from 2.7 to 18.7 million for the eight cohorts designated F through M. Extrapolated abundances at 20 days for cohorts N through Q, each of which was observed only twice, varied widely. If the mortality rates of cohorts N and O were estimated accurately and did not increase at later dates, they potentially could have made large contributions to 20-day-old abundances and to subsequent recruitment.

Striped bass larval mortality followed a pattern in the Potomac in 1987. The earliest-produced eggs and larvae (i.e. before 24 April) suffered complete mortality. The mortality rates of cohorts hatched between 24 April and 8 May were low to moderate (Table 8). Higher mortality rates apparently were experienced by cohorts hatched after 8 May, although too few data are available for cohorts hatched between 18 and 29 May to draw conclusions. The potential contributions to recruitment were similar for cohorts hatched between 24 April and 17 May, based upon estimated survivorship at 20 days posthatch. It is possible that striped bass larvae hatched between 18 and 23 May also contributed substantially to juvenile stage abundance, based upon the extrapolated 20-day-old abundance estimates.

White Perch: Nine cohorts of white perch larvae were observed on two or more cruises, exclusive of occurrences on Cruise 6. Their estimated mortality rates were lower, on average, than those for striped bass, and more variable (Table 10). Abundance data from Cruise 6, which were unexplainably high, were not included in the white perch larval mortality estimates. Mortality rates for white perch are probably less reliable than those for striped bass, although the patterns of survivorship and potential contributions to juvenile abundances are believed to be accurately described.

Table 10. White perch. Instantaneous daily mortality coefficients (Z) of 3-day cohorts that were on observed two or more cruises. Regression statistics for the exponential model are provided. Estimates of N_0 for cohorts observed only twice are extrapolated values. Potomac River, 1987.

HATCH DATES	COHORT #	# CRUISES OBSERVED	RANGE (DAYS) OF AGE CLASSES OBSERVED	Z	s.e.	EST. N_0 x 10^6	s.e. (N_0)	r^2
4/24-26	F	2	3-43	0.1089		490.0		
4/27-29	G	2	9-39	-0.1489				
4/30-5/2	H	3	6-33	-0.0539				
5/3-5	I	4	9-33	0.0850	0.018	1299.0	5.0×10^8	0.922
5/6-8	J	3	6-30	0.1055	0.022	3907.0	2.1×10^9	0.960
5/9-11	K	3	3-27	0.0775	0.015	2864.0	8.1×10^8	0.965
5/12-14	L	2	9-24	0.0617		1580.0		
5/15-17	M	2	6-21	0.0533		988.3		
5/18-20	N	2	3-18	0.0788		839.9		
			MEAN Z =	0.0815				
			MEAN Z = (> 2 DATA PTS)	0.0893				

The seven Z values that indicated declining abundances of a cohort ranged from Z=0.053 to Z=0.109, which are equivalent to 5.1 to 10.3% per day mortality rates. Large catches of larvae of cohorts G and H on the last cruise (4-5 June) resulted in apparent increases in their cohort abundances and negative Z. For cohorts with positive Z values, the mean instantaneous mortality was Z=0.082 (S.E.=0.0191), an average mortality rate of 7.9% per day for larvae hatched in the period 24 April to 20 May. For cohorts I, J, and K, each of which was observed $\geq$3 times and also occurred when larvae were $\geq$20 days posthatch, mean instantaneous mortality rate was Z=0.089 (S.E.=0.014).

White perch cohorts A through E were observed only once, on either Cruise 1 or 2 (Table 7). When observed, they ranged in mean age from 1.5 to 10.5 days. These cohorts, which were hatched between 9 and 23 April, apparently suffered complete mortality. We observed no white perch larvae with estimated hatch dates before 9 April.

Survivorship at 15 and 20 days was estimated for seven white perch cohorts (Table 11). Cohorts hatched between 3 and 17 May contributed from 2.4 to 6.1×10^8 larvae to the 20-day-old survivorship. The cohort hatched on 9-11 May was estimated to have made the largest contribution to numbers of 20-day-old abundance. Estimated numbers of white perch survivors at 20 days posthatch from individual cohorts often were more than 10 times as abundant as striped bass survivors at the same age (Tables 9 and 11).

