11-21-1985

Relative contribution of three Virginia rivers to spawning activity of striped bass, Morone saxatilis

John E. Olney
Virginia Institute of Marine Science

George C. Grant
Virginia Institute of Marine Science

Gary Hill
Virginia Institute of Marine Science

Relative Contribution of Three Virginia Rivers to Spawning Activity of Striped Bass, *Morone saxatilis*

Project AFC-14-1

Completion report to the U. S. Department of Commerce, NOAA, National Marine Fisheries Service, P. L. 89-304

by

John E. Olney, George C. Grant and Gary Hill

Virginia Institute of Marine Science
and
School of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

21 November 1985

Relative Contribution of Three Virginia Rivers to Spawning Activity of Striped Bass, *Morone saxatilis*

INTRODUCTION

Initial documentation of spawning activity of striped bass in the tidal freshwater portions of Virginia rivers was provided by Tresselt (1952), Massman et al. (1952, 1962), Rinaldo (1971) and Merriner et al. (1980). Recently, a series of pilot ichthyoplankton surveys of these habitats has resulted in data describing patterns of abundance of eggs and larvae in three separate rivers during three separate years: the Pamunkey and Mattaponi Rivers in spring 1980 (Grant and Olney 1981); the James River in 1981 (Grant and Olney 1982); and the Rappahannock in 1982 (Olney et al. 1983). These surveys were conducted in response to the objectives of the Emergency Striped Bass Study (Chafee Amendment to the Anadromous Fish Act) and have provided spatial and temporal details of spawning activity (Figures 1-4) used in the preparation of management regulations promulgated by the Virginia Marine Resources Commission.

An important but neglected objective of this recent research effort was the provision of reliable data on annual variability of egg deposition between river systems and the relative contribution of each of Virginia's major rivers to the annual spawn. Comparisons of the three-year data set (1980-1982) indicated an order of magnitude difference in absolute egg abundance on the Rappahannock River in 1982 (Olney et al. 1983), however concurrent data from the James and York river systems were lacking during that year. As a result, an assessment of the relative contribution of the Rappahannock to the total Virginia spawn in 1982 was not possible. Efforts to obtain additional funding to accomplish these objectives in 1983 were thwarted by changing priorities in the Emergency Striped Bass Study monitoring program. Thus, the ancillary collection of 140 samples in 17 total cruises on the James, Pamunkey, and Rappahannock during a separately funded project in 1983, was considered fortuitous. The results of our analysis of these collections as well as a reexamination of the 1980-1982 survey data are the subjects of this report.

METHODOLOGY

Sampling strategies employed during pilot surveys in 1980-1982 were repeated in spring 1983. Weekly surveys were conducted on each river during the six-week period 5 April - 13 May 1883 (Tables 1-3). One weekly sampling cruise on the James River was missed (week of April 18) as a result of severe weather. Plankton sampling did not continue beyond 13 May since the objectives of a separately funded project that supported these cruises did not include assessment of larval abundance. As a result, larval striped bass were only collected on two cruises in each river between 2-13 May 1983.

Regular collections at each station consisted of 2-10 minute stepped oblique (usually 0.5 - 2 min. per 2-meter interval) tows of a 60 cm bongo sampler equipped with .333 mm mesh nets. Both nets were metered with General Oceanics flowmeters for volumetric estimates and catches were combined on board before preservation with 5-8% buffered formalin. All collections were made in daylight hours. Ancillary data at each station included surface and bottom measurements of temperature, salinity and dissolved oxygen. Maximum depth of visibility was determined by Secchi disc.

Whole collections were sorted for Morone saxatilis eggs and larvae under a stereomicroscope. We elected a conservative count in collections with damaged eggs, talleying only intact eggs and separated embryoes.

Egg production estimates were calculated following a modification of the techniques of Houde (1977) after Sette and Ahlstrom (1948) and Ahlstrom (1954, 1959). Tidally averaged water volume estimates (Table 4) were calculated based on Cronin (1971). Mean low and mean high water volumes ($10^6 m^3$) were averaged at each river mile and means were summed over each three-mile stratum. Catches of striped bass eggs were standardized between stations to obtain abundance per m 100^3 of water strained:

$$n_j = \frac{c_j \times 100}{v_j} \qquad (1)$$

Where n_j = number of eggs/$_{100m}{}^3$ at station j

c_j = the egg count at station j

v_j = the volume strained by both nets (in cubic meters) at station j

Numbers of eggs were estimated in the 3-mile stratum represented by each randomly selected station:

$$p_j = \frac{c_j}{v_j} \cdot V_j \qquad (2)$$

Where

p_j = number of eggs estimated in the stratum represented by station j

V_j = volume (10^6 cubic meters) of the stratum represented by station j (Table 4)

c_j = defined in equation 1

v_j = defined in equation 1

Cruise production estimates, variance estimates, and annual egg production estimates were calculated without modification to Houde's (1977:65) equations 4-6. Striped bass spawning periods were assumed to be 44 days in duration (1 April -15 May) in calculations of egg production and variance. Exceptions occurred in data sets from the Pamunkey River in 1980 when a cruise date fell on 16 May and from the James River in 1981 where a single egg was collected during the cruise of 21-22 May. This latter value was omitted from the data set.

Duration of the egg stage was calculated for each cruise following a modification of Setzler et al. (1980:15):

$$I = \frac{-4.60T + 131.6}{24} \qquad (3)$$

Where

I = duration of the egg stage (days)

T = average water column temperature

(^{o}C) during cruise j.

Female biomass necessary to produce the observed annual egg deposition was calculated following a modification of Houde (1977:66):

$$B_F = \frac{P_a}{F} \qquad (4)$$

Where

B_F = female biomass (kg)

P_a = calculated annual egg production

F = fecundity estimate of 2.146×10^5 eggs/kg.

The fecundity value utilized in equation 4 was derived following Setzler et al. (1980:13) using the equation $F = 2.18 \times 10^5 W - 1.17 \times 10^4$ where W is weight in kg. A value of 3.4 kg was used in this relationship since this value represented the mean weight of a 1978 yearclass female striped bass captured in pound nets on the Rappahannock River in spring 1983 (Loesch and Kriete 1983). This estimated fecundity value was used in calculations of B_F (equation 4) in 1980 and 1982 although fishery data were not available on the York River system in 1980 and 1978 yearclass fish may not have contributed significantly to the spawn on the Rappahannock in 1982.

Comparable values of F are reported by Hardy (1978) on a range of female sizes from 2.3-29.5 kg. Fecundity values expressed as eggs per unit body weight may not vary significantly with age. In Hardy's (1978) data set, F ranged from 1.42 X 10^5 eggs/kg (22.6 kg individual) to 2.79 X 10^6 eggs/kg (14.5 kg individual).

RESULTS OF THE 1983 SURVEYS

Physical Characteristics

Mean water column temperatures ranged from 11.1 - 16.4°C during April and from 17.5 - 21.0°C in May (Tables 1-3). During initial cruises on all rivers, temperatures ranged from 11.4 - 12.8°C, and represented values within the range of observed spawning (10.0 - 25.0°C, Hardy 1978) but well below peak activity ranges. A cold front and severe weather depressed temperatures on the Rappahannock and Pamunkey rivers during the week of April 22 (Tables 1 and 3) and forced cancellation of a weekly cruise on the James.

Saline waters (using 0.5 o/oo as the upper limit for designation of fresh water) were infrequently encountered indicating that sampling was confined to known spawning regions (Figs. 1-4). Dissolved oxygen levels remained at or near saturation, ranging from 7.6 - 11.4 mg/l and water transparency, as measured by Secchi depth, only rarely exceeded 0.5 m.

Egg and Larval Catches

Tables 5-10 present catch data for eggs and larvae in all rivers. During initial cruises (5 April, 8 April), eggs were present in low densities at only one station each on the Pamunkey and James. On April 9, however, spawning was well underway on the Rappahannock with egg densities ranging from 1.9 - 27.9 eggs/100m^3 at six positive stations (Table 5). In the subsequent weekly sampling period (13-15 April) spawning activity increased moderately with density values estimated between 0.7 - 30.8 eggs/100m^3 at 10 total positive stations on the Rappahannock and Pamunkey rivers. This trend was reversed during the third weekly sampling period (22-23 April) when lowered water temperatures interrupted spawning and depressed density estimates on each river (Tables 5 and 7).

Peak spawning activity during the sampling period was observed in the last week of April on the Rappahannock and Pamunkey rivers but not until the subsequent sampling period (2 May) on the James. During these cruises, recorded egg density ranges at positive stations were 1.0 - 477 eggs/100m^3 on the Rappahannock (Table 5), 1.2 - 195 eggs/100m^3 on the James (Table 6) and 0.8 - 66 eggs/100m^3 on the Pamunkey River (Table 7). At periods of peak spawning activity, eggs were distributed between river miles 40-61 (Rappahannock), 33-58 (James) and 27-51 on the Pamunkey (river miles 27 - 29 are actually located in the York River below West Point, Virginia).

Data describing distribution and abundance of larval striped bass are limited since sampling ceased on 13 May. Sampling during the period 2-13 May (two cruises on each river) yielded 439 total larvae on the Rappahannock (Table 8), 155 larvae on the James (Table 9) and only 41 specimens on the Pamunkey River (Table 10). Total number of positive stations and density ranges observed were: 10, 4.8 - 103.1 larvae/100m^3 - Rappahannock; 9, 0.7 - 31.5 - James; 7, 1.6 - 23.2 - Pamunkey. Length frequency distributions are presented in Table 11.

EGG PRODUCTION ESTIMATES, 1980-1983

Table 12 summarizes results of ichthyoplankton surveys conducted in the major spawning rivers of Virginia during the four year period 1980-1984. Details of the 1980-1982 surveys are described by Grant and Olney (1981, 1982) and Olney et al (1983). The following comparisons are based on these previous reports and the 1983 data described herein (Tables 13-23).

Spatial and Temporal Comparisons

Rappahannock River

Data sets resulting from the 1982 and 1983 surveys (Tables 13 and 14) reveal consistent trends in spatial and temporal distribution of eggs on the Rappahannock River. Spawning was observed along a 26-mile portion of the river in 1982 (miles 42-68) and along a 23 mile stretch in 1983. Summed values of p_j (estimated total number of eggs represented by each stratum) ranged from 1.1 - 105.6 (eggs X 10^6) within strata between river miles 39 and 68 in 1982 and from 0.2 - 101.4 (eggs X 10^6) between river miles 39 and 62 in 1983. Peak spawning tended to shift slightly upstream in the 1983 season. Greatest egg production was observed in an eleven mile segment (51-62) in 1982 and an eight mile segment (48-56) in 1983. Despite this variability, stations representing stratum 54-56 contributed the greatest total percentage production during each year (1982 - 34.5%; 1983-47.2%; Tables 13-14). This river segment includes the area from Devil's Reach near Saunders Wharf upstream to Blind Point.

Some temporal variability in cruise egg production values (P_i) were observed between years and may have been partly due to mid-spawning temperature depressions observed on the Rappahannock in 1983 during the week of 22 April (Figure 5). Cruise production estimates ranged from 0.007 - 1.332 (eggs X 10^8) in 1982 and 0.009-1.615 (eggs X 10^8) in 1983 (Table 20). Peak production values were observed during the cruises of 21 April 1982 and 29 April 1983.

James River

Values of p_j calculated from surveys in 1981 and 1983 on the James River are presented in Tables 15 and 16. Comparisons of these data sets (Fig. 6) are made difficult because of an insufficient level of sampling effort during both years (4 cruises in 1981 and 5 cruises in 1983). Variances calculated for values of P_i (Table 21) are high, especially during 1981, and reflect the sensitivity of variance calculations to large values of D_i (the number of days represented by each cruise). Despite these limitations spatial trends are apparent and directly related to a severe drought in 1981 that confined spawning activity during that year to the upper reaches of the spawning grounds (Grant and Olney 1982). As a result, 65% of the total 1981 egg production is attributed to stations representing two strata between miles 60-65 (Table 15) while peak egg production in 1983 was observed to cover a large area further down stream (Table 16). These annually shifting centers of spawning activity, however, appear to be the only spatial effect of the drought since total river area used for spawning (approximately 27 miles) did not change between years.

