The University of Maryland System
Center for Environmental and Estuarine Studies
Chesapeake Biological Laboratory
Solomons, MD 20688-0038

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Egg Production, Spawning Biomass and Factors Influencing Recruitment of Striped Bass in the Potomac River and Upper Chesapeake Bay

REPORT TO:

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by

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EXTENDED ABSTRACT

Ichthyoplankton surveys in the Potomac River and Upper Chesapeake Bay were carried out in 1989 to estimate striped bass egg productions, age-specific spawning biomasses of adult females, cohort-specific larval growth and mortality rates, and hatch dates of 8.0 mm larvae survivors. Possible consequences to recruitment of environmental factors were examined in 1989 and for data collected in 1987-1988. In 1989, 18 surveys in the Potomac River and 14 surveys in the Upper Bay were completed in the 3 April to 15 June period. Primary ichthyoplankton samplers were a 60-cm, 333-μm mesh plankton net and a 2 m^2, 700-μm mesh Tucker trawl. Spawning by striped bass, which is strongly influenced by water temperature, commenced on 2 April and was essentially completed by 29 May in the Potomac River. In the Upper Bay, spawning commenced on 10 April and extended into June. The temporal and spatial occurrences and distributions of eggs and larvae in both spawning areas are described and discussed in relation to environmental factors (temperature, rainfall, river discharge, pH, conductivity, zooplankton abundances). The estimated 1989 egg productions were: Potomac River -- 11.33 $\times 10^9$ (S.E. 1.96 $\times 10^9$) and Upper Bay -- 14.57 $\times 10^9$ (S.E. 5.69 $\times 10^9$). Corresponding female biomasses were: Potomac River -- 55,501 kg; Upper Bay -- 70,808 kg.

The 1982 year-class females contributed the highest percentage of eggs in each system: Potomac River -- 41.8%; Upper Bay -- 54.7%. Egg production estimates in the Potomac River from 1987-1989 did not differ significantly among years, ranging from 6.65 $\times 10^9$ to 11.33 $\times 10^9$, but increased by eight-fold in the Upper Bay in 1989 (14.57 $\times 10^9$) compared to 1988 (1.78 $\times 10^9$). Spawning was more protracted in 1989 than in either 1987 or 1988 in the Potomac, or 1988 in the Upper Bay. Females older than age 10, which had contributed substantially to Potomac egg production in 1987 and 1988, apparently were absent in 1989. A small percentage of females older than age

10 continued to contribute modestly (4.5%) to Upper Bay egg production in 1989. The gillnet catches of adult females, when compared with cumulative egg production based upon ichthyoplankton collections, indicated that female daily catch-per-unit-effort did not provide an accurate index of daily egg production.

Larvae length-frequency distributions were converted to age-frequency distributions from otolith-aged subsamples and derived age-length keys. Mean annual growth rates of striped bass larvae in 1989, based upon a stable-age distribution assumption, were 0.20 mm d^{-1} in the Potomac River and 0.29 mm d^{-1} in the Upper Bay. Back-calculated, 3-day cohort growth rates from otolith increment analysis ranged from 0.11 to 0.36 mm d^{-1} in the Potomac River and from 0.18 to 0.36 mm d^{-1} in the Upper Bay. Growth rates of Potomac larvae in 1989 were similar to those observed in 1987, but higher than 1988 rates. Mean mortality rates, based upon the stable-age distribution assumption for 1989, were $Z = 0.29\ d^{-1}$ and $0.73\ d^{-1}$, respectively, in the Potomac River and Upper Bay. Cohort-specific mortality rates for 3-day larval cohorts, which varied significantly in both spawning areas, generally were lowest for cohorts hatched near the middle of the spawning season.

Most "potential recruits" in 1989, estimated as abundances of larvae at 8.0 mm SL, were hatched in the 20 April - 11 May and 19-21 May periods in the Potomac, and the 17 May to 4 June period in the Upper Bay. Estimated abundance of striped bass larvae at 8.0 mm SL in the Potomac was highest in 1987 (181 million), lowest in 1988 (23 million), and intermediate in 1989 (45 million). Estimated abundance at 8.0 mm SL in the Upper Bay was 49 million in 1989. Relative abundances at 8.0 mm SL in 1987-1989 corresponded to juvenile index values obtained several weeks later in the Potomac River.

Temperature has a strong and profound effect on striped bass spawning, egg and yolk-sac larvae survival, and larvae growth. Lethal low temperatures

($\leq 12^{\circ}C$) caused episodic mortalities of eggs and yolk-sac larvae, especially in 1987 and 1988, and to a lesser extent in 1989. Effects of other environmental factors (zooplankton abundance, pH, river discharge, rainfall, turbidity) on larvae survival and growth were either not significant, were ambiguous, or interacted with temperature. We detected no evidence of density-dependent factors operating to regulate striped bass larvae growth or mortality rates in 1987-1989. No clear relationships between zooplankton prey levels and larvae survival or growth could be established.

Late-hatched cohorts were demonstrated to contribute a high proportion of potential recruits in 1987-1989, primarily because temperatures were more favorable for growth and survival in mid and late May. Episodic mortalities in the Potomac River associated with temperature falling to lethal levels caused massive losses of eggs and yolk-sac larvae in April 1987 and 1988, and possibly in early May 1989. Minor spawning peaks in May 1987, 1988 and 1989 supplied most prerecruit striped bass in the Potomac River. The high recruitment of striped bass in the Upper Bay in 1989 probably resulted from major spawning peaks that took place relatively late in the season (17 to 26 May and 1-4 June).

Recruitment variability in Chesapeake Bay striped bass is strongly dependent upon temperature regimes that 1) temporally structure spawning seasons, 2) can cause episodic losses of eggs and larvae, and 3) affect larval growth rates. Larval 3-day cohorts have variable survival and growth rates, and prerecruits are more likely to have been hatched from hatch dates in mid-May or later than on earlier dates, even though egg production may be lower late in the season. Most 3-day cohorts produced in 1987-1989 did not contribute substantially to recruitment. Estimates of the abundance of surviving larvae at 8.0 mm SL could be used as an index of potential recruitment level for Chesapeake Bay stocks. Results and conclusions of research reported here are compared with earlier studies of striped bass in the Chesapeake Bay and other spawning areas.

INTRODUCTION

Striped bass stocks in the Chesapeake Bay and along the Atlantic Coast declined in the 1970s and early 1980s due to successive recruitment failures (Boreman and Austin 1985; Goodyear et al. 1985), largely attributable to high mortality rates of early life stages coincident with declining egg production (Goodyear 1985a). A fishing moratorium that was imposed in the Chesapeake Bay and stringent regulations placed on fishing of coastal migratory striped bass were enacted to protect the modest 1982 year-class and have resulted in increasing abundances of the spawning stock in the Chesapeake Bay (Maryland DNR 1991), and a partial restoration of the fishery in 1990 and 1991.

Although stock numbers and biomass are increasing under strict management, recruitments continued to be highly variable in the 1985-1989 period (Maryland DNR 1991) and there still is little consensus about causes of year-class success and failures. High and variable mortality of egg and larvae stages are the cause of variable striped bass recruitments (Goodyear 1985b). The causes of mortality and its variability have been attributed, sometimes based on contradictory and conflicting evidence, to low pH, contaminants, low temperature, variable river flows, larval nutrition, nutrient loading and other environmental factors (Goodyear 1985b; Hall 1991; Setzler-Hamilton et al. 1988; Setzler-Hamilton 1991). In reality, it is probable that all of these factors affect mortality rates of eggs and larvae and the importance of any single factor varies in impact from year to year.

We previously estimated the cohort-specific growth and mortality rates of Potomac River striped bass larvae in 1987 and 1988, and of Upper Bay larvae in 1988 (Houde et al. 1988a, 1988b, 1990). In addition, we estimated annual egg productions and female spawner biomasses. In 1989, we conducted egg and larvae surveys again in the Potomac River and Upper Bay spawning areas. The emphasis in 1989 was placed upon estimating egg production from repeated surveys done at short time intervals and upon estimating hatch dates and abundances of potential recruits, based upon collections of both early and late-stage larvae.

Objectives of the 1989 program were to define and describe the spawning season and to estimate egg production by striped bass in the two major Maryland spawning areas, the Upper Bay and Potomac River. Using our egg production data and Maryland Department of Natural Resources gillnet catch-per-unit-effort data, age-specific spawning biomasses of female striped bass were estimated. Hatch dates, growth rates and mortality rates of larval cohorts produced in three-day intervals were estimated from the age distributions and abundances of striped bass larvae collected in the surveys. A further objective was to identify environmental factors that affected cohort survival and growth. Finally, whenever possible, a synthesis was undertaken to contrast and compare striped bass spawning and early-life-stage dynamics in the Upper Bay and Potomac River for the period 1987-1989.

STUDY AREAS AND SURVEYS

1. Eggs and Larvae

Potomac River (Figure 1): Sixteen surveys on R/V PISCES, a 25-ft outboard-powered boat, were carried out from 3 April to 28 May 1989 (Table 1). Stations 1 to 9 (Table 2) were sampled on each survey. Stations 10 and 11 were sampled only on 3 April and 20 May. A sampling crew from the Chesapeake Biological Laboratory made these collections.

Upper Bay (Figure 2): Twelve surveys on a 20-ft, outboard-powered boat were carried out from 14 April to 30 May (Table 1). Nine stations were designated and scheduled for sampling on each date. A Maryland DNR sampling crew made the Upper Bay collections.

2. Late Stage Larvae

Potomac River (Figure 3): Two surveys on 52-ft R/V ORION were carried out at four stations on 1-2 June and 8-9 June 1989 (Table 1).

Upper Bay (Figure 4): Two surveys on 52-ft R/V ORION were carried out at six stations on 5-6 June and 14-15 June (Table 1).

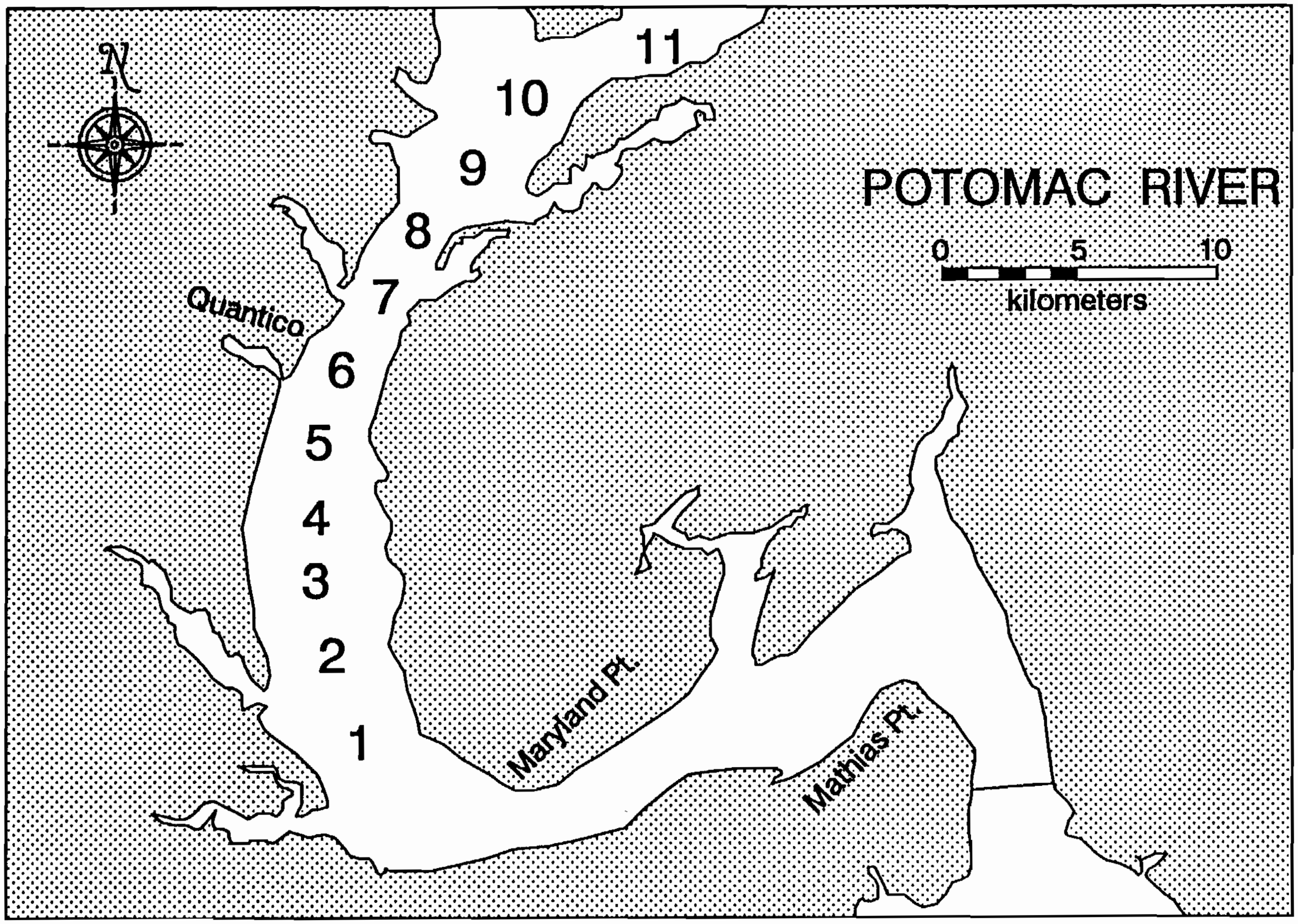


Figure 1. Potomac River sampling area and stations, 1989. Stations designated here were sampled with the 60-cm, 333-μm mesh plankton net. Zooplankton samples (20-cm, 53-μm mesh plankton net) were collected at Stations 3 and 7.

Table 1. Potomac River and Upper Bay 1989 surveys to estimate abundances of striped bass eggs and larvae.

Potomac River

Survey	Boat	Dates
1	Pisces	3 April
2	"	6 April
3	"	13 April
4	"	17 April
5	"	21 April
6	"	24 April
7	"	27 April
8	"	30 April
9	"	3 May
10	"	6 May
11	"	9 May
12	"	12 May
13	"	16 May
14	"	20 May
15	"	24 May
16	"	28 May
17	Orion	1-2 June
18	"	8-9 June

Upper Bay

Survey	Boat	Dates
1	DNR	14 April
2	"	20 April
3	"	24 April
4	"	27 April
5	"	2 May
6	"	5 May
7	"	11 May
8	"	15 May
9	"	18 May
10	"	23 May
11	"	25 May
12	"	30 May
13	Orion	5-6 June
14	"	14-15 June

Table 2. Small boat surveys. Ichthyoplankton and zooplankton samples collected in the Potomac River and Upper Bay, 1989. Letters designate gears and types of collections. See Figures 1 and 2 for station locations and Table 1 for survey dates.

Potomac River

Stations	Surveys															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	-	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
3	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B
4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
5	-	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
6	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
7	A	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B
8	A,B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
9	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
10	A	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-
11	A	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-

Upper Bay

Stations	Surveys											
	1	2	3	4	5	6	7	8	9	10	11	12
1	A	A	A	A	-	A	A	A	A	A	A	-
2	A	A	A	A	-	A	A	A	A	A	A	A
3	A,B	A,B	A,B	A,B	-	-	A	A,B	A,B	A	A	A
4	A	A	A	A	-	-	A,B	A	A	A	A	A
5	A	A	A	A	A	-	A	A	A	A	A	A
6	A	A	A	A	-	-	A	A	A	A	A	A
7	A	A	A	A	-	-	A	A	A	A	A	A
8	A,B	A,B	A,B	A,B	A,B	-	A,B	A,B	A,B	A	A	A
9	A	A	A	A	A	-	A	A	A	A	A	A

A = 60-cm plankton net, 333-μm meshes, ichthyoplankton, oblique tows.
B = 20-cm plankton net, 53-μm meshes, zooplankton, vertical lifts.

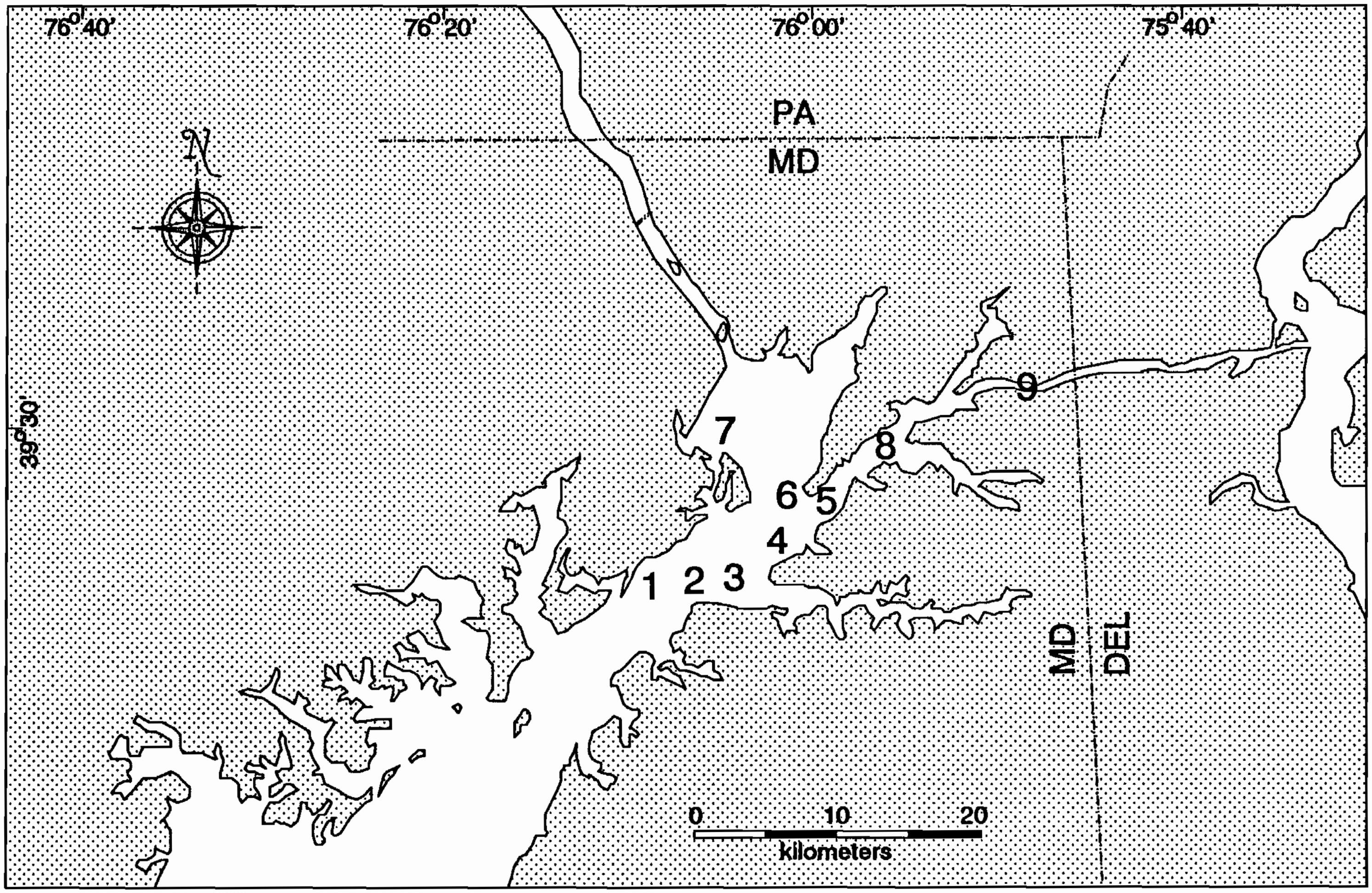


Figure 2. Upper Bay sampling area and stations, 1989. Stations designated here were sampled with the 60-cm, 333-μm mesh plankton net. Zooplankton samples (20-cm, 53-μm mesh plankton net) were collected at Stations 3 and 8.

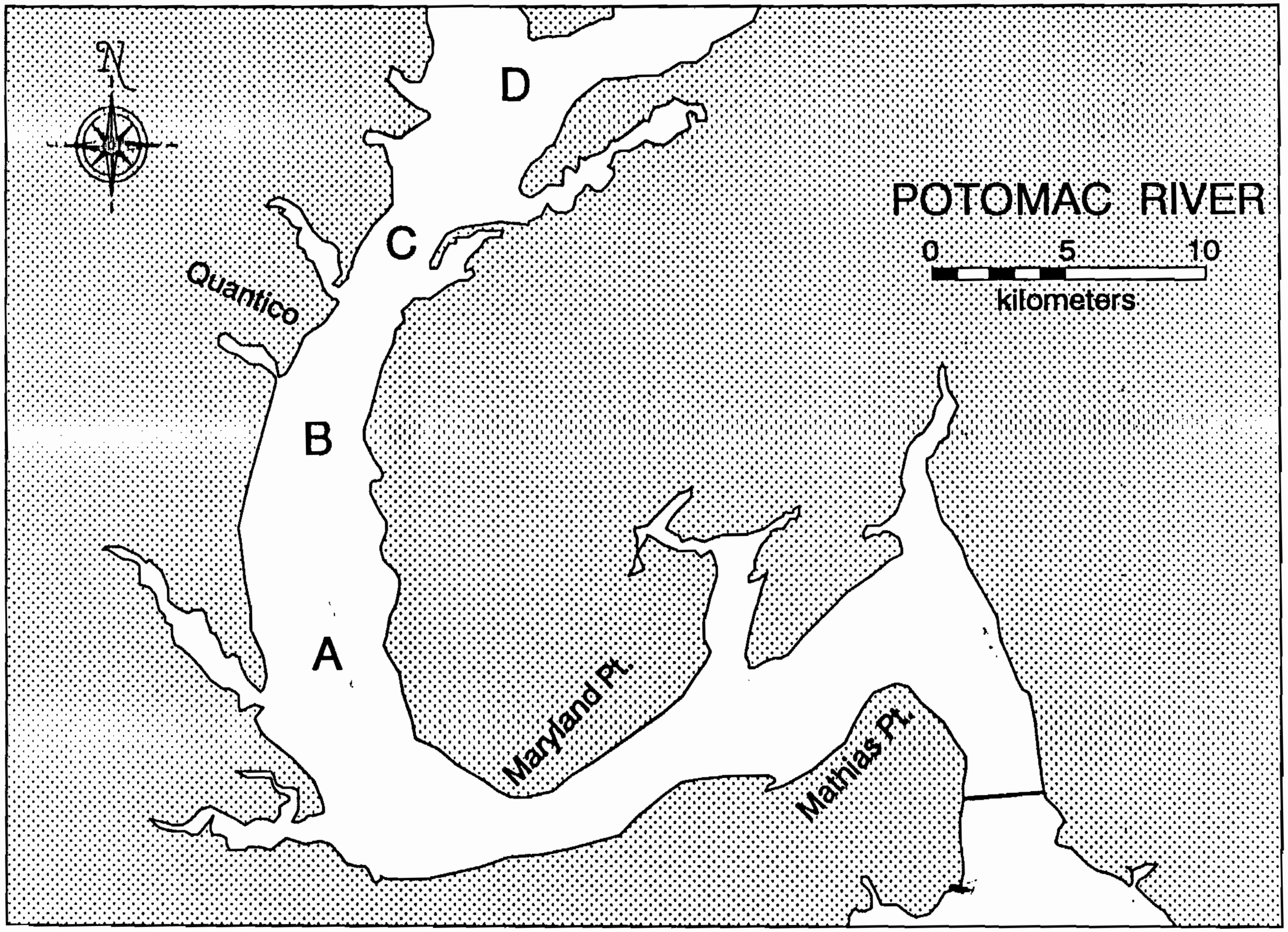


Figure 3. Potomac River, 1989. Stations sampled with the 2 m^2 Tucker trawl deployed from R/V ORION, 1-2 June and 8-9 June 1989.

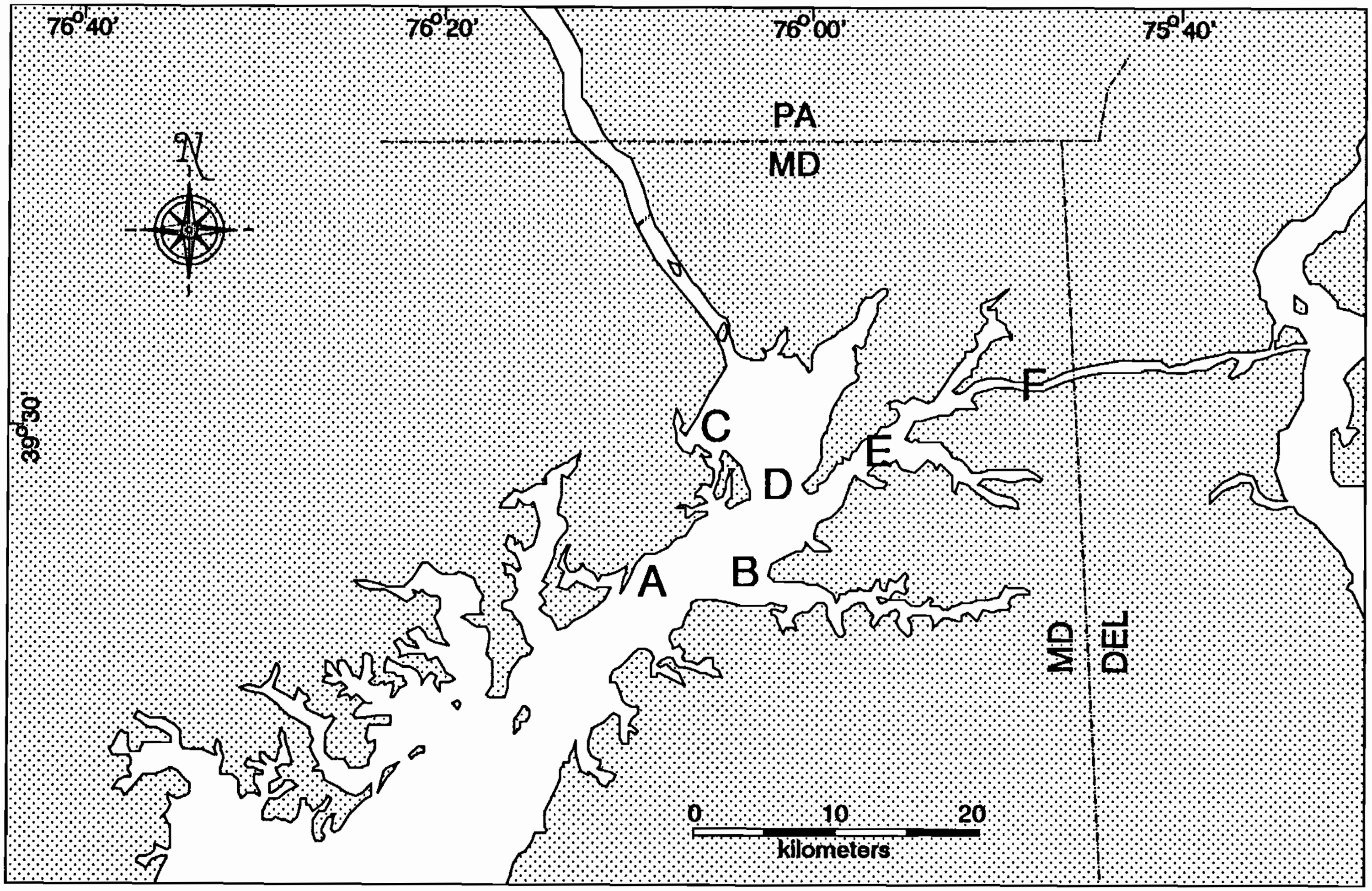


Figure 4. Upper Bay, 1989. Stations sampled with the 2 m² Tucker trawl deployed from R/V ORION, 5-6 June and 14-15 June 1989.

METHODS

Sampling and Samples

Net Tows: Duplicate, oblique tows of a 60-cm bridled plankton net with 333-μm mesh (Gear A, Table 2) of 5-min duration were made from within 1-m of bottom to surface. The tows filtered a mean volume of 96.2 m^3 (S.E. = 1.0) in the Potomac River (n = 284) and a mean volume of 89.6 m^3 (S.E. = 0.6) in the Upper Bay (n = 181). These tows provided striped bass egg and larvae catches for abundance estimates in Surveys 1-16 on the Potomac and Surveys 1-12 in the Upper Bay. The plankton net collections were fixed initially in 5% buffered formalin and transferred within 48-h to 95% ethanol for storage. All fish eggs and larvae were sorted from each sample.

Vertical lifts of a 20-cm, 53-μm mesh plankton net (Gear B, Tables 2 and 3) were used to estimate zooplankton densities. On most surveys, net lifts were made at two stations in the Potomac and two in the Upper Bay. Zooplankton samples were fixed and preserved in 5% buffered formalin.

A 2-m^2 Tucker trawl, rigged with two opening-closing nets of 700-μm mesh, was the primary gear used to sample striped bass larvae on survey cruises 17 and 18 in the Potomac River and 13 and 14 in the Upper Bay (Table 1). Striped bass larvae collected in this gear were used to estimate cohort abundances of "potential recruits" and to estimate hatch dates of larval cohorts that had survived to June. Two tows of the Tucker trawl (Gear C, Table 3) were made at each station. Each tow consisted of two 5-min segments -- 1) a stepped oblique segment from near-bottom to mid-depth and 2) a stepped oblique segment from mid-depth to surface. Tucker trawl tows filtered a mean volume of 402 m^3 (S.E. = 37.2) in the Potomac (n = 30) and a mean volume of 497 m^3 (S.E. = 14.6) in the Upper Bay (n = 18). Tucker trawl samples were fixed in 5% buffered formalin and transferred within 72 h to 95%

Table 3. Surveys, stations and types of samples collected from R/V ORION in the Potomac River and Upper Bay, 1989. Letters under "Surveys" designate gears and types of collections. For station locations, see Figures 3 and 4.

Potomac River

Stations	Surveys	
	1-2 June	8-9 June
A	C,D	C,D,E
B	B,C,D	B,C,D,E
B - Night	C,D	C,D
C	B,C,D	B,C,D,E
C - Night	B,C,D	C,D
D	C,D	C,D

Upper Bay

Stations	Surveys	
	5-6 June	14-15 June
A	C,D	C,D
B	B,C,D	B,C,D,E
B - Night	B,C,D	B,C,D
C	B,C,D	C,D,E
D	C,D	B,C,D,E
D - Night	C,D	B,C,D
E	B,C,D	C,D,E
F	C,D	C,D

Gears
B = 20 cm plankton net, 53-μm meshes, zooplankton vertical lift.
C = 2 m^2 Tucker trawl, 700-μm meshes; duplicate oblique tows, bottom to mid-depth and mid-depth to surface.
D = 60-cm plankton net in bottom sled, 505-μm meshes, duplicate tows.
E = 16-ft otter trawl, fine mesh codend liner, duplicate tows.

ethanol. Fish eggs and larvae were sorted from the whole sample or from aliquots when numbers of larvae exceeded 4,000. A randomly-selected subsample of at least 500 larvae was identified, and the striped bass larvae measured (mm SL).

A 16-ft bottom trawl with 6.4 mm mesh codend liner was towed at several stations in the Potomac and Upper Bay on the June survey cruises (Gear E, Table 3). Duplicate tows of 10-min duration were made in an attempt to sample larger length-classes of striped bass larvae that might not have been vulnerable to other sampling gears. Samples of young-of-the-year striped bass and white perch were fixed in 5% formalin and transferred within 72 h to 95% ethanol.

Environmental Data

Temperature, salinity, and conductivity were measured in the Potomac River and Upper Bay at surface, mid-depth, and near bottom at each station. The pH was measured at surface. In the Upper Bay, dissolved oxygen at surface, mid-depth, and near bottom also was measured.

Rainfall data for the Potomac River and Upper Bay were obtained from the NOAA weather station at National Airport, Washington, D.C. and the Baltimore-Washington International Airport, respectively. Temperature, river stage and discharge data for the Potomac River were obtained from the Occoquan Watershed Monitoring Laboratory station at the Woodrow Wilson Bridge. Similar data for the Upper Bay were obtained from the U.S. Geological Survey station at Conowingo, Maryland. In addition, continuous records of temperature, pH and dissolved oxygen were made available to us from *in situ* Datasonde recorders installed near Station 4 on the Potomac River (Figure 1) and near Stations 5, 8 and 9 in the Upper Bay (Figure 2).[1]

Zooplankton Densities

1988 Samples

Previously unexamined zooplankton samples from the Potomac River were analyzed and results are included in this report. Methods to estimate zooplankton densities in the Potomac River in 1988 were similar to those used in 1987 (Houde et al. 1988a). One-hundred liter, pumped zooplankton samples were collected from near-bottom, mid-depth, and surface at each station on all surveys. The pump delivered 30-40 ℓ min^{-1} onto a 35-μm screen, which retained all zooplankton that was potential food of fish larvae. Samples were preserved in 5% formalin.

Potomac River 1988 samples from each of three subareas, representing stations 1, 2 (subarea 1), 3, 4 (subarea 2), and 5,6 (subarea 3) (Figure 1 in Houde et al. 1990) were randomly selected for analysis of zooplankton. Stations (odd or even) were randomly selected from each subarea. In addition, the station having the maximum striped bass larvae density on each survey was included in the zooplankton analysis. Each near-bottom, mid-depth and surface sample was split in half in a Folsom splitter. The three half samples then were pooled to provide an integrated, water-column zooplankton sample for analysis. A total of 33 samples were analyzed.

1989 Samples

Zooplankton samples were collected during the 1989 season by a vertical lift from near-bottom to surface of a 20-cm, 53-μm mesh plankton net. Samples were obtained on every survey at stations 3 and 7 in the Potomac River

[1]Data provided by Lenwood Hall, Johns Hopkins University. Present address: The University of Maryland System, Wye Research and Education Center, Box 169, Queenstown, MD 21658.

(Figure 1) and at stations 3 and 8 in the Upper Bay (Figure 2), and were preserved in 5% buffered formalin. To estimate zooplankton densities at each station, the sample volume was reduced to 50-100 mℓ, and three 1-mℓ aliquots of each sample were examined. The counts of zooplankton in each aliquot were divided by the volume filtered (0.19 to 0.80 m^3) for each sample to estimate densities.

For the 1988 and 1989 samples, taxa known to be important foods of Morone larvae were identified. Zooplankton were categorized and are reported as macrozooplankton (copepod adults, copepodites, cladocera) or microzooplankton (copepod nauplii, rotifers).

Ichthyoplankton Identification

Descriptions of striped bass and white perch larvae provided by Mansueti (1958), Lippson and Moran (1974) and Hardy (1978) were used to facilitate identifications. Larvae in length-classes 8-13 mm SL were cleared with trypsin to reveal developing skeletal features, which serve to distinguish striped bass and white perch (Olney et al. 1983).

Otolith Preparation and Analysis

Daily increments in otoliths were counted to determine larvae ages and to identify cohorts. The otoliths of white perch and striped bass larvae were described previously (Houde et al. 1988a). It was demonstrated in laboratory experiments that both species laid down one otolith increment per day after initiation of increment formation, which was temperature dependent in each species (Houde and Morin 1990).

Sagittal otoliths were removed from each fish by 1) clearing the larvae in trypsin or "epon" to render the otoliths visible, 2) placing the fish on a microscope slide and then 3) teasing the otoliths away from the tissue.

Otoliths of fish <8 mm SL then were mounted in "epon" under cover slip and heated for 1 day at 60°C to harden the epoxy. Otoliths of fish >8 mm SL were embedded in "epon" and heated for 1 day to harden the epoxy. Then, they were ground in a transverse plane to near the nucleus with 400-grit sandpaper, ground to the nucleus with 600-grit sandpaper, and then polished with alumina paste. Finally, the otoliths were etched in a buffered solution of 7% EDTA for 20-40 sec and remounted in epon epoxy under a cover slip (Radtke 1984).

Otoliths were read under 1000x magnification using a compound light microscope. Projections of otolith images were made onto a monitor via a TV camera and measurements were made using a computer-interfaced JAVA image analysis system (Jandel Corp.). Measurements were made from the center of the otolith nucleus to 1) the nucleus edge, to 2) each increment, and to 3) the edge of the otolith. Measurements were made along the clearest radius in the concentric, smaller otoliths and along the antirostrum in larger otoliths. Measurements were stored in ASCII format by the JAVA system for later statistical analysis and back-calculation applications.

Back-Calculation of Lengths-at-Age

Body size-otolith radius relationships were derived for striped bass larvae in the Potomac River and Upper Bay. This information, combined with measurements of otolith radii to each of the daily increments, allowed larval lengths at earlier ages to be back-calculated. Several authors recently have discussed problems and appropriate methods to back-calculate lengths-at-age of fishes (Francis 1990; Campana 1990; Secor 1990). We used the "biological-intercept" method proposed by Campana (1990) to back-calculate striped bass larval lengths. The method is a modified version of the Fraser-Lee method, used in a previous analysis (Houde et al. 1990). Campana's (1990) method corrects for the phenomenon of faster-growing fish having proportionately smaller otoliths than slower growing fish of the same body size (Secor and Dean 1989; Reznick et al. 1989).

The back-calculation formula is:

$$L_t = L_c + (O_t - O_c) \cdot (L_c - L_a)/(O_c - O_a)$$

where L_t = length (mm) at age t

L_a = body length (mm) at hatch.

L_c = body length (mm) at capture

O_a = otolith radius (μm) at hatch

O_c = otolith radius (μm) at capture

O_t = otolith radius (μm) at age t

An L_a of 4.0 mm SL (standard length) was chosen to back-calculate lengths-at-age of striped bass larvae for 1987, 1988, and 1989 data. The otolith radius-at-hatch was the nucleus radius (μm), the distance from the focus to the edge of the nucleus. The "biological intercept" method, like the Fraser-Lee method, has the desirable property of not presuming that larvae from all cohorts or populations have the same otolith radius - standard length relationship.

Adult Female Data

Gillnet catch-per-unit-effort (CPUE) data were provided to us by Maryland Department of Natural Resources, Tidewater Administration. The age-specific CPUE data for mature female striped bass from the Potomac River and Upper Bay in 1989, which index the relative abundances of female age-classes that were present, were weighted by the age-specific fecundities of each age-class that was represented. In this way it was possible to index the age-specific spawning potential on each collection date and examine it with respect to actual egg production estimated from ichthyoplank-ton collections on the same dates. It also was possible to partition the annual egg production estimates from ichthyoplankton collections among the component age-classes of female striped bass. Then, the age-specific biomasses and numbers of adult females that spawned in the Potomac and Upper Bay were calculated from the egg production estimates and gillnet CPUE data.

ANALYSIS

Egg and Larvae Abundances

Numbers of eggs or larvae (N) in each net tow were expressed as densities (D), number per 100 m^3 (D = N/V), based on flowmeter readings from which volumes filtered (V) were estimated. Some Tucker trawl samples and a few 60-cm net samples were unmetered. Volumes filtered by these tows were assigned the 1989 mean values for 5-min tows of those gears from the data on volumes filtered that were available. The abundance of eggs or larvae (A), expressed as numbers under 1.0 m^2 of water surface, was derived from the density estimates: A = dD, where d = water depth (m) at the station. The mean densities and abundances of eggs and larvae at each station on each survey were calculated from the two 60-cm, 333-μm net tows that were made at each station.

The estimated "riverwide" (Potomac) and "areawide" (Upper Bay) abundances of striped bass eggs and larvae were calculated by expanding the mean densities at a station to the volume of the river segment or bay segment represented by each station. The areas and volumes represented by stations were obtained from Cronin (1971). Mean depths, areas, and volumes of each river and bay segment that were designated in 1989 have been tabulated (Table 4).

Egg Production

Abundance estimates of striped bass eggs from each survey were used to estimate daily and seasonal egg production. The estimated river and bay segment abundances were converted to daily egg production after considering effects of river temperatures and estimated incubation times (from Polgar 1976, in Setzler et al. 1980). Survey egg productions were estimated by

Table 4. Mean station depths, areas and volumes represented by stations and subareas in 1989 Potomac River and Upper Bay striped bass egg and larvae surveys. Maps of areas and stations are provided as Figures 1 and 2.

Potomac River

Subarea	Station	Mean Depth (m)	Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)
I	1	3.7	92.7	342.9
II	2	3.6	28.3	101.8
	3	3.8	23.1	87.6
III	4	4.1	13.6	55.8
	5	4.7	10.4	48.7
	6	5.9	11.2	66.3
IV	7	4.4	14.6	64.2
	8	3.1	30.3	94.0
V	9	5.2	36.8	191.1
		Total	260.9	1,052.5

Upper Bay

Subarea	Station	Mean Depth (m)	Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)
I	1	4.9	32.9	159.3
	2	4.8	21.1	101.6
III	3	4.5	51.9	233.5
	4	3.6	27.2	98.7
	5	3.6	12.0	42.6
	6	3.4	24.3	81.5
II	7	1.4	106.6	144.0
IV	8	2.2	20.1	44.1
	9	12.0	5.3	63.5
		Total	301.4	968.8

multiplying daily egg production by the number of days represented by each survey. It was assumed that the mean daily egg production during a survey occurred on the day of the survey plus one-half the days since the previous survey and one-half the days until the next survey. The date of first spawning was assumed to have been 2 April in the Potomac River and 10 April in the Upper Bay. The last dates of spawning were assumed to have been 29 May in the Potomac River and 31 May in the Upper Bay. Some spawning probably occurred after the assumed final spawn dates and plankton-net surveys. That egg production contributed little to the 1989 totals in the Potomac River, although its contribution may have been significant in the Upper Bay.

The analytical method of Pennington and Berrien (1984) was used to estimate egg production. In this method, which is effective to estimate means and variances when the frequency of zero catches is significant, egg catches are assumed to follow a delta distribution. The method allows two estimates of egg production to be obtained in the Potomac River and in the Upper Bay. The first estimate is derived by treating the data as from a single series of surveys. A second estimate was obtained after partitioning the survey series into two separate series. In the Potomac, Series I included egg abundance data from Surveys 1, 3, 5, 7, 9, 11, 13 and 15 while Series II included Surveys 2, 4, 6, 8, 10, 12, 14 and 16. In the Upper Bay, Series I included Surveys 1, 3, 5, 7, 9 and 11 while Series II included Surveys 2, 4, 6, 8, 10 and 12. This partitioning allowed mean egg production to be estimated for each series in addition to providing variance estimates that included temporal as well as spatial components.

The egg production method also required that the survey area be divided into subareas (Table 4). Five subareas were designated in the Potomac, each represented by one to three stations (Subarea I included Station 1; Subarea II included Stations 2 and 3; Subarea III included Stations 4, 5 and 6; Subarea

IV included Stations 7 and 8; Subarea V included Station 9). On each survey date there were from 2 to 6 samples collected within each Potomac subarea from which the subarea egg production estimates were obtained. Four subareas were designated in the Upper Bay; Subarea I included Stations 1 and 2; Subarea II included only Station 7; Subarea III included Stations 3, 4, 5 and 6; Subarea IV included Stations 8 and 9. The number of samples per subarea on each survey date ranged from 2 to 8 in the Upper Bay.

Spawning Biomass and Age-Specific Spawning Potential

Data on gillnet catch-per-unit-effort (CPUE)[1] for striped bass females from spawning areas of the Potomac River and Upper Bay in 1989 were used in combination with our egg production estimates and the Mihursky et al. (1987) weight-specific fecundities to derive estimates of 1) biomass of spawning females, 2) numbers of spawning females by age-class, 3) numbers of eggs contributed by each age-class that was represented in the gillnet catches and 4) date-specific, potential relative egg production by each age-class, based upon the proportional representation of female age classes in the CPUE data. All striped bass females ≥4 years of age that were gillnetted on the spawning grounds in 1987-1989 were presumed to be mature (Mihursky et al. 1987). For analysis purposes, we assumed that the CPUE of ≥4-year-old females in the gillnet catches accurately represented the proportional contributions of females from each age-class.

Gillnet sets in the Potomac were made on 32 days, from 3 April to 19 May 1989. Nets were set on 44 days in the Upper Bay, from 10 April to 25 May. Mean CPUE for females in each age-class was derived by summing the age-specific daily CPUE and dividing by the number of days that the nets were set.

[1]Data provided by Maryland Department of Natural Resources, Tidewater Administration, Fisheries Division, Courtesy of S. Early and T. Sminkey.

Age-specific fecundities were obtained by 1) developing a weight-on -age equation from the Mihursky et al. (1987) data, 2) converting the female age data to weights, and 3) estimating the weight-specific fecundities using the Mihursky et al. equation for fecundity-on-weight. The weight-on-age equation is:

$$W_a = 1,747.26\ A - 5,348.23 \qquad r^2 = .94$$

where W is weight in grams and A is age in years. The fecundity-on-weight equation is:

$$F_w = 206.82\ W - 13,097.60 \qquad r^2 = .95$$

where F is fecundity in number of eggs.

The number of spawning females can be estimated from the egg production estimates. In this analysis the estimate of egg production from the "partitioned series" was presumed to be best. The number of striped bass females was calculated from the expression:

$$N = \frac{P}{\Sigma\ b_a F_w}$$

where N = number of females, P = egg production, b_a = proportional CPUE for each age or weight-class, and F_w = fecundity of each weight-class. The number of females in each age-class then can be estimated from the expression:

$$N_a = N \times b_a.$$

Finally, the number of eggs produced by each age-class is:

$$P_a = N_a \times F_a$$

where F_a is the fecundity of each age-class.

Larvae Length-Frequency Distributions and Adjustments

The observed length-frequency distributions of larvae were subject to two systematic errors: escapement by some fraction of small larvae through plankton-net meshes and avoidance of the gear by some larger larvae.

We adjusted the survey length-frequency distributions in 1989 by a sequential procedure that depended on correcting the standard 60-cm, 333-μm mesh catches. Because no data were available in 1989 to compare night vs day catches in the 333-μm tows, the same correction factors used to adjust catches of larvae in 505-μm mesh net tows for night vs day gear avoidance in 1987 and 1988 (Houde et al. 1990) were applied to 1989 catches. These correction factors represent the ratios of night-collected to day-collected larvae in 60-cm net, 505-μm mesh tows for each 0.5 mm length-class. Because there was no difference in catches of larvae >5.0 mm in a comparison of 505-μm and 333-μm tows, and because the 505-μm catches, once corrected for extrusion, were not significantly different from catches of larvae in the 2 m^2 Tucker trawl (Houde et al. 1988b, 1990), we did not further correct the day-night adjusted 333-μm mesh catches for gear avoidance.

No gear avoidance or extrusion adjustments were applied to striped bass eggs because the eggs are passive and too large to be extruded.

Age-Length Keys

Otolith-aged larvae from represented length-classes were used to determine the proportion of larvae in each 0.5 mm length-class that fell within each one-day age class. This determination was the basis for developing age-length keys from which measured, but unaged, larvae could be assigned an estimated age. The age-length keys were developed from regressions of ages on larval lengths. The regression statistics (slopes and standard errors) provided an otolith-based estimate of mean age and its variance for each 0.5 mm length-class. The age distribution of larvae in a 0.5 mm length-class was assumed to be normally distributed. Then, the proportion of larvae of each age in a 0.5 mm length-class was estimated by calculating a normal standard deviate and estimating the probability that larvae were in a given age-class. When probabilities were very low ($P<0.025$), proportions in those age-classes were added to the adjacent age-class.

Larvae Age-Frequency Distributions

The age-length keys were used to convert larvae length-frequency distributions to age-frequency distributions. To compensate for potential errors in aging larvae and the lack of multiple age-length keys, we aggregated the age-frequency distributions into 3-day classes (cohorts). By following the trajectories of growth and mortality in three-day cohorts, it was possible to estimate rates, identify episodic mortalities, and relate such mortalities to significant environmental events.

Errors in aging are possible because 1) otolith increments may not always be formed daily, 2) otolith increments may be incorrectly counted, and 3) the age of first increment deposition may vary. We believe that all three sources of error occur in striped bass larvae. We adjusted the apparent cohort ages, based upon otolith increments, to account for variability in age of first increment deposition, which was demonstrated to be temperature-dependent (Houde and Morin 1990). The age of first increment deposition potentially can vary from 1-5 days posthatch for striped bass hatched in the 12-21°C temperature range. Ages were assigned to larvae based on temperature data, predicted day posthatch of first increment deposition and otolith increment numbers. Although it remains possible that a small fraction of the larvae were assigned to an incorrect 3-day class, the potential for error was small.

Estimating Growth Rates

Three methods were used to estimate growth rates of larvae, all dependent upon otolith-aging.

1) Aggregated-Sample Mean Growth Rate: Standard lengths and otolith-derived ages of the entire sample of 1989 otolith-aged larvae from each area were analyzed. The linear regression coefficients of standard lengths on otolith-derived ages provided estimates of the growth rates.

2) Individual Cohort Growth Rates: The otolith-aged larvae from sequential surveys were assigned to their respective 3-day cohorts. Larval lengths were regressed on cohort ages and the cohort-specific growth rates were determined from linear regression models.

$$L_t = a + g(t)$$

where L_t = standard length (mm)

a = regression intercept, an estimate of length (mm) at age 0

t = age, in days posthatch; ages were assigned from otolith increment number adjusted to account for temperature effects on age of first increment deposition

g = regression coefficient, an estimate of growth rate (mm/d).

Possible differences among cohort-specific growth rates were tested by Analysis of Covariance. Predicted lengths-at-age were compared to determine if cohorts differed in mean lengths at specific ages. Inverse prediction was used to estimate the cohort-specific ages of larvae at 8.0 mm SL.

3) <u>Back-Calculation of Larval Growth Rates and Variability</u>: This method, partly described under "<u>Otolith Preparation and Analysis</u>" provided the most information on growth of individual larvae, growth of cohorts, and variability in growth.

Growth rates of 3-day cohorts were derived from the exponential regressions of the mean back-calculated lengths-at-age on larval ages. The procedure allowed among-cohort comparisons of growth rates (Analysis of Covariance) and comparisons of growth experienced by cohorts produced early and late in the season.

Accurate estimates of growth rates and lengths-at-age based on back-calculation procedures depend upon a predictable otolith size-body size relationship. If otolith growth and body growth are seriously decoupled, then the ability to estimate larval growth rates and to back-calculate lengths-at-age could be compromised (Secor and Dean 1989). In our laboratory experiments, some otolith growth did occur in the smallest striped bass larvae in the absence of body growth (Houde et al. 1990). If such non-growing larvae survived for significant time in the wild and were collected in significant numbers, it is possible that lengths-at-age could have been overestimated for some larvae based on the back-calculation procedures. The use of the "biological intercept" method to back-calculate lengths-at-age for larvae in individual cohorts will tend to minimize the potential for such errors.

<u>Mortality Rate Estimates</u>

Regressions of the decline in abundances between surveys of identified 3-day cohorts of striped bass larvae provided estimates of cohort-specific mortality rates. A mean daily mortality rate was estimated under a stable age distribution assumption, in which the abundance-at-age estimates of larvae from all 3-day cohorts were pooled over all surveys.

Assignment of larvae collected in each survey into 3-day cohorts in effect defined the birth-date distributions and the estimates of abundances of each cohort for that survey. Cohorts that were initially abundant or which experienced good survival had a high probability of being collected on more than one survey. The abundance of each 3-day cohort of striped bass was estimated on each sampling date that the cohort occurred, which traced the cohort's decline in abundance as the season progressed.

The decline in abundance of each 3-day cohort is a measure of its mortality. Daily instantaneous mortality coefficients for the pooled survey mean abundance-at-age estimates (based upon the stable age distribution assumption) and for the cohort-specific analysis were calculated from an exponential model of decline in abundance of each 3-day cohort:

$$N_t = N_0 e^{-Zt}$$

where N_t = estimated abundance of larvae on the last date that the cohort was sampled or at specified ages during the season

N_0 = estimated abundance at time zero (i.e. hatching)

Z = instantaneous daily mortality coefficient (d^{-1})

t = age, in days.

Cohorts that experienced episodic mortalities were identified from their high mortality rates and/or their disappearance from samples during the season. Cohorts with better survivorship had relatively low mortality rates and appeared on two or more survey dates. The environmental characteristics associated with high cohort survival or episodic mortality are reported and discussed.

Cohort Hatch Dates

The assignment of striped bass into 3-day cohorts also defined their hatch dates. The relative abundances of cohorts and their estimated hatch dates were tracked and compared.

RESULTS

1989 Environmental Data Summaries

Potomac River

Temperature: Mean water temperatures during the surveys ranged from 12.8 to 25.2°C (Table 5). Mean survey temperatures and continuously-recorded temperatures fluctuated between 11.4 and 13.4°C during the 1-17 April period and were below the 12° level that is lethal for striped bass eggs and larvae on 10-11 April (Figure 5). Mean and continuous temperatures rose steadily from 12.9° on the 17 April cruise (Survey 4) to 18.0° on 3 May (Survey 9), then dropped to 13.7° on 12 May (Survey 12), and subsequently increased to a high of 25.2°C on 8 June (Survey 18). Continuous temperature data at Wilson Bridge indicated that temperatures did dip below 12° on 12 May and remained near 12° for the 11-14 May period.

Salinity and Conductivity

The water was fresh (0 ppt) at stations 3-9 on all surveys in 1989. Salinities >1 ppt were recorded at Station 1 (Figure 1) during the first 8 surveys (1-30 April) but not subsequently. Salinity averaged over all surveys was 0 ppt at all stations except Station 1. Conductivity values in the 1989 Potomac season also were determined for each station on each survey (Table 6). In 1989, riverwide abundance of striped bass larvae was highest in the area represented by Station 1, where mean conductivity was 1491 micro-ohms, the highest mean value recorded.

pH

Mean water column pH values in the Potomac ranged from 6.7 - 7.4 (Table

Table 5. Potomac River, 1989. Mean water column temperatures (°C) at each station for each survey. Also given are survey and station means.

	SURVEY																		
Station	1 4/3	2 4/6	3 4/13	4 4/17	5 4/21	6 4/24	7 4/27	8 4/30	9 5/3	10 5/6	11 5/9	12 5/12	13 5/16	14 5/20	15 5/24	16 5/28	17 6/1	18 6/8	Station Mean
1	12.2	13.3	11.6	12.2	15.5	15.4	16.8	17.1	17.7	17.0	15.9	14.7	14.5	17.4	18.8	20.2	--	--	15.6
2	--	13.4	11.0	13.3	15.2	15.3	15.3	17.0	17.9	17.2	15.3	14.0	14.0	17.0	18.8	20.5	--	--	15.7
3	12.3	13.5	11.7	13.4	14.1	15.0	15.8	17.2	17.7	17.0	15.1	13.9	14.0	16.6	19.0	20.6	--	--	15.4
4	12.9	13.5	11.5	13.1	14.9	14.8	16.5	17.0	17.8	16.0	14.9	13.8	14.0	17.4	19.0	20.9	--	--	15.5
5	--	13.6	11.8	12.9	14.9	14.7	16.4	17.2	18.1	16.3	15.0	13.7	14.0	16.3	19.6	21.6	--	--	15.7
6	13.0	13.2	11.2	13.0	15.0	15.0	17.0	17.2	18.2	16.4	15.0	13.5	13.8	16.2	19.8	21.0	--	--	15.5
7	13.0	13.3	11.2	12.8	14.2	15.3	17.0	17.4	18.1	16.3	15.2	13.6	13.7	16.2	19.6	20.9	--	--	15.5
8	12.9	13.2	11.2	12.9	14.7	15.2	17.3	17.8	18.0	16.1	14.0	13.3	13.5	17.3	19.8	21.3	--	--	15.5
9	13.0	13.4	11.1	12.7	14.9	15.3	16.9	17.8	18.1	16.0	14.4	13.0	13.4	16.7	20.0	20.7	--	--	15.5
10	13.0	--	--	--	--	--	--	--	--	--	--	--	--	16.9	--	--	--	--	14.9
11	12.9	--	--	--	--	--	--	--	--	--	--	--	--	17.0	--	--	--	--	15.0
A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	22.9	25.4	24.1
B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	23.7	25.3	24.5
C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	23.3	25.1	24.2
D	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	23.3	25.2	24.3
E	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	22.5	--	22.5
Survey Mean	12.8	13.4	11.4	12.9	14.8	15.1	16.6	17.3	18.0	16.5	15.0	13.7	13.9	16.8	19.4	20.9	23.2	25.2	

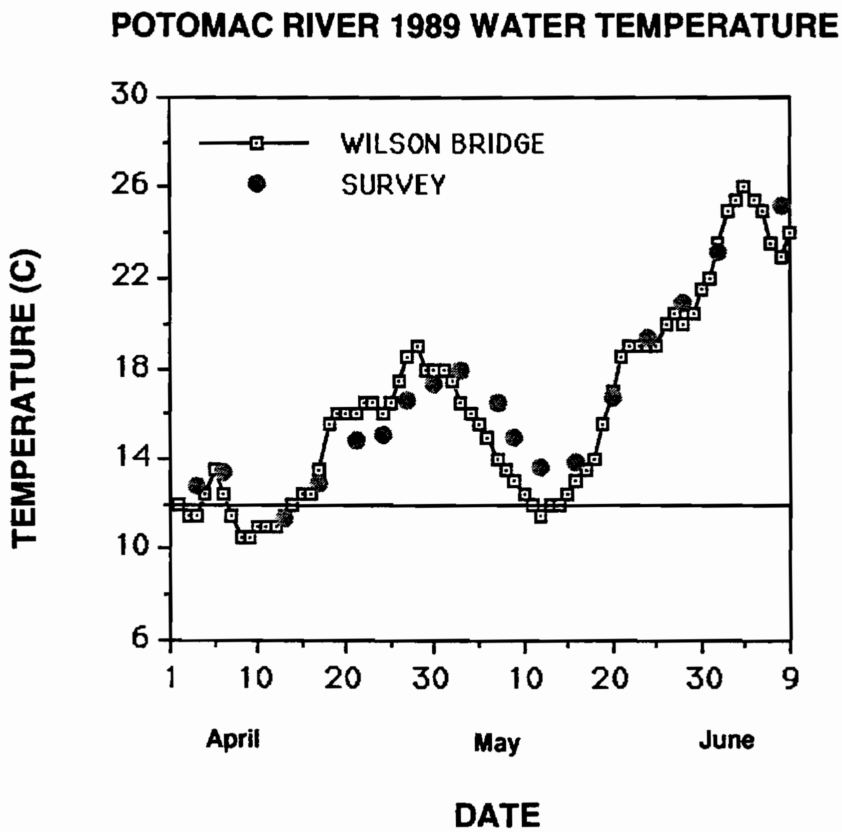


Figure 5. Potomac River water temperatures, 1989. Continuous temperatures recorded at Wilson Bridge. Mean temperatures indicated during each survey.

Table 6. Potomac River, 1989. Mean water column conductivity values (micro-ohms) at each station for each survey. Also given are survey and station means.

Station	SURVEY																		Station
	1 4/3	2 4/6	3 4/13	4 4/17	5 4/21	6 4/24	7 4/27	8 4/30	9 5/3	10 5/6	11 5/9	12 5/12	13 5/16	14 5/20	15 5/24	16 5/28	17 6/1	18 6/8	Mean
1	4016.7	200.0	4010.0	2970.0	1133.3	2450.0	3933.3	3623.3	374.0	220.7	171.0	134.3	143.0	155.0	164.0	161.0	--	--	1491.2
2	--	200.0	236.7	1303.3	317.7	1586.7	1766.7	1936.7	227.0	202.0	141.3	138.0	146.0	150.0	154.7	162.3	--	--	577.9
3	1226.7	200.0	173.3	220.0	712.3	701.7	743.3	783.3	270.0	225.0	132.7	133.7	139.3	154.7	152.3	165.0	--	--	383.3
4	630.0	200.0	190.0	178.7	185.0	280.0	631.7	--	225.3	221.0	128.0	139.0	138.0	152.0	150.3	200.0	--	--	242.6
5	--	200.0	140.0	200.0	188.0	206.3	268.0	211.7	241.0	188.0	128.3	139.7	136.3	150.0	150.3	180.0	--	--	181.8
6	713.3	220.0	240.0	178.0	190.7	194.0	206.3	220.0	242.3	174.0	122.3	140.0	139.3	149.7	152.7	187.0	--	--	216.9
7	686.7	220.0	153.3	179.3	191.3	206.7	208.3	232.0	208.7	200.0	130.0	138.7	139.7	149.3	152.3	190.3	--	--	211.7
8	726.7	243.3	180.0	188.7	201.0	209.7	229.0	244.0	258.0	158.3	140.0	139.7	142.0	147.7	164.7	205.3	--	--	223.6
9	786.7	206.7	240.0	200.0	212.7	222.3	242.7	252.3	260.0	145.0	139.7	139.0	142.0	148.0	172.3	210.3	--	--	232.5
10	816.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	816.7
11	940.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	940.0
A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1300.0	443.3	871.7
B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	191.5	210.5	201.0
C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	202.7	226.0	214.3
D	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	220.7	265.7	243.2
E	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2580.0	--	2580.0
Survey Mean	1171.5	210.0	618.1	624.2	370.2	673.0	914.4	937.9	256.3	191.6	137.0	138.0	140.6	150.7	157.1	184.6	899.0	286.4	447.8

7). Mean pH values were ≥6.9, except on survey 11 (9 May) when mean pH was 6.7 (Table 7). The low pH on this survey occurred immediately after a period of heavy rainfall (>2.0 inches) and at a time when river discharge was high (Figure 6B).

Rainfall and River Discharge

Rainfall, measured at Washington National Airport, exceeded 0.5 inches during five periods (Figure 6A). Heaviest rainfalls were recorded during the 29 April - 5 May period and on 23 May. Potomac River discharge was similar in 1989 to 1988, with maximum discharges recorded during the 5-25 May period (Figure 6B). In contrast, maximum river discharge in 1987 occurred earlier, during the 7-27 April period (Houde et al. 1988a, 1990). The integrated discharge for the 1 April - 31 May period was highest in 1987 (1.84×10^6 cfs), and equal for the 1988 and 1989 seasons (1.56 and 1.57×10^6 cfs, respectively).

Upper Bay

Temperature

Mean survey temperatures in the Upper Bay ranged from 10.3 to 23.8°C (Table 8). Temperatures rose above 15°C on 27 April, and remained above 15°C until 11 May (Figure 7). Temperatures were below 14°C from 11-17 May, reaching a low of 12°C on 11-12 May, but increased steadily during the remainder of the spawning season.

Salinity and Conductivity

Salinities >1.0 ppt were recorded at Stations 1-3 (Figure 2) from 21 April - 5 May and occasionally at station 9 in the C&D Canal. Mean

Table 7. Potomac River, 1989. Mean water column pH values at each station for each survey. Also given are survey and station means.

Station	SURVEY 1 4/3	2 4/6	3 4/13	4 4/17	5 4/21	6 4/24	7 4/27	8 4/30	9 5/3	10 5/6	11 5/9	12 5/12	13 5/16	14 5/20	15 5/24	16 5/28	17 6/1	18 6/8	Station Mean
1	6.87	7.28	7.08	7.27	--	--	7.44	--	--	6.68	6.90	7.22	6.75	6.98	6.78	6.97	--	--	7.0
2	--	7.00	7.48	--	--	--	6.80	--	7.31	6.88		7.30	7.04	6.97	6.82	7.04	--	--	7.1
3	6.99	7.22	6.82	--	--	--	6.70	--	7.06	7.38	6.57	7.25	6.72	7.09	6.85	7.01	--	--	7.0
4	7.12	7.15	6.90	--	--	--	7.04	--	7.11	7.46	6.78	6.93	6.87	6.94	6.81	7.33	--	--	7.0
5	--	--	6.85	6.65	--	--	7.03	--	7.38	7.19	6.68	7.27	6.90	7.11	7.18	7.05	--	--	7.0
6	6.81	7.20	6.98	--	--	--	7.00	--	7.49	7.22	6.72	6.86	6.90	7.09	7.13	7.59	--	--	7.1
7	7.17	7.32	6.82	--	6.95	--	6.93	--	7.40	7.47	6.95	6.64	6.72	7.19	6.96	7.39	--	--	7.1
8	7.03	7.16	7.00	--	7.03	--	6.75	--	7.42	7.25	6.18	6.72	6.97	7.20	7.12	7.38	--	--	7.0
9	6.98	6.77	6.81	--	7.02	--	6.88	--	7.44	7.29	6.67	6.90	7.00	7.23	7.08	7.09	--	--	7.0
10	6.92	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.9
11	6.60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.6
A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.21	7.40	7.3
B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.18	7.40	7.3
C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.90	7.52	7.2
D	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.39		7.4
E	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.17		7.2
Survey Mean	6.9	7.1	7.0	7.0	7.0		7.0		7.3	7.2	6.7	7.0	6.9	7.1	7.0	7.2	7.2	7.4	

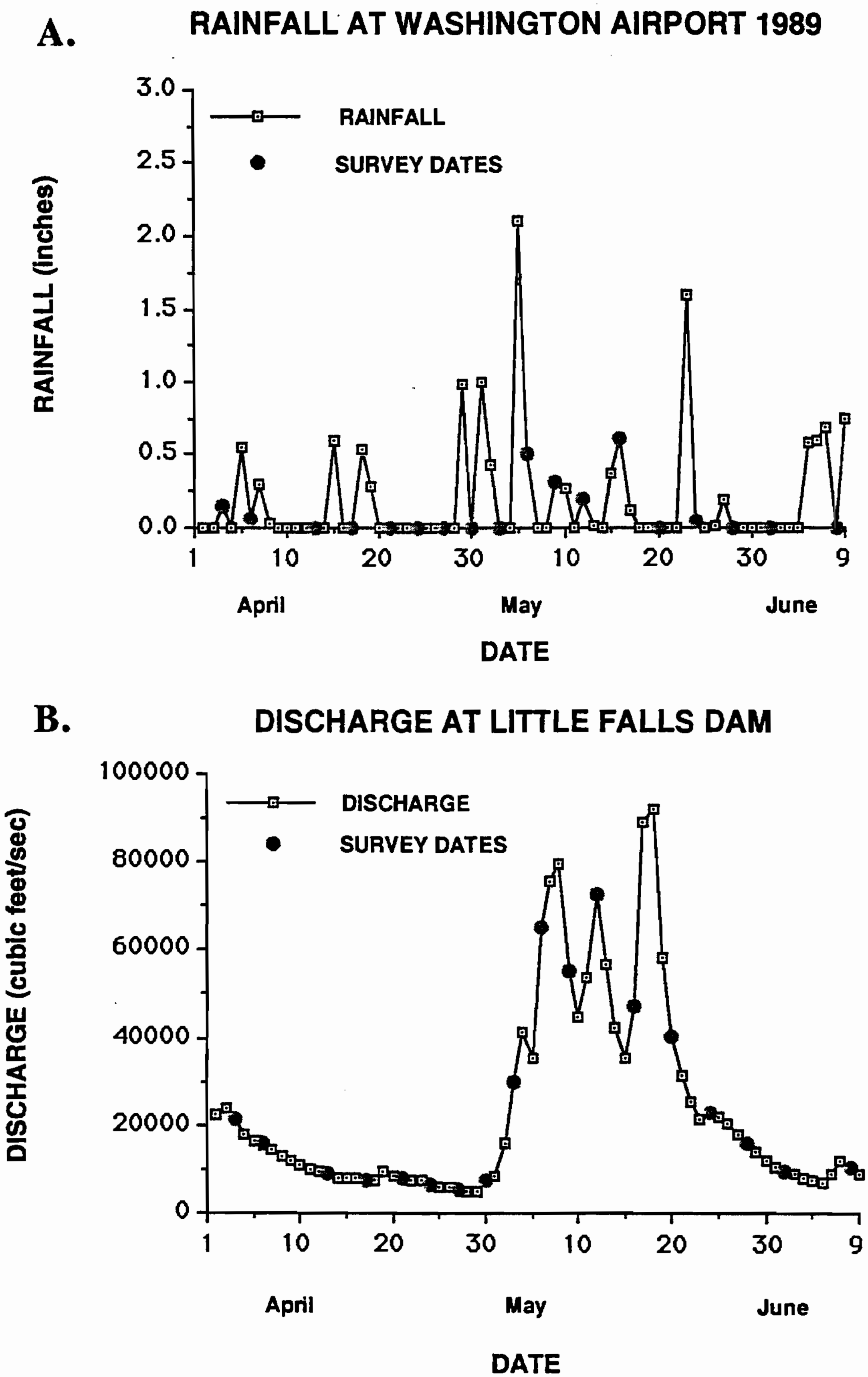


Figure 6. Potomac River, 1989. A. Rainfall recorded at National Airport and B. river discharge at Little Falls Dam.

Table 8. Upper Bay, 1989. Mean water column temperatures (°C) at each station for each survey. Also given are survey and station means.

Station	SURVEY 1 4/14	2 4/20	3 4/24	4 4/27	5 5/2	6 5/5	7 5/11	8 5/15	9 5/18	10 5/23	11 5/25	12 5/30	13 6/5	14 6/14	Station Mean
1	9.9	12.4	12.5	14.5	--	14.6	12.6	12.2	12.9	17.5	17.9	--	--	--	13.6
2	10.2	12.8	13.0	15.0	--	15.1	12.5	12.4	13.0	17.6	17.8	20.1	--	--	14.5
3	10.4	13.1	13.0	15.0	--	15.3	12.2	11.9	13.7	17.8	17.9	19.4	--	--	14.5
4	10.5	14.2	13.6	16.5	--	--	13.9	--	12.7	17.9	18.0	19.5	--	--	15.1
5	10.4	13.9	--	17.0	16.0	--	12.9	11.9	16.6	18.4	--	20.1	--	--	15.1
6	9.6	14.4	14.0	17.0	--	--	11.4	11.8	13.5	18.0	18.7	20.7	--	--	14.8
7	10.1	13.0	12.7	15.5	--	--	11.2	11.1	13.1	17.2	18.5	19.9	--	--	14.3
8	10.4	14.0	14.0	16.0	15.8	--	14.5	15.0	16.0	18.5	18.9	20.1	--	--	15.8
9	11.1	14.0	14.0	16.0	15.2	--	14.2	16.1	15.8	19.3	19.5	20.6	--	--	16.1
A	--	--	--	--	--	--	--	--	--	--	--	--	24.0	22.8	23.4
B	--	--	--	--	--	--	--	--	--	--	--	--	23.9	22.9	23.4
C	--	--	--	--	--	--	--	--	--	--	--	--	22.9	21.9	22.4
D	--	--	--	--	--	--	--	--	--	--	--	--	24.5	22.6	23.5
E	--	--	--	--	--	--	--	--	--	--	--	--	--	23.1	23.1
F	--	--	--	--	--	--	--	--	--	--	--	--	22.9	23.0	23.0
Survey Mean	10.3	13.5	13.2	15.8	15.7	15.0	12.8	12.8	14.1	18.0	18.4	20.0	23.8	22.7	

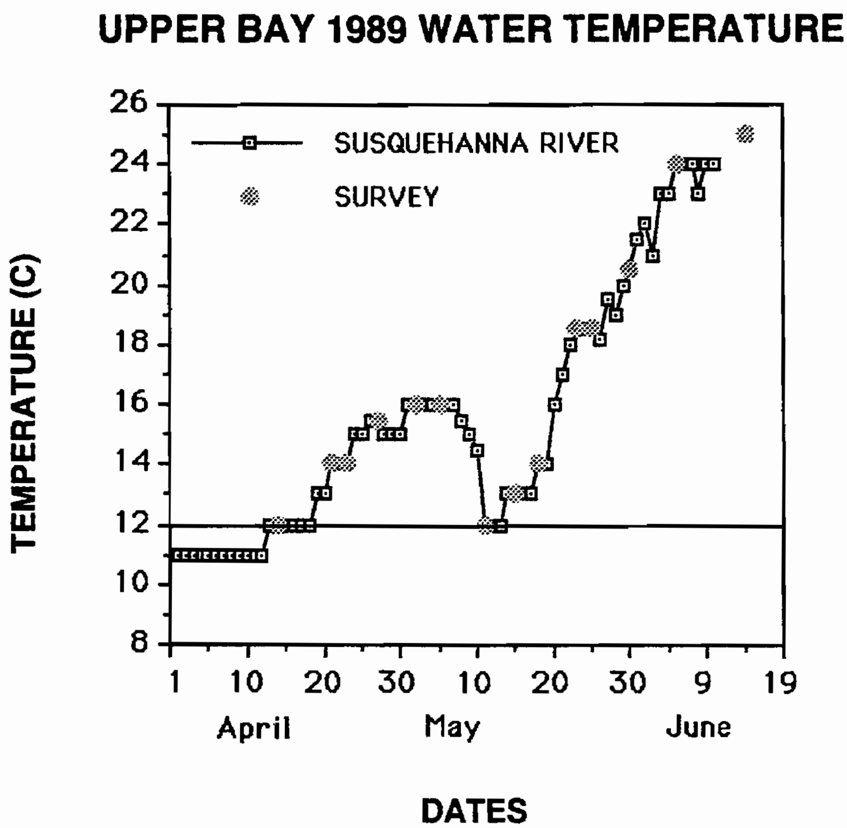


Figure 7. Upper Bay water temperatures, 1989. Continuous temperatures recorded at Conowingo Dam, Susquehanna River. Mean temperatures indicated during each survey.

conductivities were 2,788 and 615 micro-ohms at Stations 1 and 9, respectively, where striped bass larvae were most abundant (Table 9).

pH

Mean water column pH values ranged from 7.0 - 7.3 during the 14 surveys (Table 10). Lowest pH values were recorded during the 24 April and 23 May surveys. Discharge from the Susquehanna River was at its peak on 23 May (Figure 8B).

Rainfall and River Discharge

Daily rainfall measured at Baltimore-Washington International Airport was ≥1.0 inches on four dates (5 May, 25 May, 15 June and 7 June) (Figure 8A). The greatest rainfall (approximately 2.5 inches) fell on 25 May, just after the period of highest discharge (5-23 May) from the Susquehanna River (Figure 8B). Integrated discharge from the Susquehanna River into the Upper Bay during the 1 April - 31 May 1989 period was 5.29×10^6 cfs, a considerably higher value than the 3.02×10^6 cfs recorded in 1988. Highest river discharge occurred earlier (5-23 May) in 1989 than in 1988 (20-25 May).

Dissolved Oxygen

Mean dissolved oxygen values for each survey ranged from 7.2 - 10.9 ppm (Table 11). Lowest oxygen values were recorded on the last survey dates, 5 and 14 June.

Egg and Larvae Data Summaries, 1989

Catches of fish eggs and larvae in each survey from the standard tows of the 60-cm sampler are given in Appendix tables 1A - 28A. In the Potomac

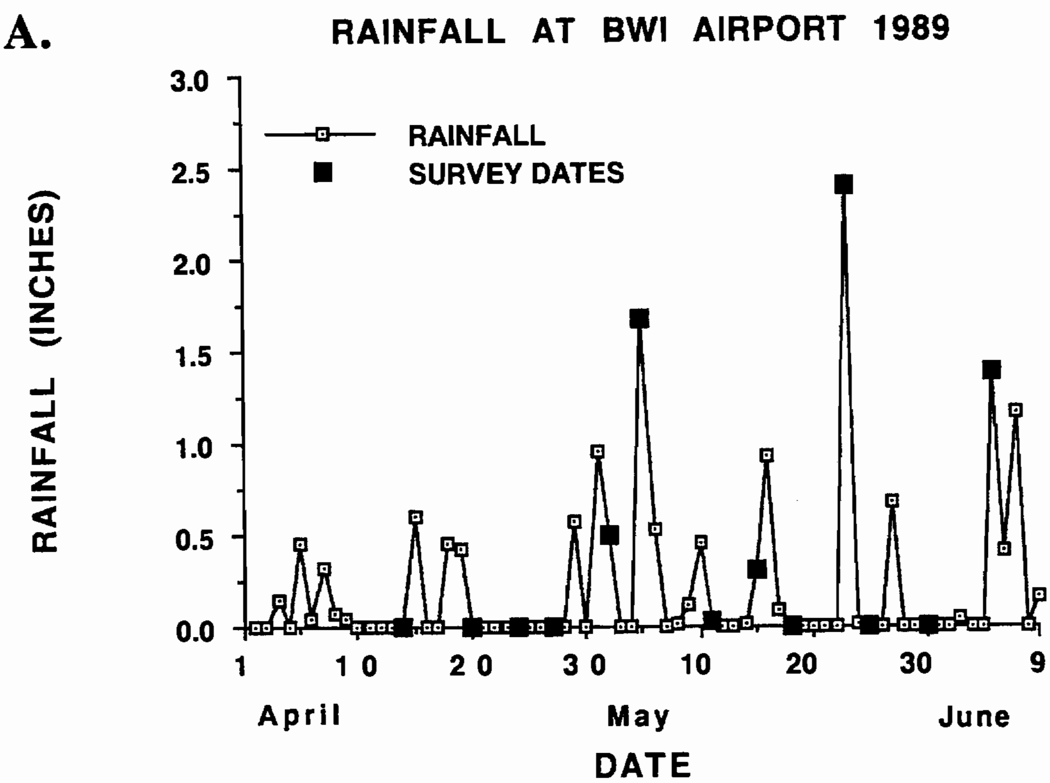
Table 9. Upper Bay, 1989. Mean water column conductivity values (micro-ohms) at each station for each survey. Also given are survey and station means.