Several cohorts of white perch larvae were represented from spawnings that took place after 18-20 May. The fate of those cohorts, in terms of survival and potential contribution to juvenile abundances, is unknown because we ended our cruises on 4-5 June. We do note that estimated survivorship at 20 days posthatch was declining for cohorts spawned after 9-11 May (Table 11). Cohorts

Table 11. White perch. Predicted survivorships of larvae at 15 and 20 days posthatch. Potomac River, 1987. Estimates were made using the regression statistics in Table 8. Asterisks denote estimates made for cohorts that were not actually sampled at $\geq$15 or $\geq$20 days.

Cohort Hatch Dates	Cohort	# Cruises Observed	Est. N @ 15 Days	Upper 80% CI @ N_{15}	Lower 80% CI @ N_{15}	Est. N @ 20 Days	Upper 80% CI @ N_{20}	Lower 80% CI @ N_{20}
4/9-11	A	1	0	0	0	0	0	0
4/12-14	B	1	0	0	0	0	0	0
4/15-17	C	1	0	0	0	0	0	0
4/18-20	D	1	0	0	0	0	0	0
4/21-23	E	1	0	0	0	0	0	0
4/24-26	F	2	9.6×10^{7}	-	-	5.6×10^{7}	-	-
4/27-29	G	3	-	-	-	-	-	-
4/30-5/2	H	4	-	-	-	-	-	-
5/3-5	I	5	3.6×10^{8}	5.1×10^{8}	2.6×10^{8}	2.4×10^{8}	3.4×10^{8}	1.7×10^{8}
5/6-8	J	5	8.0×10^{8}	1.5×10^{9}	4.4×10^{8}	4.7×10^{8}	8.6×10^{8}	2.6×10^{8}
5/9-11	K	4	9.0×10^{8}	1.3×10^{9}	6.1×10^{8}	6.1×10^{8}	9.7×10^{8}	3.8×10^{8}
5/12-14	L	4	6.3×10^{8}	-	-	4.6×10^{8}	-	-
5/15-17	M	3	4.4×10^{8}	-	-	3.4×10^{8}	-	-
5/18-20	N	3	2.6×10^{8}	-	-	1.7×10^{8}	-	-

N, O, P, and Q potentially could have contributed significantly to recruitment. But, the low initial abundances of cohorts R and S make it unlikely that they made significant contributions (Table 7).

<u>Growth</u>: Growth rates of striped bass and white perch larvae have been estimated by several methods, all of which were dependent on otolith-aging. The results of the several methods differ in their ability to detect variability in growth rates. The back-calculated growth rates of individual larvae have not been estimated yet, but will be reported when the analysis is completed.

<u>Striped Bass</u>: An "average" growth rate, based on the entire sample that has been otolith-aged (Figure 12), was 0.28 mm per day (S.E.=0.007). This estimate was obtained from the linear regression

$$L = 4.00 + 0.28t$$

$$n = 172$$

$$r^2 = 0.91$$

where L = standard length, mm

t = age posthatch, days.

The estimate does not provide any measure of among-cohort variability in growth rate. The observed variation in length-at-age (Figure 12) indicates that individual striped bass larvae varied by approximately 5 mm in length at 30 days posthatch.

The growth rates of striped bass larvae from 10 cohorts also were estimated, based on cohort-specific linear regressions of the lengths at age of individuals that were otolith-aged (Table 12 and 9A). Cohort-specific growth rates ranged from 0.18 to 0.43 mm per day (Table 12; Figure 13). The among-