As in the above discussion, temporal trends are obscured due to insufficient sampling effort (as a result of funding delays, sampling did not begin in 1981 until 22 April). Cruise production estimates (Table 21) peaked in the first week of May 1983 but variance associated with 1981 data precludes similar observations.

Pamunkey River

Data sets resulting from the 1980 and 1983 surveys are presented in Tables 17-18 and 22. Spawning was observed in both years along similar portions of the estuary although 1983 sampling included an additional stratum in the York River below West Point (miles 27-29). This stratum may have produced eggs in 1980 as well (Grant and Olney 1981). Within these strata, summed values of p_j ranged from 1.3 - 18.2 (eggs X 10^6) in 1980 and from 0.8 - 19.2 (eggs X 10^6) in 1983. During both years, spawning activity was observed to be evenly spread over approximately 20 river miles (27-47) although almost 32% of total 1980 production was attributed to stations within stratum 33-35.

Some temporal variability in values of P_i were observed between years and, as in the case of the Rappahannock data set, these differences may have been due to mid-spawning temperature depressions in 1983 (Fig. 7). Cruise production estimates ranged from 0.5 - 26.9 (eggs X 10^6) in 1980 and 0.4 - 58.3 (eggs X 10^6) in 1983. Peak production values were observed on 22 April 1980 and 27 April - 4 May 1983 (Table 22).

Mattaponi River

Egg production estimates based on the 1980 survey are presented in Fig. 8 and Tables 19 and 23 [and spatial and temporal trends in egg distribution were described by Grant and Olney (1981)]. This system was not surveyed in 1983.

Annual Production and Female Biomass

Values of annual egg production calculated from 1980-1983 surveys of Virginia's major spawning grounds (Tables 20-23) varied from 1.499 - 7.242 (eggs X 10^8). The upper value of this range may be more justifiably reported as 5.81 X 10^8 eggs (Rappahannock 1983) since large variance estimates and confidence intervals associated with James River data (Table 21) indicate considerable error. These values are comparable to annual egg production estimates reported during some years in the Roanoke system (Hassler et al. 1981), larger than values reported by Boynton (cited by

Setzler et al. 1980:46) on the Potomac but smaller than Potomac river production values calculated by Polgar (1977).

Biomass of 1978 yearclass females (average weight, 3.4 kg; calculated fecundity given in equation 4) necessary to produce the observed 1983 egg deposition was estimated to be 2707 kg (± 1498 kg) on the Rappahannock River and 1022 kg (± 756 kg) on the Pamunkey. These values were not calculated for the James in 1983 due to the large errors associated with James River egg production estimates. Summing the upper and lower biomass estimates for the Rappahannock and Pamunkey rivers yields a total biomass range of 1475 - 5983 kg necessary to produce the cumulative egg deposition in these two rivers in 1983. Thus, if only 1978 yearclass females (average weight, 3.4 kg) were spawning in 1983, these values indicate that as few as 434 or as many as 1760 individuals could have produced the observed spawn in these two rivers.

DISCUSSION

Variance estimates of cruise egg abundance and total egg production based on Houde's (1977) model are forced by values of D_i and A_{ij} (Houde's 1977:65 equation 4). As a result, James River estimates are large since sampling effort was reduced relative to other rivers and total James River volume ($508.75 \times 10^6 m^3$) exceeds the volume of all other rivers combined ($370.58 \times 10^6 m^3$). Thus, our original objective of examining the relative contribution of three rivers based on annual egg production fails since reliable data from the James in 1983 are not available. Examination of cruise production estimates on each river, however, provides some insight into relative spawning activity on these rivers (Tables 20-23) since values of P_i have lower variances than values of P_a. During periods of peak spawning activity in 1982 and 1983, Rappahannock River production was one order of magnitude above James River estimates and two orders of magnitude above those from the Pamunkey River. These data suggest that the greatest spawning activity occurred on the Rappahannock in spring 1982 and 1983.

As discussed by Houde (1977) variance estimates so obtained are subject to considerable uncertainty and probably do not account for all sources of variability in these data sets. Among those unaccounted sources are day to day variability in spawning and within stratum variability. Reduction in values of D_i can improve these estimates and within stratum replication (presently absent in our sampling strategy) could improve production estimate reliability. Some balance between these increases in sampling effort and cost effectiveness of ichthyoplankton survey data must be reached, however. We believe, that despite the uncertainty surrounding production values presented herein, these data are useful first-order estimates of Virginia's contribution to the total Chesapeake Bay striped bass egg production.

REFERENCES

Ahlstrom, E. H. 1954. Distribution and abundance of egg and larval populations of the Pacific sardine. U. S. Fish Wildl. Serv., Fish. Bull. 56:83-140.

Ahlstrom, E. H. 1959. Distribution and abundance of eggs of the Pacific sardine, 1952-1956. U. S. Fish Wildl. Serv., Fish. Bull. 60:185-213.

Cronin, W. B. 1971. Volumetric, areal, and tidal statistics of the

Chesapeake Bay estuary and its tributaries. Chesapeake Bay Institute Spec. Report 20.

Grant, G. C. and J. E. Olney. 1981. Assessment of larval striped bass, Morone saxatilis (Walbaum), stocks in Maryland and Virginia waters. Part II. Assessment of spawning activity in major Virginia rivers. Final Report, Segment 1, to the National Marine Fisheries Service, Gloucester, Mass. (Grant No. NA80FAD-VA1B), 39 pp.

Grant, G. C. and J. E. Olney. 1982. Assessment of larval striped bass, Morone saxatilis (Walbaum), stocks in Maryland and Virginia waters. Part II. Assessment of Spawning Activity in Major Virginia Rivers. Final Rept., Segment 2, to the National Marine Fisheries Service, Gloucester, Mass. (Grant No. NA81FAD-VA3B), 42 pp.

Hardy, J. D., Jr. 1978. Development of fishes of the mid-Atlantic Bight: An atlas of the egg, larval and juvenile stages. Vol. III. Aphredoderidae through Rachycentridae. U. S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS-78/12, 394 p.

Hassler, W. W., N. L. Hill, and J. T.Brown. 1981. The status and abundance of striped bass, Morone saxatilis, in the Roanoke River and Albermarle Sound, North Carolina, 1956-1980. North Carolina Department of Natural Resources and Community Development Division of Marine Fisheries. Special Scientific Report No. 38:1-156.

Houde, E. D. 1977. Abundance and potential yield of the round herring, Etrumeus teres, and aspects of its early life history in the eastern Gulf of Mexico. Fish. Bull. 75:61-89.

Loesch, J. G. and W. H. Kriete, Jr. 1983. Striped bass research, Virginia. Part II. Characterization of Virginia's striped bass commercial fisheries, October 1982 -September 1983. Annual Report, VIMS, Gloucester Point, VA., 51 pp.

Massmann, W. H., E. C. Ladd and H. N. McCutcheon. 1952. A biological survey of the Rappahannock River, Virginia. Part 1. Virginia Fisheries Lab, Gloucester Point, VA 112 pp. (Mimeo).

Massmann, W. H., E. B. Joseph and J. J. Norcross. 1962. Fishes and fish larvae collected from Atlantic plankton cruises of R/V Pathfinder, March 1961 - March 1962. Virginia Inst. of Mar. Sci. Spec. Sci. Rept. No. 33, 20 p.

Merriner, J. V., A. D. Estes, and R. K. Dias. 1980. Ichthyoplankton Entrainment Studies at Vepco Neclear Power Station. Final Technical Report 1975-1978. Va. Inst. Mar. Sci., Gloucester Pt., VA. Sections IIa and IIb. 602 p.

Olney, J. E., B. H.Comyns and G. C. Grant. 1983. Assessment of larval striped bass, Morone saxatilis (Walbaum) stocks in Maryland and Virginia waters. Part II. Assessment of spawning activity in major Virginia rivers. Fianl Report, Segment 3, to the NMFS, Gloucester, Mass. (Grant No. NA81FAD-VA55B), 38 pp, Appendix I.

Polgar, T. T. 1977. Striped bass ichthyoplankton abundance, mortality, and production estimation for the Potomac River population. IN W. Van Winkle (ed), Proceedings of a conference on assessing the effects of power-plant-induced mortality on fish poplations, Gatlinburg, IN Pergamon Press, pp. 110-126.

Rinaldo, R. G. 1971. Analysis of Morone saxatilis and Morone americanus spawning and nursery area in the York-Pamunkey River, Virginia. M.A. thesis, College of William and Mary, Williamsburg, VA. 56 pp.

Sette, O. E. and E. H. Ahlstrom. 1948. Estimations of abundance of the eggs of the Pacific pilchard, Sardinops caerulea, off southern

California during 1940 and 1941. J. Mar. Res. 7:511-542.

Setzler, E. M., W. R. Boynton, K. V. Wood, H. H. Zion, L. Lubbers, N. K. Mountford, P. Frere, L. Tucker and J. A. Mihursky. 1980. Synopsis of biological data on striped bass, *Morone saxatilis* (Walbaum). NOAA Tech. Rep. NMFS circ. 433. FAP Synop. 121, 69 p.

Tresselt, E. F. 1952. Spawning grounds of the striped bass or rock, *Roccus saxatilis* (Walbaum), in Virginia. Bull. Bingham Oceanogr. Coll. 14(1):98-110.

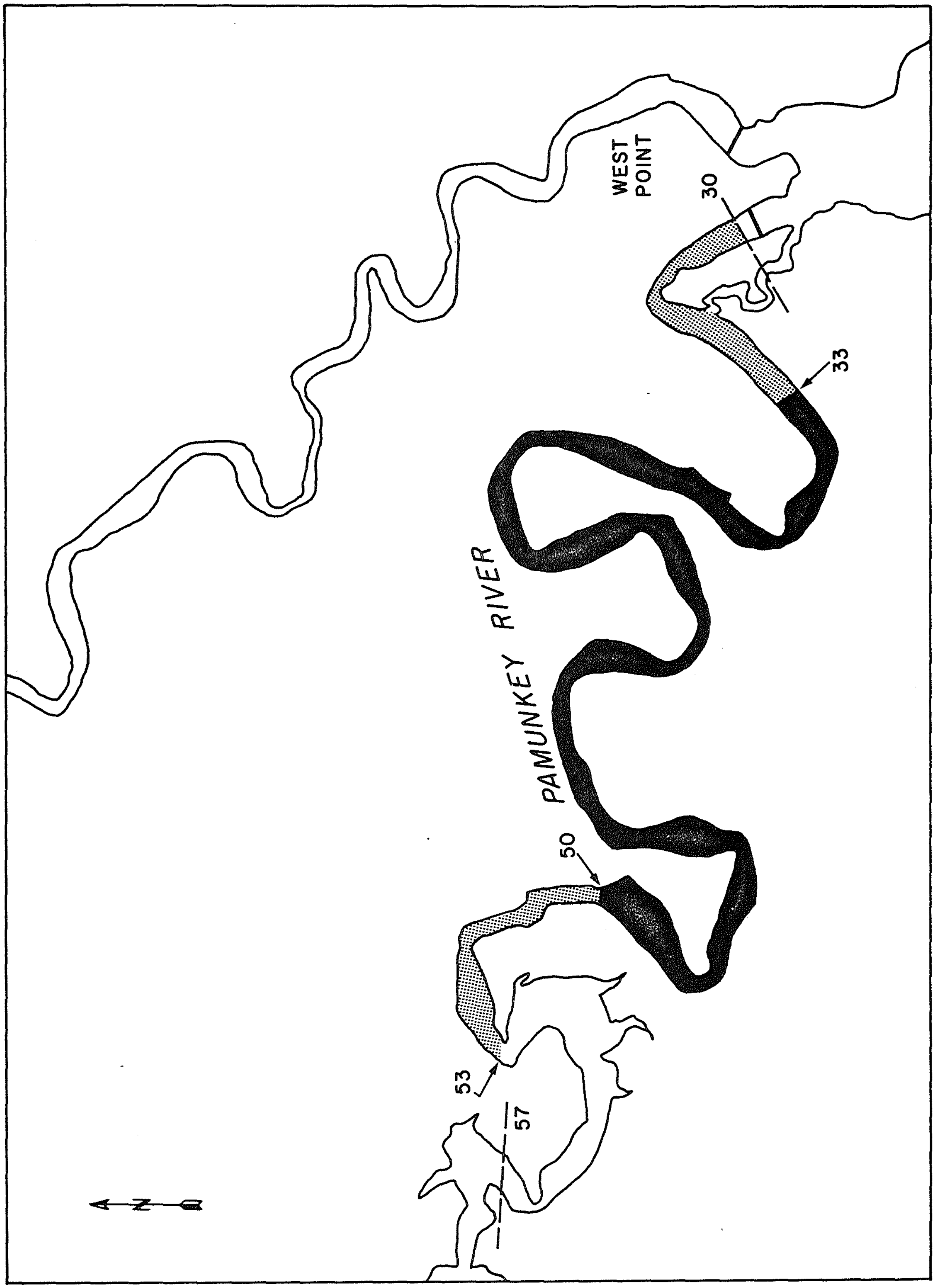


Fig. 1. Spatial extent of striped bass eggs, Pamunkey River, spring 1980. Darkest area represents greatest spawning activity.

