600	1	0	0	0	12.2	5,408	4,828	0	2,414
	200	0	0	0	0	12.3	5,443	0	0	0

Raw data and instantaneous egg production estimates

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
910427	2200	0	0	1	0	9.2	4,378	0	3,909	1,954
	1800	0	0	0	0	9.7	4,546	0	0	0
	1400	0	0	0	0	10.0	4,647	0	0	0
	1000	0	0	0	0	10.4	4,784	0	0	0
	600	0	1	0	0	10.8	4,921	4,394	0	2,197
	200	0	0	0	0	11.6	5,198	0	0	0
910428	1000	0	0	0	0	9.0	4,311	0	0	0
	600	0	0	0	0	9.1	4,344	0	0	0
	200	0	0	1	1	9.2	4,378	0	7,817	3,909
	1400	0	0	0	0	9.2	4,378	0	0	0
	1800	3	1	2	6	9.4	4,445	15,874	31,748	23,811
	2200	6	2	3	4	9.4	4,445	31,748	27,779	29,764
910429	1800	11	9	17	8	9.3	4,411	78,771	98,464	88,618
	2200	3	3	1	1	9.3	4,411	23,631	7,877	15,754
	200	1	1	0	3	9.4	4,445	7,937	11,905	9,921
	600	8	6	8	8	9.4	4,445	55,559	63,496	59,527
	1000	2	0	2	1	9.5	4,478	7,997	11,995	9,996
	1400	4	7	5	9	9.6	4,512	44,314	56,400	50,357
910430	200	.	.	.	.	8.9	4,278	.	.	.
	600	0	0	0	1	8.9	4,278	0	3,819	1,910
	1000	0	2	1	0	8.9	4,278	7,639	3,819	5,729
	1400	0	1	0	0	8.9	4,278	3,819	0	1,910
	1800	2	0	0	1	8.9	4,278	7,639	3,819	5,729
	2200	2	3	0	1	9.0	4,311	19,246	3,849	11,547
910501	200	1	2	2	1	9.1	4,344	11,637	11,637	11,637
	600	0	0	0	0	9.2	4,378	0	0	0
	1000	1	0	1	1	9.2	4,378	3,909	7,817	5,863
	1400	1	3	3	0	9.3	4,411	15,754	11,816	13,785
	1800	0	0	0	1	9.3	4,411	0	3,939	1,969
	2200	3	1	1	0	9.4	4,445	15,874	3,968	9,921
910502	200	1	3	2	2	9.5	4,478	15,994	15,994	15,994
	600	1	0	1	1	9.5	4,478	3,998	7,997	5,998
	1000	9	7	5	5	9.5	4,478	63,976	39,985	51,980
	1400	15	21	20	15	9.6	4,512	145,029	141,000	143,014
	2200	19	9	13	13	9.6	4,512	112,800	104,743	108,771
	1800	8	6	8	15	10.0	4,647	58,091	95,436	76,763

Raw data and instantaneous egg production estimates

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
910503	200	1	3	1	4	9.6	4,512	16,114	20,143	18,129
	600	3	4	4	6	9.6	4,512	28,200	40,286	34,243
	1000	7	2	3	5	9.6	4,512	36,257	32,229	34,243
	1400	3	0	4	4	9.6	4,512	12,086	32,229	22,157
	1800	1	0	1	0	9.6	4,512	4,029	4,029	4,029
	2200	3	0	3	1	9.8	4,580	12,267	16,355	14,311
910504	200	1	2	5	0	9.5	4,478	11,995	19,992	15,994
	600	6	7	9	5	9.5	4,478	51,980	55,979	53,980
	1000	27	19	24	33	9.5	4,478	183,930	227,913	205,922
	1400	8	14	12	9	9.5	4,478	87,967	83,968	85,967
	1800	3	2	4	2	9.5	4,478	19,992	23,991	21,992
	2200	2	0	1	1	9.5	4,478	7,997	7,997	7,997
910505	1400	13	11	14	11	9.4	4,445	95,244	99,212	97,228
	1800	1	4	4	5	9.4	4,445	19,842	35,716	27,779
	2200	5	3	2	11	9.4	4,445	31,748	51,590	41,669
	200	2	1	2	1	9.5	4,478	11,995	11,995	11,995
	600	3	1	1	1	9.5	4,478	15,994	7,997	11,995
	1000	4	2	2	4	9.5	4,478	23,991	23,991	23,991
910506	200	4	2	3	3	9.4	4,445	23,811	23,811	23,811
	600	2	5	8	4	9.4	4,445	27,779	47,622	37,701
	1000	9	23	17	7	9.4	4,445	126,991	95,244	111,117
	1400	51	23	37	17	9.4	4,445	293,668	214,298	253,983
	1800	27	27	28	21	9.4	4,445	214,298	194,456	204,377
	2200	15	18	4	1	9.4	4,445	130,960	19,842	75,401
910507	200	2	5	8	4	9.4	4,445	27,779	47,622	37,701
	600	11	10	10	7	9.4	4,445	83,338	67,464	75,401
	1000	9	14	16	11	9.4	4,445	91,275	107,149	99,212
	1400	15	11	15	15	9.4	4,445	103,181	119,054	111,117
	1800	11	12	13	11	9.4	4,445	91,275	95,244	93,259
	2200	9	4	14	14	9.4	4,445	51,590	111,117	81,354
910508	600	49	57	44	41	9.3	4,411	417,489	334,779	376,134
	1000	69	82	160	182	9.3	4,411	594,724	1,346,991	970,858
	1400	193	152	178	202	9.3	4,411	1,358,807	1,496,657	1,427,732
	1800	158	131	138	71	9.3	4,411	1,138,247	823,161	980,704
	2200	79	82	75	96	9.3	4,411	634,110	673,496	653,803
	200	16	25	6	11	9.4	4,445	162,708	67,464	115,086