Station	SURVEY 1 4/14	2 4/20	3 4/24	4 4/27	5 5/2	6 5/5	7 5/11	8 5/15	9 5/18	10 5/23	11 5/25	12 5/30	13 6/5	14 6/14	Station Mean
1	210.00	6236.67	7996.67	--	--	9156.67	201.67	131.67	160.67	572.67	425.67	--	--	--	2788.04
2	210.00	4196.67	6763.33	--	--	5596.67	214.67	130.00	161.67	542.00	186.67	188.33	--	--	1819.00
3	216.00	1813.33	4470.00	--	--	4206.67	189.67	138.67	186.33	214.00	174.67	189.33	--	--	1181.67
4	218.00	235.67	1489.00	--	--	--	561.00	--	149.33	148.67	166.00	191.00	--	--	394.83
5	218.33	402.67	--	--	1266.67	--	386.00	132.33	429.00	173.67	--	197.00	--	--	400.71
6	213.33	248.67	--	--	--	--	142.00	126.67	146.67	156.00	171.67	206.33	--	--	176.42
7	216.33	255.33	--	--	--	--	146.00	125.67	144.00	158.33	176.67	218.00	--	--	180.04
8	291.33	535.33	--	--	864.33	--	688.00	470.67	419.33	256.33	253.67	231.00	--	--	445.59
9	506.33	658.33	--	--	1956.67	--	485.67	546.33	341.67	373.33	370.33	300.67	--	--	615.48
A	--	--	--	--	--	--	--	--	--	--	--	--	189.67	724.00	456.83
B	--	--	--	--	--	--	--	--	--	--	--	--	228.67	335.00	281.83
C	--	--	--	--	--	--	--	--	--	--	--	--	211.00	232.67	221.83
D	--	--	--	--	--	--	--	--	--	--	--	--	208.00	229.00	218.50
E	--	--	--	--	--	--	--	--	--	--	--	--	--	275.33	275.33
F	--	--	--	--	--	--	--	--	--	--	--	--	890.00	1810.00	1350.00
Survey Mean	255.52	1622.30	5179.75		1362.56		334.96	225.25	237.63	288.33	240.67	215.25	345.47	601.00	

Table 10. Upper Bay, 1989. Mean water column pH at each station for each survey. Also given are survey and station means.

	SURVEY														
Station	1 4/14	2 4/20	3 4/24	4 4/27	5 5/2	6 5/5	7 5/11	8 5/15	9 5/18	10 5/23	11 5/25	12 5/30	13 6/5	14 6/14	Station Mean
1	6.89	6.99	7.06	--	--	7.15	7.19	6.92	7.04	6.87	6.99	--	--	--	7.0
2	7.29	7.05	7.06	--	--	7.13	7.17	7.03	7.04	6.99	7.04	7.13	--	--	7.1
3	7.35	7.13	6.64	--	--	7.17	7.24	7.12	7.02	7.06	7.08	7.21	--	--	7.1
4	7.42	7.43	7.26	--	--	--	7.09	--	7.21	6.88	7.16	7.18	--	--	7.2
5	7.39	7.07	--	--	6.88	--	7.22	7.21	6.96	7.16	--	7.40	--	--	7.2
6	7.50	8.48	--	--	--	--	7.20	7.23	7.19	7.22	7.38	8.11	--	--	7.5
7	7.45	7.70	--	--	--	--	7.26	7.22	7.12	7.18	7.29	7.76	--	--	7.4
8	7.26	7.05	--	--	7.31	--	7.06	6.95	7.01	6.98	6.88	6.94	--	--	7.0
9	7.22	7.04	--	--	7.32	--	7.04	6.97	6.92	6.90	7.02	6.73	--	--	7.0
A	--	--	--	--	--	--	--	--	--	--	--	--	--	7.08	7.1
B	--	--	--	--	--	--	--	--	--	--	--	--	6.72	7.08	6.9
C	--	--	--	--	--	--	--	--	--	--	--	--	7.84	7.24	7.5
D	--	--	--	--	--	--	--	--	--	--	--	--	7.44	7.38	7.4
E	--	--	--	--	--	--	--	--	--	--	--	--	--	7.01	7.0
F	--	--	--	--	--	--	--	--	--	--	--	--	6.96	6.95	7.0
Survey Mean	7.3	7.3	7.0		7.2	7.2	7.2	7.1	7.1	7.0	7.1	7.3	7.2	7.1	

A.



B.

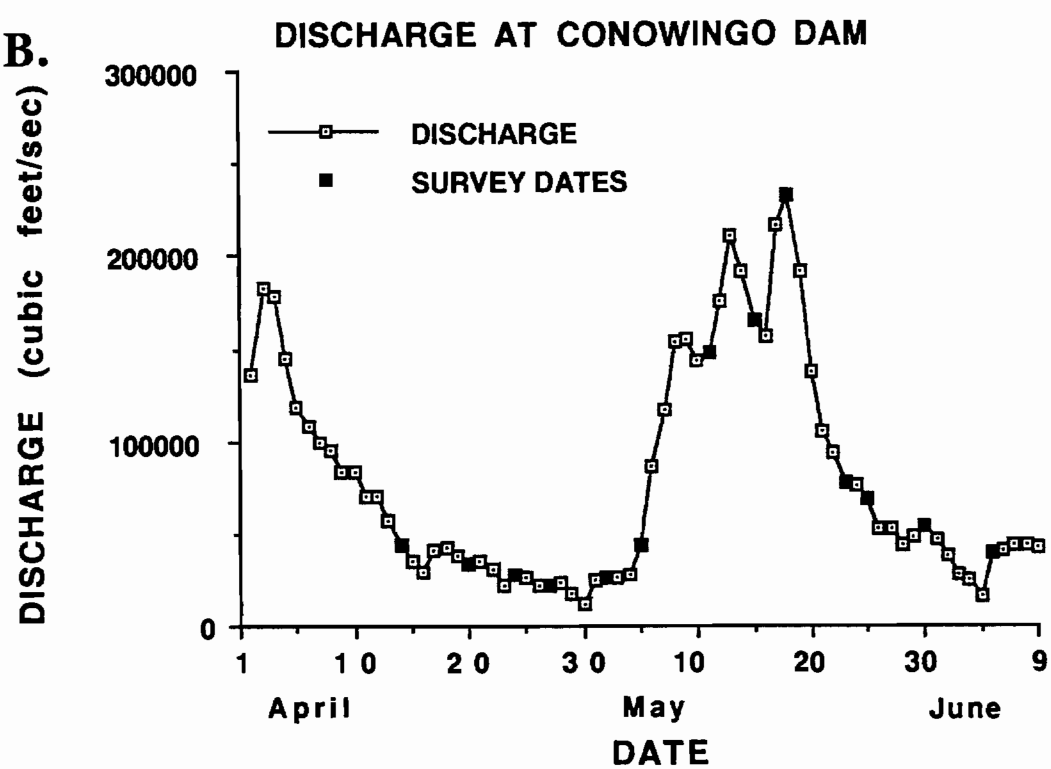


Figure 8. Upper Bay, 1989. A. Rainfall recorded at Baltimore-Washington International Airport and B. Susquehanna River discharge at Conowingo Dam.

Table 11. Upper Bay, 1989. Mean water column dissolved oxygen values at each station for each survey. Also given are survey and station means.

Station	SURVEY 1 4/14	2 4/20	3 4/24	4 4/27	5 5/2	6 5/5	7 5/11	8 5/15	9 5/18	10 5/23	11 5/25	12 5/30	13 6/5	14 6/14	Station Mean
1	10.77	9.38	8.73	--	--	8.62	9.94	11.36	10.75	8.91	8.33	--	--	--	9.6
2	10.91	9.47	8.84	--	--	8.65	9.80	11.45	10.78	8.96	8.53	8.25	--	--	9.6
3	11.08	9.84	9.22	--	--	9.46	10.26	11.42	10.53	9.19	8.53	8.99	--	--	9.8
4	10.91	10.74	9.51	--	--	--	9.08	--	11.28	8.82	8.77	9.59	--	--	9.8
5	11.05	9.44	--	--	8.63	--	9.84	11.59	8.77	8.56	8.95	9.47	--	--	9.6
6	11.63	12.37	--	--	--	--	10.87	11.78	11.23	9.35	--	10.63	--	--	11.1
7	11.38	11.50	--	--	--	--	10.93	11.71	11.07	9.48	9.09	10.17	--	--	10.7
8	10.54	9.24	--	--	8.80	--	8.69	8.58	8.86	8.54	7.83	8.39	--	--	8.8
9	10.24	9.28	--	--	8.47	--	8.46	8.08	7.87	8.25	7.74	8.09	--	--	8.5
A	--	--	--	--	--	--	--	--	--	--	--	--	6.57	6.93	6.8
B	--	--	--	--	--	--	--	--	--	--	--	--	8.27	6.37	7.3
C	--	--	--	--	--	--	--	--	--	--	--	--	9.03	7.57	8.3
D	--	--	--	--	--	--	--	--	--	--	--	--	9.03	8.83	8.9
E	--	--	--	--	--	--	--	--	--	--	--	--	--	6.87	6.9
F	--	--	--	--	--	--	--	--	--	--	--	--	6.63	6.60	6.6
Survey Mean	10.9	10.1	9.1		8.6	8.6	9.8	10.8	10.1	8.9	8.5	9.2	7.9	7.2	

River, Morone spp. larvae (striped bass plus white perch) and clupeid larvae were common, especially on the last two surveys (24, 28 May). Other larvae collected were cyprinids, atherinids, gobiids and percids. Mean densities of Morone spp. larvae ranged from 37/100 m^3 on 16 May to 1084 100 m^3 on 28 May. Clupeid larvae mean densities ranged from 0.2/100 m^3 on 3 April to 2080/100 m^3 on 28 May, and exceeded Morone densities on 6 and 28 May. In the Upper Bay, Morone spp. larvae mean density ranged from 0.2/100 m^3 on 5 May to 750/100 m^3 on 25 May. Densities of Morone and Clupeid larvae were highest on the last two surveys, 25 and 30 May. Mean clupeid densities ranged from 0/100 m^3 on 14 April to 96/100 m^3 on 30 May.

Potomac River: Totals of 19,352 striped bass eggs and 2,928 larvae were collected in 292 tows of the 60-cm, 333-μm net. Eggs were collected on every survey and larvae were collected on 13 of the 16 surveys (Table 12). Eggs and larvae occurred at all of the nine usual stations that were sampled during the standard-net surveys. The highest percentages of the eggs were collected at Stations 4 and 5. More than 74% of the eggs occurred in collections from surveys 6, 7 and 14 (24 April, 27 April and 20 May). The biggest catches of striped bass larvae were made at Stations 1 to 4. More than 87% of the larvae were collected on the last two surveys (24 and 28 May).

The mean density (no./100 m^3) of striped bass eggs at Potomac River stations was 73.48 in 1989 (Table 13; Figure 9). Mean abundance (number under 1 m^2) was 3.15. Both density and abundance were highest on Survey 7 (27 April) when mean river temperature was 16.6°C. Striped bass eggs were most abundant at Stations 4 and 5 (Table 13), near the middle of the Potomac sampling area (Figure 1). Lowest egg abundances were recorded from Station 1, the most downstream station.

The highest mean densities and abundances of striped bass larvae in the

Table 12. Potomac River 1989. Striped bass eggs and larvae. Catches in duplicate tows of 5-min duration, 60-cm net, 333 μm mesh.

	SURVEY															
	1 3-Apr		2 6-Apr		3 13-Apr		4 17-Apr		5 21-Apr		6 24-Apr		7 27-Apr		8 30-Apr	
STATION	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
1	0	0	2	3	0	0	0	0	1	0	3	0	7	0	0	0
	0	0	7	2	0	1	0	0	5	1	4	1	0	0	0	0
2			8	0	0	0	0	0	305	1	31	2	62	1	0	0
			2	2	0	0	0	0	269	2	31	1	99	1	0	0
3	0	0	25	0	0	0	4	1	63	1	192	7	866	6	13	0
	0	0	7	1	2	0	1	0	43	1	363	13	434	1	7	0
4	0	0	71	0	10	0	20	0	309	0	1130	16	757	2	293	5
	0	0	58	2	10	0	40	0	193	1	607	33	476	0	193	2
5			1	0	1	0	32	0	210	0	754	3	1171	3	87	0
			6	1	1	0	34	0	298	0	273	22	1891	11	185	1
6	13	0	0	0	0	0	3	0	41	0	55	1	440	1	29	1
	6	0	3	0	0	0	11	0	24	0	289	2	751	3	21	1
7	31	0	3	0	0	1	1	0	194	0	5	0	95	0	8	2
	4	0	15	0	0	0	1	0	176	0	36	1	215	1	111	0
8	8	0	38	0	0	0	0	0	84	0	13	0	21	1	51	9
	4	0	64	0	0	0	1	0	134	1	8	0	23	0	122	11
9	0	0	0	3	2	0	0	0	9	0	23	2	220	5	12	11
	0	0	2	0	0	0	2	0	55	0	31	2	178	2	77	16
10	0	0														
	0	0														
11	0	0														
	0															
TOTALS *	66	0	312	14	26	2	150	1	2413	8	3848	106	7706	38	1209	59
PERCENT*	0.34	0.00	1.61	0.48	0.13	0.07	0.78	0.03	12.47	0.27	19.88	3.62	39.82	1.30	6.25	2.02

* Totals and percent exclusive of stations 10, 11.

Table 12 (cont.). Potomac River 1989. Striped bass eggs and larvae. Catches in duplicate tows of 5-min duration, 60-cm net, 333 μm mesh.

	SURVEY																			
	9 3-May		10 6-May		11 9-May		12 12-May		13 16-May		14 20-May		15 24-May		16 28-May		TOTALS		PERCENT	
STATION	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
1	9	7	0	1	1	10	0	10	0	0	0	0	1	61	1	202	67	481	0.33	16.43
	13	12	13	2	0	7	0	1	0	0	0	0	0	36	0	124				
2	4	2	1	2	2	7	1	1	0	0	0	0	39	126	0	125	854	469	4.41	16.02
	0	4	0	1	0	0	0	3	0	0	0	0	0	68	0	120				
3	17	5	5	0	3	7	2	1	0	0	0	0	41	76	0	65	2115	383	10.93	13.08
	27	5	0	11	0	2	0	0	0	0	0	0	0	105	0	75				
4	33	1	3	0	11	1	2	0	0	0	55	0	58	272	0	44	4393	688	22.70	23.50
	47	0	0	0	0	2	1	0	1	0	15	0	0	268	0	39				
5	0	2	0	0	2	1	1	0	0	0	55	0	2	35	3	44	5108	212	26.40	7.24
	0	3	0	0	6	0	5	0	0	0	83	0	7	41	0	45				
6	2	8	0	0	6	0	7	0	7	0	45	0	2	5	0	7	1798	63	9.29	2.15
	1	13	1	0	6	0	6	0	3	0	18	0	8	17	0	4				
7	0	6	0	0	5	0	4	0	0	0	163	0	5	76	1	12	1284	294	6.63	10.04
	0	3	16	0	6	0	2	0	1	0	176	0	8	176	2	16				
8	6	1	10	0	208	0	0	0	1	0	1180	0	7	6	5	12	2617	78	13.52	2.66
	0	3	0	0	47	0	0	0	0	0	575	0	7	20	0	14				
9	3	3	3	0	3	0	4	0	3	0	152	0	30	81	3	13	1116	260	5.77	8.88
	10	4	0	0	0	0	0	0	0	0	267	0	23	111	4	7				
10											456	0								
											240	0								
11											19	0								
											57	0								
TOTALS *	172	82	52	17	306	37	35	16	16	0	2784	0	238	1580	19	968	19352	2928		
PERCENT*	0.89	2.80	0.27	0.58	1.58	1.26	0.18	0.55	0.08	0.00	14.39	0.00	1.23	53.96	0.10	33.06				

* Totals and percent exclusive of stations 10, 11.

Table 13. Potomac River 1989. Striped bass egg density (#/100 m3) and abundance (#/m2) for duplicate, 5-min. tows of the 60-cm, 333 µm net. D = density; A = abundance.

	SURVEY															
	1 3-Apr		2 6-Apr		3 13-Apr		4 17-Apr		5 21-Apr		6 24-Apr		7 27-Apr		8 30-Apr	
Station	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A
1	0.00	0.00	4.59	0.17	0.00	0.00	0.00	0.00	3.66	0.14	3.60	0.13	3.30	0.12	0.00	0.00
2			5.38	0.19	0.00	0.00	0.00	0.00	352.02	12.67	29.99	1.08	81.79	2.94	0.00	0.00
3	0.00	0.00	17.57	0.67	0.97	0.04	3.13	0.12	56.78	2.16	268.51	10.20	652.42	24.79	11.19	0.43
4	0.00	0.00	73.11	3.00	11.26	0.46	35.71	1.46	310.81	12.74	906.42	37.16	578.10	23.70	295.64	12.12
5			4.06	0.19	0.93	0.04	40.57	1.91	309.76	14.56	498.88	23.45	1553.34	73.01	156.63	7.36
6	8.38	0.49	1.63	0.10	0.00	0.00	8.08	0.48	37.91	2.24	157.31	9.28	569.16	33.58	28.14	1.66
7	16.79	0.74	10.13	0.45	0.00	0.00	0.81	0.04	208.74	9.18	16.90	0.74	149.88	6.59	66.76	2.94
8	5.07	0.16	57.24	1.77	0.00	0.00	0.60	0.02	123.01	3.81	9.12	0.28	24.06	0.75	100.11	3.10
9	0.00	0.00	1.20	0.06	1.04	0.05	1.32	0.07	36.50	1.90	26.26	1.37	203.06	10.56	53.36	2.77
10																
11																
MEAN *	4.32	0.20	19.44	0.73	1.58	0.07	10.02	0.45	159.91	6.60	213.00	9.30	423.90	19.56	79.09	3.38

* Means exclusive of stations 10 & 11

Table 13 (cont.). Potomac River 1989. Striped bass egg density (#/100 m3) and abundance (#/m2) for duplicate, 5-min. tows of the 60-cm, 333 µm net. D = density; A = abundance.

	SURVEY																	
	9 3-May		10 6-May		11 9-May		12 12-May		13 16-May		14 20-May		15 24-May		16 28-May			
Station	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	Mean Density	Mean Abundance
1	11.48	0.42	7.30	0.27	0.55	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.02	0.43	0.02	2.21	0.08
2	2.17	0.08	0.56	0.02	1.06	0.04	0.51	0.02	0.00	0.00	0.00	0.00	18.40	0.66	0.00	0.00	32.79	1.18
3	28.49	1.08	1.51	0.06	1.44	0.05	0.93	0.04	0.00	0.00	0.00	0.00	17.37	0.66	0.00	0.00	66.27	2.52
4	50.09	2.05	2.50	0.10	5.85	0.24	1.44	0.06	0.52	0.02	38.71	1.59	25.22	1.03	0.00	0.00	145.96	5.98
5	0.00	0.00	0.00	0.00	5.16	0.24	2.68	0.13	0.00	0.00	81.61	3.84	4.39	0.21	1.52	0.07	177.31	8.33
6	1.59	0.09	0.53	0.03	7.69	0.45	6.07	0.36	5.32	0.31	36.63	2.16	4.94	0.29	0.00	0.00	54.59	3.22
7	0.00	0.00	9.41	0.41	6.07	0.27	2.89	0.13	0.56	0.02	198.21	8.72	5.63	0.25	1.53	0.07	43.39	1.91
8	3.41	0.11	5.95	0.18	147.09	4.56	0.00	0.00	0.53	0.02	1106.21	34.29	7.05	0.22	2.58	0.08	99.50	3.08
9	7.43	0.39	1.61	0.08	1.76	0.09	1.94	0.10	1.50	0.08	261.51	13.60	26.85	1.40	3.63	0.19	39.31	2.04
10																		
											451.95	23.50						
11																		
											40.06	2.08						
MEAN *	11.63	0.47	3.26	0.13	19.63	0.66	1.83	0.09	0.94	0.05	191.43	7.13	12.26	0.53	1.08	0.05	73.48	3.15

* Means exclusive of stations 10 & 11

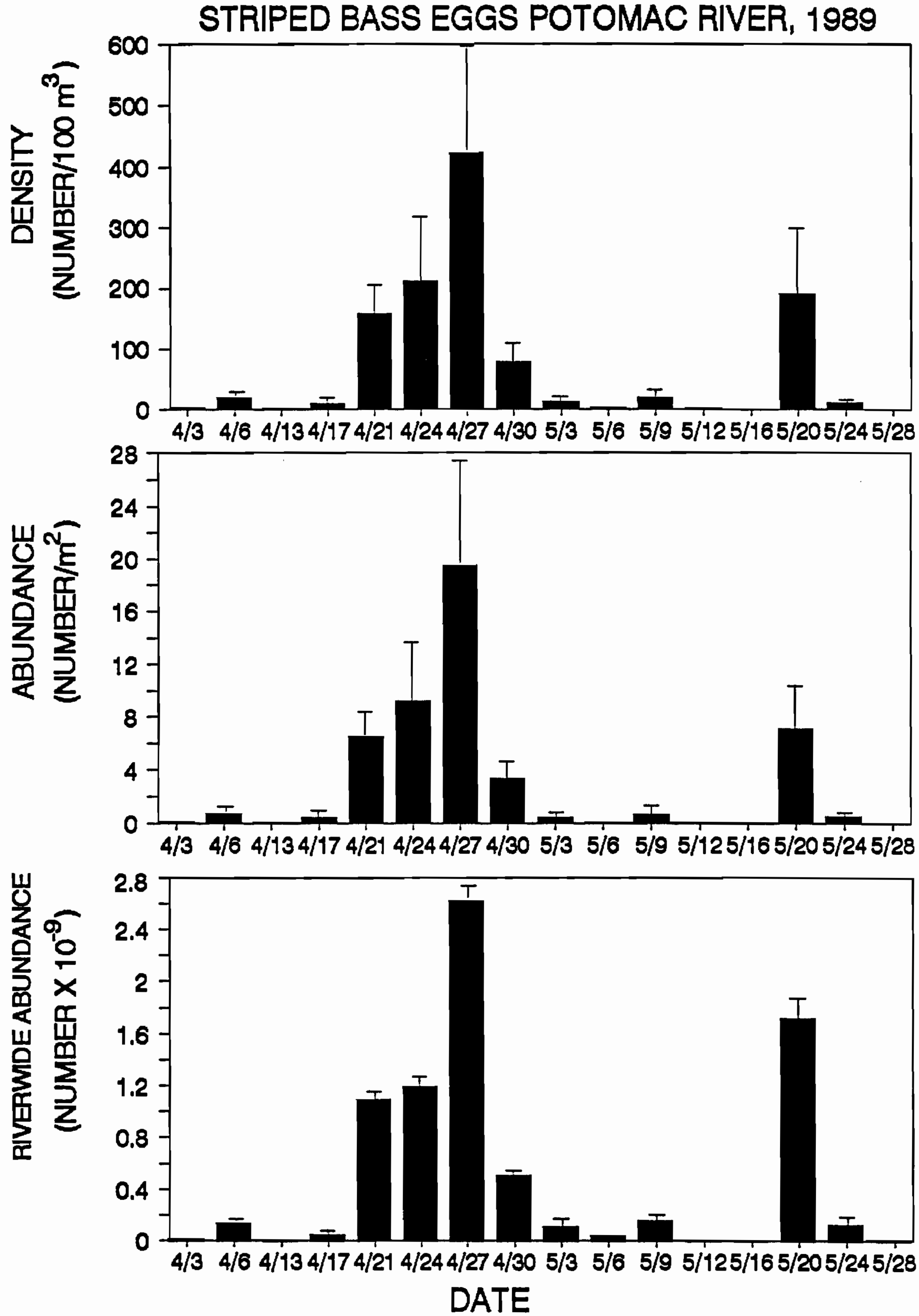


Figure 9. Potomac River, 1989. Striped bass egg densities (no./100 m^3), abundances (no./m^2), and riverwide abundances (billions) on each survey date.

Potomac occurred on the last two surveys, 24 and 28 May (Table 14; Figure 10). Densities were 80.1 and 51.8 per 100 m^3, and abundances were 3.4 and 2.0 per m^2, respectively, on those dates. Densities and abundances of striped bass larvae always were much lower on the earlier sampling dates.

Striped bass larvae in the Potomac were most abundant (number under 1 m^2 of river surface) at Stations 1-4 in 1989 (Table 14), although substantial numbers occurred throughout the nursery area. On average, larvae were approximately two times more abundant at Stations 1-4 than at stations farther upstream except for Station 9 which had larval abundances nearly equal to those at Stations 1-4. The areas of peak larvae abundances were displaced only a few km downstream from the area (Stations 4 and 5) where egg abundance was highest (Table 13).

The mean water column abundances (number under 1 m^2) of striped bass eggs and larvae differed substantially among the three years of our research on the Potomac River. Mean egg abundance was highest in 1989, but the highest mean larval abundance occurred in 1987 (Table 15).

Estimated riverwide abundances of striped bass eggs and larvae on each Potomac River survey (Tables 16 and 17) were derived from the station estimates expanded to the total volume represented by each station, (i.e. segment abundances). The summed segment abundance totals on each survey are the estimated abundances of eggs and larvae present in the Potomac on each sampling date. Riverwide egg abundances were highest during surveys 5 to 8 (21-30 April) and on survey 14 (20 May) (Table 16; Figure 9). Riverwide larvae abundances in 1989 were less than 1×10^8 on all surveys except 15 and 16 (24 and 28 May), the last two 60-cm sampler survey dates (Table 16; Figure 10).

It is apparent that there was little survival of larvae from the substantial egg production in the period 19-29 April (Figures 9 and 10). Most

Table 14. Potomac River 1989. Striped bass larvae density (#/100 m3) and abundance (#/m2) for duplicate, 5-min. tows of the 60-cm, 333 µm net. D = density; A = abundance.

	SURVEY															
	1 3-Apr		2 6-Apr		3 13-Apr		4 17-Apr		5 21-Apr		6 24-Apr		7 27-Apr		8 30-Apr	
Station	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A
1	0.00	0.00	2.59	0.10	0.50	0.02	0.00	0.00	0.61	0.02	0.53	0.02	0.00	0.00	0.00	0.00
2			1.08	0.04	0.00	0.00	0.00	0.00	1.84	0.07	1.43	0.05	1.02	0.04	0.00	0.00
3	0.00	0.00	0.53	0.02	0.00	0.00	0.64	0.02	1.08	0.04	9.67	0.37	3.49	0.13	0.00	0.00
4	0.00	0.00	1.20	0.05	0.00	0.00	0.00	0.00	0.61	0.03	26.10	1.07	0.97	0.04	4.25	0.17
5			0.58	0.03	0.00	0.00	0.00	0.00	0.00	0.00	11.32	0.53	7.19	0.34	0.59	0.03
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.08	1.91	0.11	1.12	0.07
7	0.00	0.00	0.00	0.00	0.53	0.02	0.00	0.00	0.00	0.00	0.44	0.02	0.48	0.02	1.10	0.05
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.02	0.00	0.00	0.58	0.02	11.62	0.36
9	0.00	0.00	1.58	0.08	0.00	0.00	0.00	0.00	0.00	0.00	1.95	0.10	3.57	0.19	16.03	0.83
MEAN =	0.00	0.00	0.84	0.03	0.11	0.00	0.07	0.00	0.52	0.02	5.87	0.25	2.13	0.10	3.86	0.17

Table 14. (cont.) Potomac River 1989. Striped bass larvae density (#/100 m3) and abundance (#/m2) for duplicate, 5-min. tows of the 60-cm, 333 μm net. D = density; A = abundance.

	SURVEY																	
	9 3-May		10 6-May		11 9-May		12 12-May		13 16-May		14 20-May		15 24-May		16 28-May		Mean	Mean
Station	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	Density	Abundance
1	9.92	0.37	1.67	0.06	9.22	0.34	4.69	0.17	0.00	0.00	0.00	0.00	45.66	1.69	141.45	5.23	13.55	0.50
2	3.17	0.11	1.73	0.06	3.72	0.13	1.90	0.07	0.00	0.00	0.00	0.00	89.26	3.21	120.09	4.32	15.02	0.54
3	6.42	0.24	5.98	0.23	4.49	0.17	0.46	0.02	0.00	0.00	0.00	0.00	84.70	3.23	76.45	2.91	12.12	0.46
4	0.65	0.03	0.00	0.00	1.67	0.07	0.00	0.00	0.00	0.00	0.00	0.00	232.79	9.54	40.27	1.65	19.28	0.79
5	2.71	0.13	0.00	0.00	0.63	0.03	0.00	0.00	0.00	0.00	0.00	0.00	39.10	1.84	42.68	2.01	6.99	0.33
6	11.20	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.88	0.64	6.49	0.38	2.06	0.12
7	4.91	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.28	4.81	14.25	0.63	8.19	0.36
8	2.18	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.77	0.40	13.48	0.42	2.57	0.08
9	3.94	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	96.70	5.03	10.75	0.56	8.41	0.44
MEAN =	5.01	0.23	1.04	0.04	2.19	0.08	0.78	0.03	0.00	0.00	0.00	0.00	80.13	3.38	51.77	2.01	9.80	0.40

Table 15. Potomac River and Upper Bay, 1987-1989. Striped bass egg and larvae mean densities (no. per 100 m^3) and abundances (no. under 1 m^2) from ichthyoplankton surveys in each of the years.

Potomac River, 1987-1989

Year	Eggs		Larvae	
	Density	Abundance	Density	Abundance
1987	25.14	1.81	18.87	1.32
1988	20.70	0.98	5.31	0.25
1989	73.48	3.15	9.80	0.40

Upper Bay, 1988 and 1989

Year	Eggs		Larvae	
	Density	Abundance	Density	Abundance
1988	8.21	0.65	1.07	0.08
1989	77.90	4.25	17.75	1.00

Table 16. Potomac River 1989. Estimated riverwide abundances of striped bass eggs.

RIVER SEGMENT	SURVEY 1 3-Apr	2 6-Apr	3 13-Apr	4 17-Apr	5 21-Apr	6 24-Apr	7 27-Apr	8 30-Apr	9 3-May	10 6-May	11 9-May	12 12-May	13 16-May	14 20-May	15 24-May	16 28-May	SEGMENT MEAN	SEGMENT TOTAL	% OF TOTAL
1	0.00E+00	1.57E+07	0.00E+00	0.00E+00	1.25E+07	1.23E+07	1.13E+07	0.00E+00	3.94E+07	2.50E+07	1.88E+06	0.00E+00	0.00E+00	0.00E+00	1.54E+06	1.48E+06	7.58E+06	1.21E+08	1.54
2		5.47E+06	0.00E+00	0.00E+00	3.58E+08	3.05E+07	8.33E+07	0.00E+00	2.21E+06	5.72E+05	1.08E+06	5.19E+05	0.00E+00	0.00E+00	1.87E+07	0.00E+00	3.34E+07	5.01E+08	6.38
3	0.00E+00	1.54E+07	8.51E+05	2.74E+06	4.97E+07	2.35E+08	5.72E+08	9.81E+06	2.50E+07	1.32E+06	1.26E+06	8.11E+05	0.00E+00	0.00E+00	1.52E+07	0.00E+00	5.81E+07	9.29E+08	11.83
4	0.00E+00	4.08E+07	6.29E+06	1.99E+07	1.74E+08	5.06E+08	3.23E+08	1.65E+08	2.80E+07	1.40E+06	3.27E+06	8.06E+05	2.88E+05	2.16E+07	1.41E+07	0.00E+00	8.15E+07	1.30E+09	16.60
5		1.98E+06	4.54E+05	1.98E+07	1.51E+08	2.43E+08	7.57E+08	7.63E+07	0.00E+00	0.00E+00	2.51E+06	1.31E+06	0.00E+00	3.97E+07	2.14E+06	7.38E+05	8.64E+07	1.30E+09	16.49
6	5.56E+06	1.08E+06	0.00E+00	5.36E+06	2.51E+07	1.04E+08	3.78E+08	1.87E+07	1.05E+06	3.49E+05	5.10E+06	4.02E+06	3.53E+06	2.43E+07	3.27E+06	0.00E+00	3.62E+07	5.79E+08	7.38
7	1.08E+07	6.51E+06	0.00E+00	5.18E+05	1.34E+08	1.09E+07	9.62E+07	4.29E+07	1.05E+00	6.04E+06	3.90E+06	1.85E+06	3.61E+05	1.27E+08	3.62E+06	9.83E+05	2.79E+07	4.46E+08	5.68
8	4.77E+06	5.38E+07	0.00E+00	5.60E+05	1.16E+08	8.57E+06	2.26E+07	9.41E+07	3.21E+06	5.60E+06	1.38E+08	0.00E+00	4.95E+05	1.04E+09	6.63E+06	2.42E+06	9.35E+07	1.50E+09	19.06
9	0.00E+00	2.30E+06	1.99E+06	2.51E+06	6.98E+07	5.02E+07	3.88E+08	1.02E+08	1.42E+07	3.08E+06	3.37E+06	3.71E+06	2.87E+06	4.80E+08	5.13E+07	6.93E+06	7.39E+07	1.18E+09	15.05
SURVEY TOTAL	2.11E+07	1.43E+08	9.58E+06	5.14E+07	1.09E+09	1.20E+09	2.63E+09	5.09E+08	1.13E+08	4.34E+07	1.61E+08	1.30E+07	7.54E+06	1.73E+09	1.17E+08	1.26E+07	5.54E+07	7.85E+09	
% OF TOTAL	0.27	1.82	0.12	0.65	13.87	15.29	33.48	6.48	1.44	0.55	2.05	0.17	0.10	22.06	1.48	0.16			

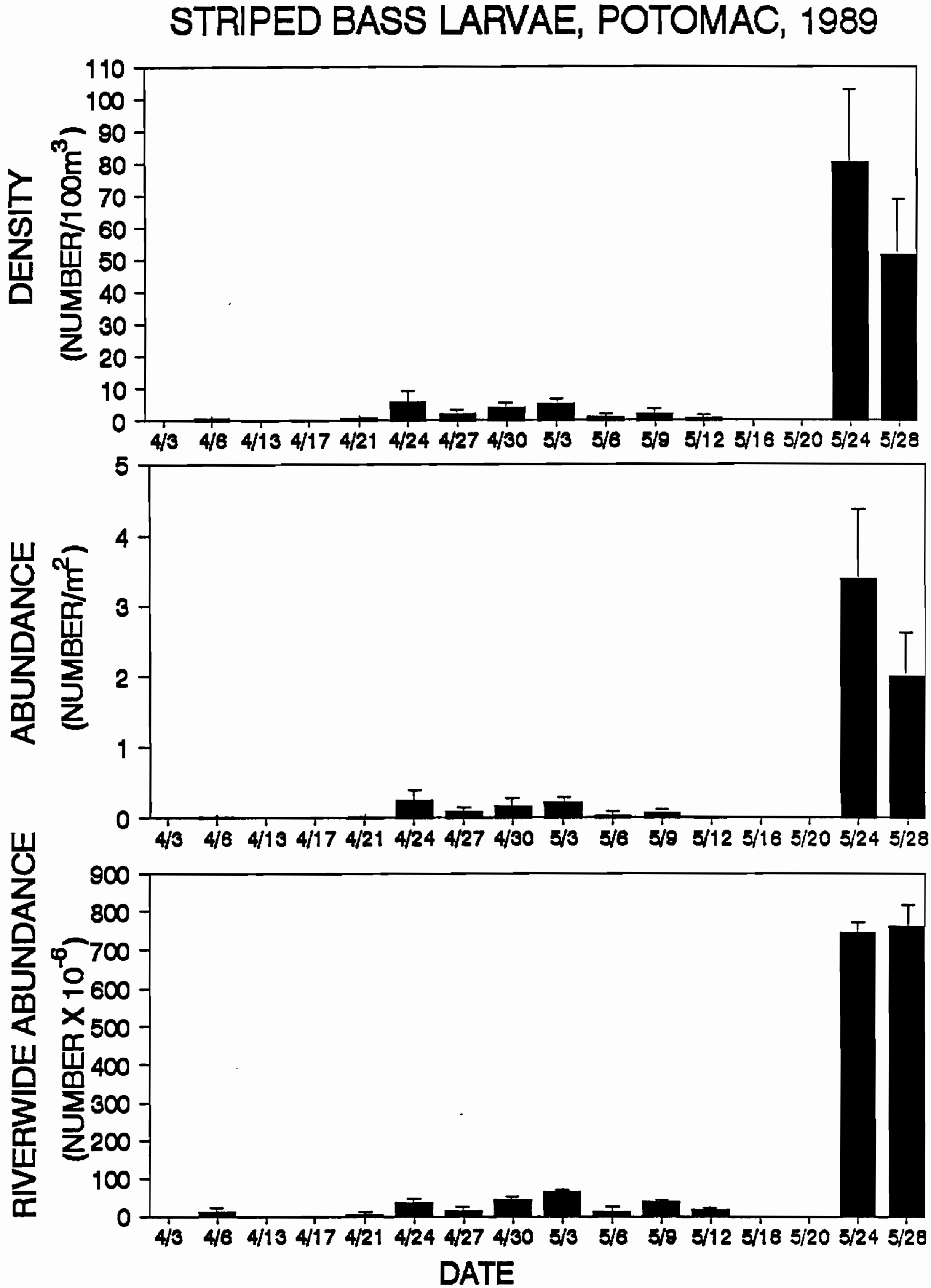


Figure 10. Potomac River, 1989. Striped bass larvae densities (no./100 m^3), abundances (no./m^2), and riverwide abundances (millions) on each survey date.

larvae were survivors of egg production in the 18-26 May period. When expressed as riverwide abundances, it can be seen that the highest percentages of eggs were in the middle and most upstream segments of the River (Table 16). Larvae abundance, expressed by river segment were more complex. The highest percentage (42%) was estimated to be in the relatively large volume of the most downstream station, segment 1, but substantial numbers were found in segments 2 to 4 and, surprisingly, in segment 9, the most upstream river segment (Table 17).

Upper Bay: Totals of 13,265 striped bass eggs and 2,804 larvae were collected in 181 tows of the 60-cm, 333-μm net during 12 Upper Bay surveys. Eggs occurred during all surveys except Survey 6 (5 May) when only two stations were sampled (Table 18). Biggest catches were recorded on dates encompassed by surveys 4-7 (27 April to 11 May) and on survey 10 (23 May). Most larvae (98.5%) were collected on the last three surveys, from 23 to 30 May (Table 18). No larvae were collected before survey 3 (24 April). The biggest egg catches were from Station 8 (Elk River) and Station 9 (C&D Canal). Large numbers of eggs also were collected at Stations 3 and 4 (Table 18; Figure 2). Eggs were uncommon at Station 7 (Susquehanna Flats).

Biggest catches of larvae in the Upper Bay (Figure 2) were made at Stations 8 and 9 (Table 18). Small catches of larvae occurred near the middle of the sampling area (Stations 4 and 5) and moderate catches were made at the southern end of the survey area (Stations 1, 2, 3). No larvae were collected at Stations 6 and 7.

The mean density of striped bass eggs in the Upper Bay was 77.90 per 100 m^3 in 1989 (Table 19; Figure 11). Mean abundance was 4.25 per m^2. For surveys that sampled the entire Upper Bay area (all surveys except 5 and 6, on 2 and 5 May), highest egg densities and abundances were recorded on Survey 10 (23 May)

Table 17. Potomac River 1989. Estimated riverwide abundances of striped bass larvae.

RIVER SEGMENT	SURVEY 1 3-Apr	2 6-Apr	3 13-Apr	4 17-Apr	5 21-Apr	6 24-Apr	7 27-Apr	8 30-Apr	9 3-May	10 6-May	11 9-May	12 12-May	13 16-May	14 20-May	15 24-May	16 28-May	SEGMENT MEAN	SEGMENT TOTAL	% OF TOTAL
1	0.00E+00	8.88E+06	1.71E+06	0.00E+00	2.09E+06	1.82E+06	0.00E+00	0.00E+00	3.40E+07	5.72E+06	3.16E+07	1.61E+07	0.00E+00	0.00E+00	1.57E+08	4.85E+08	4.65E+07	7.44E+08	42.06
2		1.09E+06	0.00E+00	0.00E+00	1.88E+06	1.46E+06	1.04E+06	0.00E+00	3.23E+06	1.76E+06	3.79E+06	1.93E+06	0.00E+00	0.00E+00	9.09E+07	1.22E+08	1.53E+07	2.29E+08	12.97
3	0.00E+00	4.61E+05	0.00E+00	5.62E+05	9.42E+05	8.48E+06	3.05E+06	0.00E+00	5.62E+06	5.24E+06	3.93E+06	4.06E+05	0.00E+00	0.00E+00	7.42E+07	6.70E+07	1.06E+07	1.70E+08	9.61
4	0.00E+00	6.73E+05	0.00E+00	0.00E+00	3.41E+05	1.46E+07	5.42E+05	2.37E+06	3.63E+05	0.00E+00	9.32E+05	0.00E+00	0.00E+00	0.00E+00	1.30E+08	2.25E+07	1.08E+07	1.72E+08	9.75
5		2.83E+05	0.00E+00	0.00E+00	0.00E+00	5.51E+06	3.50E+06	2.87E+05	1.32E+06	0.00E+00	3.08E+05	0.00E+00	0.00E+00	0.00E+00	1.90E+07	2.08E+07	3.40E+06	5.10E+07	2.89
6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.16E+05	1.27E+06	7.45E+05	7.43E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.22E+06	4.31E+06	1.37E+06	2.19E+07	1.24
7	0.00E+00	0.00E+00	3.38E+05	0.00E+00	0.00E+00	2.82E+05	3.06E+05	7.06E+05	3.15E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.02E+07	9.15E+06	5.26E+06	8.41E+07	4.76
8	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.28E+05	0.00E+00	5.47E+05	1.09E+07	2.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E+07	1.27E+07	2.42E+06	3.87E+07	2.19
9	0.00E+00	3.02E+06	0.00E+00	0.00E+00	0.00E+00	3.73E+06	6.83E+06	3.06E+07	7.53E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+08	2.05E+07	1.61E+07	2.57E+08	14.54
SURVEY TOTAL	0.00E+00	1.44E+07	2.05E+06	5.62E+05	5.78E+06	3.68E+07	1.71E+07	4.57E+07	6.47E+07	1.27E+07	4.06E+07	1.84E+07	0.00E+00	0.00E+00	7.45E+08	7.64E+08	1.24E+07	1.77E+09	
% OF TOTAL	0.00	0.81	0.12	0.03	0.33	2.08	0.97	2.58	3.66	0.72	2.29	1.04	0.00	0.00	42.14	43.23			

Table 18. Upper Bay, 1989. Striped bass eggs and larvae.
Catches in duplicate tows of 5-min duration, 60-cm. net, 333-um mesh.

	SURVEY													
	1		2		3		4		5		6		7	
	14-Apr		20-Apr		24-Apr		27-Apr		2-May		5-May		11-May	
STATION	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
1	0	0	0	0	0	0	0	0			0	0	105	0
	0	0	0	0	0	0	4	0			0	0	390	0
2	0	0	3	0	1	0	1	0			0	0	57	0
	0	0	6	0	0	0	0	0			0	0	321	0
3	0	0	8	0	0	0	39	0					313	0
	0	0	6	0	1	1	0	0					713	0
4	0	0	49	0	3	0	15	0					15	0
	0	0	76	0	19	1	689	0					124	0
5	0	0	29	0	18	0	14	0	2	0			33	0
	0	0	25	0	28	0	18	0	0	0			143	1
6	0	0	30	0	14	0	404	0					82	0
	0	0	49	0	0	0	146	0					20	0
7	0	0	0	0	0	0	4	0					9	0
	0	0	0	0	0	0	0	0					9	0
8	2	0	44	0	0	0	66	0	52	0			22	4
	2	0	8	0	0	0	10	0	59	0			21	2
9	0	0	0	0	2	0	11	0	1209	3			14	3
	0	0	13	0	4	0	3	0	1225	4			40	8
TOTALS	4	0	346	0	90	2	1424	0	2547	7	0	0	2431	18
PERCENT	0.03	0.00	2.61	0.00	0.68	0.07	10.74	0.00	19.20	0.25	0.00	0.00	18.33	0.64

Table 18 (cont.). Upper Bay, 1989. Striped bass eggs and larvae.
Catches in duplicate tows of 5-min duration, 60-cm. net, 333-um mesh.

	SURVEY 8 15-May		9 18-May		10 23-May		11 25-May		12 30-May		Totals		Percent	
STATION	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
1	6	0	40	0	33	145	15	237			695	630	5.24	22.47
	16	0	59	0			27	248						
2	7	0	61	0	129	174	49	59	9	7	706	290	5.32	10.34
	0	0	13	0			27	43	22	7				
3	36	0	19	0	123	100	64	14	6	0	1624	183	12.24	6.53
	22	0	3	0	219	54	47	11	5	3				
4			6	0	416	0	30	0	0	1	1802	4	13.58	0.14
			6	0	325	2	29	0	0	0				
5	0	0	14	0			14	0	7	3	379	14	2.86	0.50
	0	0	4	0			13	6	17	4				
6	0	0	0	0	4	0	0	0	1	0	778	0	5.87	0.00
			0	0	23	0	0	0	5	0				
7	0	0	0	0	9	0	0	0	1	0	78	0	0.59	0.00
	0	0	0	0	40	0	4	0	2	0				
8	55	2	40	3	2272	152	83	338	14	60	3910	977	29.48	34.84
	32	1	37	1	1008	232	61	113	22	69				
9	10	1	18	2	462	50	15	194	25	81	3293	706	24.82	25.18
	11	0	9	5	207	86	10	141	5	128				
TOTALS	195	4	329	11	5270	995	488	1404	141	363	13265	2804	100.00	100.00
PERCENT	1.47	0.14	2.48	0.39	39.73	35.49	3.68	50.07	1.06	12.95				

Table 19. Upper Bay 1989. Striped bass egg density (#/100 m3) and abundance (#/m2) for duplicate, 5-min. tows of the 60-cm, 333 µm net.
D = density; A = abundance.

	SURVEY													
	1 14-Apr		2 20-Apr		3 24-Apr		4 27-Apr		5 2-May		6 5-May		7 11-May	
STATION	D	A	D	A	D	A	D	A	D	A	D	A	D	A
1	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.11			0.00	0.00	275.00	13.34
2	0.00	0.00	5.25	0.25	0.53	0.03	0.56	0.03			0.00	0.00	210.00	10.12
3	0.00	0.00	7.37	0.33	0.60	0.03	21.67	0.97					570.00	25.65
4	0.00	0.00	68.83	2.50	12.98	0.47	378.67	13.75					77.22	2.80
5	0.00	0.00	31.57	1.12	30.30	1.08	15.60	0.56	1.05	0.04			97.78	3.48
6	0.00	0.00	44.46	1.49	7.95	0.27	292.85	9.81					56.67	1.90
7	0.00	0.00	0.00	0.00	0.00	0.00	2.30	0.03					10.00	0.14
8	2.17	0.05	28.40	0.62	0.00	0.00	36.53	0.80	59.94	1.31			27.84	0.61
9	0.00	0.00	8.55	1.03	3.19	0.38	7.48	0.90	1353.31	162.40			30.00	3.60
MEAN =	0.24	0.01	21.60	0.82	6.17	0.25	84.22	2.99	471.44	54.58	0.00	0.00	150.50	6.85

Table 19 (cont.). Upper Bay 1989. Striped bass egg density (*/100 m3) and abundance (*/m2) for duplicate, 5-min. tows of the 60-cm, 333 μm net. D= density; A= abundance.

	SURVEY											
	8 15-May		9 18-May		10 23-May		11 25-May		12 30-May		Mean	Mean
STATION	D	A	D	A	D	A	D	A	D	A	Density	Abundance
1	16.14	0.78	58.80	2.85	35.48	1.72	23.60	1.14			41.13	2.00
2	4.38	0.21	40.22	1.94	140.22	6.76	39.84	1.92	16.33	0.79	41.57	2.00
3	38.55	1.73	13.31	0.60	209.46	9.43	60.05	2.70	5.63	0.25	92.66	4.17
4			7.89	0.29	390.00	14.16	31.38	1.14	0.00	0.00	107.44	3.90
5	0.00	0.00	9.96	0.35			15.00	0.53	12.90	0.46	21.42	0.76
6	0.00	0.00	0.00	0.00	14.72	0.49	0.00	0.00	2.96	0.10	41.96	1.41
7	0.00	0.00	0.00	0.00	27.99	0.38	2.13	0.03	1.53	0.02	4.39	0.06
8	48.22	1.06	45.55	1.00	1690.72	37.03	74.18	1.62	18.95	0.41	184.77	4.05
9	13.63	1.64	16.86	2.02	358.93	43.07	13.44	1.61	17.82	2.14	165.75	19.89
MEAN =	15.11	0.68	21.40	1.01	358.44	14.13	28.85	1.19	9.51	0.52	77.90	4.25

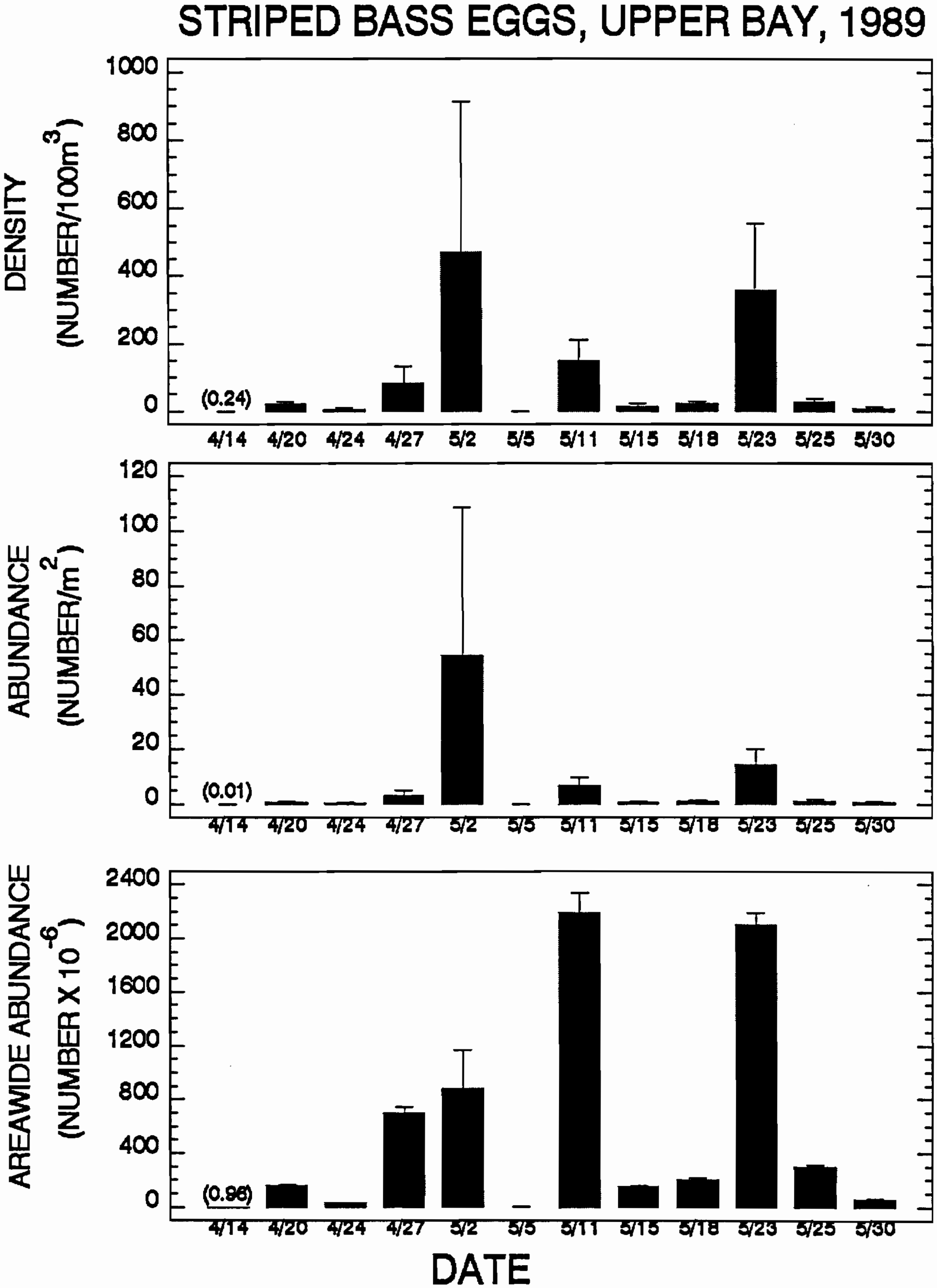


Figure 11. Upper Bay, 1989. Striped bass egg densities (no./100 m^3), abundances (no./m^2), and riverwide abundances (millions) on each survey date.

and on Survey 7 (11 May) when mean temperatures were 18.0 and 12.8°C, respectively. Densest egg concentrations occurred at Stations 8 and 9. Eggs were most abundant (number under 1 m^2) in the C&D Canal (Station 9), with high abundances also observed at Stations 3 and 4 and 8 (Table 19). Lowest egg densities and abundances in the Upper Bay were observed at Station 7 on the Susquehanna Flats.

Highest densities and abundances of striped bass larvae in the Upper Bay were observed from 23-30 May, during the last three surveys. Mean density peaked at 89.4 per 100 m^3 during Survey 10 (23 May), while mean abundance peaked at 4.8 per m^2 during Survey 11 (25 May) (Table 20; Figure 12).

Densest concentrations of larvae in the Upper Bay occurred at Stations 1, 2, 8 and 9. Larvae were most abundant at Station 1 near the southern boundary of the larval nursery and at Station 9 in the C&D Canal (Table 20). The area in which larvae were observed to be abundant was relatively restricted, compared to that in which eggs were common (Table 19).

The mean densities and abundances of striped bass eggs and larvae in the Upper Bay differed substantially between 1988 and 1989 (Table 15). Both eggs and larvae were approximately one order of magnitude more dense and abundant in 1989.

Areawide abundances of striped bass eggs and larvae, from the expanded station estimates, indicated that spawning peaked during Surveys 7 and 10 (11 May and 23 May) in the Upper Bay, when 2.2×10^9 and 2.1×10^9 eggs, respectively, were present (Table 21; Figure 11). Spawning also may have been intense on Survey 5 (2 May), but only three stations were sampled on that date. Areawide striped bass larvae abundances were highest during Surveys 10 and 11 (23 and 25 May) (Table 22; Figure 12). Larvae abundances that exceeded 1×10^8 were estimated only during the period 23-30 May, on the last three 60-cm sampler survey dates.

Table 20. Upper Bay 1989. Striped bass larvae density (#/100 m3) and abundance (#/m2) for duplicate, 5-min. tows of the 60-cm, 333 µm net. D = density; A = abundance.

	SURVEY													
	1		2		3		4		5		6		7	
	14-Apr		20-Apr		24-Apr		27-Apr		2-May		5-May		11-May	
STATION	D	A	D	A	D	A	D	A	D	A	D	A	D	A
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.60	0.03	0.00	0.00					0.00	0.00
4	0.00	0.00	0.00	0.00	0.60	0.02	0.00	0.00					0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.56	0.02
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			4.05	0.09
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.85	0.46			6.11	0.73
MEAN =	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	1.28	0.15	0.00	0.00	1.19	0.09

Table 20 (cont.). Upper Bay 1989. Striped bass larvae density (#/100 m3) and abundance (#/m2) for duplicate, 5-min. tows of the 60-cm, 333 µm net. D = density; A = abundance.

	SURVEY											
	8 15-May		9 18-May		10 23-May		11 25-May		12 30-May			
STATION	D	A	D	A	D	A	D	A	D	A	Mean Density	Mean Abundance
1	0.00	0.00	0.00	0.00	155.91	7.56	272.47	13.21			42.84	2.08
2	0.00	0.00	0.00	0.00	189.13	9.12	53.73	2.59	7.26	0.35	22.74	1.10
3	0.00	0.00	0.00	0.00	94.66	4.26	13.52	0.61	1.61	0.07	11.04	0.50
4			0.00	0.00	1.05	0.04	0.00	0.00	0.53	0.02	0.24	0.01
5	0.00	0.00	0.00	0.00			3.33	0.12	3.76	0.13	0.77	0.03
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	1.66	0.04	2.33	0.05	197.94	4.33	234.39	5.13	67.89	1.49	46.21	1.01
9	0.68	0.08	4.17	0.50	76.70	9.20	180.11	21.61	123.51	14.82	35.92	4.31
MEAN =	0.29	0.01	0.72	0.06	89.42	4.31	84.17	4.81	25.57	2.11	17.75	1.00

Table 21. Upper Bay 1989. Estimated areawide abundances of striped bass eggs.

	SURVEY														
	1 14-Apr	2 20-Apr	3 24-Apr	4 27-Apr	5 2-May	6 5-May	7 11-May	8 15-May	9 18-May	10 23-May	11 25-May	12 30-May	SEGMENT MEAN	SEGMENT TOTAL	% OF TOTAL
SEGMENT 1	0.00E+00	0.00E+00	0.00E+00	3.71E+06		0.00E+00	4.38E+08	2.57E+07	9.37E+07	5.65E+07	3.76E+07		6.55E+07	6.55E+08	9.65
2	0.00E+00	5.34E+06	5.35E+05	5.65E+05		0.00E+00	2.13E+08	4.45E+06	4.09E+07	1.43E+08	4.05E+07	1.66E+07	4.23E+07	4.64E+08	6.85
3	0.00E+00	1.72E+07	1.41E+06	5.06E+07			1.33E+09	9.00E+07	3.11E+07	4.89E+08	1.40E+08	1.31E+07	2.16E+08	2.16E+09	31.87
4	0.00E+00	6.80E+07	1.28E+07	3.74E+08			7.62E+07		7.79E+06	3.85E+08	3.10E+07	0.00E+00	1.06E+08	9.55E+08	14.06
5	0.00E+00	1.34E+07	1.29E+07	6.65E+06	4.48E+05		4.17E+07	0.00E+00	4.24E+06		6.39E+06	5.50E+06	9.12E+06	9.12E+07	1.34
6	0.00E+00	3.62E+07	6.48E+06	2.39E+08			4.62E+07	0.00E+00	0.00E+00	1.20E+07	0.00E+00	2.41E+06	3.42E+07	3.42E+08	5.04
7	0.00E+00	0.00E+00	0.00E+00	3.31E+06			1.44E+07	0.00E+00	0.00E+00	4.03E+07	3.06E+06	2.20E+06	6.33E+06	6.33E+07	0.93
8	9.59E+05	1.25E+07	0.00E+00	1.61E+07	2.64E+07		1.23E+07	2.13E+07	2.01E+07	7.46E+08	3.27E+07	8.36E+06	8.15E+07	8.95E+08	13.21
9	0.00E+00	5.43E+06	2.03E+06	4.75E+06	8.59E+08		1.90E+07	8.65E+06	1.07E+07	2.28E+08	8.53E+06	1.13E+07	1.05E+08	1.16E+09	17.05
CRUISE TOTAL	9.59E+05	1.58E+08	3.62E+07	6.98E+08	8.86E+08	0.00E+00	2.19E+09	1.50E+08	2.08E+08	2.10E+09	3.00E+08	5.95E+07	7.41E+07	6.79E+09	
% OF TOTAL	0.01	2.33	0.53	10.28	13.05	0.00	32.29	2.21	3.07	30.92	4.42	0.88			

Table 22. Upper Bay 1989. Estimated areawide abundances of striped bass larvae.

SEGMENT	SURVEY 1 14-Apr	2 20-Apr	3 24-Apr	4 27-Apr	5 2-May	6 5-May	7 11-May	8 15-May	9 18-May	10 23-May	11 25-May	12 30-May	SEGMENT MEAN	SEGMENT TOTAL	% OF TOTAL
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.48E+08	4.34E+08		6.83E+07	6.83E+08	41.16
2	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.92E+08	5.46E+07	7.38E+06	2.31E+07	2.54E+08	15.33
3	0.00E+00	0.00E+00	1.41E+06	0.00E+00			0.00E+00	0.00E+00	0.00E+00	2.21E+08	3.16E+07	3.77E+06	2.58E+07	2.58E+08	15.54
4	0.00E+00	0.00E+00	5.88E+05	0.00E+00			0.00E+00		0.00E+00	1.04E+06	0.00E+00	5.25E+05	2.39E+05	2.15E+06	0.13
5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		2.37E+05	0.00E+00	0.00E+00		1.42E+06	1.60E+06	3.26E+05	3.26E+06	0.20
6	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
7	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
8	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		9.81E+05	5.32E+05	5.38E+05	1.06E+08	4.99E+07	3.20E+07	1.72E+07	1.90E+08	11.43
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.59E+06		5.64E+06	0.00E+00	3.65E+06	6.50E+07	9.62E+07	9.56E+07	2.44E+07	2.69E+08	16.20
SURVEY TOTAL	0.00E+00	0.00E+00	1.99E+06	0.00E+00	2.59E+06	0.00E+00	6.86E+06	5.32E+05	4.19E+06	8.33E+08	6.68E+08	1.41E+08	1.77E+07	1.66E+09	
% OF TOTAL	0.00	0.00	0.12	0.00	0.16	0.00	0.41	0.03	0.25	50.25	40.28	8.50			

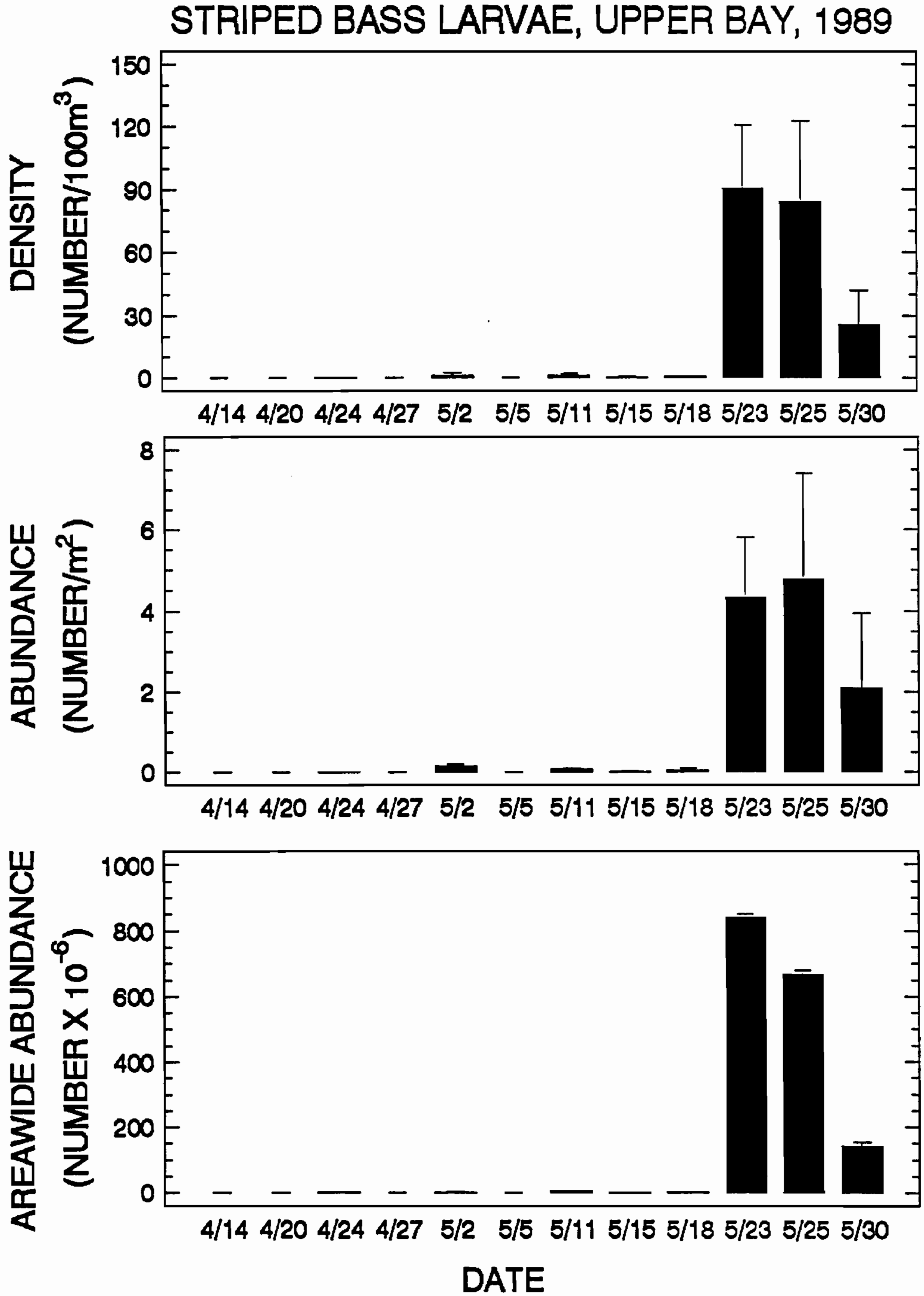


Figure 12. Upper Bay, 1989. Striped bass larvae densities (no./100 m^3), abundances (no./m^2), and riverwide abundances (millions) on each survey date.

Although 1989 striped bass egg and larvae densities in the Upper Bay were highest at Stations 8 and 9 (Tables 19 and 20), i.e. Elk River and C&D Canal, respectively, the areawide estimates (Tables 21 and 22) indicated that most of the eggs and larvae were distributed elsewhere. The Upper Bay segments 3 and 4, which are in the mainstem Bay (Figure 2), contained 46% of the eggs (Table 21) while mainstem segments 1-3 contained most of the larvae (72% of all larvae) (Table 22). The Elk River and C&D Canal did support a high proportion of the eggs (30%) and larvae (28%) but, because of their relatively low segment volumes (Table 4), their overall contributions were less than suggested by the mean densities (no. per 100 m^3).

Potomac River and Upper Bay Comparisons: In 1988, the mean egg abundances were higher in the Potomac River than in the Upper Bay. In 1989, mean egg abundances and densities were similar in the Potomac River and Upper Bay (Table 15). Spawning peaks in the Upper Bay occurred about three weeks later than peaks in the Potomac River during 1988 and 1989. Peak spawning in 1989 in the Potomac River occurred from 20-30 April while that in the Upper Bay occurred from 11-23 May. Mean water temperatures during the 1989 peak spawning periods ranged from 14.8 - 17.3°C in the Potomac and from 12.8 to 18.0°C in the Upper Bay. In 1988, peak spawning occurred from 7-28 April in the Potomac River when mean river temperatures were 13.2 to 14.9°C and occurred from 3-25 May 1988 in the Upper Bay when temperatures were 13.2 to 20.0°C.

Mean abundance of larvae, standardized to 1 m^2 of surface, was more than two times higher in the Upper Bay than in the Potomac River in 1989 but the reverse situation prevailed in 1988 (Table 15). The mean larval density and standardized abundance estimates in the Potomac River in 1987 were nearly identical to the Upper Bay estimates in 1989. Because no surveys were carried out in the Upper Bay in 1987, we have no estimates of egg and larvae densities and abundances to compare with the Potomac in that year. In 1987, the high larval abundance index in the Potomac corresponded to a high juvenile survey index. The high larval abundance index in the Upper Bay in 1989 also was followed by a high juvenile abundance index (Maryland DNR 1991).

Zooplankton Densities

Potomac River

Mean zooplankton densities in the Potomac River were highest in 1987 and lowest in 1989 (Table 23A; Figure 13). Comparable data for the 1976-1977 period also are included (Setzler-Hamilton et al. 1980). The mean densities of zooplankton categories in 1989, except for adult copepods and copepodites, were only half as abundant as in 1988 and were much less abundant than in 1987 (Table 23A). The densities of zooplankton during the last two weeks of May, when striped bass larvae normally are most abundant, were very much higher in 1987 than in 1988 or 1989 (Table 23B).

Zooplankton abundances during periods when most first-feeding striped bass larvae occurred were higher in 1987 than in 1988 or 1989. Micro-zooplankton abundances were low (34/liter) in the 16-22 April period following the 16-17 April major (but unsuccessful) spawning peak of the 1987 season, but increased to 278/liter on 22 May, a week after the secondary spawning peak when 31% of the year's estimated egg production was spawned (Figure 13). In 1988, microzooplankton densities were relatively low, averaging 36, 31, and 89/liter one week after the spawning peaks on 7, 14 and 27 April. In 1989, microzooplankton densities the week following periods of peak spawning (21-27 April, 20 May) were low (44-93/liter, 54/liter) (Figure 13).

Zooplankton densities were highest in 1987 at the stations where striped

Table 23a. Mean densities (number/liter) of zooplankton taxa during April and May in the Potomac River, 1976-1977, 1987-1989, and in the Upper Bay 1989. Estimates are averaged over stations and surveys, and include standard errors of the means. The 1976-77 data are from Setzler-Hamilton et al. (1980) and are included for comparative purposes.

ɜs	Cladocerans
	30.9 ± 8.7
;	187.1 + 154.6
	29.2 + 12.9
	14.6 ± 7.3
	6.5 ± 1.7
	3.1 ± 1.5

ıxa in the Potomac
ſay. Estimates are
ʳrors of the means.
ıd are included for

ɜs	Cladocerans
	36.8 + 14.4
	6.9 + 1.4
	53.8 + 21.2
	8.8 ± 2.7
	3.8 ± 2.3

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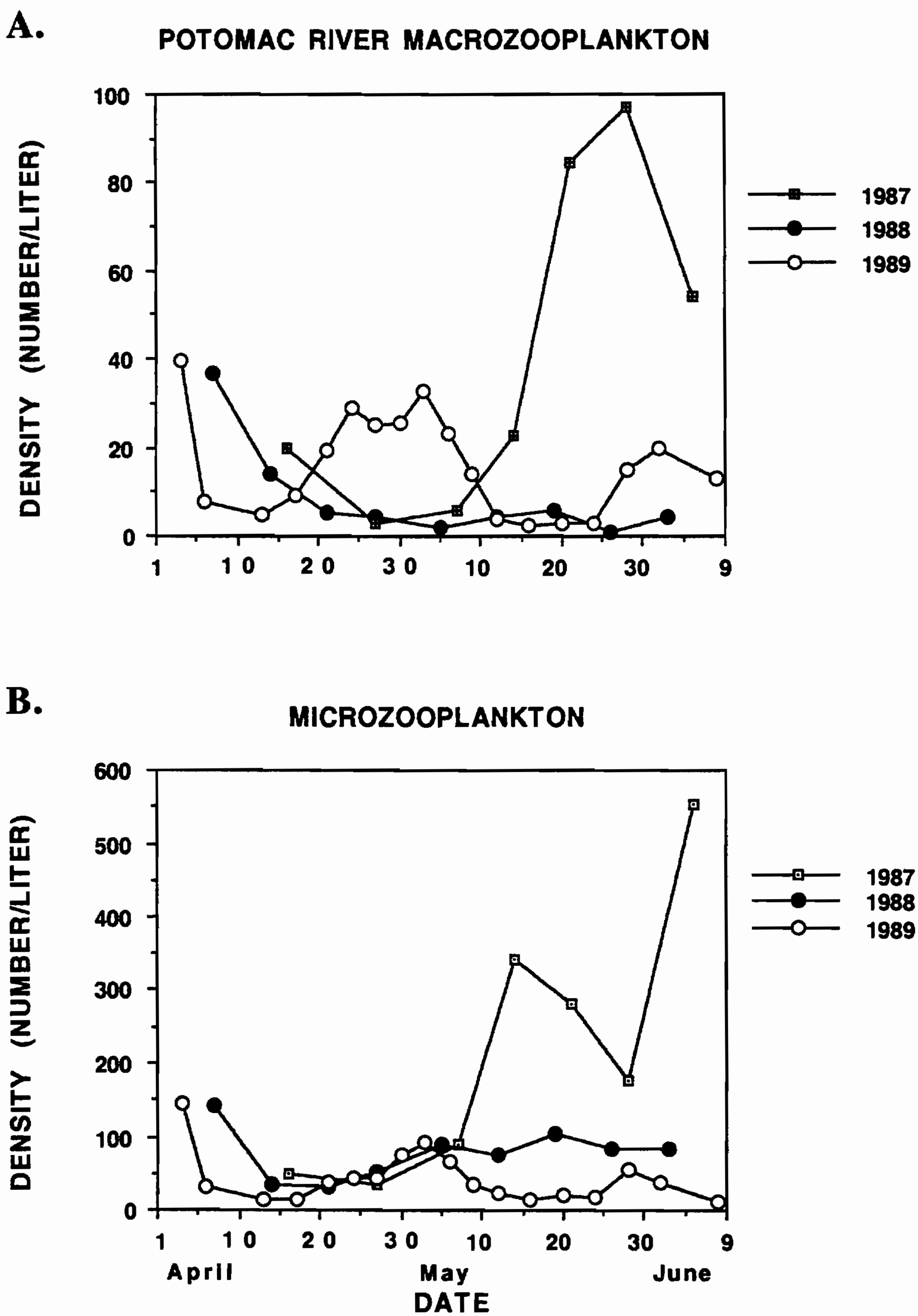


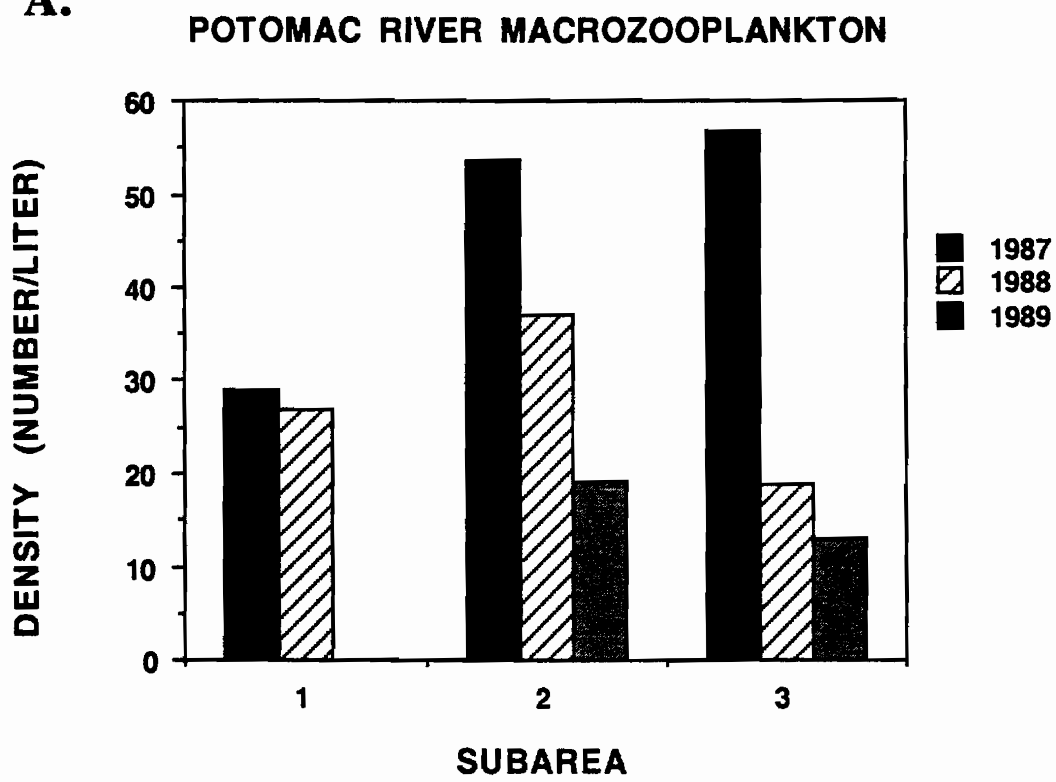
Figure 13. Potomac River zooplankton densities. Mean densities (number/liter) on each survey date, 1987-1989. A. Macrozooplankton (Adult copepods, copepodites, cladocera). B. Microzooplankton (copepod nauplii, rotifers).

bass larvae occurred in greatest abundance. To compare zooplankton densities among years in which different stations were sampled, stations were grouped into subareas (Figure 14): Subarea 1 (1987-88 Stations 1 and 2), 2 (1987-88 Stations 3 and 4; 1989 Station 3), and 3 (1987-88 stations 5 and 6; 1989 Station 7). Macrozooplankton densities in the subareas where striped bass larvae were most abundant averaged 53/liter (subarea 2) in 1987, 27/liter (subarea 1) in 1988, and 19/liter (subarea 2) in 1989 (Figure 14). Microzooplankton densities averaged 259/liter (subarea 2) in 1987, 115/liter (subarea 1) in 1988, and 47/liter (subarea 2) in 1989 (Figure 14).