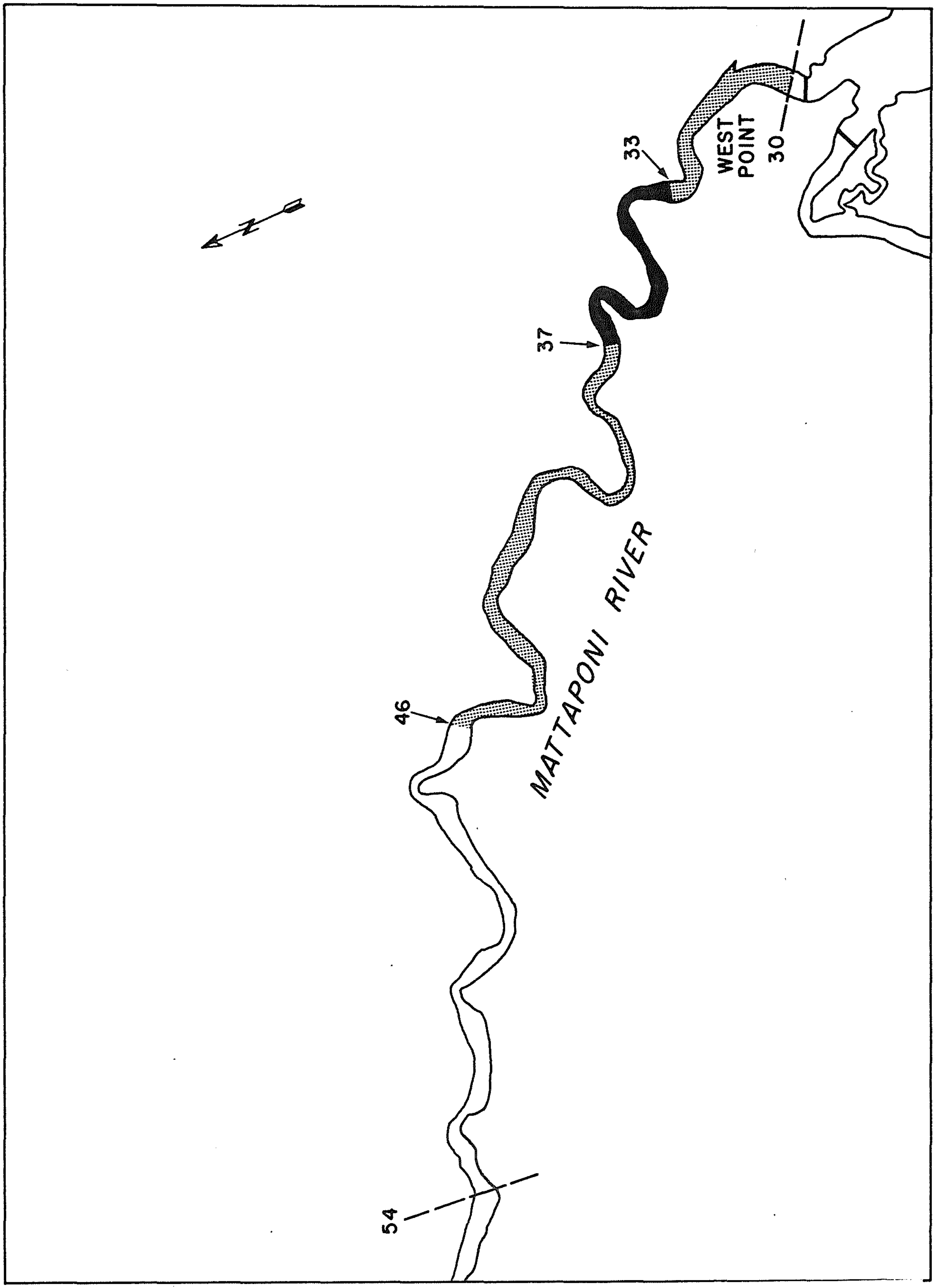


Fig. 2. Spatial extent of striped bass eggs, Mattaponi River, spring 1980. Darkest area represents greatest spawning activity.

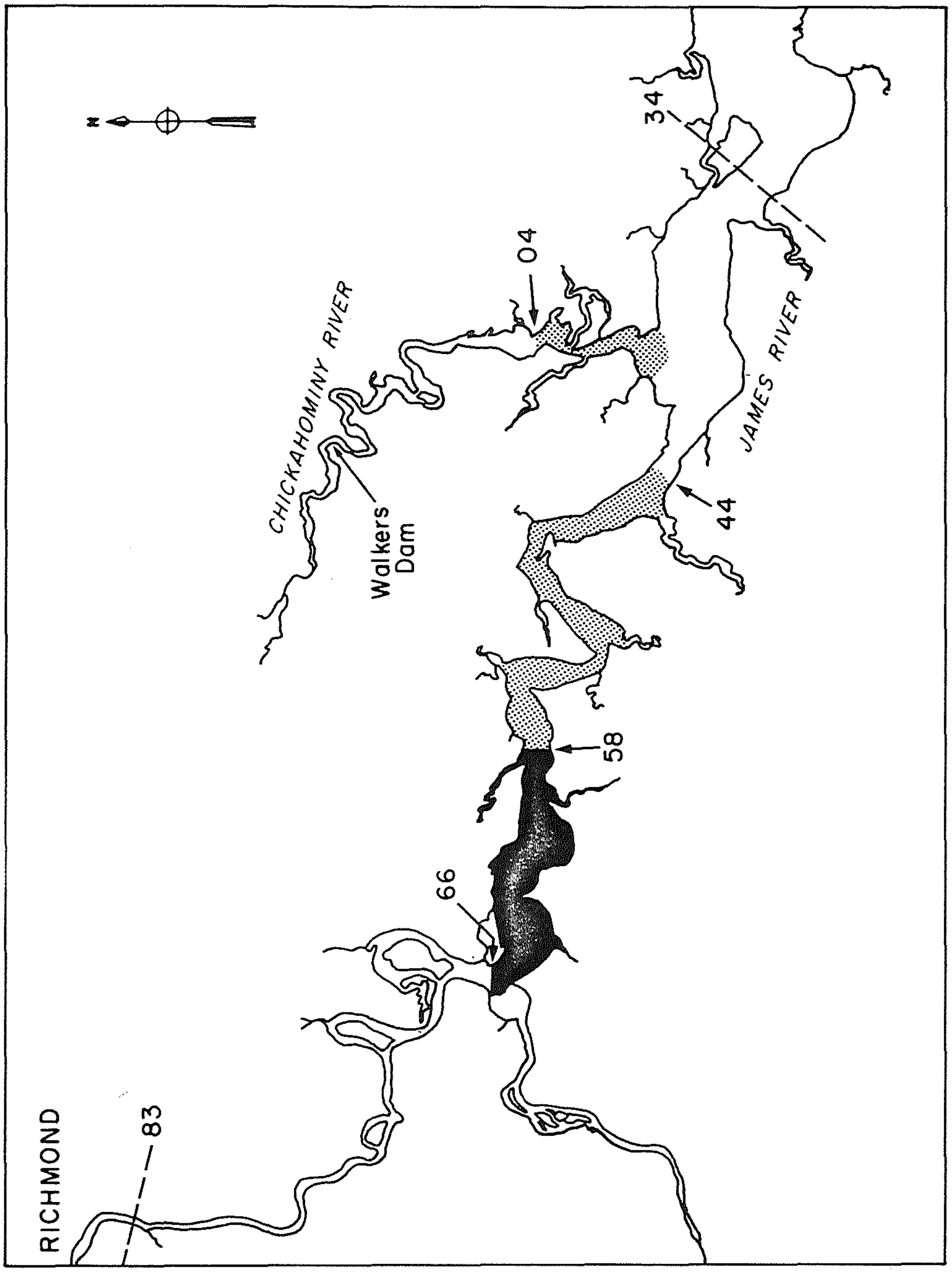


Fig. 3 . Spatial extent of striped bass eggs, James River, spring 1981. Darkest area represents greatest spawning activity.