Raw data and instantaneous egg production estimates

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
910509	200	70	68	71	82	9.3	4,411	543,523	602,601	573,062
	600	105	85	92	73	9.3	4,411	748,328	649,864	699,096
	1000	80	93	122	115	9.3	4,411	681,373	933,441	807,407
	1400	75	118	118	121	9.3	4,411	760,144	941,318	850,731
	1800	25	33	41	41	9.3	4,411	228,437	322,963	275,700
	2200	16	13	18	27	9.3	4,411	114,219	177,236	145,727
910510	2200	11	17	21	21	9.1	4,344	108,607	162,911	135,759
	1800	10	14	16	23	9.2	4,378	93,808	152,438	123,123
	200	10	20	7	7	9.3	4,411	118,157	55,140	86,649
	600	13	4	7	13	9.3	4,411	66,956	78,771	72,864
	1000	16	19	16	11	9.3	4,411	137,850	106,341	122,096
	1400	12	12	6	13	9.3	4,411	94,526	74,833	84,679
910511	2200	30	31	77	88	8.9	4,278	232,987	630,212	431,599
	600	14	7	14	23	9.0	4,311	80,831	142,417	111,624
	1000	29	40	44	23	9.0	4,311	265,588	257,890	261,739
	1400	96	53	35	65	9.0	4,311	573,517	384,911	479,214
	1800	84	82	81	38	9.0	4,311	638,952	458,044	548,498
	200	10	9	13	7	9.1	4,344	73,698	77,577	75,637
910512	200	100	82	95	92	8.9	4,278	695,142	714,240	704,691
	600	80	72	180	188	8.9	4,278	580,558	1,405,563	993,061
	1000	198	123	211	262	8.9	4,278	1,226,048	1,806,606	1,516,327
	1400	158	142	185	217	8.9	4,278	1,145,839	1,535,424	1,340,632
	1800	96	106	109	164	8.9	4,278	771,532	1,042,714	907,123
	2200	34	31	39	52	8.9	4,278	248,265	347,571	297,918
910513	600	25	15	37	30	8.8	4,245	151,593	253,918	202,755
	200	43	35	53	58	8.9	4,278	297,918	423,960	360,939
	1000	26	36	14	26	8.9	4,278	236,807	152,779	194,793
	1400	26	20	39	32	8.9	4,278	175,695	271,182	223,439
	1800	13	14	24	22	8.9	4,278	103,126	175,695	139,410
	2200	29	27	47	44	8.9	4,278	213,890	347,571	280,731
910514	200	.	.	.	.	.	.	.	.	.
	600	119	159	183	182	8.9	4,278	1,061,811	1,394,104	1,227,958
	1000	223	260	225	330	8.9	4,278	1,844,801	2,119,802	1,982,302
	1400	417	469	420	423	8.9	4,278	3,384,045	3,219,808	3,301,926
	1800	84	85	88	84	8.9	4,278	645,489	656,948	651,219
	2200	37	53	49	32	9.0	4,311	346,420	311,778	329,099