Adult copepod and copepod nauplii densities in 1987 and 1989 tended to be highest at downriver stations (subareas 1 and 2), and lower at stations upstream (Figure 15). In contrast, cladocerans were more abundant at upriver stations (Figure 16A). In 1988, peak densities of both cladocerans and adult copepods occurred in the middle of the survey area (subarea 2). Copepod nauplii densities tended to be highest in downstream subareas. Rotifers were most abundant in the middle of the survey area in 1987, downriver in 1988, and upriver in 1989 (Figure 16B).

Temporal trends in Potomac River zooplankton densities were different in 1987 than in 1988 and 1989 (Figures 13, 17, 18). In 1987, adult copepod and copepodite (chiefly Eurytemora affinis) densities were high in mid-April and in the last two weeks in May (Figure 17). Copepod nauplii densities in 1987 peaked during the second week of May. In 1988 and 1989, densities of copepod nauplii were highest in early April, dropped precipitously by mid-April, and remained low. Adult copepod densities in 1988 also dropped precipitously after a peak in early April. In 1989, adult copepods were most abundant in early April, declined in mid-April and then recovered to higher levels in late April before falling to low levels in May (Figure 17). Cladoceran densities, chiefly Bosmina longirostris, increased steadily from lows in early April to

A.



B.

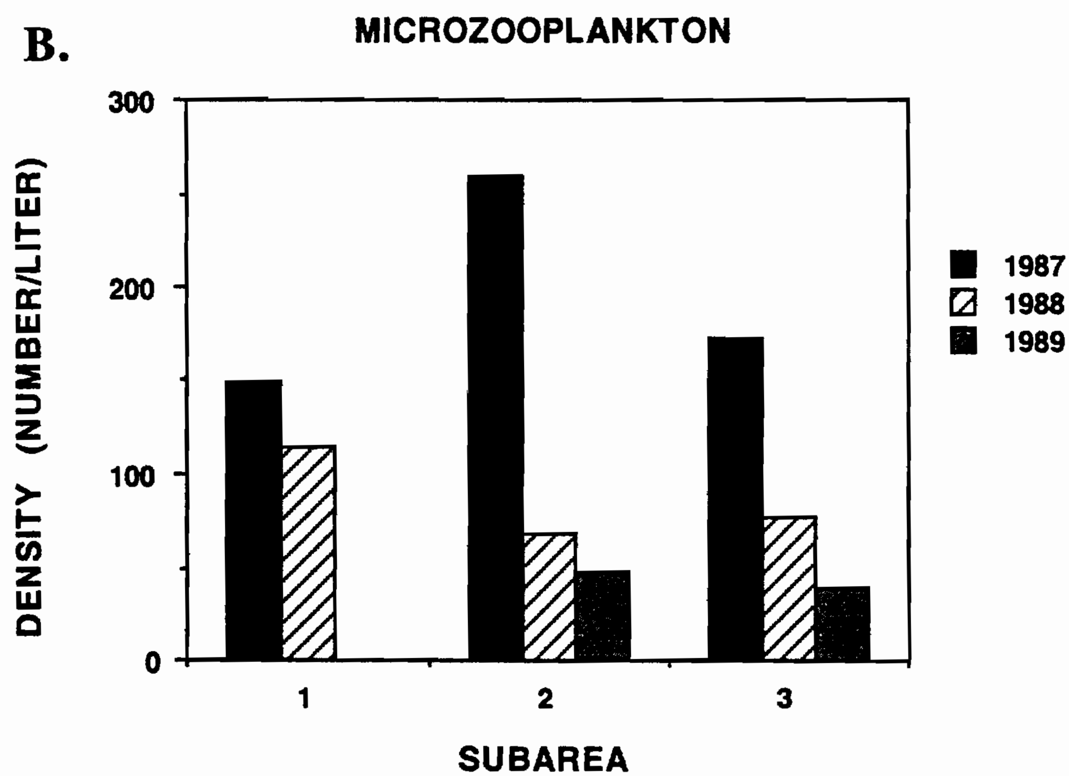


Figure 14. Potomac River: mean zooplankton densities by subareas, 1987-1989.
A. Macrozooplankton (adult copepods, copepodites, cladocera). B. Microzooplankton (copepod nauplii, rotifers). Subareas are defined in text.

A.

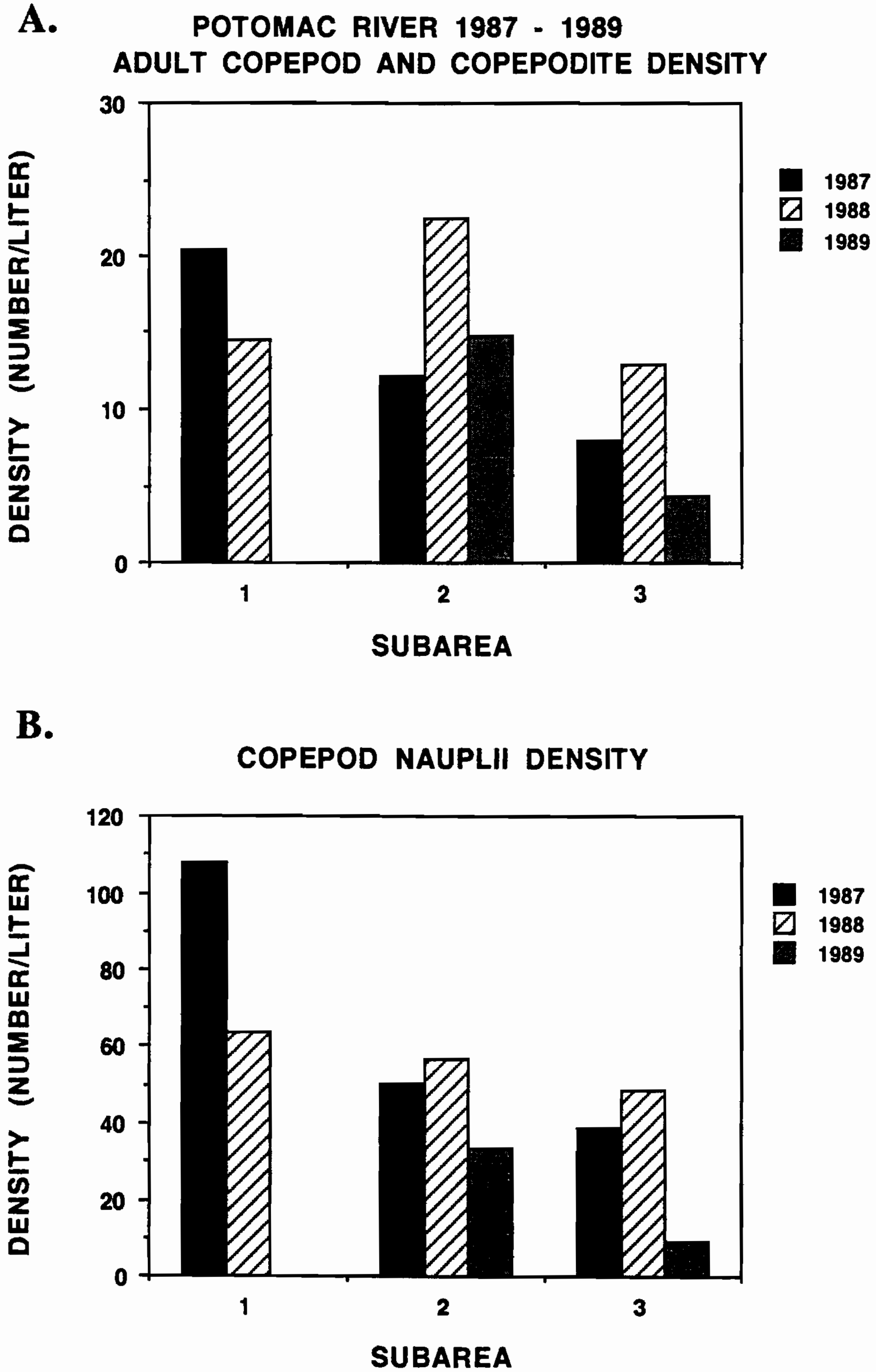
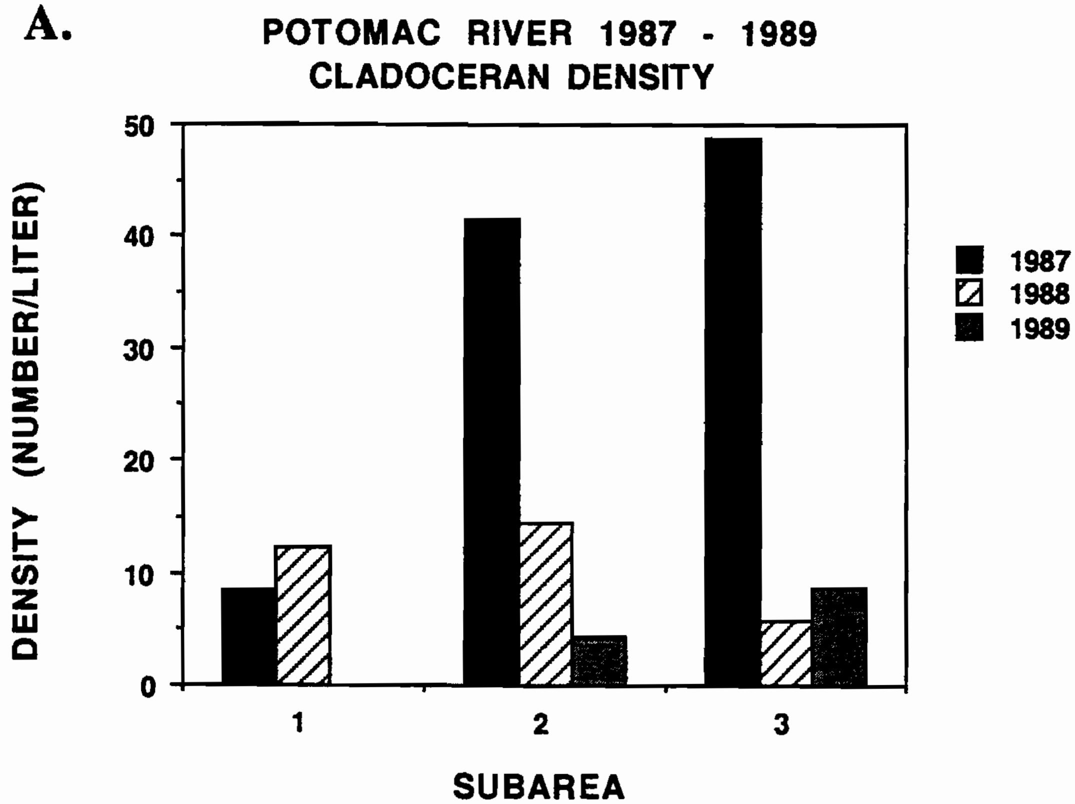


Figure 15. Potomac River: Copepod (A) and copepod nauplii (B) mean densities in three subareas, 1987-1989. Subarea I was not sampled in 1989. Subareas are defined in text.

A.



B.

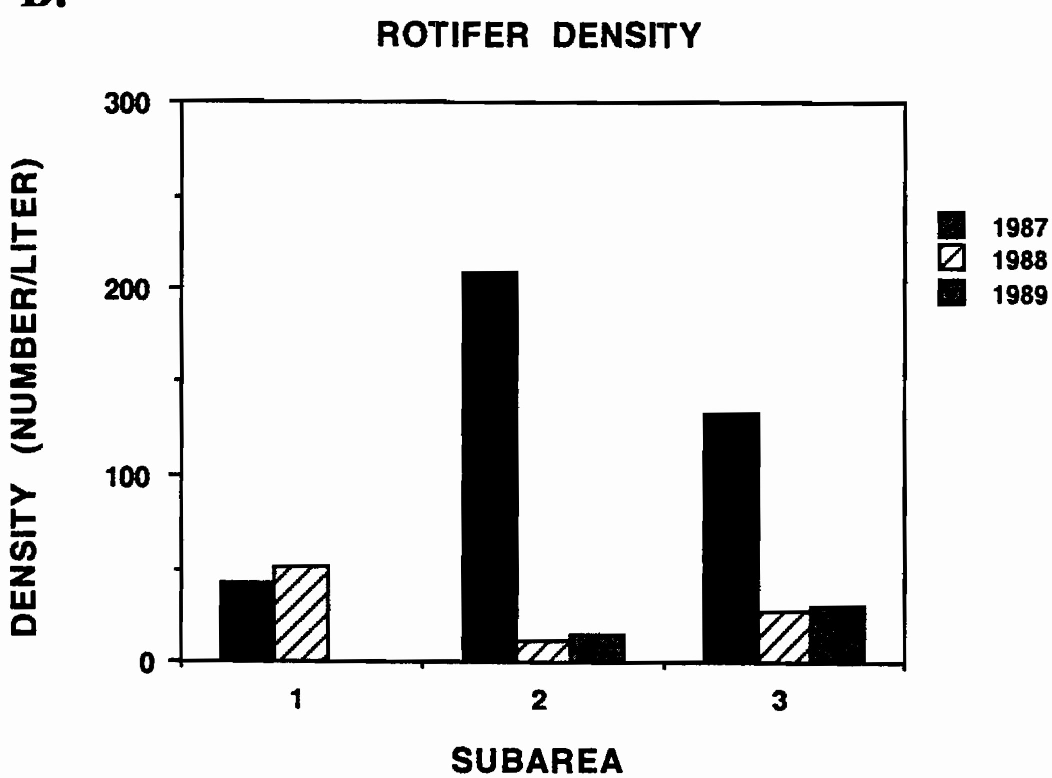
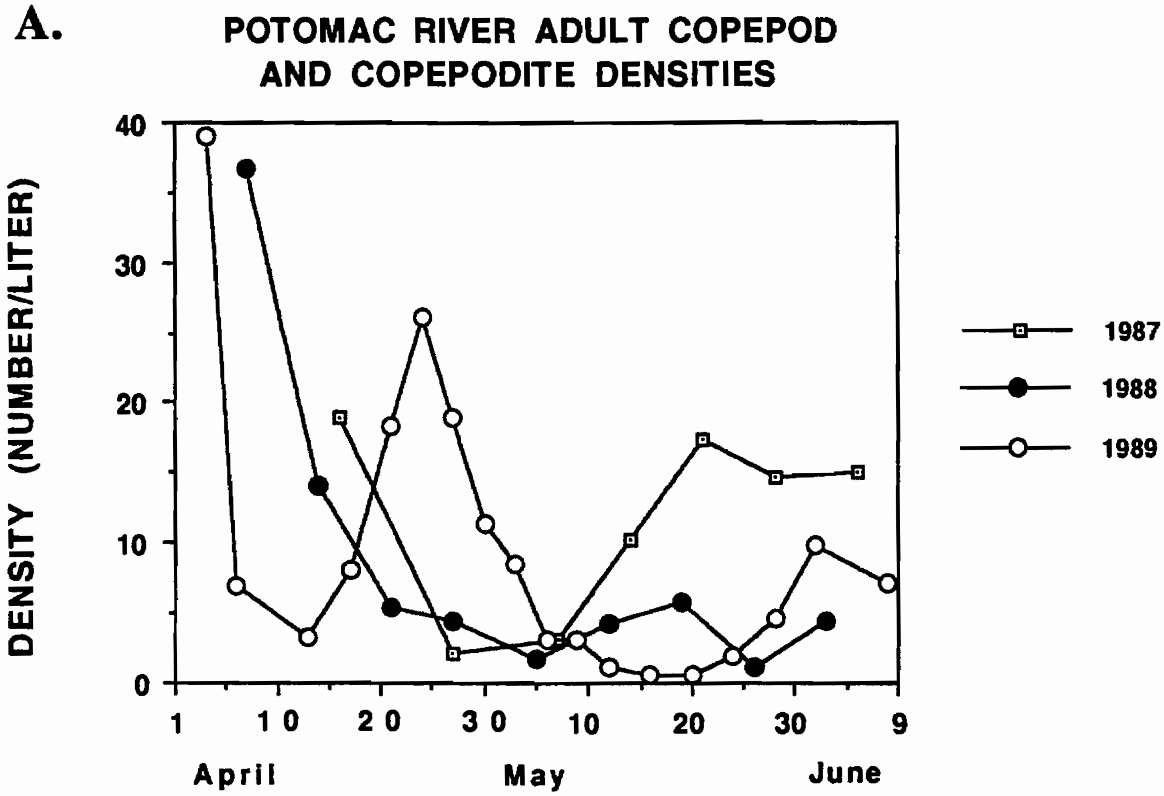


Figure 16. Potomac River: Cladocera (A) and rotifer (B) mean densities in three subareas, 1987-1989. Subarea I was not sampled in 1989. Subareas are defined in text.

A.



B.

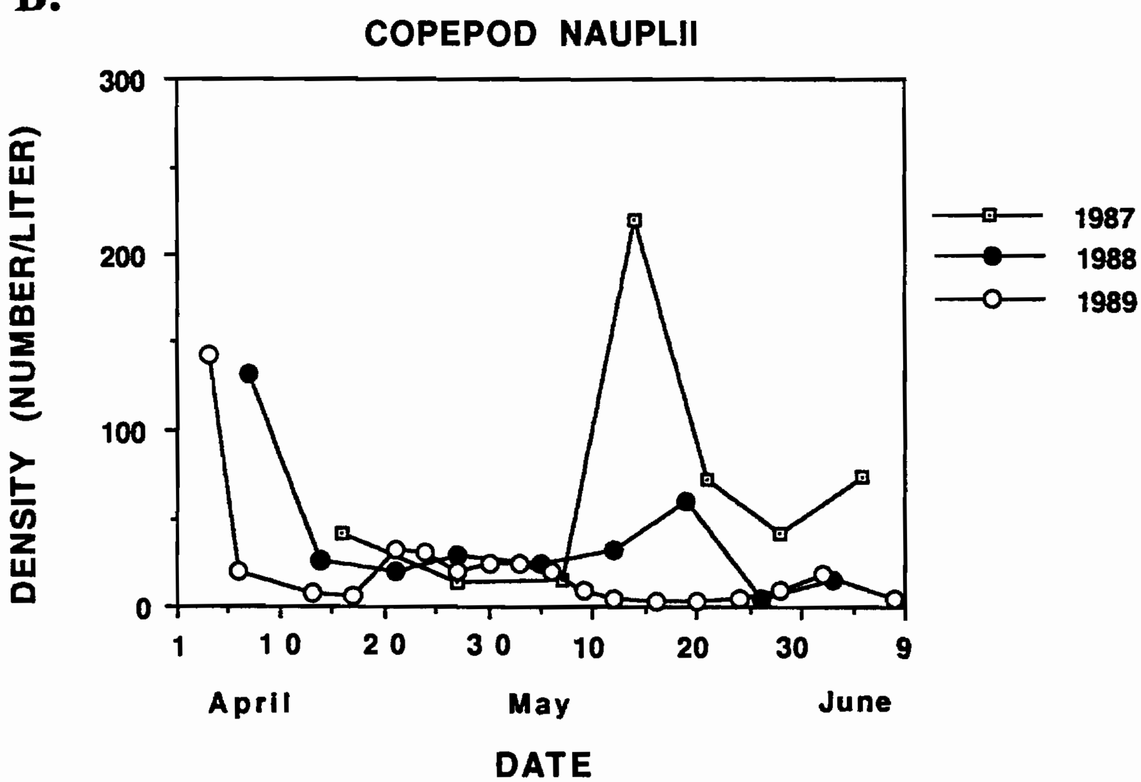


Figure 17. Potomac River: Copepod (A) and copepod nauplii (B) mean densities by survey date, 1987-1989.

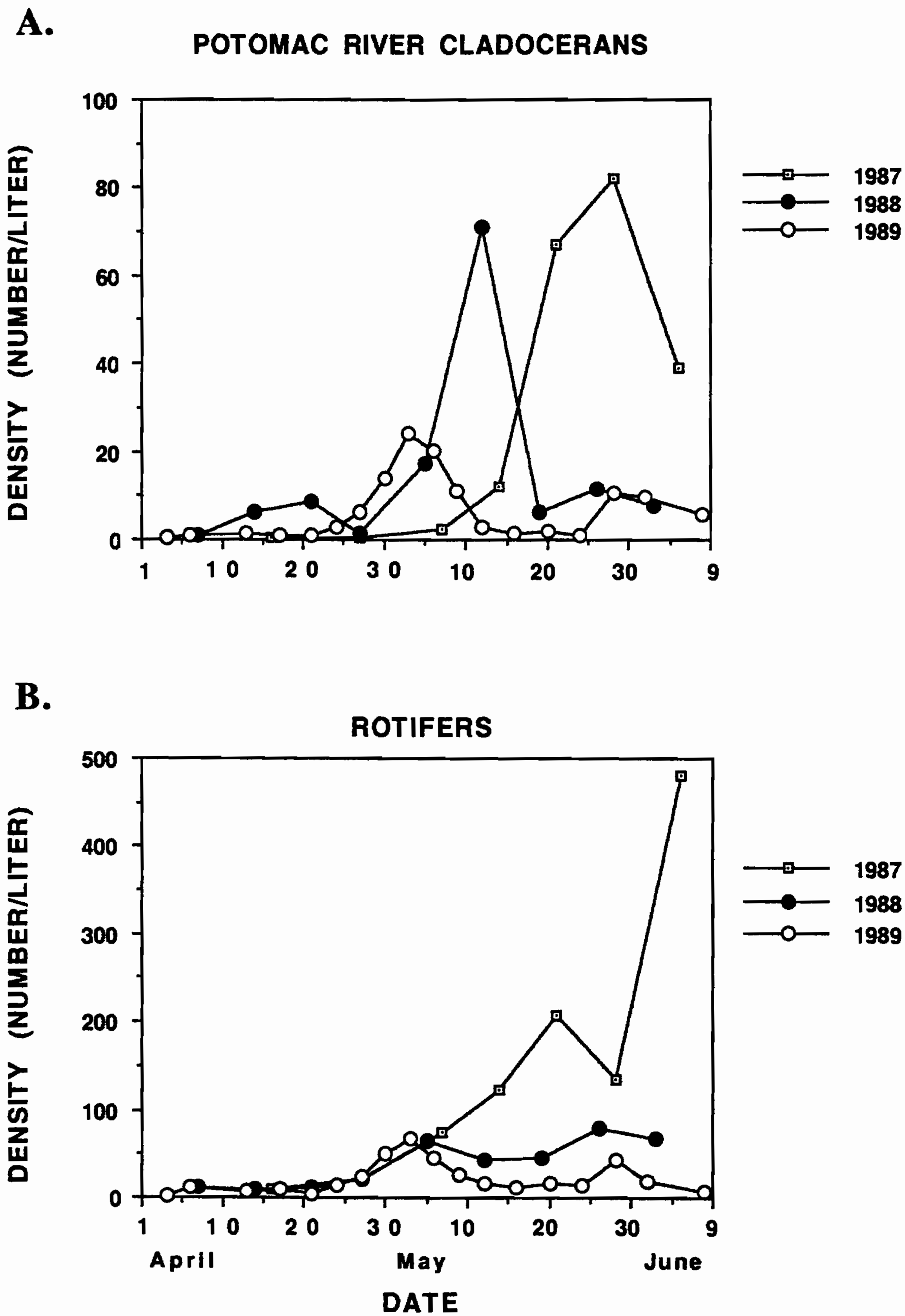


Figure 18. Potomac River: Cladocera (A) and rotifer (B) mean densities by survey date, 1987-1989.

peak abundances during the first two weeks of May in 1988 and 1989, but in the last two weeks of May in 1987 (Figure 18). Densities of rotifers peaked at relatively low levels during the first week of May in 1988 and 1989, but at a high level during the last two weeks of May and the first week in June in 1987 (Figure 18).

Upper Bay

Data on mean densities of zooplankton in the Upper Bay, which were available only for 1989, were compared to densities in the Potomac River (Table 23A). The mean densities of rotifers in the Upper Bay during 1989 were lower than Potomac River 1987 densities but higher than 1988 and 1989 Potomac densities. Upper Bay copepod nauplii densities were similar to Potomac River 1987 densities and higher than 1988-89 densities. Adult copepod densities in the Upper Bay in 1989 were similar to those observed for 1987-1989 in the Potomac. Cladoceran densities in 1989 were lower in the Upper Bay than in any year in the Potomac (Table 23).

Upper Bay densities of macrozooplankton (adult copepods and copepodites, cladocerans) were low, averaging 11.6 ± 1.6/liter and 3.3 ± 1.5/liter, respectively (Figure 19). Mean macrozooplankton densities increased from a low of 4/liter on 14 April to 16/liter on 24 April, declined steadily to 5/liter on 15 May, and then increased steadily to a high of 34/liter on 12 June (Figure 19). Macrozooplankton densities differed little between the two stations that were sampled on 14 April, 24-27 April, 11 May and 14 June (Figure 20). Macrozooplankton densities were higher at station 8, where striped bass larvae were most abundant, on 20 April and in the 15 May - 5 June period. Densities of copepods were considerably higher than cladoceran densities on each survey (Figure 21).

Microzooplankton densities during 1989 were higher in the Upper Bay in

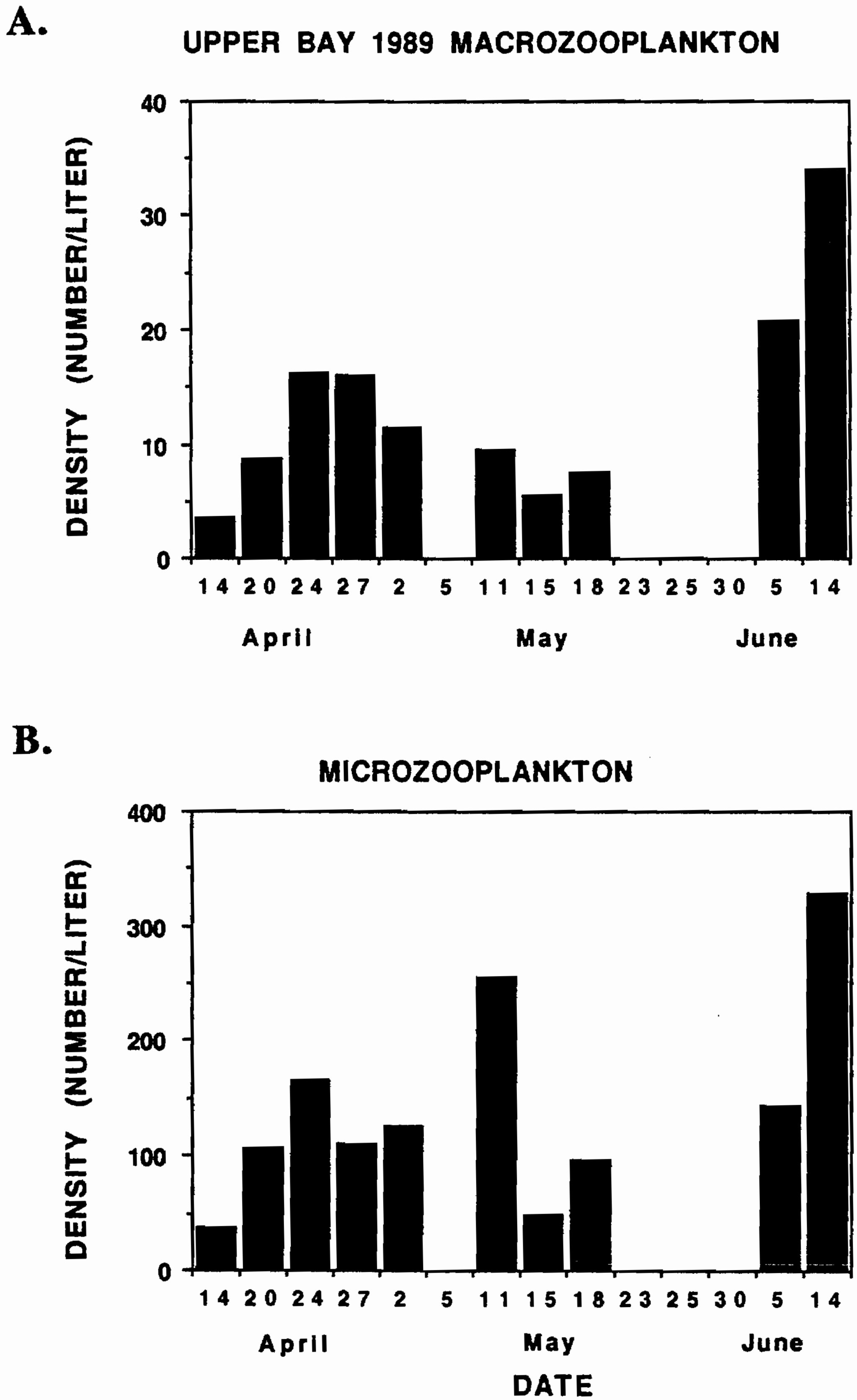


Figure 19. Upper Bay, 1989. Macrozooplankton (A) and microzooplankton (B) mean densities by survey date.

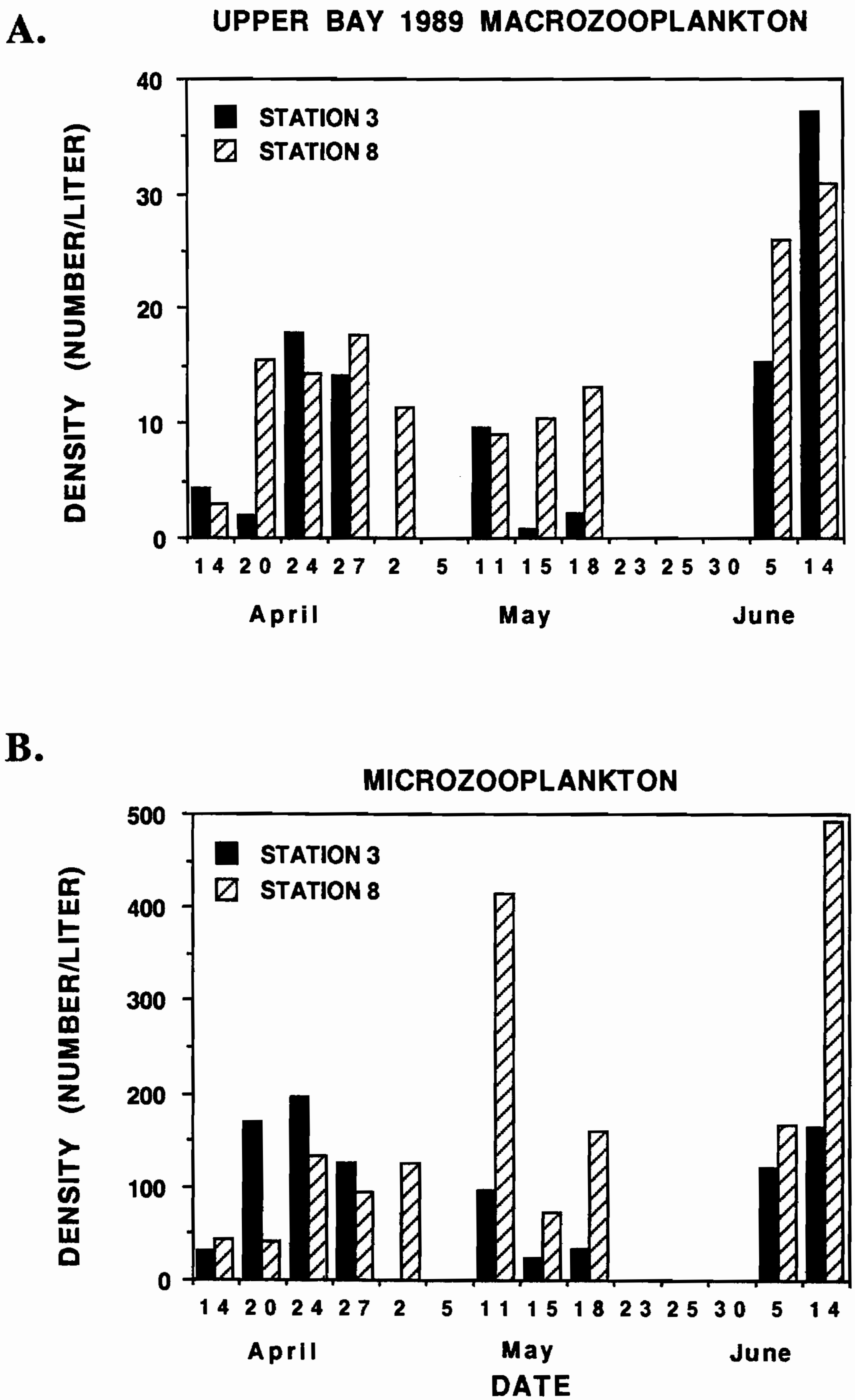
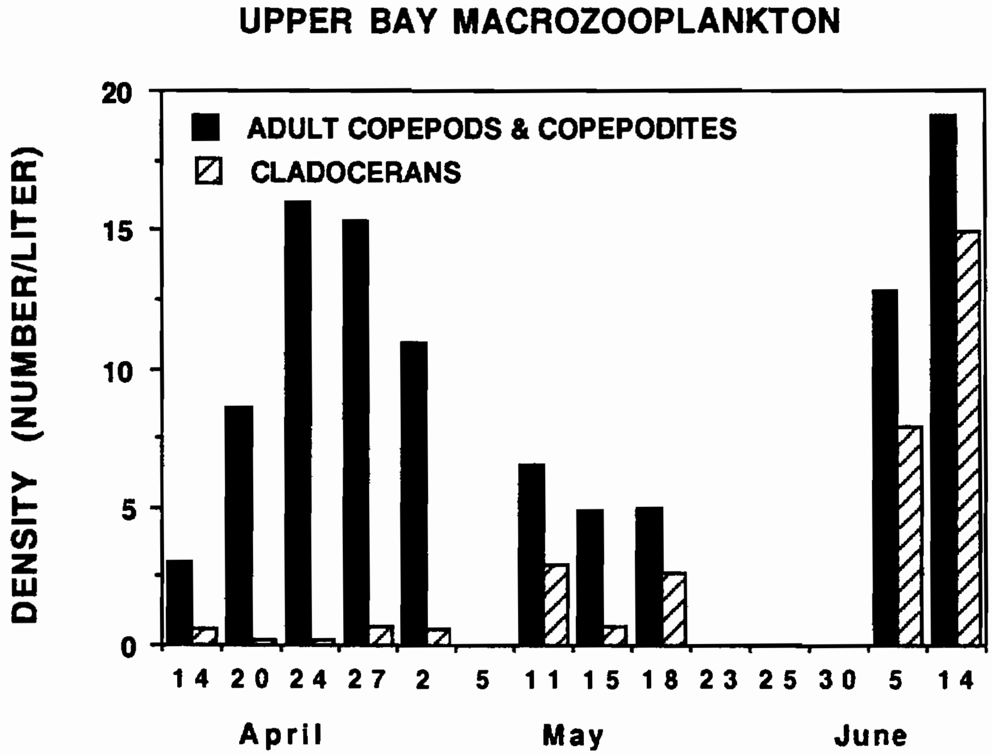


Figure 20. Upper Bay, 1989. Macrozooplankton mean densities (A), and microzooplankton mean densities (B) by survey date at the two sampling stations.

A.



B.

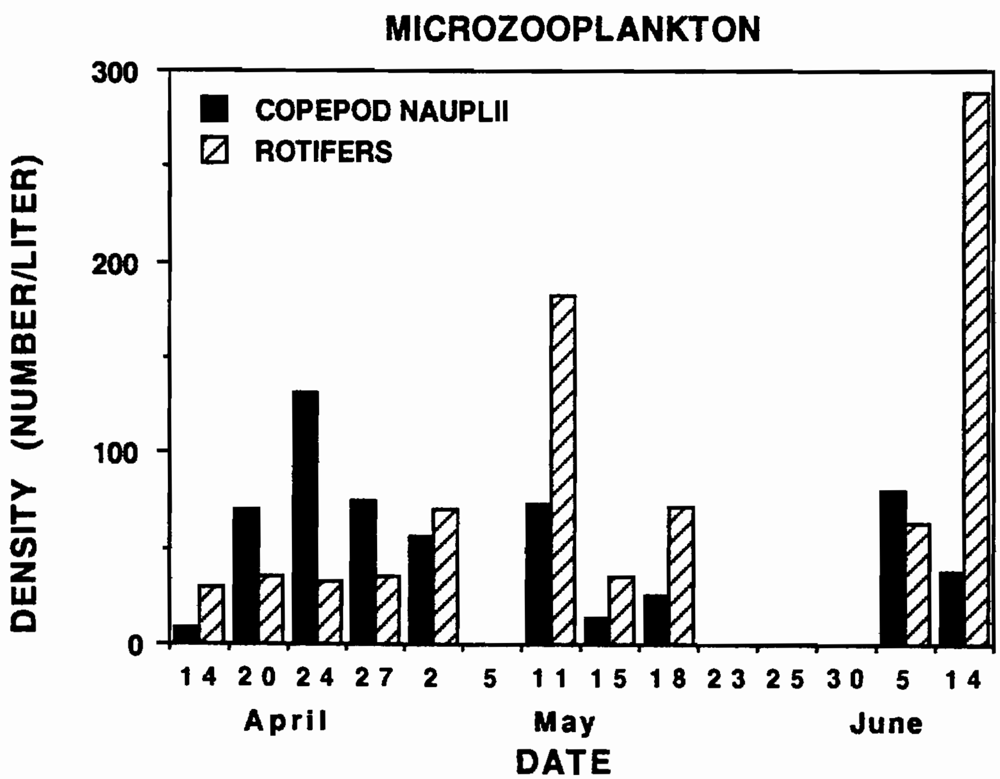


Figure 21. Upper Bay, 1989. Copepod and cladocera (A) and copepod nauplii and rotifer (B) densities by survey date.

1989 (Figure 19) than in the Potomac River in 1988 and 1989 (Table 23a), and exceeded Potomac River 1987 densities from 14 April until the second week in May. Upper Bay mean microzooplankton densities increased from a low of 39/liter on 14 April to 257/liter on 11 May, then declined to 49/liter on 15 May, and subsequently increased to a peak of 328/liter on 12 June (Figure 19). Mean microzooplankton densities one week after striped bass spawning peaks (27 April - 2 May, 11 May 1989) were 126-257/liter, and 98/liter, respectively. No zooplankton data were collected in the week following 22 May, when a third spawning peak occurred.

Densities of Upper Bay microzooplankton differed little between the two stations that were sampled on 14 April and from 24-27 April, and were higher at station 3 on 20 April. But, microzooplankton densities were higher at station 8, where striped bass larvae were most abundant, from 11 May through the remainder of the season (Figure 20). Copepod nauplii densities exceeded rotifer densities from 17 to 27 April, after which rotifer densities increased and predominated (Figure 21).

Striped Bass Egg Production and Spawning Biomass

Potomac River Egg Production

The 1989 Potomac River spawning season began approximately 1 April and extended to 30 May during the period when mean river temperatures rose from 12 to 21°C. Unlike the 1987 and 1988 seasons, peak egg production did not occur near the beginning of the season in 1989 but occurred during the last ten days of April, with a secondary peak on 20 May (Table 24; Figure 22).

The 1989 single survey series estimate of egg production in the Potomac River was 11.14×10^9 eggs, standard deviation = 1.26×10^9. The partitioned

Table 24. Potomac River, 1989. Egg productions based upon single survey estimates for each survey period.

Survey	Date	Number of Days Represented	Egg Production: Number (x 10^8)	Egg Production: Percent	Egg Production: Cumulative Percent
1	3 Apr	3.5	0.31	0.3	0.3
2	6 Apr	5.0	2.34	2.1	2.4
3	13 Apr	5.5	0.15	0.1	2.5
4	17 Apr	4.0	0.73	0.7	3.2
5	21 Apr	3.5	14.94	13.4	16.6
6	24 Apr	3.0	14.35	12.9	29.5
7	27 Apr	3.0	36.18	32.5	62.0
8	30 Apr	3.0	7.28	6.5	68.5
9	3 May	3.0	1.71	1.5	70.0
10	6 May	3.0	0.59	0.5	70.5
11	9 May	3.0	1.28	1.2	71.7
12	12 May	3.5	0.17	0.2	71.9
13	16 May	4.0	0.11	0.1	72.0
14	20 May	4.0	28.34	25.4	97.4
15	24 May	4.0	2.59	2.3	99.7
16	28 May	3.5	0.34	0.3	100.0
Totals		58.5	111.43	100.0	

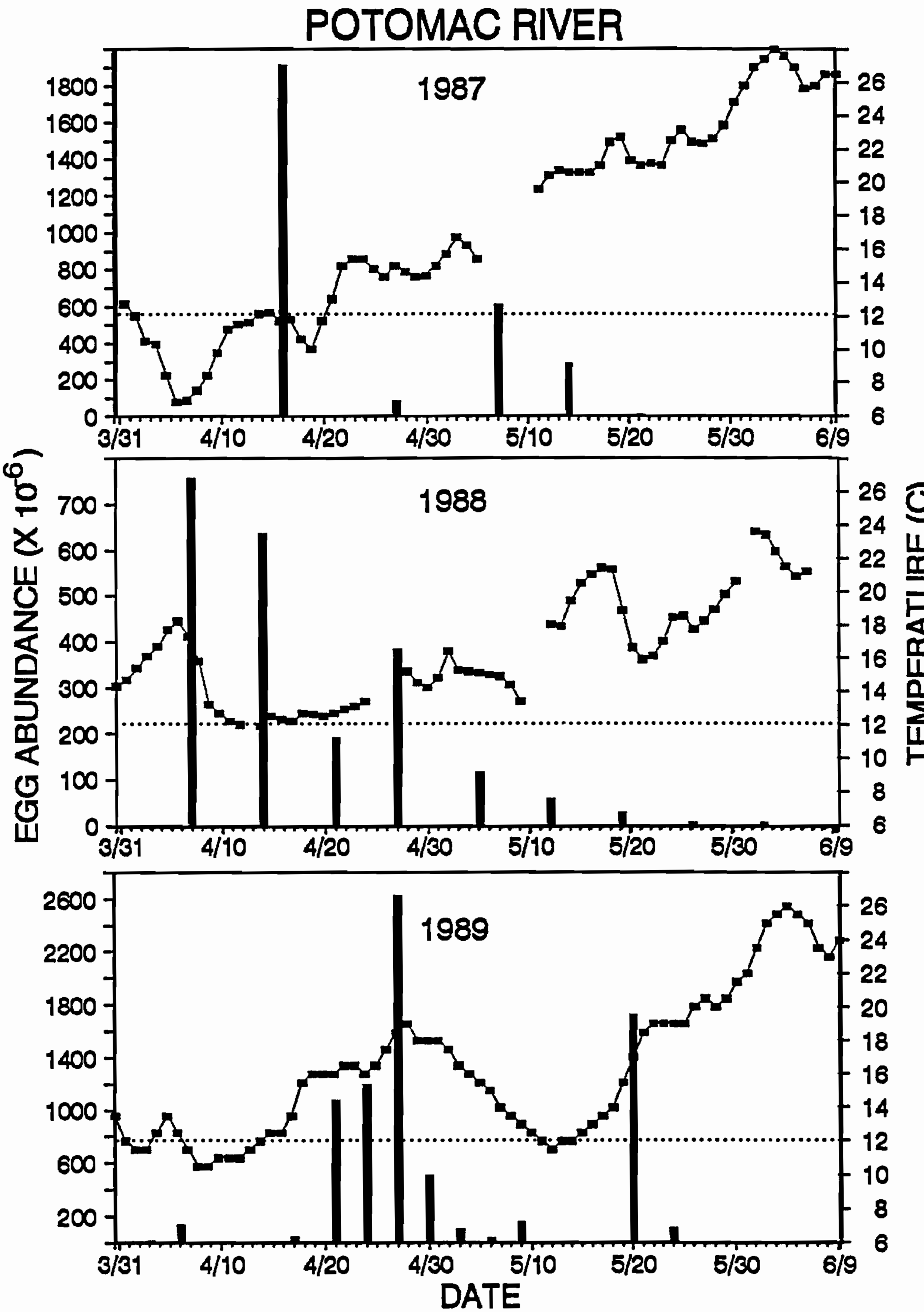


Figure 22. Potomac River, 1987-1989. Riverwide egg abundances (millions) estimated on each survey date during the three years of sampling effort. Water temperatures recorded at Wilson Bridge during the spawning season also are given. The 12°C critical low temperature, at which 100% egg and yolk-sac larvae mortality may occur, also is indicated.

survey series estimate was similar, 11.33 x 10^9 eggs, standard deviation = 1.96 x 10^9 (Table 25). Based upon the partitioned series estimate, little egg production (1.5% of total) occurred in Subarea I, but considerable production occurred in all other Subareas (Table 25). The highest egg production (38.5%) occurred in Subarea III (1989 Stations 4, 5, and 6, Figure 1). Remaining egg production was evenly spread among stations and areas represented by Subareas II, IV through V.

Spawning was spatially more homogeneous in 1989 than in 1987 or 1988. Using 1989 subareas as reference, most of the egg production occurred in Subarea III in 1987 (69.6%) and 1988 (50.1%). In 1989, 38.5% of the eggs were spawned in Subarea III, a significant percentage of the spawn, but lower than the 1987 or 1988 fractions in that subarea. In 1989, a higher fraction of the striped bass egg production (42.8%) occurred upstream, in Subareas IV and V, than occurred there in the previous two years (15.1% and 16.2% in 1987 and 1988, respectively).

The Potomac River 1989 egg production estimate was the highest in the 1987-1989 three year series (Figure 23), although not significantly different from 1987 or 1988, because of relatively large standard deviations. Partitioned series estimates of egg productions and their coefficients of variation [(Standard deviation ÷ estimate) x 100] in the Potomac were: 1987 -- 9.47 x 10^9 (64%); 1988 -- 6.65 x 10^9 (34%); 1989 -- 11.33 x 10^9 (17%). The relative variability of the estimates declined each year because of better survey design and station selection, but especially because of increased temporal coverage in 1989. Mean egg production in the Potomac for the three-year period was 9.15 x 10^9 eggs.

Cumulative percent egg production in the Potomac River in 1989 indicated that spawning was approximately 50% completed by 26 April (Table 24; Figure 24). The cumulative percent egg production curve differed in 1989 from those

Table 25. Potomac River, 1989. Egg production estimates for striped bass. Subareas and stations designated in Table 4 and Figure 2.

Subareas	Single-Survey Series Estimates		Partitioned-Survey Series Estimates	
	Egg Production ($\times 10^{9}$)	Variance ($\times 10^{16}$)	Egg Production ($\times 10^{9}$)	Variance ($\times 10^{16}$)
I	0.166	0.19	0.168	<0.01
II	1.916	35.39	1.960	121.73
III	4.258	44.43	4.358	71.43
IV	2.840	53.66	2.859	173.98
V	1.962	24.07	1.986	16.31
Total	11.142	157.74	11.332	383.45
Standard Deviation		1.256×10^{9}		1.958×10^{9}

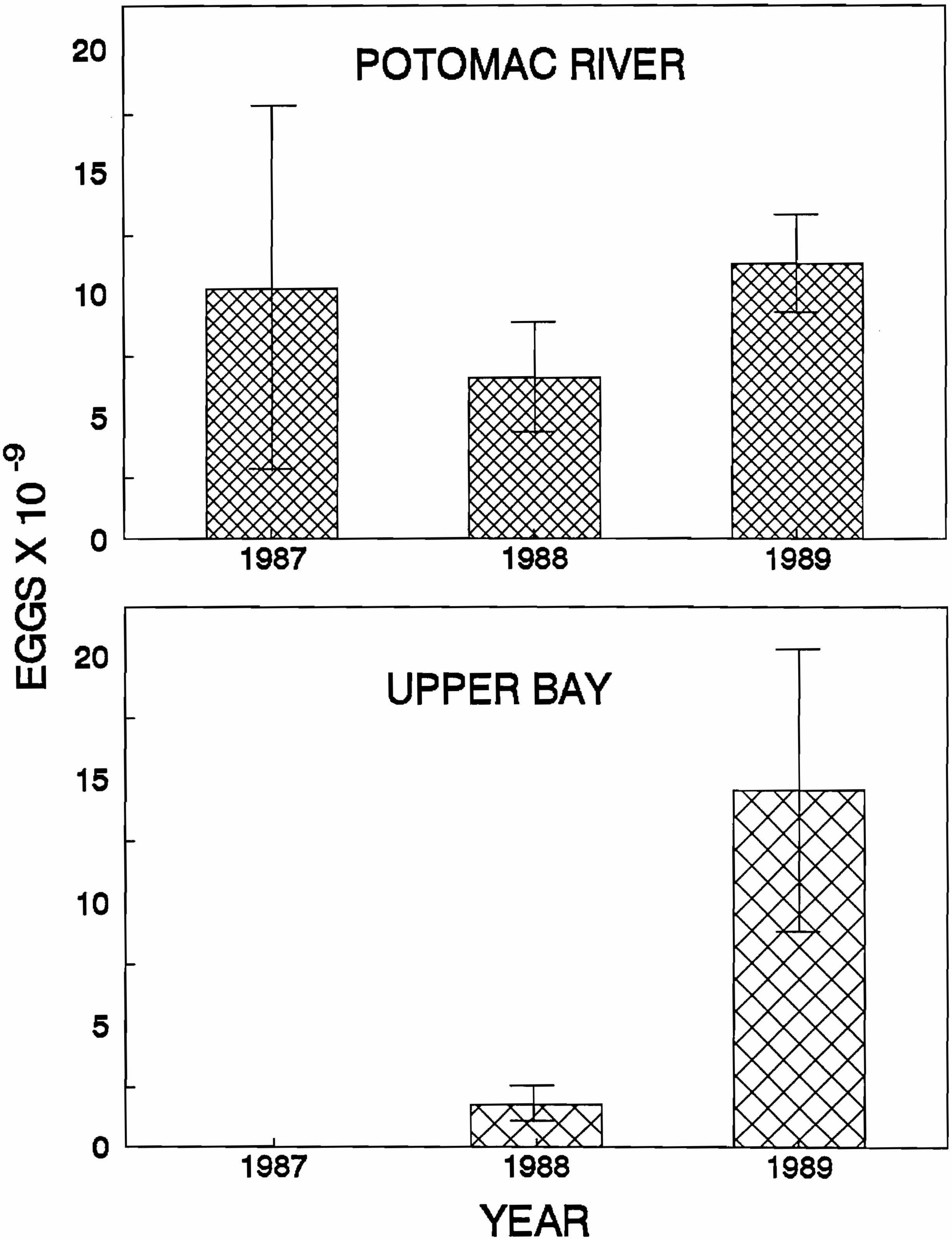


Figure 23. Potomac River, 1987-1989, and Upper Bay, 1988-1989. Estimated annual egg productions (billions). Error bars designate ± 1 standard deviation.

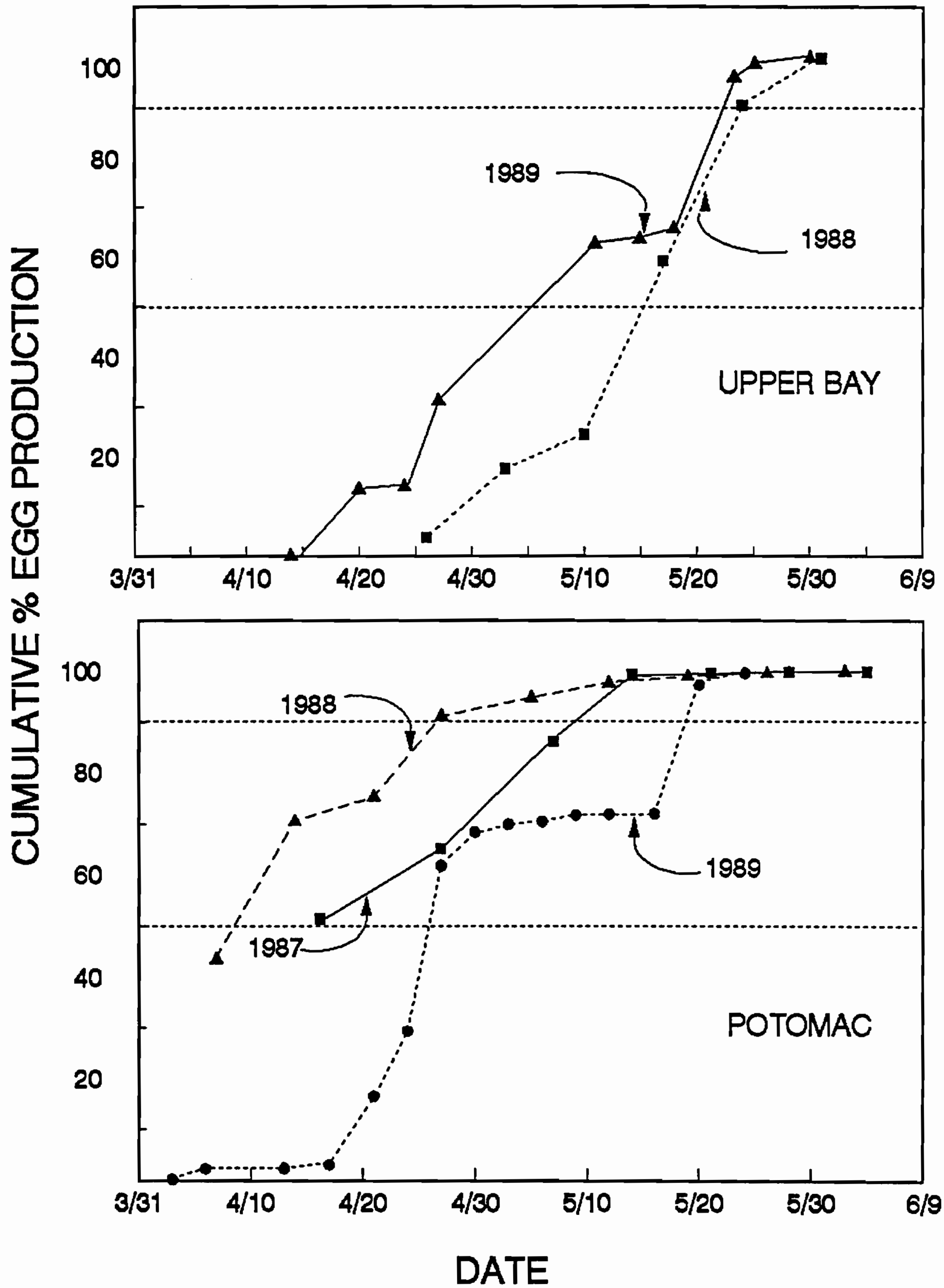


Figure 24. Potomac River, 1987-1989, and Upper Bay, 1988-1989. Cumulative percentage egg productions in each year in relation to survey date for each of the spawning areas.

observed in 1987 and 1988, when higher percentages of Potomac River egg productions occurred at the beginning of the spawning seasons (Figure 24). More than 50% of annual egg production was completed by 16 April in 1987 and 10 April in 1988.

Upper Bay Egg Production

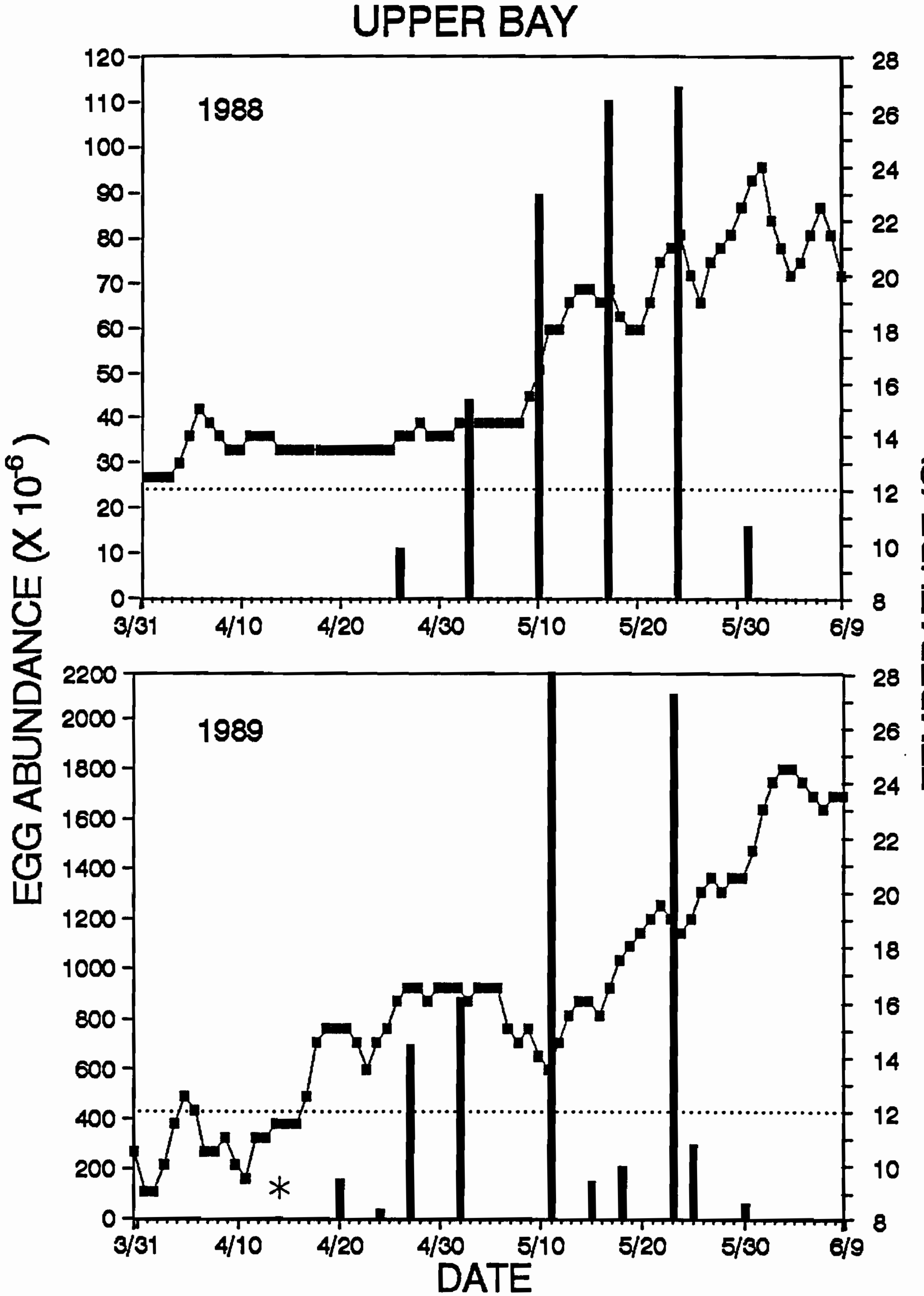
Striped bass spawned in the Upper Bay from approximately 11 April to 1 June 1989, the period when mean temperatures increased from 10.3 to 20.0°C. Peak 1989 egg production occurred in the period 27 April - 23 May (Table 26; Figure 25).

The single survey series estimate of egg production in the Upper Bay in 1989 was 15.54 x 10^9 eggs, standard deviation = 2.94 x 10^9 (Table 27). The partitioned series estimate was slightly lower, 14.57 x 10^9 eggs, standard deviation = 5.69 x 10^9. Based upon the partitioned series estimate, most of the 1989 egg production (67.6%) occurred in Subarea III (Stations 3, 4, 5, 6) of the Upper Bay. This percentage was higher than that in 1988 (41.5%) for this subarea. In 1989, little egg production (0.8%) was recorded in Subarea II (Station 7, Susquehanna Flats), although this area contributed 20.5% in 1988. Subarea IV (C&D Canal and its approaches -- Stations 8 and 9) produced 17.9% of the 1989 eggs and 26.1% in 1988. Subarea I (Stations 1 and 2) contributed essentially the same fraction of egg production in 1989 and 1988 (13.7% and 11.9%, respectively).

The Upper Bay egg production estimate for 1989 was considerably higher than that for 1988 (Figure 23). The two partitioned survey series estimates and coefficients of variation are: 1988 -- 1.78 x 10^9 (39.7%) and 1989 -- 14.57 x 10^9 (39.0%). Although the estimates lack precision, it seems certain that Upper Bay egg production increased substantially in 1989 compared to 1988.

Table 26. Upper Bay, 1989. Egg productions based upon single survey estimates for each survey period.

Survey	Date	Number of Days Represented	Egg Production Number ($\times 10^8$)	Egg Production Percent	Egg Production Cumulative Percent
1	14 Apr	7.0	0.01	<0.01	<0.01
2	20 Apr	5.0	20.90	13.5	13.5
3	24 Apr	3.5	0.81	0.5	14.0
4	27 Apr	8.5	27.09	17.4	31.4
5	2 May	---	---	---	---
6	5 May	---	---	---	---
7	11 May	9.0	48.60	31.3	62.7
8	15 May	3.5	1.66	1.1	63.8
9	18 May	4.0	2.93	1.9	65.7
10	23 May	3.5	47.10	30.3	95.9
11	25 May	3.5	4.38	2.8	98.7
12	30 May	4.0	1.94	1.3	100.0
Totals		51.5	155.43	100.0	



∗ - Abundance on 4/14 = 0.96 x 10^6

Figure 25. Upper Bay, 1988-1989. Areawide egg abundances (millions) estimated on each survey date during the two years of sampling effort. Water temperatures during the spawning season also are given. The 12°C critical low temperature, at which 100% mortality of eggs and yolk-sac larvae may occur, also is indicated.

Table 27. Upper Bay, 1989. Egg production estimates for striped bass. Subareas and stations designated in Table 4 and Figure 2.

Subareas	Single-Survey Series Estimates		Partitioned-Survey Series Estimates	
	Egg Production (x 10^9)	Variance (x 10^{16})	Egg Production (x 10^9)	Variance (x 10^{16})
I	2.562	69.97	1.996	152.22
II	0.125	0.19	0.114	0.22
III	10.362	773.08	9.847	2,667.00
IV	2.493	19.72	2.612	412.97
Total	15.542	862.96	14.569	3,232.41
Standard Deviation		2.938 x 10^9		5.685 x 10^9

Table 28. Potomac River, 1989. Estimated numbers, biomasses, and percentages of spawning female striped bass by age-class, and the number and percent of egg production contributed by each age-class.

Year Class	Age	Females			Egg Production	
		Number	Percent	Biomass (kg)	Number ($\times 10^9$)	Percent
1985	4	260	2.3	427	0.085	0.7
1984	5	3,924	35.1	13,295	2.698	23.8
1983	6	3,635	32.5	18,666	3.813	33.7
1982	7	3,358	30.0	23,113	4.736	41.8
		11,177		55,501	11.332	

Cumulative percentage egg production in the Upper Bay in 1989 indicated that spawning was 50% completed by 5 May and approximately 90% completed by 22 May (Table 26; Figure 24). Spawning was more protracted in 1989 than in 1988. The date at which 50% egg production was completed occurred approximately eight days later (16 May) in 1988 (Figure 24).

Numbers and Spawning Biomass of Adult Females, and Age-Specific Egg Production

Potomac River

The estimated number and biomass of Potomac River adult females in 1989 that produced eggs were 11,177 females and 55,501 kg, respectively (Table 28). Based upon the Maryland DNR gillnet CPUE data, the proportion of spawners was evenly distributed (30.0 - 35.1%) among 5-7 year-old females from the 1982, 1983 and 1984 year-classes (Table 29). Because they were larger and had correspondingly higher fecundities, estimated egg production by the 1982 year-class, age 7 females, was higher (41.8% of total) than that of the other year-classes. The estimated spawning biomass of adult females represents only a fraction of the striped bass biomass in the river because the estimate does not include males or immature females.

The biomass estimate is no more accurate or precise than the egg production estimate. Based upon the partitioned survey series egg production estimate and its standard deviation (Table 25), the approximate 90% confidence limits on 1989 female spawning biomass are 39.8 to 71.2 metric tons. There was little evidence, based upon our egg production estimates, that spawning biomass increased significantly in the Potomac River during the 1987-89 period. The spawning biomass approximate 90% confidence limits for the three years were: 1987 -- >0 to 94.3 metric tons; 1988 -- 14.5 to 50.6 metric tons; 1989 -- 39.8 to 71.2 metric tons.

Table 29. Potomac River, 1989. Mean gillnet catch-per-unit-effort (CPUE) and proportional contribution of females at each age to the 1989 Potomac River spawning population. Estimated mean weights and age-specific fecundities of each age group also are given.

Year-Class	Age (yr)	Mean CPUE[a] (No. per 1,000 yd)	Proportional CPUE	Weight (g)	Fecundity (No. eggs)	Fecundity-Specific CPUE (Column 3 x Column 6) x 10^6	Proportional Fecundity-Specific CPUE[b]
1985	4	0.1933	0.0233	1,641	326,297	0.0631	0.0075
1984	5	2.9120	0.3511	3,388	687,630	2.0024	0.2381
1983	6	2.6976	0.3252	5,135	1,049,002	2.8298	0.3365
1982	7	2.4915	0.3004	6,883	1,410,373	3.5139	0.4179
		8.2944				8.4092	

[a]Data from Maryland DNR, Tidewater Administration.
[b]CPUE adjusted for age-specific fecundity. An estimate of potential fractional contribution to egg production by each age group.

The 1982 year class females contributed most to Potomac River egg production in 1987, 1988 and 1989. Estimated percent contributions of the 1982 year class, calculated from fecundity-specific, gillnet CPUE data and egg productions in each year were: 1987 -- 51.6%; 1988 -- 46.5%; 1989 -- 41.8% (Figure 26A). In 1987, 38.0% of Potomac River egg production was estimated to have been by females >10 years of age. That percentage declined to 24.4% in 1988, and to 0.0% in 1989 (Figure 26B). The estimated fractions of the females on the spawning ground that were >10 years old, based upon Maryland DNR gillnet CPUE data, were 7.1% in 1987, 5.7% in 1988 and 0.0% in 1989. The 1987 and 1988 data illustrate the potentially high egg production that can accrue from relatively small numbers of highly fecund, large striped bass.

Upper Bay

Estimated numbers and biomass of Upper Bay adult females in 1989 were 12,805 females and 70,808 kg, respectively (Table 30). The 1982 year class represented 44.1% of the females, based upon Maryland DNR gillnet CPUE, and it spawned 54.7% of the eggs. The combined 1983 and 1984 year classes were represented by 48.1% of the females and contributed 36.4% to Upper Bay egg production.

The approximate .90 confidence limits on the biomass estimate, derived from the partitioned series egg production estimate and its standard deviation (Table 27), is 25.5 to 116.1 metric tons. It is highly probable that 1989 spawning biomass had increased considerably from 1988, when the estimated biomass confidence limits were 3.0 to 42.4 metric tons.

The 1982 year class dominated egg production and spawning biomass in the Upper Bay during 1988 and 1989. In 1988, the 1982 year-class females contributed 72.1% to egg production, compared to 54.7% in 1989 (Table 31; Figure 26A). Based upon observed egg production and proportioned CPUE, there

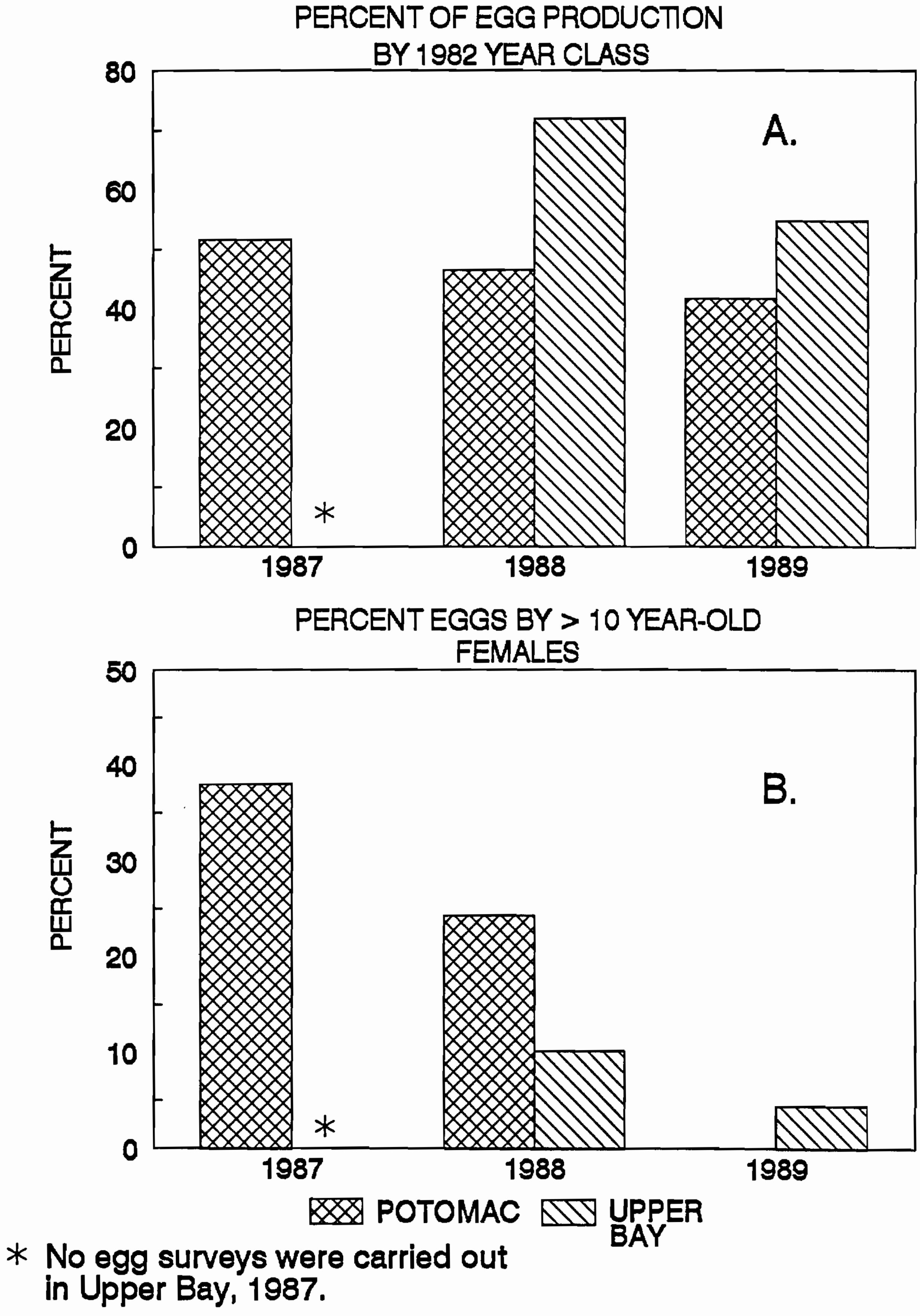


Figure 26. A. Annual egg production by females of the 1982 year-class in the Potomac River, 1987-1989, and Upper Bay, 1988-1989. B. Percentage contributions to annual egg productions by >10 year-old females in each area and year.

Table 30. Upper Bay, 1989. Estimated numbers, biomasses, and percentages of spawning female striped bass by age-class, and the number and percent of egg production contributed by each age-class.

Year Class	Age	Females			Egg Production	
		Number	Percent	Biomass (kg)	Number (x 10^9)	Percent
1985	4	613	4.8	1,006	0.200	1.4
1984	5	3,198	25.0	10,385	2.199	15.1
1983	6	2,962	23.1	15,210	3.107	21.3
1982	7	5,648	44.1	38,875	7.966	54.7
1981	8	247	1.9	2,132	0.438	3.0
1977	12	41	0.3	640	0.132	0.9
1971	18	49	0.4	1,279	0.263	1.8
1970	19	46	0.4	1,281	0.264	1.8
		12,805		70,808	14.569	

Table 31. Upper Bay, 1989. Mean gillnet catch-per-unit-effort (CPUE) and proportional contribution of females at each age to the 1989 Upper Bay spawning population. Estimated mean weights and age-specific fecundities of each age group also are given.

Year-Class	Age (yr)	Mean CPUE[a] (No. per 1,000 yd)	Proportional CPUE	Weight (g)	Fecundity (No. eggs)	Fecundity-Specific CPUE (Column 3 x Column 6) x 10^6	Proportional Fecundity-Specific CPUE[b]
1985	4	0.6428	0.0479	1,641	326,297	0.2097	0.0137
1984	5	3.3481	0.2497	3,388	687,630	2.3022	0.1509
1983	6	3.1003	0.2313	5,135	1,049,002	3.2522	0.2132
1982	7	5.9140	0.4411	6,883	1,410,373	8.3409	0.5467
1981	8	0.2584	0.0193	8,630	1,771,776	0.4578	0.0300
1977	12	0.0434	0.0032	15,619	3,217,255	0.1396	0.0092
1971	18	0.0509	0.0038	26,102	5,385,370	0.2741	0.0180
1970	19	0.0487	0.0036	27,850	5,746,895	0.2799	0.0183
		13.4066				15.2564	

[a]Data from Maryland DNR, Tidewater Administration.
[b]CPUE adjusted for age-specific fecundity. An estimate of potential fractional contribution to egg production by each age group.

was a probable large increase in the estimated numbers of 1982 females on the Upper Bay spawning grounds in 1989 (5,648), compared to 1988 (1,220). The estimated total egg production by the 1982 year class increased five-fold, from 1.28×10^9 in 1988 to 7.97×10^9 in 1989. Females >10 years old constituted 2.2% of the spawning females in 1988 and contributed 10.2% to egg production. Females >10 years old constituted only 1.1% of adult females in 1989 but still contributed 4.5% of the eggs (Table 31; Figure 26B).

Potomac River vs. Upper Bay

Egg production estimates in the Potomac River and Upper Bay were similar in 1989 (Tables 25 and 27), indicating that spawning biomasses of adult females also were similar (Tables 28 and 30). The egg production estimates did not change appreciably during the 1987-89 period in the Potomac River but increased greatly between 1988 and 1989 in the Upper Bay. The estimated numbers of 1982 year-class females declined in the Potomac River between 1987 and 1989, from 7,104 to 3,358, suggesting a 31% annual mortality rate. Despite the large apparent decline in numbers (52.7%) of the 1982 year class, egg production in the Potomac by that year class declined only by 11% in the 1987-89 period because of individual female growth and increasing fecundity. In the Upper Bay, egg production by 1982 year-class females was estimated to have increased dramatically (522%) from 1988 to 1989 as both numbers and weights of 1982 females increased. Females older than age 10 were unrepresented in gillnet catches in the Potomac in 1989 but still occurred in the Upper Bay. Although uncommon, old females made a relatively high contribution to egg production as indicated by their estimated age-specific contributions (Tables 30 and 31).