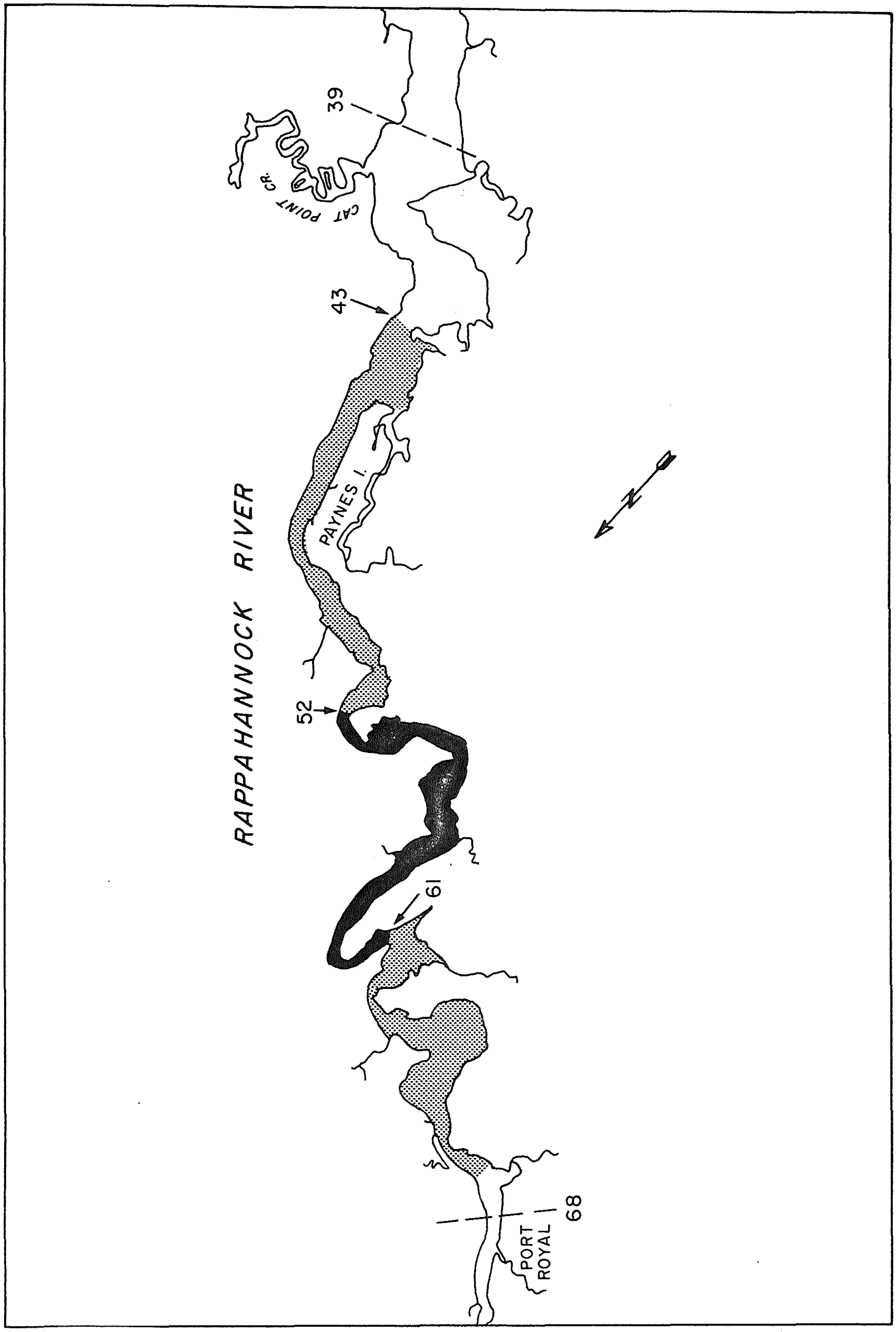
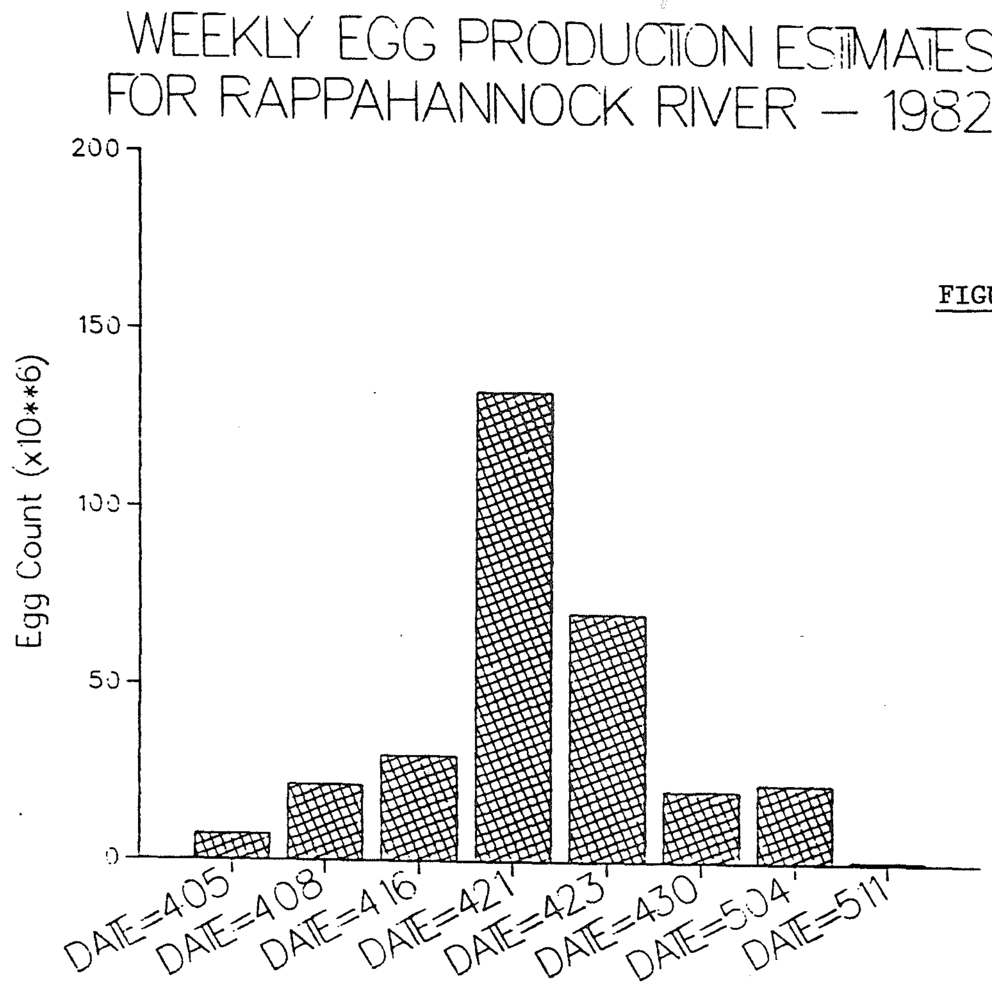


Fig. 4. Spatial extent of striped bass eggs, Rappahannock River, spring 1982. Darkest area represents greatest spawning activity.

FIGURE 5


WEEKLY EGG PRODUCTION ESTIMATES
FOR RAPPAHANNOCK RIVER — 1982
Egg Count (x10**6)
200
150
100
50
0
DATE=405
DATE=408
DATE=416
DATE=421
DATE=423
DATE=430
DATE=504
DATE=511

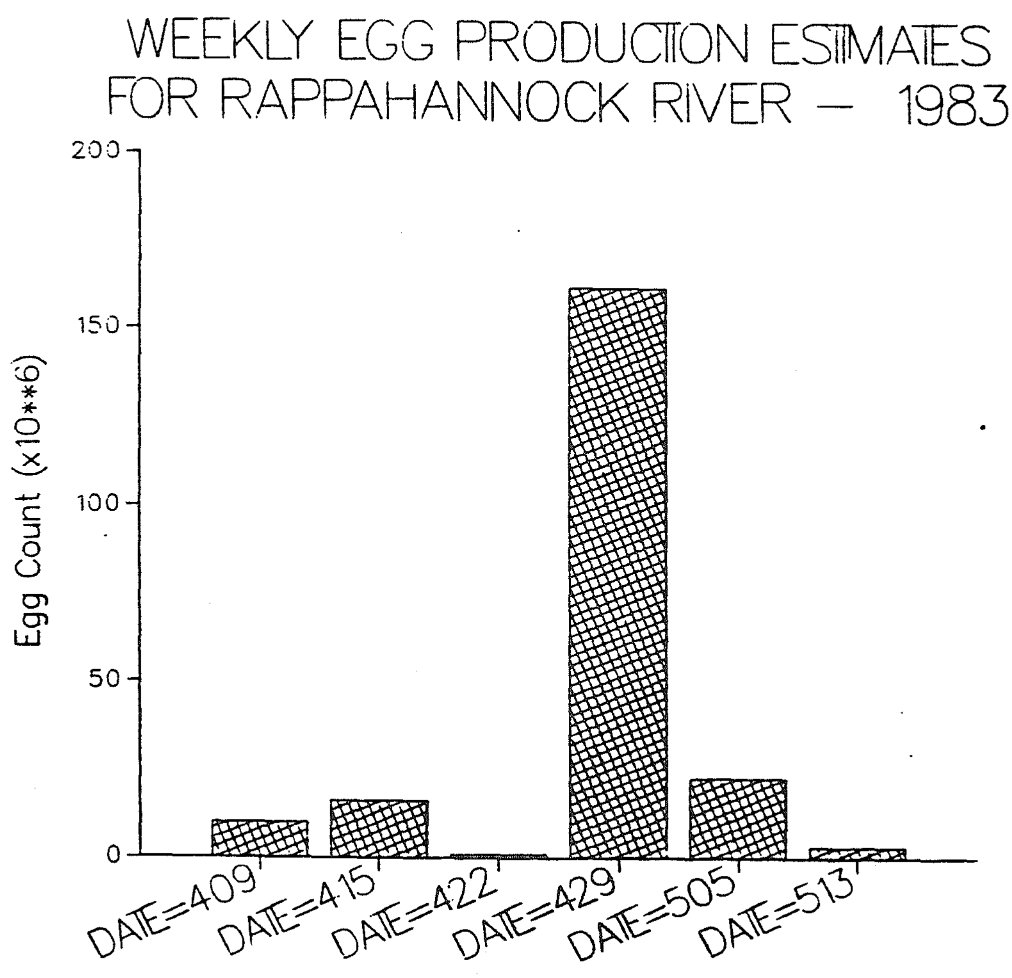
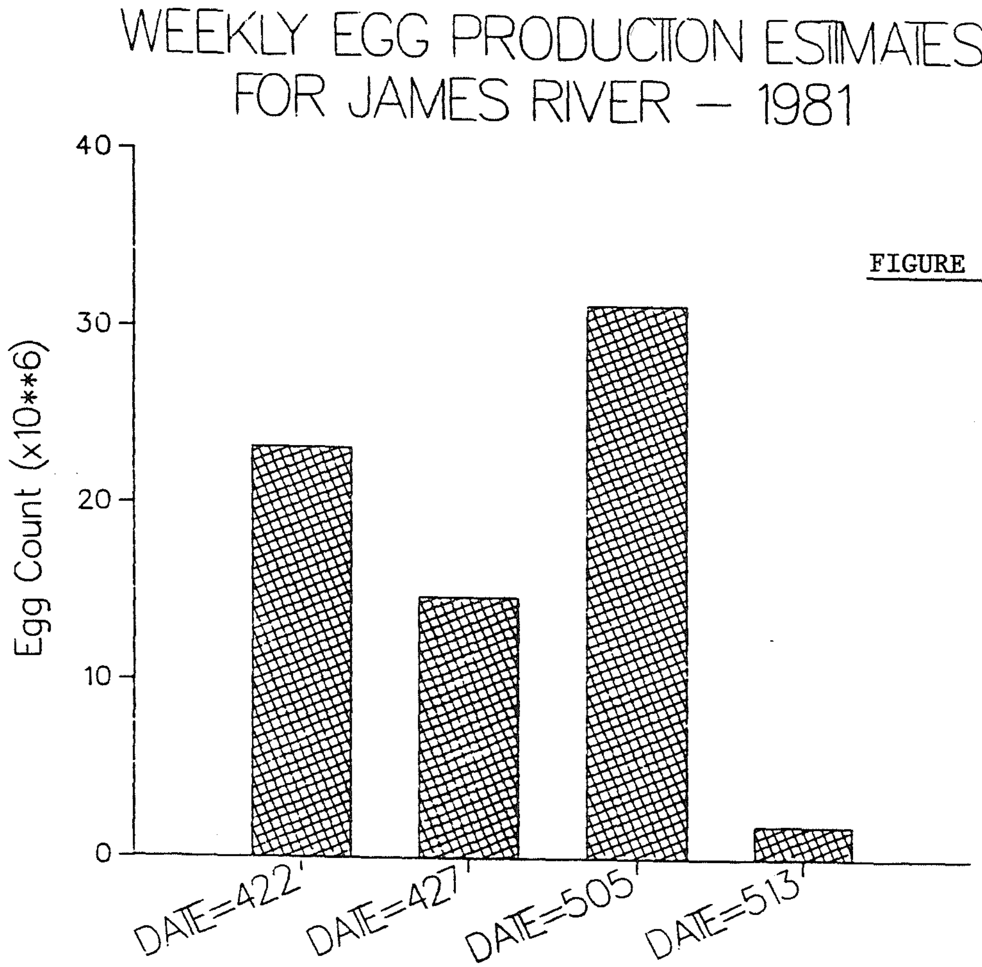
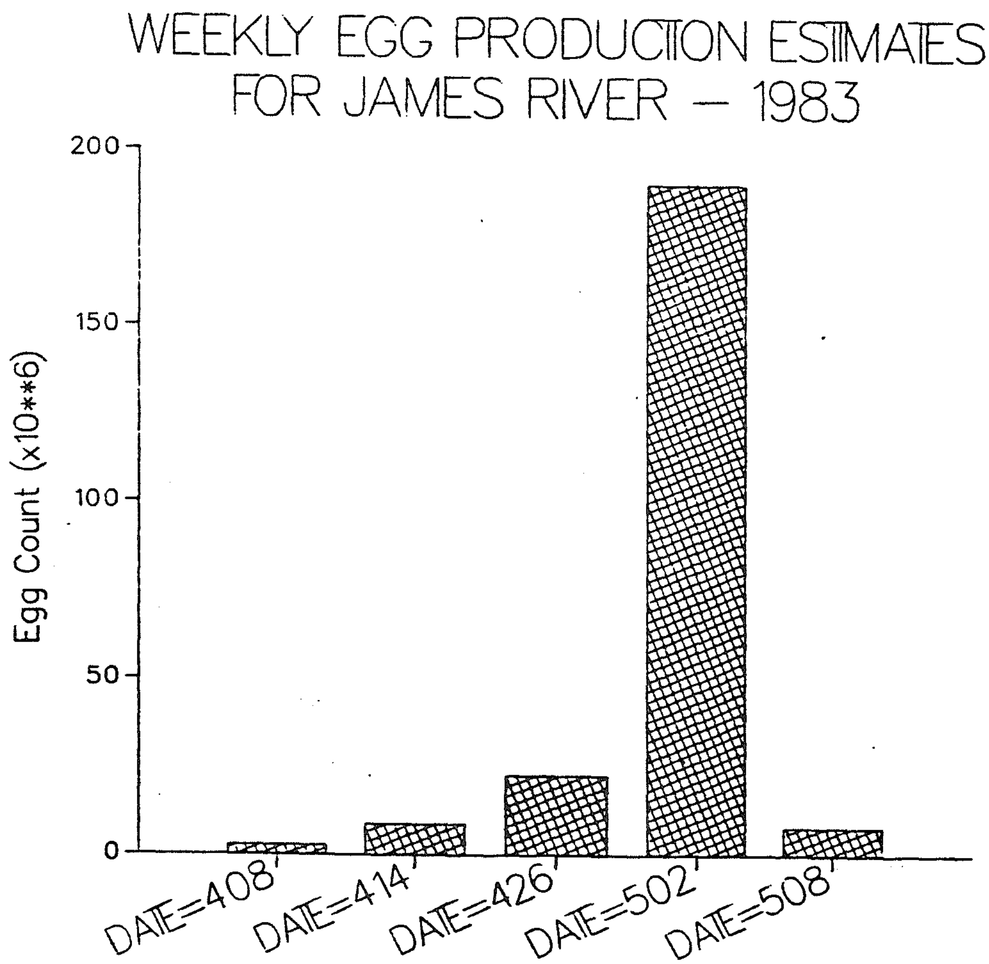