Raw data and instantaneous egg production estimates

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	1400	.	.	.	.	.	.	.	.	.
	200	39	62	61	53	9.0	4,311	388,760	438,798	413,779
	600	39	52	48	49	9.0	4,311	350,269	373,363	361,816
	1000	36	29	43	66	9.0	4,311	250,192	419,553	334,872
	1800	21	33	46	23	9.0	4,311	207,852	265,588	236,720
	2200	30	18	53	51	9.0	4,311	184,757	400,307	292,532
910516	200	50	32	8	33	8.9	4,278	313,196	156,598	234,897
	600	42	26	42	45	8.9	4,278	259,724	332,293	296,008
	1000	54	59	73	85	8.9	4,278	431,599	603,475	517,537
	2200	26	24	45	39	8.9	4,278	190,973	320,835	255,904
	1400	39	39	68	67	9.0	4,311	300,230	519,629	409,930
	1800	14	14	40	32	9.0	4,311	107,775	277,136	192,455
910517	200	38	29	24	46	8.9	4,278	255,904	267,362	261,633
	1000	25	26	31	29	8.9	4,278	194,793	229,168	211,980
	1400	7	24	15	19	8.9	4,278	118,403	129,862	124,133
	1800	33	42	36	37	8.9	4,278	286,460	278,821	282,640
	2200	19	16	15	13	8.9	4,278	133,681	106,945	120,313
	600	38	41	32	40	9.0	4,311	304,079	277,136	290,608
910518	200	26	27	36	48	8.9	4,278	202,432	320,835	261,633
	600	35	34	45	36	8.9	4,278	263,543	309,377	286,460
	1000	44	52	77	57	8.9	4,278	366,669	511,808	439,238
	1400	53	53	97	88	8.9	4,278	404,863	706,601	555,732
	1800	20	21	26	30	8.9	4,278	156,598	213,890	185,244
	2200	52	39	59	63	8.9	4,278	347,571	465,975	406,773
910519	200	51	53	43	68	8.9	4,278	397,224	423,960	410,592
	600	48	68	66	87	8.9	4,278	443,058	584,378	513,718
	1000	77	85	59	82	8.9	4,278	618,753	538,544	578,649
	1400	31	28	52	50	8.9	4,278	225,348	389,585	307,467
	1800	19	24	36	25	9.0	4,311	165,512	234,795	200,154
	2200	11	28	15	21	9.0	4,311	150,115	138,568	144,341
910520	1800	1	1	1	2	6.9	3,623	6,469	9,704	8,087
	2200	0	0	1	3	6.9	3,623	0	12,939	6,469
	1400	14	18	7	15	7.5	3,818	109,074	74,989	92,031
	1000	7	11	3	12	8.0	3,981	63,980	53,317	58,649
	600	8	6	17	23	8.8	4,245	53,057	151,593	102,325
	200	13	15	15	16	9.0	4,311	107,775	119,322	113,549

Raw data and instantaneous egg production estimates

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
910521	200	3	3	3	3	7.4	3,785	20,277	20,277	20,277
	600	3	3	2	2	7.4	3,785	20,277	13,518	16,898
	1000	7	7	12	12	7.8	3,916	48,944	83,904	66,424
	1400	7	8	8	5	8.0	3,981	53,317	46,208	49,762
	1800	10	6	16	11	8.2	4,047	57,809	97,552	77,680
	2200	8	2	4	3	8.5	4,145	37,012	25,909	31,461
910522	200	4	5	3	4	8.5	4,145	33,311	25,909	29,610
	600	5	6	4	9	8.5	4,145	40,714	48,116	44,415
	1000	15	9	6	8	8.5	4,145	88,830	51,817	70,324
	1800	11	9	16	13	8.5	4,145	74,025	107,336	90,681
	1400	6	5	6	10	8.6	4,178	41,038	59,691	50,365
	2200	8	8	7	12	8.6	4,178	59,691	70,884	65,287
910523	200	.	.	.	.	.	.	.	.	.
	600	14	14	24	27	8.8	4,245	106,115	193,281	149,698
	1000	5	6	8	9	8.8	4,245	41,688	64,427	53,057
	1400	3	5	13	5	8.8	4,245	30,319	68,217	49,268
	1800	7	2	9	18	8.8	4,245	34,108	102,325	68,217
	2200	7	6	11	14	8.8	4,245	49,268	94,746	72,007
910524	200	8	7	13	11	8.8	4,245	56,847	90,956	73,902
	600	16	13	22	22	8.8	4,245	109,905	166,752	138,328
	1000	17	24	41	19	8.8	4,245	155,383	227,389	191,386
	1400	12	14	13	12	8.8	4,245	98,535	94,746	96,640
	1800	14	17	24	31	8.8	4,245	117,484	208,440	162,962
	2200	21	20	22	20	8.8	4,245	155,383	159,172	157,278
910525	200	18	13	22	26	8.8	4,245	117,484	181,911	149,698
	600	16	13	7	5	8.8	4,245	109,905	45,478	77,691
	1000	7	7	18	17	8.8	4,245	53,057	132,644	92,851
	1400	6	6	8	4	8.8	4,245	45,478	45,478	45,478
	1800	6	12	11	10	8.8	4,245	68,217	79,586	73,902
	2200	24	23	35	22	8.8	4,245	178,122	216,020	197,071
910526	200	15	8	19	16	8.8	4,245	87,166	132,644	109,905
	600	22	20	24	26	8.9	4,278	160,417	190,973	175,695
	1000	20	17	32	45	8.9	4,278	141,320	294,099	217,709
	1400	10	14	23	25	8.9	4,278	91,667	183,334	137,501
	1800	16	43	34	41	8.9	4,278	225,348	286,460	255,904
	2200	25	24	26	21	8.9	4,278	187,154	179,515	183,334