Potential and Actual Egg Production

The age-specific CPUE data from Maryland DNR gillnet surveys, when examined by date of collection, can be considered an index of potential egg production. The CPUE data first were adjusted for age-specific fecundity (Table 32) and then tabulated by 10-day collection periods to give the percentage potential egg production within 10-day periods in the Potomac River and Upper Bay during 1987, 1988 and 1989 (Tables 33 and 34). These potential percentage egg productions, partitioned by age-class and date, were compared to the estimated percentage egg productions from the ichthyoplankton surveys during the same periods.

Potomac River

During 1987 and 1988, actual egg production occurred earlier than the potential production predicted from gillnet CPUE data, but in 1989 the situation was reversed (Tables 24 and 33; Figure 27). In 1989, cumulative percent egg production from egg abundance data was estimated to be 50% completed by 26 April and 90% completed by 19 May, but the corresponding estimates from gillnet CPUE were 19 April and 1 May (Table 35; Figure 27). In 1987 and 1988, egg abundance data indicated that 50% egg production was completed by 16 and 9 April, respectively, while gillnet CPUE predicted 50% completion dates of 25 April in 1987 and 22 April in 1988. The 90% egg production estimates for 1987 were 10 May from the egg abundance data but 3 May from the gillnet CPUE. The 90% egg production estimates for 1988 were 26 April from egg abundance data and 10 May from the gillnet CPUE.

The gillnet CPUE potential egg production predictors indicated that 50% egg production in the Potomac River was expected between 19 and 25 April and that 90% egg production was completed between 1 and 10 May in 1987-1989 (Table 35). Actual egg abundance data in 1987-1989 gave a broader range of dates; 50% production, 9-26 April; 90% production, 26 April-19 May. The gillnet

Table 32. Potential relative contributions to egg production by female age groups, 1987-1989, Potomac River and Upper Bay. Estimates are derived from Maryland DNR gillnet catch-per-unit-effort data that were adjusted for age-specific fecundities.

Year	Potomac River			Upper Bay		
	Age Group	Year Class	Percent Contribution	Age Group	Year Class	Percent Contribution
1987	4	1983	10.4	4	1983	2.9
	5	1982	51.6	5	1982	60.2
	11	1976	4.5	7	1980	0.5
	14	1973	7.7	9	1978	1.8
	16-18	1971-1969	17.0	14	1973	20.2
	19	1968	8.8	15	1972	4.1
				16-18	1971-1969	10.2
1988	4	1984	3.4	4	1984	3.2
	5	1983	25.7	5	1983	10.2
	6	1982	46.5	6	1982	72.1
	15	1973	15.8	7	1981	3.2
	16	1972	8.6	10	1978	1.2
				15	1973	3.1
				16	1972	1.1
				18	1970	5.8
1989	4	1985	0.8	4	1985	1.4
	5	1984	23.8	5	1984	15.0
	6	1983	33.7	6	1983	21.2
	7	1982	41.8	7	1982	54.7
				8	1981	3.0
				12	1977	0.9
				18	1971	1.8
				19	1970	1.8

Table 33. Potomac River, 1987, 1988 and 1989. Percent of annual potential striped bass egg production, based on Maryland DNR gillnet catch-per-unit-effort data and age-specific fecundities of individual females that were collected within ten-day periods in 1987, 1988, and 1989.

			Collection Dates						
Year	Year Class	Age	1-10 Apr	11-20 Apr	21-30 Apr	1-10 May	11-20 May	21-22 May	Totals
1987	1983	4	0	1.4	1.7	4.6	2.2	0.5	10.4
	1982	5	0	14.5	19.4	14.1	3.6	0	51.6
	1976	11	0	4.5	0	0	0	0	4.5
	1973	14	0	0	0	7.7	0	0	7.7
	1969-71	16-18	0	0	0	17.0	0	0	17.0
	1968	19	8.8	0	0	0	0	0	8.8
	Total		8.8	20.4	21.1	43.4	5.8	0.5	100.0
	Cumulative %		8.8	29.2	50.3	93.7	99.5	100.0	

Year	Year Class	Age	1-10 Apr	11-20 Apr	21-30 Apr	1-10 May	11-20 May	21-22 May	Totals
1988	1984	4	0	0.4	0.7	0.3	2.0	0	3.4
	1983	5	0	7.0	4.8	7.0	6.8	0	25.6
	1982	6	0	13.7	9.8	12.4	10.6	0	46.5
	1973	15	0	10.1	0	5.7	0	0	15.8
	1972	16	0	8.6	0	0	0	0	8.6
	Total		0.0	39.9	15.3	25.5	19.4	0.0	100.0
	Cumulative %		0.0	39.9	55.2	80.7	100.0	100.0	

Year	Year Class	Age	1-10 Apr	11-20 Apr	21-30 Apr	1-10 May	11-20 May	Totals
1989	1985	4	0	0	0	0.8	0	0.8
	1984	5	1.5	8.3	6.3	7.8	0	23.8
	1983	6	1.7	3.7	10.7	17.5	0	33.6
	1982	7	19.2	4.7	11.3	6.6	0	41.8
	Total		22.4	16.8	28.2	32.6	0.0	0.00
	Cumulative %		22.4	39.2	67.4	100.0	100.0	100.00

Table 34. Upper Bay, 1987, 1988 and 1989. Percent of annual potential striped bass egg production, based on Maryland DNR gillnet catch-per-unit-effort data and age-specific fecundities of individual females that were collected within ten-day periods in 1987, 1988 and 1989.

Year	Year Class	Age	Collection Dates: 11-20 Apr	21-30 Apr	1-10 May	11-20 May	21-22 May	Totals
1987	1983	4	0.3	1.2	0.7	0.7	0	2.9
	1982	5	4.7	11.0	13.2	29.2	2.2	60.3
	1980	7	0	0	0.5	0	0	0.5
	1978	9	1.8	0	0	0	0	1.8
	1973	14	16.6	1.6	0	2.0	0	20.2
	1972	15	2.8	1.3	0	0	0	4.1
	1970	17	7.6	0	2.6	0	0	10.2
	Total		33.9	15.0	17.0	31.9	2.2	100.0
	Cumulative %		33.9	48.9	65.9	97.8	100.0	

Year	Year Class	Age	11-20 Apr	21-30 Apr	1-10 Apr	11-20 May	21-22 May	Totals
1988	1984	4	0.1	1.2	1.0	0.5	0.4	3.2
	1983	5	0.3	2.9	2.2	2.5	2.3	10.2
	1982	6	1.4	13.5	16.8	27.1	13.3	72.1
	1981	7	0.8	0.4	1.5	0.7	0	3.3
	1978	10	0	1.2	0	0	0	1.2
	1973	15	0	0	1.3	1.9	0	3.1
	1972	16	0	0	1.2	0	0	1.2
	1970	18	5.7	0	0	0	0	5.7
	Total		8.4	19.14	24.0	32.6	16.0	100.0
	Cumulative %		8.4	27.5	51.5	84.1	100.0	

Year	Year Class	Age	1-10 Apr	11-20 Apr	21-30 Apr	1-10 May	11-20 May	21-25 May	Totals
1989	1985	4	0	0	0.3	0.1	0.3	0.7	1.4
	1984	5	0	1.5	3.4	6.1	2.5	1.5	15.0
	1983	6	0	2.7	5.7	8.7	3.0	1.1	21.2
	1982	7	0.7	5.6	6.9	13.2	16.0	12.5	54.9
	1981	8	0	0	0	0.6	2.4	0	3.0
	1977	12	0	0.9	0	0	0	0	0.9
	1971	18	0	0	0	1.8	0	0	1.8
	1970	19	0	0	0	1.8	0	0	1.8
	Total		0.7	10.7	16.3	32.3	24.2	15.8	100.0
	Cumulative %		0.7	11.4	27.7	60.0	84.2	100.0	

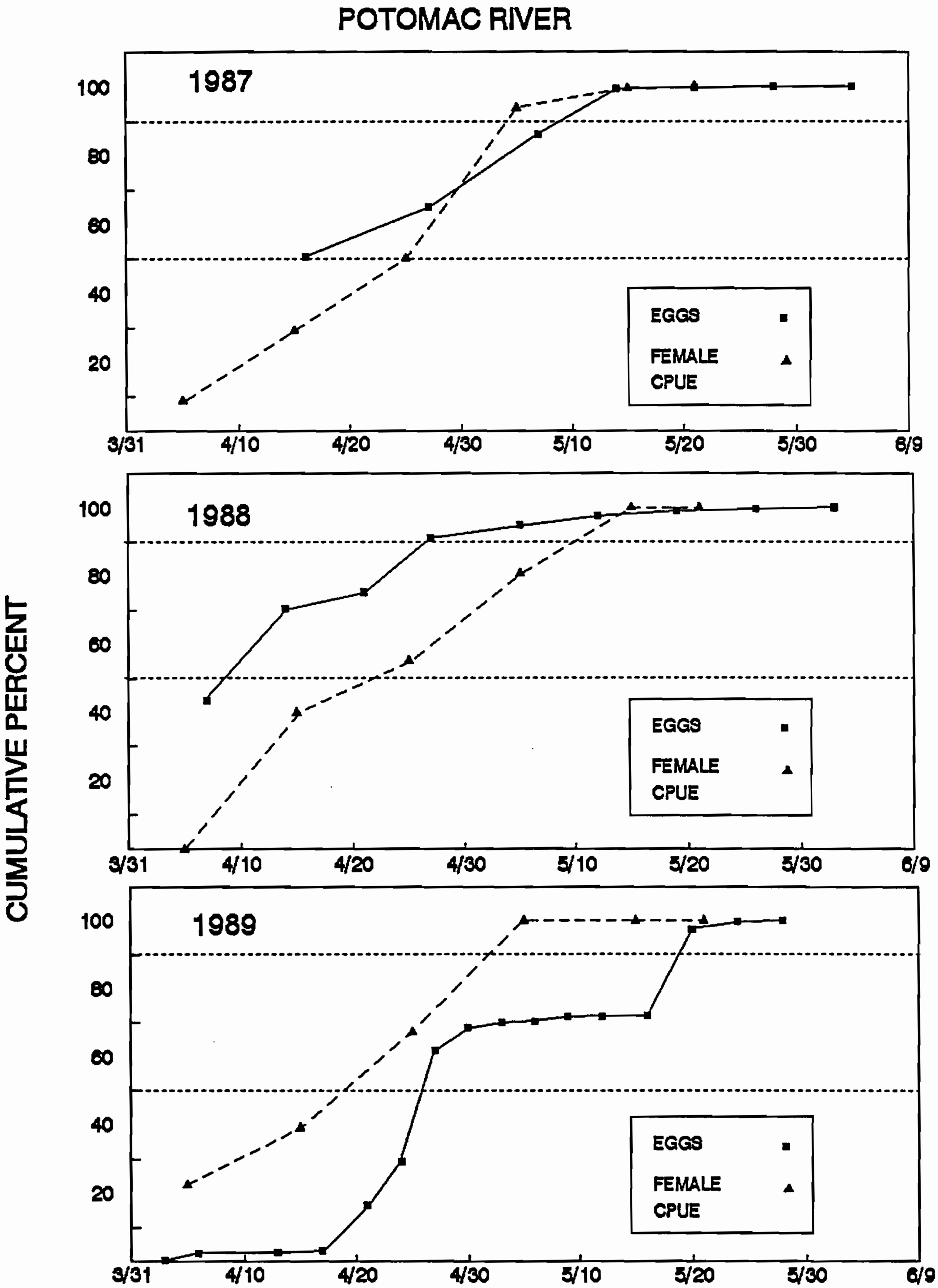


Figure 27. Potomac River, 1987-1989. Comparison of estimated cumulative percentage egg productions in relation to survey date, based upon ichthyoplankton survey estimates (eggs) and upon gillnet surveys of adult females (female CPUE).

Table 35. Estimated dates of 50% and 90% actual (egg surveys) and potential (fecundity-adjusted gillnet CPUE) cumulative egg production in the Potomac River and Upper Bay.

	Potomac River			Upper Bay		
50%	1987	1988	1989	1987	1988	1989
Actual	16 April	9 April	26 April	--	16 May	5 May
Potential	25 April	22 April	19 April	26 April	4 May	1 May

	Potomac River			Upper Bay		
90%	1987	1988	1989	1987	1988	1989
Actual	10 May	26 April	19 May	--	24 May	22 May
Potential	3 May	10 May	1 May	12 May	17 May	17 May

surveys broadly categorize the age structure and fluctuating abundances of female striped bass on the spawning grounds, but they were not good predictors of the temporal variability and extent of egg production in the Potomac River.

Upper Bay

In 1989, egg production estimated from the ichthyoplankton surveys in the Upper Bay followed the potential production predicted from gillnet CPUE more closely than in 1988 (Table 35; Figure 28). In 1989, cumulative egg production was estimated to be 50% completed on 5 May and 1 May, respectively, based upon the egg abundance and gillnet CPUE data (Table 35). The 90% egg production estimates were 22 May and 17 May, respectively, for egg abundance and gillnet CPUE data. In contrast, the 1988 estimates differed considerably, based upon the two data sets. Actual egg abundance data provided estimated dates for 50 and 90% cumulative egg production of 16 May and 24 May, respectively. The comparable estimated dates based upon gillnet CPUE potential egg production were 4 May and 17 May (Table 35; Figure 28). The gillnet CPUE data indicated that potential egg production was temporally similar in 1988 and 1989. But, the actual egg abundance data indicated that most spawning was completed considerably earlier in 1989 than in 1988 and that spawning was more protracted in 1989. Gillnet surveys in 1987 indicated that 50% and 90% potential egg productions in the Upper Bay were completed by 26 April and 12 May (Table 35; Figure 28), dates approximately one week earlier than in 1988 and 1989.

Age-Specific Female Contributions to Egg Production

The 1982 year class made the biggest contributions to potential egg production in each year from 1987-1989 in both the Potomac River and Upper Bay. The fecundity-adjusted CPUE data indicated that 1982 year-class females

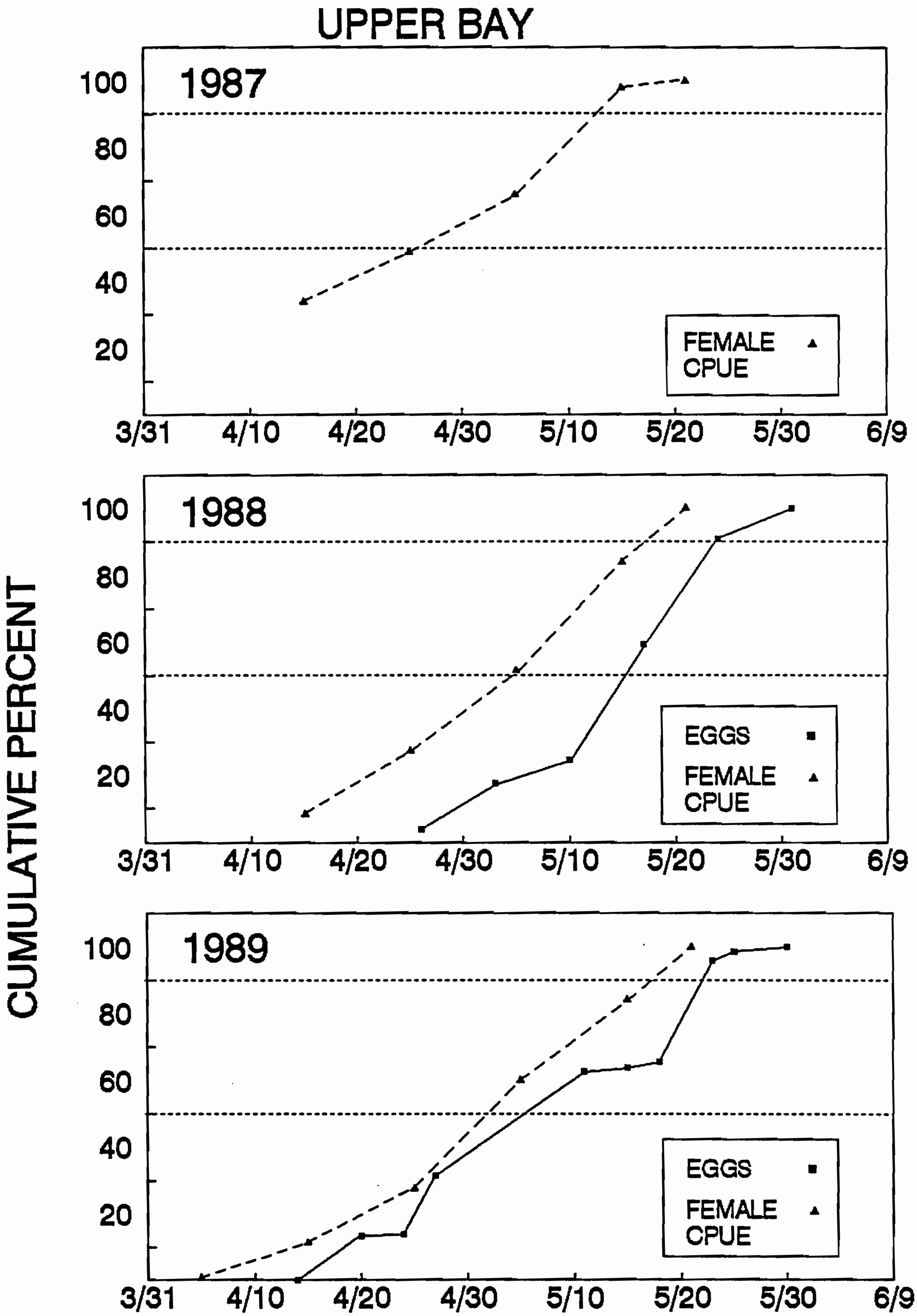


Figure 28. Upper Bay, 1987-1989. Comparison of estimated cumulative percentage egg productions in relation to survey date, based upon ichthyoplankton survey estimates (eggs) and upon gillnet surveys of adult females (female CPUE). There was no ichthyoplankton survey in the Upper Bay in 1987.

in the Potomac spawned 51.6, 46.5, and 41.8% of the eggs in 1987, 1988, and 1989, respectively (Table 32). Estimated percentage spawn by 1982 year-class females was even higher in the Upper Bay where fecundity-adjusted CPUE indicated percent egg productions of 60.2, 72.1, and 54.7% in 1987, 1988, and 1989. Females > age 7 potentially made very significant contributions to egg production in the Potomac River during 1987 and 1988 but no females > age 7 were represented there in 1989 gillnet catches (Table 32). Females > age 7 made potentially significant contributions to egg production in the Upper Bay during each of the three years, although their relative importance declined from 1987-1989 (Table 32).

Anecdotal information, based upon gillnet surveys and hatchery collections of adult striped bass spawners, indicated that older females were present on the spawning grounds earlier in the season. The fecundity-adjusted CPUE data, combined for 1987, 1988 and 1989 collections in the Potomac River and Upper Bay, do not give a clear indication that most potential egg production by ≤ age 7 females occurs later in the season than egg production by older females (Table 36). The fecundity-adjusted CPUE of these young females does appear to be spread more uniformly throughout the season and perhaps only young females contribute to spawning in the last several days of the season. There was an indication that most potential spawning by > age 7 females occurs relatively early in the season. During 1987-1989 in the Potomac River, 51% and 32% of potential spawning by > age 7 and ≤ age 7 females, respectively, occurred by 20 April. For the same years in the Upper Bay, 64% and 7% of potential spawning by the > age 7 and ≤ age 7 females, respectively, occurred by 20 April (Table 36).

Larva Length - Otolith Length Relationship

Table 36. Potomac River and Upper Bay. Dates and percent potential egg production by ≤7 and >7 years age-classes of female striped bass, 1987-1989 data. Results derived from fecundity-adjusted, gillnet CPUE data of Maryland DNR.

Potomac River

Age (yr)	1-10 April	11-20 April	21-30 April	1-10 May	11-20 May	21-31 May
≤7	9.4	22.6	27.2	29.9	10.6	0.2
>7	14.1	37.2	0.0	48.7	0.0	0.0

Upper Bay

Age (yr)	1-10 April	11-20 April	21-30 April	1-10 May	11-20 May	21-31 May
≤7	0.3	7.1	19.0	26.1	33.7	13.9
>7	0.0	64.2	7.3	17.1	11.4	0.0

Potomac River

A second-order polynominal provided the best fit to lengths of 1989 Potomac River striped bass larvae in relation to otolith radii (Figure 29):

$$L = 5.01 + 0.0354(R) - 2.64 \cdot 10^{-5}(R)^2$$

$n = 177$
$r^2 = .884$
$S.E._{b1} = .0022$
$S.E._{b2} = 1.0 \times 10^{-6}$

where L = larva standard length (mm) and R is otolith radius (µm).

There were significant differences ($P<.0001$) in the Potomac River standard length otolith radius relationships among the three years (relationship for 1987 and 1988 given in Houde et al. 1988, 1990). Larva lengths and otolith radii were $\log_{10}$ transformed and the relationships were compared among years (analysis of covariance with otolith radius as covariant) for all larvae and for larvae in the 5.0-12.0 mm SL size range. For either length range, striped bass larvae in 1989 had the largest otoliths and larvae in 1987 had the smallest otoliths at each body length.

The relationship between length and otolith radius varied significantly ($P<.004$) among 3-day larval cohorts. Cohorts hatched before 7 May, when temperatures experienced by cohorts during the first 20 days posthatch averaged <17°C, had relatively larger otoliths per unit body length than did cohorts hatched after 7 May, when temperatures were warmer.

Upper Bay

A linear body length-otolith radius relationship (Figure 30) was derived for Upper Bay striped bass larvae:

$$L = 4.84 + 0.03(R)$$

$n = 193$
$r^2 = 0.944$
$S.E._b = 0.0006$

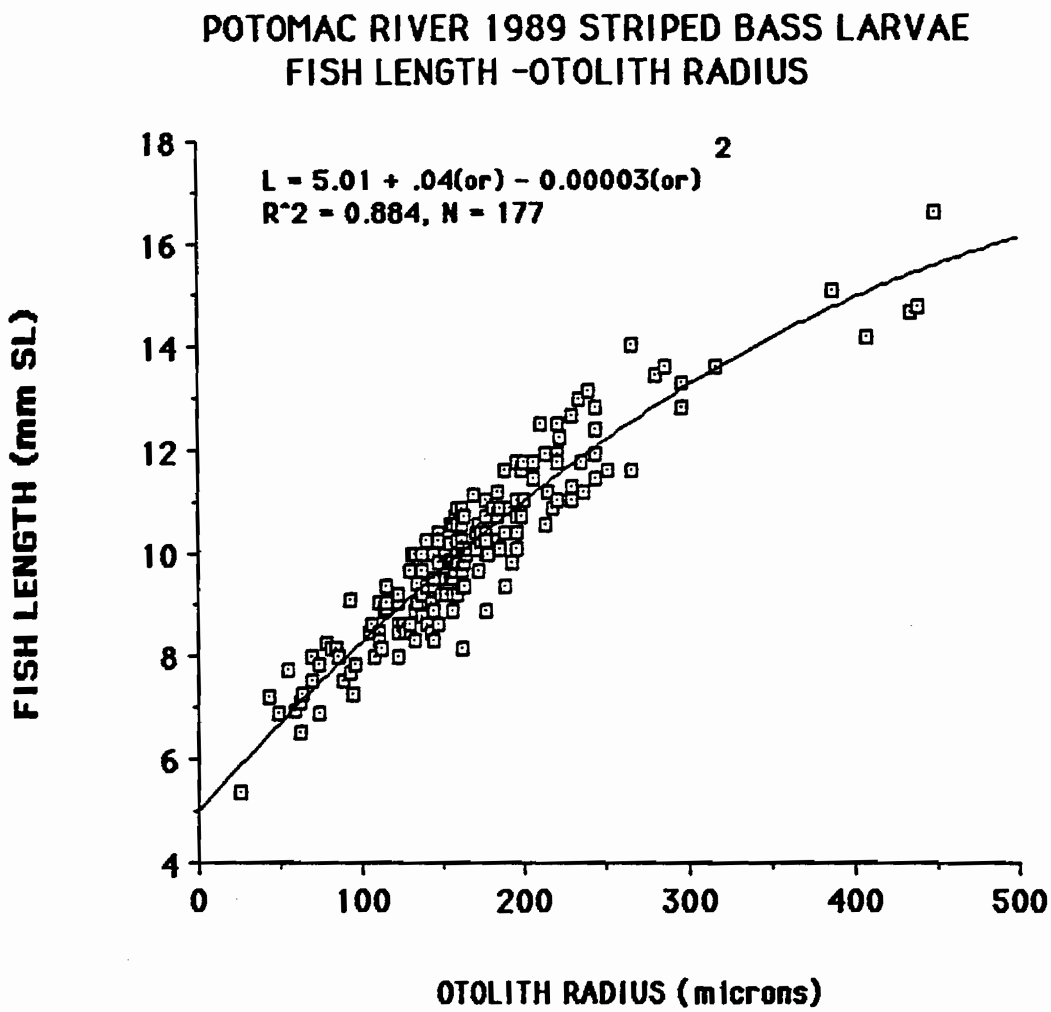


Figure 29. The fish-length-otolith radius relationship for striped bass larvae collected in the Potomac River, 1989.

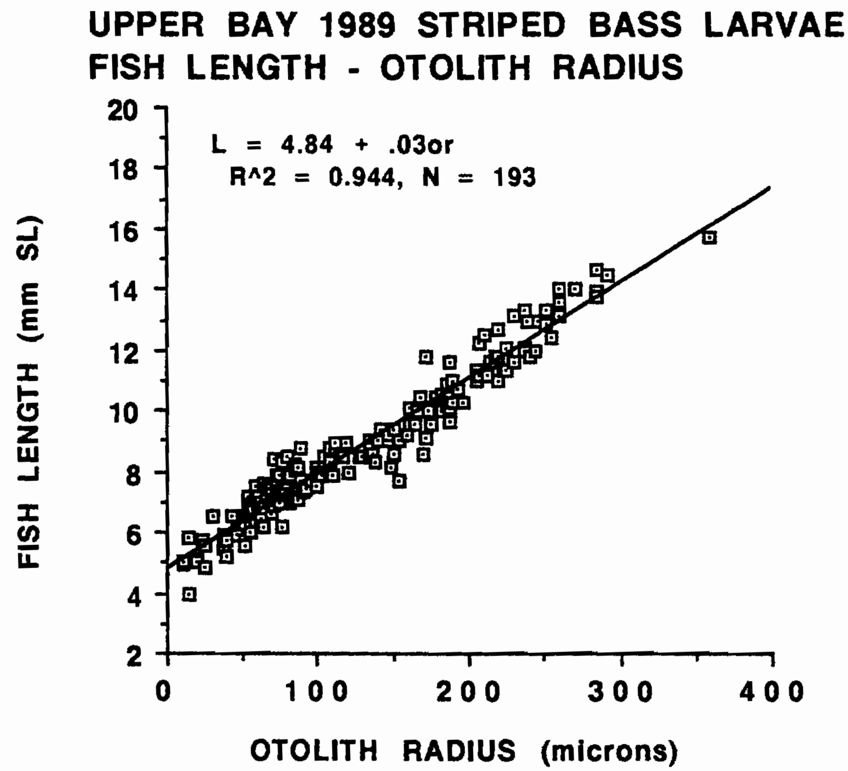


Figure 30. The fish-length-otolith radius relationship for striped bass larvae collected in the Upper Bay, 1989.

The $\log_{10}$-transformed relationship differed ($P<.0001$; analysis of covariance) from that for 1989 Potomac River larvae. Upper Bay striped bass larvae had larger otoliths than did Potomac River striped bass at equal standard lengths. In the Upper Bay there were significant differences ($P<.03$) among 3-day larval cohorts in the standard length otolith-radius relationship. With a few exceptions, cohorts that hatched early in the season had larger otoliths relative to their standard lengths than did cohorts hatched later in the season.

Larval Length Frequencies

Potomac River

Catch data from tows of the 60-cm, 333-µm net were used to generate the 1989 Potomac River length-frequency distributions and to estimate riverwide abundances of larvae within length classes. The length range of larvae sampled by the 60-cm net was 3-11 mm SL. Most larvae were 3-5 mm SL. The catches of larvae in 1989 were smaller and included fewer large larvae than 1987 catches. But, the catches in 1989 were larger and included bigger larvae than were observed in 1988.

The survey-specific length frequencies (Table 37) were converted to mean densities (no. per 100 m^3) of larvae in 0.5 mm length classes. After correcting for daytime avoidance of the sampler, numbers of larvae in 0.5 mm length classes per river segment and riverwide were calculated for each survey (Appendix Tables 29A-39A).

The daytime avoidance correction procedures were the same as those applied to 1988 larval length frequencies (Houde et al. 1990). In that procedure, the night and day collections of striped bass larvae from 1987 and

Table 37. Potomac River, 1989. Length frequencies of striped bass larvae in 292 tows of the 60-cm, 333 μm mesh sampler on 16 surveys. Modal and mean lengths also are given.

Length Class (mm)	SURVEY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
3		5			5	36	9	20	41	4	20	7			286	65	498
3.5		6			1	30	10	16	13	6	12	5			404	118	621
4		3				31	7	20	14	3	4				458	206	746
4.5					1	3	8	3	10	1	1				261	346	634
5						4	4		2	3					88	174	275
5.5					1	2			2						37	32	74
6												2			30		32
6.5															13	1	14
7												1			3		4
7.5																2	2
8												1				3	4
8.5																6	6
9																7	7
9.5																	
10																6	6
10.5																1	1
11																1	1
Totals =	0	14	2*	1*	8	106	38	59	82	17	37	16	0	0	1580	968	2925
Mean Length		3.7			3.6	3.8	4.1	3.8	3.7	4.0	3.5	4.0			4.2	4.6	4.3
Modal Length		3.5			3.0	3.0	3.5	3.5	3.0	3.5	3.0	3.0			4.0	4.5	4.0

*These larvae were lost before they could be measured.

1988 collections had been combined to generate night-to-day catch ratios for larvae 3.0 - 5.5 mm SL. For larvae 6.0 - 13.5 mm SL, regression equations had been derived to express night and day densities as a function of length, from which night-to-day catch ratios for each length class were estimated.

The riverwide abundances of striped bass larvae in 0.5 mm length classes (Appendix Tables 29A-39A) are illustrated in Figure 31. No larvae >6.0 mm were present before Survey 12 on 12 May, and larvae >8.0 mm were not collected until Survey 16 on 28 May. Only three larvae were collected in Surveys 3 and 4. They were lost before they could be measured and are not included in the length-frequency analysis. It is probable that they were newly-hatched larvae of 3-5 mm SL.

Potomac River striped bass larvae were more abundant and were represented by more length classes in 1987 than in either 1988 or 1989. The survey-averaged riverwide mean abundances by 0.5 mm length classes for seven 1987 surveys, nine 1988 surveys, and sixteen 1989 surveys are illustrated in Figure 32.

Mean survey abundance of all length classes of striped bass larvae in 1989 was 581.5 x 10^6, compared to 1,187.5 x 10^6 larvae in 1987 and 275.1 x 10^6 in 1988. Mean abundance of <5.0 mm striped bass larvae in 1989 was similar to 1987 but higher than 1988. The abundance of 5.5 - 11.0 mm larvae in 1989 declined rapidly compared to 1987 (Figure 32).

Potomac River Tucker Trawl Catches: A total of 3,580 striped bass larvae were collected in 32 Tucker trawl tows during two Potomac River surveys in 1989 (Table 38). Mean density of larvae in the 0.5 mm length classes was 11.24 larvae/1,000 m^3, a value intermediate between 1987 (19.90 larvae/1,000 m^3) and 1988 (0.05 larvae/1,000 m^3). Densities of Tucker trawl larvae <8.0 mm were highest in 1987 than in 1988, and intermediate in 1987 (Figure 33). For

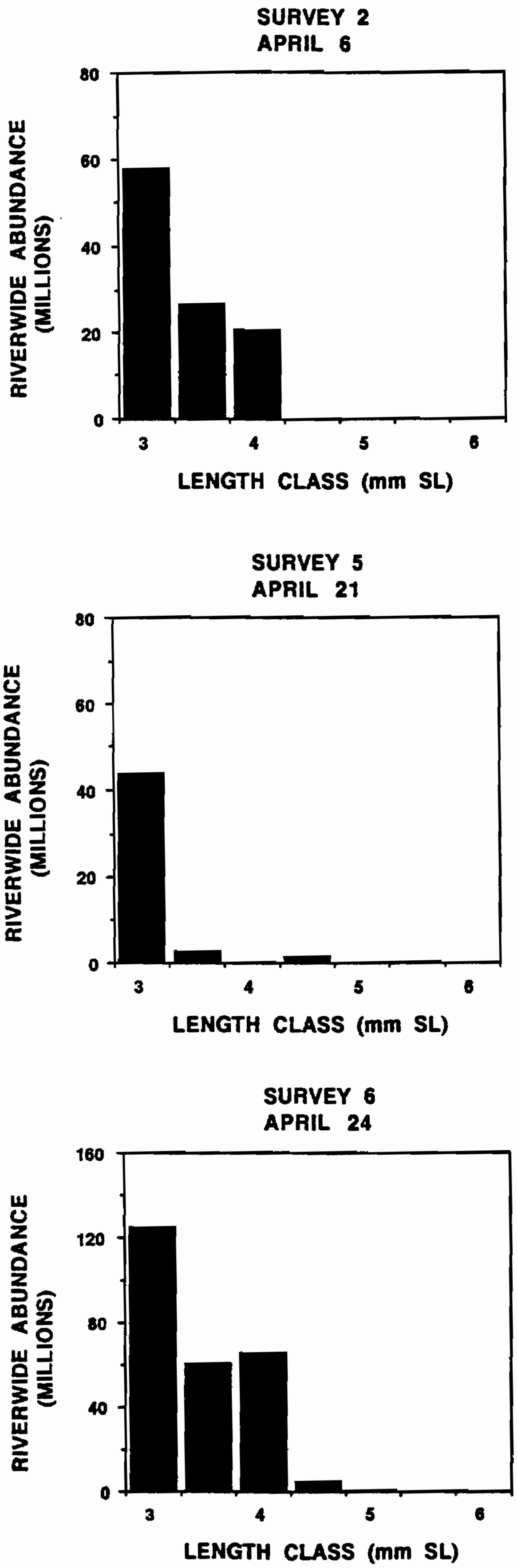


Figure 31. Potomac River, 1989. Estimated riverwide abundances presented as length-frequency distributions of striped bass larvae in 0.5 mm length classes for eleven surveys. Corrections for daytime avoidance by larvae were applied. Note that Y-axis scale changes from survey to survey.

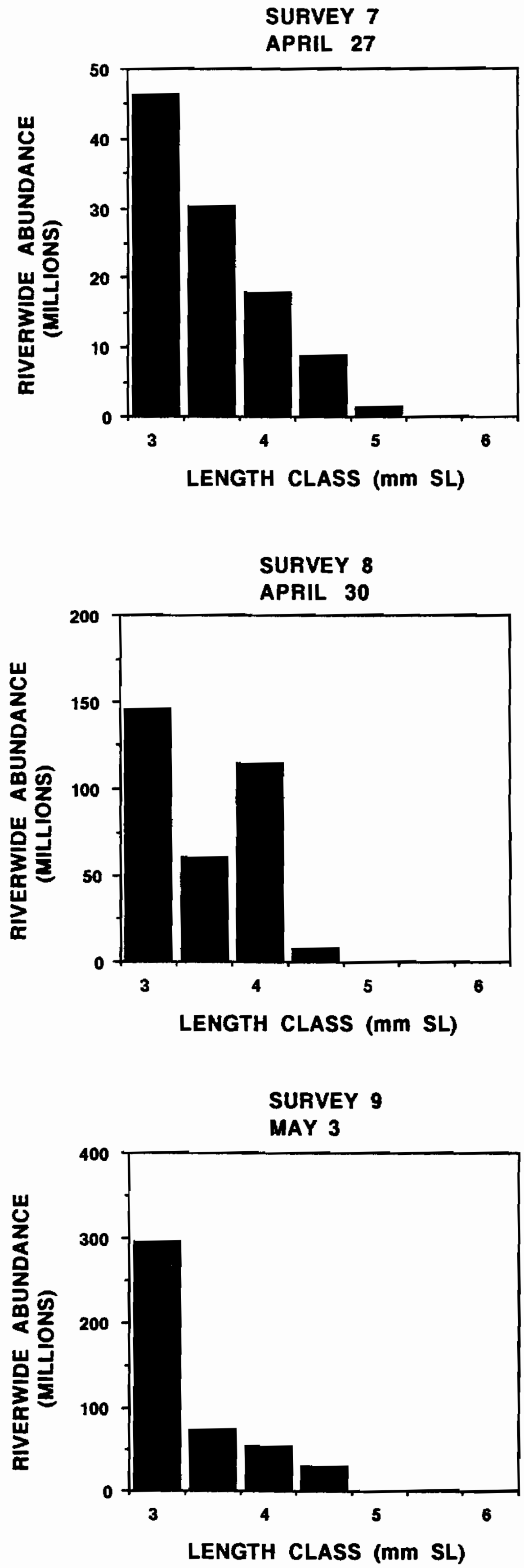
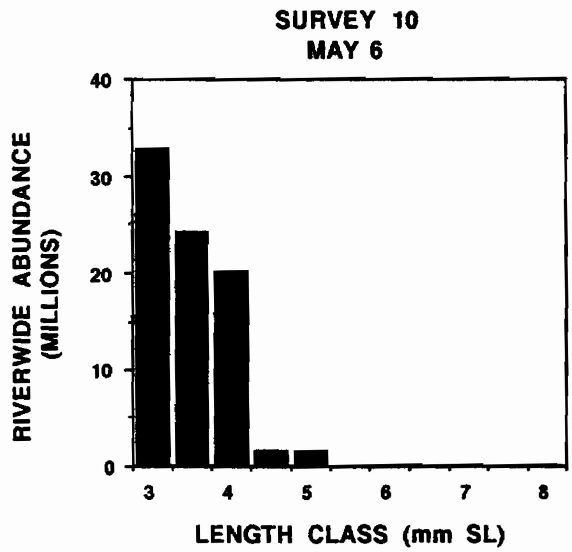
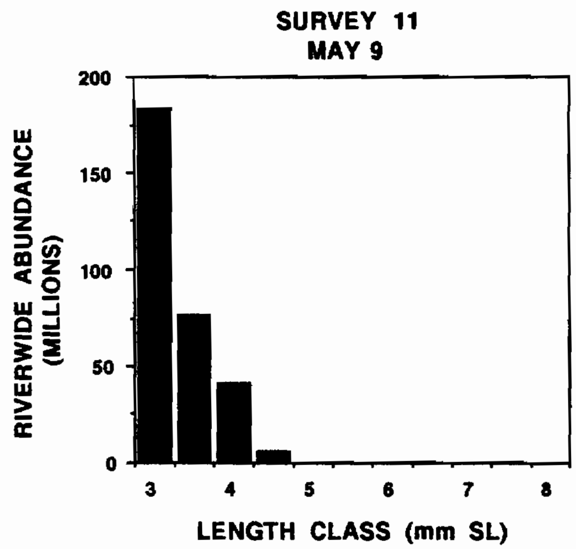
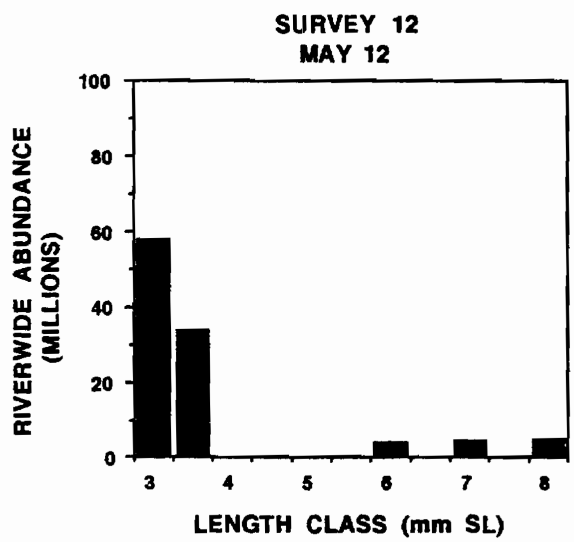


Figure 31. (Continued)







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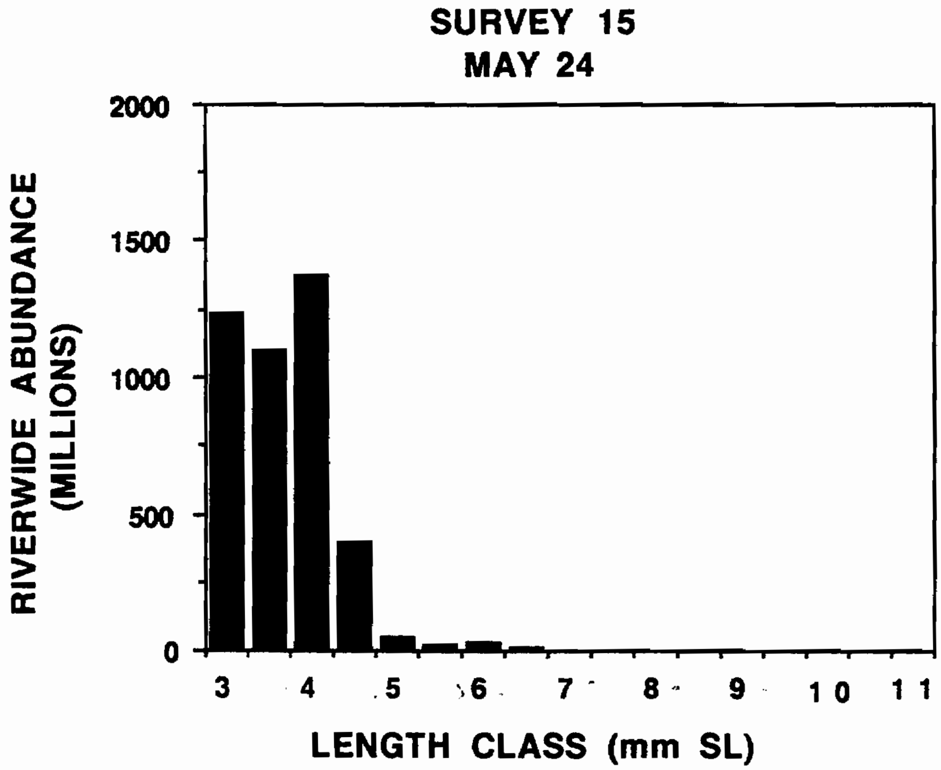

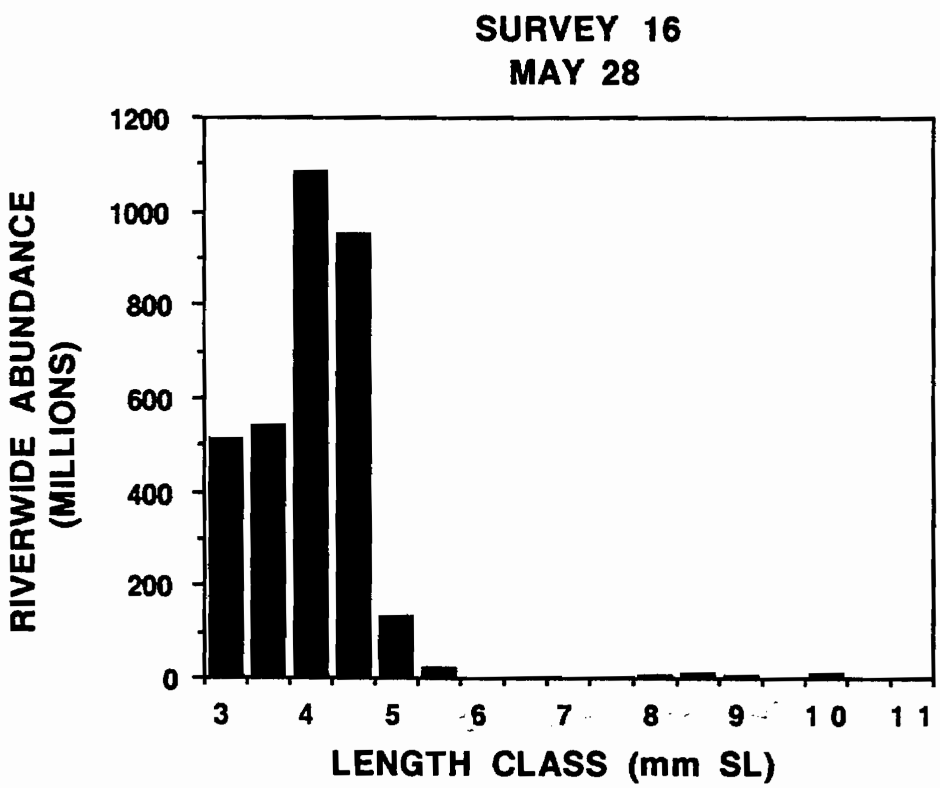

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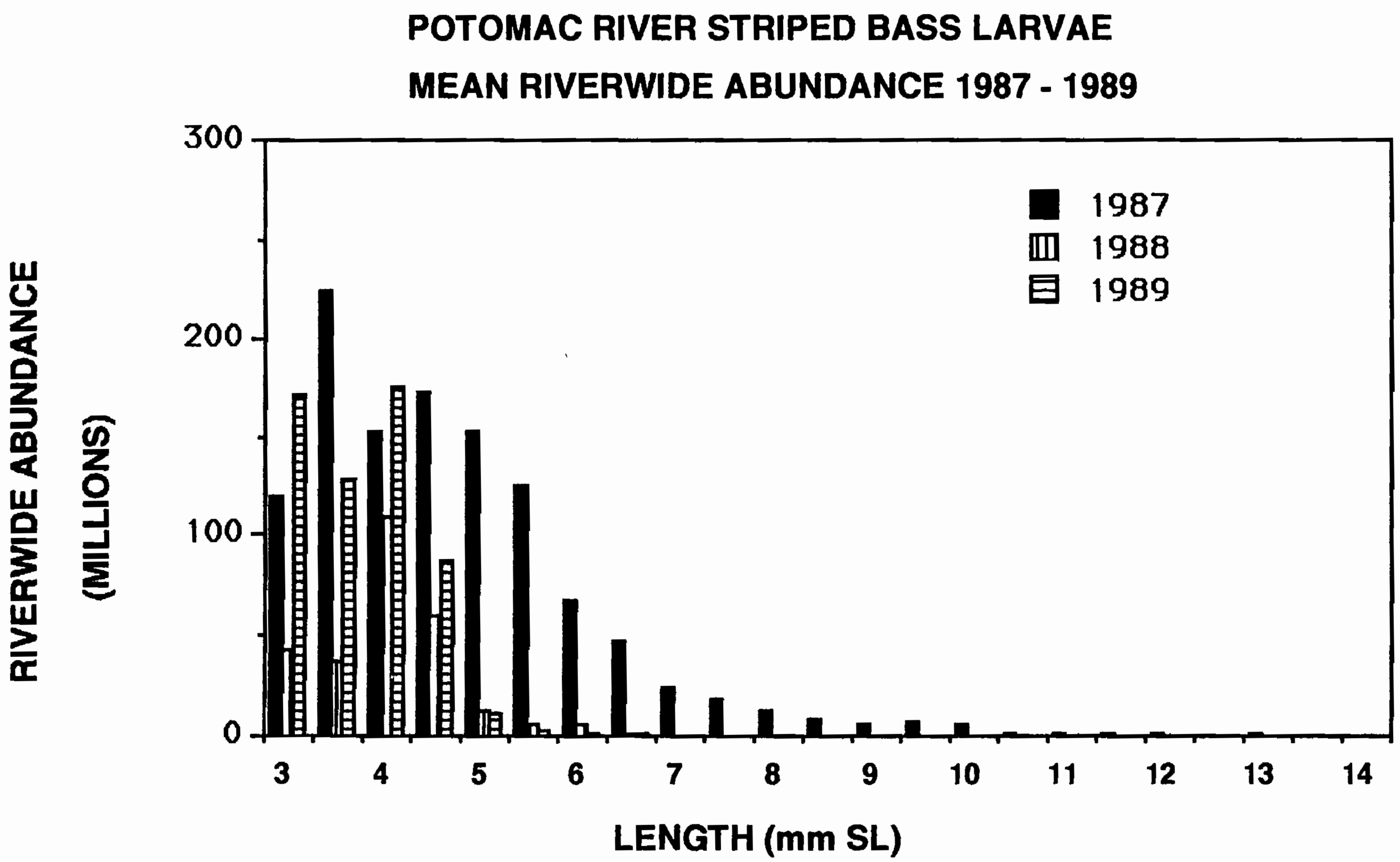


Figure 32. Potomac River, 1987-1989. Survey-averaged riverwide mean abundances of striped bass larvae by 0.5 mm length classes for the 7 surveys and 8 stations in 1987, 9 surveys and 6 stations in 1988, and 16 surveys and 9 stations in 1989.

Table 38. Potomac River, 1989. Striped bass larvae length frequencies and mean densities (#/1000m3) collected in the 2m2 Tucker trawl at stations A, B, C, and D (Figure 3), surveys 17 and 18 (1-2 and 8-9 June).

	SURVEY					
	17		18		Totals	
Length Class (mm)	No.	Mean Density	No.	Mean Density	No.	Mean Density
3.0						
3.5	1	0.12			1	0.06
4.0	32	4.12	9	1.08	41	2.60
4.5	113	13.97	11	13.92	124	13.94
5.0	302	39.56	11	13.92	313	26.74
5.5	326	41.73	26	15.68	352	28.71
6.0	285	35.19	60	34.55	345	34.87
6.5	155	18.73	54	6.43	209	12.58
7.0	94	11.75	25	4.79	119	8.27
7.5	21	2.20	34	7.03	55	4.61
8.0	7	0.36	85	19.33	92	9.85
8.5	17	2.06	178	34.14	195	18.10
9.0	9	1.13	177	39.42	186	20.28
9.5	22	2.55	261	49.72	283	26.13
10.0	24	3.04	301	56.39	325	29.72
10.5	30	3.63	250	39.06	280	21.35
11.0	15	1.86	145	26.85	160	14.36
11.5	26	3.22	132	24.57	158	13.89
12.0	21	2.56	44	10.68	65	6.62
12.5	8	1.05	49	8.67	57	4.86
13.0	4	0.50	33	4.66	37	2.58
13.5	5	0.68	34	4.72	39	2.70
14.0			48	9.23	48	4.61
14.5			17	4.25	17	2.13
15.0			8	0.96	8	0.48
15.5			39	4.63	39	2.32
16.0						
16.5			22	2.68	22	1.34
17.0			2	0.89	2	0.44
17.5						
18.0						
18.5						
19.0			8	1.00	8	0.50
Totals	1517		2063		3580	
Mean Density	9.05		16.27		11.24	
Mean Length	6.22		9.71		6.75	
Modal Length	5.5		10.0		5.5	

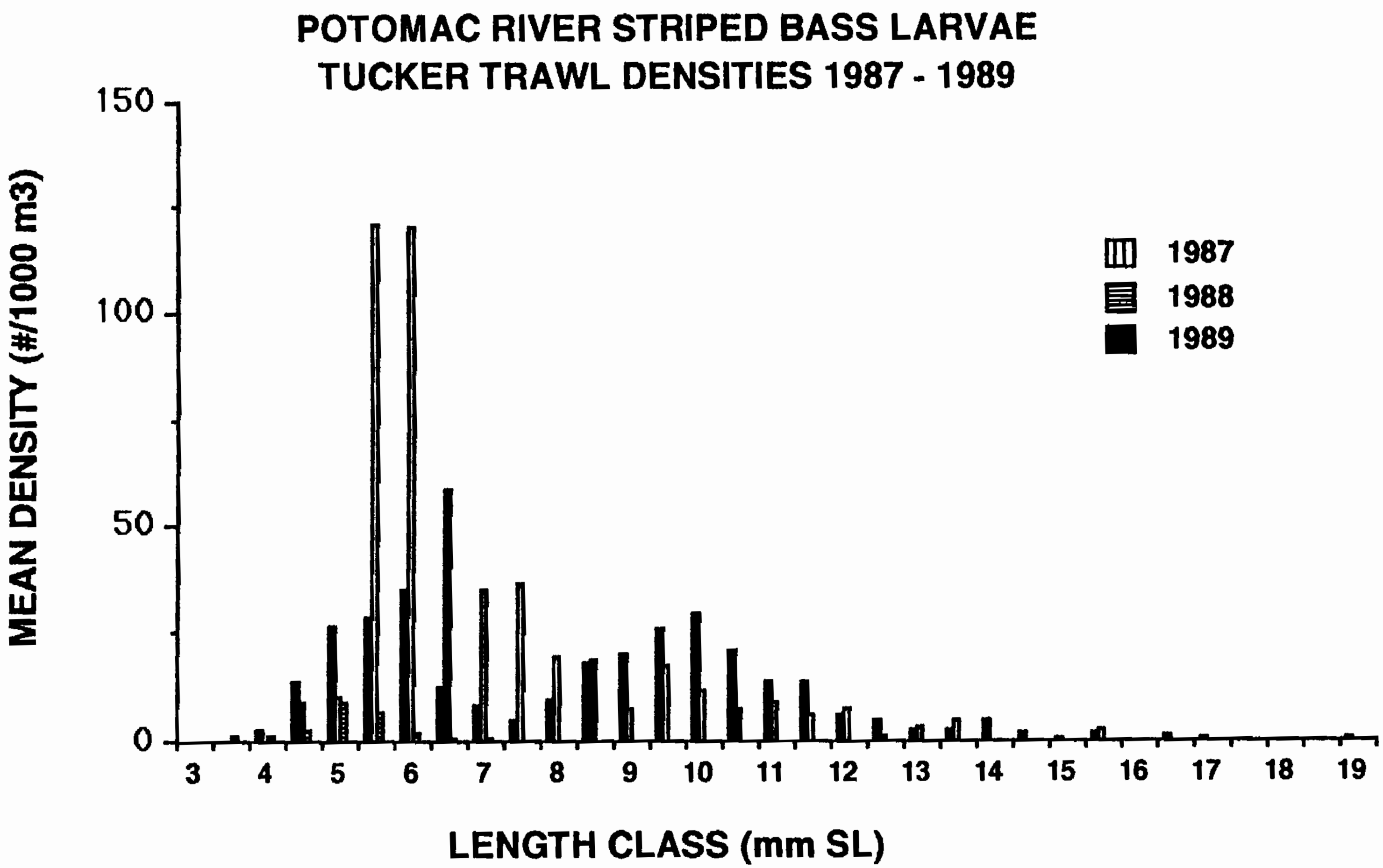


Figure 33. Potomac River, 1987-1989. Densities (no. per 1000 m³) of striped bass larvae by 0.5 mm length classes collected in the 2 m² Tucker trawl on the 3 surveys- 22 May-6 June 1987, 3 surveys- 19 May-3 June 1988, and the 2 surveys- 1-8 June 1989.

larvae 10.0-11.5 mm, estimated densities on the dates of collection were highest in 1989, followed by 1987 and 1988 (Figure 33). Relatively few larvae ≥12.0 mm were collected in the Tucker trawl. Observed densities of 12.0 to 15.5 mm larvae were similar in 1987 and 1989. The few striped bass larvae >16.0 mm that were collected occurred in 1989 catches. In 1988, no larvae >11.0 mm were collected in the Tucker trawl.

Upper Bay

Length frequencies of Upper Bay striped bass larvae collected in 194 tows of the 60-cm sampler indicated that most larvae were newly-hatched, 3.0 - 5.0 mm SL (Table 39), and were hatched during the 23-30 May 1989 period (Surveys 10-12). No larvae >6.5 mm were collected in the 60-cm sampler. The areawide abundance estimates of larvae in each 0.5 mm length class (Appendix Tables 40-47) (Figure 34) indicate that no larvae ≥6.5 mm were present before 18 May (Survey 9).

Mean survey-averaged abundance of newly-hatched 3.0 - 5.0 mm striped bass larvae was 996.7×10^6, an estimate 1.7 times higher than the survey-averaged abundance in the Potomac River in 1989 and 20 times higher than the survey-averaged abundance in the Upper Bay in 1988 (Figure 35).

Upper Bay Tucker Trawl Catches

A total of 3,233 striped bass larvae were caught in 48 Tucker trawl tows in the Upper Bay in 1989 (Table 40). Densities of larvae caught in Tucker trawls at Stations A, B, D, E, F on two survey dates (5-6, 14-15 June) averaged 6.81 larvae/1,000 m^3, compared to the 1988 mean density of 0.33 larvae/1000 m^3 during the 17 May - 1 June period. Compared to Potomac River Tucker trawl catches in 1989, mean densities of Upper Bay larvae <7.5 mm were similar, but densities of larvae >8.0 mm were lower in the Upper Bay (Figure

Table 39. Upper Bay, 1989. Length frequencies of striped bass larvae in 194 tows of the 60-cm, 333 μm mesh sampler on 12 surveys. Modal and mean lengths also are given.

Length Class (mm)	SURVEY 1	2	3	4	5	6	7	8	9	10	11	12	Totals
3					4		4		2	440	501	32	983
3.5			2				4	1	3	320	169	58	557
4					3		2	1	1	183	286	102	578
4.5							6	2	2	44	352	91	497
5									1	8	80	61	150
5.5							2		1		12	15	30
6											4	3	7
6.5									1			1	2
Totals =	0	0	2	0	7	0	18	4	11	995	1404	363	2804
Mean Length =			3.8		3.8		4.2	4.9	4.5	3.4	3.9	4.5	3.8
Modal Length =			3.5		3.0		4.5	4.5	3.5	3.0	3.0	4.0	3.0

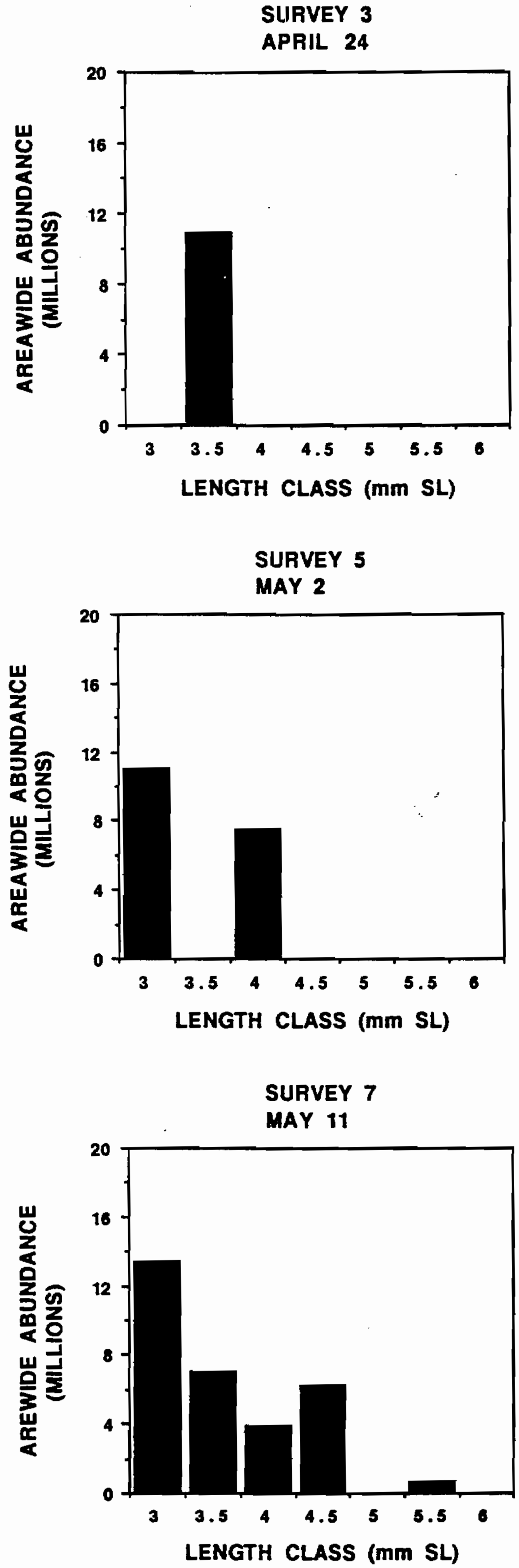
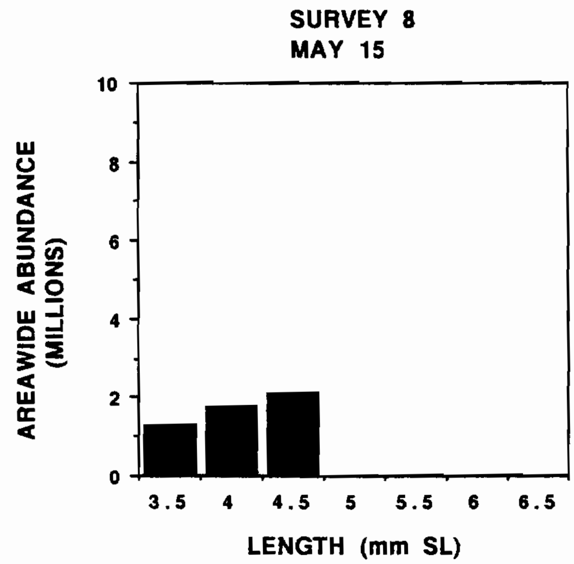
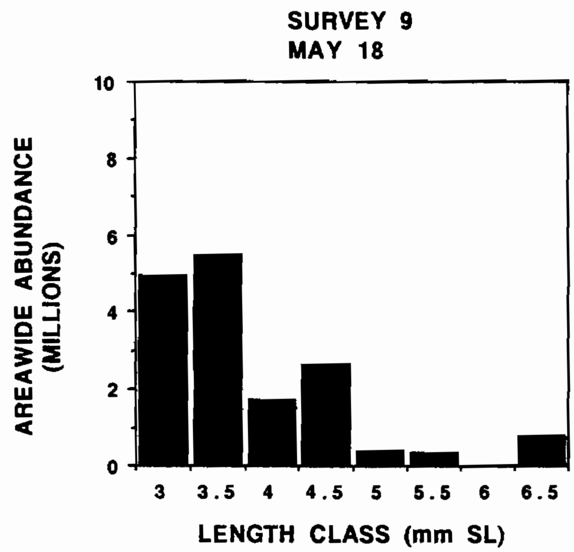
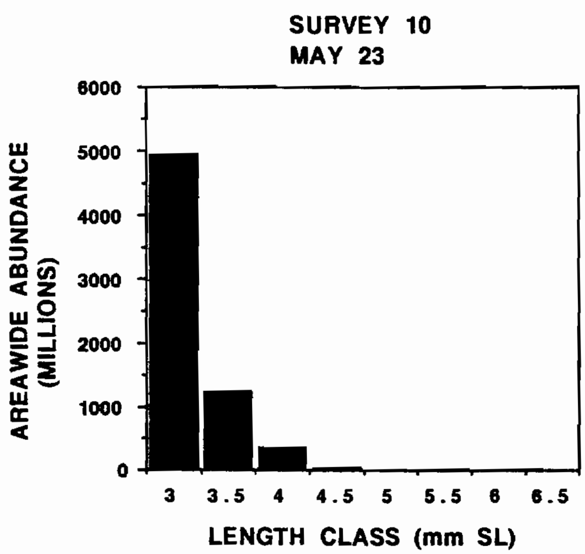


Figure 34. Upper Bay, 1989. Estimated areawide abundances presented as length-frequency distributions of striped bass larvae in 0.5 mm length classes for 8 surveys. Corrections for daytime avoidance by larvae were applied. Note that Y-axis scale changes from survey to survey.







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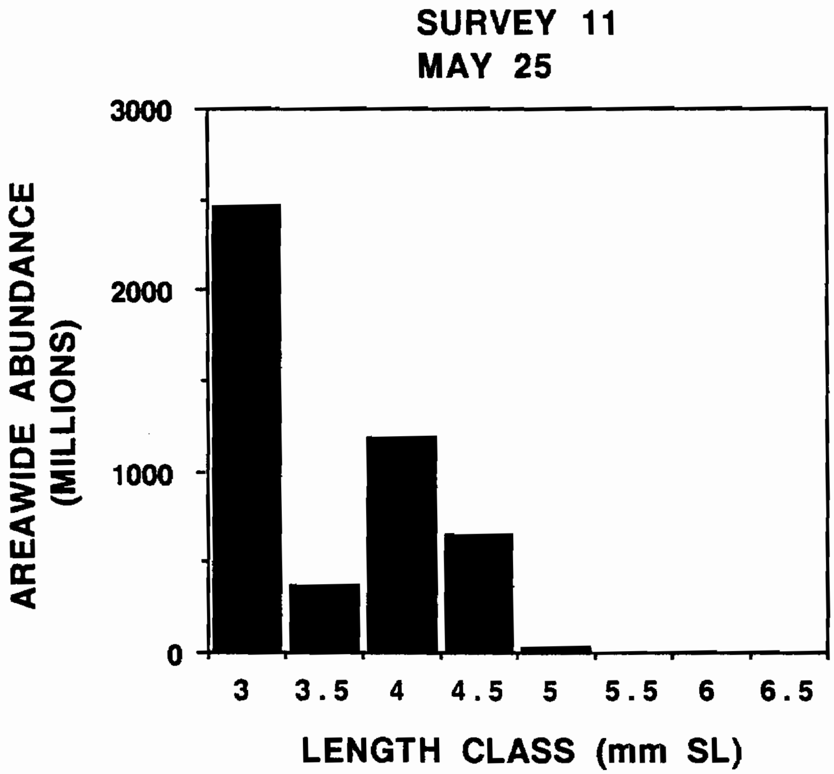

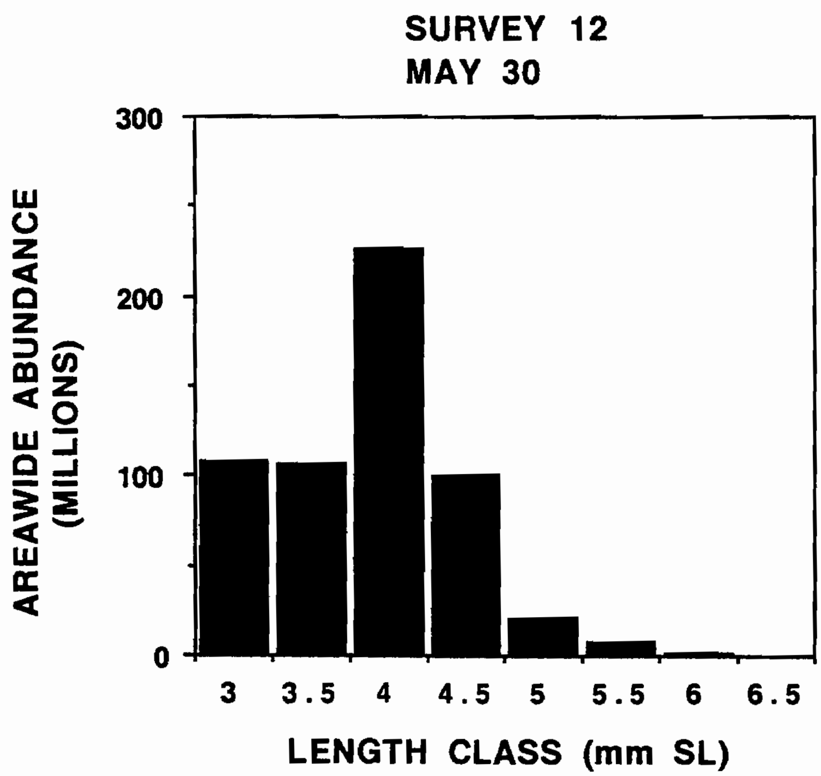

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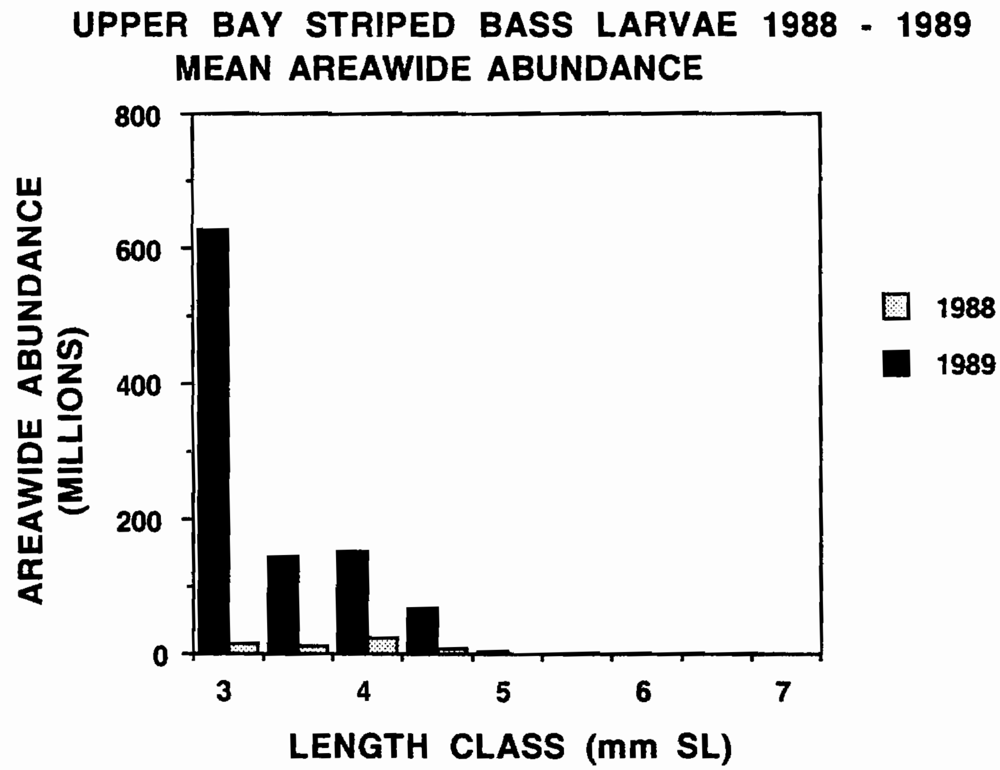


Figure 35. Upper Bay, 1988-1989. Survey-averaged areawide mean abundances of striped bass larvae by 0.5 mm length classes for the 6 surveys and 11 stations in 1988, and the 12 surveys and 9 stations in 1989.

Table 40. Upper Bay, 1989. Striped bass larvae length frequencies and mean densities (#/1000m3) collected in the 2m2 Tucker trawl at stations A, B, D, E, and F (Figure 4), surveys 13 and 14 (5-6 and 14-15 June).

	SURVEY					
	13		14		Totals	
Length Class (mm)	No.	Mean Density	No.	Mean Density	No.	Mean Density
3.0	3	0.4	1	0.12	4	0.26
3.5	16	2.12	5	0.61	21	1.37
4.0	59	7.44	2	0.28	61	3.86
4.5	133	16.57	8	1.03	141	8.80
5.0	175	22.22	19	2.42	194	12.32
5.5	168	21.19	34	4.22	202	12.71
6.0	291	37.01	43	5.43	334	21.22
6.5	416	52.48	52	6.52	468	29.50
7.0	330	41.74	37	4.80	367	23.27
7.5	364	46.17	33	4.36	396	25.26
8.0	179	22.74	33	4.40	212	13.57
8.5	62	7.90	34	4.42	96	6.16
9.0	12	1.52	44	5.46	55	3.49
9.5	8	1.00	70	9.27	78	5.13
10.0	8	1.00	82	10.37	90	5.68
10.5	9	1.14	76	9.62	85	5.38
11.0	6	0.77	64	7.98	70	4.37
11.5	1	0.13	64	8.15	65	4.14
12.0			75	9.33	82	4.67
12.5	2	0.26	70	8.64	72	4.45
13.0			40	4.98	40	2.49
13.5			28	3.50	28	1.75
14.0			28	3.40	28	1.70
14.5	1	0.12	21	2.62	22	1.37
15.0			7	0.86	7	0.43
15.5			2	0.23	2	0.12
16.0			6	0.73	6	0.37
16.5			4	0.46	4	0.23
17.0						
17.5			2	0.23	2	0.12
18.0						
18.5						
19.0			1	0.13	1	0.07
TOTALS	2243		985		3233	
Mean density	14.19		4.15		6.81	
Mean Length	6.14		10.18		7.83	
Modal Length	6.5		10.0		6.5	

36). These densities, which were derived from catches on only two survey dates in each system, are only partially comparable because of the differences in spawning dates and probable availability of larvae in similar length ranges in the Potomac and Upper Bay.

Age-Length Relationships

Separate age-length relationships to convert larval length frequencies (Appendix Tables 29-47, Figures 31, 34) into age frequencies were developed for striped bass larvae from the Potomac River and Upper Bay (Appendix Tables 48A and 49A). Larvae were assigned proportionally to 1-day age classes (Appendix Tables 50A and 51A) and then aggregated into 3-day cohorts. The regression equations, given below, which describe the age-length relationships were different for larvae from the Potomac and Upper Bay.

Potomac River:

$$A = -9.64 + 3.39\ (L) \qquad r^2 = 0.69,\quad n = 1.79,\quad S.E._b = 0.17$$

Upper Bay:

$$A = -50.63 + 17.70\ (L) - 1.55\ (L^2) + 0.05\ (L^3)$$

$$r^2 = 0.85,\quad n = 193,\quad S.E._{b1} = 2.71,\quad S.E._{b2} = 0.29,\quad S.E._{b3} = 0.01$$

where A = age in days and L = standard length in mm. Upper Bay larvae were younger than Potomac River larvae for a given length.

Larval Age Frequencies

Potomac River 1989

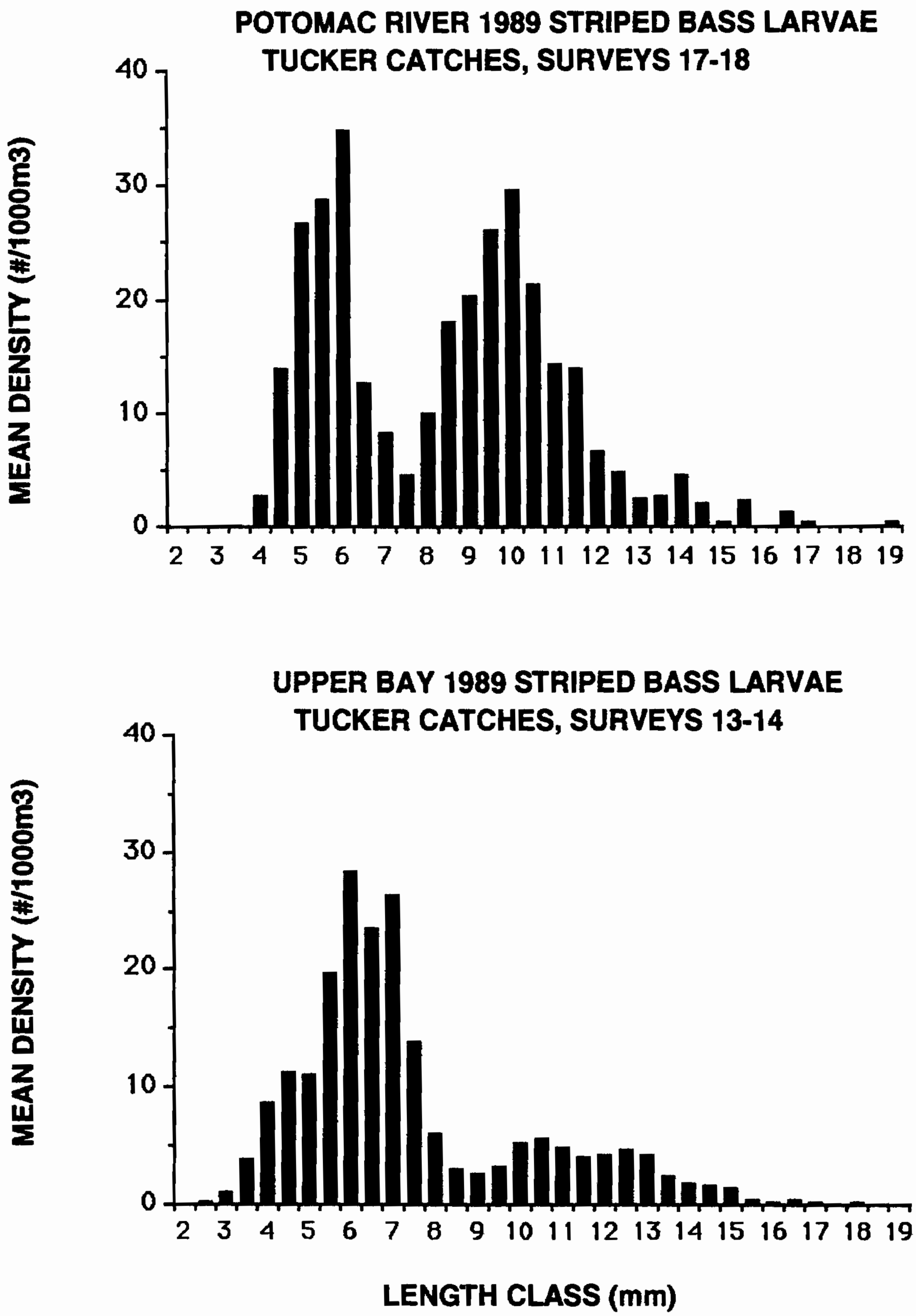


Figure 36. Densities (no. per 1,000 m^3) of striped bass larvae in 0.5 mm length classes collected in the 2 m^2 Tucker trawl in A. Potomac River, on surveys 17 and 18, 1-2 and 8-9 June 1989 (data from Table 38). B. Upper Bay, on surveys 13 and 14, 5-6 and 14-15 June 1989 (data from Table 40).