WEEKLY EGG PRODUCTION ESTIMATES
FOR RAPPAHANNOCK RIVER — 1983
Egg Count (x10**6)
200
150
100
50
0
DATE=409
DATE=415
DATE=422
DATE=429
DATE=505
DATE=513

FIGURE 6


WEEKLY EGG PRODUCTION ESTIMATES
FOR JAMES RIVER – 1981
Egg Count (x10**6)
40
30
20
10
0
DATE=422
DATE=427
DATE=505
DATE=513


WEEKLY EGG PRODUCTION ESTIMATES
FOR JAMES RIVER – 1983
Egg Count (x10**6)
200
150
100
50
0
DATE=408
DATE=414
DATE=426
DATE=502
DATE=508

WEEKLY EGG PRODUCTION ESTIMATES
FOR PAMUNKEY RIVER — 1980

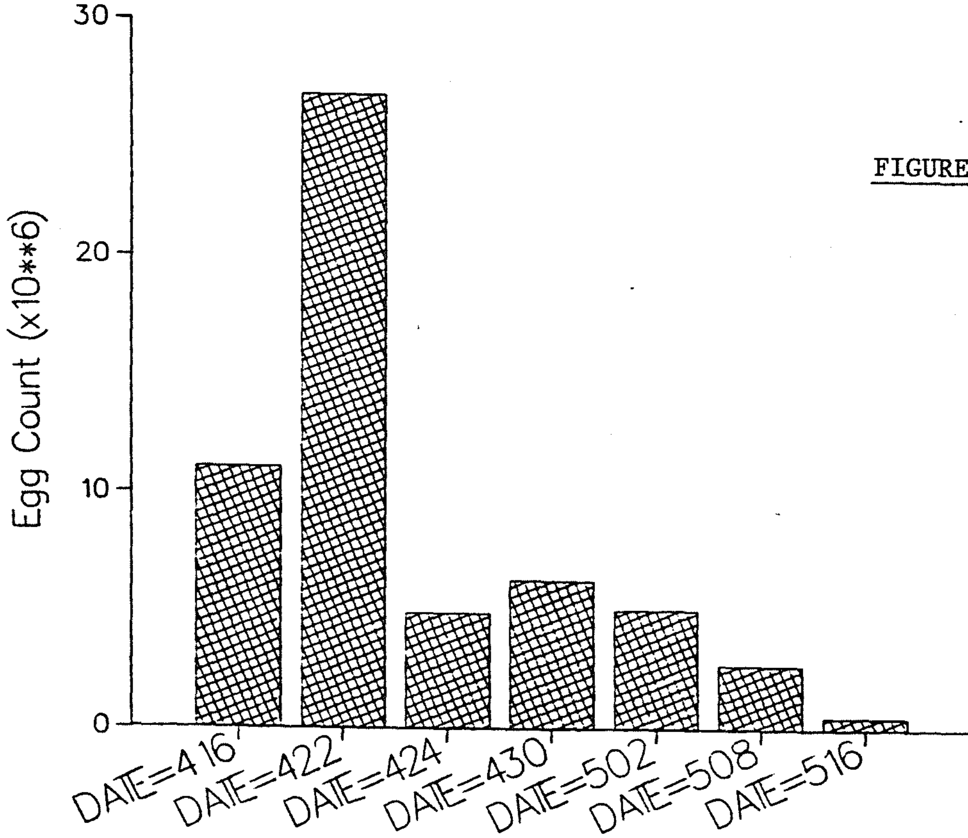
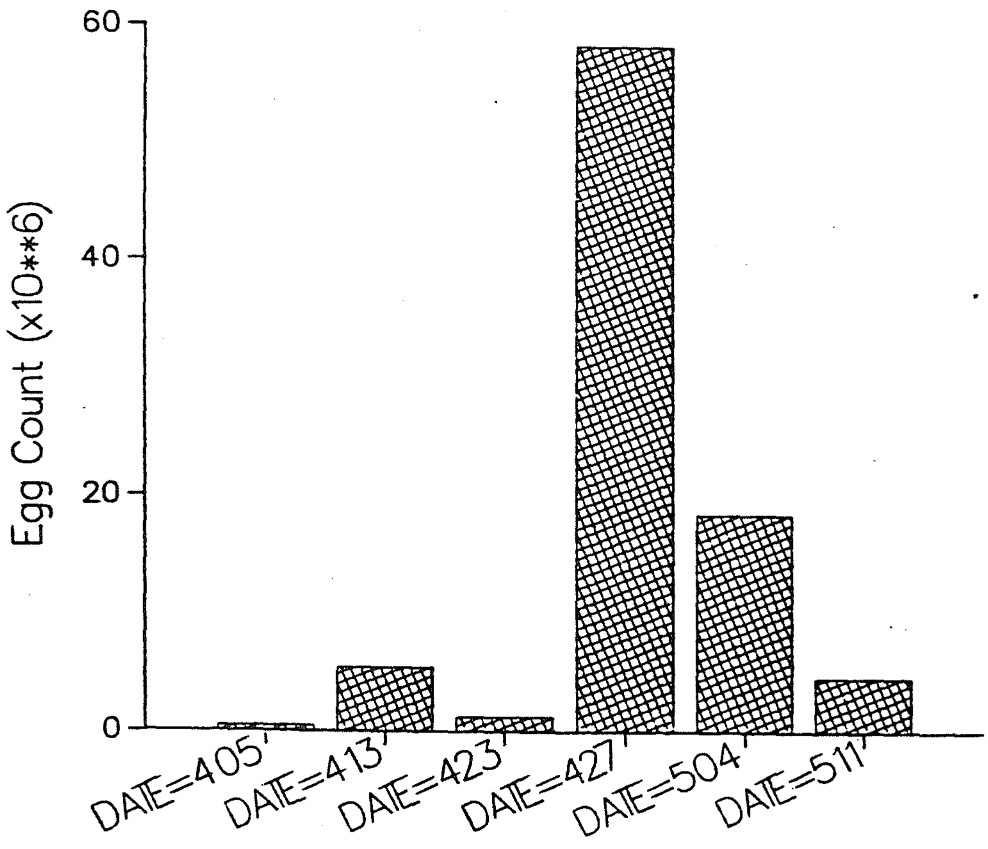


FIGURE 7

WEEKLY EGG PRODUCTION ESTIMATES
FOR PAMUNKEY RIVER — 1983



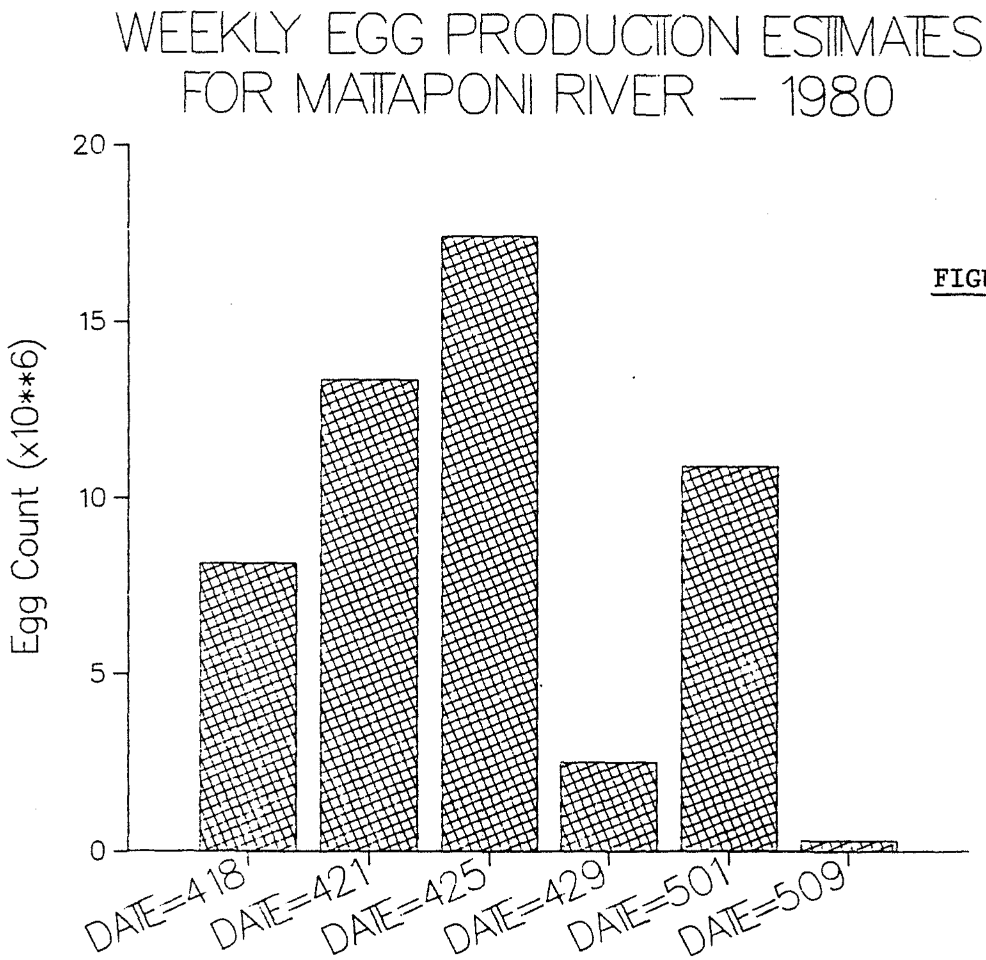

WEEKLY EGG PRODUCTION ESTIMATES
FOR MATTAPONI RIVER — 1980
Egg Count (x10**6)
20
15
10
5
0
DATE=418
DATE=421
DATE=425
DATE=429
DATE=501
DATE=509

FIGURE 8

Table 1. Physical data and water volume filtered (m^3) from egg production survey of the Rappahannock River, spring 1983. Mean temperatures (°C), salinities (o/oo) and dissolved oxygen concentrations (mg/l) are presented. Secchi disc depth in meters.