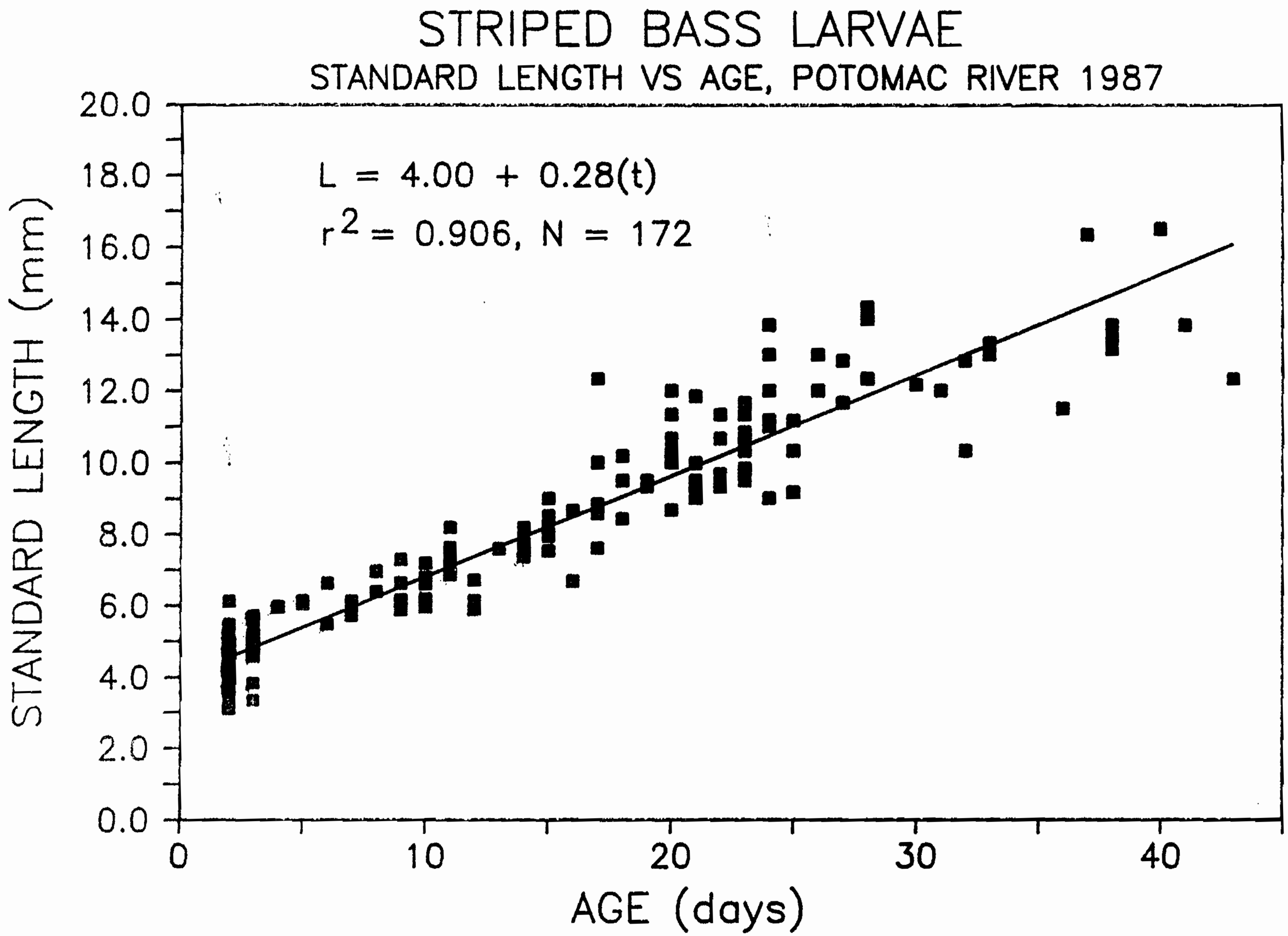


Figure 12. Growth of striped bass based on the entire sample of otolith-aged larvae, Potomac River, 1987.

Table 12. Striped bass. Cohort-specific growth rates (mm/day) of 10 cohorts, based on otolith-aged larvae. Rates are given for all larvae that were aged and for larvae ≤20 days posthatch. Samples from cohorts F, G, and H did not include larvae ≤20 days-old. Potomac River, 1987.