Striped bass larvae <10 days old were most abundant from 24-28 May, with secondary peaks occurring from 30 April to 3 May and on 9 May (Appendix Table 50, Figure 37). Larvae older than 10.5 days posthatch were not collected before 12 May, and larvae of 19.5 days posthatch and older were not collected until the final survey, 28 May. The >19.5 days posthatch larvae observed on 28 May had been hatched in the 1-10 May period. Striped bass eggs were most abundant from 21-27 April and on 14 May (Table 16).

Mean abundance of newly-hatched striped bass larvae in 1989 (<4.5 days posthatch) was 0.4 times lower than in 1987 in the Potomac River and 0.8 times lower than in 1988 (Table 41). Abundance of first-feeding larvae (4.5 - 7.5 days posthatch) in 1989 was 0.6 times lower than in 1987, but 7.7 times higher than in 1988. At age 10.5 days posthatch, striped bass larvae from the 60-cm sampler were 18.7 times less abundant in 1989 than in 1987. By 20 days posthatch, 1989 larvae were 13.2 times less abundant than 1987 larvae but were equal in abundance to 1988 larvae.

<u>Upper Bay 1989</u>

Newly-hatched striped bass larvae (median age <4.5 days) were most abundant in the Upper Bay during the 23-30 May period (Appendix Table 51; Figure 38). Abundances of first-feeding larvae (4.5 - 7.5 days old and older) also were low before 23-30 May, and larvae older than median age 10.5 days were collected by the 60-cm sampler only on 18 May. No larvae as old as 20 days posthatch were collected by the 60-cm sampler during the entire sampling period, 14 April - 30 May. Mean abundance of age 1.5 days posthatch larvae was 13.7 times higher in 1989 in the Upper Bay than in 1988, and 3.9 times higher than in the Potomac River in 1989 (Table 41). Upper Bay first-feeding larvae (4.5 to 7.5 days) were 23.6 times more abundant in 1989 than in 1988,

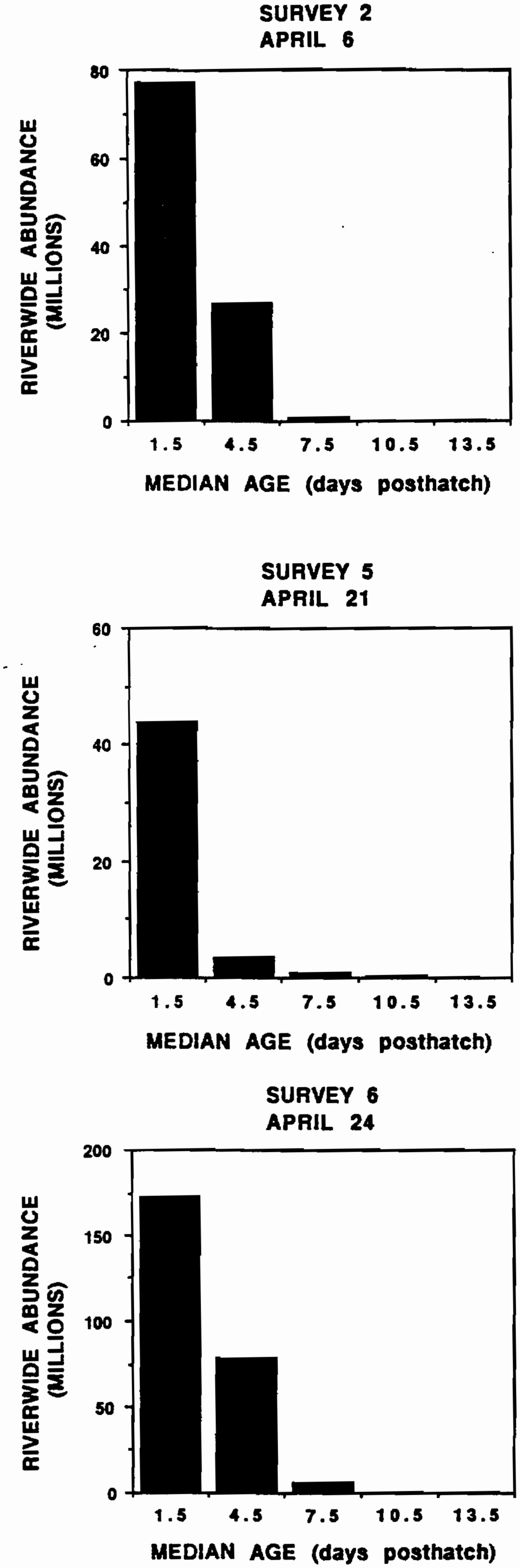
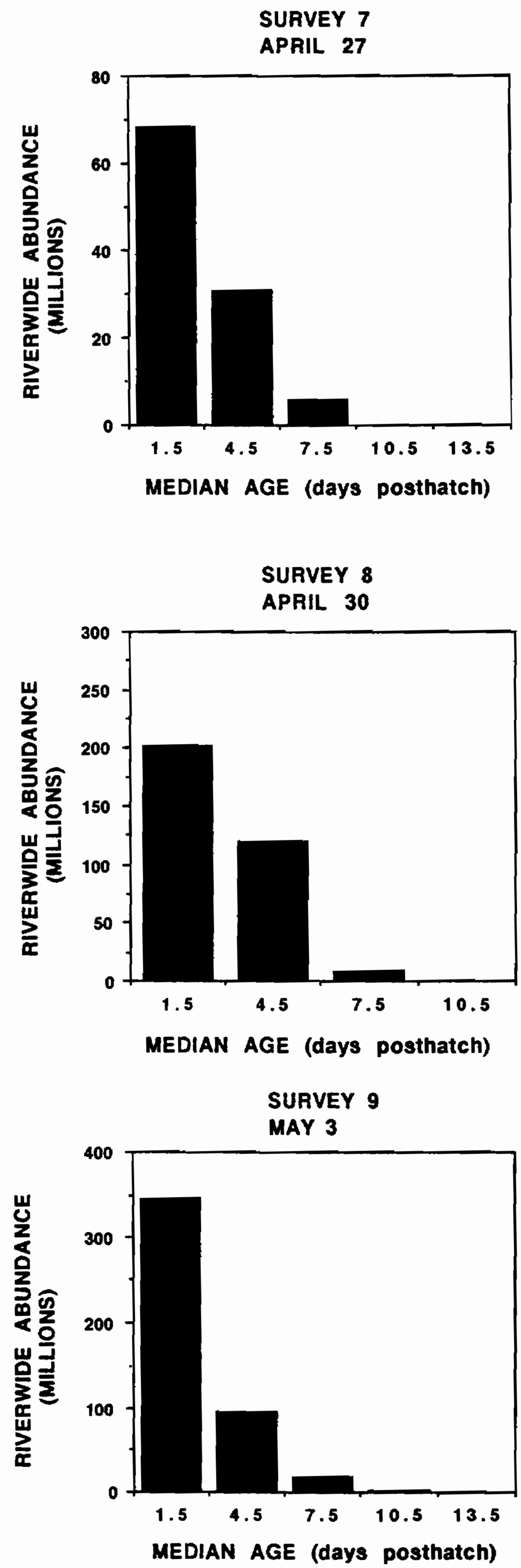


Figure 37. Potomac River, 1989. Age-frequency distributions of striped bass larvae, presented as riverwide abundance-at-median ages for the eleven surveys. Note that Y-axis scale changes from survey to survey.



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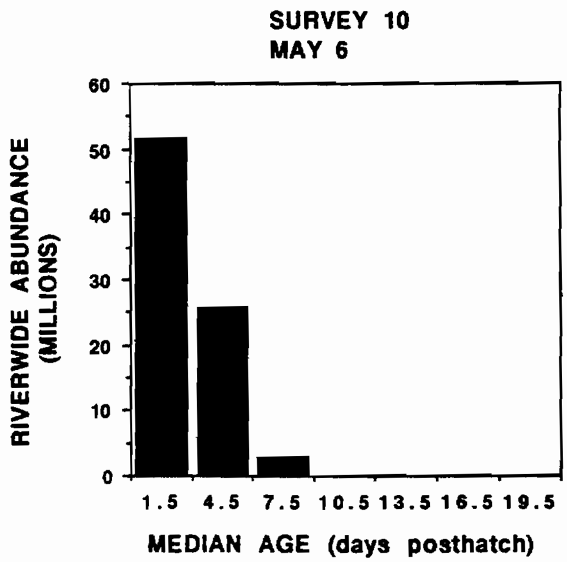
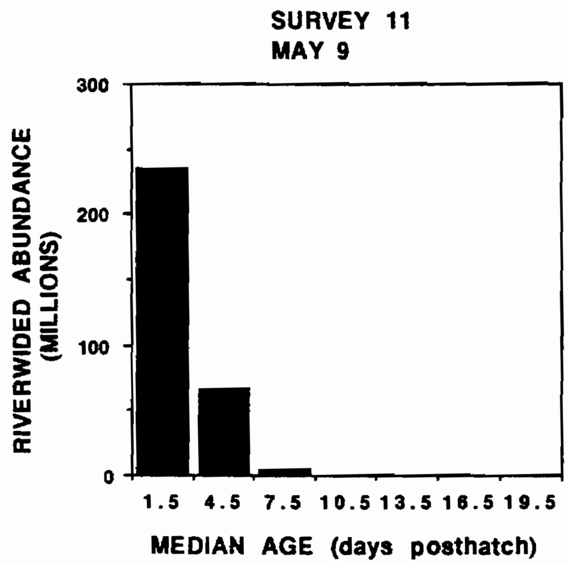




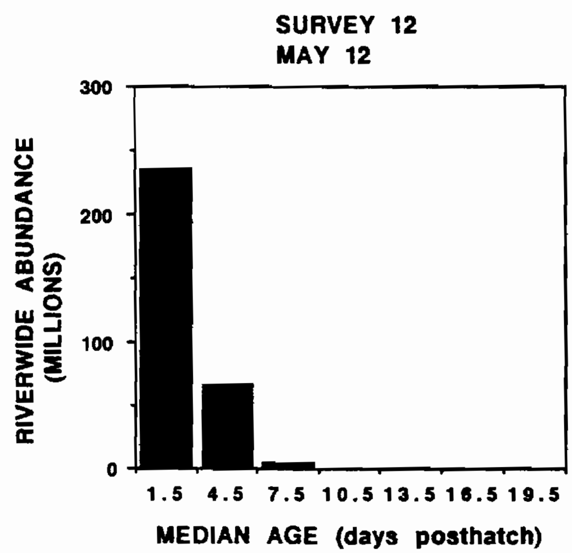
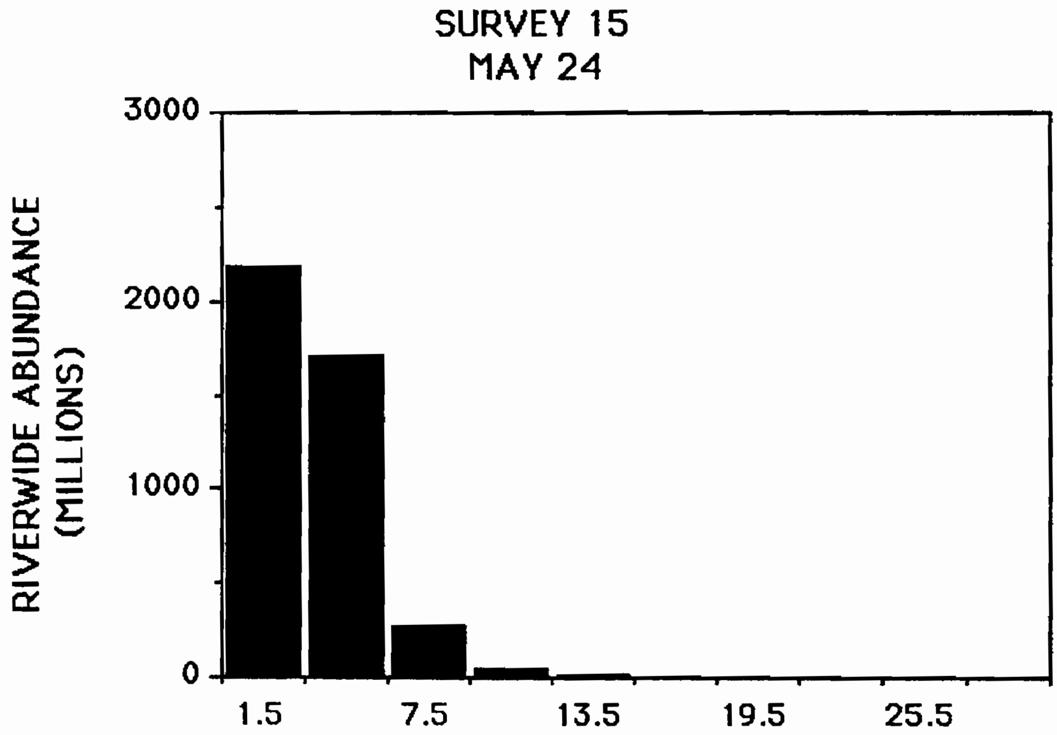


Figure 37. (Continued)



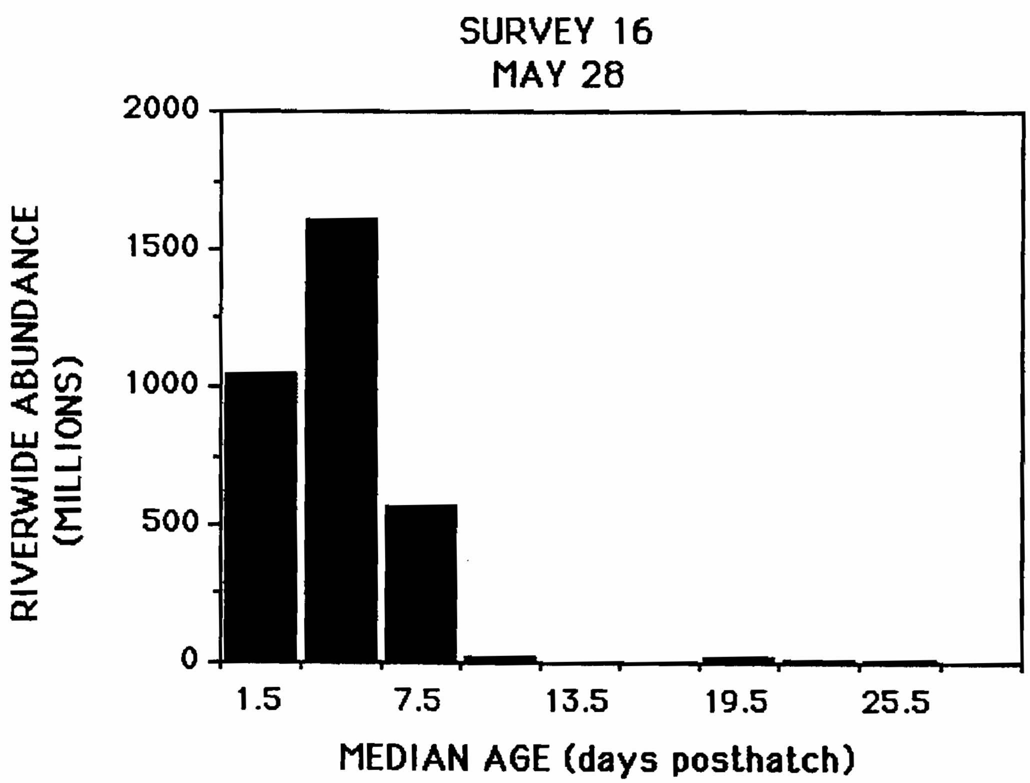
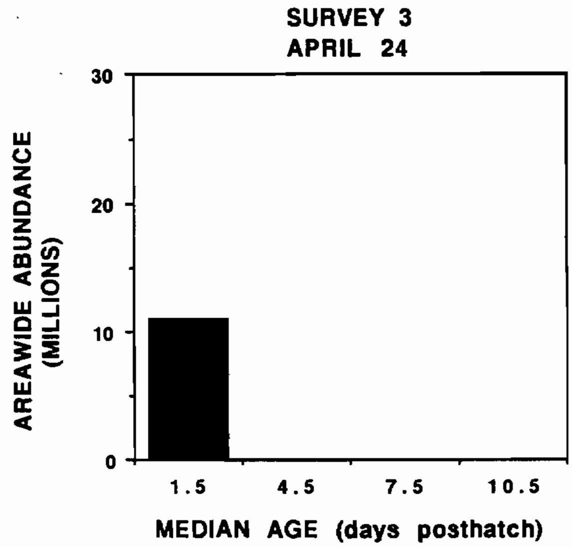
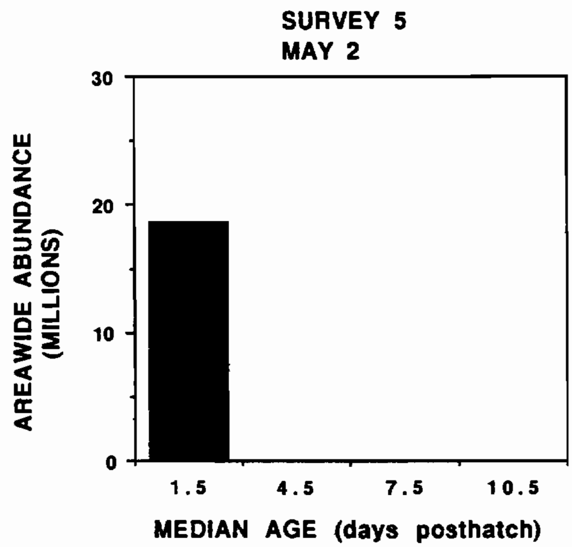


Figure 37. (Continued)

Table 41. Striped bass larvae, Potomac River, 1987-1989 and Upper Bay, 1988-1989. Estimated mean riverwide abundances (millions) at age of 3-day age groups. Tabulated abundances are averaged over all stations and surveys.

Median Age	Potomac River			Upper Bay	
	1987	1988	1989	1988	1989
1.5	36.79	20.56	15.73	4.47	61.33
4.5	16.70	1.36	13.02	0.06	1.49
7.5	10.09	0.73	3.08	<0.01	0.16
10.5	4.26	0.20	0.23	--	0.04
13.5	2.02	0.03	0.07	--	0.01
16.5	0.91	0.03	0.03	--	--
19.5	0.79	0.06	0.06	--	--
22.5	0.15	--	0.02	--	--
25.5	0.12	--	0.03	--	--
28.5	0.11	--	0.01	--	--
31.5	0.06	--	--	--	--
34.5	0.03	--	--	--	--





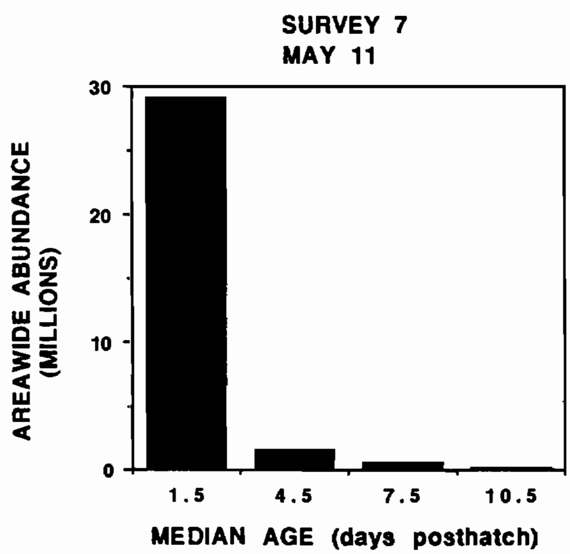
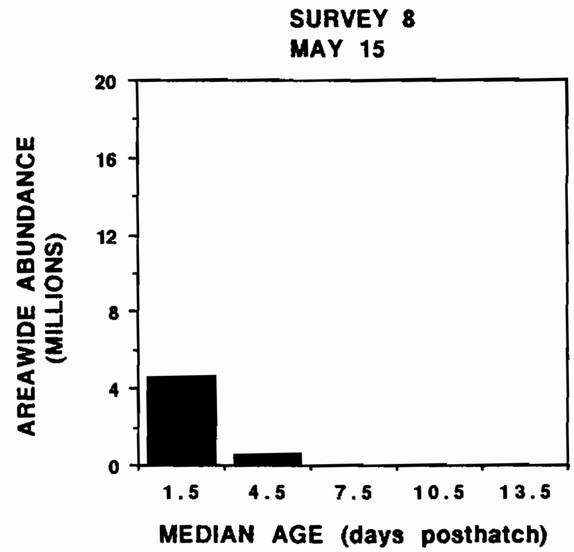
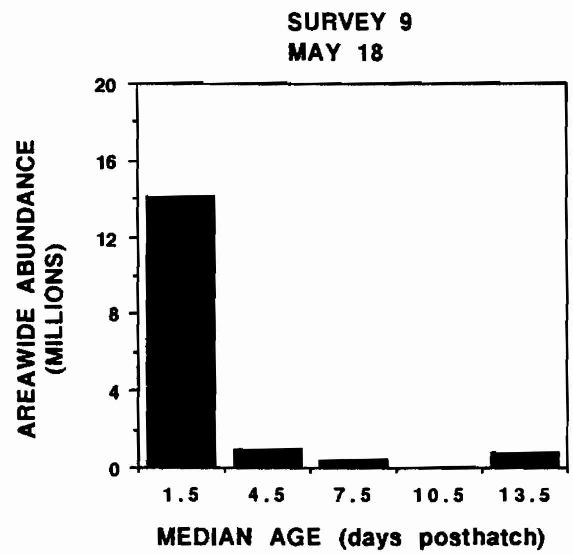
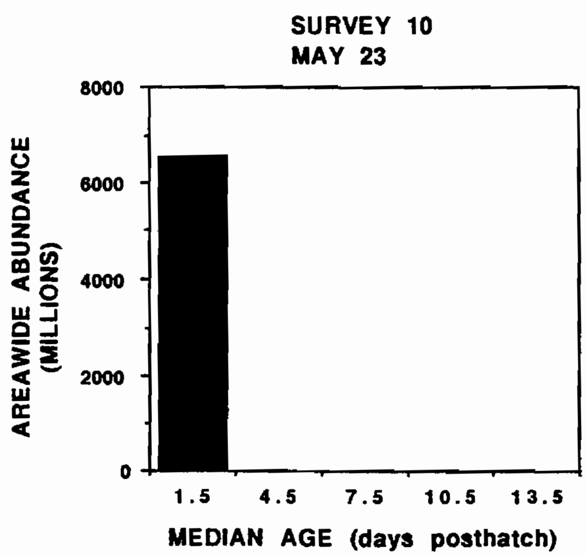


Figure 38. Upper Bay, 1989. Age-frequency distributions of striped bass larvae, presented as areawide abundances-at-median ages for the eight surveys. Note that Y-axis scale changes from survey to survey.







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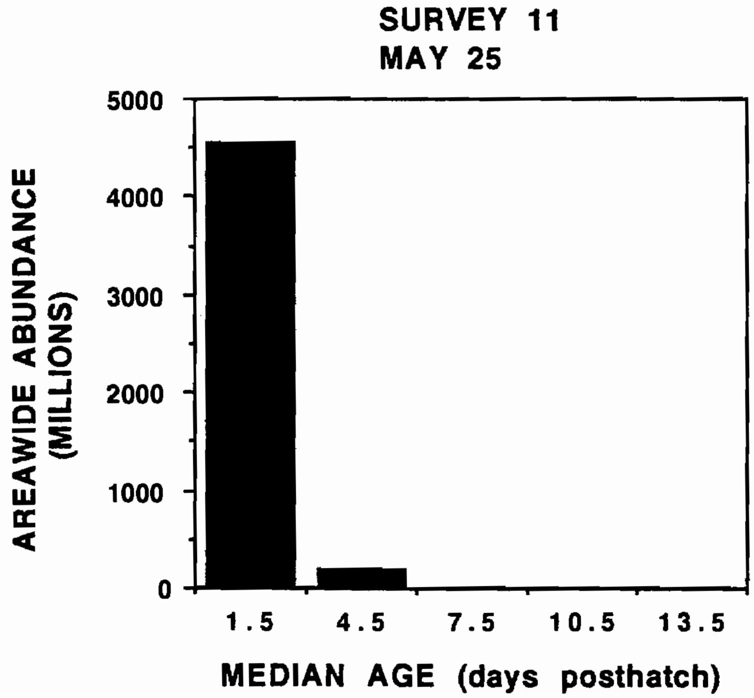


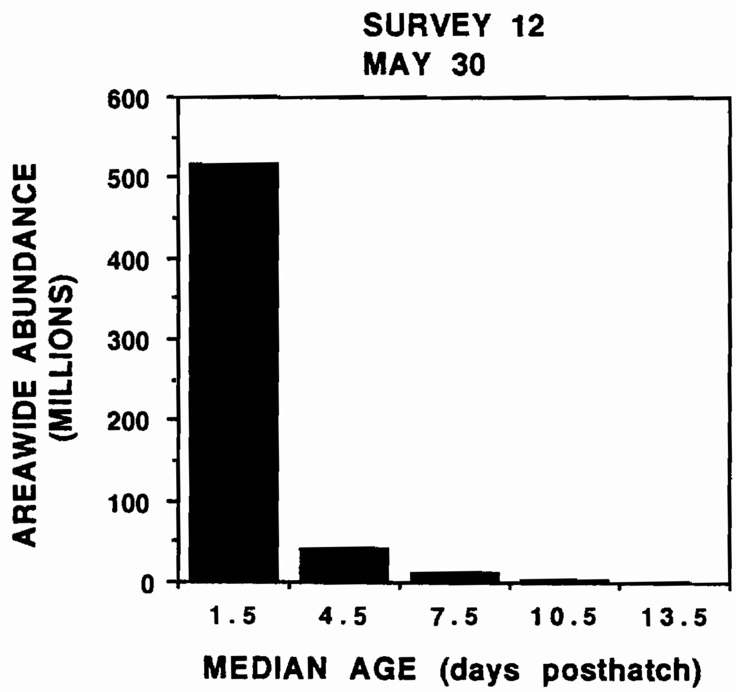


Figure 38. (Continued)

but were an order of magnitude lower in abundance than numbers estimated in the Potomac River in 1987 and 1989, and about equal to the 1988 Potomac abundance. By 10.5 days posthatch, 1989 Upper Bay larvae were estimated to be 5.8 times less abundant than 1989 Potomac River larvae (Table 41).

Growth

Potomac River

Aggregated Sample Mean Growth Rate

The mean growth rate in 1989 of all otolith-aged, Potomac River striped bass larvae was 0.20 mm d^{-1} (Figure 39). There was considerable variability about the linear regression relationship. For larvae <30 days posthatch, the growth rate was 0.23 mm d^{-1}, a somewhat higher rate than that of the sample with older larvae included. The 0.20 mm d^{-1} growth rate of the aged 1989 Potomac River striped bass larvae was identical to the 1988 mean growth rate of aged larvae, but was significantly lower ($P<0.001$) than the estimated 0.26 mm d^{-1} for 1987 larvae (Figure 39).

Cohort-Specific Growth Rates

Cohort-specific growth rates were estimated for larvae hatched from 17 April through 26 May 1989. Growth rates of 3-day cohorts were significantly different ($P=0.003$), ranging from -0.01 mm d^{-1} to 0.70 mm d^{-1} (Table 42). Because lengths-at-age of individuals were variable, and the length range of larvae in each cohort available for aging was limited, the regression fits were poor for some cohorts. Although there was no apparent relationship or trend in growth rate with respect to date of hatch, mean length-at-age, adjusted for the covariate age (analysis of covariance), tended to increase as the season progressed (Table 42). Larvae hatched before 5 May, which

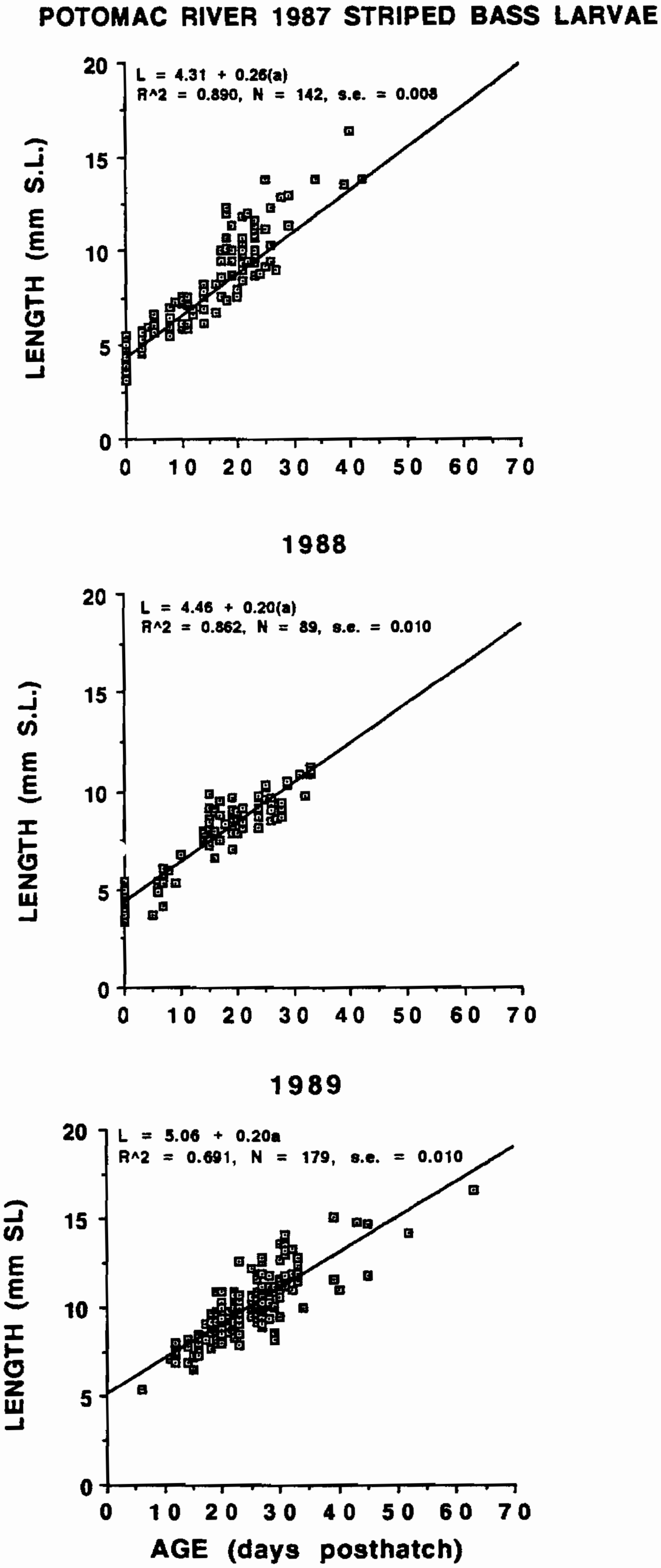


Figure 39. Potomac River, 1987-1989. Standard lengths of striped bass larvae in relation to otolith-derived ages for all aged larvae in each year. Regression coefficients estimate the mean growth rates (mm d^{-1}).

Table 42. Striped bass larvae, Potomac River 1989. Regressions of length (mm S.L.) at capture on age (days posthatch) of striped bass larvae in 3-day cohorts. The regression coefficients of the growth equation are the growth rates (mm d-1).

Cohort	Hatch Date	Growth Equation	S.E. Slope	r 2	n	Mean Age	Predicted Length 20 d.p.h.	Predicted Age at 8 mm
F	17-Apr	L = 4.41 + 0.18(a)	0.0303	0.972	3	37.3	8.0	19.9
G	20-Apr	L = 4.81 + 0.05(a)	0.1386	0.102	3	6.0	5.7	68.3
H	23-Apr	L = -11.33 + 0.58(a)	0.1866	0.905	3	41.3	0.3	33.3
I	26-Apr	L = 3.23 + 0.27(a)		1.000	2	29.0	8.6	17.7
J	29-Apr	L = -6.59 + 0.55(a)	0.1540	0.616	10	33.0	4.4	26.5
K	2-May	L = 3.29 + 0.21(a)	0.0289	0.415	11	29.2	8.1	19.4
L	5-May	L = 1.09 + 0.34(a)	0.0485	0.657	27	26.6	7.9	20.3
M	8-May	L = 1.05 + 0.37(a)	0.0425	0.820	19	27.3	8.5	18.8
N	11-May	L = 1.48 + 0.36(a)	0.0597	0.678	19	24.9	8.7	18.1
O	14-May	L = 4.35 + 0.25(a)	0.0940	0.364	14	24.5	9.4	14.6
P	17-May	L = 0.02 + 0.45(a)	0.4036	0.400	25	22.1	9.0	17.7
Q	20-May	L = 3.16 + 0.32(a)	0.1133	0.581	28	18.4	9.6	15.1
R	23-May	L = -3.34 + 0.70(a)	0.4537	0.324	7	16.3	10.7	16.2
S	26-May	L = 7.94 - 0.01(a)	0.1968	0.001	7	13.4	7.7	-6.0
*All Cohorts		L = 5.06 + 0.20(a)	0.0102	0.691	179	24.3	9.1	14.7
*All Cohorts (ages1-30)		L = 4.75 + 0.22(a)	0.0145	0.594	153	22.3	9.2	14.8
*Cohorts B, F-L		L = 4.22 + 0.21(a)	0.0140	0.797	60	29.1	8.4	18.0
Cohorts M-S		L = 3.70 + 0.28(a)	0.0155	0.736	119	21.9	9.3	15.4

* Cohort 'B', hatched 4-6 April, had one larva and was included in these regression equations.

experienced water temperatures below 17°C during the 20-day posthatch period, grew at 0.21 mm d^{-1}, a significantly slower (P<.002) rate than the 0.28 mm d^{-1} mean rate of cohorts hatched after 5 May, when temperatures were warmer (Table 42).

Predicted length, based on all cohorts, at 20 days posthatch was 9.1 mm SL (Table 42). Cohorts hatched after 5 May had a predicted length at 20 days posthatch of 9.3 mm SL while those hatched on or before 5 May had predicted length of 8.4 mm SL. The predicted age at 8.0 mm SL varied among cohorts but averaged 14.7 days posthatch when data from all cohorts were considered (Table 42). Cohorts hatched after 5 May were predicted to reach 8.0 mm SL approximately 2.6 days sooner than those hatched on earlier dates.

Back-Calculated Growth

The 1989 mean growth rate of Potomac River striped bass larvae, based on back-calculated lengths-at-age of all 3-day cohorts combined, was 0.18 mm d^{-1} (Figure 40), a rate similar to the back-calculated growth rate of 1988 larvae, but significantly lower (P<0.001) than the 0.26 mm d^{-1} rate estimated for 1987 larvae (Houde et al. 1990). Exponential growth models provided the best fits to length-at-age data of individual cohorts based on the back-calculation formula (Table 43). Back-calculated growth rates from 5-20 days posthatch of the 3-day cohorts ranged from 0.11 to 0.36 mm d-1 (P<0.001), and clearly increased as the season progressed (Table 43; Figure 41). The estimated growth rate of cohort 'G', hatched early in the season (20 April), was an exception. It had a relatively high mean rate of 0.31 mm d^{-1}. The difference in growth rates among cohorts resulted in differences in estimated length at 20 days posthatch of up to 4.6 mm and an estimated difference in age at 8.0 mm of up to 21 days. Cohorts hatched on or before 5 May, which experienced mean water temperatures below 17°C during the first 20 days posthatch, had a mean

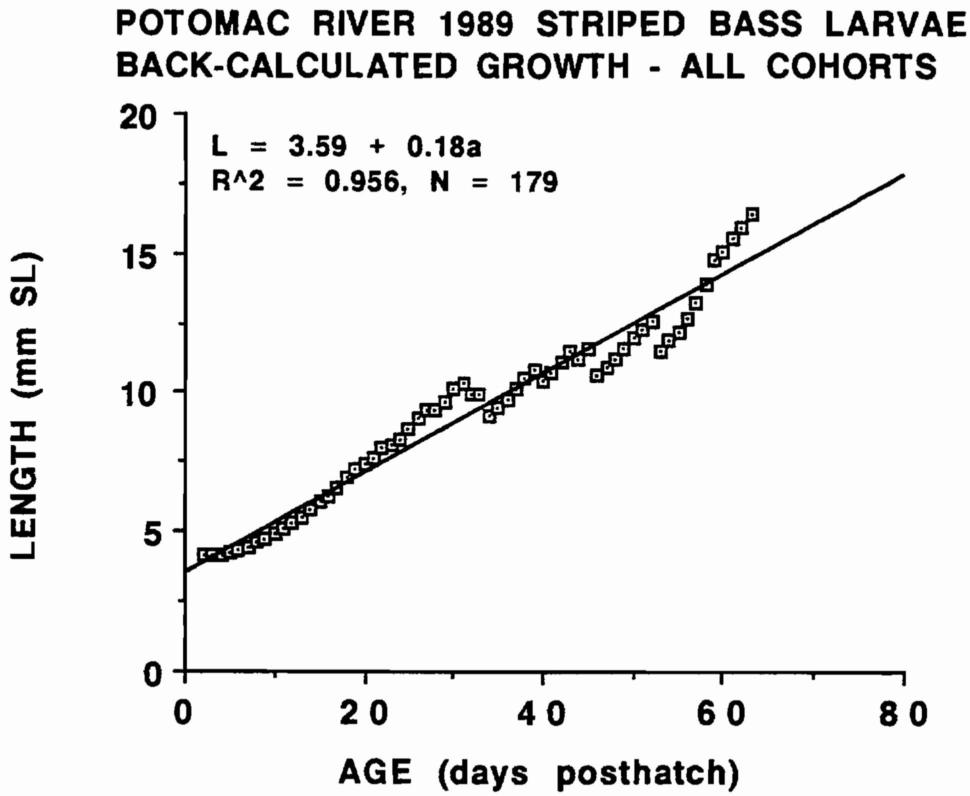


Figure 40. Potomac River, 1989. Mean back-calculated lengths-at-age of all otolith-aged striped bass larvae.

Table 43. Striped bass, Potomac River 1989. Regressions of back-calculated length (mm S.L.) on age (days posthatch) of otolith-aged striped bass larvae in 3-day cohorts. The biological intercept method of Campana (1991) was used to back-calculate lengths-at-age.

Cohort	Hatch Date	Growth Equation	S.E. Slope	r 2	n	Predicted Length at 5 d.p.h.	Predicted Length at 20 d.p.h.	Mean Growth Rate (5-20 dph mm/day)	Predicted Age at 8 mm
B	5-Apr	Ln(L) = 1.2070 + 0.0239(a)	0.0003	0.992	1	3.77	5.39	0.11	36.5
F	17-Apr	Ln(L) = 1.2751 + 0.0241(a)	0.0007	0.966	3	4.04	5.80	0.12	33.4
G	20-Apr	Ln(L) = 1.2591 + 0.0475(a)	0.0055	0.974	3	4.47	9.11	0.31	17.3
H	23-Apr	Ln(L) = 1.1955 + 0.0313(a)	0.0006	0.985	3	3.87	6.18	0.15	28.2
I	26-Apr	Ln(L) = 1.2539 + 0.0305(a)	0.0010	0.962	2	4.08	6.45	0.16	27.1
J	29-Apr	Ln(L) = 1.2286 + 0.0359(a)	0.0007	0.987	10	4.09	7.00	0.19	23.7
K	2-May	Ln(L) = 1.2422 + 0.0353(a)	0.0007	0.990	11	4.13	7.02	0.19	23.7
L	5-May	Ln(L) = 1.2171 + 0.0371(a)	0.0007	0.989	27	4.06	7.09	0.20	23.2
M	8-May	Ln(L) = 1.1505 + 0.0415(a)	0.0008	0.989	19	3.89	7.25	0.22	22.4
N	11-May	Ln(L) = 1.1103 + 0.0444(a)	0.0013	0.981	19	3.79	7.38	0.24	21.8
O	14-May	Ln(L) = 1.1236 + 0.0450(a)	0.0013	0.985	14	3.85	7.57	0.25	21.2
P	17-May	Ln(L) = 1.1432 + 0.0479(a)	0.0017	0.978	25	3.99	8.18	0.28	19.5
Q	20-May	Ln(L) = 1.2033 + 0.0504(a)	0.0016	0.984	28	4.29	9.13	0.32	17.4
R	23-May	Ln(L) = 1.2869 + 0.0510(a)	0.0012	0.994	7	4.67	10.04	0.36	15.5
S	26-May	Ln(L) = 1.2045 + 0.0503(a)	0.0023	0.975	7	4.29	9.12	0.32	17.4
All Cohorts		L = 3.59 + 0.18(a)	0.0049	0.956	179	4.49	7.19	0.18	28.2
All Cohorts (ages1-30)		Ln(L) = 1.2800 + 0.0350(a)	0.0006	0.990	160	4.28	7.24	0.20	22.8
Cohorts B, F-L		Ln(L) = 1.4499 + 0.0215(a)	0.0006	0.950	60	4.74	6.55	0.12	29.3
Cohorts M-S		Ln(L) = 1.2617 + 0.0386(a)	0.0013	0.970	119	4.28	7.66	0.23	21.2

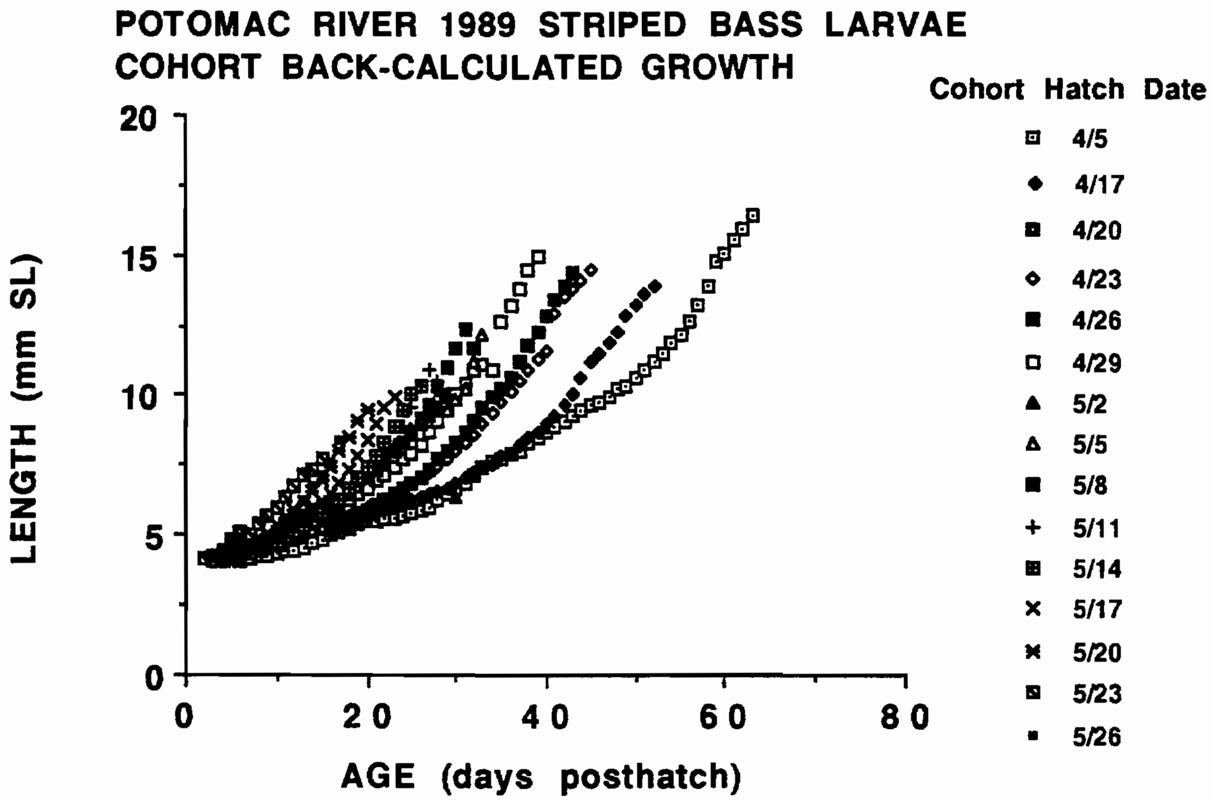


Figure 41. Potomac River, 1989. Mean back-calculated lengths-at-age of otolith-aged striped bass larvae in each 3-day cohort.

back-calculated growth rate of 0.12 mm d^{-1}, a rate significantly less than that of larvae hatched after 5 May, which grew at 0.23 mm d^{-1} (Table 43; Figure 42).

Growth rates of 1989 cohorts estimated by the back-calculation procedure generally were lower than those calculated directly from estimated lengths-at-age at the time of collection (Tables 42 and 43). The back-calculation method indicated that individual larvae were growing exponentially, while the aggregated sample and individual cohort length-at-age methods suggested that linear models described the growth-in-length of Potomac River striped bass larvae in 1989. The cohort-specific, exponential models based upon the back-calculation procedure are believed to depict cohort growth more accurately because they incorporate the growth patterns and histories of individual larvae into the analysis.

Upper Bay

Aggregated Sample Mean Growth Rate

Upper Bay striped bass larvae grew at a mean rate of 0.29 mm d^{-1} in 1989 (Figure 43). The variability about the length-age regression was lower (r^2 = .83) than for the comparable Potomac River regression in 1989 (r^2 = 0.67). Although the growth rate of Upper Bay larvae apparently was higher than the mean growth rate in the Potomac River, there was only a small significant difference in adjusted mean larval lengths (9.0 mm Upper Bay vs 8.7 mm Potomac River; P<.03) adjusted by analysis of covariance with age as the covariate).

Cohort-Specific Growth Rates

Cohort-specific growth rates varied significantly (P<.0001) and ranged from 0.23 mm d^{-1} for larvae hatched on 5 May to 0.61 mm d^{-1} for larvae hatched on 14 May (Table 44). Cohort growth rates, after adjusting for age by

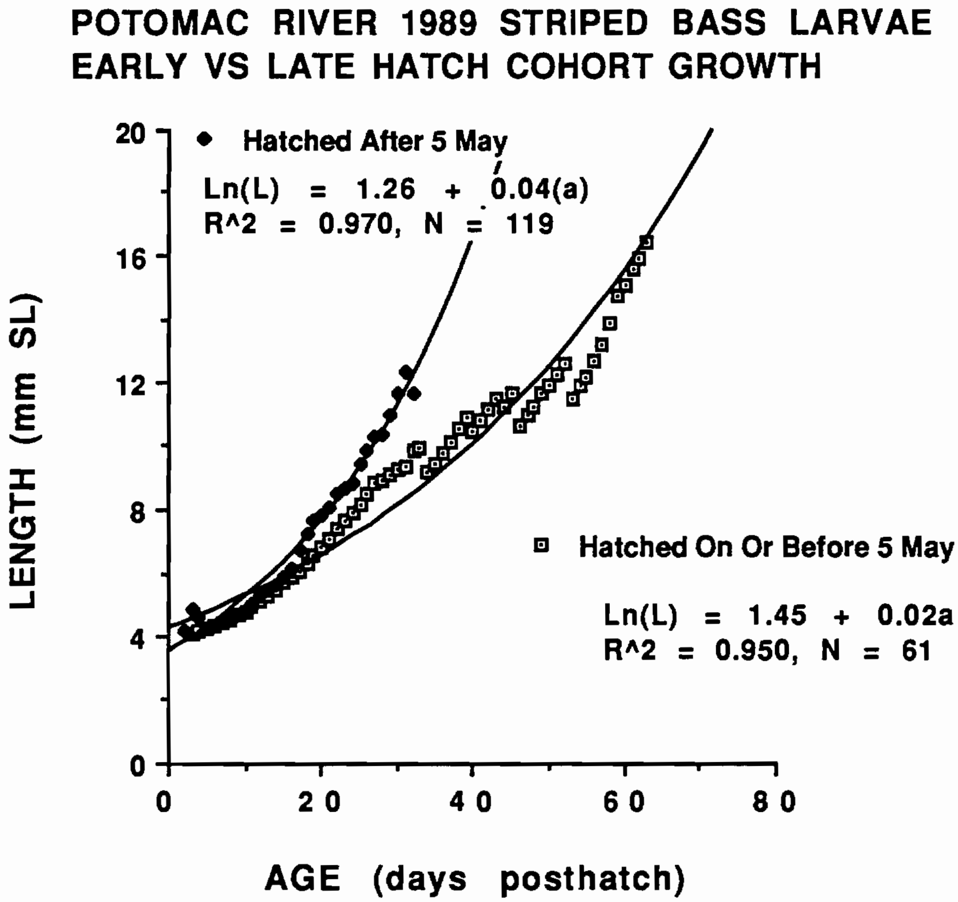


Figure 42. Potomac River, 1989. Mean back-calculated lengths-at-age of all otolith-aged striped bass larval cohorts hatched before and after 5 May. The early cohorts were hatched when temperatures were ≤17°C. Exponential models are fit to give the growth rates in each case.

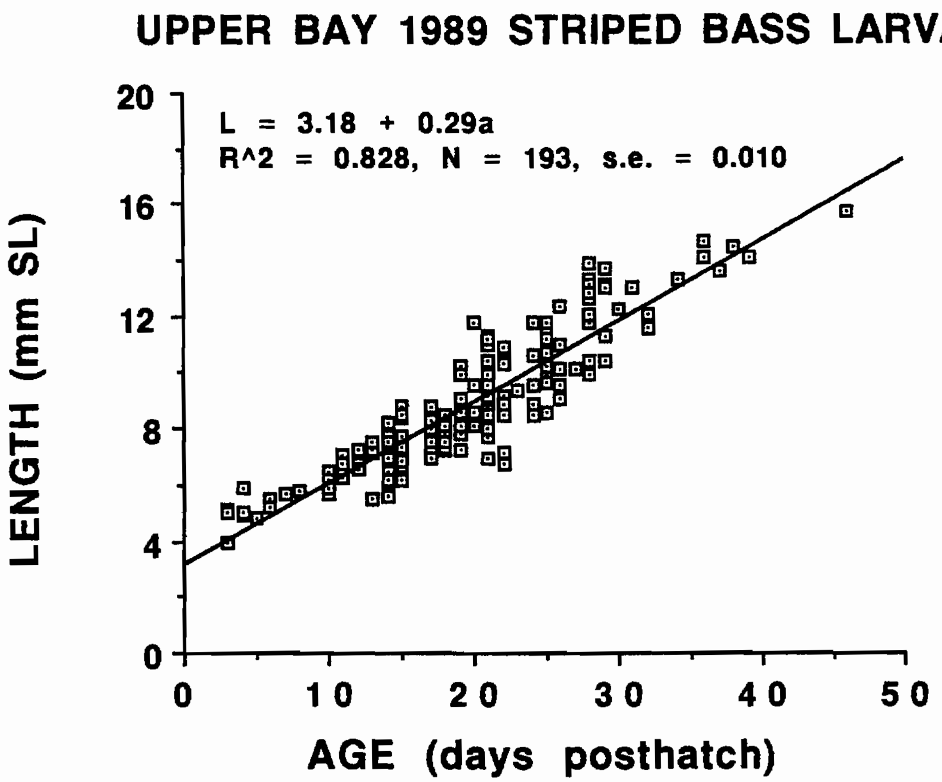


Figure 43. Upper Bay, 1989. Standard lengths of striped bass larvae in relation to otolith-derived ages for all aged larvae. Regression coefficient estimates the mean growth rate.

Table 44. Striped bass larvae, Upper Bay 1989. Regressions of length (mm S.L.) at capture on age (days posthatch) of striped bass larvae in 3-day cohorts. The regression coefficients of the growth equation are the growth rates (mm d-1).

Cohort	Hatch Date	Growth Equation	S.E. Slope	r 2	n	Mean Age	Predicted Length 20 d.p.h.	Predicted Age at 8 mm
L	5-May	L = 5.32 + 0.23(a)	0.5342	0.256	4	38.3	9.92	11.7
M	8-May	L = -3.71 + 0.50(a)	0.0414	0.980	5	32.2	6.29	23.4
N	11-May	L = 8.52 + 0.35(a)	0.1191	0.754	8	28.0	15.52	-1.5
O	14-May	L = -4.95 + 0.61(a)	0.0715	0.783	20	26.4	7.25	21.2
P	17-May	L = 0.89 + 0.38(a)	0.0332	0.780	39	21.3	8.49	18.7
Q	20-May	L = 3.20 + 0.28(a)	0.0303	0.692	40	17.4	8.80	17.1
R	23-May	L = 3.07 + 0.30(a)	0.0396	0.610	47	16.7	9.07	16.4
S	26-May	L = 3.85 + 0.24(a)	0.0261	0.859	17	12.1	8.65	17.3
T	29-May	L = 3.62 + 0.30(a)	0.0573	0.931	4	12.8	9.62	14.6
U	1-Jun	L = 3.93 + 0.26(a)	0.0346	0.896	8	7.4	9.13	15.7
All Cohorts		L = 3.18 + 0.29(a)	0.0095	0.828	193	19.4	8.98	16.6

analysis of covariance, increased as the season progressed.

The predicted length of Upper Bay larvae at 20 days posthatch ranged from 6.3 to 15.5 mm SL for the 10 cohorts that were analyzed (Table 44). For combined cohorts, predicted length at 20 days posthatch was 8.98 mm SL. The predicted ages at 8.0 mm SL for the 10 cohorts, excepting one anomalous estimate, ranged from 11.7 to 23.4 days (Table 44). For combined cohorts, the predicted age at 8.0 mm was 16.6 days.

Back-Calculated Growth

Back-calculated growth rate of all aged 1989 Upper Bay striped bass larvae averaged 0.19 mm d^{-1} in the 5-20 day posthatch period. An exponential model provided the best fit to the Upper Bay data (Figure 44). For Upper Bay larvae <30 days of age, back-calculated growth rate was 0.22 mm d^{-1} (Table 45), significantly higher ($P<0.001$) than the 0.20 mm d^{-1} growth rate of Potomac River larvae <30 days old.

The cohort-specific, back-calculated growth rates of Upper Bay striped bass larvae, which differed significantly from each other ($P<.001$), ranged from 0.18 mm d^{-1} to 0.36 mm d^{-1} (Table 45), and increased as the season progressed (Figure 45). The predicted range of lengths at 20 days posthatch of Upper Bay larvae cohorts, based upon back-calculation, was 6.8 to 10.2 mm SL, and the range of predicted ages at 8.0 mm SL was 15.1 to 24.7 days (Table 45). The potential maximum difference among cohorts would result in a length difference of 3.4 mm at 20 days posthatch, or an age difference of 9.6 days at 8.0 mm (Table 45). For larvae <30 days old from combined cohorts, the predicted lengths at 20 days posthatch were 7.2 mm SL in the Potomac River and 7.6 mm SL in the Upper Bay, while predicted ages at 8.0 mm SL were 22.8 days and 21.3 days in the Potomac and Upper Bay, respectively (Tables 43 and 45).

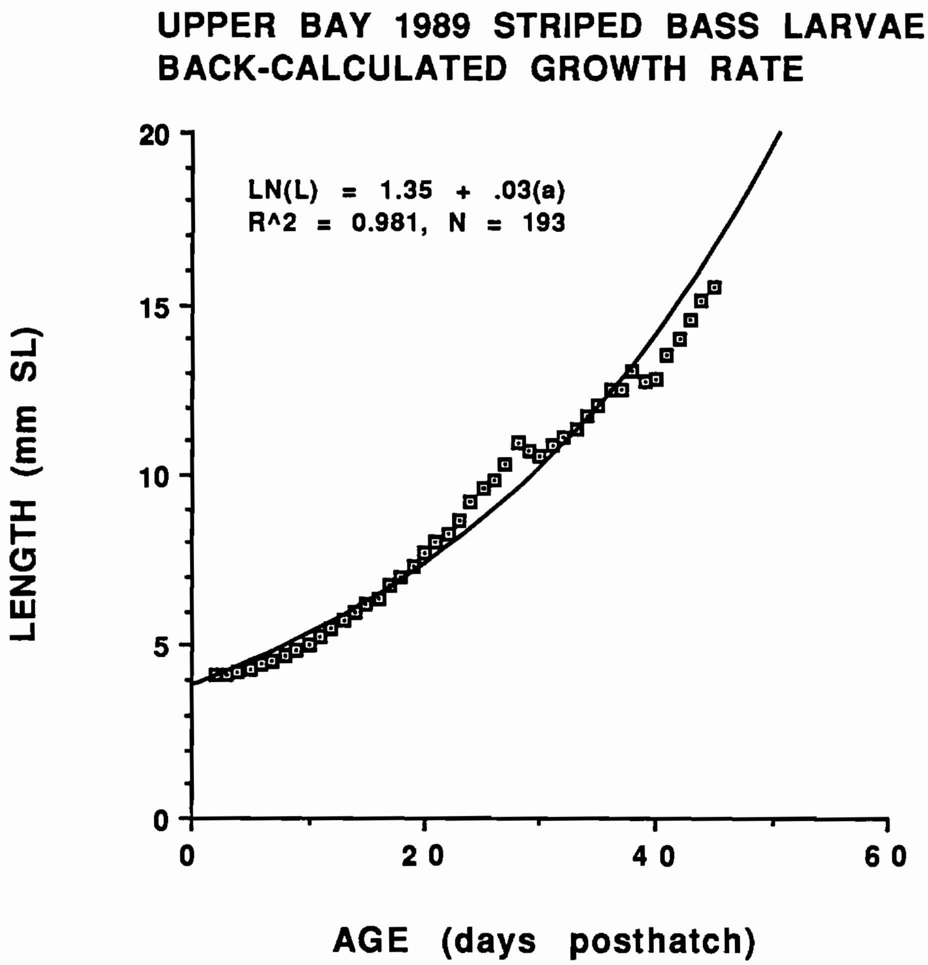


Figure 44. Upper Bay, 1989. Mean back-calculated lengths-at-age of all otolith-aged striped bass larvae.

Table 45. Striped bass, Upper Bay 1989. Regressions of back-calculated length (mm S.L.) on age (days posthatch) of otolith-aged striped bass larvae in 3-day cohorts. The biological intercept method of Campana (1991) was used to back-calculate lengths-at-age.

Cohort	Hatch Date	Growth Equation	S.E. Slope	r 2	n	Predicted Length at 5 d.p.h.	Predicted Length at 20 d.p.h.	Mean Growth Rate (5-20 dph mm/day)	Predicted Age at 8 mm
J	29-Apr	Ln(L) = 1.2632 + 0.0330(a)	0.0008	0.979	1	4.17	6.84	0.18	24.7
L	5-May	Ln(L) = 1.1557 + 0.0375(a)	0.0004	0.996	1	4.58	7.97	0.23	20.1
M	8-May	Ln(L) = 1.1010 + 0.0427(a)	0.0007	0.991	6	3.76	6.87	0.21	23.8
N	11-May	Ln(L) = 1.0392 + 0.0445(a)	0.0012	0.981	6	3.71	6.94	0.22	23.4
O	14-May	Ln(L) = 1.0889 + 0.0471(a)	0.0015	0.974	11	4.34	8.09	0.25	19.7
P	17-May	Ln(L) = 1.1772 + 0.0437(a)	0.0011	0.987	34	4.06	7.69	0.24	20.9
Q	20-May	Ln(L) = 1.2468 + 0.0422(a)	0.0009	0.992	50	4.21	7.82	0.24	20.6
R	23-May	Ln(L) = 1.2418 + 0.0452(a)	0.0010	0.992	47	4.34	8.19	0.26	19.4
S	26-May	Ln(L) = 1.2904 + 0.0405(a)	0.0020	0.968	17	4.39	8.92	0.30	17.7
T	29-May	Ln(L) = 1.2682 + 0.0508(a)	0.0020	0.981	14	4.46	8.37	0.26	18.9
U	1-Jun	Ln(L) = 1.3329 + 0.0482(a)	0.0019	0.984	4	4.84	10.20	0.36	15.1
V	4-Jun	Ln(L) = 1.3162 + 0.0468(a)	0.0015	0.992	2	4.71	9.51	0.32	16.3
All Cohorts		Ln(L) = 1.3488 + 0.0324(a)	0.0007	0.981	193	4.53	7.37	0.19	22.6
Ages 1-30		Ln(L) = 1.2753 + 0.0378(a)	0.0007	0.991	166	4.32	7.62	0.22	21.3

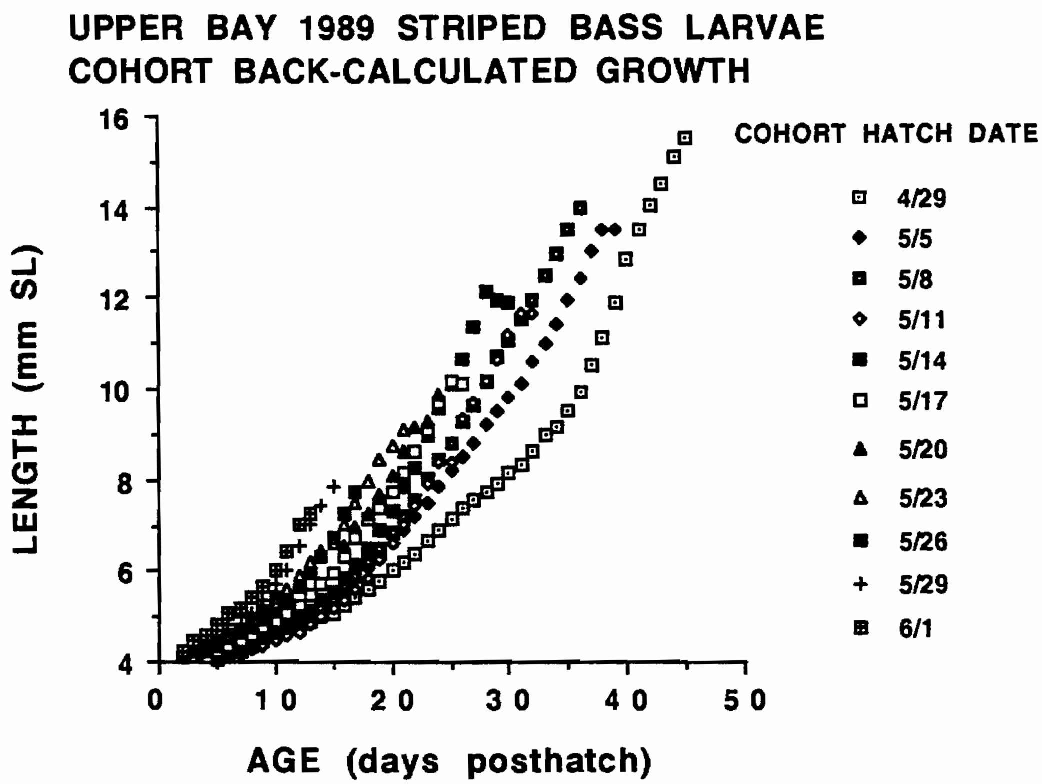


Figure 45. Upper Bay, 1989. Mean back-calculated lengths-at-age of otolith-aged striped bass larvae in each 3-day cohort.

Environmental Factors and Growth

The Pearson product-moment correlation coefficients among environmental factors that were considered for inclusion in a multiple regression analysis, in which cohort-specific growth rate, mortality rate and abundance at 8.0 mm SL were the dependent variables, were calculated for the Potomac River and Upper Bay (Table 46). Factors that were significantly correlated (alpha = 0.05) were not selected as independent variables for multiple regression analyses.

A forward, stepwise regression procedure was used to determine the relationship between back-calculated cohort-specific growth rate and the independent variables mean temperature, river discharge, mean zooplankton density, striped bass larvae density, initial striped bass larvae cohort abundance, and Morone spp. (i.e. striped bass plus white perch) larvae density for Potomac River and Upper Bay larvae. There was a strong and positive regression relationship ($r^2 = 0.645$) between cohort-specific growth rate and temperature (Figure 46). The growth rate - temperature relationship did not differ significantly between the two areas (P>0.40) or among years (P>0.25). The relationship for combined cohorts from the Potomac River 1987-89 and the Upper Bay 1989 is:

$$G = -0.07 + 0.02T \qquad r^2 = 0.645, \quad n = 45, \quad s.e._b = 0.0018$$

where G = growth rate (mm d^{-1}), and T = mean temperature during the first 20 days posthatch. None of the remaining independent variables contributed significantly to the multiple regression model.

Table 46a. Potomac River 1987 - 1989. Simple correlation coefficients between environmental variables averaged over the first 20 days posthatch for surviving striped bass larvae cohorts. N = number of data points, which equals the number of larval cohorts that were observed up to at least 20 days posthatch. Asterisks indicate significant correlations at the alpha=0.05 level.

1987

N=13

	Discharge	Cladoc. Density	Copepod Density	Rotifer Density	Naupili Density	Temperature	pH	Turbidity	Rainfall
Discharge	1.000	* -0.841	* -0.945	* -0.958	* -0.786	* -0.975	* 0.861	* 0.917	-0.092
Cladoc. Density		1.000	* 0.954	* 0.730	* 0.678	* 0.902	* -0.807	* -0.786	-0.331
Copepod Density			1.000	* 0.883	* 0.744	* 0.962	* -0.886	* -0.886	-0.141
Rotifer Density				1.000	* 0.744	* 0.924	* -0.756	* -0.954	0.248
Naupili Density					1.000	* 0.819	* -0.572	* -0.672	0.256
Temperature						1.000	* -0.799	* -0.923	-0.091
pH							1.000	* 0.695	-0.200
Turbidity								1.000	0.117
Rainfall									1.000

1988

N=10

	Discharge	Cladoc. Density	Copepod Density	Rotifer Density	Naupili Density	Temperature	pH	Turbidity	Rainfall	Conductivity
Discharge	1.000	0.254	* -0.867	0.308	-0.238	* 0.938	-0.471	-0.548	0.618	* -0.803
Cladoc. Density		1.000	-0.204	* 0.661	-0.173	0.282	0.145	* -0.790	0.554	-0.010
Copepod Density			1.000	-0.518	0.304	* -0.917	0.434	0.363	-0.430	* 0.934
Rotifer Density				1.000	* -0.657	0.551	-0.085	-0.377	0.137	-0.505
Naupili Density					1.000	-0.458	0.139	0.048	0.359	0.489
Temperature						1.000	-0.554	-0.427	0.453	* -0.920
pH							1.000	-0.124	-0.129	0.550
Turbidity								1.000	* -0.827	0.154
Rainfall									1.000	-0.204
Conductivity										1.000

1989

N=16

	Discharge	Cladoc. Density	Copepod Density	Rotifer Density	Naupili Density	Temperature	pH	Rainfall	Conductivity
Discharge	1.000	-0.295	* -0.855	0.479	* -0.647	-0.477	-0.279	* 0.553	* -0.712
Cladoc. Density		1.000	-0.169	* 0.947	0.004	0.093	0.392	0.729	0.310
Copepod Density			1.000	-0.259	* 0.904	0.158	-0.031	-0.449	* 0.707
Rotifer Density				1.000	-0.031	-0.162	0.126	* 0.792	0.138
Naupili Density					1.000	-0.167	-0.242	-0.212	* 0.728
Temperature						1.000	* -0.800	-0.129	0.207
pH							1.000	0.125	0.308
Rainfall								1.000	0.098
Conductivity									1.000

Table 46b. Potomac River 1987 - 1989. Simple correlation coefficients between environmental variables averaged over the first 20 days posthatch for surviving striped bass larvae cohorts. N = number of data points, which equals the number of larval cohorts that were observed up to at least 20 days posthatch. Asterisks indicate significant correlations at the alpha=0.05 level.

1987 - 1989

N=39

	Discharge	Cladoc. Density	Copepod Density	Rotifer Density	Nauplii Density	Temperature	pH	Rainfall
Discharge	1.000	* -0.394	* -0.843	* -0.411	* -0.624	* -0.454	* -0.391	* 0.590
Cladoc. Density		1.000	* 0.476	* 0.874	* 0.590	* 0.641	* 0.530	-0.201
Copepod Density			1.000	* 0.401	* 0.605	* 0.490	0.214	* -0.409
Rotifer Density				1.000	* 0.677	* 0.618	* 0.717	* -0.402
Nauplii Density					1.000	* 0.420	* 0.661	* -0.565
Temperature						1.000	* 0.403	* -0.375
pH							1.000	* -0.573
Rainfall								1.000

Table 46c. Upper Bay 1988 - 1989. Simple correlation coefficients between environmental variables averaged over the first 20 days posthatch for surviving striped bass larvae cohorts. N = number of data points, which equals the number of larval cohorts that were observed up to at least 20 days posthatch. Asterisks indicate significant correlations at the alpha=0.05 level.

1988

N=9

	Discharge	Temperature	pH	Rainfall	Conductivity	Turbidity
Discharge	1.000	0.278	* -0.770	-0.001	0.258	-0.024
Temperature		1.000	* -0.782	* -0.924	0.398	* -0.912
pH			1.000	0.568	-0.199	0.523
Rainfall				1.000	0.306	* 0.902
Conductivity					1.000	-0.583
Turbidity						1.000

1989

N=13

	Discharge	Cladoc. Density	Copepod Density	Rotifer Density	Nauplii Density	Temperature	pH	Rainfall	Conductivity
Discharge	1.000	* -0.947	* -0.944	-0.114	* -0.683	* -0.958	* -0.701	0.106	0.207
Cladoc. Density		1.000	* 0.985	-0.002	* 0.797	* 0.951	0.537	-0.016	-0.298
Copepod Density			1.000	0.011	* 0.734	* 0.957	* 0.597	-0.072	0.317
Rotifer Density				1.000	-0.423	0.066	0.357	0.359	* 0.777
Nauplii Density					1.000	* 0.637	0.199	-0.054	-0.352
Temperature						1.000	* 0.623	-0.072	-0.364
pH							1.000	-0.044	-0.070
Rainfall								1.000	-0.334
Conductivity									1.000

Table 46c (cont.). Upper Bay 1988 - 1989. Simple correlation coefficients between environmental variables averaged over the first 20 days posthatch for surviving striped bass larvae cohorts. N = number of data points, which equals the number of larval cohorts that were observed up to at least 20 days posthatch. Asterisks indicate significant correlations at the alpha=0.05 level.

1988-1989

N=22

	Discharge	Temperature	pH	Rainfall	Conductivity
Discharge	1.000	-0.412	* -0.458	0.184	-0.087
Temperature		1.000	-0.258	-0.216	-0.272
pH			1.000	* 0.572	-0.122
Rainfall				1.000	-0.111
Conductivity					1.000

Table 46d. Potomac River 1987 - 1989 and Upper Bay 1989. Simple correlation coefficients between environmental variables averaged over the first 20 days posthatch for surviving striped bass larvae cohorts. N = number of data points, which equals the number of larval cohorts that were observed up to at least 20 days posthatch. Asterisks indicate significant correlations at the alpha=0.05 level.

1987-1989

N=52

	Discharge	Cladoc. Density	Copepod Density	Rotifer Density	Nauplii Density	Temperature	pH	Rainfall
Discharge	1.000	* -0.588	* -0.571	* 0.522	* 0.328	0.117	* -0.365	* 0.521
Cladoc. Density		1.000	-0.247	* 0.569	0.053	* 0.297	-0.002	* 0.303
Copepod Density			1.000	* 0.319	* 0.642	* 0.303	* -0.524	0.129
Rotifer Density				1.000	0.083	0.106	* 0.453	-0.062
Nauplii Density					1.000	0.044	* 0.376	-0.102
Temperature						1.000	-0.011	-0.095
pH							1.000	* -0.314
Rainfall								1.000

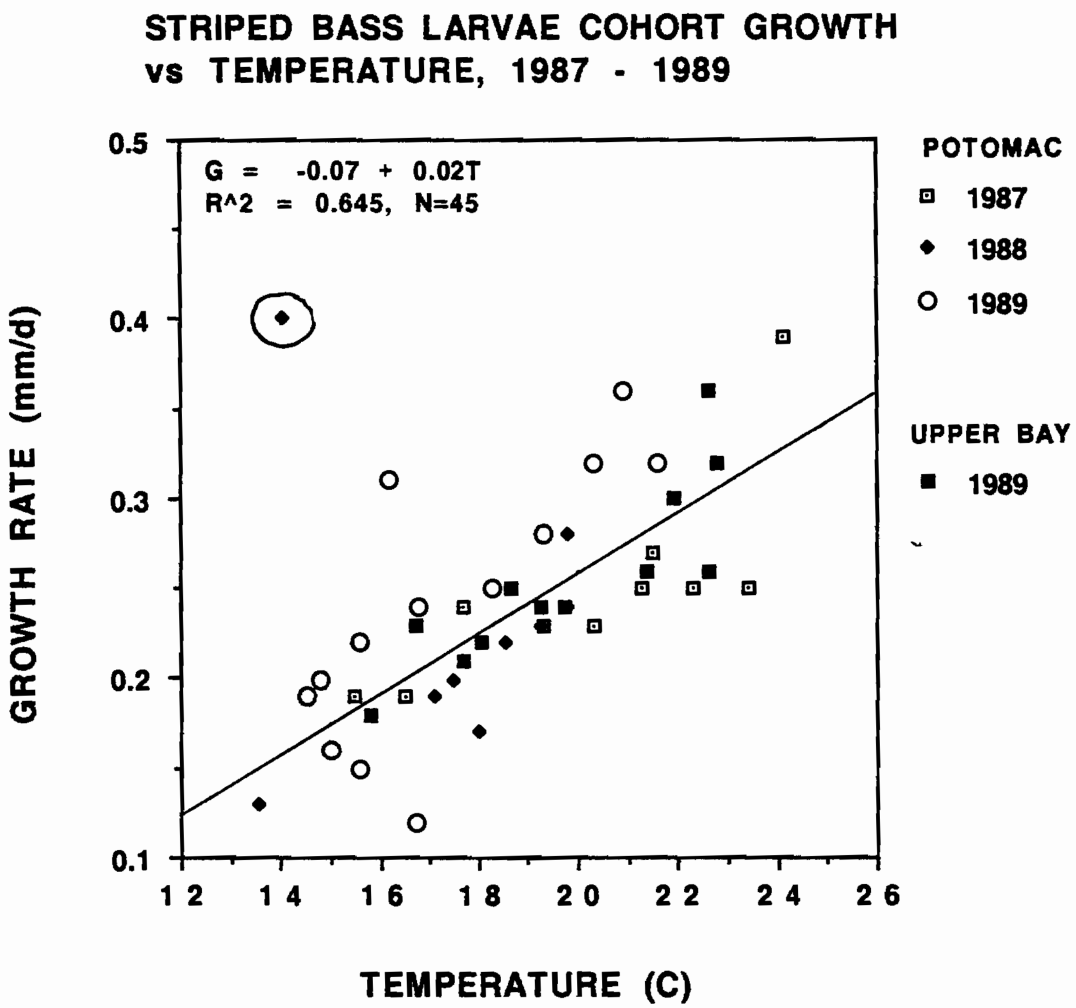


Figure 46. Potomac River, 1987-1989 and Upper Bay, 1988-1989. Back-calculated growth rates (mm d^{-1}) of striped bass larvae 3-day cohorts (from Tables 43 and 45) in relation to river temperatures averaged over the first 20 days posthatch. Circled data point is an outlier and was not included in the regression.