Strata		Date 4/9	4/15	4/22	4/29	5/5	5/13
39-41	River Mile	n.s.	n.s.	n.s.	40	n.s.	n.s.
	Temp				14.5		
	Sal				0.0		
	DO_2				9.9		
	Secchi				0.3		
	Volume				100.1		
42-44	River Mile	44	n.s.	42	44	44	44
	Temp	12.3		11.8	14.3	18.4	18.5
	Sal	0.0		0.0	0.0	0.0	.17
	DO_2	8.8		9.3	9.8	11.2	9.1
	Secchi	0.3		-	0.2	0.2	0.2
	Volume	106.9		81.9	103.5	108.4	53.7
45-47	River Mile	46	n.s.	46	46	46	47
	Temp	12.3		11.8	14.1	18.5	18.9
	Sal	0.1		0.0	0.0	0.0	0.0
	DO_2	9.3		8.5	9.4	9.9	9.8
	Secchi	0.3		0.2	0.2	0.3	0.2
	Volume	98.2		90.4	90.5	118.3	19.7
48-50	River Mile	50	50	49	50	50	49
	Temp.	12.4	13.3	11.9	14.5	18.8	19.2
	Sal	0.1	0.0	0.0	0.0	0.0	0.0
	DO_2	9.1	8.5	8.7	9.3	10.0	9.5
	Secchi	0.3	0.4	0.1	0.2	0.3	0.4
	Volume	90.7	91.3	91.0	116.5	161.7	18.7
51-53	River Mile	53	52	52	53	53	51
	Temp	12.3	13.4	11.3	14.6	19.1	19.4
	Sal	0.0	0.0	0.0	0.0	0.0	0.0
	DO_2	8.4	8.3	8.9	9.3	10.1	9.9
	Secchi	0.2	0.2	0.2	0.2	0.4	0.4
	Volume	87.9	155.9	117.9	137.0	139.6	12.7
54-56	River Mile	56	56	55	56	56	54
	Temp	12.1	13.3	11.5	15.5	19.8	19.6
	Sal	0.1	0.0	0.0	0.0	0.0	0.0
	DO_2	8.4	8.3	9.2	9.5	9.3	9.9
	Secchi	0.1	0.2	0.2	0.2	0.4	0.4
	Volume	113.3	87.6	119.7	72.8	89.9	20.7

Table 1 (Cont'd)

Strata		Date 4/9	4/15	4/22	4/29	5/5	5/13
57-59	River Mile	57	58	58	57	57	59
	Temp	12.1	13.5	11.6	16.0	19.6	20.1
	Sal	0.0	0.1	0.0	0.0	0.0	0.0
	DO_2	9.5	9.5	8.0	9.6	10.3	10.9
	Secchi	0.1	-	0.2	0.2	0.4	0.5
	Volume	50.2	119.9	75.7	105.3	164.3	26.3
60-62	River Mile	61	61	61	61	61	62
	Temp	12.3	13.4	11.3	16.3	20.4	21.0
	Sal	0.0	0.1	0.0	0.0	0.0	0.0
	DO_2	8.4	9.5	9.2	9.5	11.4	11.1
	Secchi	0.2	-	0.2	0.2	0.5	0.6
	Volume	120.6	109.5	92.9	119.9	136.1	20.0
63-65	River Mile	64	64	65	64	n.s.	n.s.
	Temp	12.3	13.6	11.8	15.8		
	Sal	0.0	0.0	0.0	0.0		
	DO_2	8.1	9.5	8.8	9.9		
	Secchi	0.1	0.2	0.2	0.2		
	Volume	71.6	85.9	82.0	97.2		
66-68	River Mile	67	68	68	67	n.s	n.s.
	Temp	11.9	13.4	11.1	16.4		
	Sal	0.0	0.0	0.0	0.0		
	DO_2	9.5	8.9	10.4	9.6		
	Secchi	0.1	0.3	0.3	0.3		
	Volume	131.9	86.2	67.9	112.9		

Table 2. Physical data and water volume filtered (m^3) from egg production survey of the James River, spring 1983. Mean temperatures (^oC), salinities (o/oo) and dissolved oxygen concentrations (mg/l) are presented. Secchi disc depth in meters.

Strata		4/8	4/14	Date 4/26	5/2	5/8
33-35	River Mile	n.s.	n.s.	n.s.	33	n.s.
	Temp				17.7	
	Sal				0.0	
	DO_2				9.2	
	Secchi				0.3	
	Volume				142.6	
36-38	River Mile	n.s.	n.s.	36	36	n.s.
	Temp			12.5	17.8	
	Sal			0.0	0.0	
	DO_2			9.0	9.5	
	Secchi			0.3	0.3	
	Volume			93.1	104.9	
39-41	River Mile	n.s.	n.s.	39	39	n.s.
	Temp			13.0	17.5	
	Sal.			0.0	0.0	
	DO_2			8.5	9.3	
	Secchi			0.3	0.3	
	Volume			111.4	117.4	
42-44	River Mile	42	44	42	42	42
	Temp	12.8	13.4	13.1	17.7	18.8
	Sal	0.1	0.0	0.0	0.0	0.0
	DO_2	8.4	8.1	8.1	8.8	8.7
	Secchi	0.2	0.1	0.3	0.3	0.5
	Volume	83.8	102.6	105.1	116.9	144.9
45-47	River Mile	46	47	45	45	45
	Temp	12.4	13.2	13.3	17.9	19.2
	Sal	0.1	0.0	0.0	0.0	0.0
	DO_2	8.6	9.3	9.0	8.8	8.6
	Secchi	0.2	0.2	0.3	0.3	0.5
	Volume	124.8	120.7	102.8	122.5	212.8
48-50	River Mile	49	48	50	50	50
	Temp	12.4	13.2	12.8	18.2	19.7
	Sal	0.0	0.0	0.0	0.0	0.0
	DO_2	9.6	8.1	9.0	8.9	9.7
	Secchi	0.1	0.2	0.4	0.4	0.6
	Volume	185.9	259.1	190.3	218.3	171.6

Table 2 (Cont'd)

Strata		4/8	4/14	4/26	5/2	5/8
				Date		
51-53	River Mile	52	52	52	52	52
	Temp	12.4	13.5	13.2	18.5	19.9
	Sal	0.2	0.0	0.0	0.0	0.0
	DO_2	9.5	9.5	9.0	8.9	8.7
	Secchi	0.2	0.2	0.4	0.4	0.4
	Volume	132.8	148.9	115.0	142.5	134.7
54-56	River Mile	56	55	56	56	56
	Temp	12.6	13.6	12.8	19.2	20.0
	Sal	0.1	0.0	0.0	0.0	0.0
	DO_2	8.6	8.1	9.0	8.7	9.7
	Secchi	0.2	0.2	0.3	0.4	0.5
	Volume	176.4	94.6	67.7	182.8	203.2
57-59	River Mile	58	58	58	58	58
	Temp	12.8	13.7	12.8	19.5	20.2
	Sal	0.0	0.0	0.0	0.1	0.0
	DO_2	8.1	8.1	9.1	8.6	9.4
	Secchi	0.3	0.2	-	0.4	-
	Volume	130.0	117.9	140.5	82.4	138.8
60-62	River Mile	62	60	60	60	n.s.
	Temp	12.7	13.6	12.9	19.6	
	Sal	0.2	0.0	0.0	0.0	
	DO_2	9.5	8.1	9.1	8.6	
	Secchi	0.3	0.3	0.3	0.4	
	Volume	61.9	87.9	98.4	64.6	
63-65	River Mile	63	64	n.s.	n.s.	n.s.
	Temp	12.7	13.6			
	Sal	0.0	0.0			
	DO_2	8.5	8.5			
	Secchi	0.3	0.3			
	Volume	110.6	115.2			

Table 3. Physical data and water volume filtered (m^3) from egg production survey of the Pamunkey River, spring 1983. Mean temperatures (°C), salinities (o/oo) and dissolved oxygen concentrations (mg/l) are presented. Secchi disc depth in meters.

Strata		4/5	4/13	4/23	4/27	5/4	5/11
				Date			
27-29	*River Mile	n.s.	n.s.	n.s.	27/29	28	n.s.
	Temp				13.9/13.7	19.4	
	Sal				1.78/0.5	0.3	
	DO_2				8.9/8.9	11.5	
	Secchi				0.4/0.4	0.2	
	Volume				87.6/95.2	41.8	
30-32	River Mile	31	31	30	30	30	31
	Temp	11.7	12.9	13.0	13.8	19.7	19.0
	Sal	1.1	0.1	1.9	0.0	0.1	1.5
	DO_2	8.7	8.6	7.6	9.1	10.9	8.1
	Secchi	0.3	0.3	0.3	0.3	0.3	0.4
	Volume	99.2	106.7	99.5	93.3	90.7	136.5
33-35	River Mile	33	34	34	35	33	33
	Temp	11.5	13.6	12.7	13.7	19.3	19.2
	Sal	0.1	0.0	0.4	0.0	0.0	0.5
	DO_2	9.1	8.1	8.1	9.1	10.8	8.1
	Secchi	0.3	0.5	0.3	0.3	0.5	0.4
	Volume	108.7	110.4	99.2	106.0	93.1	90.6
36-38	River Mile	38	37	37	36	36	36
	Temp	11.6	14.0	12.6	14.0	-	19.4
	Sal	0.1	0.0	0.0	0.0	0.0	0.0
	DO_2	8.5	8.9	8.1	9.0	9.5	8.4
	Secchi	0.4	0.5	0.3	0.4	0.5	0.3
	Volume	104.4	99.5	100.3	78.6	92.7	70.2
39-41	River Mile	39	41	40	39	40	41
	Temp	11.5	13.9	12.4	14.1	19.8	19.5
	Sal	0.1	0.0	0.0	0.0	0.0	0.0
	DO_2	8.5	8.3	8.1	9.0	10.7	8.9
	Secchi	0.4	0.5	0.3	0.4	0.5	0.5
	Volume	84.6	107.9	138.0	106.7	64.3	75.3
42-44	River Mile	44	44	43	43	43	44
	Temp	11.4	14.3	12.3	14.5	20.7	19.9
	Sal	0.1	0.0	0.0	0.0	0.0	0.0
	DO_2	9.0	8.6	8.1	9.1	8.7	9.3
	Secchi	0.4	0.5	0.3	0.4	0.5	0.5
	Volume	164.5	139.0	103.0	75.5	78.2	47.9

Table 3 (Cont'd)

Strata		4/5	4/13	Date 4/23	4/27	5/4	5/11
45-47	River Mile	45	45	47	46	47	45
	Temp	11.6	14.5	12.6	14.9	20.2	20.0
	Sal	0.1	0.0	0.0	0.0	0.0	0.0
	DO_2	9.4	9.3	7.8	9.5	10.0	9.0
	Secchi	0.4	0.6	0.3	0.4	0.5	0.5
	Volume	90.8	99.6	154.7	85.1	124.4	81.8
48-50	River Mile	49	48	50	50	50	50
	Temp	12.1	14.3	13.0	14.7	20.4	20.1
	Sal	0.0	0.1	0.0	0.0	0.0	0.0
	DO_2	9.9	8.7	8.0	8.9	9.0	8.8
	Secchi	0.4	0.6	0.3	0.6	0.5	0.6
	Volume	111.1	167.3	117.8	124.0	76.4	95.3
51-53	River Mile	53	53	n.s.	51	52	52
	Temp	12.6	14.2		15.0	20.4	20.1
	Sal	0.1	0.1		0.0	0.0	0.0
	DO_2	8.4	8.1		8.8	9.2	8.8
	Secchi	0.5	0.6		0.6	0.5	0.5
	Volume	125.3	122.4		106.5	65.6	87.3
54-56	River Mile	n.s	n.s.	n.s.	n.s.	n.s.	n.s.
	Temp						
	Sal						
	DO_2						
	Secchi						
	Volume						

*Miles 27-29 are in the main stem of the York River.