Raw data and instantaneous egg production estimates

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
910527	200	21	29	26	38	8.9	4,278	190,973	244,446	217,709
	600	46	65	36	38	8.9	4,278	423,960	282,640	353,300
	1000	49	32	75	66	8.9	4,278	309,377	538,544	423,960
	1400	21	14	13	31	8.9	4,278	133,681	168,056	150,869
	1800	11	11	11	8	8.9	4,278	84,028	72,570	78,299
	2200	15	13	10	18	8.9	4,278	106,945	106,945	106,945
910528	1800	.	.	.	.	.	.	.	.	.
	200	12	11	10	10	8.9	4,278	87,848	76,389	82,118
	600	11	14	25	26	8.9	4,278	95,487	194,793	145,140
	1000	7	11	8	8	8.9	4,278	68,750	61,111	64,931
	1400	4	4	.	.	8.9	4,278	30,556	.	30,556
	2200	34	15	25	36	9.0	4,311	188,606	234,795	211,701
910529	200	22	9	13	21	9.0	4,311	119,322	130,870	125,096
	600	30	19	30	33	9.0	4,311	188,606	242,494	215,550
	1000	21	20	45	59	9.0	4,311	157,813	400,307	279,060
	1400	4	10	26	24	9.0	4,311	53,887	192,455	123,171
	1800	0	1	2	4	9.0	4,311	3,849	23,095	13,472
	2200	7	10	15	15	9.0	4,311	65,435	115,473	90,454
910530	1400	.	.	.	.	.	.	.	.	.
	200	7	11	13	20	9.0	4,311	69,284	127,021	98,152
	600	40	38	32	37	9.0	4,311	300,230	265,588	282,909
	1000	21	28	17	16	9.0	4,311	188,606	127,021	157,813
	1800	15	7	9	5	9.0	4,311	84,680	53,887	69,284
	2200	10	7	11	7	9.0	4,311	65,435	69,284	67,359
910531	1400	0	0	0	0	8.9	4,278	0	0	0
	1800	1	2	0	0	8.9	4,278	11,458	0	5,729
	2200	9	11	8	7	8.9	4,278	76,389	57,292	66,841
	200	4	4	7	7	9.0	4,311	30,793	53,887	42,340
	600	0	1	5	9	9.0	4,311	3,849	53,887	28,868
	1000	3	4	9	15	9.0	4,311	26,944	92,379	59,661
910601	2200	.	.	.	.	.	.	.	.	.
	200	7	9	5	6	8.9	4,278	61,111	42,014	51,563
	600	2	4	3	6	8.9	4,278	22,917	34,375	28,646
	1000	1	3	1	0	8.9	4,278	15,278	3,819	9,549
	1400	0	0	0	0	8.9	4,278	0	3,819	1,910
	1800	0	0	2	3	8.9	4,278	0	19,097	9,549