Mortality

Potomac River

A "stable-age distribution" assumption led to an estimate of instantaneous mortality rate, derived from the age frequency distribution of larvae from all 1989 Potomac River surveys with the 60-cm sampler, of $Z = 0.29 \pm 0.09$, which is equivalent to 25% d^{-1}. This estimate was not significantly higher ($P>0.06$) than the stable-age distribution $Z = 0.22 \pm 0.02$ (21% d^{-1}) in 1987 or $Z = 0.34 \pm 0.17$, (29% d^{-1}) in 1988 (Figure 47). The 1989 Potomac River, cohort-specific mortality rates ranged from $Z = 0.09$ to 1.04, (9 to 65% d^{-1}) (Table 47). Mortality rates showed the same general seasonal trend observed in 1987 and 1988; i.e. a decrease for cohorts hatched from mid-April to early May, an increase to a peak for mid-May cohorts, and a subsequent decrease. As in previous years, the standard errors on the rates were high. As a consequence, it was not possible to show significant differences ($P>.88$) among the cohort-specific mortality rates.

Upper Bay

The stable-age distribution assumption mortality rate of Upper Bay striped bass larvae was $Z = 0.73 \pm 0.30$, equivalent to 52% d^{-1}. This rate is significantly higher ($P<0.003$) than the comparable estimate, $Z = 0.29$, for Potomac River larvae, but not significantly lower ($P>0.25$) than the estimate of $Z = 1.14$ (68% d^{-1}) estimated for Upper Bay larvae in 1988 (Figure 48). Cohort-specific instantaneous mortality rates calculated for each 3-day cohort differed significantly ($P<.02$), ranging from $Z = 0.19$ to 0.94, equivalent to 17 to 61% d^{-1} (Table 48). The instantaneous mortality rate of the 3-day cohort hatched on 14 May was not calculated because its estimated abundance did not decline with age. Mortality increased from 34% d^{-1} for the 2 May cohort to 50%

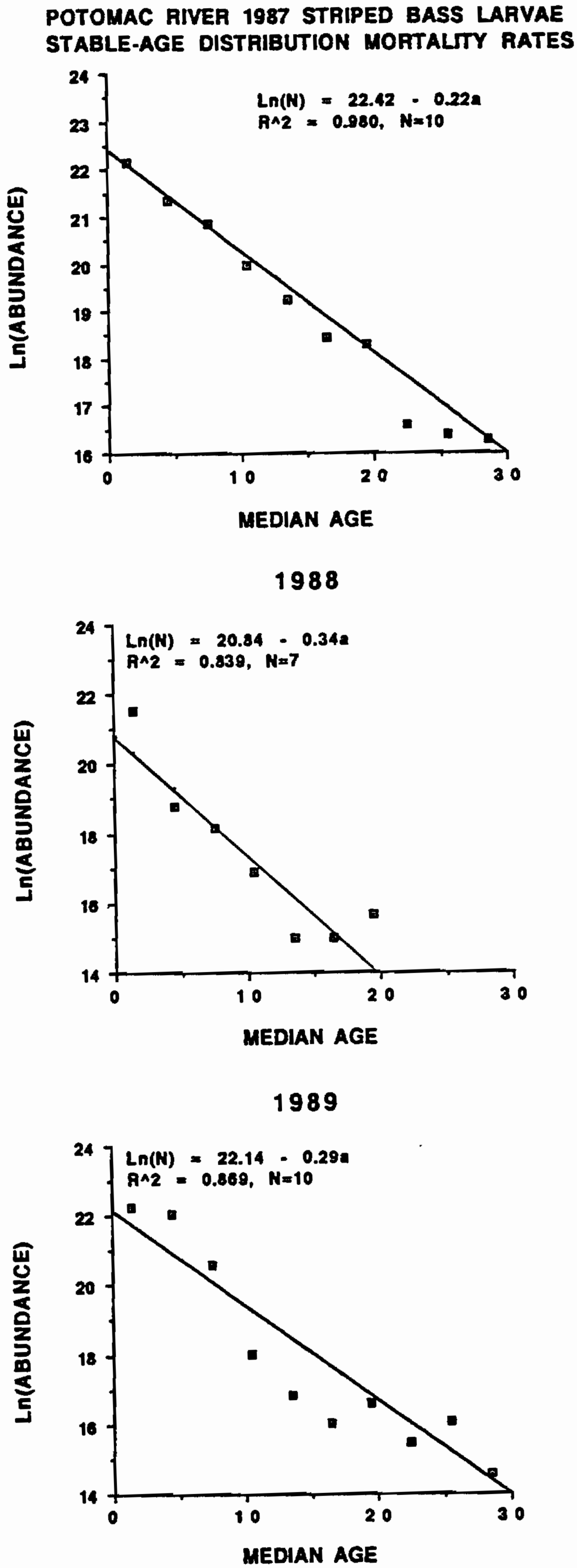


Figure 47. Potomac River, 1987-1989. The relationship between estimated abundances and ages of striped bass larvae. Regression coefficients in the exponential models are estimates of the "stable-age", mean instantaneous mortality rates. Estimated riverwide abundances-at-age were sums over all surveys (Table 6 in Houde et al. 1988b for 1987 data; Table 48 in Houde et al. 1990 for 1988 data; Table 50A, this report for 1989 data).

Table 47. Striped bass larvae, Potomac River 1989. Cohort-specific mortality rates.
Z = instantaneous daily mortality coefficient, A = percent daily mortality, and
N = number of surveys in which the cohort was collected. Abundance estimates, from which cohort mortalities were calculated, are from Appendix Table 50A. Estimated abundances at hatch are from extrapolations to age 0 of the abundance-at-age regression.

Cohort	Mean Hatch Date	N	Z	R2	S.E. (Z)	A	Estimated Abundance at Hatch
E	14-Apr	2	0.17			15.6	3.48E+06
F	17-Apr	3	0.53	0.530	0.50	41.1	1.19E+08
G	20-Apr	3	0.23	0.323	0.34	20.5	8.47E+07
H	23-Apr	5	0.21	0.633	0.09	18.9	8.38E+07
I	26-Apr	5	0.28	0.450	0.18	24.4	9.91E+07
J	29-Apr	5	0.15	0.644	0.07	13.9	7.74E+07
K	2-May	5	0.09	0.266	0.09	8.6	4.68E+07
L	5-May	3	0.12	0.800	0.06	11.3	8.01E+07
M	8-May	4	0.15	0.554	0.10	13.9	9.26E+07
N	11-May	3	0.15	0.779	0.08	13.9	8.54E+07
O	14-May	2	1.04			64.6	8.80E+11
P	17-May	2	0.88			58.5	1.95E+11
Q	20-May	2	0.32			27.4	6.22E+09
		Cohorts' Mean	0.33			25.6	
		"Stable-Age" Mean (N=10)	0.29	0.869	0.04	25.2	4.12E+09

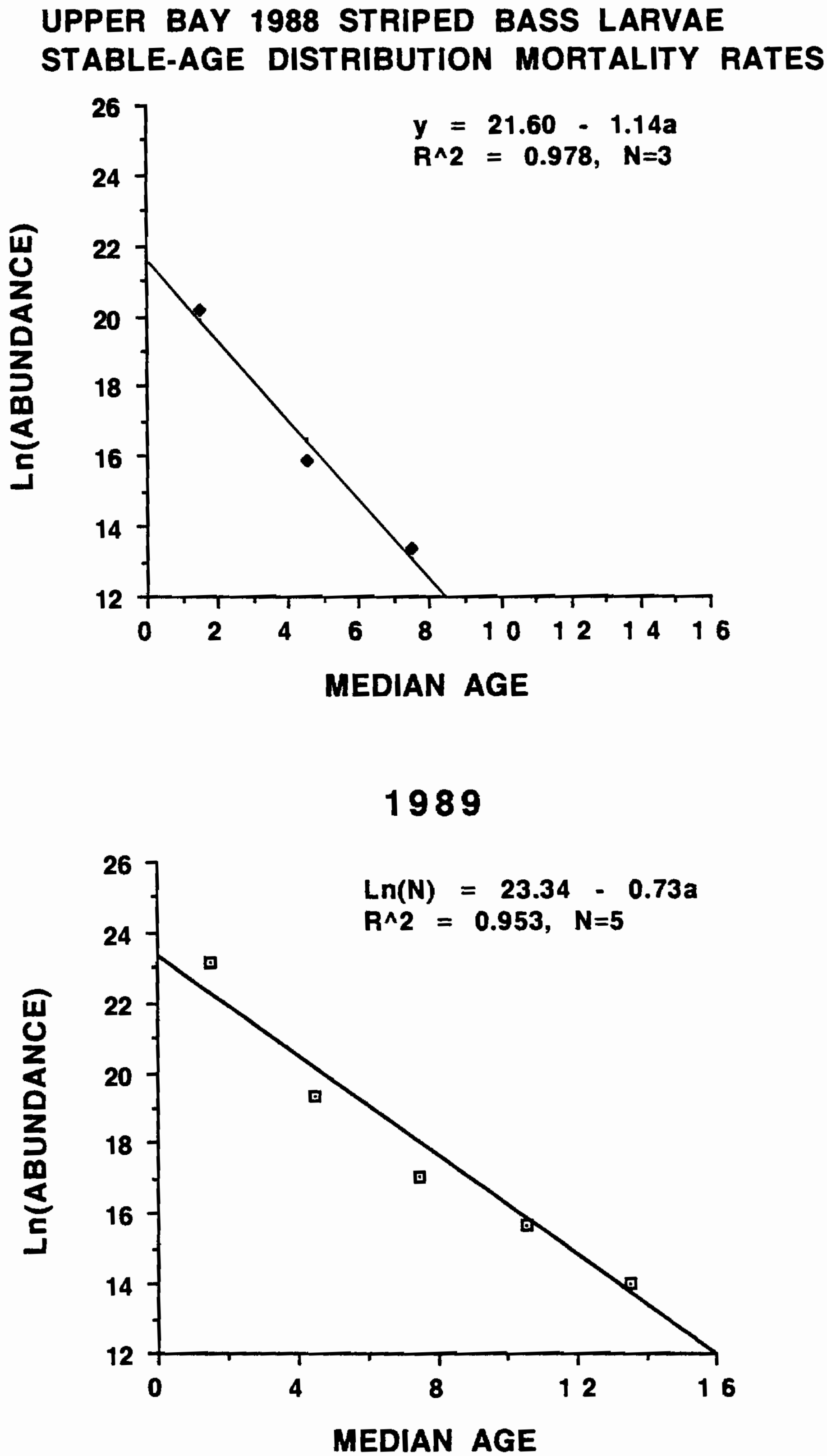


Figure 48. Upper Bay, 1988-1989. The relationship between estimated abundances and ages of striped bass larvae. Regression coefficients in the exponential models are estimates of the "stable-age", mean instantaneous mortality rates. Estimated areawide abundances-at-age were sums over all surveys (Table 52, Houde et al. 1990 for 1988 data; Table 51A, this report for 1989 data).

Table 48. Striped bass larvae, Upper Bay 1989. Cohort-specific mortality rates.
Z = instantaneous daily mortality coefficient, A = percent daily mortality, and
N = number of surveys in which the cohort was collected. Abundance estimates, from which cohort mortalities were calculated, are from Appendix Table 51A. Estimated abundances at hatch are from extrapolations to age 0 of the abundance-at-age regression.

Cohort	Mean Hatch Date	N	Z	R2	S.E.(Z)	A	Estimated Abundance at Hatch
K	2-May	2	0.42			34.3	2.25E+07
M	8-May	2	0.47			37.5	1.80E+07
N	11-May	3	0.70	0.950	0.1597	50.3	2.67E+07
P	17-May	4	0.19	0.681	0.0926	17.3	1.88E+07
Q	20-May	3	0.36	0.592	0.2965	30.2	2.89E+08
R	23-May	3	0.94	0.959	0.1956	60.9	4.86E+09
		Cohorts' Mean	0.51			38.4	
		Stable-Age Mean (N=5)	0.73	0.953	0.09	51.8	1.36E+10

d^{-1} for the 11 May cohort, then declined for mid-May cohorts before increasing to 61% d^{-1} for the 23 May cohort (Table 48). Standard errors on the cohort-specific mortality rates were high (Table 48).

G/Z Ratio

Potomac River

The ratio of instantaneous growth-in-weight rate (G) to mortality rate (Z), a measure of cohort productivity, showed similar trends for Potomac River striped bass larval cohorts in 1987, 1988 and 1989. A G/Z ratio >1.0 indicates that the biomass of a larval cohort is increasing during the time that it was sampled. The mean G/Z ratio for all 3-day cohorts in 1989 was 0.81 (Table 49), a value not significantly different (P>.67) from G/Z = 0.84 in 1988 or 1.10 in 1987. Although the G/Z ratios were not demonstrated to differ significantly (P>.588) among years, the highest value was calculated for 1987 when recruitment also was highest. The 1989 striped bass cohort-specific G/Z ratios varied widely (Table 49), from 0.18 to 1.67. The five cohorts in 1989 with G/Z ratios ≥1.0 were hatched from 29 April to 11 May. The 1989 cohorts generally had instantaneous growth coefficients that were similar to 1987 cohorts, but higher instantaneous mortality coefficients. The mid-season peak in G/Z ratio observed in 1989 was also evident in 1987 and 1988, a consequence of seasonally increasing G values and seasonally low values of Z.

Upper Bay

The mean G/Z ratio of five Upper Bay striped bass cohorts in 1989 was 0.47, a value not significantly lower (P>0.18) than the mean G/Z for the Potomac River 1989 cohorts (Table 50). The Upper Bay peak G/Z was calculated

Table 49. Striped bass larvae, Potomac River 1989. Ratios of instantaneous growth-in-weight rate (G) to mortality rate (Z) of 3-day cohorts. Larvae weights were estimated from the weight-length regression W = 6.23x10^(-4) * L^(4.2879). (Houde and Lubbers 1986). Lengths were predicted from the cohort-specific, back-calculation growth equations (Table 43).

Cohort	Mean Hatch Date	Predicted Length (mm SL) 5 days	Predicted Length (mm SL) 20 days	Predicted Weight (mg) 5 days	Predicted Weight (mg) 20 days	G	Z	G/Z
F	17-Apr	4.04	5.80	0.25	1.17	0.10	0.53	0.19
G	20-Apr	4.47	9.11	0.38	8.11	0.20	0.23	0.87
H	23-Apr	3.87	6.18	0.21	1.54	0.13	0.21	0.62
I	26-Apr	4.08	6.45	0.26	1.84	0.13	0.28	0.46
J	29-Apr	4.09	7.00	0.26	2.62	0.15	0.15	1.00
K	2-May	4.13	7.02	0.27	2.65	0.15	0.09	1.67
L	5-May	4.06	7.09	0.25	2.77	0.16	0.12	1.35
M	8-May	3.89	7.25	0.21	3.04	0.18	0.15	1.20
N	11-May	3.79	7.38	0.19	3.29	0.19	0.15	1.27
O	14-May	3.85	7.57	0.20	3.66	0.19	1.04	0.18
P	17-May	3.99	8.18	0.24	5.11	0.21	0.88	0.24
Q	20-May	4.29	9.13	0.32	8.18	0.22	0.32	0.69
R	23-May	4.67	10.04	0.46	12.30	0.22		
S	26-May	4.29	9.12	0.32	8.14	0.22		
	Mean =	4.11	7.67	0.27	4.60	0.18	0.35	0.81

Table 50. Striped bass larvae, Upper Bay 1989. Ratios of instantaneous growth-in-weight rate (G) to mortality rate (Z) of 3-day cohorts. Larvae weights were estimated from the weight-length regression W = 6.23X10^(-4)*L^(4.2879). (Houde and Lubbers 1986). Lengths were predicted from the cohort-specific, back-calculation growth equations (Table 45).

Cohort	Mean Hatch Date	Predicted Length (mm SL) 5 day	Predicted Length (mm SL) 20 day	Predicted Weight (mg) 5 day	Predicted Weight (mg) 20 day	G	Z	G/Z
M	8-May	3.72	7.06	0.17	2.72	0.18	0.47	0.39
N	11-May	3.53	6.88	0.14	2.43	0.19	0.70	0.27
P	17-May	4.04	7.78	0.25	4.12	0.19	0.19	0.98
Q	20-May	4.30	8.09	0.32	4.87	0.18	0.36	0.51
R	23-May	4.34	8.55	0.34	6.18	0.19	0.94	0.21
	Mean =	3.99	7.67	0.24	4.06	0.19	0.53	0.47

for the 17 May cohort. Despite a relatively high mean G value for Upper Bay cohorts, the G/Z ratio was low because mortality rates were high. There was no obvious seasonal trend in G/Z for Upper Bay striped bass cohorts (Table 50). The apparently lower mean G/Z in the Upper Bay in 1989 compared to the Potomac River mean G/Z for 1987, 1988 and 1989 was not significantly different (P=0.41) because of the high among-cohort variability. Cohorts hatched after 23 May 1989 in the Upper Bay could not be included in the G/Z analysis, which was applied only to cohorts that had attained at least 20 days of age during the sampling surveys. It is probable that some late-hatched cohorts had G/Z ratios higher than those calculated for cohorts M-R (Table 50).

Estimated Abundance of Striped Bass Larvae at 8 mm SL

Potomac River

The estimated abundances of striped bass cohorts at 8.0 mm SL were calculated as an index of recruitment potential from data in the growth rate and mortality rate analyses. Estimated cohort abundances at age 0 from catches in the 60-cm sampler were multiplied by their cohort-specific mortality rates from age 0 to estimated age at 8.0 mm SL (i.e. Zt) to estimate numbers at 8.0 mm.

The summed abundance at 8.0 mm SL of all Potomac River striped bass larvae based upon the 60-cm sampler collections in 1989 was 44.6 million larvae, which is 25% of the total estimated for 1987 but 1.9 times more than the number at 8.0 mm estimated for 1988 (Houde et al. 1990). Cohorts hatched from 20 April - 11 May 1989 contributed 46.8% of the potential recruits (Figure 49). The 3-day cohort hatched on 20 May (actually in the 19-21 May period) contributed an estimated 23.7 million larvae, or 53.1% of the total potential recruitment in the Potomac River. The general production pattern of

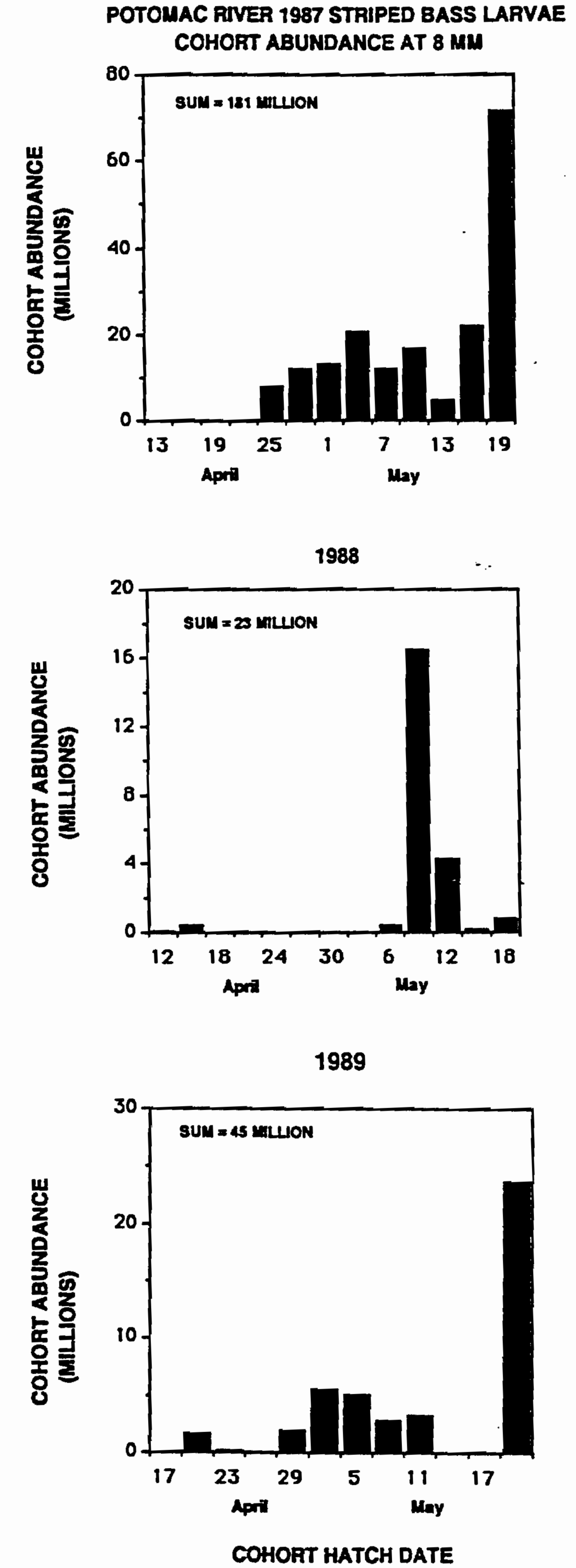


Figure 49. Potomac River, 1987-1989. Estimated riverwide abundances of striped bass larvae at 8.0 mm SL for cohorts sampled by the 60-cm net in each year. Median hatch dates of each 3-day cohort are given.

8.0 mm larvae was similar in 1987 and 1989 (Figure 49). In 1988, most 8.0 mm larvae were produced by a few cohorts hatched in the 9 - 12 May period (Figure 49).

Another estimate of potential recruitment was provided by catches of surviving larvae in the 2 m^2 Tucker Trawl on 1-2 and 8-9 June 1989. Larval densities in each 0.5 mm length class from the Tucker trawl were expanded to riverwide abundance estimates by multiplying the densities by the volume represented by each station, summing over all stations, and then converting from abundances-at-length to abundances-at-age using the age-length keys (Appendix Tables 48 and 49). Abundances were allocated to 3-day cohorts, and cohort-specific mortality rates were estimated from the combined cohort abundance estimates based upon both the 60-cm, sampler and the 2 m^2 Tucker trawl. The resulting cohort-specific abundance estimates of 8.0 mm larvae were 3.2 times higher (142 million larvae) than the estimate provided by the 60-cm net alone (Figures 49 and 50), but the distributions of cohort hatch-dates contributing to potential recruitment were similar. Cohorts hatched after 20 May were not sampled effectively by the 700-μm Tucker trawl. The 23 May hatch, in addition to the 17 and 20 May hatches, was a probable large contributor to potential recruitment. Modest numbers of 8.0 mm larvae were produced by cohorts hatched from 20 April - 11 May, and most 8.0 mm larvae (52%) originated from cohorts hatched in the 17-23 May period (Figure 50).

The relative abundance of 3-day cohorts collected in the 2 m^2 Tucker trawl on the last day of the sampling season (8 June), uncorrected for age-specific and cohort-specific differences in survival, and uncorrected for extrusion of some small larvae, indicated that some survivors on 8 June had been hatched in every 3-day period from 23 April to 7 June (Figure 51). Cohorts hatched from 11 - 20 May comprised over 57% of the total numbers

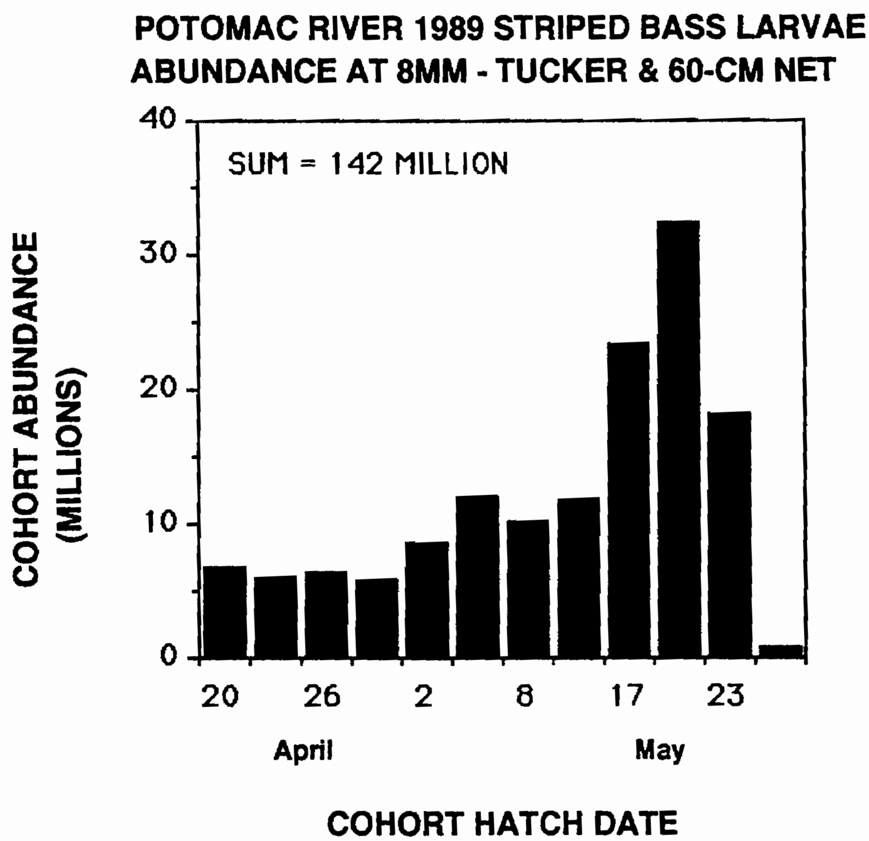


Figure 50. Potomac River, 1987-1989. Estimated riverwide abundances of striped bass larvae at 8.0 mm SL for cohorts sampled by the 60-cm net and the 2 m^2 Tucker trawl. Median hatch dates of each 3-day cohort are given.

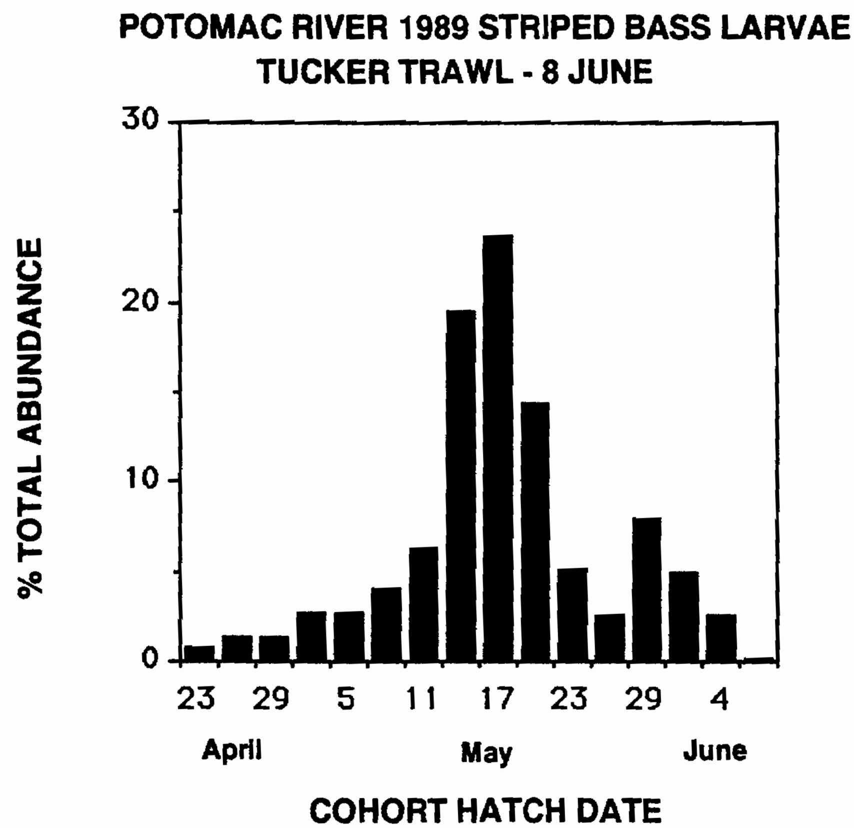
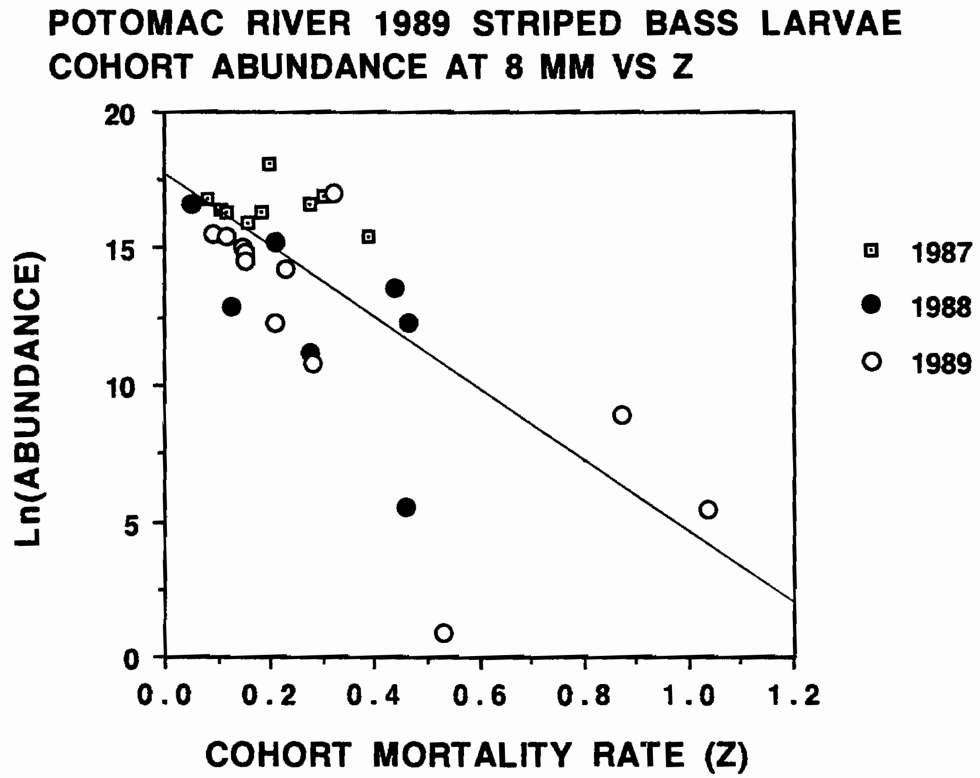


Figure 51. Potomac River, 1989. Relative abundance of striped bass larvae 3-day cohorts collected by the 2 m^2 Tucker trawl on 8-9 June. Median hatch dates of each 3-day cohort are given.

represented on 8 June. The cohorts hatched on 14 - 17 May were represented better in the 8-9 June Tucker catches (Figure 51) than they had been in the May collections od the 60-cm sampler. The discrepancy in catches between the gears may have been caused by the flood event and subsequent high river discharge (Figure 6) which occurred from 6-20 May, and which may have displaced newly-hatched larvae temporarily downstream of the area sampled by the 60-cm net. No larvae were collected on the 12 and 16 May surveys by the 60-cm sampler during the period of high discharge, but larvae from the same cohorts were collected before and after that period. Conductivities measured at stations 1 and 2, which averaged 1491 and 578 micro-ohms, respectively, were depressed during this period (Table 6), further evidence that river conditions usually conducive to larvae occurrence had been displaced downstream.

The predicted cohort abundances of 8.0 mm SL larvae were significantly related (r^2 = 0.490; n = 28; P<0.001) to cohort mortality rates (Figure 52). Although there was no statistically significant difference in this regression relationship among years, the relationship between 8.0 mm larvae abundance and cohort mortality rates was strongest for 1989 larval cohorts (r^2 = 0.525; n = 12; P<0.001) and apparently lacking for 1987 cohorts (r^2 = 0.059; n = 9; P>0.52).

The predicted 8.0 mm larval abundances were positively related (r^2 = 0.203, n = 28, P<0.01) to cohort growth rates (Figure 52) for all years combined. The relationship was strongest for 1987 cohorts (r^2 = 0.611; n = 9; P<0.02), and was weakest and not significant for 1989 cohorts (r^2 = 0.149; n = 12; P>0.21). No significant relationship was demonstrated between cohort abundances at 8.0 mm and hatch date, zooplankton density, initial cohort abundance, density of Morone species larvae, or any of the environmental parameters that were measured.



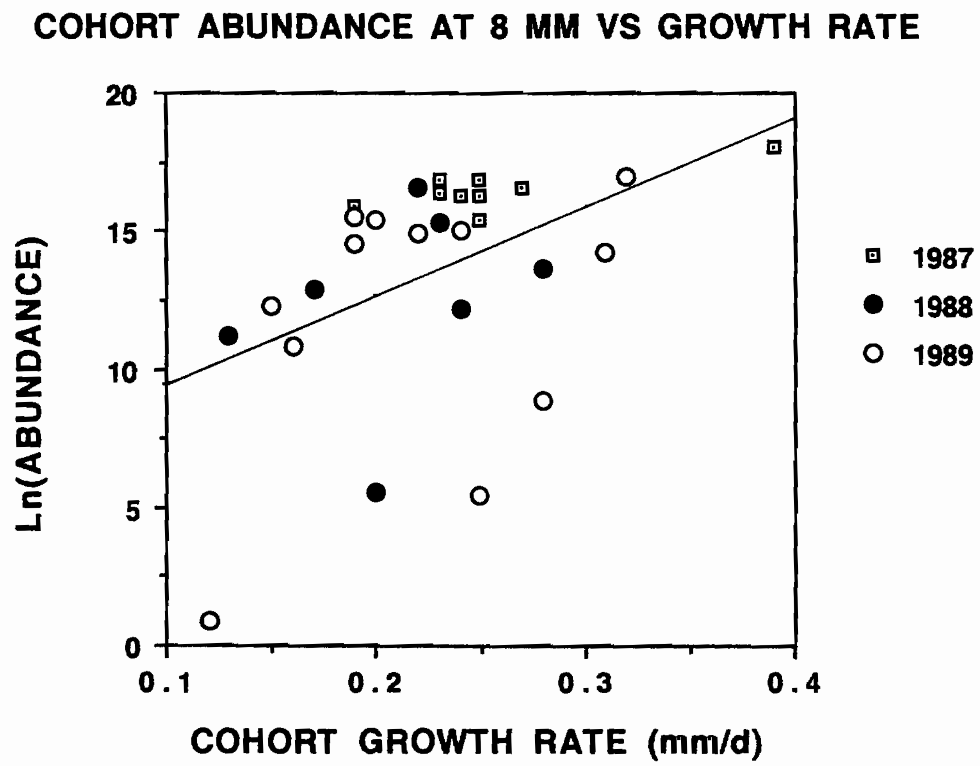


Figure 52. Potomac River, 1987-1989. Estimated riverwide $\log_e$ abundances of striped bass larvae at 8.0 mm SL for cohorts sampled by the 60-cm net in relation to A. cohort-specific instantaneous larval mortality rates. B. cohort-specific, back-calculated growth rates (mm d^{-1}) from Table 46).

Upper Bay

The abundance of 8.0 mm larvae in the Upper Bay estimated from catches in the 60-cm sampler was only 0.5 million larvae, an estimate 89 times lower than that for the Potomac River in 1989. The 8.0 mm larvae survivors were hatched from 8 - 23 May, with nearly all (99%) hatched in the 16-21 May period (Figure 53). Because most larvae in the Upper Bay were hatched from eggs spawned late in the spawning season (23 - 30 May), and would not have reached 8.0 mm length by the last date of sampling with the 60-cm sampler (30 May), a better estimate of 8.0 mm larval abundance was obtained from Tucker trawl and 60-cm net catches combined. This approach estimated the abundance of 8.0 mm larvae to be 48.7 million larvae, a higher number but still 2.9 times less than the comparable estimate generated for Potomac River 8.0 mm larvae. Potential recruits in the Upper Bay, estimated by the combined Tucker trawl and 60-cm sampler, were hatched from 29 April - 4 June (Figure 54). Most were hatched in the 17 - 26 May period and on 1 - 4 June.

Relative abundance of Tucker trawl-collected 3-day cohorts present on the last sampling day (14 June) in the Upper Bay indicated that striped bass larvae were present from hatches on 17 April - 13 June (Figure 55). Over 80% of these larvae were hatched between 17 May and 4 June.

Cohort-specific abundances of 1989 Upper Bay 8.0 mm larvae that were estimated from the combined 60-cm and Tucker trawl samples were positively correlated with cohort growth rates ($r^2 = 0.66$, $n = 12$, $P<0.001$) and temperature ($r^2 = 0.91$, $n = 12$, $P<0.001$) (Figure 56). Cohort abundances increased rapidly over most of the range of these independent variables, before decreasing at temperatures >22°C and when growth rates exceeded 0.32 mm d^{-1}.

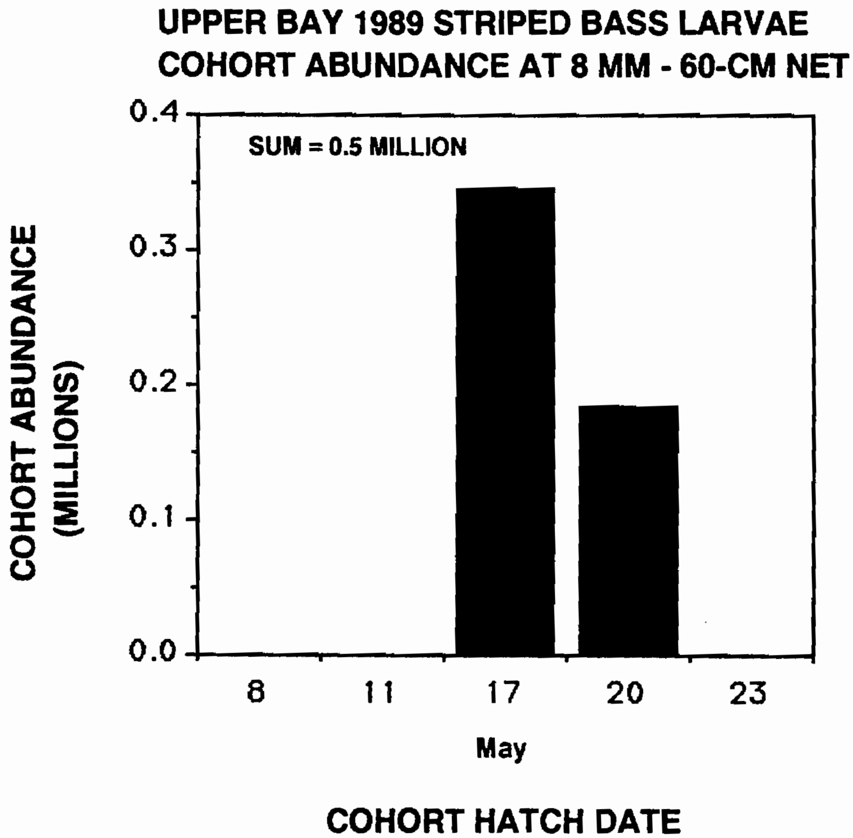


Figure 53. Upper Bay, 1989. Estimated areawide abundances of striped bass larvae at 8.0 mm SL for cohorts sampled by the 60-cm net. Median hatch dates of each 3-day cohort are given.

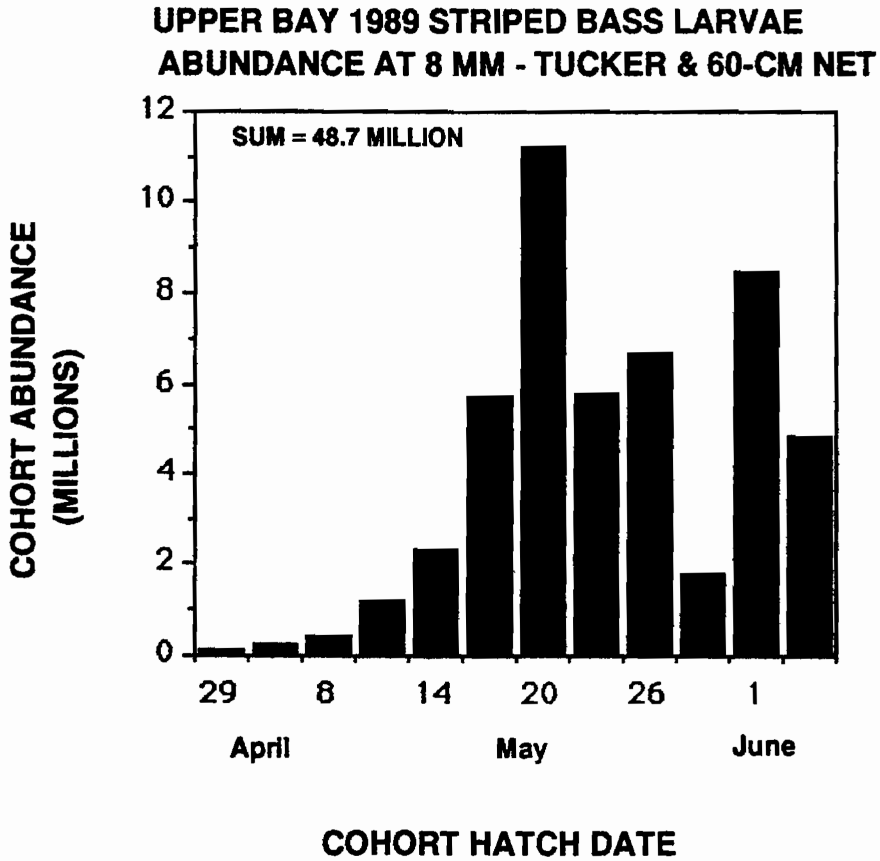


Figure 54. Upper Bay, 1989. Estimated areawide abundances of striped bass larvae at 8.0 mm SL for cohorts sampled by the 60-cm net and the 2 m^2 Tucker trawl. Median hatch dates of each 3-day cohort are given.

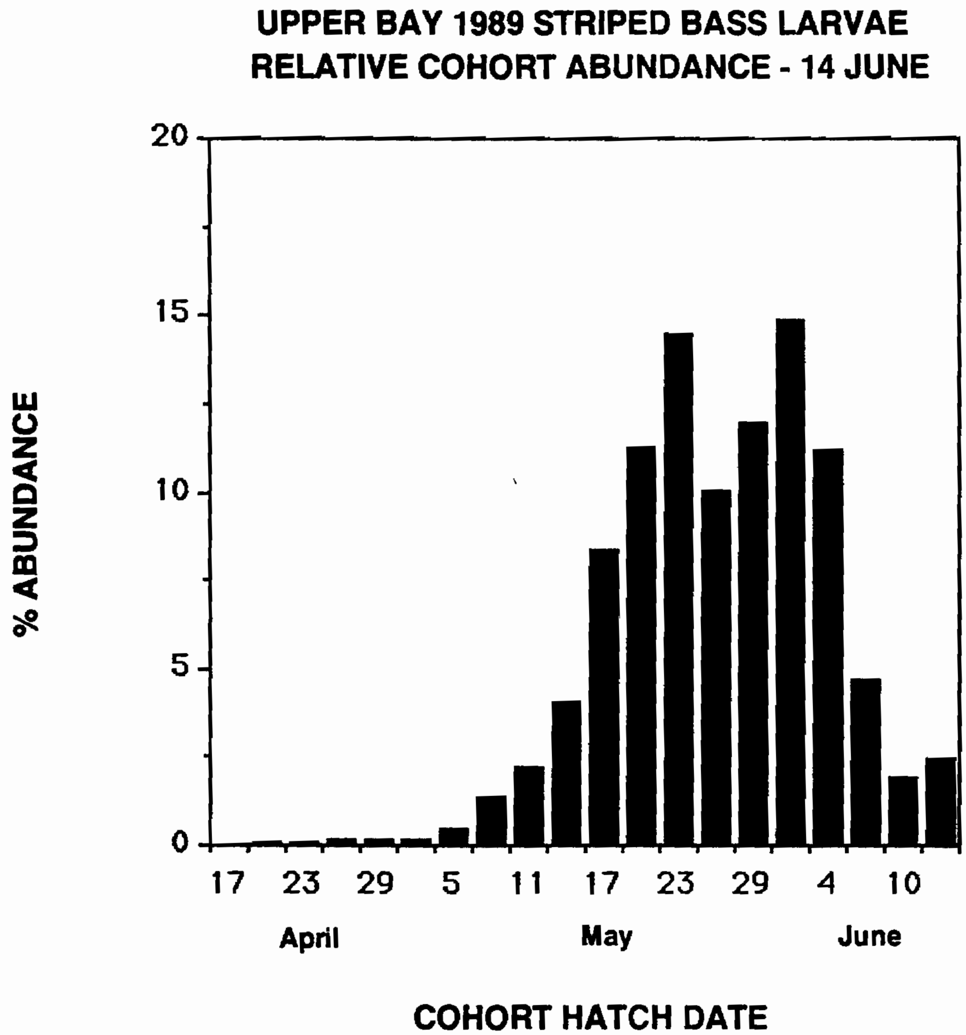


Figure 55. Upper Bay, 1989. Relative abundance of striped bass larvae 3-day cohorts collected by the 2 m² Tucker trawl on 14-15 June. Median hatch dates of each 3-day cohort are given.

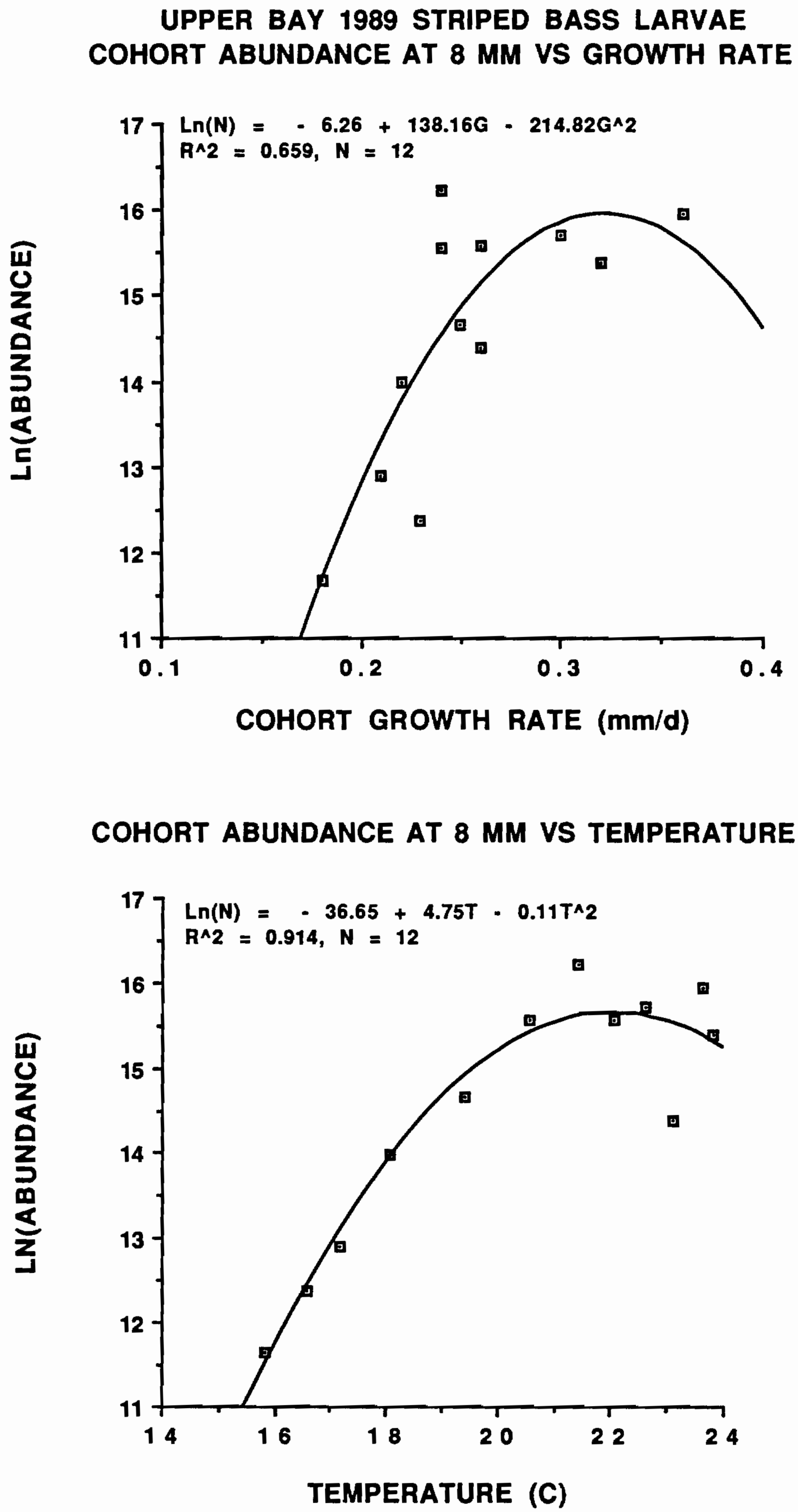


Figure 56. Upper Bay, 1989. Estimated areawide $\log_e$ abundances of striped bass larvae at 8.0 mm SL for cohorts sampled by the 60-cm net and the 2 m^2 Tucker trawl in relation to A. Cohort-specific back-calculated growth rates (mm d^{-1}) (from Table 45). B. Upper Bay water temperatures averaged over the first 20 days posthatch.

DISCUSSION

Each striped bass spawning season in Chesapeake Bay has its own peculiarities, which distinguish it from other years and shape the potential for recruitment success. There are differences in the Potomac River and Upper Bay environments within each season that affect not only the temporal progression of the spawning season but which affect potential recruitments in each system. Results reported here represent our third research year on the Potomac River and our second year in the Upper Bay. Analyses of egg production, larvae growth and survival, and relationships to environmental conditions in 1987, 1988 and 1989 describe and explain the causes of Potomac River variability in potential recruitment. Conclusions from the Upper Bay analyses remain less clear, although important temporal-spatial information on egg production, female biomass and larvae dynamics were obtained and documented for the environmental conditions observed in 1988 and 1989.

Striped bass egg production estimates in 1989 were the highest that we obtained in the 1987-1989 Potomac and 1988-1989 Upper Bay studies. Upper Bay egg production in 1989 increased more than eight-fold relative to 1988. The Potomac River egg production estimates differed relatively little among years. Although the 1989 egg production estimate was 20% higher than 1987 and 70% higher than 1988, Potomac egg productions were not judged to differ significantly among years, given the precision levels that were attained. The great increase observed in Upper Bay egg production in 1989 would not have been predicted from the fecundity-adjusted gillnet CPUE data, which declined by 37.5% in 1989 compared to 1988. In contrast, the fecundity-adjusted CPUE from gillnet catches in the Potomac River was correlated with the egg production estimates. The 1989 fecundity-specific CPUE of Potomac River females increased by 61.5% compared to 1988, which compares well with the 70%

increase in estimated egg production that was observed. In 1987, fecundity-specific CPUE of Potomac River females was 83% of the 1989 CPUE estimate and the estimated 1987 egg production was 83.5% of that estimated in 1989.

The 1982 year-class was the major producer of eggs in both the Potomac River and Upper Bay in 1989 as it had been in the previous two years. Estimated percent contribution of 1982 females declined from 51.6 to 41.8% from 1987 to 1989 in the Potomac River and from 72.0 to 54.7% from 1988 to 1989 in the Upper Bay. The annual declines in relative egg productions by 1982 females were quite small because the initial size of the 1982 year class was large compared to younger age classes now entering the spawning population. The proportional contributions by the 1982 year-class females have been maintained at high levels because of individual growth and associated increases in fecundity despite apparent reduction in numbers of 1982 females in the 1987 to 1989 period.

Egg productions in the Potomac River and Upper Bay during the 1987 to 1989 period were considerably higher than estimates for Virginia Rivers in the 1980-1989 period (Olney et al. 1991). The Virginia analysis, which focused on the Pamunkey River in 1980 to 1989, but included some estimates of egg production for the Mattaponi, James and Rappahannock Rivers from 1980 to 1983, produced estimates that ranged from 0.28 to 2.69 x 10^9 eggs. Our three-year mean estimate of egg production in the 1987-1989 for the Potomac River was 9.15 x 10^9 eggs, while the 1988-1989 two-year mean for the Upper Bay was 8.18 x 10^9 eggs.

Olney et al. (1991) reported that most spawning by striped bass occurred at night and they provided a mean estimate of daily egg mortality rate, 68%, which they used to adjust daily egg abundance estimates to numbers actually spawned. Our egg production estimates, which were derived from total egg counts (i.e. live and dead eggs) in the collections, nevertheless may have underestimated daily egg abundance and production because of predation losses and sinking of some dead eggs. Applying the Olney et al. (1991) mortality rate (68% d^{-1}, $Z = 0.047\ h^{-1}$), to our egg collections, under the assumption that on average our daytime collections were made 12 h after spawning, would increase our egg production (and spawning biomass) estimates by nearly 77%. Under those conditions, 1989 egg productions might have been as high as 20.0 x 10^9 and 25.7 x 10^9 in the Potomac River and Upper Bay, respectively. To provide historical perspective, Polgar's (1977) exponential model estimate of egg production in the Potomac River for the 1974 season, before the collapse of the spawning population, was 26.9 x 10^9 eggs, a value more than twice as high as any of our unadjusted 1987-1989 Potomac River estimates. Olney et al. (1991) noted significant increases in egg production in the Pamunkey River during the 1980-1989 period, which they attributed to gradual rebuilding of the spawning stock in the 1980s. We did not detect significant increases in Potomac River egg production from 1987 to 1989, although a dramatic increase was observed in the Upper Bay in 1989 compared to 1988.

The female spawning biomasses in the Upper Bay and Potomac River, based upon the 1989 egg production estimates, were 55,501 and 70,808 kg, respectively. These values and the estimates for the previous years seem low and may in fact underrepresent actual biomasses, although they probably do provide an index of spawning biomasses. Female spawning biomass estimates for the Potomac River were: 1987 -- 50,603 kg, 1988 -- 32,553 kg, 1989 -- 55,501 kg. The estimates for the Upper Bay were: 1988 -- 8,703 kg, 1989 -- 70,808 kg. Olney et al. (1991) calculated biomasses for Virginia rivers, based upon egg production estimates, which also seem low, ranging from only 126 kg (Mattaponi R., 1980) to 5,604 kg (Pamunkey R., 1988). Because the egg production method only leads to an estimate of mature female biomass and numbers, it greatly underestimates total biomass and numbers of striped bass in the fishable population. Biomasses and numbers of ≥ age 2 female and male striped bass almost certainly exceed our mature female estimates by at least factors of three and six, respectively, assuming that 100% maturity of females does not occur until age 8 and that annual mortality is approximately M = 0.15.

Although the Maryland DNR gillnet CPUE data on female striped bass only roughly tracks the temporal pattern of spawning in the Potomac River and Upper Bay (Figures 27 and 28; Table 35), a more intensive or better-designed gillnet survey probably could be used to delineate spawning seasons and the age-specific, temporal contributions of eggs by females in component age classes. If properly calibrated, appropriate CPUE data could be used to estimate or index egg production.

In general, older females of teleost fishes spawn earlier in a season than do younger females and anecdotal information indicated that this age-specific schedule applied to striped bass in the Chesapeake Bay. Our analysis on the aggregated 1987, 1988, and 1989 data supports this view but the result is not clearcut (Table 36), possibly because few old females remained in the stock in the 1987 to 1989 period. It is apparent that after gillnet CPUE was adjusted for age-specific fecundity and examined by 10-day periods younger females (≤ age 7) were present on the spawning grounds more uniformly during the season and that most older females were netted earlier in the season, generally in April. If the presence of females on the spawning grounds during the 10-day periods indicates that they spawned during those periods, eggs are produced more uniformly throughout the season by ≤ age 7 females than by older females. Egg production by the relatively uncommon older females is more probable early in the season during the time when sudden temperature declines occur that often are lethal to striped bass eggs and yolk-sac larvae (Houde et al. 1988b, 1990).

There is evidence that older striped bass females produce larger and better quality eggs than do smaller females (Zastrow et al. 1989) and that large eggs develop into larvae that are both larger at hatch and which maintain a size advantage during the first 25 d posthatch (Monteleone and Houde 1990). If significant numbers of older females are present in spawning stocks, progeny of potentially better quality will be produced, which are better able to tolerate marginal growth and feeding conditions early in the season. There are tradeoffs here because the progeny of old females, produced early in the season, may experience unfavorable or lethal conditions. Nevertheless, contributions of progeny by large females will tend to spread the reproductive effort over a longer spawning season. In stocks that are lightly fished or rigorously managed, a large fraction of egg production would be from older females and a tendency to shift egg production to earlier dates would be expected. Under this scenario, eggs produced by younger females that spawn later in the season, under more favorable temperature regimes, would be most likely to contribute recruits in most years. Our Potomac River results, and perhaps Upper Bay results, support the hypothesis that late-season spawning contributed disproportionately to recruitments. As the Chesapeake Bay striped bass stocks rebuild through adaptive management, and age structure shifts toward older ages, it will be important to determine how the probability of recruitment success is affected and whether older or younger females in the stock are most likely to contribute recruits.

The collapse of Chesapeake Bay striped bass stocks during the late 1970s and early 1980s caused shifts in age structure, initially toward dominance by older females because of failed recruitments and subsequently toward dominance by young females as older females declined in abundance and recent recruits, especially the 1982 year class, became the major contributors to egg production. Houde et al. (1988b, 1990) emphasized the relatively important contribution to egg production of a few old and highly fecund females in the Potomac River and Upper Bay. In 1987, 38% of Potomac River egg production was by > age 7 females which represented only 20% of the gillnet catch. The percentage egg production by > age 7 females declined in 1988 to 24%, contributed by only 6% of the females and then to 0% in 1989. In the Upper Bay, 11% of 1988 egg production was attributable to > age 7 females (less than 3% of the gillnet catch), which decreased to 7.5% in 1989 (females >7 were 3.0% of the gillnet catch). Because the 1982 year class remains relatively abundant, its contribution to egg production will continue to be important in the next few years and, presumably, the average quality of its eggs will increase as 1982 females continue to increase in size.

Striped bass spawning seasonality in the Chesapeake Bay varies among tributaries, and is strongly influenced by temperature (Kernehan et al. 1981; Uphoff 1989; Houde et al. 1990; Olney et al. 1991). Water temperatures exceeding 12°C generally occur before spawning begins (Setzler-Hamilton and Hall 1991) and spawning peaks often are associated with quickly rising temperatures (Olney et al. 1991). Peak spawning in the Potomac River occurred from 15 April to 10 May in 1987, 5 to 30 April in 1988 and 20 April to 22 May in 1989. Spawning occurs later in the Upper Bay because water temperatures are cooler there in April and early May. Upper Bay peak spawns occurred from approximately 1 May to 25 May in 1988 and from 25 April to 25 May in 1989. Setzler-Hamilton et al. (1980) reported that peak spawns in the Potomac during the 1970s had occurred in the third and fourth weeks of April, while Johnson and Koo (1975) and Kernehan et al. (1981) noted that peak spawns in the Upper Bay during the 1970s had occurred between 20 April and 10 May.

Temperature conditions and river discharges are dynamic and variable during the striped bass spawning season. Peak river discharges usually follow storms that also cause drops in water temperatures. The temperatures sometimes drop to 14°C, which can cause some mortality (Morgan et al. 1981), or may decline to <12°C, a lethal level for eggs and yolk-sac larvae (Setzler-Hamilton and Hall 1991). Such temperature declines caused complete or extensive mortalities of eggs and young larvae from peak Potomac River spawns in early to mid-April in 1987 and 1988. In each year the peak spawns had occurred before 20 April and no survivors were present in late-season collections that had hatch dates before the temperature events. In 1989, peak spawns in the Potomac did not occur until the last 10 days of April. Temperature did decline sharply to 12°C in the 1-10 May 1989 period, which apparently killed most larvae from the earlier hatches, although some survivors from those hatch dates were observed in Tucker trawl catches in early June. No 100% lethal temperature events were recorded in the Upper Bay in 1988 or 1989, although temperature drops to near 12°C from 1-10 May 1989 delayed peak spawning and were believed responsible for significant losses of eggs and yolk-sac larvae from earlier spawns. The temperature-mediated delay in peak spawning may have been fortuitous and could have been a significant factor leading to the successful recruitment in the Upper Bay, which appears to have resulted mostly from spawning that took place in the 20 May - 1 June 1989 period.

High river discharges after heavy rains are associated with falling temperatures in the spawning tributaries. Uphoff (1989) found that the Choptank River juvenile index from 1980-1985 was negatively correlated with minimum temperatures during peak spawning periods. Kernehan et al. (1981) observed sharp declines in abundance of Upper Bay eggs and larvae after low temperature events during the 1970s and postulated that these events had major impacts on recruitment success. Dey (1981) made similar observations on the Hudson River population in 1976, when a low temperature event killed all larvae hatched during early season peak spawns.

Episodic mortalities can be a major factor affecting striped bass recruitment levels, but they need not be catastrophic. Houde et al. (1988b) noted that >50% of the 1987 Potomac River egg production was eliminated by a low temperature event in mid-April. Nevertheless, the juvenile index value for the Potomac in 1987 equalled the 34-year mean, indicating favorable conditions for larvae growth and survival from secondary spawns in the 10-15 May period. This result indicates that successful recruitments to Chesapeake Bay striped bass stocks can result from temporally-restricted, favorable environmental conditions that support better than average survival and growth rates of a few larval cohorts. The subtle nature of such factors and their probable importance are not intuitively obvious although effects of such processes on recruitment levels can be demonstrated in a straightforward way (Houde 1989). For example, the 1987 episodic loss of eggs and larvae in the Potomac had no greater impact than would a 2.5% d^{-1} increase in mean larvae mortality rate have had in the absence of that temperature episode.

Spawning areas within the Potomac River and Upper Bay are quite consistent from year to year. Rainfall and river discharge appear to influence the distributions of eggs and larvae but do not cause major shifts in distribution. In the Potomac River, the greatest riverwide egg abundances in 1987-1989 were located in a 15-km segment bounded by the 1989 stations 2 through 6. Late-season, secondary spawning peaks, which contributed high percentages of potential recruits in each year, tended to occur approximately 10 km farther upstream, near Stations 8 and 9. Spawning areas in 1987-1989 were similar to Potomac River areas identified in the 1970s (Setzler-Hamilton et al. 1980; Ulanowicz and Polgar 1980).

Ulanowicz and Polgar (1980) were essentially correct in stating that the center of spawning activity in the Potomac varied little from year to year but that subsequent dispersal of eggs and larvae could be variable. Larvae distributions in the Potomac River generally shift downstream from the center of egg distributions. However, the centers of larvae distributions in each year were less than 10 km downstream from those of eggs. Larvae distributions were most restricted in 1988, when abundance was lowest, and were most dispersed in 1987, the year of highest abundance. In 1987, larvae were dispersed and common throughout the river segments represented by 1989 Stations 1 through 8, but they were common only at Stations 1 through 4 in 1988. In 1989, a year of intermediate abundance, larvae were most common in segments represented by Stations 1 through 4, but they also were abundant upstream in the segment represented by Station 9.

Spawning in the Upper Bay was most intense in 1988 and 1989 near the western end of the C&D Canal. Highest densities of eggs were found there in each of the years, as they were in surveys carried out in the 1970s (Johnson and Koo 1975; Kernehan et al. 1981). Because the volume of the Canal and its Elk River approach is a small fraction of the Upper Bay volume, egg abundances and production were higher in the Bay itself, within segments represented by the 1989 Stations 4, 6 and 7 in 1988 and by Stations 1-4 in 1989. The Elk River (Station 8) and C&D Canal (Station 9) were relatively important contributors to the Upper Bay total spawn in 1989 compared to 1988. In 1989, approximately 30% of the total spawn occurred in segments represented by Elk River - C&D Canal Stations 8 and 9, while only 12% occurred there in 1988.

The role of the Susquehanna Flats as a spawning area remains enigmatic. In 1988, we did not locate any areas of high egg abundance in the entire Upper Bay, but the Susquehanna Flats station area contributed significantly (17.5%) to the 1988 Upper Bay egg production. In 1989, when a heavy spawn occurred, the contribution of the Susquehanna Flats was minor (0.9%). In terms of mean density (no./100 m^3) or mean abundance (number under 1 m^2), egg numbers were low on the Susquehanna Flats, but its extensive area may allow significant egg production to occur there in some years. Neither Johnson and Koo (1975) nor Kernehan et al. (1981) thought that the Flats contributed significantly to striped bass egg production in the 1970s. Their conclusion may be correct, but there was spawning activity there in 1988 and 1989 and it contributed significantly to the Upper Bay total in 1988.

Upper Bay larvae distributions differed to a degree from the egg distributions. In 1989, larvae were most abundant in Bay segments represented by Stations 1 through 3, near the southern boundary of our sampling area (72%) and in the Elk River - C&D Canal segments (28%) (Stations 8 and 9), with virtually no larvae found in other Upper Bay areas. In contrast, most 1988 larvae were in segments represented by the 1989 Stations 2, 3, and 4 (62%) and only 4% of the 1988 larvae were in the Elk River - C&D Canal. Kernehan et al. (1981) reported that egg and larvae abundances in the Canal and its approaches were diluted by net transport toward and loss to the Delaware Bay. That assessment probably is correct, although the potential importance of such losses may vary from year to year, dependent upon the coincidence of spawning events and variable, weather-influenced hydrodynamics of the Canal. In neither 1988 nor 1989 were any larvae collected at the single Susquehanna Flats station, indicating that while some egg production occurs there, the Susquehanna Flats is not an important nursery area for Upper Bay striped bass larvae.

Striped bass larvae mean mortality rates in the Potomac River and Upper Bay were inversely related to abundances of late-stage larvae estimated from the Tucker trawl samples and to subsequent juvenile index values. In the Potomac River, the 1987 instantaneous larval mortality rate, based upon a stable-age distribution assumption, was lowest ($Z = 0.22 \pm 0.02$, 20% d^{-1}) when mean Tucker trawl densities were highest (19.90 larvae/1000 m^3) and the juvenile index value (6.4) approximated the long-term mean (6.2). In 1988, the mortality rate was highest ($Z = 0.34 \pm 0.17$, 29% d^{-1}), mean Tucker trawl density was lowest (0.05 larvae/1000 m^3) and the juvenile index was only 0.4. The 1989 mortality rate ($Z = 0.29 \pm 0.09$, 25% d^{-1}), Tucker trawl density (11.24 larvae/1000 m^3), and juvenile index (2.2) were intermediate between 1987 and 1988. In the Upper Bay in 1988, the stable-age distribution mortality rate was very high ($Z = 1.14 \pm 2.16$, 68% d^{-1}), and Tucker trawl mean densities (0.04 larvae/1000 m^3) and the juvenile index (7.3) were lower than comparable values in 1989 ($Z = 0.73 \pm 0.30$, 52% d^{-1}; Tucker trawl mean density 6.50 larvae/1000 m^3; juvenile index 19.6). The 1989 Upper Bay juvenile index was considerably higher than the long-term Upper Bay mean index of 12.4, and was the highest index observed there since 1974.

The magnitude of the observed difference in stable-age distribution mortality rates in both 1988 and 1989 between the Potomac ($Z = 0.34$ and 0.29, respectively) and Upper Bay (1.14 and 0.73, respectively) may be partly an artifact related to time of sampling. Because temperatures in Upper Bay waters warm later than in the Potomac and spawning peaks generally occur later in the Upper Bay, cohorts hatched during the last week of May or the first week of June, which may have experienced the most favorable survival and growth conditions, were undersampled in the Upper Bay by the 60-cm net surveys which were completed before 1 June. Only 15.7% of the striped bass eggs were collected after 20 May 1989 in the Potomac River and spawning was essentially completed there by 24 May, but 44% of the Upper Bay eggs were collected after 20 May 1989, indicating that significant spawning continued during the late May period when sampling was terminated. The larvae abundance estimates provided by the Tucker trawl in June, combined with the earlier 60-cm net collections, may have provided a reasonable estimate of abundance of those late-hatched cohorts, which were potential contributors to recruitment. In future surveys of striped bass larvae abundance, effort in the Upper Bay should continue routinely through the second week of June to insure that cohorts spawned late in the season are sampled. Kernehan et al. (1981) noted that some spawning occurred as late as July in the Upper Bay during the 1970's, although they reported that most egg production was completed by early June.

We were unable to demonstrate significant relationships between cohort-specific larvae mortality rates and growth rates, larvae cohort abundances, or any of the environmental parameters that we measured. Despite an increased frequency of sampling in 1989, the standard errors of the estimated cohort-specific mortality rates were as high as in previous years, and it was not possible to show statistically that mortality rates differed significantly among cohorts or years, although it seemed obvious that substantial differences did occur. The absence of a demonstrable response in cohort-specific mortality rates to abiotic or biotic factors is due to the high variability and low precision of abundance estimates of the larval cohorts.

If growth rates were inversely related to mortality rates, as they are in the laboratory (Chesney 1989; Daniel 1976; Rogers and Westin 1981; Tsai 1991), one would expect mortality rates of faster-growing cohorts hatched later in the season to be low. But, the temporal pattern of cohort mortality rates in the Potomac each year was an observed initial decrease, followed by an increase in the mortality rates. As river temperatures warmed, cohort growth rates increased, and presumably components of mortality affected by nutritional or other growth-related factors decreased. Further increases in temperature may have been associated with increased predator abundances or increased metabolic demands, which required higher consumption rates, until such effects countered the expected decrease in mortality rate associated with growth-related effects.

Whether cohort-specific mortalities have a temporal trend or not, the shorter stage durations experienced by faster-growing cohorts will tend to reduce their cumulative mortality and thus enhance their potential contribution to recruitment. The mean annual mortality rates of combined Potomac River striped bass larvae cohorts were inversely correlated with both annual mean larval growth rate and the juvenile index. This result indicates that effects of growth on mortality at the individual cohort level is difficult to evaluate but that such effects do operate and can be discerned when cohorts are aggregated and annual mean effects are analyzed.

A comparable estimate of mean larvae mortality rate in the Potomac River, based upon a stable-age distribution assumption, was obtained by Polgar (1977) for 1974 striped bass. Stable-age distribution mortalities of yolk-sac and finfold larvae were $Z = 0.32$ and 0.13, respectively, which are in the range of cohort-specific mortality rates that we estimated for 1987 - 1989. Polgar's (1977) estimates were based on assumed average durations between developmental stages. Dey (1981) reported mortality rates for Hudson River striped bass larvae of $Z = 0.19$ and 0.16 during 1975 and 1976. Stable-age distribution mortality rates of Sacramento-San Joaquin River striped bass ranged from $Z = 0.21 - 0.32$ for the 7-year period 1978-1986 (Low 1986).

Uphoff (1989) estimated that mean annual mortality rates, based upon the stable-age distribution assumption, for Choptank River striped bass larvae 6-12 mm TL ranged from $Z = 0.06-0.21$ for the 1980-1985 period, rates generally lower than the mean rates we have estimated for the Potomac River and Upper Bay. In the Choptank River, discharge was positively correlated and temperature was negatively correlated with annual mortality rate. Mean annual instantaneous mortality rate of Choptank River larvae was negatively correlated ($r^2 = 0.71$, $n = 6$) with mean annual growth rate (Uphoff 1989), a result similar to that observed during 1987 - 1989 on the Potomac River.

The observed mean annual growth rates of Potomac River and Upper Bay striped bass larvae were positively related to temperatures experienced during the first 20 days posthatch. In both 1988 and 1989, 38% of the Potomac River cohorts grew at rates <0.20 mm d^{-1}, but only 20% of cohorts grew that slowly in 1987. Mean temperatures experienced by most cohorts during their first 20 days posthatch were lower in 1988 and 1989 than in 1987. Cohort-specific growth rates of Upper Bay striped bass larvae were among the highest observed in either area, and they bore the same relationship to temperature as did Potomac River cohorts, increasing by an estimated 0.02 mm d^{-1} for each 1.0 degree rise in temperature. The consistency of the linear response of striped bass growth-in-length rates with respect to temperature is notable, especially considering the wide range between areas and among years of observed temperatures and the wide range in densities of zooplankton that can serve as larval food.

Similar relationships between annual growth rates of striped bass larvae and temperatures were reported earlier for the Potomac River (Setzler-Hamilton et al. 1980; Martin and Setzler-Hamilton 1983), the Choptank River (Uphoff 1989), the Hudson River (Dey 1981), and the Sacramento-San Joaquin River (Low 1986). Temperature effects on growth also were documented in laboratory studies (Rogers et al. 1977; Rogers and Westin 1981). Mean lengths of surviving Potomac River striped bass larvae in 1924, 1977 and 1980-1982, at the end of May, were longest in 1977 and 1982 when temperatures were highest (Setzler-Hamilton et al. 1980b; Martin and Setzler-Hamilton 1983).

Uphoff's (1989) mean growth rates of Choptank River striped bass larvae from 1981 - 1986, estimated from modes of larval length-frequency distributions, were higher (0.37 - 0.56 mm d^{-1}) than our Potomac River and Upper Bay estimates for similar temperature ranges and lengths. Estimated larval growth rates, back-calculated from otolith-aged South Carolina striped bass juveniles in 1987, also were higher (0.35 - 0.68 mm d^{-1}) than our estimates (Secor 1990). Larval growth rates of Hudson River striped bass larvae in 1973-1976, estimated from the increase in mean length observed from a designated mean hatch date to 15 July, were 0.10 - 0.20 mm d^{-1} (Dey 1981). Mean annual growth rates estimated from modes in length frequency distributions of striped bass larvae in 1978 - 1986 in the Sacramento - San Joaquin Rivers ranged from 0.29 to 0.46 mm d^{-1} (Low 1986).

The absence of a statistically significant effect of variable prey concentration on cohort-specific growth, survival, and abundance at 8.0 mm was surprising because estimated zooplankton densities were highest in the Potomac River and Upper Bay in years when annual mean growth rates, survival rates, and the juvenile index values were highest. Previous studies of Potomac River striped bass larvae in 1976-77 and 1980-82 indicated fastest growth occurred in 1977 and 1982 when zooplankton densities and temperatures were highest (Martin and Setzler-Hamilton 1983). However, the 1982 juvenile index was better than average, while the 1977 juvenile index was poor (Early et al. 1990). The importance of zooplankton density as a factor affecting striped bass larvae vital rates, abundances and recruitment success has been debated in the literature without resolution for many years.

It has been demonstrated in the laboratory that growth and survival of striped bass larvae increase with increasing prey concentrations (Daniel 1976, Miller 1976; Rogers and Westin 1981; Chesney 1989; Tsai 1991). Results of early laboratory studies on feeding indicated that good larval growth and survival were obtained only at prey densities much higher than were normally observed in nature (Miller 1976), and led to speculation that most striped bass larvae would starve at ambient prey concentrations (Martin et al. 1985; Setzler-Hamilton et al. 1980b), unless they encountered patches of higher prey concentrations. Studies by Houde and Lubbers (1986), Chesney (1989), and Tsai

(1991) have demonstrated that striped bass larvae can grow well and survive at the modest prey densities (100 zooplanktors/ℓ) commonly observed in Chesapeake Bay tributaries. Although higher growth rates than those we estimated for Potomac River and Upper Bay larvae have been reported in some laboratory studies (Rogers 1978, as cited in Boreman 1983) under similar mean temperature and prey level conditions, such results might be an artifact of the particular culture method that was used. When striped bass larvae were cultured at 19°C, at a prey level of 100 copepods/ℓ, under light, turbidity and turbulence levels found in the wild, they grew at a mean rate of 0.28 mm d^{-1} (Chesney 1989), which is similar to rates estimated in our study.

The strong correlation between striped bass larvae growth and temperature, combined with the ability of larvae to survive periods of apparently suboptimal prey densities, may have obscured any effect of prey density on cohort-specific growth rate. In the 1987 Potomac River and the 1989 Upper Bay 1989 seasons, when high growth rates of striped bass larvae were observed, zooplankton densities increased as the season progressed and were correlated with temperature. In the 1988 and 1989 Potomac River seasons, zooplankton densities were not significantly correlated with temperature, yet growth rates of larval cohorts did not differ significantly from the 1987 rates at similar temperatures. Striped bass larvae are highly resistant to starvation, and in laboratory studies newly-hatched larvae can survive for up to 3 weeks without food (Eldridge et al. 1981; Rogers and Westin 1981). Although striped bass larvae that were starved initially for a few days may not overcome the size advantage gained by those which have fed continuously (Rogers and Westin 1981), starved larvae can commence feeding and grow well if prey concentrations increase. Eldridge et al. (1981) did find that striped bass larvae could overcome initial periods of starvation. They reported that survival rates and lengths were similar at 31 days for larvae deprived of food from 7 to 18 days after fertilization. However, larval weights at 31 days were inversely correlated with starvation times, and reflected effects of starvation more clearly than did lengths or survival rates (Eldridge et al. 1981).