Table 4. Tidally averaged total water volume ($10^6 M^3$) per stratum on four Virginia rivers. Calculations based on Cronin 1971. Pamunkey River stratum 27-29 is actually within the main stem of the York River.

Stratum Midpoint	James	Rappahannock	Pamunkey	Mattaponi
28			26.36	
31			15.40	10.04
34	69.37		13.64	7.47
37	76.49		12.36	8.82
40	68.54	24.31	12.74	8.13
43	57.30	31.07	12.10	9.09
46	42.43	27.79	12.22	7.64
49	34.68	18.39	11.79	
52	35.07	15.09	10.17	
55	29.55	18.97		
58	37.99	12.30		
61	27.86	19.20		
64	18.60	16.24		
67	10.87	9.25		
Total	508.75	192.61	126.78	51.19

Table 5. Total catches of striped bass eggs from the Rappahannock River, spring 1983 (n.s. = stratum not sampled).

River Mile Stratum		Date 4/9	4/15	4/22	4/29	5/5	5/13
39-41	River Mile	n.s.	n.s.	n.s.	40	n.s.	n.s.
	Total eggs				1		
	Egg density (No./100m^3)				1.00		
42-44	River Mile	44	n.s.	42	44	44	44
	Total eggs	2		0	1	17	0
	Egg density (No./100m^3)	1.87			0.97	15.68	
45-47	River Mile	46	n.s.	46	46	46	47
	Total eggs	2		0	8	42	1
	Egg density (No./100m^3)	2.04			8.84	35.50	5.08
48-50	River mile	50	50	49	50	50	49
	Total eggs	0	9	1	174	28	0
	Egg density (No./100m^3)		9.86	1.10	149.36	17.32	
51-53	River mile	53	52	52	53	53	51
	Total eggs	5	17	1	221	18	0
	Egg density (No./100m^3)	5.69	10.90	0.85	161.31	12.89	
54-56	River mile	56	56	55	56	56	54
	Total eggs	14	22	1	347	9	2
	Egg density (No./100m^3)	12.36	25.11	0.84	476.65	10.01	9.66
57-59	River mile	57	58	58	57	57	59
	Total eggs	14	33	3	108	10	0
	Egg density (No./100m^3)	27.89	27.52	3.96	102.56	6.09	
60-62	River mile	61	61	61	61	61	62
	Total eggs	14	25	0	23	1	0
	Egg density (No./100m^3)	11.61	22.83		19.18	0.73	
63-65	River Mile	64	64	65	64	n.s.	n.s.
	Total eggs	0	0	0	0		
	Egg density (No./100m^3)						

Table 5 (Cont'd)

River Mile Stratum		4/9	4/15	4/22	4/29	5/5	5/13
66-68	River Mile	67	68	68	67	n.s.	n.s.
	Total eggs	0	0	0	0		
	Egg density (No./100m^3)						

Table 6. Total catches of striped bass eggs from the James River, spring 1983 (n.s. = stratum not sampled).

River mile Stratum		4/8	4/14	Date 4/26	5/2	5/8
33-35	River mile	n.s.	n.s.	n.s.	33	n.s.
	Total eggs				19	
	Egg density (No./100m^3)				13.32	
36-38	River mile	n.s.	n.s.	36	36	n.s.
	Total eggs			3	52	
	Egg density (No./100m^3)			3.22	49.57	
39-41	River mile	n.s.	n.s.	39	39	n.s.
	Total eggs			10	43	
	Egg density (No./100m^3)			8.98	36.63	
42-44	River mile	42	44	42	42	42
	Total eggs	0	0	22	7	0
	Egg density (No./100m^3)			20.93	5.99	
45-47	River mile	46	47	45	45	45
	Total eggs	0	0	4	16	1
	Egg density (No./100m^3)			3.89	13.06	0.47
48-50	River mile	49	48	50	50	50
	Total eggs	0	0	0	233	1
	Egg density (No./100m^3)				106.73	0.58
51-53	River mile	52	52	52	52	52
	Total eggs	1	12	0	278	3
	Egg density (No./100m^3)	0.75	8.06		195.09	2.23
54-56	River mile	56	55	56	56	56
	Total eggs	0	19	0	19	13
	Egg density (No./100m^3)		20.08		10.39	6.40
57-59	River mile	58	58	58	58	58
	Total eggs	0	0	1	1	18
	Egg density (No./100m^3)			0.71	1.21	12.97

Table 6 (Cont'd)

River mile Stratum		4/8	4/14	4/26	5/2	5/8
60-62	River mile	62	60	60	60	n.s.
	Total eggs	0	0	0	0	
	Egg density (No./100m^3)					
63-65	River mile	63	64	n.s.	n.s.	n.s.
	Total eggs	0	0			
	Egg density (No./100m^3)					

Table 7. Total catches of striped bass eggs from the Pamunkey River, spring 1983 (n.s. = stratum not sampled).

River mile stratum		Date 4/5	4/13	4/23	4/27	5/4	5/11
27-29	River mile	n.s.	n.s.	n.s.	27/29	28	n.s.
(This stratum	Total eggs				2/61	1	
is in	Egg density				2.3/64.1	2.39	
York R.)	(No./100m^3)						
30-32	River mile	31	31	30	30	30	31
	Total eggs	0	2	2	61	0	0
	Egg density		1.87	2.01	65.38		
	(No./100m^3)						
33-35	River mile	33	34	34	35	33	33
	Total eggs	0	34	3	70	34	4
	Egg density		30.80	3.02	66.04	36.52	4.42
	(No./100m^3)						
36-38	River mile	38	37	37	36	36	36
	Total eggs	0	0	0	42	15	4
	Egg density				53.44	16.18	5.70
	(No./100m3)						
39-41	River Mile	39	41	40	39	40	41
	Total eggs	3	6	3	49	10	14
	Egg density	3.55	5.6	2.17	45.92	15.55	18.59
	(No./100m^3)						
42-44	River mile	44	44	43	43	43	44
	Total eggs	0	1	2	10	18	1
	Egg density		0.72	1.94	13.25	23.02	2.09
	(No./100m^2)						
45-47	River mile	45	45	47	46	47	45
	Total eggs	0	1	0	56	37	3
	Egg density		1.00		65.8	29.74	3.67
	(No./100m^3)						
48-50	River Mile	49	48	50	50	50	50
	Total eggs	0	0	0	1	12	1
	Egg density				0.81	15.71	1.05
	(No./100m^3)						
51-53	River mile	53	53	n.s.	51	52	52
	Total eggs	0	0		1	4	1
	Egg density				0.94	6.10	1.15
	(No/100m^3)						

Table 8. Catches of striped bass larvae in the Rappahannock River, spring 1983.

River Mile Stratum		Date 5/5	5/13
42-44	River mile	44	44
	Total larvae	41	3
	Larval density (No./100m^3)	37.8	5.6
45-47	River mile	46	47
	Total larvae	122	13
	Larval density (No./100m^3)	103.1	65.9
48-50	River mile	50	49
	Total larvae	63	0
	Larval density (No./100m^3)	38.9	0
51-53	River mile	53	51
	Total larvae	111	5
	Larval density (No./100m^3)	79.5	39.4
54-56	River mile	56	54
	Total larvae	35	1
	Larval density (No./100m^3)	38.9	4.8
57-59	River mile	57	59
	Total larvae	45	0
	Larval density (No./100m^3)	27.4	0
60-62	River mile	61	62
	Total larvae	0	0
	Larval density (No./100m^3)	0	0
	Total larvae per cruise	417	22

Table 9. Catches of striped bass larvae in the James River, spring 1983 (n.s. = stratum not sampled).

River mile stratum		Date 5/2	Date 5/8
33-35	River mile	33	n.s.
	Total larvae	0	
	Larval density (No./100m^3)	0	
36-38	River mile	36	n.s.
	Total larvae	0	
	Larval density (No./100m^3)	0	
39-41	River mile	39	n.s.
	Total larvae	0	
	Larval density (No./100m^3)	0	
42-44	River mile	42	42
	Total larvae	0	14
	Larval density (No./100m^3)	0	9.6
45-47	River mile	45	45
	Total larvae	30	15
	Larval density (No./100m^3)	24.5	7.0
48-50	River mile	50	50
	Total larvae	5	54
	Larval density (No./100m^3)	2.3	31.5
51-53	River mile	52	52
	Total larvae	1	18
	Larval density (No./100m^3)	0.7	13.4
54-56	River mile	56	56
	Total larvae	0	12
	Larval density (No./100m^3)	0	5.9

(Table 9 - Continued)

River mile stratum		Date 5/2	5/8
57-59	River mile	58	58
	Total larvae	0	6
	Larval density (No./100m^3)	0	4.3
60-62	River mile	60	n.s.
	Total larvae	0	
	Larval density (No./100m^3)	0	
	Total larvae per cruise	36	119

Table 10. Catches of striped bass larvae in the Pamunkey River, spring 1983 (n.s. = not sampled).

River mile stratum		Date 5/4	5/11
27-29 (This stratum is in the York River)	River mile	28	n.s.
	Total larvae	1	
	Larval density (No./100m^3)	2.3	
30-32	River mile	30	31
	Total larvae	0	0
	Larval density (No./100m^3)	0	0
33-35	River mile	33	33
	Total larvae	0	0
	Larval density (No./100m^3)	0	0
36-38	River mile	36	36
	Total larvae	2	0
	Larval density (No./100m^3)	2.2	0
39-41	River mile	40	41
	Total larvae	0	0
	Larval density (No./100m^3)	0	0
42-44	River mile	43	44
	Total larvae	0	3
	Larval density (No./100m^3)	0	6.3
45-47	River mile	47	45
	Total larvae	2	19
	Larval density (No./100m^3)	1.6	23.2
48-50	River mile	50	50
	Total larvae	0	6
	Larval density (No./100m^3)	0	6.3
51-53	River mile	52	52
	Total larvae	0	5
	Larval density (No./100m^3)	0	5.7
	Total larvae per cruise	5	36

Table 11. Length (mm NL) frequency distribution of striped bass larvae captured in May 1983. Abbreviations are J - James R.; P - Pamunkey R.; R - Rappahannock R.

Date	5/2	5/4	5/5	5/8	5/11	5/13	
River	J	P	R	J	P	R	Totals
2.0 - 2.9	8	1	6	1	1	1	18
3.0 - 3.9	20	8	125	14	1		168
4.0 - 4.9	8		176	55	11		250
5.0 - 5.9			103	43	20	8	174
6.0 - 6.9			7	6		10	23
7.0 - 7.9						2	2
Totals	36	9	417	119	33	21	635

Table 12. Summary of striped bass egg and larval survey data from major Virginia tributaries, 1980-1983.

1980-1982	PAMUNKEY	MATTAPONI	JAMES	RAPPAHANNOCK
First sampling date	16 Apr 1980	18 Apr 1980	22 Apr 1981	5 Apr 1982
Last sampling date	13 Jun 1980	14 Jun 1980	18 Jun 1981	23 Jun 1982
Total survey cruises	13	13	9	19
Total stations	108	100	123	174
Total eggs	500	720	428	1976
Total larvae	162	153	431	4792
1983				
First sampling date	5 Apr 1983	-	8 Apr 1983	9 Apr 1983
Last sampling date	11 May 1983	-	8 May 1983	13 May 1983
Total survey cruises	6	-	5	6
Total stations	50	-	41	49
Total eggs	569	-	776	1174
Total larvae	41	-	155	439

Table 13. Estimated total number of eggs ($X10^6$) in the area represented by each station sampled on the Rappahannock River in 1982. Abbreviations used are NS - not sampled.