Raw data and instantaneous egg production estimates

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
910602	1800	.	.	.	.	.	.	.	.	.
	200	4	2	8	11	8.9	4,278	22,917	72,570	47,743
	600	6	5	10	9	8.9	4,278	42,014	72,570	57,292
	1000	2	3	1	2	8.9	4,278	19,097	11,458	15,278
	1400	6	5	2	2	8.9	4,278	42,014	15,278	28,646
	2200	1	2	1	1	8.9	4,278	11,458	7,639	9,549
910603	2200	.	.	.	.	.	.	.	.	.
	200	1	4	5	3	8.9	4,278	19,097	30,556	24,827
	600	5	7	1	2	8.9	4,278	45,834	11,458	28,646
	1000	2	2	6	1	8.9	4,278	15,278	26,736	21,007
	1400	0	1	0	2	8.9	4,278	3,819	7,639	5,729
	1800	5	2	4	2	8.9	4,278	26,736	22,917	24,827
910604	200	2	1	3	2	9.0	4,311	11,547	19,246	15,396
	600	4	3	6	8	9.0	4,311	26,944	53,887	40,416
	1000	0	0	0	0	9.0	4,311	0	0	0
	1400	0	0	0	0	9.0	4,311	0	0	0
	1800	4	1	0	0	9.0	4,311	19,246	0	9,623
	2200	0	1	4	0	9.0	4,311	3,849	15,396	9,623
910605	1800	2	0	2	2	8.9	4,278	7,639	15,278	11,458
	2200	0	0	1	2	8.9	4,278	0	11,458	5,729
	200	0	0	3	1	9.0	4,311	0	15,396	7,698
	1000	3	1	1	0	9.0	4,311	15,396	3,849	9,623
	1400	0	0	0	0	9.0	4,311	0	0	0
	600	5	2	4	5	9.1	4,344	27,152	34,910	31,031
910606	200	0	0	0	0	8.9	4,278	0	0	0
	600	0	0	0	0	8.9	4,278	0	0	0
	1000	0	0	2	0	8.9	4,278	0	7,639	3,819
	1400	0	3	0	1	8.9	4,278	11,458	3,819	7,639
	1800	0	1	0	0	8.9	4,278	3,819	0	1,910
	2200	0	1	2	0	8.9	4,278	3,819	7,639	5,729
910607	200	0	0	0	0	8.9	4,278	0	0	0
	600	0	1	0	0	8.9	4,278	3,819	0	1,910
	1000	0	0	0	0	8.9	4,278	0	0	0
	1400	0	0	0	0	8.9	4,278	0	0	0
	1800	0	2	2	1	8.9	4,278	7,639	11,458	9,549
	2200	2	1	1	0	8.9	4,278	11,458	3,819	7,639

Raw data and instantaneous egg production estimates

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
910608	200	1	0	0	0	8.9	4,278	3,819	0	1,910
	600	3	3	2	4	8.9	4,278	22,917	22,917	22,917
	1000	2	2	1	0	8.9	4,278	15,278	3,819	9,549
	1400	0	0	1	0	8.9	4,278	0	3,819	1,910
	1800	2	4	0	4	8.9	4,278	22,917	15,278	19,097
	2200	0	0	0	0	8.9	4,278	0	0	0
910609	200	1	1	1	1	8.9	4,278	7,639	7,639	7,639
	600	0	2	0	2	8.9	4,278	7,639	7,639	7,639
	1000	0	0	0	1	8.9	4,278	0	3,819	1,910
	1400	0	2	0	1	8.9	4,278	7,639	3,819	5,729
	1800	1	0	2	6	8.9	4,278	3,819	30,556	17,188
	2200	1	0	1	2	8.9	4,278	3,819	11,458	7,639
910610	2200	0	0	0	0	6.9	3,623	0	0	0
	1800	0	0	0	0	7.1	3,688	0	0	0
	1400	0	0	0	0	7.6	3,850	0	0	0
	1000	0	2	0	0	8.3	4,080	7,285	0	3,642
	600	0	2	8	11	8.7	4,212	7,521	71,445	39,483
	200	0	1	1	1	8.8	4,245	3,790	7,580	5,685
910611	600	.	.	.	.	.	.	.	.	.
	2200	0	0	0	0	6.0	3,333	0	0	0
	1800	0	0	0	0	6.1	3,365	0	0	0
	1400	0	0	0	0	6.2	3,397	0	0	0
	1000	0	0	0	0	6.3	3,429	0	0	0
	200	3	0	0	1	6.7	3,558	9,531	3,177	6,354
910612	1000	0	0	0	0	5.8	3,269	0	0	0
	1400	0	0	0	0	5.8	3,269	0	0	0
	1800	9	8	7	11	5.8	3,269	49,620	52,539	51,080
	2200	6	1	8	4	5.8	3,269	20,432	35,026	27,729
	200	0	0	0	1	5.9	3,301	0	2,947	1,474
	600	0	0	0	0	5.9	3,301	0	0	0
910613	1800	0	0	0	0	5.6	3,205	0	0	0
	2200	0	0	0	0	5.6	3,205	0	0	0
	600	1	0	1	1	5.7	3,237	2,890	5,781	4,336
	1000	0	0	0	0	5.7	3,237	0	0	0
	1400	0	0	0	0	5.7	3,237	0	0	0
	200	0	0	0	0	5.8	3,269	0	0	0
910614	200	0	1	0	0	5.3	.	.	.	.
	600	0	0	1	0	5.3	.	.	.	.
	1000	0	0	0	0	5.6	3,205	0	0	0