It is possible that the lack of a relationship between temperature-adjusted, cohort-specific growth rates and prey densities may be an artifact of back-calculating growth rates from mostly older, surviving larvae. Growth rates of larval survivors may have been higher than growth rates of larvae which died, effectively obscuring any effect of lower prey densities on growth. Because otoliths had deteriorated in small larvae that were collected in both 1988 and 1989, only the older and larger larvae provided otoliths to back-calculate growth rates in these years.

Cohort-specific abundances of 8.0 mm striped bass larvae, estimated from the 60-cm net collections in the Potomac River, generally corresponded to mean larvae vital rates, and to recruitment levels predicted by the juvenile index in 1987-1989 (Table 51). In the Potomac River, despite similar egg productions and mean growth rates in 1987 and 1989, the 1987 larval mortality rate was lower and, consequently, the G/Z ratio was higher. As a result, larvae abundance at 8.0 mm SL was higher and the juvenile index was higher in 1987 than in 1989. In 1988, the lowest Potomac River egg production, mean larval growth rate and survival rate resulted in the lowest G/Z ratio in the three years and, consequently, the lowest abundance of 8.0 mm larvae as well as the lowest juvenile index. The lack of reliable growth data for the Upper Bay striped bass larvae in 1988 precluded a detailed comparison of vital rates, egg production and recruitment levels between 1988 and 1989 (Table 51). In 1989, mortality rate was lower and egg production ten-fold higher, probable factors that led to the higher Upper Bay recruitment index in 1989.

Indications that striped bass recruitment level is fixed by the early

Table 51. Potomac River and Upper Bay. Mean instantaneous larval growth-in-weight rates (G), stable-age instantaneous larval mortality rates (Z), G/Z ratios, egg productions and larval abundances at 8.0 mm SL. Also given are striped bass juvenile index values (from MD DNR 1991). "n.d." = no data.

	YEAR		G (d-1)	Z (d-1)	G/Z (d-1)	Egg Production (X10^9)	Summed Cohort Abundance (X10^6) at 8.0 mm SL	Juvenile Index
Potomac	1987	stable-age	0.17	0.22	0.74	9.47	180.9	6.4
		cohorts' range	0.14-0.22	0.08-0.39	0.41-1.96			
	1988	stable-age	0.15	0.34	0.44	6.65	22.9	0.4
		cohorts' range	0.13-0.18	0.05-0.46	0.33-1.02			
	1989	stable-age	0.17	0.29	0.59	11.33	44.6	2.2
		cohorts' range	0.10-0.22	0.10-1.04	0.16-1.57			
Upper Bay	1988	stable-age	n.d.	1.14	n.d.	1.78	n.d.	7.3
		cohorts' range	n.d.	n.d.	n.d.		n.d.	
	1989	stable-age	0.19	0.73	0.26	14.57	48.7	19.4
		cohorts' range	0.14-0.21	0.22-0.94	0.21-0.86			

postlarval stage (8.0-10.0 mm TL) have come from research on populations in the Choptank River (Uphoff 1989) and in California (Low 1986). Uphoff (1989) found a correlation coefficient of r ≥0.90 between abundance of ≥10.0 mm TL larvae and the Choptank River juvenile index 1980-1985. Low (1986) found that abundances of Sacramento-San Joaquin River striped bass larvae ≥8.0 mm TL were correlated significantly with catches of >38 mm TL juveniles in 1978-1986. Correlations between recruitment indices and postlarval abundance at 8.0 - 10.0 mm TL may be related to a decline of mortality rates coincident with notochord flexion, and development and ossification of fin rays and spines, which begin at this stage (Fritzsche and Johnson 1980; Olney et al. 1983) and which probably increase swimming and feeding ability of larvae as well as their ability to avoid predators.

The difference in mean temperatures between 1987, 1988 and 1989 in the Potomac River would be expected to result in significant differences in production of 8.0 mm larvae and recruitment. If initial larvae abundances had been 10 billion and larval mortality rates had been the same in each year (Z = 0.25), the 2.6°C difference in mean temperature observed in the 20 April - 5 June period in 1987-1989 would have been expected to result in a 1.8-fold difference in larval abundance at 8.0 mm, due solely to temperature effects on stage duration. The 4°C difference in mean temperature in 1987 - 1989 experienced by Potomac River larval cohorts which survived to at least 20 days (Table 52A) would account for a 2.5-fold difference in abundance of 8.0 mm larvae. The strong positive influence of temperature on larval growth rate (Figure 46) would be expected to result in an average increase of 13 million, 8.0 mm larvae for each 1°C rise in mean temperature between 13 and 23°C. At temperatures higher than the optimum range of 18-21°C for yolk-sac larvae or 21-24°C for post-yolk sac larvae growth (Rogers et al. 1977), mortality might increase due to increased metabolic costs or stress, and might negate the positive benefit of shorter stage durations at high temperatures.

An influence of temperature on production of 8.0 mm larvae cohorts was evident in all years in the Potomac River and Upper Bay (Figures 57 and 58). Cohorts hatched early in the season produced few recruits despite high egg productions, particularly in 1987 and 1988. Temperatures in all 3 years in the Potomac River and the Upper Bay in 1989 dropped near to or below 12°C early in the season, and undoubtedly played a role in the low contributions to recruitment by early-season cohorts through either episodic mortalities, or through lower growth rates and longer stage durations, which would increase cumulative mortalities. Cohorts hatched towards the end of the spawning season experienced higher temperatures, had higher growth rates, and contributed more to recruitment, despite lower egg production, than did cohorts hatched earlier (Figures 57 and 58). The mismatch that indicated high, early-season egg production often occurring at times when environmental conditions were unfavorable for growth and survival was noted previously for the Potomac River (Ulanowicz and Polgar 1980), Upper Bay (Kernehan et al. 1981) and Hudson River striped bass stocks (Dey 1981).

In years of poor recruitment, factors that contributed to higher larval mortality rates may be more influential than factors that affected growth. In the Potomac River 1988 and 1989, years of poor recruitment, larval cohort abundances at 8.0 mm were correlated significantly with cohort mortality rates, but not with larval growth rates. In the Potomac River 1987 and the Upper Bay 1989, years of average and above-average recruitments, respectively, larval cohort abundances at 8.0 mm were significantly correlated with cohort-specific larval growth rates, but not larval mortality rates.

Although episodic mortalities due to temperature or pH can dramatically alter the initial abundances of eggs and larvae in any year, subtle differences in environmental conditions may be at least as important in

POTOMAC RIVER 1987 STRIPED BASS
TEMPERATURE, SPAWNING, & 8 mm LARVAE

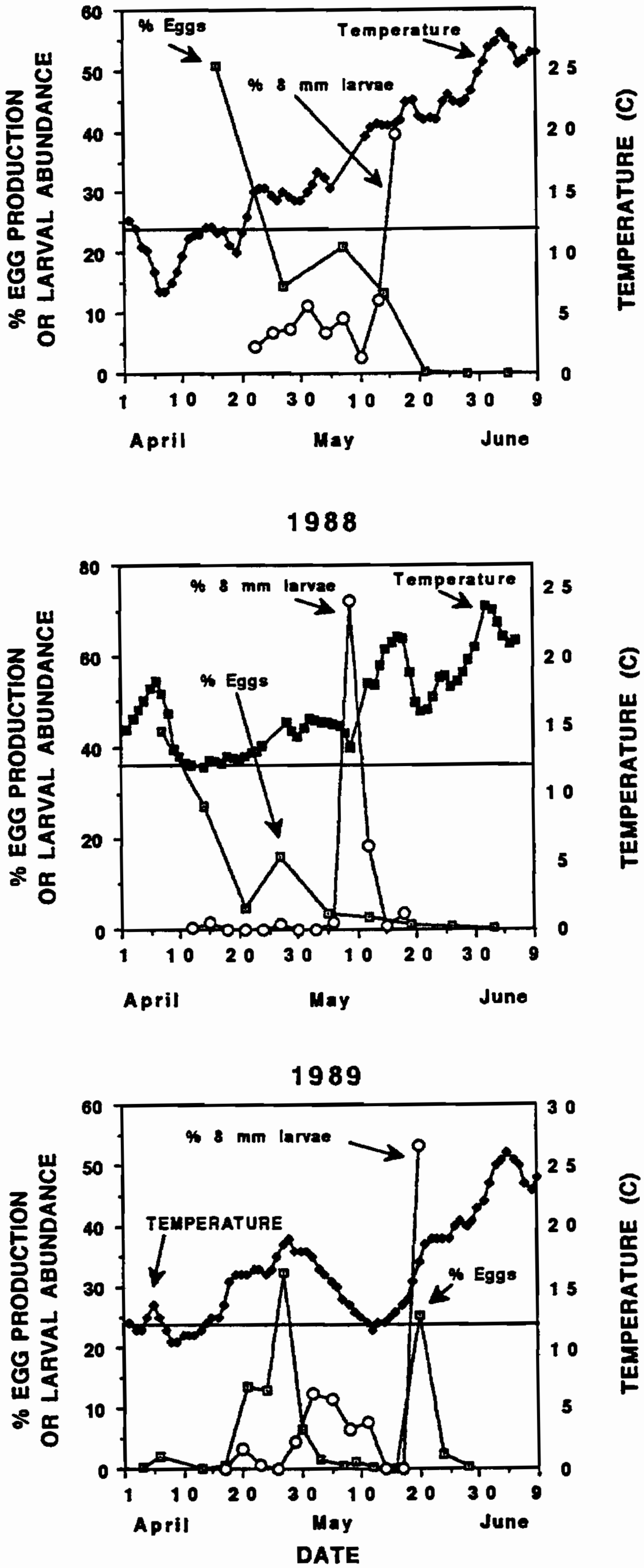


Figure 57. Potomac River, 1987-1989. River temperatures at Wilson Bridge, percent egg production, and percent estimated abundance by hatch dates of striped bass larvae at 8.0 mm SL in 3-day cohorts from egg production in A. 1987. B. 1988. C. 1988. Larval abundances at 8.0 mm were estimated from 60-cm net samples. A horizontal line indicates the 12°C critical low temperature at which 100% mortality of egg and yolk-sac larvae may occur.

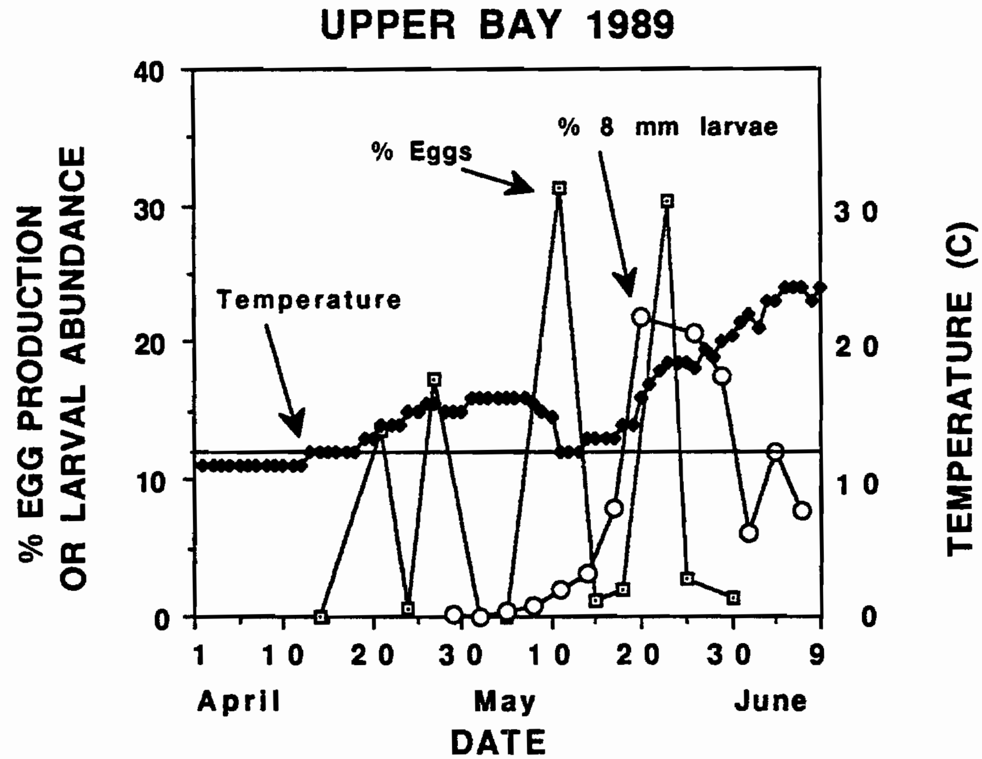


Figure 58. Upper Bay, 1989. River temperatures at Conowingo Dam, percent egg production, and percent estimated abundance by hatch dates of striped bass larvae at 8.0 mm SL in 3-day cohorts from that egg production. Larval abundances at 8.0 mm were estimated from 60-cm net and 2 m² Tucker trawl samples. A horizontal line indicates the 12°C critical low temperature at which 100% mortality of egg and yolk-sac larvae may occur.

shaping year-class strength (Houde 1989; Houde et al. 1990). Because of collinearity among many of the environmental and striped bass egg/larvae variables, it was difficult to identify any single factor as the cause of recruitment variability in either the Potomac River or the Upper Bay. The variables associated with higher recruitments from 1987-1989 may have differed in the Potomac and in the Upper Bay. Examining the mean estimates of measured environmental parameters experienced by surviving larvae cohorts during the first 20 days posthatch (Tables 52A and 52B) indicates that in the Potomac River in 1987, when mean larvae growth rate, mean larvae survival rate, and recruitment level were the highest of the three years, environmental variables were significantly different from 1988 or 1989. Mean temperature, turbidity, pH, and zooplankton density all were highest in 1987, while mean rainfall and river discharge were lower. Mean cohort egg abundances and initial larval abundances were not significantly different among the three years. Abundances and densities of potentially competitive white perch larvae were highest in 1987, suggesting that the same environmental conditions favorable for striped bass larvae survival and growth also may favor white perch recruitment success.

In the Upper Bay, where the 1989 juvenile index was nearly 3 times as high as the 1988 index, the greatest measurable difference between years was in egg production. Mean egg production of cohorts that survived to 8.0 mm SL was an order-of magnitude higher in 1989 than in 1988 (Table 52B). There were no significant differences between 1988 and 1989 in most of the environmental variables measured in the Upper Bay. Mean temperature, river discharge and conductivity were very similar in each year. Mean rainfall and pH were higher in 1989 than in 1988.

Compared to the Potomac River in 1987 - 1989, mean densities of zooplankton taxa (except cladocerans) available to surviving striped bass

Table 52a. Potomac River 1987-1989. Means and standard errors of environmental variables, zooplankton densities, densities of striped bass larvae, and Morone species larvae averaged over the first 20 days posthatch of observed 3-day striped bass larvae cohorts, and mean cohort egg abundances and initial striped bass larval abundances of surviving 3-day cohorts.

		1987	1988	1989
Temperature	mean	21.38	17.78	17.27
	s.e.	0.83	0.79	0.75
Total Discharge (cfs)	mean	273837	730266	607436
	s.e.	71343	85744	64308
pH	mean	7.54	7.21	7.05
	s.e.	0.04	0.04	0.03
Turbidity (ntu)	mean	31.0	17.4	______
	s.e.	2.6	3.1	
Conductivity (micro-ohms)	mean	______	660.0	117.1
	s.e.		67.8	87.8
Rainfall (inches)	mean	1.69	2.72	4.32
	s.e.	0.32	0.37	0.30
Cladoceran Density (#/l)	mean	83.9	13.1	8.9
	s.e.	9.7	11.1	8.8
Copepod Density (#/l)	mean	15.5	3.2	9.0
	s.e.	2.3	2.8	2.1
Rotifer Density (#/l)	mean	449.8	57.4	24.4
	s.e.	50.6	60.8	45.6
Nauplii Density (#/l)	mean	78.8	35.2	14.9
	s.e.	5.4	6.4	4.8
Striped Bass Density (#/100m3)	mean	93.6	7.0	78.3
	s.e.	16.1	19.4	14.5
Morone Larvae Density (#/100m3)	mean	480.4	151.7	367.6
	s.e.	56.4	67.8	50.8
Egg Abundance (x10^6)	mean	198.6	243.6	557.8
	s.e.	293.3	293.2	175.3
Initial Larval Abundance (x10^6)	mean	1215.2	256.0	8720.3
	s.e.	4458.1	5460.1	4283.2

Table 52b. Upper Bay 1988-1989. Means and standard errors of environmental variables, zooplankton densities, densities of striped bass larvae, and Morone species larvae averaged over the first 20 days posthatch of observed 3-day striped bass larvae cohorts, and mean cohort egg abundances and initial striped bass larval abundances of surviving 3-day cohorts.

		1988	1989
Temperature	mean	20.25	20.04
	s.e.	0.87	0.73
Total Discharge	mean	1530281	1770238
(cfs)	s.e.	306346	254895
pH	mean	6.90	7.07
	s.e.	0.04	0.04
Turbidity	mean	16.0	______
(ntu)	s.e.	0.9	
Conductivity	mean	862.4	821.5
(micro-ohms)	s.e.	156.4	130.1
Rainfall	mean	1.99	5.13
(inches)	s.e.	0.39	0.32
Cladoceran Density	mean	______	7.4
(#/l)	s.e.		1.3
Copepod Density	mean	______	12.8
(#/l)	s.e.		1.1
Rotifer Density	mean	______	149.9
(#/l)	s.e.		31.5
Nauplii Density	mean	______	70.6
(#/l)	s.e.		9.1
Striped Bass	mean	13.4	115.7
Density (#/100m3)	s.e.	17.4	15.7
Morone Larvae	mean	48.4	337.2
Density (#/100m3)	s.e.	60.4	54.6
Egg Abundance	mean	74.6	841.5
(x10^6)	s.e.	322.5	272.5
Initial Larval	mean	______	781.9
Abundance (x10^6)	s.e.		687.8

cohorts in the Upper Bay in 1989 were second only to densities estimated in the Potomac River during 1987 (Tables 52A and 52B). Upper Bay mean pH was lower than in the Potomac in 1988 but equal in 1989. Mean turbidity did not differ between the areas in 1988.

Statistical analyses of striped bass recruitment variability repeatedly have identified environmental conditions, specifically temperature and cumulative river discharge, preceding or during the spawning season, as being associated with year-class variability in the Chesapeake Bay (Setzler-Hamilton et al. 1980b; Kohlenstein 1980; Polgar et al. 1985; Summers and Rose 1987; Uphoff 1989), in the Hudson River (Polgar et al. 1985; Summers and Rose 1987) and in the Sacramento-San Joaquin Rivers (Stevens 1977). Analyses that correlate recruitment variability with environmental variables and adult stock size date from Merriman's (1941) observation that strong striped bass year classes often followed cold winters, and occurred when adult stock sizes were low. Setzler-Hamilton et al. (1980b) regressed the Potomac River juvenile index on mean monthly air temperatures in November through March and cumulative river flows in March through June. They reported that recruitment was negatively correlated with cold December air temperatures and positively correlated with high cumulative river discharge in April.

Kohlenstein (1980) fit a stock-recruitment model to Potomac River juvenile index data and found that, although cold December air temperatures and high April river discharges explained most (47-66%) of the variability in the juvenile index, spawning stock biomass explained an additional 10-26%, depending upon the time series (1954-1978, 1962-1978, 1964-1978, 1966-1978) examined. The proportion of variance in recruitment explained by spawning stock size was highest at low spawning stock levels. Polgar et al. (1985) correlated Potomac River striped bass landings with air temperatures during December, March and April, and cumulative river discharges during April of the year when the fish were hatched, and reported significant positive relationships with April temperatures and river discharges. Summers and Rose (1987) found that adult stock size as well as April air temperatures and river discharges during the year of hatch were highly correlated ($r^2 = 0.72$) with lagged striped bass landings.

It is evident from our research that conditions which enhance larval growth rate and survival rate in the period from hatch to approximately 8.0 mm SL can enhance recruitment. In the Potomac River, relatively warm temperatures during peak spawns in April, and high production of zooplankton prey during periods of peak larvae production, were associated with high larval growth rate, high larval survival, and high Potomac River recruitment in 1987-1989 period. In the Upper Bay, temperatures and other factors favorable for larval growth may occur later, during May. Despite the apparent dominant influence of temperature on striped bass recruitment and recruitment variability, the probable importance of spawning stock biomass to recruitment must not be underestimated. In the Upper Bay, when the temperature regimes experienced by surviving 1988 and 1989 cohorts were similar, the higher recruitment in 1989 resulted from a much higher egg production.

High river discharge during April has been proposed to positively influence Potomac River striped bass recruitment either by keeping negatively-buoyant eggs afloat, thereby reducing egg mortality (Albrecht 1964), or by increasing nutrient loadings to the nursery area, and stimulating production of zooplankton prey (Heinle et al. 1976, Tsai et al. 1991). Our results indicate that the timing of discharge events in April and their relationship to other environmental factors, as well as peak spawns in that month, all will interact to influence survivorship and recruitment potential. Although cumulative April Potomac River discharge was highest in 1987, the year of highest recruitment, most of the April discharge occurred in the 1-23

April period (Houde et al. 1988a), and coincided with the sudden drop in temperature to below 12°C which killed over 50% of the total egg production. The cumulative May discharge in the Potomac River was lower in 1987 than in 1988 or 1989, and total discharges during the first 20 days posthatch experienced by surviving larvae cohorts were lowest in 1987 (Table 52A). River discharges were not correlated significantly with larvae cohort-specific growth rates, mortality rates or cohort abundances at 8.0 mm SL. Uphoff (1989) found that Choptank River flow was positively correlated with postlarval mortality from 1980-1985, although the 1989 juvenile index, the highest recruitment index ever recorded in the Choptank River (Early et al. 1990), coincided with monthly river flows in April through June that were 2-6 times above average. In the Sacramento-San Joaquin Rivers, where critically low flows occur, cumulative flow during the striped bass spawning season was positively associated with recruitment success (Stevens 1977).

We examined our data for potential density-dependent effects on larval growth or mortality rate, but none were detected in any of the three years. Neither the mean nor maximum density or abundance of striped bass or white perch larvae significantly affected striped bass larvae cohort-specific growth or mortality rates, or cohort survival at 8.0 mm. The diets of striped bass and white perch larvae do overlap in the 5.0 - 7.0 mm length range (Beaven and Mihursky 1979; Takacs 1992), and, if larval densities were high enough, competition for limited prey resources might lead to density-dependent growth effects. It is possible that density-dependent effects on growth or mortality cannot be detected unless spawning biomass of striped bass exceeds a high threshold level, or the combined white perch and striped bass spawning stocks are high enough to saturate Bay tributaries with larvae. Such conditions could lead to competitive feeding between larvae of the two species, and consequently, a density-dependent response in survival or growth. Because environmental conditions are dynamic and variable in striped bass spawning/nursery areas, only long-time series of egg productions, larval abundances and larval vital rates are likely to reveal whether density-dependent factors are important regulators of early life processes that affect year-class success in Chesapeake Bay.

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Appendix Table 1A. Potomac River, 1989. Survey 1. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 3 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	1	0	1	0	0	0
		DENSITY	0.99	0.00	0.99	0.00	0.00	0.00
		MEAN DENS.	0.50	0.00	0.49	0.00	0.00	0.00
3	1	NUMBER	2	0	2	0	0	0
		DENSITY	1.96	0.00	1.96	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.98	0.00	0.98	0.00	0.00	0.00
4	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	3	0	1	0	2	0
		DENSITY	2.73	0.00	0.91	0.00	1.82	0.00
		MEAN DENS.	1.36	0.00	0.45	0.00	0.91	0.00
6	1	NUMBER	1	0	0	0	1	13
		DENSITY	0.88	0.00	0.00	0.00	0.88	11.50
	2	NUMBER	9	0	3	5	1	6
		DENSITY	7.89	0.00	2.63	4.39	0.88	5.26
		MEAN DENS.	4.39	0.00	1.32	2.19	0.88	8.38
7	1	NUMBER	14	0	13	1	0	31
		DENSITY	13.59	0.00	12.62	0.97	0.00	30.10
	2	NUMBER	2	0	2	0	0	4
		DENSITY	1.74	0.00	1.74	0.00	0.00	3.48
		MEAN DENS.	7.67	0.00	7.18	0.49	0.00	16.79

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
8	1	NUMBER	60	0	55	0	5	8
		DENSITY	45.80	0.00	41.98	0.00	3.82	6.11
	2	NUMBER	34	0	30	0	4	4
		DENSITY	34.34	0.00	30.30	0.00	4.04	4.04
		MEAN DENS.	40.07	0.00	36.14	0.00	3.93	5.07
9	1	NUMBER	594	0	590	1	3	0
		DENSITY	550.00	0.00	546.30	0.93	2.78	0.00
	2	NUMBER	519	0	514	2	3	0
		DENSITY	489.62	0.00	484.91	1.89	2.83	0.00
		MEAN DENS.	519.81	0.00	515.60	1.41	2.80	0.00
10	1	NUMBER	613	0	607	1	5	0
		DENSITY	583.81	0.00	578.10	0.95	4.76	0.00
	2	NUMBER	791	0	786	0	5	0
		DENSITY	841.49	0.00	836.17	0.00	5.32	0.00
		MEAN DENS.	712.65	0.00	707.13	0.48	5.04	0.00
11	1	NUMBER	810	0	807	0	3	0
		DENSITY	952.94	0.00	949.41	0.00	3.53	0.00
	2	NUMBER	414	0	414	0	0	0
		DENSITY	422.45	0.00	422.45	0.00	0.00	0.00
		MEAN DENS.	687.70	0.00	685.93	0.00	1.76	0.00
		TOTAL NUMBER	3867	0	3825	10	32	66
		MEAN DENSITY OVER STATIONS	219.46	0.00	217.25	0.15	1.70	3.36

Appendix Table 2A. Potomac River, 1989. Survey 2. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 6 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	63	3	57	2	1	2
		DENSITY	66.32	3.16	60.00	2.11	1.05	2.11
	2	NUMBER	30	2	26	0	2	7
		DENSITY	30.30	2.02	26.26	0.00	2.02	7.07
		MEAN DENS.	48.31	2.59	43.13	1.05	1.54	4.59
2	1	NUMBER	283	0	280	1	2	8
		DENSITY	304.30	0.00	301.08	1.08	2.15	8.60
	2	NUMBER	320	2	316	1	1	2
		DENSITY	344.09	2.15	339.78	1.08	1.08	2.15
		MEAN DENS.	324.19	1.08	320.43	1.08	1.61	5.38
3	1	NUMBER	775	0	773	0	2	25
		DENSITY	861.11	0.00	858.89	0.00	2.22	27.78
	2	NUMBER	797	1	793	0	3	7
		DENSITY	838.95	1.05	834.74	0.00	3.16	7.37
		MEAN DENS.	850.03	0.53	846.81	0.00	2.69	17.57
4	1	NUMBER	724	0	722	1	1	71
		DENSITY	778.49	0.00	776.34	1.08	1.08	76.34
	2	NUMBER	541	2	539	0	0	58
		DENSITY	651.81	2.41	649.40	0.00	0.00	69.88
		MEAN DENS.	715.15	1.20	712.87	0.54	0.54	73.11
5	1	NUMBER	1145	0	1143	2	0	1
		DENSITY	1301.14	0.00	1298.86	2.27	0.00	1.14
	2	NUMBER	1329	1	1324	0	4	6
		DENSITY	1545.35	1.16	1539.53	0.00	4.65	6.98
		MEAN DENS.	1423.24	0.58	1419.20	1.14	2.33	4.06

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	835	0	829	0	6	0
		DENSITY	1113.33	0.00	1105.33	0.00	8.00	0.00
	2	NUMBER	899	0	894	0	5	3
		DENSITY	977.17	0.00	971.74	0.00	5.43	3.26
		MEAN DENS.	1045.25	0.00	1038.54	0.00	6.72	1.63
7	1	NUMBER	783	0	780	0	3	3
		DENSITY	889.77	0.00	886.36	0.00	3.41	3.41
	2	NUMBER	970	0	965	0	5	15
		DENSITY	1089.89	0.00	1084.27	0.00	5.62	16.85
		MEAN DENS.	989.83	0.00	985.32	0.00	4.51	10.13
8	1	NUMBER	617	0	607	0	10	38
		DENSITY	678.02	0.00	667.03	0.00	10.99	41.76
	2	NUMBER	597	0	586	11	0	64
		DENSITY	678.41	0.00	665.91	12.50	0.00	72.73
		MEAN DENS.	678.22	0.00	666.47	6.25	5.49	57.24
9	1	NUMBER	1857	3	1824	4	26	0
		DENSITY	1954.74	3.16	1920.00	4.21	27.37	0.00
	2	NUMBER	309	0	301	0	8	2
		DENSITY	372.29	0.00	362.65	0.00	9.64	2.41
		MEAN DENS.	1163.51	1.58	1141.33	2.11	18.50	1.20
		TOTAL NUMBER	12874	14	12759	22	79	312
		MEAN DENSITY OVER STATIONS	804.19	0.84	797.12	1.35	4.88	19.44

Appendix Table 3A. Potomac River, 1989. Survey 3. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 13 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	1	0	1	0	0	0
		DENSITY	0.94	0.00	0.94	0.00	0.00	0.00
	2	NUMBER	3	1	2	0	0	0
		DENSITY	3.00	1.00	2.00	0.00	0.00	0.00
		MEAN DENS.	1.97	0.50	1.47	0.00	0.00	0.00
2	1	NUMBER	133	0	124	8	1	0
		DENSITY	131.68	0.00	122.77	7.92	0.99	0.00
	2	NUMBER	408	0	404	1	3	0
		DENSITY	408.00	0.00	404.00	1.00	3.00	0.00
		MEAN DENS.	269.84	0.00	263.39	4.46	2.00	0.00
3	1	NUMBER	414	0	410	4	0	0
		DENSITY	414.00	0.00	410.00	4.00	0.00	0.00
	2	NUMBER	903	0	902	0	1	2
		DENSITY	876.70	0.00	875.73	0.00	0.97	1.94
		MEAN DENS.	645.35	0.00	642.86	2.00	0.49	0.97
4	1	NUMBER	504	0	494	3	7	10
		DENSITY	592.94	0.00	581.18	3.53	8.24	11.76
	2	NUMBER	918	0	889	7	22	10
		DENSITY	987.10	0.00	955.91	7.53	23.66	10.75
		MEAN DENS.	790.02	0.00	768.55	5.53	15.95	11.26
5	1	NUMBER	368	0	360	1	7	1
		DENSITY	328.57	0.00	321.43	0.89	6.25	0.89
	2	NUMBER	391	0	384	3	4	1
		DENSITY	379.61	0.00	372.82	2.91	3.88	0.97
		MEAN DENS.	354.09	0.00	347.12	1.90	5.07	0.93

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	392	0	370	17	5	0
		DENSITY	350.00	0.00	330.36	15.18	4.46	0.00
	2	NUMBER	196	0	175	15	6	0
		DENSITY	178.18	0.00	159.09	13.64	5.45	0.00
		MEAN DENS.	264.09	0.00	244.72	14.41	4.96	0.00
7	1	NUMBER	851	1	837	6	7	0
		DENSITY	895.79	1.05	881.05	6.32	7.37	0.00
	2	NUMBER	690	0	658	18	14	0
		DENSITY	633.03	0.00	603.67	16.51	12.84	0.00
		MEAN DENS.	764.41	0.53	742.36	11.41	10.11	0.00
8	1	NUMBER	478	0	438	19	21	0
		DENSITY	459.62	0.00	421.15	18.27	20.19	0.00
	2	NUMBER	475	0	449	16	10	0
		DENSITY	465.69	0.00	440.20	15.69	9.80	0.00
		MEAN DENS.	462.65	0.00	430.67	16.98	15.00	0.00
9	1	NUMBER	397	0	369	15	13	2
		DENSITY	413.54	0.00	384.38	15.63	13.54	2.08
	2	NUMBER	99	0	85	12	2	0
		DENSITY	95.19	0.00	81.73	11.54	1.92	0.00
		MEAN DENS.	254.37	0.00	233.05	13.58	7.73	1.04
		TOTAL NUMBER	7621	2	7351	145	123	26
		MEAN DENSITY OVER STATIONS	422.98	0.11	408.24	7.81	6.81	1.58

Appendix Table 4A. Potomac River, 1989. Survey 4. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 17 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.00	0.00	0.00	0.00	0.00	0.00
2	1	NUMBER	38	0	35	2	1	0
		DENSITY	44.19	0.00	40.70	2.33	1.16	0.00
	2	NUMBER	29	0	29	0	0	0
		DENSITY	34.12	0.00	34.12	0.00	0.00	0.00
		MEAN DENS.	39.15	0.00	37.41	1.16	0.58	0.00
3	1	NUMBER	671	1	666	3	1	4
		DENSITY	860.26	1.28	853.85	3.85	1.28	5.13
	2	NUMBER	720	0	720	0	0	1
		DENSITY	808.99	0.00	808.99	0.00	0.00	1.12
		MEAN DENS.	834.62	0.64	831.42	1.92	0.64	3.13
4	1	NUMBER	293	0	291	1	1	20
		DENSITY	348.81	0.00	346.43	1.19	1.19	23.81
	2	NUMBER	278	0	267	9	2	40
		DENSITY	330.95	0.00	317.86	10.71	2.38	47.62
		MEAN DENS.	339.88	0.00	332.14	5.95	1.79	35.71
5	1	NUMBER	469	0	467	1	1	32
		DENSITY	558.33	0.00	555.95	1.19	1.19	38.10
	2	NUMBER	112	0	106	5	1	34
		DENSITY	141.77	0.00	134.18	6.33	1.27	43.04
		MEAN DENS.	350.05	0.00	345.06	3.76	1.23	40.57

					Larvae			
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	382	0	359	18	5	3
		DENSITY	483.54	0.00	454.43	22.78	6.33	3.80
	2	NUMBER	319	0	310	7	2	11
		DENSITY	358.43	0.00	348.31	7.87	2.25	12.36
		MEAN DENS.	420.99	0.00	401.37	15.32	4.29	8.08
7	1	NUMBER	358	0	353	4	1	1
		DENSITY	146.72	0.00	144.67	1.64	0.41	0.41
	2	NUMBER	384	0	377	7	0	1
		DENSITY	462.65	0.00	454.22	8.43	0.00	1.20
		MEAN DENS.	304.69	0.00	299.44	5.04	0.20	0.81
8	1	NUMBER	302	0	296	2	4	0
		DENSITY	372.84	0.00	365.43	2.47	4.94	0.00
	2	NUMBER	199	0	191	2	6	1
		DENSITY	236.90	0.00	227.38	2.38	7.14	1.19
		MEAN DENS.	304.87	0.00	296.41	2.43	6.04	0.60
9	1	NUMBER	100	0	86	3	11	0
		DENSITY	116.28	0.00	100.00	3.49	12.79	0.00
	2	NUMBER	104	0	83	6	15	2
		DENSITY	136.84	0.00	109.21	7.89	19.74	2.63
		MEAN DENS.	126.56	0.00	104.61	5.69	16.26	1.32
		TOTAL NUMBER	4758	1	4636	70	51	150
		MEAN DENSITY OVER STATIONS	302.31	0.07	294.21	4.59	3.45	10.02

Appendix Table 5A. Potomac River, 1989. Survey 5. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 21 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	37	0	34	2	0	1
		DENSITY	45.12	0.00	41.46	2.44	0.00	1.22
	2	NUMBER	55	1	54	0	0	5
		DENSITY	67.07	1.22	65.85	0.00	0.00	6.10
		MEAN DENS.	56.10	0.61	53.66	1.22	0.00	3.66
2	1	NUMBER	936	1	932	2	1	305
		DENSITY	1141.46	1.22	1136.59	2.44	1.22	371.95
	2	NUMBER	1504	2	1501	0	0	269
		DENSITY	1856.79	2.47	1853.09	0.00	0.00	332.10
		MEAN DENS.	1499.13	1.84	1494.84	1.22	0.61	352.02
3	1	NUMBER	322	1	319	2	0	63
		DENSITY	338.95	1.05	335.79	2.11	0.00	66.32
	2	NUMBER	301	1	299	1	0	43
		DENSITY	330.77	1.10	328.57	1.10	0.00	47.25
		MEAN DENS.	334.86	1.08	332.18	1.60	0.00	56.78
4	1	NUMBER	290	0	290	0	0	309
		DENSITY	362.50	0.00	362.50	0.00	0.00	386.25
	2	NUMBER	253	1	251	1	0	193
		DENSITY	308.54	1.22	306.10	1.22	0.00	235.37
		MEAN DENS.	335.52	0.61	334.30	0.61	0.00	310.81
5	1	NUMBER	185	0	183	1	1	210
		DENSITY	225.61	0.00	223.17	1.22	1.22	256.10
	2	NUMBER	182	0	182	0	0	298
		DENSITY	221.95	0.00	221.95	0.00	0.00	363.41
		MEAN DENS.	223.78	0.00	222.56	0.61	0.61	309.76

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	129	0	120	9	0	41
		DENSITY	151.76	0.00	141.18	10.59	0.00	48.24
	2	NUMBER	130	0	127	3	0	24
		DENSITY	149.43	0.00	145.98	3.45	0.00	27.59
		MEAN DENS.	150.59	0.00	143.58	7.02	0.00	37.91
7	1	NUMBER	292	0	288	4	1	194
		DENSITY	343.53	0.00	338.82	4.71	1.18	228.24
	2	NUMBER	303	0	298	3	2	176
		DENSITY	325.81	0.00	320.43	3.23	2.15	189.25
		MEAN DENS.	334.67	0.00	329.63	3.97	1.66	208.74
8	1	NUMBER	119	0	118	1	0	84
		DENSITY	135.23	0.00	134.09	1.14	0.00	95.45
	2	NUMBER	118	1	112	4	1	134
		DENSITY	132.58	1.12	125.84	4.49	1.12	150.56
		MEAN DENS.	133.91	0.56	129.97	2.82	0.56	123.01
9	1	NUMBER	214	0	211	1	2	9
		DENSITY	232.61	0.00	229.35	1.09	2.17	9.78
	2	NUMBER	301	0	300	1	0	55
		DENSITY	345.98	0.00	344.83	1.15	0.00	63.22
		MEAN DENS.	289.29	0.00	287.09	1.12	1.09	36.50
		TOTAL NUMBER	5671	8	5619	35	8	2413
		MEAN DENSITY OVER STATIONS	373.09	0.52	369.75	2.24	0.50	159.91

Appendix Table 6A. Potomac River, 1989. Survey 6. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 24 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	4	0	4	0	0	3
		DENSITY	3.92	0.00	3.92	0.00	0.00	2.94
	2	NUMBER	5	1	4	0	0	4
		DENSITY	5.32	1.06	4.26	0.00	0.00	4.26
		MEAN DENS.	4.62	0.53	4.09	0.00	0.00	3.60
2	1	NUMBER	25	2	22	1	0	31
		DENSITY	23.36	1.87	20.56	0.93	0.00	28.97
	2	NUMBER	30	1	28	0	1	31
		DENSITY	30.00	1.00	28.00	0.00	1.00	31.00
		MEAN DENS.	26.68	1.43	24.28	0.47	0.50	29.99
3	1	NUMBER	117	7	110	0	0	192
		DENSITY	110.38	6.60	103.77	0.00	0.00	181.13
	2	NUMBER	172	13	159	0	0	363
		DENSITY	168.63	12.75	155.88	0.00	0.00	355.88
		MEAN DENS.	139.50	9.67	129.83	0.00	0.00	268.51
4	1	NUMBER	299	16	282	1	0	1130
		DENSITY	305.10	16.33	287.76	1.02	0.00	1153.06
	2	NUMBER	331	33	297	1	0	607
		DENSITY	359.78	35.87	322.83	1.09	0.00	659.78
		MEAN DENS.	332.44	26.10	305.29	1.05	0.00	906.42
5	1	NUMBER	314	3	304	6	1	754
		DENSITY	314.00	3.00	304.00	6.00	1.00	754.00
	2	NUMBER	1586	22	1558	3	3	273
		DENSITY	1416.07	19.64	1391.07	2.68	2.68	243.75
		MEAN DENS.	865.04	11.32	847.54	4.34	1.84	498.88

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	222	1	216	5	0	55
		DENSITY	209.43	0.94	203.77	4.72	0.00	51.89
	2	NUMBER	249	2	245	1	1	289
		DENSITY	226.36	1.82	222.73	0.91	0.91	262.73
		MEAN DENS.	217.90	1.38	213.25	2.81	0.45	157.31
7	1	NUMBER	413	0	404	6	3	5
		DENSITY	183.56	0.00	179.56	2.67	1.33	2.22
	2	NUMBER	257	1	251	5	0	36
		DENSITY	225.44	0.88	220.18	4.39	0.00	31.58
		MEAN DENS.	204.50	0.44	199.87	3.53	0.67	16.90
8	1	NUMBER	443	0	435	8	0	13
		DENSITY	388.60	0.00	381.58	7.02	0.00	11.40
	2	NUMBER	396	0	390	6	0	8
		DENSITY	338.46	0.00	333.33	5.13	0.00	6.84
		MEAN DENS.	363.53	0.00	357.46	6.07	0.00	9.12
9	1	NUMBER	738	2	724	11	1	23
		DENSITY	738.00	2.00	724.00	11.00	1.00	23.00
	2	NUMBER	745	2	735	8	0	31
		DENSITY	709.52	1.90	700.00	7.62	0.00	29.52
		MEAN DENS.	723.76	1.95	712.00	9.31	0.50	26.26
		TOTAL NUMBER	6346	106	6168	62	10	3848
		MEAN DENSITY OVER STATIONS	319.77	5.87	310.40	3.06	0.44	213.00

Appendix Table 7A. Potomac River, 1989. Survey 7. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 27 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	6	0	6	0	0	7
		DENSITY	5.66	0.00	5.66	0.00	0.00	6.60
	2	NUMBER	8	0	8	0	0	0
		DENSITY	7.34	0.00	7.34	0.00	0.00	0.00
		MEAN DENS.	6.50	0.00	6.50	0.00	0.00	3.30
2	1	NUMBER	21	1	20	0	0	62
		DENSITY	21.88	1.04	20.83	0.00	0.00	64.58
	2	NUMBER	38	1	37	0	0	99
		DENSITY	38.00	1.00	37.00	0.00	0.00	99.00
		MEAN DENS.	29.94	1.02	28.92	0.00	0.00	81.79
3	1	NUMBER	198	6	189	2	1	866
		DENSITY	196.04	5.94	187.13	1.98	0.99	857.43
	2	NUMBER	15	1	8	6	0	434
		DENSITY	15.46	1.03	8.25	6.19	0.00	447.42
		MEAN DENS.	105.75	3.49	97.69	4.08	0.50	652.42
4	1	NUMBER	110	2	105	3	0	757
		DENSITY	106.80	1.94	101.94	2.91	0.00	734.95
	2	NUMBER	32	0	31	1	0	476
		DENSITY	28.32	0.00	27.43	0.88	0.00	421.24
		MEAN DENS.	67.56	0.97	64.69	1.90	0.00	578.10
5	1	NUMBER	786	3	775	6	2	1171
		DENSITY	763.11	2.91	752.43	5.83	1.94	1136.89
	2	NUMBER	712	11	698	2	1	1891
		DENSITY	741.67	11.46	727.08	2.08	1.04	1969.79
		MEAN DENS.	752.39	7.19	739.76	3.95	1.49	1553.34

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	378	1	354	23	0	440
		DENSITY	363.46	0.96	340.38	22.12	0.00	423.08
	2	NUMBER	540	3	515	22	0	751
		DENSITY	514.29	2.86	490.48	20.95	0.00	715.24
		MEAN DENS.	438.87	1.91	415.43	21.53	0.00	569.16
7	1	NUMBER	696	0	577	119	0	95
		DENSITY	696.00	0.00	577.00	119.00	0.00	95.00
	2	NUMBER	512	1	423	87	1	215
		DENSITY	487.62	0.95	402.86	82.86	0.95	204.76
		MEAN DENS.	591.81	0.48	489.93	100.93	0.48	149.88
8	1	NUMBER	248	1	219	27	1	21
		DENSITY	288.37	1.16	254.65	31.40	1.16	24.42
	2	NUMBER	749	0	711	38	0	23
		DENSITY	772.16	0.00	732.99	39.18	0.00	23.71
		MEAN DENS.	530.27	0.58	493.82	35.29	0.58	24.06
9	1	NUMBER	1651	5	1579	66	1	220
		DENSITY	1684.69	5.10	1611.22	67.35	1.02	224.49
	2	NUMBER	1143	2	1032	107	2	178
		DENSITY	1166.33	2.04	1053.06	109.18	2.04	181.63
		MEAN DENS.	1425.51	3.57	1332.14	88.27	1.53	203.06
		TOTAL NUMBER	7843	38	7287	509	9	7706
		MEAN DENSITY OVER STATIONS	438.73	2.13	407.65	28.44	0.51	423.90

Appendix Table 8A. Potomac River, 1989. Survey 8. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 30 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

STATION	REP		Larvae TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	1	0	1	0	0	0
		DENSITY	1.08	0.00	1.08	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.54	0.00	0.54	0.00	0.00	0.00
2	1	NUMBER	30	0	24	6	0	0
		DENSITY	36.14	0.00	28.92	7.23	0.00	0.00
	2	NUMBER	27	0	24	3	0	0
		DENSITY	29.35	0.00	26.09	3.26	0.00	0.00
		MEAN DENS.	32.75	0.00	27.50	5.24	0.00	0.00
3	1	NUMBER	24	0	13	11	0	13
		DENSITY	26.97	0.00	14.61	12.36	0.00	14.61
	2	NUMBER	19	0	11	8	0	7
		DENSITY	21.11	0.00	12.22	8.89	0.00	7.78
		MEAN DENS.	24.04	0.00	13.41	10.62	0.00	11.19
4	1	NUMBER	417	5	322	90	0	293
		DENSITY	502.41	6.02	387.95	108.43	0.00	353.01
	2	NUMBER	353	2	315	36	0	193
		DENSITY	435.80	2.47	388.89	44.44	0.00	238.27
		MEAN DENS.	469.11	4.25	388.42	76.44	0.00	295.64
5	1	NUMBER	384	0	318	66	0	87
		DENSITY	421.98	0.00	349.45	72.53	0.00	95.60
	2	NUMBER	511	1	449	61	0	185
		DENSITY	601.18	1.18	528.24	71.76	0.00	217.65
		MEAN DENS.	511.58	0.59	438.84	72.15	0.00	156.63

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
			Larvae					
6	1	NUMBER	465	1	428	35	1	29
		DENSITY	528.41	1.14	486.36	39.77	1.14	32.95
	2	NUMBER	181	1	147	33	0	21
		DENSITY	201.11	1.11	163.33	36.67	0.00	23.33
		MEAN DENS.	364.76	1.12	324.85	38.22	0.57	28.14
7	1	NUMBER	534	2	490	42	0	8
		DENSITY	586.81	2.20	538.46	46.15	0.00	8.79
	2	NUMBER	632	0	568	63	1	111
		DENSITY	710.11	0.00	638.20	70.79	1.12	124.72
		MEAN DENS.	648.46	1.10	588.33	58.47	0.56	66.76
8	1	NUMBER	960	9	543	407	1	51
		DENSITY	1129.41	10.59	638.82	478.82	1.18	60.00
	2	NUMBER	1491	11	727	752	1	122
		DENSITY	1713.79	12.64	835.63	864.37	1.15	140.23
		MEAN DENS.	1421.60	11.62	737.23	671.60	1.16	100.11
9	1	NUMBER	975	11	498	466	0	12
		DENSITY	1133.72	12.79	579.07	541.86	0.00	13.95
	2	NUMBER	585	16	280	278	11	77
		DENSITY	704.82	19.28	337.35	334.94	13.25	92.77
		MEAN DENS.	919.27	16.03	458.21	438.40	6.63	53.36
		TOTAL NUMBER	7589	59	5158	2357	15	1209
		MEAN DENSITY OVER STATIONS	488.01	3.86	330.81	152.35	0.99	79.09

Appendix Table 9A. Potomac River, 1989. Survey 9. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 3 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	301	7	249	44	1	9
		DENSITY	310.31	7.22	256.70	45.36	1.03	9.28
	2	NUMBER	235	12	170	50	3	13
		DENSITY	247.37	12.63	178.95	52.63	3.16	13.68
		MEAN DENS.	278.84	9.92	217.82	49.00	2.09	11.48
2	1	NUMBER	766	2	622	142	0	4
		DENSITY	832.61	2.17	676.09	154.35	0.00	4.35
	2	NUMBER	721	4	593	124	0	0
		DENSITY	751.04	4.17	617.71	129.17	0.00	0.00
		MEAN DENS.	791.83	3.17	646.90	141.76	0.00	2.17
3	1	NUMBER	192	5	161	26	0	17
		DENSITY	237.04	6.17	198.77	32.10	0.00	20.99
	2	NUMBER	204	5	155	41	3	27
		DENSITY	272.00	6.67	206.67	54.67	4.00	36.00
		MEAN DENS.	254.52	6.42	202.72	43.38	2.00	28.49
4	1	NUMBER	78	1	37	38	2	33
		DENSITY	101.30	1.30	48.05	49.35	2.60	42.86
	2	NUMBER	27	0	24	2	1	47
		DENSITY	32.93	0.00	29.27	2.44	1.22	57.32
		MEAN DENS.	67.11	0.65	38.66	25.89	1.91	50.09
5	1	NUMBER	669	2	396	270	1	0
		DENSITY	682.65	2.04	404.08	275.51	1.02	0.00
	2	NUMBER	445	3	194	248	0	0
		DENSITY	500.00	3.37	217.98	278.65	0.00	0.00
		MEAN DENS.	591.33	2.71	311.03	277.08	0.51	0.00

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	982	8	580	388	6	2
		DENSITY	1033.68	8.42	610.53	408.42	6.32	2.11
	2	NUMBER	939	13	596	325	4	1
		DENSITY	1009.68	13.98	640.86	349.46	4.30	1.08
		MEAN DENS.	1021.68	11.20	625.69	378.94	5.31	1.59
7	1	NUMBER	565	6	321	231	5	0
		DENSITY	620.88	6.59	352.75	253.85	5.49	0.00
	2	NUMBER	693	3	320	366	3	0
		DENSITY	745.16	3.23	344.09	393.55	3.23	0.00
		MEAN DENS.	683.02	4.91	348.42	323.70	4.36	0.00
8	1	NUMBER	581	1	266	310	4	6
		DENSITY	660.23	1.14	302.27	352.27	4.55	6.82
	2	NUMBER	704	3	402	292	7	0
		DENSITY	756.99	3.23	432.26	313.98	7.53	0.00
		MEAN DENS.	708.61	2.18	367.27	333.13	6.04	3.41
9	1	NUMBER	680	3	165	509	3	3
		DENSITY	731.18	3.23	177.42	547.31	3.23	3.23
	2	NUMBER	737	4	196	533	3	10
		DENSITY	856.98	4.65	227.91	619.77	3.49	11.63
		MEAN DENS.	794.08	3.94	202.66	583.54	3.36	7.43
		TOTAL NUMBER	9519	82	5447	3939	46	172
		MEAN DENSITY OVER STATIONS	576.78	5.01	329.02	239.60	2.84	11.63

Appendix Table 10A. Potomac River, 1989. Survey 10. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 6 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	278	1	81	193	3	0
		DENSITY	302.17	1.09	88.04	209.78	3.26	0.00
	2	NUMBER	309	2	87	220	0	13
		DENSITY	347.19	2.25	97.75	247.19	0.00	14.61
		MEAN DENS.	324.68	1.67	92.90	228.49	1.63	7.30
2	1	NUMBER	682	2	313	365	2	1
		DENSITY	766.29	2.25	351.69	410.11	2.25	1.12
	2	NUMBER	778	1	290	485	2	0
		DENSITY	948.78	1.22	353.66	591.46	2.44	0.00
		MEAN DENS.	857.54	1.73	352.67	500.79	2.34	0.56
3	1	NUMBER	227	0	94	131	2	5
		DENSITY	136.75	0.00	56.63	78.92	1.20	3.01
	2	NUMBER	195	11	85	81	18	0
		DENSITY	211.96	11.96	92.39	88.04	19.57	0.00
		MEAN DENS.	174.35	5.98	74.51	83.48	10.39	1.51
4	1	NUMBER	90	0	5	84	1	3
		DENSITY	150.00	0.00	8.33	140.00	1.67	5.00
	2	NUMBER	1	0	1	0	0	0
		DENSITY	1.00	0.00	1.00	0.00	0.00	0.00
		MEAN DENS.	75.50	0.00	4.67	70.00	0.83	2.50
5	1	NUMBER	23	0	3	11	9	0
		DENSITY	29.87	0.00	3.90	14.29	11.69	0.00
	2	NUMBER	2	0	0	0	2	0
		DENSITY	2.22	0.00	0.00	0.00	2.22	0.00
		MEAN DENS.	16.05	0.00	1.95	7.14	6.96	0.00

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	73	0	21	45	7	0
		DENSITY	90.12	0.00	25.93	55.56	8.64	0.00
	2	NUMBER	26	0	7	17	2	1
		DENSITY	27.37	0.00	7.37	17.89	2.11	1.05
		MEAN DENS.	58.75	0.00	16.65	36.73	5.37	0.53
7	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	144	0	48	91	5	16
		DENSITY	169.41	0.00	56.47	107.06	5.88	18.82
		MEAN DENS.	84.71	0.00	28.24	53.53	2.94	9.41
8	1	NUMBER	88	0	53	28	7	10
		DENSITY	104.76	0.00	63.10	33.33	8.33	11.90
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	52.38	0.00	31.55	16.67	4.17	5.95
9	1	NUMBER	55	0	35	8	12	3
		DENSITY	59.14	0.00	37.63	8.60	12.90	3.23
	2	NUMBER	18	0	2	5	11	0
		DENSITY	20.45	0.00	2.27	5.68	12.50	0.00
		MEAN DENS.	39.80	0.00	19.95	7.14	12.70	1.61
		TOTAL NUMBER	2989	17	1125	1764	83	52
		MEAN DENSITY OVER STATIONS	187.08	1.04	69.23	111.55	5.26	3.26

Appendix Table 11A. Potomac River, 1989. Survey 11. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 9 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	102	10	24	63	5	1
		DENSITY	112.09	10.99	26.37	69.23	5.49	1.10
	2	NUMBER	204	7	78	113	6	0
		DENSITY	217.02	7.45	82.98	120.21	6.38	0.00
		MEAN DENS.	164.55	9.22	54.68	94.72	5.94	0.55
2	1	NUMBER	210	7	97	97	9	2
		DENSITY	223.40	7.45	103.19	103.19	9.57	2.13
	2	NUMBER	112	0	64	34	14	0
		DENSITY	117.89	0.00	67.37	35.79	14.74	0.00
		MEAN DENS.	170.65	3.72	85.28	69.49	12.16	1.06
3	1	NUMBER	142	7	59	66	10	3
		DENSITY	136.54	6.73	56.73	63.46	9.62	2.88
	2	NUMBER	100	2	41	55	2	0
		DENSITY	112.36	2.25	46.07	61.80	2.25	0.00
		MEAN DENS.	124.45	4.49	51.40	62.63	5.93	1.44
4	1	NUMBER	62	1	31	25	5	11
		DENSITY	65.96	1.06	32.98	26.60	5.32	11.70
	2	NUMBER	48	2	14	29	3	0
		DENSITY	54.55	2.27	15.91	32.95	3.41	0.00
		MEAN DENS.	60.25	1.67	24.44	29.78	4.36	5.85
5	1	NUMBER	45	1	16	26	2	2
		DENSITY	56.96	1.27	20.25	32.91	2.53	2.53
	2	NUMBER	4	0	2	1	1	6
		DENSITY	5.19	0.00	2.60	1.30	1.30	7.79
		MEAN DENS.	31.08	0.63	11.43	17.11	1.92	5.16

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
			Larvae					
6	1	NUMBER	88	0	23	48	17	6
		DENSITY	111.39	0.00	29.11	60.76	21.52	7.59
	2	NUMBER	97	0	37	52	8	6
		DENSITY	125.97	0.00	48.05	67.53	10.39	7.79
		MEAN DENS.	118.68	0.00	38.58	64.15	15.95	7.69
7	1	NUMBER	188	0	118	70	0	5
		DENSITY	211.24	0.00	132.58	78.65	0.00	5.62
	2	NUMBER	134	0	92	40	2	6
		DENSITY	145.65	0.00	100.00	43.48	2.17	6.52
		MEAN DENS.	178.44	0.00	116.29	61.06	1.09	6.07
8	1	NUMBER	69	0	55	13	1	208
		DENSITY	81.18	0.00	64.71	15.29	1.18	244.71
	2	NUMBER	37	0	20	17	0	47
		DENSITY	38.95	0.00	21.05	17.89	0.00	49.47
		MEAN DENS.	60.06	0.00	42.88	16.59	0.59	147.09
9	1	NUMBER	13	0	13	0	0	3
		DENSITY	15.29	0.00	15.29	0.00	0.00	3.53
	2	NUMBER	54	0	29	19	6	0
		DENSITY	64.29	0.00	34.52	22.62	7.14	0.00
		MEAN DENS.	39.79	0.00	24.91	11.31	3.57	1.76
		TOTAL NUMBER	1709	37	813	768	91	306
		MEAN DENSITY OVER STATIONS	105.33	2.19	49.99	47.43	5.72	19.63

Appendix Table 12A. Potomac River, 1989. Survey 12. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 12 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	1888	10	1624	253	1	0
		DENSITY	1600.00	8.47	1376.27	214.41	0.85	0.00
	2	NUMBER	1335	1	1093	240	1	0
		DENSITY	1202.70	0.90	984.68	216.22	0.90	0.00
		MEAN DENS.	1401.35	4.69	1180.48	215.31	0.87	0.00
2	1	NUMBER	74	1	39	34	0	1
		DENSITY	75.51	1.02	39.80	34.69	0.00	1.02
	2	NUMBER	63	3	36	23	1	0
		DENSITY	58.33	2.78	33.33	21.30	0.93	0.00
		MEAN DENS.	66.92	1.90	36.56	28.00	0.46	0.51
3	1	NUMBER	113	1	81	31	0	2
		DENSITY	104.63	0.93	75.00	28.70	0.00	1.85
	2	NUMBER	84	0	63	20	1	0
		DENSITY	85.71	0.00	64.29	20.41	1.02	0.00
		MEAN DENS.	95.17	0.46	69.64	24.56	0.51	0.93
4	1	NUMBER	62	0	47	15	0	2
		DENSITY	60.19	0.00	45.63	14.56	0.00	1.94
	2	NUMBER	91	0	62	28	1	1
		DENSITY	85.85	0.00	58.49	26.42	0.94	0.94
		MEAN DENS.	73.02	0.00	52.06	20.49	0.47	1.44
5	1	NUMBER	30	0	17	13	0	1
		DENSITY	28.04	0.00	15.89	12.15	0.00	0.93
	2	NUMBER	42	0	26	16	0	5
		DENSITY	37.17	0.00	23.01	14.16	0.00	4.42
		MEAN OENS.	32.60	0.00	19.45	13.15	0.00	2.68

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	117	0	91	25	1	45
		DENSITY	136.05	0.00	105.81	29.07	1.16	52.33
	2	NUMBER	23	0	20	2	1	18
		DENSITY	26.74	0.00	23.26	2.33	1.16	20.93
		MEAN DENS.	81.40	0.00	64.53	15.70	1.16	36.63
7	1	NUMBER	38	0	38	0	0	163
		DENSITY	44.71	0.00	44.71	0.00	0.00	191.76
	2	NUMBER	27	0	26	1	0	176
		DENSITY	31.40	0.00	30.23	1.16	0.00	204.65
		MEAN DENS.	38.05	0.00	37.47	0.58	0.00	198.21
8	1	NUMBER	43	0	40	3	0	1180
		DENSITY	54.43	0.00	50.63	3.80	0.00	1493.67
	2	NUMBER	42	0	39	2	1	575
		DENSITY	52.50	0.00	48.75	2.50	1.25	718.75
		MEAN DENS.	53.47	0.00	49.69	3.15	0.63	1106.21
9	1	NUMBER	3	0	3	0	0	152
		DENSITY	3.90	0.00	3.90	0.00	0.00	197.40
	2	NUMBER	27	0	25	2	0	267
		DENSITY	32.93	0.00	30.49	2.44	0.00	325.61
		MEAN DENS.	18.41	0.00	17.19	1.22	0.00	261.51
10	1	NUMBER	25	0	24	1	0	456
		DENSITY	32.47	0.00	31.17	1.30	0.00	592.21
	2	NUMBER	6	0	6	0	0	240
		DENSITY	7.79	0.00	7.79	0.00	0.00	311.69
		MEAN DENS.	20.13	0.00	19.48	0.65	0.00	451.95
11	1	NUMBER	37	0	37	0	0	19
		DENSITY	41.57	0.00	41.57	0.00	0.00	21.35
	2	NUMBER	54	0	53	1	0	57
		DENSITY	55.67	0.00	54.64	1.03	0.00	58.76
		MEAN DENS.	48.62	0.00	48.11	0.52	0.00	40.06

Appendix Table 13A. Potomac River, 1989. Survey 13. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 16 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	27	0	16	11	0	0
		DENSITY	31.76	0.00	18.82	12.94	0.00	0.00
	2	NUMBER	6	0	3	3	0	0
		DENSITY	6.82	0.00	3.41	3.41	0.00	0.00
		MEAN DENS.	19.29	0.00	11.12	8.18	0.00	0.00
2	1	NUMBER	22	0	13	9	0	0
		DENSITY	22.68	0.00	13.40	9.28	0.00	0.00
	2	NUMBER	44	0	19	24	1	0
		DENSITY	44.44	0.00	19.19	24.24	1.01	0.00
		MEAN DENS.	33.56	0.00	16.30	16.76	0.51	0.00
3	1	NUMBER	113	0	67	46	0	0
		DENSITY	113.00	0.00	67.00	46.00	0.00	0.00
	2	NUMBER	119	0	64	54	1	0
		DENSITY	119.00	0.00	64.00	54.00	1.00	0.00
		MEAN DENS.	116.00	0.00	65.50	50.00	0.50	0.00
4	1	NUMBER	118	0	88	30	0	0
		DENSITY	124.21	0.00	92.63	31.58	0.00	0.00
	2	NUMBER	83	0	64	19	0	1
		DENSITY	85.57	0.00	65.98	19.59	0.00	1.03
		MEAN DENS.	104.89	0.00	79.31	25.58	0.00	0.52
5	1	NUMBER	61	0	43	17	1	0
		DENSITY	61.00	0.00	43.00	17.00	1.00	0.00
	2	NUMBER	72	0	49	23	0	0
		DENSITY	73.47	0.00	50.00	23.47	0.00	0.00
		MEAN DENS.	67.23	0.00	46.50	20.23	0.50	0.00

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	36	0	24	11	1	7
		DENSITY	40.00	0.00	26.67	12.22	1.11	7.78
	2	NUMBER	33	0	30	3	0	3
		DENSITY	31.43	0.00	28.57	2.86	0.00	2.86
		MEAN DENS.	35.71	0.00	27.62	7.54	0.56	5.32
7	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	21	0	17	4	0	1
		DENSITY	23.60	0.00	19.10	4.49	0.00	1.12
		MEAN DENS.	11.80	0.00	9.55	2.25	0.00	0.56
8	1	NUMBER	33	0	33	0	0	1
		DENSITY	34.74	0.00	34.74	0.00	0.00	1.05
	2	NUMBER	36	0	31	5	0	0
		DENSITY	39.13	0.00	33.70	5.43	0.00	0.00
		MEAN DENS.	36.93	0.00	34.22	2.72	0.00	0.53
9	1	NUMBER	49	0	46	3	0	3
		DENSITY	49.00	0.00	46.00	3.00	0.00	3.00
	2	NUMBER	49	0	47	2	0	0
		DENSITY	48.04	0.00	46.08	1.96	0.00	0.00
		MEAN DENS.	48.52	0.00	46.04	2.48	0.00	1.50
		TOTAL NUMBER	922	0	654	264	4	16
		MEAN DENSITY OVER STATIONS	52.66	0.00	37.35	15.08	0.23	0.94

Appendix Table 14A. Potomac River, 1989. Survey 14. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 20 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	21	0	15	6	0	0
		DENSITY	21.00	0.00	15.00	6.00	0.00	0.00
	2	NUMBER	76	0	44	31	1	0
		DENSITY	85.39	0.00	49.44	34.83	1.12	0.00
		MEAN DENS.	53.20	0.00	32.22	20.42	0.56	0.00
2	1	NUMBER	208	0	179	29	0	0
		DENSITY	214.43	0.00	184.54	29.90	0.00	0.00
	2	NUMBER	125	0	99	26	0	0
		DENSITY	128.87	0.00	102.06	26.80	0.00	0.00
		MEAN DENS.	171.65	0.00	143.30	28.35	0.00	0.00
3	1	NUMBER	73	0	61	12	0	0
		DENSITY	83.91	0.00	70.11	13.79	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	41.95	0.00	35.06	6.90	0.00	0.00
4	1	NUMBER	91	0	79	9	3	55
		DENSITY	101.11	0.00	87.78	10.00	3.33	61.11
	2	NUMBER	62	0	49	13	0	15
		DENSITY	67.39	0.00	53.26	14.13	0.00	16.30
		MEAN DENS.	84.25	0.00	70.52	12.07	1.67	38.71
5	1	NUMBER	73	0	43	29	1	55
		DENSITY	83.91	0.00	49.43	33.33	1.15	63.22
	2	NUMBER	43	0	29	14	0	83
		DENSITY	51.81	0.00	34.94	16.87	0.00	100.00
		MEAN DENS.	67.86	0.00	42.18	25.10	0.57	81.61

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	78	0	54	23	1	7
		DENSITY	81.25	0.00	56.25	23.96	1.04	7.29
	2	NUMBER	69	0	41	27	1	6
		DENSITY	55.65	0.00	33.06	21.77	0.81	4.84
		MEAN DENS.	68.45	0.00	44.66	22.87	0.92	6.07
7	1	NUMBER	114	0	75	39	0	4
		DENSITY	107.55	0.00	70.75	36.79	0.00	3.77
	2	NUMBER	70	0	46	24	0	2
		DENSITY	70.00	0.00	46.00	24.00	0.00	2.00
		MEAN DENS.	88.77	0.00	58.38	30.40	0.00	2.89
8	1	NUMBER	57	0	31	25	1	0
		DENSITY	55.34	0.00	30.10	24.27	0.97	0.00
	2	NUMBER	105	0	58	47	0	0
		DENSITY	89.74	0.00	49.57	40.17	0.00	0.00
		MEAN DENS.	72.54	0.00	39.83	32.22	0.49	0.00
9	1	NUMBER	73	0	52	21	0	4
		DENSITY	70.87	0.00	50.49	20.39	0.00	3.88
	2	NUMBER	72	0	42	30	0	0
		DENSITY	69.90	0.00	40.78	29.13	0.00	0.00
		MEAN DENS.	70.39	0.00	45.63	24.76	0.00	1.94
		TOTAL NUMBER	4420	16	3487	909	8	35
		MEAN DENSITY OVER STATIONS	218.80	0.78	171.86	45.75	0.41	1.83

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
		TOTAL NUMBER	1214	0	1000	206	8	3556
		MEAN DENSITY OVER STATIONS	62.40	0.00	51.56	10.43	0.42	201.35

Appendix Table 15A. Potomac River, 1989. Survey 15. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 24 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

STATION	REP		Larvae TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	588	61	474	50	2	1
		DENSITY	529.73	54.95	427.03	45.05	1.80	0.90
	2	NUMBER	434	36	365	33	0	0
		DENSITY	438.38	36.36	368.69	33.33	0.00	0.00
		MEAN DENS.	484.06	45.66	397.86	39.19	0.90	0.45
2	1	NUMBER	339	126	190	19	2	39
		DENSITY	319.81	118.87	179.25	17.92	1.89	36.79
	2	NUMBER	333	68	239	26	0	0
		DENSITY	292.11	59.65	209.65	22.81	0.00	0.00
		MEAN DENS.	305.96	89.26	194.45	20.37	0.94	18.40
3	1	NUMBER	157	76	65	16	0	41
		DENSITY	133.05	64.41	55.08	13.56	0.00	34.75
	2	NUMBER	171	105	51	14	0	0
		DENSITY	171.00	105.00	51.00	14.00	0.00	0.00
		MEAN DENS.	152.03	84.70	53.04	13.78	0.00	17.37
4	1	NUMBER	548	272	210	63	2	58
		DENSITY	476.52	236.52	182.61	54.78	1.74	50.43
	2	NUMBER	546	268	215	60	2	0
		DENSITY	466.67	229.06	183.76	51.28	1.71	0.00
		MEAN DENS.	471.59	232.79	183.18	53.03	1.72	25.22
5	1	NUMBER	215	35	80	94	4	2
		DENSITY	247.13	40.23	91.95	108.05	4.60	2.30
	2	NUMBER	264	41	109	113	1	7
		DENSITY	244.44	37.96	100.93	104.63	0.93	6.48
		MEAN DENS.	245.79	39.10	96.44	106.34	2.76	4.39

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	80	5	29	46	0	2
		DENSITY	84.21	5.26	30.53	48.42	0.00	2.11
	2	NUMBER	125	17	78	30	0	8
		DENSITY	121.36	16.50	75.73	29.13	0.00	7.77
		MEAN DENS.	102.78	10.88	53.13	38.77	0.00	4.94
7	1	NUMBER	281	76	139	66	0	5
		DENSITY	242.24	65.52	119.83	56.90	0.00	4.31
	2	NUMBER	359	176	116	67	0	8
		DENSITY	312.17	153.04	100.87	58.26	0.00	6.96
		MEAN DENS.	277.21	109.28	110.35	57.58	0.00	5.63
8	1	NUMBER	202	6	183	13	0	7
		DENSITY	212.63	6.32	192.63	13.68	0.00	7.37
	2	NUMBER	324	20	289	15	0	7
		DENSITY	311.54	19.23	277.88	14.42	0.00	6.73
		MEAN DENS.	262.09	12.77	235.26	14.05	0.00	7.05
9	1	NUMBER	1440	81	797	562	0	30
		DENSITY	1484.54	83.51	821.65	579.38	0.00	30.93
	2	NUMBER	1799	111	1134	554	0	23
		DENSITY	1781.19	109.90	1122.77	548.51	0.00	22.77
		MEAN DENS.	1632.86	96.70	972.21	563.95	0.00	26.85
		TOTAL NUMBER	8205	1580	4763	1841	13	238
		MEAN DENSITY OVER STATIONS	437.15	80.13	255.10	100.78	0.70	12.21

Appendix Table 16A. Potomac River, 1989. Survey 16. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 28 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
			Larvae					
1	1	NUMBER	1997	202	1647	146	2	1
		DENSITY	1721.55	174.14	1419.83	125.86	1.72	0.86
	2	NUMBER	1300	124	1105	68	3	0
		DENSITY	1140.35	108.77	969.30	59.65	2.63	0.00
		MEAN DENS.	1430.95	141.45	1194.56	92.76	2.18	0.43
2	1	NUMBER	1179	125	986	61	7	0
		DENSITY	1144.66	121.36	957.28	59.22	6.80	0.00
	2	NUMBER	916	120	752	39	5	0
		DENSITY	906.93	118.81	744.55	38.61	4.95	0.00
		MEAN DENS.	1025.80	120.09	850.92	48.92	5.87	0.00
3	1	NUMBER	553	65	416	68	4	0
		DENSITY	643.02	75.58	483.72	79.07	4.65	0.00
	2	NUMBER	599	75	460	62	2	0
		DENSITY	617.53	77.32	474.23	63.92	2.06	0.00
		MEAN DENS.	630.27	76.45	478.97	71.49	3.36	0.00
4	1	NUMBER	2431	44	1333	1051	3	0
		DENSITY	2337.50	42.31	1281.73	1010.58	2.88	0.00
	2	NUMBER	2078	39	1140	896	3	0
		DENSITY	2037.25	38.24	1117.65	878.43	2.94	0.00
		MEAN DENS.	2187.38	40.27	1199.69	944.50	2.91	0.00
5	1	NUMBER	1892	44	899	948	1	3
		DENSITY	1911.11	44.44	908.08	957.58	1.01	3.03
	2	NUMBER	1368	45	828	490	5	0
		DENSITY	1243.64	40.91	752.73	445.45	4.55	0.00
		MEAN DENS.	1577.37	42.68	830.40	701.52	2.78	1.52

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	2202	7	827	1367	1	0
		DENSITY	2621.43	8.33	984.52	1627.38	1.19	0.00
	2	NUMBER	2599	4	1196	1399	0	0
		DENSITY	3022.09	4.65	1390.70	1626.74	0.00	0.00
		MEAN DENS.	2821.76	6.49	1187.61	1627.06	0.60	0.00
7	1	NUMBER	2348	12	1462	874	0	1
		DENSITY	2348.00	12.00	1462.00	874.00	0.00	1.00
	2	NUMBER	3727	16	1573	2138	0	2
		DENSITY	3842.27	16.49	1621.65	2204.12	0.00	2.06
		MEAN DENS.	3095.13	14.25	1541.82	1539.06	0.00	1.53
8	1	NUMBER	2011	12	1095	904	0	5
		DENSITY	2073.20	12.37	1128.87	931.96	0.00	5.15
	2	NUMBER	1611	14	307	1290	0	0
		DENSITY	1678.13	14.58	319.79	1343.75	0.00	0.00
		MEAN DENS.	1875.66	13.48	724.33	1137.85	0.00	2.58
9	1	NUMBER	14601	13	1547	13034	7	3
		DENSITY	16592.05	14.77	1757.95	14811.36	7.95	3.41
	2	NUMBER	11555	7	836	10708	4	4
		DENSITY	11110.58	6.73	803.85	10296.15	3.85	3.85
		MEAN DENS.	13851.31	10.75	1280.90	12553.76	5.90	3.63
		TOTAL NUMBER	54967	968	18409	35543	47	19
		MEAN DENSITY OVER STATIONS	3166.18	51.77	1032.13	2079.66	2.62	1.08

Appendix Table 17A. Upper Bay, 1989. Survey 1. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 14 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.00	0.00	0.00	0.00	0.00	0.00
2	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	1	0	1	0	0	0
		DENSITY	1.06	0.00	1.06	0.00	0.00	0.00
		MEAN DENS.	0.53	0.00	0.53	0.00	0.00	0.00
3	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.00	0.00	0.00	0.00	0.00	0.00
4	1	NUMBER	1	0	0	0	1	0
		DENSITY	1.22	0.00	0.00	0.00	1.22	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.61	0.00	0.00	0.00	0.61	0.00
5	1	NUMBER	1	0	0	0	1	0
		DENSITY	1.15	0.00	0.00	0.00	1.15	0.00
	2	NUMBER	1	0	0	0	1	0
		DENSITY	1.09	0.00	0.00	0.00	1.09	0.00
		MEAN DENS.	1.12	0.00	0.00	0.00	1.12	0.00

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.00	0.00	0.00	0.00	0.00	0.00
7	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.00	0.00	0.00	0.00	0.00	0.00
8	1	NUMBER	0	0	0	0	0	2
		DENSITY	0.00	0.00	0.00	0.00	0.00	2.15
	2	NUMBER	2	0	2	0	0	2
		DENSITY	2.20	0.00	2.20	0.00	0.00	2.20
		MEAN DENS.	1.10	0.00	1.10	0.00	0.00	2.17
9	1	NUMBER	6	0	6	0	0	0
		DENSITY	8.00	0.00	8.00	0.00	0.00	0.00
	2	NUMBER	6	0	5	0	1	0
		DENSITY	7.06	0.00	5.88	0.00	1.18	0.00
		MEAN DENS.	7.53	0.00	6.94	0.00	0.59	0.00
		TOTAL NUMBER	18	0	14	0	4	4
		MEAN DENSITY OVER STATIONS	1.21	0.00	0.95	0.00	0.26	0.24