STRATUM	DATE									
	5 Apr	8 Apr	16 Apr	21 Apr	23 Apr	30 Apr	4 May	11 May	TOTAL	% TOTAL
39-41	NS	NS	NS	NS	NS	NS	NS	NS	NS	0
42-44	NS	NS	NS	0	0	1.606	0.217	0	1.823	0.6
45-47	NS	NS	0	4.141	1.000	5.764	1.198	0	12.103	4.0
48-50	NS	1.017	0	13.827	4.423	3.757	4.932	0	27.956	9.1
51-53	NS	7.687	0.910	16.859	17.376	3.107	2.356	0	48.295	15.8
54-56	NS	5.040	0.867	50.859	41.417	4.018	3.407	0	105.608	34.5
57-59	1.213	1.585	0	41.554	3.160	1.242	6.093	0.214	55.061	18.0
60-62	4.441	6.198	27.312	5.954	3.197	0.814	2.953	0	50.869	16.6
63-65	1.200	0	0.219	0	0	0	0.976	0.499	2.894	0.9
66-68	0.420	0	0.561	0	0	0	0.168	0	1.149	0.4
69-71	0	0	0	NS	NS	NS	NS	NS	0	0

Table 14. Estimated total number of eggs ($X10^6$) in the area represented by each station sampled on the Rappahannock River in 1983. Abbreviations used are NS - not sampled.

STRATUM	DATE							
	9 Apr	15 Apr	22 Apr	29 Apr	5 May	13 May	Total	% Total
39-41	NS	NS	NS	0.243	NS	NS	0.243	0.1
42-44	0.581	NS	0	0.301	4.872	0	5.754	2.7
45-47	0.567	NS	0	2.747	9.866	1.412	14.592	7.0
48-50	0	1.870	0.202	27.467	3.185	0	32.724	15.2
51-53	0.859	1.645	0.128	24.342	1.945	0	28.919	13.5
54-56	2.345	4.763	0.159	90.421	1.899	1.833	101.420	47.2
57-59	3.430	3.385	0.487	12.615	0.749	0	20.666	9.6
60-62	2.229	4.383	0	3.683	0.140	0	10.435	4.9
63-65	0	0	0	0	NS	NS	0	0

Table 15. Estimated total number of eggs ($X10^6$) in the area represented by each station sampled on the James River in 1981. NS - not sampled

STRATUM	DATE					
	22 Apr	27-28 Apr	5-6 May	13-15 May	Total	% Total
33-35	0	NS	NS	NS	0	0
36-38	0	NS	NS	NS	0	0
39-41	0	0	0	0	0	0
42-44	0	0	6.787	0	6.787	9.5
45-47	0.465	0	2.384	0	2.849	4.0
48-50	0.441	0	0.567	0	1.008	1.4
51-53	4.050	0	0	0	4.050	5.7
54-56	0.506	2.156	0	0.726	3.388	4.8
57-59	15.155	9.421	2.602	1.159	28.337	39.8
60-62	2.028	3.069	12.871	0	17.968	25.2
63-65	0.565	0.106	5.127	0	5.798	8.1
66-68	NS	0	1.017	0	1.017	1.4

Table 16 . Estimated total number of eggs ($X10^6$) in the area represented by each station sampled on the James River in 1983. NS - not sampled

STRATUM	DATE						
	8 Apr	14 Apr	26 Apr	2 May	8 May	Total	% Total
33-35	NS	NS	NS	9.240	NS	9.240	4.0
36-38	NS	NS	2.463	37.916	NS	40.379	17.6
39-41	NS	NS	6.155	25.106	NS	31.261	13.6
42-44	0	0	11.993	3.432	0	15.425	6.7
45-47	0	0	1.651	5.541	0.199	7.391	3.2
48-50	0	0	0	37.014	0.201	37.215	16.2
51-53	0.263	2.827	0	68.418	0.782	72.290	31.5
54-56	0	5.934	0	3.070	1.891	10.895	4.7
57-59	0	0	0.270	0.460	4.927	5.657	2.5
60-62	0	0	0	0	NS	0	0
63-65	0	0	NS	NS	NS	0	0
66-68	NS	NS	NS	NS	NS	NS	0

Table 17. Estimated total number of eggs ($X10^6$) in the area represented by each station sampled on the Pamunkey River in 1980. NS - not sampled.

STRATUM	DATE								
	16 Apr	22 Apr	24 Apr	30 Apr	2 May	8 May	16 May	Total	% Total
27-29	NS	NS	NS	NS	NS	NS	NS	NS	
30-32	3.846	0.336	0	0	0.813	0	0	4.995	8.7
33-35	3.561	14.547	0.116	0	0	0	0	18.224	31.8
36-38	1.355	2.978	1.858	0.884	0.138	0	0	7.213	12.6
39-41	2.304	0.684	0.191	5.038	0.873	0	0.131	9.221	16.1
42-44	0	1.476	1.574	0	0	0	0	3.050	5.3
45-47	0	6.793	0.498	0.120	1.348	0.466	0.278	9.503	16.6
48-50	0	0	0.656	0	0.855	2.267	0.093	3.871	6.7
51-53	0	0.087	0	0.180	1.045	0	0	1.312	2.3

Table 18. Estimated total number of eggs ($X10^6$) in the area represented by each station sampled on the Pamunkey River in 1983. NS - not sampled.

STRATUM	DATE							
	5 Apr	13 Apr	23 Apr	27 Apr	4 May	11 May	Total	% Total
27-29	NS	NS	NS	16.897	0.630	NS	17.527	19.8
30-32	0	0.288	0.310	10.069	0	0	10.666	12.1
33-35	0	4.201	0.412	9.008	4.984	0.603	19.208	21.7
36-38	0	0	0	6.605	1.999	0.705	9.309	10.5
39-41	0.452	0.713	0.276	5.850	1.981	2.368	11.642	13.2
42-44	0	0.087	0.235	1.603	2.785	0.253	4.964	5.6
45-47	0	0.122	0	8.041	3.634	0.444	12.246	13.8
48-50	0	0	0	0.096	1.852	0.124	2.072	2.3
51-53	0	0	NS	0.096	0.620	0.117	0.833	0.9

Table 19 . Estimated total number of eggs ($X10^6$) in the area represented by each station sampled on the Mattaponi River, 1980.

STRATUM	DATE							
	18 Apr	21 Apr	25 Apr	29 Apr	1 May	9 May	Total	% Total
30-32	4.593	0.107	0.813	0	5.561	0	11.074	21.0
33-35	2.237	11.700	8.366	0.515	4.930	0	27.748	52.7
36-38	1.301	1.105	7.494	1.837	0.287	0.291	12.315	23.4
39-41	0	0.316	0.750	0.159	0.140	0	1.365	2.6
42-44	0	0.153	0	0	0	0	0.153	0.3
45-47	0	0.030	0	0	0	0	0.030	0.1

Table 20. Annual spawning and female biomass estimates for the Rappahannock River, 1982-3. Abbreviations used are: D_i - days represented by each cruise; d_i - duration of the egg stage; P_i - cruise egg production estimates; $S^2_{P_i}$ - variance estimate; CI - 95% confidence interval.

Year	Cruise Date	Daily Spawning Estimate (eggs $X10^6$)	D_i (days)	d_i (days)	P_i (eggs $X10^8$)	$S^2_{P_i}$ ($X10^{16}$)	Annual Egg Production (eggs $X10^8$)	CI (egg $X10^8$)	Female Biomass (Kg)
1982	5 Apr	1.323	5.5	3.0	0.073	0.038			
	8 Apr	3.915	5.5	3.7	0.215	0.082			
	16 Apr	4.595	6.5	2.9	0.299	1.304			
	21 Apr	38.054	3.5	2.4	1.332	0.317			
	23 Apr	15.682	4.5	2.6	0.706	0.663			
	30 Apr	3.693	5.5	2.3	0.203	0.300			
	4 May	4.055	5.5	1.9	0.223	1.799			
	11 May	0.095	7.5	1.7	0.007	0.229			
Annual Total			44		3.058	4.733	5.45	± 1.508	2540
1983	9 Apr	0.910	11.0	3.1	0.100	2.533			
	15 Apr	2.469	6.5	2.9	0.161	0.055			
	22 Apr	0.140	7.0	3.3	0.009	0.037			
	29 Apr	24.846	6.5	2.6	1.615	10.167			
	5 May	3.237	7.0	1.8	0.227	1.974			
	13 May	0.541	6.0	1.7	0.032	1.366			
Annual Total			44		2.144	16.132	5.81	± 3.214	2707

Table 21. Annual spawning and female biomass estimates for the James River, 1981 and 1983. Abbreviations used as in Table 20 .

Year	Cruise Date	Daily Spawning Estimate (eggs $X10^6$)	D_i (days)	d_i (days)	P_i (eggs $X10^7$)	$S^2_{P_i}$ ($X10^{17}$)	Annual Egg Production (eggs $X10^8$)	CI (eggs $X10^8$)	Female Biomass (Kg)
1981	22 Apr	0.967	24	2.3	2.321	4.678			
	27-28 Apr	2.108	7	1.9	1.475	0.269			
	5-6 May	3.919	8	1.8	3.135	2.168			
	13-15 May	0.377	5	1.7	0.189	0.001			
Annual Total			44		7.120	7.115	4.380	± 8.268	Not calculated
1983	8 Apr	0.003	10	3.1	0.263	0			
	14 Apr	0.973	9	2.9	0.876	0.016			
	26 Apr	2.503	9	3.0	2.253	1.269			
	2 May	31.699	6	1.9	19.020	2.934			
	8 May	0.800	10	1.7	0.800	0.895			
Annual Total			44		23.212	5.114	7.242	± 6.269	Not calculated

Table 22 . Annual spawning and female biomass estimates for the Pamunkey River, 1980 and 1983. Abbreviations used as in Table 20 .

Year	Cruise Date	Daily Spawning Estimate (eggs X10^6)	D_i (days)	d_i (days)	P_i (eggs X10^6)	$S^2_{P_i}$ (X10^{15})	Annual Egg Production (eggs X10^8)	CI (eggs X10^8)	Female Biomass (Kg)
1980	16 Apr	0.615	18	2.6	11.065	2.601			
	22 Apr	6.725	4	2.1	26.901	8.522			
	24 Apr	1.223	4	1.9	4.893	1.333			
	30 Apr	1.575	4	2.1	6.301	3.270			
	2 May	1.268	4	2.0	5.072	2.640			
	8 May	0.390	7	1.9	2.733	0.982			
	16 May	0.006	8	1.5	0.502	4.263			
Annual Total			45		57.467	23.611	1.723	± .581	803
1983	5 Apr	0.090	5	3.2	0.452	0			
	13 Apr	0.601	9	2.8	5.412	7.959			
	23 Apr	0.176	7	3.1	1.233	0.486			
	27 Apr	10.593	5.5	2.8	58.264	1[illegible].203			
	4 May	2.641	7	2.1	18.487	13.399			
	11 May	0.616	7.5	1.7	4.618	5.159			
Annual Total			44		88.466	41.206	2.193	±1.624	1022

Table 23. Annual spawning and biomass estimates for the Mattaponi River, 1980. Abbreviations used as in Table 20 .

Cruise Date	Daily Spawning Estimate (eggs X10^6)	D_i (days)	d_i (days)	P_i (eggs X10^6)	$S^2_{P_i}$ (X10^{15})	Annual Egg Production (eggs X10^8)	CI (egg X10^7)	Female Biomass (Kg)
18 Apr	0.440	18.5	2.5	8.131	1.175			
21 Apr	3.816	3.5	2.2	13.357	2.235			
25 Apr	4.356	4.0	1.8	17.424	1.195			
29 Apr	0.837	3.0	2.1	2.512	0.137			
1 May	2.183	5.0	2.2	10.917	2.350			
9 May	0.029	10.0	1.9	0.291	0			
Annual Total		44.0		52.632	7.092	1.499	3.438	699