Appendix Table 18A. Upper Bay, 1989. Survey 2. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 20 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	1	0	1	0	0	0
		DENSITY	1.06	0.00	1.06	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.53	0.00	0.53	0.00	0.00	0.00
2	1	NUMBER	0	0	0	0	0	3
		DENSITY	0.00	0.00	0.00	0.00	0.00	3.00
	2	NUMBER	1	0	1	0	0	6
		DENSITY	1.25	0.00	1.25	0.00	0.00	7.50
		MEAN DENS.	0.63	0.00	0.63	0.00	0.00	5.25
3	1	NUMBER	1	0	1	0	0	8
		DENSITY	1.01	0.00	1.01	0.00	0.00	8.08
	2	NUMBER	0	0	0	0	0	6
		DENSITY	0.00	0.00	0.00	0.00	0.00	6.67
		MEAN DENS.	0.51	0.00	0.51	0.00	0.00	7.37
4	1	NUMBER	33	0	33	0	0	49
		DENSITY	37.08	0.00	37.08	0.00	0.00	55.06
	2	NUMBER	20	0	20	0	0	76
		DENSITY	21.74	0.00	21.74	0.00	0.00	82.61
		MEAN DENS.	29.41	0.00	29.41	0.00	0.00	68.83
5	1	NUMBER	17	0	17	0	0	29
		DENSITY	19.77	0.00	19.77	0.00	0.00	33.72
	2	NUMBER	10	0	10	0	0	25
		DENSITY	11.76	0.00	11.76	0.00	0.00	29.41
		MEAN DENS.	15.77	0.00	15.77	0.00	0.00	31.57

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	12	0	11	1	0	30
		DENSITY	13.79	0.00	12.64	1.15	0.00	34.48
	2	NUMBER	3	0	3	0	0	49
		DENSITY	3.33	0.00	3.33	0.00	0.00	54.44
		MEAN DENS.	8.56	0.00	7.99	0.57	0.00	44.46
7	1	NUMBER	103	0	103	0	0	0
		DENSITY	113.19	0.00	113.19	0.00	0.00	0.00
	2	NUMBER	40	0	39	1	0	0
		DENSITY	43.96	0.00	42.86	1.10	0.00	0.00
		MEAN DENS.	78.57	0.00	78.02	0.55	0.00	0.00
8	1	NUMBER	64	0	63	0	1	44
		DENSITY	71.11	0.00	70.00	0.00	1.11	48.89
	2	NUMBER	69	0	69	0	0	8
		DENSITY	68.32	0.00	68.32	0.00	0.00	7.92
		MEAN DENS.	69.71	0.00	69.16	0.00	0.56	28.40
9	1	NUMBER	27	0	27	0	0	0
		DENSITY	34.18	0.00	34.18	0.00	0.00	0.00
	2	NUMBER	16	0	16	0	0	13
		DENSITY	21.05	0.00	21.05	0.00	0.00	17.11
		MEAN DENS.	27.61	0.00	27.61	0.00	0.00	8.55
		TOTAL NUMBER	417	0	414	2	1	346
		MEAN DENSITY OVER STATIONS	25.70	0.00	25.51	0.12	0.06	21.60

Appendix Table 19A. Upper Bay, 1989. Survey 3. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 24 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	10	0	10	0	0	0
		DENSITY	11.63	0.00	11.63	0.00	0.00	0.00
	2	NUMBER	4	0	4	0	0	0
		DENSITY	4.40	0.00	4.40	0.00	0.00	0.00
		MEAN DENS.	8.01	0.00	8.01	0.00	0.00	0.00
2	1	NUMBER	2	0	2	0	0	1
		DENSITY	2.11	0.00	2.11	0.00	0.00	1.05
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	1.05	0.00	1.05	0.00	0.00	0.53
3	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	3	1	2	0	0	1
		DENSITY	3.61	1.20	2.41	0.00	0.00	1.20
		MEAN DENS.	1.81	0.60	1.20	0.00	0.00	0.60
4	1	NUMBER	4	0	4	0	0	3
		DENSITY	4.44	0.00	4.44	0.00	0.00	3.33
	2	NUMBER	9	1	8	0	0	19
		DENSITY	10.71	1.19	9.52	0.00	0.00	22.62
		MEAN DENS.	7.58	0.60	6.98	0.00	0.00	12.98
5	1	NUMBER	18	0	18	0	0	18
		DENSITY	27.27	0.00	27.27	0.00	0.00	27.27
	2	NUMBER	52	0	52	0	0	28
		DENSITY	61.90	0.00	61.90	0.00	0.00	33.33
		MEAN DENS.	44.59	0.00	44.59	0.00	0.00	30.30

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	42	0	37	5	0	14
		DENSITY	47.73	0.00	42.05	5.68	0.00	15.91
	2	NUMBER	4	0	4	0	0	0
		DENSITY	5.00	0.00	5.00	0.00	0.00	0.00
		MEAN DENS.	26.36	0.00	23.52	2.84	0.00	7.95
7	1	NUMBER	177	0	175	1	1	0
		DENSITY	184.38	0.00	182.29	1.04	1.04	0.00
	2	NUMBER	306	0	304	2	0	0
		DENSITY	347.73	0.00	345.45	2.27	0.00	0.00
		MEAN DENS.	266.05	0.00	263.87	1.66	0.52	0.00
8	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	34	0	34	0	0	0
		DENSITY	41.98	0.00	41.98	0.00	0.00	0.00
		MEAN DENS.	20.99	0.00	20.99	0.00	0.00	0.00
9	1	NUMBER	106	0	106	0	0	2
		DENSITY	115.22	0.00	115.22	0.00	0.00	2.17
	2	NUMBER	89	0	89	0	0	4
		DENSITY	93.68	0.00	93.68	0.00	0.00	4.21
		MEAN DENS.	104.45	0.00	104.45	0.00	0.00	3.19
		TOTAL NUMBER	860	2	849	8	1	90
		MEAN DENSITY OVER STATIONS	53.43	0.13	52.74	0.50	0.06	6.17

Appendix Table 20A. Upper Bay, 1989. Survey 4. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 27 April, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	9	0	9	0	0	0
		DENSITY	9.78	0.00	9.78	0.00	0.00	0.00
	2	NUMBER	1	0	1	0	0	4
		DENSITY	1.16	0.00	1.16	0.00	0.00	4.65
		MEAN DENS.	5.47	0.00	5.47	0.00	0.00	2.33
2	1	NUMBER	4	0	4	0	0	1
		DENSITY	4.44	0.00	4.44	0.00	0.00	1.11
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	2.22	0.00	2.22	0.00	0.00	0.56
3	1	NUMBER	3	0	3	0	0	39
		DENSITY	3.33	0.00	3.33	0.00	0.00	43.33
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	1.67	0.00	1.67	0.00	0.00	21.67
4	1	NUMBER	3	0	3	0	0	15
		DENSITY	3.30	0.00	3.30	0.00	0.00	16.48
	2	NUMBER	3	0	3	0	0	689
		DENSITY	3.23	0.00	3.23	0.00	0.00	740.86
		MEAN DENS.	3.26	0.00	3.26	0.00	0.00	378.67
5	1	NUMBER	17	0	14	3	0	14
		DENSITY	16.04	0.00	13.21	2.83	0.00	13.21
	2	NUMBER	25	0	24	0	1	18
		DENSITY	25.00	0.00	24.00	0.00	1.00	18.00
		MEAN DENS.	20.52	0.00	18.60	1.42	0.50	15.60

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	67	0	64	3	0	404
		DENSITY	73.63	0.00	70.33	3.30	0.00	443.96
	2	NUMBER	52	0	51	1	0	146
		DENSITY	50.49	0.00	49.51	0.97	0.00	141.75
		MEAN DENS.	62.06	0.00	59.92	2.13	0.00	292.85
7	1	NUMBER	235	0	232	3	0	4
		DENSITY	270.11	0.00	266.67	3.45	0.00	4.60
	2	NUMBER	254	0	249	1	0	0
		DENSITY	306.02	0.00	300.00	1.20	0.00	0.00
		MEAN DENS.	288.07	0.00	283.33	2.33	0.00	2.30
8	1	NUMBER	28	0	28	0	0	66
		DENSITY	26.67	0.00	26.67	0.00	0.00	62.86
	2	NUMBER	16	0	15	1	0	10
		DENSITY	16.33	0.00	15.31	1.02	0.00	10.20
		MEAN DENS.	21.50	0.00	20.99	0.51	0.00	36.53
9	1	NUMBER	22	0	22	0	0	11
		DENSITY	23.91	0.00	23.91	0.00	0.00	11.96
	2	NUMBER	16	0	16	0	0	3
		DENSITY	16.00	0.00	16.00	0.00	0.00	3.00
		MEAN DENS.	19.96	0.00	19.96	0.00	0.00	7.48
		TOTAL NUMBER	755	0	738	12	1	1424
		MEAN DENSITY OVER STATIONS	47.19	0.00	46.16	0.71	0.06	84.22

Appendix Table 21A. Upper Bay, 1989. Survey 5. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 2 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
5	1	NUMBER	12	0	11	1	0	2
		DENSITY	12.63	0.00	11.58	1.05	0.00	2.11
	2	NUMBER	12	0	12	0	0	0
		DENSITY	12.37	0.00	12.37	0.00	0.00	0.00
		MEAN DENS.	12.50	0.00	11.98	0.53	0.00	1.05
8	1	NUMBER	15	0	12	3	0	52
		DENSITY	16.67	0.00	13.33	3.33	0.00	57.78
	2	NUMBER	37	0	34	3	0	59
		DENSITY	38.95	0.00	35.79	3.16	0.00	62.11
		MEAN DENS.	27.81	0.00	24.56	3.25	0.00	59.94
9	1	NUMBER	3	3	0	0	0	1209
		DENSITY	3.61	3.61	0.00	0.00	0.00	1456.63
	2	NUMBER	5	4	1	0	0	1225
		DENSITY	5.10	4.08	1.02	0.00	0.00	1250.00
		MEAN DENS.	4.36	3.85	0.51	0.00	0.00	1353.31
		TOTAL NUMBER	84	7	70	7	0	2547
		MEAN DENSITY OVER STATIONS	14.89	1.28	12.35	1.26	0.00	471.44

Appendix Table 22A. Upper Bay, 1989. Survey 6. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 5 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	1	0	1	0	0	0
		DENSITY	0.90	0.00	0.90	0.00	0.00	0.00
		MEAN DENS.	0.45	0.00	0.45	0.00	0.00	0.00
2	1	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
	2	NUMBER	0	0	0	0	0	0
		DENSITY	0.00	0.00	0.00	0.00	0.00	0.00
		MEAN DENS.	0.00	0.00	0.00	0.00	0.00	0.00
		TOTAL NUMBER	1	0	1	0	0	0
		MEAN DENSITY OVER STATIONS	0.23	0.00	0.23	0.00	0.00	0.00

Appendix Table 23A. Upper Bay, 1989. Survey 7. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 11 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	18	0	11	6	1	105
		DENSITY	20.00	0.00	12.22	6.67	1.11	116.67
	2	NUMBER	43	0	15	9	19	390
		DENSITY	47.78	0.00	16.67	10.00	21.11	433.33
		MEAN DENS.	33.89	0.00	14.44	8.33	11.11	275.00
2	1	NUMBER	25	0	25	0	0	57
		DENSITY	27.78	0.00	27.78	0.00	0.00	63.33
	2	NUMBER	18	0	14	3	1	321
		DENSITY	20.00	0.00	15.56	3.33	1.11	356.67
		MEAN DENS.	23.89	0.00	21.67	1.67	0.56	210.00
3	1	NUMBER	36	0	35	1	0	313
		DENSITY	40.00	0.00	38.89	1.11	0.00	347.78
	2	NUMBER	29	0	27	1	1	713
		DENSITY	32.22	0.00	30.00	1.11	1.11	792.22
		MEAN DENS.	36.11	0.00	34.44	1.11	0.56	570.00
4	1	NUMBER	9	0	7	2	0	15
		DENSITY	10.00	0.00	7.78	2.22	0.00	16.67
	2	NUMBER	30	0	26	4	0	124
		DENSITY	33.33	0.00	28.89	4.44	0.00	137.78
		MEAN DENS.	21.67	0.00	18.33	3.33	0.00	77.22
5	1	NUMBER	43	0	37	6	0	33
		DENSITY	47.78	0.00	41.11	6.67	0.00	36.67
	2	NUMBER	21	1	20	0	0	143
		DENSITY	23.33	1.11	22.22	0.00	0.00	158.89
		MEAN DENS.	35.56	0.56	31.67	3.33	0.00	97.78

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	25	0	25	0	0	82
		DENSITY	27.78	0.00	27.78	0.00	0.00	91.11
	2	NUMBER	5	0	5	0	0	20
		DENSITY	5.56	0.00	5.56	0.00	0.00	22.22
		MEAN DENS.	16.67	0.00	16.67	0.00	0.00	56.67
7	1	NUMBER	87	0	85	2	0	9
		DENSITY	96.67	0.00	94.44	2.22	0.00	10.00
	2	NUMBER	70	0	63	2	5	9
		DENSITY	77.78	0.00	70.00	2.22	5.56	10.00
		MEAN DENS.	87.22	0.00	82.22	2.22	2.78	10.00
8	1	NUMBER	24	4	18	1	1	22
		DENSITY	35.29	5.88	26.47	1.47	1.47	32.35
	2	NUMBER	32	2	24	4	2	21
		DENSITY	35.56	2.22	26.67	4.44	2.22	23.33
		MEAN DENS.	35.42	4.05	26.57	2.96	1.85	27.84
9	1	NUMBER	25	3	16	2	4	14
		DENSITY	27.78	3.33	17.78	2.22	4.44	15.56
	2	NUMBER	23	8	9	4	2	40
		DENSITY	25.56	8.89	10.00	4.44	2.22	44.44
		MEAN DENS.	26.67	6.11	13.89	3.33	3.33	30.00
		TOTAL NUMBER	563	18	462	47	36	2431
		MEAN DENSITY OVER STATIONS	34.75	1.19	28.52	2.90	2.22	150.50

Appendix Table 24A. Upper Bay, 1989. Survey 8. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 15 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	6	0	6	0	0	6
		DENSITY	9.09	0.00	9.09	0.00	0.00	9.09
	2	NUMBER	14	0	13	0	1	16
		DENSITY	20.29	0.00	18.84	0.00	1.45	23.19
		MEAN DENS.	14.69	0.00	13.97	0.00	0.72	16.14
2	1	NUMBER	7	0	7	0	0	7
		DENSITY	8.75	0.00	8.75	0.00	0.00	8.75
	2	NUMBER	4	0	4	0	0	0
		DENSITY	4.65	0.00	4.65	0.00	0.00	0.00
		MEAN DENS.	6.70	0.00	6.70	0.00	0.00	4.38
3	1	NUMBER	33	0	31	1	1	36
		DENSITY	43.42	0.00	40.79	1.32	1.32	47.37
	2	NUMBER	20	0	19	1	0	22
		DENSITY	27.03	0.00	25.68	1.35	0.00	29.73
		MEAN DENS.	35.22	0.00	33.23	1.33	0.66	38.55
5	1	NUMBER	4	0	3	0	1	0
		DENSITY	5.00	0.00	3.75	0.00	1.25	0.00
	2	NUMBER	3	0	1	0	2	0
		DENSITY	3.33	0.00	1.11	0.00	2.22	0.00
		MEAN DENS.	4.17	0.00	2.43	0.00	1.74	0.00
6	1	NUMBER	4	0	2	0	2	0
		DENSITY	5.06	0.00	2.53	0.00	2.53	0.00
	2	NUMBER						
		DENSITY						
		MEAN DENS.	5.06	0.00	2.53	0.00	2.53	0.00

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
7	1	NUMBER	50	0	42	7	1	0
		DENSITY	64.94	0.00	54.55	9.09	1.30	0.00
	2	NUMBER	47	0	42	1	4	0
		DENSITY	62.67	0.00	56.00	1.33	5.33	0.00
		MEAN DENS.	63.80	0.00	55.27	5.21	3.32	0.00
8	1	NUMBER	10	2	8	0	0	55
		DENSITY	10.53	2.11	8.42	0.00	0.00	57.89
	2	NUMBER	11	1	10	0	0	32
		DENSITY	13.25	1.20	12.05	0.00	0.00	38.55
		MEAN DENS.	11.89	1.66	10.23	0.00	0.00	48.22
9	1	NUMBER	9	1	8	0	0	10
		DENSITY	12.16	1.35	10.81	0.00	0.00	13.51
	2	NUMBER	9	0	9	0	0	11
		DENSITY	11.25	0.00	11.25	0.00	0.00	13.75
		MEAN DENS.	11.71	0.68	11.03	0.00	0.00	13.63
		TOTAL NUMBER	231	4	205	10	12	195
		MEAN DENSITY OVER STATIONS	19.16	0.29	16.92	0.82	1.12	15.11

Appendix Table 25A. Upper Bay, 1989. Survey 9. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 18 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	7	0	6	0	1	40
		DENSITY	8.14	0.00	6.98	0.00	1.16	46.51
	2	NUMBER	10	0	6	1	3	59
		DENSITY	12.05	0.00	7.23	1.20	3.61	71.08
		MEAN DENS.	10.09	0.00	7.10	0.60	2.39	58.80
2	1	NUMBER	41	0	34	0	7	61
		DENSITY	44.57	0.00	36.96	0.00	7.61	66.30
	2	NUMBER	31	0	29	1	1	13
		DENSITY	33.70	0.00	31.52	1.09	1.09	14.13
		MEAN DENS.	39.13	0.00	34.24	0.54	4.35	40.22
3	1	NUMBER	13	0	13	0	0	19
		DENSITY	15.85	0.00	15.85	0.00	0.00	23.17
	2	NUMBER	37	0	33	0	4	3
		DENSITY	42.53	0.00	37.93	0.00	4.60	3.45
		MEAN DENS.	29.19	0.00	26.89	0.00	2.30	13.31
4	1	NUMBER	22	0	16	0	6	6
		DENSITY	28.95	0.00	21.05	0.00	7.89	7.89
	2	NUMBER	20	0	19	0	1	6
		DENSITY	26.32	0.00	25.00	0.00	1.32	7.89
		MEAN DENS.	27.63	0.00	23.03	0.00	4.61	7.89
5	1	NUMBER	34	0	31	3	0	14
		DENSITY	36.96	0.00	33.70	3.26	0.00	15.22
	2	NUMBER	18	0	18	0	0	4
		DENSITY	21.18	0.00	21.18	0.00	0.00	4.71
		MEAN DENS.	29.07	0.00	27.44	1.63	0.00	9.96

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	7	0	5	0	2	0
		DENSITY	8.97	0.00	6.41	0.00	2.56	0.00
	2	NUMBER	17	0	5	0	12	0
		DENSITY	19.77	0.00	5.81	0.00	13.95	0.00
		MEAN DENS.	14.37	0.00	6.11	0.00	8.26	0.00
7	1	NUMBER	5	0	2	0	3	0
		DENSITY	5.88	0.00	2.35	0.00	3.53	0.00
	2	NUMBER	21	0	14	3	4	0
		DENSITY	25.30	0.00	16.87	3.61	4.82	0.00
		MEAN DENS.	15.59	0.00	9.61	1.81	4.17	0.00
8	1	NUMBER	42	3	37	1	1	40
		DENSITY	48.28	3.45	42.53	1.15	1.15	45.98
	2	NUMBER	28	1	27	0	0	37
		DENSITY	34.15	1.22	32.93	0.00	0.00	45.12
		MEAN DENS.	41.21	2.33	37.73	0.57	0.57	45.55
9	1	NUMBER	29	2	25	2	0	18
		DENSITY	37.66	2.60	32.47	2.60	0.00	23.38
	2	NUMBER	18	5	13	0	0	9
		DENSITY	20.69	5.75	14.94	0.00	0.00	10.34
		MEAN DENS.	29.18	4.17	23.71	1.30	0.00	16.86
		TOTAL NUMBER	400	11	333	11	45	329
		MEAN DENSITY OVER STATIONS	26.16	0.72	21.76	0.72	2.96	21.40

Appendix Table 26A. Upper Bay, 1989. Survey 10. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 23 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	304	145	157	0	0	33
		DENSITY	326.88	155.91	168.82	0.00	0.00	35.48
	2	NUMBER						
		DENSITY						
		MEAN DENS.	326.88	155.91	168.82	0.00	0.00	35.48
2	1	NUMBER	467	174	266	1	0	129
		DENSITY	507.61	189.13	289.13	1.09	0.00	140.22
	2	NUMBER						
		DENSITY						
		MEAN DENS.	507.61	189.13	289.13	1.09	0.00	140.22
3	1	NUMBER	373	100	252	3	1	123
		DENSITY	460.49	123.46	311.11	3.70	1.23	151.85
	2	NUMBER	206	54	152	0	0	219
		DENSITY	251.22	65.85	185.37	0.00	0.00	267.07
		MEAN DENS.	355.86	94.66	248.24	1.85	0.62	209.46
4	1	NUMBER	102	0	102	0	0	416
		DENSITY	107.37	0.00	107.37	0.00	0.00	437.89
	2	NUMBER	156	2	154	0	0	325
		DENSITY	164.21	2.11	162.11	0.00	0.00	342.11
		MEAN DENS.	135.79	1.05	134.74	0.00	0.00	390.00
6	1	NUMBER	490	0	488	2	0	4
		DENSITY	544.44	0.00	542.22	2.22	0.00	4.44
	2	NUMBER	370	0	369	0	1	23
		DENSITY	402.17	0.00	401.09	0.00	1.09	25.00
		MEAN DENS.	473.31	0.00	471.65	1.11	0.54	14.72

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
7	1	NUMBER	1594	0	1589	4	1	9
		DENSITY	1771.11	0.00	1765.56	4.44	1.11	10.00
	2	NUMBER	1224	0	1219	1	4	40
		DENSITY	1406.90	0.00	1401.15	1.15	4.60	45.98
		MEAN DENS.	1589.00	0.00	1583.35	2.80	2.85	27.99
8	1	NUMBER	211	152	52	4	1	2272
		DENSITY	217.53	156.70	53.61	4.12	1.03	2342.27
	2	NUMBER	265	232	29	4	0	1008
		DENSITY	273.20	239.18	29.90	4.12	0.00	1039.18
		MEAN DENS.	245.36	197.94	41.75	4.12	0.52	1690.72
9	1	NUMBER	207	50	122	31	0	462
		DENSITY	211.22	51.02	124.49	31.63	0.00	471.43
	2	NUMBER	284	86	178	12	0	207
		DENSITY	338.10	102.38	211.90	14.29	0.00	246.43
		MEAN DENS.	274.66	76.70	168.20	22.96	0.00	358.93
		TOTAL NUMBER	6253	995	5129	62	8	5270
		MEAN DENSITY OVER STATIONS	488.56	89.42	388.23	4.24	0.57	358.44

Appendix Table 27A. Upper Bay, 1989. Survey 11. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 25 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
1	1	NUMBER	1238	237	976	10	1	15
		DENSITY	1391.01	266.29	1096.63	11.24	1.12	16.85
	2	NUMBER	1493	248	1235	9	1	27
		DENSITY	1677.53	278.65	1387.64	10.11	1.12	30.34
		MEAN DENS.	1534.27	272.47	1242.13	10.67	1.12	23.60
2	1	NUMBER	1565	59	1487	13	2	49
		DENSITY	1596.94	60.20	1517.35	13.27	2.04	50.00
	2	NUMBER	1150	43	1113	1	0	27
		DENSITY	1263.74	47.25	1223.08	1.10	0.00	29.67
		MEAN DENS.	1430.34	53.73	1370.21	7.18	1.02	39.84
3	1	NUMBER	268	14	240	3	0	64
		DENSITY	291.30	15.22	260.87	3.26	0.00	69.57
	2	NUMBER	284	11	266	4	0	47
		DENSITY	305.38	11.83	286.02	4.30	0.00	50.54
		MEAN DENS.	298.34	13.52	273.45	3.78	0.00	60.05
4	1	NUMBER	1002	0	995	7	0	30
		DENSITY	1065.96	0.00	1058.51	7.45	0.00	31.91
	2	NUMBER	1726	0	1696	30	0	29
		DENSITY	1836.17	0.00	1804.26	31.91	0.00	30.85
		MEAN DENS.	1451.06	0.00	1431.38	19.68	0.00	31.38
5	1	NUMBER	235	0	198	34	1	14
		DENSITY	261.11	0.00	220.00	37.78	1.11	15.56
	2	NUMBER	263	6	222	32	2	13
		DENSITY	292.22	6.67	246.67	35.56	2.22	14.44
		MEAN DENS.	276.67	3.33	233.33	36.67	1.67	15.00

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
6	1	NUMBER	488	0	241	246	1	0
		DENSITY	483.17	0.00	238.61	243.56	0.99	0.00
	2	NUMBER	734	0	607	127	0	0
		DENSITY	772.63	0.00	638.95	133.68	0.00	0.00
		MEAN DENS.	627.90	0.00	438.78	188.62	0.50	0.00
7	1	NUMBER	479	0	421	58	0	0
		DENSITY	526.37	0.00	462.64	63.74	0.00	0.00
	2	NUMBER	246	0	193	53	0	4
		DENSITY	261.70	0.00	205.32	56.38	0.00	4.26
		MEAN DENS.	394.04	0.00	333.98	60.06	0.00	2.13
8	1	NUMBER	676	338	318	10	0	83
		DENSITY	711.58	355.79	334.74	10.53	0.00	87.37
	2	NUMBER	560	113	412	14	1	61
		DENSITY	560.00	113.00	412.00	14.00	1.00	61.00
		MEAN DENS.	635.79	234.39	373.37	12.26	0.50	74.18
9	1	NUMBER	622	194	297	127	0	15
		DENSITY	668.82	208.60	319.35	136.56	0.00	16.13
	2	NUMBER	497	141	249	106	0	10
		DENSITY	534.41	151.61	267.74	113.98	0.00	10.75
		MEAN DENS.	601.61	180.11	293.55	125.27	0.00	13.44
		TOTAL NUMBER	13526	1404	11166	884	9	488
		MEAN DENSITY OVER STATIONS	805.56	84.17	665.58	51.58	0.53	28.85

Appendix Table 28A. Upper Bay, 1989. Survey 12. Number and density (No./100M3) of fish eggs and larvae collected in replicated tows of the 60-cm sampler with 333-um meshes on 30 May, 1989. (The category 'other' includes Gobiid, Atherinid, Percid, and Cyprinid larvae). SB= Morone saxatilis WP=Morone americana

			Larvae					
STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
2	1	NUMBER	467	7	430	30	0	9
		DENSITY	467.00	7.00	430.00	30.00	0.00	9.00
	2	NUMBER	409	7	358	44	0	22
		DENSITY	439.78	7.53	384.95	47.31	0.00	23.66
		MEAN DENS.	453.39	7.26	407.47	38.66	0.00	16.33
3	1	NUMBER	1148	0	819	329	0	6
		DENSITY	1125.49	0.00	802.94	322.55	0.00	5.88
	2	NUMBER	1100	3	1016	81	0	5
		DENSITY	1182.80	3.23	1092.47	87.10	0.00	5.38
		MEAN DENS.	1154.14	1.61	947.71	204.82	0.00	5.63
4	1	NUMBER	166	1	58	106	1	0
		DENSITY	176.60	1.06	61.70	112.77	1.06	0.00
	2	NUMBER	243	0	84	159	0	0
		DENSITY	253.13	0.00	87.50	165.63	0.00	0.00
		MEAN DENS.	214.86	0.53	74.60	139.20	0.53	0.00
5	1	NUMBER	294	3	273	18	0	7
		DENSITY	316.13	3.23	293.55	19.35	0.00	7.53
	2	NUMBER	624	4	587	33	0	17
		DENSITY	670.97	4.30	631.18	35.48	0.00	18.28
		MEAN DENS.	493.55	3.76	462.37	27.42	0.00	12.90
6	1	NUMBER	656	0	108	548	0	1
		DENSITY	636.89	0.00	104.85	532.04	0.00	0.97
	2	NUMBER	362	0	320	42	0	5
		DENSITY	358.42	0.00	316.83	41.58	0.00	4.95
		MEAN DENS.	497.65	0.00	210.84	286.81	0.00	2.96

Larvae

STATION	REP		TOTAL	SB	WP	CLUPEID	OTHER	SB EGGS
7	1	NUMBER	1298	0	1260	34	4	1
		DENSITY	1311.11	0.00	1272.73	34.34	4.04	1.01
	2	NUMBER	1328	0	1289	38	1	2
		DENSITY	1355.10	0.00	1315.31	38.78	1.02	2.04
		MEAN DENS.	1333.11	0.00	1294.02	36.56	2.53	1.53
8	1	NUMBER	230	60	151	19	0	14
		DENSITY	242.11	63.16	158.95	20.00	0.00	14.74
	2	NUMBER	203	69	121	13	0	22
		DENSITY	213.68	72.63	127.37	13.68	0.00	23.16
		MEAN DENS.	227.89	67.89	143.16	16.84	0.00	18.95
9	1	NUMBER	382	81	287	12	1	25
		DENSITY	454.76	96.43	341.67	14.29	1.19	29.76
	2	NUMBER	570	128	428	14	0	5
		DENSITY	670.59	150.59	503.53	16.47	0.00	5.88
		MEAN DENS.	562.68	123.51	422.60	15.38	0.60	17.82
		TOTAL NUMBER	9480	363	7589	1520	7	141
		MEAN DENSITY OVER STATIONS	617.16	25.57	495.35	95.71	0.46	9.51

Appendix Table 29A. Potomac River 1989. Survey 2, 6 April.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	3	1.536	5.267	0	0.000	0.000	0	0.000	0.000	2	1.205	0.672	0	0.000	0.000
3.5	1	0.526	1.804	1	0.269	0.274	1	0.526	0.461	0	0.000	0.000	1	0.581	0.283
4.0	1	0.526	1.804	1	0.269	0.274	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	5	2.588	8.875	2	0.538	0.548	1	0.526	0.461	2	1.205	0.672	1	0.581	0.283

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	5	5.939	57.850
3.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	2	1.053	2.010	6	4.832	26.624
4.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	1	0.526	1.005	3	3.083	20.622
4.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	3	1.579	3.015	14	13.854	105.096

Appendix Table 30A. Potomac River 1989. Survey 5, 21 April.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	1	0.610	2.092	3	1.844	1.877	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	1	0.549	0.481	0	0.000	0.000	0	0.000	0.000
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	1	0.526	0.461	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.610	0.340	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	1	0.610	2.092	3	1.844	1.877	2	1.075	0.942	1	0.610	0.340	0	0.000	0.000

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	1	0.562	0.528	0	0.000	0.000	5	4.497	43.802
3.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.481	2.650
4.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.461	1.484
5.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.340	0.313
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	1	0.562	0.528	0	0.000	0.000	8	5.779	48.249

Appendix Table 31A. Potomac River 1989. Survey 6, 24 April.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	0	0.000	0.000	2	0.967	0.984	11	5.191	4.547	19	10.126	5.650	3	1.403	0.683
3.5	1	0.532	1.824	0	0.000	0.000	4	2.065	1.809	16	8.529	4.759	6	2.806	1.367
4.0	0	0.000	0.000	1	0.467	0.475	4	1.946	1.705	14	7.442	4.153	12	5.242	2.553
4.5	0	0.000	0.000	0	0.000	0.000	1	0.472	0.413	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	0.935	0.455
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	0.935	0.455
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	1	0.532	1.824	3	1.434	1.460	20	9.674	8.474	49	26.097	14.562	25	11.321	5.513

mm class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	COMBINED Freq	COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.500	0.955	36	12.820	124.867
3.5	1	0.472	0.313	0	0.000	0.000	0	0.000	0.000	1	0.500	0.955	30	11.027	60.759
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.476	0.909	32	9.795	65.529
4.5	0	0.000	0.000	1	0.439	0.282	0	0.000	0.000	1	0.476	0.909	3	1.604	5.165
5.0	2	0.909	0.603	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	4	1.058	1.143
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.00	0.000	2	0.455	0.419
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.00	0.000	0	0.000	0.000
Totals	3	1.381	0.916	1	0.439	0.282	0	0.000	0.000	4	1.952	3.728	107	36.759	257.882

Appendix Table 32A. Potomac River 1989. Survey 7, 27 April.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	0	0.000	0.000	0	0.000	0.000	1	0.515	0.451	1	0.485	0.271	3	1.631	0.794
3.5	0	0.000	0.000	0	0.000	0.000	3	1.485	1.301	0	0.000	0.000	3	1.544	0.752
4.0	0	0.000	0.000	1	0.521	0.530	3	1.485	1.301	1	0.485	0.271	2	1.146	0.558
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	4	2.292	1.116
5.0	0	0.000	0.000	1	0.500	0.509	0	0.000	0.000	0	0.000	0.000	1	0.573	0.279
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	2	1.021	1.039	7	3.485	3.053	2	0.970	0.542	13	7.186	3.499

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	1	0.481	0.319	0	0.000	0.000	0	0.000	0.000	3	1.530	2.922	9	4.757	46.333
3.5	0	0.000	0.000	0	0.000	0.000	1	0.581	0.546	3	1.531	2.924	10	5.523	30.432
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	7	2.660	17.795
4.5	2	0.952	0.631	0	0.000	0.000	0	0.000	0.000	1	0.510	0.974	7	2.721	8.762
5.0	1	0.476	0.316	1	0.476	0.306	0	0.000	0.000	0	0.000	0.000	4	1.409	1.522
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	4	1.909	1.266	1	0.476	0.306	1	0.581	0.546	7	3.571	6.820	37	17.070	104.844

Appendix Table 33A. Potomac River 1989. Survey 8, 30 April.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm	Station 1			Station 2			Station 3			Station 4			Station 5		
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	3	2.108	1.176	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	1.054	0.588	1	0.588	0.286
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	1.054	0.588	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	7	4.216	2.352	1	0.588	0.286

mm	Station 6			Station 7			Station 8			Station 9			ALL STATIONS COMBINED		No./seg (xE-6)
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/seg (xE-6)	(Cor#1) (D/N)
3.0	0	0.000	0.000	0	0.000	0.000	8	4.638	4.360	8	4.972	9.497	19	15.032	146.412
3.5	1	0.556	0.369	1	0.549	0.352	6	3.475	3.266	5	3.228	6.165	16	11.027	60.759
4.0	1	0.568	0.377	1	0.549	0.352	4	2.339	2.199	12	7.145	13.647	20	17.163	114.820
4.5	0	0.000	0.000	0	0.000	0.000	2	1.163	1.093	2	0.689	1.316	4	2.409	7.757
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	2	1.124	0.746	2	1.098	0.704	20	11.615	10.918	27	16.034	30.625	59	45.631	329.748

Appendix Table 34A. Potomac River 1989. Survey 9, 3 May.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	7	3.880	13.305	5	2.344	2.386	10	6.413	5.618	0	0.000	0.000	0	0.000	0.000
3.5	5	2.632	9.025	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.562	0.274
4.0	1	0.722	2.476	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	3	1.634	0.796
4.5	4	2.165	7.424	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.510	0.248
5.0	0	0.000	0.000	1	0.781	0.795	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	1	0.526	1.804	0	0.000	0.000	0	0.000	0.000	1	0.649	0.362	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	19	9.925	34.034	6	3.125	3.181	10	6.413	5.618	1	0.649	0.362	5	2.706	1.318

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	8	4.434	2.940	8	4.372	2.807	0	0.000	0.000	3	1.744	3.331	41	30.387	295.969
3.5	5	2.328	1.543	0	0.000	0.000	1	0.568	0.534	2	1.119	2.137	14	13.513	74.457
4.0	4	2.274	1.508	1	0.538	0.345	2	1.075	1.011	2	1.075	2.053	14	8.189	54.784
4.5	4	2.160	1.432	0	0.000	0.000	1	0.538	0.506	0	0.000	0.000	10	9.610	30.944
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.795	0.859
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	2.166	1.993
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	21	11.196	7.423	9	4.910	3.152	4	2.181	2.051	7	3.938	7.522	82	64.660	459.006

Appendix Table 35A. Potomac River 1989. Survey 10, 7 May.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	1	0.543	1.862	1	0.562	0.572	2	1.087	0.952	0	0.000	0.000	0	0.000	0.000
3.5	1	0.562	1.927	1	0.562	0.572	4	2.174	1.904	0	0.000	0.000	0	0.000	0.000
4.0	1	0.562	1.927	1	0.610	0.621	1	0.543	0.476	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	1	0.543	0.476	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	3	1.630	1.428	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	3	1.667	5.716	3	1.734	1.765	11	5.977	5.236	0	0.000	0.000	0	0.000	0.000

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	COMBINED Freq	COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	4	3.386	32.980
3.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	6	4.404	24.266
4.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	3	3.024	20.231
4.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.476	1.533
5.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	3	1.428	1.542
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	17	12.718	80.551

Appendix Table 36A. Potomac River 1989. Survey 11, 9 May.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	7	3.793	13.006	3	1.862	1.896	7	3.368	2.950	2	1.136	0.634	1	0.633	0.308
3.5	6	3.262	11.185	4	1.862	1.896	1	0.561	0.491	1	0.568	0.317	0	0.000	0.000
4.0	3	1.631	5.593	0	0.000	0.000	1	0.561	0.491	0	0.000	0.000	0	0.000	0.000
4.5	1	0.532	1.824	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	17	9.218	31.609	7	3.724	3.792	9	4.490	3.932	3	1.704	0.951	1	0.633	0.308

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	20	18.794	183.054
3.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	12	13.889	76.528
4.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	4	6.084	40.702
4.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	1.824	5.873
5.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	37	40.591	306.157

Appendix Table 37A. Potomac River 1989. Survey 12, 12 May.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm	Station 1			Station 2			Station 3			Station 4			Station 5		
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)
3.0	3	1.210	4.149	3	1.389	1.414	1	0.463	0.406	0	0.000	0.000	0	0.000	0.000
3.5	5	1.661	5.696	1	0.510	0.519	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	1	0.605	2.075	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
7.0	1	0.605	2.075	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
7.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
8.0	1	0.605	2.075	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	11	4.686	16.068	4	1.899	1.933	1	0.463	0.406	0	0.000	0.000	0	0.000	0.000

mm	Station 6			Station 7			Station 8			Station 9			ALL STATIONS COMBINED		No./seg (xE-6)
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/seg (xE-6)	(Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	7	5.969	58.138
3.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	6	6.215	34.245
4.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	2.075	4.088
6.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
7.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	2.075	4.607
7.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
8.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	2.075	5.167
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	16	18.409	106.245

ppendix Table 38A. Potomac River 1989. Survey 15, 24 May.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	13	5.824	19.970	31	14.519	14.780	34	14.839	12.999	145	62.462	34.854	12	6.262	3.050
3.5	17	7.658	26.258	55	25.286	25.741	45	20.788	18.210	173	94.412	52.682	7	3.972	1.934
4.0	14	6.306	21.624	62	28.201	28.709	51	24.110	21.120	184	79.677	44.460	12	6.579	3.204
4.5	20	9.555	32.764	44	20.220	20.584	40	19.362	16.961	35	15.120	8.437	20	10.557	5.141
5.0	14	6.689	22.935	2	1.033	1.052	11	5.605	4.910	3	1.124	0.627	9	4.313	2.100
5.5	8	4.040	13.855	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	6	2.778	1.353
6.0	8	4.040	13.855	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	5	2.315	1.127
6.5	3	1.515	5.195	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	4	1.852	0.902
7.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.463	0.225
Totals	97	45.627	156.456	194	89.259	90.866	181	84.704	74.200	540	252.795	141.060	76	39.091	19.036

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	1	0.485	0.322	30	13.084	8.400	3	1.443	1.356	16	8.351	15.950	285	127.269	1239.600
3.5	2	0.971	0.644	79	34.362	22.060	6	2.885	2.712	19	9.964	19.032	404	200.297	1103.636
4.0	4	2.024	1.342	96	41.462	26.619	12	5.906	5.552	24	12.049	23.014	459	206.314	1380.241
4.5	10	4.936	3.273	43	18.597	11.939	5	2.540	2.388	44	22.315	42.621	260	123.202	396.710
5.0	4	1.983	1.314	4	1.774	1.139	0	0.000	0.000	41	20.248	38.674	88	42.768	46.189
5.5	1	0.485	0.322	0	0.000	0.000	0	0.000	0.000	22	11.096	21.192	37	18.399	16.927
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	17	8.454	16.147	30	14.809	29.174
6.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	6	3.170	6.055	13	6.537	13.662
7.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	3	1.057	2.019	4	1.520	3.374
tals	22	10.884	7.217	252	109.279	70.157	26	12.774	12.008	192	96.704	184.704	1580	741.115	4229.515

Appendix Table 39A. Potomac River 1989. Survey 16, 28 May.
Station and riverwide estimated abundances of striped bass larvae for each 0.5 mm length class.
The riverwide abundance corrections are for day-night avoidance.

mm	Station 1			Station 2			Station 3			Station 4			Station 5		
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)
3.0	17	7.537	25.845	2	1.080	1.099	7	3.617	3.169	4	1.850	1.032	9	4.444	2.164
3.5	46	20.013	68.623	16	7.918	8.061	11	5.838	5.114	14	6.951	3.878	11	5.202	2.533
4.0	74	31.872	109.291	37	18.236	18.564	30	16.734	14.659	18	8.756	4.886	29	13.939	6.788
4.5	139	60.411	207.150	97	47.448	48.302	50	27.019	23.669	26	12.636	7.051	26	12.525	6.100
5.0	41	17.668	60.583	66	32.027	32.603	33	17.821	15.611	17	8.319	4.642	7	3.283	1.599
5.5	8	3.336	11.439	14	6.837	6.960	5	2.996	2.624	2	1.188	0.663	1	0.455	0.221
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
7.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
7.5	0	0.000	0.000	1	0.540	0.550	0	0.000	0.000	0	0.000	0.000	1	0.455	0.221
8.0	0	0.000	0.000	1	0.540	0.550	1	0.620	0.543	0	0.000	0.000	1	0.455	0.221
8.5	1	0.618	2.119	0	0.000	0.000	2	1.188	1.041	0	0.000	0.000	2	0.960	0.468
9.0	0	0.000	0.000	4	1.919	1.954	1	0.620	0.543	0	0.000	0.000	2	0.960	0.468
9.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
10.0	0	0.000	0.000	5	2.459	2.503	0	0.000	0.000	1	0.572	0.319	0	0.000	0.000
10.5	0	0.000	0.000	1	0.540	0.550	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
11.0	0	0.000	0.000	1	0.540	0.550	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	326	141.455	485.049	245	120.084	122.246	140	76.453	66.973	83	40.272	22.471	89	42.677	20.783

mm	Station 6			Station 7			Station 8			Station 9			ALL STATIONS COMBINED		No./seg (xE-6)
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/seg (xE-6)	(Cor#1) (D/N)
3.0	0	0.000	0.000	4	2.031	1.304	8	4.232	3.978	14	7.414	14.161	65	52.752	513.804
3.5	0	0.000	0.000	10	5.093	3.270	6	3.223	3.029	4	2.038	3.893	119	98.401	542.190
4.0	4	2.353	1.560	7	3.546	2.277	5	2.800	2.632	1	0.561	1.072	206	161.728	1081.960
4.5	2	1.190	0.789	3	1.531	0.983	3	1.563	1.469	0	0.000	0.000	346	295.513	951.552
5.0	3	1.772	1.175	4	2.046	1.314	4	1.660	1.560	1	0.739	1.411	174	120.498	130.138
5.5	1	0.595	0.394	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	32	22.301	20.517
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.5	1	0.581	0.385	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.385	0.805
7.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
7.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	0.771	1.812
8.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	3	1.314	3.272
8.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	6	3.628	9.614
9.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	7	2.965	8.361
9.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
10.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	6	2.822	9.200
10.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.550	1.958
11.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.550	2.178
Totals	11	6.491	4.303	28	14.247	9.148	26	13.478	12.668	20	10.752	20.536	968	764.178	3277.361

Appendix Table 40A. Upper Bay, 1989. Survey 3 , 23 April.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	1	0.602	1.406	1	0.595	0.587	0	0.000	0.000
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	1	0.602	1.406	1	0.595	0.587	0	0.000	0.000

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	1.993	10.981
4.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	1.993	10.981

Appendix Table 41A. Upper Bay, 1989. Survey 5, 2 May.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	4	1.786	1.134	4	1.134	11.046
3.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	3	1.786	1.134	3	1.134	7.587
4.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	7	3.572	2.268	7	2.268	18.633

Appendix Table 42A. Upper Bay, 1989. Survey 7, 11 May.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.556	0.237
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.556	0.237

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.000	0.000	0	0.000	0.000	1	0.735	0.324	3	1.667	1.059	4	1.383	13.470
3.5	0	0.000	0.000	0	0.000	0.000	2	1.291	0.569	2	1.111	0.705	4	1.274	7.020
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.556	0.353	2	0.590	3.947
4.5	0	0.000	0.000	0	0.000	0.000	3	2.026	0.893	3	1.667	1.059	6	1.952	6.285
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	1.111	0.705	2	0.705	0.649
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	6	4.052	1.786	11	6.112	3.881	18	5.904	31.371

Appendix Table 43A. Upper Bay, 1989. Survey 8, 15 May.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	1	0.526	0.232	0	0.000	0.000	1	0.232	1.278
4.0	0	0.000	0.000	0	0.000	0.000	1	0.602	0.265	0	0.000	0.000	1	0.265	1.773
4.5	0	0.000	0.000	0	0.000	0.000	1	0.526	0.232	1	0.676	0.429	2	0.661	2.128
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	3	1.654	0.729	1	0.676	0.429	4	1.158	5.179

Appendix Table 44A. Upper Bay, 1989. Survey 9, 18 May.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
3.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.000	0.000	0	0.000	0.000	2	1.150	0.507	0	0.000	0.000	2	0.507	4.938
3.5	0	0.000	0.000	0	0.000	0.000	1	0.610	0.269	2	1.149	0.730	3	0.999	5.504
4.0	0	0.000	0.000	0	0.000	0.000	1	0.575	0.254	0	0.000	0.000	1	0.254	1.699
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	2	1.299	0.825	2	0.825	2.657
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.575	0.365	1	0.365	0.394
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.575	0.365	1	0.365	0.336
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.575	0.365	1	0.365	0.763
Totals	0	0.000	0.000	0	0.000	0.000	4	2.335	1.030	7	4.173	2.650	11	3.680	16.291

Appendix Table 45A. Upper Bay, 1989. Survey 10, 23 May.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm	Station 1			Station 2			Station 3			Station 4			Station 5		
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)
3.0	120	128.589	204.842	122	132.697	134.820	97	59.594	139.152	0	0.000	0.000	0	0.000	0.000
3.5	25	27.325	43.529	48	51.859	52.689	54	33.120	77.335	1	0.526	0.519	0	0.000	0.000
4.0	0	0.000	0.000	4	4.576	4.649	3	1.937	4.523	1	0.526	0.519	0	0.000	0.000
4.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	145	155.914	248.371	174	189.132	192.158	154	94.651	221.010	2	1.052	1.038	0	0.000	0.000

mm	Station 6			Station 7			Station 8			Station 9			ALL STATIONS COMBINED		No./seg (xE-6)
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/seg (xE-6)	(Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	66	34.136	15.054	35	19.431	12.340	440	506.208	4930.466
3.5	0	0.00	0.000	0	0.000	0.000	148	75.887	33.466	45	24.982	15.860	321	223.398	1230.923
4.0	0	0.00	0.000	0	0.000	0.000	133	68.799	30.340	41	23.228	14.750	182	54.781	366.485
4.5	0	0.00	0.000	0	0.000	0.000	32	16.338	7.205	12	7.305	4.640	44	11.845	38.141
5.0	0	0.00	0.000	0	0.000	0.000	5	2.779	1.226	3	1.754	1.110	8	2.336	2.523
5.5	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	0	0.000	0.000	0	0.000	0.000	384	197.939	87.291	136	76.700	48.700	995	798.568	6568.538

Appendix Table 46A. Upper Bay, 1989. Survey 11, 25 May.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm Class	Station 1 Freq	Station 1 #/100m3	Station 1 #/seg (xE-6)	Station 2 Freq	Station 2 #/100m3	Station 2 #/seg (xE-6)	Station 3 Freq	Station 3 #/100m3	Station 3 #/seg (xE-6)	Station 4 Freq	Station 4 #/100m3	Station 4 #/seg (xE-6)	Station 5 Freq	Station 5 #/100m3	Station 5 #/seg (xE-6)
3.0	138	77.446	123.371	40	20.887	21.221	24	12.985	30.320	0	0.000	0.000	5	2.778	1.183
3.5	27	15.334	24.427	12	6.089	6.186	1	0.538	1.256	0	0.000	0.000	1	0.556	0.237
4.0	147	82.589	131.564	29	15.202	15.445	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
4.5	166	92.928	148.034	21	11.551	11.736	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.0	7	4.173	6.648	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
5.5	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	485	272.470	434.044	102	53.729	54.588	25	13.523	31.576	0	0.000	0.000	6	3.334	1.420

mm Class	Station 6 Freq	Station 6 #/100m3	Station 6 #/seg (xE-6)	Station 7 Freq	Station 7 #/100m3	Station 7 #/seg (xE-6)	Station 8 Freq	Station 8 #/100m3	Station 8 #/seg (xE-6)	Station 9 Freq	Station 9 #/100m3	Station 9 #/seg (xE-6)	ALL STATIONS COMBINED Freq	ALL STATIONS COMBINED #/seg (xE-6)	No./seg (xE-6) (Cor#1) (D/N)
3.0	0	0.00	0.000	0	0.000	0.000	203	105.450	46.503	91	49.023	31.130	501	253.728	2471.311
3.5	0	0.00	0.000	0	0.000	0.000	69	35.756	15.768	59	31.834	20.215	169	68.089	375.170
4.0	0	0.00	0.000	0	0.000	0.000	54	27.842	12.278	57	30.401	19.305	287	178.592	1194.780
4.5	0	0.00	0.000	0	0.000	0.000	98	51.638	22.772	66	35.239	22.377	351	204.919	659.839
5.0	0	0.00	0.000	0	0.000	0.000	24	12.260	5.407	49	25.523	16.207	80	28.262	30.523
5.5	0	0.00	0.000	0	0.000	0.000	3	1.449	0.639	9	4.741	3.011	12	3.650	3.358
6.0	0	0.00	0.000	0	0.000	0.000	0	0.000	0.000	4	2.346	1.490	4	1.490	2.935
Totals	0	0.000	0.000	0	0.000	0.000	451	234.395	103.367	335	172.020	113.735	1404	733.590	4737.916

Appendix Table 47A. Upper Bay, 1989. Survey 12, 30 May.
Station and areawide estimated abundances of striped bass larvae for each 0.5 mm length class.
The areawide abundance corrections are for day-night avoidance.

mm	Station 1			Station 2			Station 3			Station 4			Station 5		
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)
3.0	1	0.538	0.857	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.538	0.229
3.5	1	0.538	0.857	2	1.075	1.092	0	0.000	0.000	0	0.000	0.000	2	1.075	0.458
4.0	0	0.000	0.000	1	0.538	0.547	0	0.000	0.000	0	0.000	0.000	1	0.538	0.229
4.5	2	1.038	1.654	0	0.000	0.000	0	0.000	0.000	1	0.532	0.525	2	1.075	0.458
5.0	3	1.613	2.570	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.538	0.229
5.5	7	3.538	5.636	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
6.0	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
Totals	14	7.265	11.574	3	1.613	1.639	0	0.000	0.000	1	0.532	0.525	7	3.764	1.603

mm	Station 6			Station 7			Station 8			Station 9			UB89- CRUISE-12 ALL STATIONS COMBINED		No./seg (xE-6)
Class	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/100m3	#/seg (xE-6)	Freq	#/seg (xE-6)	(Cor#1) (D/N)
3.0	0	0.000	0.000	0	0.000	0.000	9	4.772	2.104	21	12.462	7.913	32	11.103	108.143
3.5	0	0.000	0.000	0	0.000	0.000	22	11.615	5.122	31	18.397	11.682	58	19.211	105.853
4.0	0	0.000	0.000	0	0.000	0.000	30	15.878	7.002	70	41.095	26.095	102	33.873	226.610
4.5	0	0.000	0.000	0	0.000	0.000	25	13.309	5.869	60	35.458	22.516	90	31.022	99.891
5.0	0	0.000	0.000	0	0.000	0.000	35	18.082	7.974	23	13.377	8.494	62	19.267	20.808
5.5	0	0.000	0.000	0	0.000	0.000	5	2.649	1.168	3	2.003	1.272	15	8.076	7.430
6.0	0	0.000	0.000	0	0.000	0.000	2	1.062	0.468	1	0.717	0.455	3	0.923	1.818
6.5	0	0.000	0.000	0	0.000	0.000	1	0.526	0.232	0	0.000	0.000	1	0.232	0.485
Totals	0	0.000	0.000	0	0.000	0.000	129	67.893	29.939	209	123.509	78.427	363	123.707	571.038

Table 48A. Age-length key based upon 179 otolith-aged striped bass larvae collected in the Potomac River, 1989. The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups. The age-length equation for Potomac River striped bass larvae is : $A = -9.64 + 3.39(L)$, where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days)												
	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99
3	0.5871	0.2494	0.1234	0.0401									
3.5	0.1251	0.2456	0.3172	0.2170	0.0951								
4		0.0322	0.1363	0.2996	0.3200	0.1664	0.0455						
4.5				0.0446	0.1851	0.3574	0.2919	0.1210					
5						0.0643	0.2513	0.3967	0.2329	0.0548			
5.5								0.0951	0.3374	0.4015	0.1660		
6										0.1469	0.4363	0.3460	0.0708
6.5												0.2358	0.5159
7													0.0294
7.5													
8													
8.5													
9													
9.5													
10													
10.5													
11													
11.5													
12													
12.5													
13													
13.5													
14													
14.5													
15													
15.5													
16													

Table 48A (cont.). Age-length key based upon 179 otolith-aged striped bass larvae collected in the Potomac River, 1989. The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups. The age-length equation for Potomac River striped bass larvae is : $A = -9.64 + 3.39(L)$, where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days)											
	13-13.99	14-14.99	15-15.99	16-16.99	17-17.99	18-18.99	19-19.99	20-20.99	21-21.99	22-22.99	23-23.99	24-24.99
3												
3.5												
4												
4.5												
5												
5.5												
6												
6.5	0.2483											
7	0.3451	0.5217	0.1038									
7.5		0.0559	0.5273	0.4168								
8				0.1210	0.6896	0.1894						
8.5						0.2709	0.6899	0.0392				
9								0.5636	0.4364			
9.5									0.0294	0.8414	0.1292	
10											0.1635	0.8365
10.5												
11												
11.5												
12												
12.5												
13												
13.5												
14												
14.5												
15												
15.5												
16												

Table 48A (cont.). Age-length key based upon 179 otolith-aged striped bass larvae collected in the Potomac River, 1989. The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups. The age-length equation for Potomac River striped bass larvae is : A = -9.64 + 3.39(L), where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days) 25-25.99	26-26.99	27-27.99	28-28.99	29-29.99	30-30.99	31-31.99	32-32.99	33-33.99	34-34.99	35-35.99	36-36.99
3												
3.5												
4												
4.5												
5												
5.5												
6												
6.5												
7												
7.5												
8												
8.5												
9												
9.5												
10												
10.5	1											
11		0.0287	0.7846	0.1867								
11.5				0.1841	0.7553	0.0606						
12						0.4562	0.5438					
12.5							0.0853	0.5991	0.3156			
13									0.2483	0.5781	0.1736	
13.5										0.0548	0.3816	0.4633
14												0.1539
14.5												
15												
15.5												
16												

Table 48A (cont.). Age-length key based upon 179 otolith-aged striped bass larvae collected in the Potomac River, 1989. The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups. The age-length equation for Potomac River striped bass larvae is : A = -9.64 + 3.39(L), where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days) 37-37.99	38-38.99	39-39.99	40-40.99	41-41.99	42-42.99	43-43.99	44-44.99	45-45.99	46-46.99	47-47.99	48-48.99
3												
3.5												
4												
4.5												
5												
5.5												
6												
6.5												
7												
7.5												
8												
8.5												
9												
9.5												
10												
10.5												
11												
11.5												
12												
12.5												
13												
13.5	0.1003											
14	0.4525	0.3342	0.0594									
14.5	0.0418	0.2459	0.4414	0.2334	0.0375							
15			0.1093	0.3232	0.3808	0.1867						
15.5				0.0359	0.1674	0.3563	0.3090	0.1314				
16						0.0838	0.2318	0.3472	0.2438	0.0934		

Table 49A. Age-length key based upon 193 otolith-aged striped bass larvae collected in the Upper Bay, 1989. The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups. The age-length equation for Upper Bay striped bass larvae is : $A = -50.63 + 17.70(L) - 1.55(L^2) + 0.05(L^3)$, where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days) 0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99
3	1												
3.5	1												
4	0.9515	0.0485											
4.5	0.0951	0.2756	0.3715	0.2062	0.0516								
5					0.2207	0.5050	0.2743						
5.5								0.2207	0.6563	0.1230			
6											0.6141	0.3859	
6.5													0.4247
7													
7.5													
8													
8.5													
9													
9.5													
10													
10.5													
11													
11.5													
12													
12.5													
13													
13.5													
14													
14.5													
15													
15.5													
16													

Table 49A (cont.). Age-length key based upon 193 otolith-aged striped bass larvae collected in the Upper Bay, 1989. The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups. The age-length equation for Upper Bay striped bass larvae is : A = -50.63 + 17.70(L) - 1.55(L^2) + 0.05(L^3), where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days)											
	13-13.99	14-14.99	15-15.99	16-16.99	17-17.99	18-18.99	19-19.99	20-20.99	21-21.99	22-22.99	23-23.99	24-24.99
3												
3.5												
4												
4.5												
5												
5.5												
6												
6.5	0.5753											
7		0.5438	0.4562									
7.5				0.9131	0.0869							
8					0.3409	0.6591						
8.5						0.0582	0.9419					
9								0.9177	0.0823			
9.5									0.8133	0.1867		
10										0.7257	0.2743	
10.5											0.6217	0.3783
11												0.5000
11.5												
12												
12.5												
13												
13.5												
14												
14.5												
15												
15.5												
16												

Table 49A (cont.). Age-length key based upon 193 otolith-aged striped bass larvae collected in the Upper Bay, 1989. The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups. The age-length equation for Upper Bay striped bass larvae is : $A = -50.63 + 17.70(L) - 1.55(L^2) + 0.05(L^3)$, where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days) 25-25.99	26-26.99	27-27.99	28-28.99	29-29.99	30-30.99	31-31.99	32-32.99	33-33.99	34-34.99	35-35.99	36-36.99
3												
3.5												
4												
4.5												
5												
5.5												
6												
6.5												
7												
7.5												
8												
8.5												
9												
9.5												
10												
10.5												
11	0.5000											
11.5	0.3228	0.6772										
12		0.1251	0.7498	0.1251								
12.5				0.5279	0.4721							
13					0.1020	0.6803	0.2177					
13.5							0.1867	0.6266	0.1867			
14									0.1762	0.5153	0.2817	0.2680
14.5											0.1151	0.3371
15												
15.5												
16												

Table 49A (cont.). Age-length key based upon 193 otolith-aged striped bass larvae collected in the Upper Bay, 1989.
The table contains probabilities that larvae in the 0.5 mm length classes will be included in 1-day age-groups.
The age-length equation for Upper Bay striped bass larvae is : A = -50.63 + 17.70(L) - 1.55(L^2) + 0.05(L^3),
where A = larvae age and L = standard length (mm).

Standard Length (mm)	Age (days)													
	37-37.99	38-38.99	39-39.99	40-40.99	41-41.99	42-42.99	43-43.99	44-44.99	45-45.99	46-46.99	47-47.99	48-48.99	49-49.99	50-50.99
3														
3.5														
4														
4.5														
5														
5.5														
6														
6.5														
7														
7.5														
8														
8.5														
9														
9.5														
10														
10.5														
11														
11.5														
12														
12.5														
13														
13.5														
14														
14.5	0.3818	0.1660												
15	0.0806	0.1691	0.2982	0.2827	0.1439	0.0455								
15.5			0.0294	0.0709	0.1511	0.2247	0.2327	0.1682	0.0846	0.0384				
16						0.0409	0.0611	0.1099	0.1550	0.1848	0.1740	0.1320	0.0793	0.0630

Table 50A. Striped bass larvae, Potomac River 1989. Estimated riverwide abundance-at-age for larvae in 0.5 mm length-classes. Cohort hatch dates, median age (days) of 3-day cohorts also are provided.

Survey 2, 6 April

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	57.850	33.964	14.428	7.139	2.320								
3.5	26.624	3.331	6.539	8.445	5.777	2.532							
4.0	20.622		0.664	2.811	6.178	6.599	3.432	0.938					
4.5	0.000												
5.0	0.000												
5.5	0.000												
6.0	0.000												
Totals	105.096	37.294	21.631	18.395	14.276	9.131	3.432	0.938	0.000	0.000	0.000	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		4/5	4/4	4/3	4/2	4/1	*3/31	3/30					
Cohort		B	B	A	A	A	-A	-A					

Survey 5, 21 April

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	43.802	25.716	10.924	5.405	1.756								
3.5	2.650	0.332	0.651	0.841	0.575	0.252							
4.0	0.000												
4.5	1.484				0.066	0.275	0.530	0.433	0.180				
5.0	0.000												
5.5	0.313								0.030	0.106	0.126	0.052	
6.0	0.000												
Totals	48.249	26.048	11.575	6.246	2.389	0.527	0.530	0.433	0.209	0.106	0.126	0.052	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		4/20	4/19	4/18	4/17	4/16	4/15	4/14	4/13	4/12	4/11	4/10	
Cohort		G	G	F	F	F	E	E	E	D	D	D	

Table 50A. (Continued)

Survey 6, 24 April

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	124.867	73.309	31.142	15.409	5.007								
3.5	60.759	7.601	14.922	19.273	13.185	5.778							
4.0	65.529		2.110	8.932	19.632	20.969	10.904	2.982					
4.5	5.165				0.230	0.956	1.846	1.508	0.625				
5.0	1.143						0.073	0.287	0.453	0.266	0.063		
5.5	0.419								0.040	0.141	0.168	0.070	
6.0	0.000												
Totals	257.882	80.910	48.174	43.613	38.055	27.704	12.823	4.776	1.118	0.408	0.231	0.070	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		4/23	4/22	4/21	4/20	4/19	4/18	4/17	4/16	4/15	4/14	4/13	
Cohort		H	H	G	G	G	F	F	F	E	E	E	

Survey 7, 27 April

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	46.333	27.202	11.555	5.717	1.858								
3.5	30.432	3.807	7.474	9.653	6.604	2.894							
4.0	17.795		0.573	2.425	5.331	5.694	2.961	0.810					
4.5	8.762				0.391	1.622	3.132	2.558	1.060				
5.0	1.522						0.098	0.382	0.604	0.354	0.083		
5.5	0.000												
6.0	0.000												
Totals	104.844	31.009	19.603	17.796	14.184	10.210	6.190	3.750	1.664	0.354	0.083	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		4/26	4/25	4/24	4/23	4/22	4/21	4/20	4/19	4/18	4/17		
Cohort		I	I	H	H	H	G	G	G	F	F		

Table 50A. (Continued)

Survey 8, 30 April

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	146.412	85.964	36.517	18.068	5.871								
3.5	60.759	7.601	14.922	19.273	13.185	5.778							
4.0	114.820		3.697	15.650	34.400	36.742	19.106	5.224					
4.5	7.757				0.346	1.436	2.772	2.264	0.939				
5.0	0.000												
5.5	0.000												
6.0	0.000												
Totals	329.748	93.565	55.137	52.991	53.802	43.956	21.878	7.489	0.939	0.000	0.000	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		4/29	4/28	4/27	4/26	4/25	4/24	4/23	4/22				
Cohort		J	J	I	I	I	H	H	H				

Survey 9, 3 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	295.969	173.763	73.815	36.527	11.868								
3.5	74.457	9.315	18.287	23.618	16.157	7.081							
4.0	54.584		1.764	7.467	16.418	17.531	9.116	2.493					
4.5	30.944				1.380	5.728	11.059	9.033	3.744				
5.0	0.859						0.055	0.216	0.341	0.200	0.047		
5.5	1.993								0.190	0.672	0.800	0.331	
6.0	0.000												
Totals	459.006	183.078	93.865	67.607	45.819	30.339	20.231	11.741	4.275	0.872	0.847	0.331	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		5/2	5/1	4/30	4/29	4/28	4/27	4/26	4/25	4/24	4/23	4/22	
Cohort		K	K	J	J	J	I	I	I	H	H	H	

Table 50A. (Continued)

Survey 10, 6 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	32.979	19.362	8.225	4.070	1.322								
3.5	24.266	3.036	5.960	7.697	5.266	2.308							
4.0	20.231		0.651	2.757	6.061	6.474	3.366	0.921					
4.5	1.533				0.068	0.284	0.548	0.447	0.185				
5.0	1.542						0.099	0.388	0.612	0.359	0.085		
5.5	0.000												
6.0	0.000												
Totals	80.551	22.398	14.524	14.524	12.718	9.065	4.013	1.755	0.797	0.359	0.085	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		5/5	5/4	5/3	5/2	5/1	4/30	4/29	4/28	4/27	4/26		
Cohort		L	L	K	K	K	J	J	J	I	I		

Survey 11, 9 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	183.054	107.471	45.654	22.584	7.340								
3.5	76.528	9.574	18.795	24.275	16.607	7.278							
4.0	40.702		1.311	5.548	12.194	13.025	6.773	1.852					
4.5	5.873				0.262	1.087	2.099	1.714	0.711				
5.0	0.000												
5.5	0.000												
6.0	0.000												
Totals	306.157	117.045	65.760	52.411	36.403	21.390	8.872	3.566	0.711	0.000	0.000	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		5/8	5/7	5/6	5/5	5/4	5/3	5/2	5/1				
Cohort		M	M	L	L	L	K	K	K				

Table 50A. (Continued)

Survey 12, 12 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	13-13.99	14-14.99	15-15.99	16-16.99	17-17.99	18-18.99
3.0	58.138	34.133	14.500	7.174	2.331															
3.5	34.245	4.284	8.411	10.863	7.431	3.257														
4.0	0.000																			
4.5	0.000																			
5.0	0.000																			
5.5	0.000																			
6.0	4.088										0.601	1.784	1.414	0.289						
6.5	0.000																			
7.0	4.607													0.136	1.590	2.403	0.478			
7.5	0.000																			
8.0	5.167																	0.625	3.563	0.979
Totals	106.245	38.417	22.910	18.037	9.762	3.257	0.000	0.000	0.000	0.000	0.601	1.784	1.414	0.425	1.590	2.403	0.478	0.625	3.563	0.979
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
Cohort Hatch Date		5/11	5/10	5/9	5/8	5/7					5/2	5/1	4/30	4/29	4/28	4/27	4/26	4/25	4/24	4/23
Cohort		N	N	M	M	M					K	K	J	J	J	I	I	I	H	H

Table 50A. (Continued)

Survey 15, 24 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	13-13.99	14-14.99	15-15.99	16-16.99	17-17.99	18-18.99
3.0	1239.600	727.769	321.642	159.145	51.716															
3.5	1103.636	138.065	243.305	314.235	214.972	94.211														
4.0	1380.241		44.332	187.652	412.476	440.562	229.092	62.642												
4.5	396.710				17.670	73.335	141.599	115.648	47.939											
5.0	46.189						2.969	11.605	18.319	10.755	2.531									
5.5	16.927									1.610	5.711	6.796	2.810							
6.0	29.174										4.286	12.729	10.094	2.066						
6.5	13.662												3.221	7.048	3.392					
7.0	3.374													0.100	1.164	1.760	0.350			
7.5	0.000																			
8.0	0.000																	0.000	0.000	0.000
Totals	4229.515	865.834	624.653	691.167	720.410	620.064	374.426	190.208	67.935	16.469	13.613	15.538	13.316	9.123	4.557	1.760	0.350			
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
Cohort Hatch Date		5/23	5/22	5/21	5/20	5/19	5/18	5/17	5/16	5/15	5/14	5/13	5/12	5/11	5/10	5/9	5/8			
Cohort		R	R	Q	Q	Q	P	P	P	O	O	O	N	N	N	M	M			

Table 50A. (Continued)

Survey 16, 28 May

mm Class	Totals (xE6)	Age-Class (days) 0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	13-13.99	14-14.99	15-15.99	16-16.99	17-17.99	18-18.99	19-19.99	20-20.99	21-21.99	22-22.99
3.0	513.804	301.654	128.143	63.403	20.604																			
3.5	542.190	67.828	133.162	171.983	117.655	51.562																		
4.0	1081.960		34.839	147.471	324.155	346.227	180.038	49.229																
4.5	951.552				42.439	176.132	340.085	277.758	115.138															
5.0	130.138						8.368	32.704	51.626	30.309	7.132													
5.5	20.517								1.951	6.922	8.238	3.406												
6.0	0.000																							
6.5	0.805												0.190	0.415	0.200									
7.0	0.000																							
7.5	1.812															0.101	0.955	0.755						
8.0	3.272																	0.396	2.256	0.620				
8.5	9.614																			2.605	6.635	0.377		
9.0	8.361																					4.712	3.649	
9.5	0.000																							
10.0	9.200																							
10.5	1.958																							
11.0	2.179																							
Totals	3277.364	369.482	296.144	382.857	504.853	573.922	528.491	359.691	168.715	37.232	15.369	3.406	0.190	0.415	0.200	0.101	0.955	1.151	2.256	3.225	6.635	5.089	3.649	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5
Cohort Hatch Date		5/27	5/26	5/25	5/24	5/23	5/22	5/21	5/20	5/19	5/18	5/17	5/16	5/15	5/14	5/13	5/12	5/11	5/10	5/9	5/8	5/7	5/6	
Cohort		S	S	S	R	R	R	Q	Q	Q	P	P	P	O	O	O	N	N	N	M	M	M	L	

Table 50A. (Continued)

mm Class	Totals (xE6)	23-23.99	24-24.99	25-25.99	26-26.99	27-27.99	28-28.99
3.0	513.804						
3.5	542.190						
4.0	1081.960						
4.5	951.552						
5.0	130.138						
5.5	20.517						
6.0	0.000						
6.5	0.805						
7.0	0.000						
7.5	1.812						
8.0	3.272						
8.5	9.614						
9.0	8.361						
9.5	0.000						
10.0	9.200	1.504	7.696				
10.5	1.958			1.958			
11.0	2.179				0.063	1.709	0.407
Totals	3277.364	1.504	7.696	1.958	0.063	1.709	0.407
Median Age		23.5	24.5	25.5	26.5	27.5	28.5
Cohort Hatch Date		5/4	5/3	5/2	5/1	4/30	5/29
Cohort		L	K	K	K	J	J

Table 51A. Striped bass larvae, Upper Bay 1989. Estimated areawide abundance-at-age for larvae in 0.5 mm length-classes. Cohort hatch dates, median age (days) of 3-day cohorts also are provided.

Survey 3, 24 April

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	0.000												
3.5	10.981	10.981											
4.0	0.000												
4.5	0.000												
5.0	0.000												
5.5	0.000												
6.0	0.000												
Totals	10.981	10.981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		4/23											
Cohort		H											

Survey 5, 2 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	11.046	11.046											
3.5	0.000												
4.0	7.587	7.219	0.368										
4.5	0.000												
5.0	0.000												
5.5	0.000												
6.0	0.000												
Totals	18.633	18.265	0.368	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		5/1	4/30										
Cohort		K	J										

Survey 7, 11 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	13.470	13.470											
3.5	7.020	7.020											
4.0	3.947	3.756	0.191										
4.5	6.285	0.598	1.732	2.335	1.296	0.324							
5.0	0.000												
5.5	0.649								0.143	0.426	0.080		
6.0	0.000												
Totals	31.371	24.843	1.924	2.335	1.296	0.324	0.000	0.000	0.143	0.426	0.080	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		5/10	5/9	5/8	5/7	5/6			5/3	5/2	5/1		
Cohort		N	M	M	M	L			K	K	K		

Table 51A. (Continued)

Survey 8, 15 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99
3.0	0.000												
3.5	1.278	1.278											
4.0	1.773	1.687	0.086										
4.5	2.128	0.202	0.586	0.791	0.439	0.110							
5.0	0.000												
5.5	0.000												
6.0	0.000												
Totals	5.179	3.167	0.672	0.791	0.439	0.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
Cohort Hatch Date		5/14	5/13	5/12	5/11	5/10							
Cohort		O	O	N	N	N							

Survey 9, 18 May

mm Class	Totals (xE6)	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	13-13.99
3.0	4.938	4.938													
3.5	5.504	5.504													
4.0	1.699	1.617	0.082												
4.5	2.657	0.253	0.732	0.987	0.548	0.137									
5.0	0.394					0.087	0.199	0.108							
5.5	0.336								0.074	0.221	0.041				
6.0	0.000														
6.5	0.763													0.324	0.439
7.0	0.000														
Totals	16.291	12.311	0.815	0.987	0.548	0.224	0.199	0.108	0.074	0.221	0.041	0.000	0.000	0.324	0.439
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
Cohort Hatch Date		5/17	5/16	5/15	5/14	5/13	5/12	5/11	5/10	5/9	5/8			5/5	5/4
Cohort		P	P	O	O	O	N	N	N	M	M			L	L

Table 51A. (Continued)

Survey 10, 23 May

mm Class	Totals (xE6)	Age-Class (days) 0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	13-13.99
3.0	4930.466	4930.466													
3.5	1230.923	1230.923													
4.0	366.485	348.710	17.775												
4.5	38.141	3.627	10.512	14.169	7.865	1.968									
5.0	2.523					0.557	1.274	0.692							
5.5	0.000														
6.0	0.000														
6.5	0.000														
7.0	0.000														
Totals	6568.538	6513.727	28.286	14.169	7.865	2.525	1.274	0.692	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
Cohort Hatch Date		5/22	5/21	5/20	5/19	5/18	5/17	5/16							
Cohort		R	Q	Q	Q	P	P	P							

Survey 11, 25 May

mm Class	Totals (xE6)	Age-Class (days) 0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	13 13.99
3.0	2471.311	2471.311													
3.5	375.170	375.170													
4.0	1194.780	1136.833	57.947												
4.5	659.839	62.751	181.852	245.130	136.059	34.048									
5.0	30.523					6.736	15.414	8.372							
5.5	3.358								0.741	2.204	0.413				
6.0	2.935											1.802	1.133		
6.5	0.000														
7.0	0.000														
Totals	4737.916	4046.065	239.798	245.130	136.059	40.784	15.414	8.372	0.741	2.204	0.413	1.802	1.133	0.000	0.000
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
Cohort Hatch Date		5/24	5/23	5/22	5/21	5/20	5/19	5/18	5/17	5/16	5/15	5/14	5/12		
Cohort		R	R	R	Q	Q	Q	P	P	P	O	O	O		

Table 51A. (Continued)

Survey 12, 30 May

mm Class	Totals (xE6)	Age-Class (days) 0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	13-13.99
3.0	108.143	108.143													
3.5	105.853	105.853													
4.0	226.610	215.619	10.991												
4.5	99.891	9.500	27.530	37.110	20.598	5.154									
5.0	20.808					4.592	10.508	5.708							
5.5	7.430								1.640	4.876	0.914				
6.0	1.818											1.116	0.702		
6.5	0.485													0.206	0.279
7.0	0.000														
Totals	571.038	439.115	38.521	37.110	20.598	9.747	10.508	5.708	1.640	4.876	0.914	1.116	0.702	0.206	0.279
Median Age		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
Cohort Hatch Date		5/29	5/28	5/27	5/26	5/25	5/24	5/23	5/22	5/21	5/20	5/19	5/18	5/17	5/16
Cohort		T	T	S	S	S	R	R	R	Q	Q	Q	P	P	P