HATCH DATES	COHORT	all fish			fish < 20 days		
		n	rate	s.e.	n	rate	s.e.
4/24-4/26	F	4	0.296	0.044			
4/27-4/29	G	27	0.276	0.011			
4/30-5/2	H	8	0.176	0.021			
5/3-5/5	I	11	0.238	0.023	6	0.288	0.054
5/6-5/8	J	11	0.328	0.033	4	0.297	0.043
5/9-5/11	K	14	0.263	0.029	7	0.188	0.024
5/12-5/14	L	63	0.299	0.012	43	0.244	0.021
5/15-5/17	M	38	0.310	0.017	34	0.325	0.018
5/18-5/20	N	15	0.430	0.064	15	0.430	0.064
5/21-5/23	O	4	0.318	0.071	4	0.318	0.071
		MEAN	0.293			0.299	

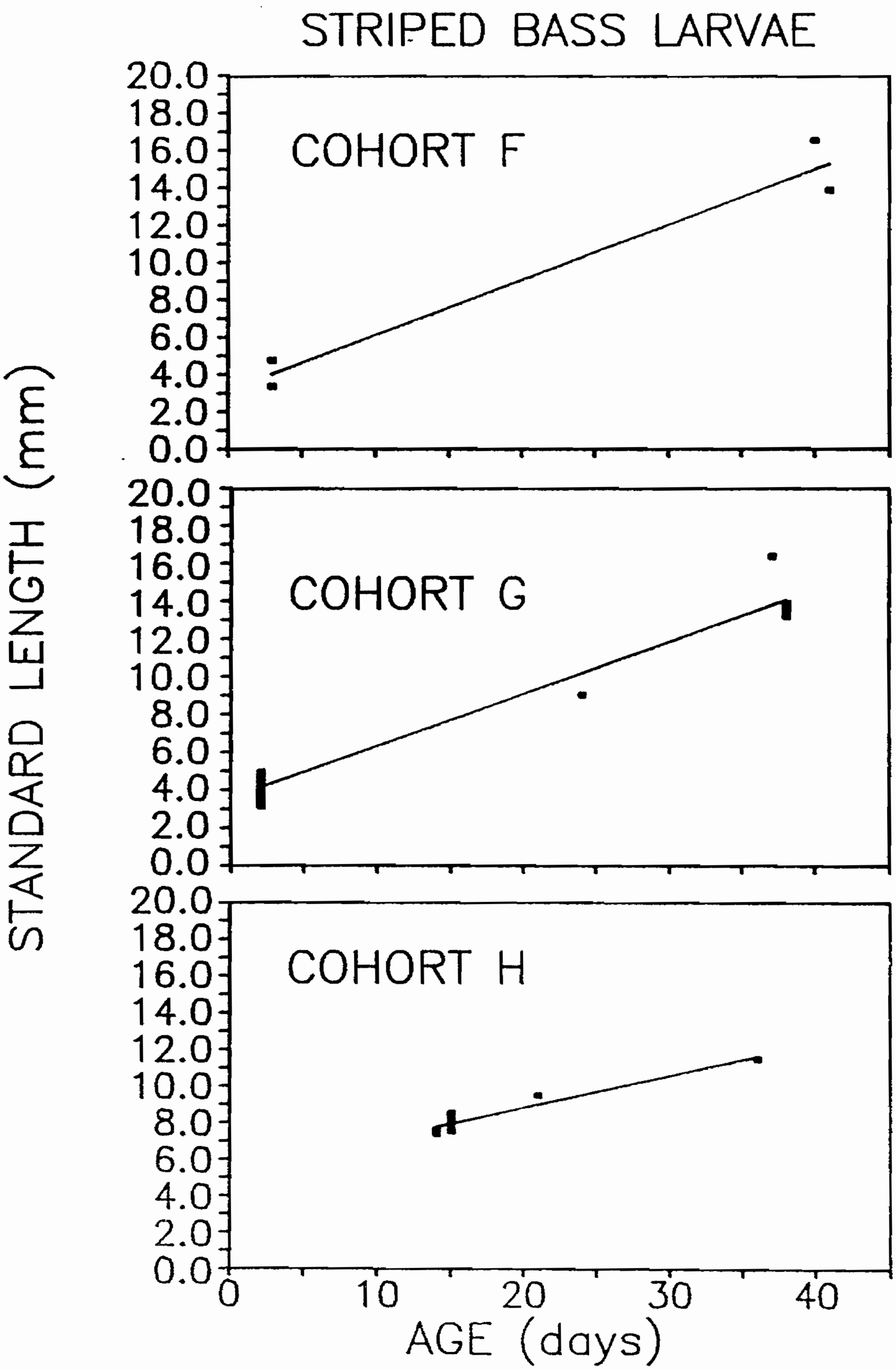
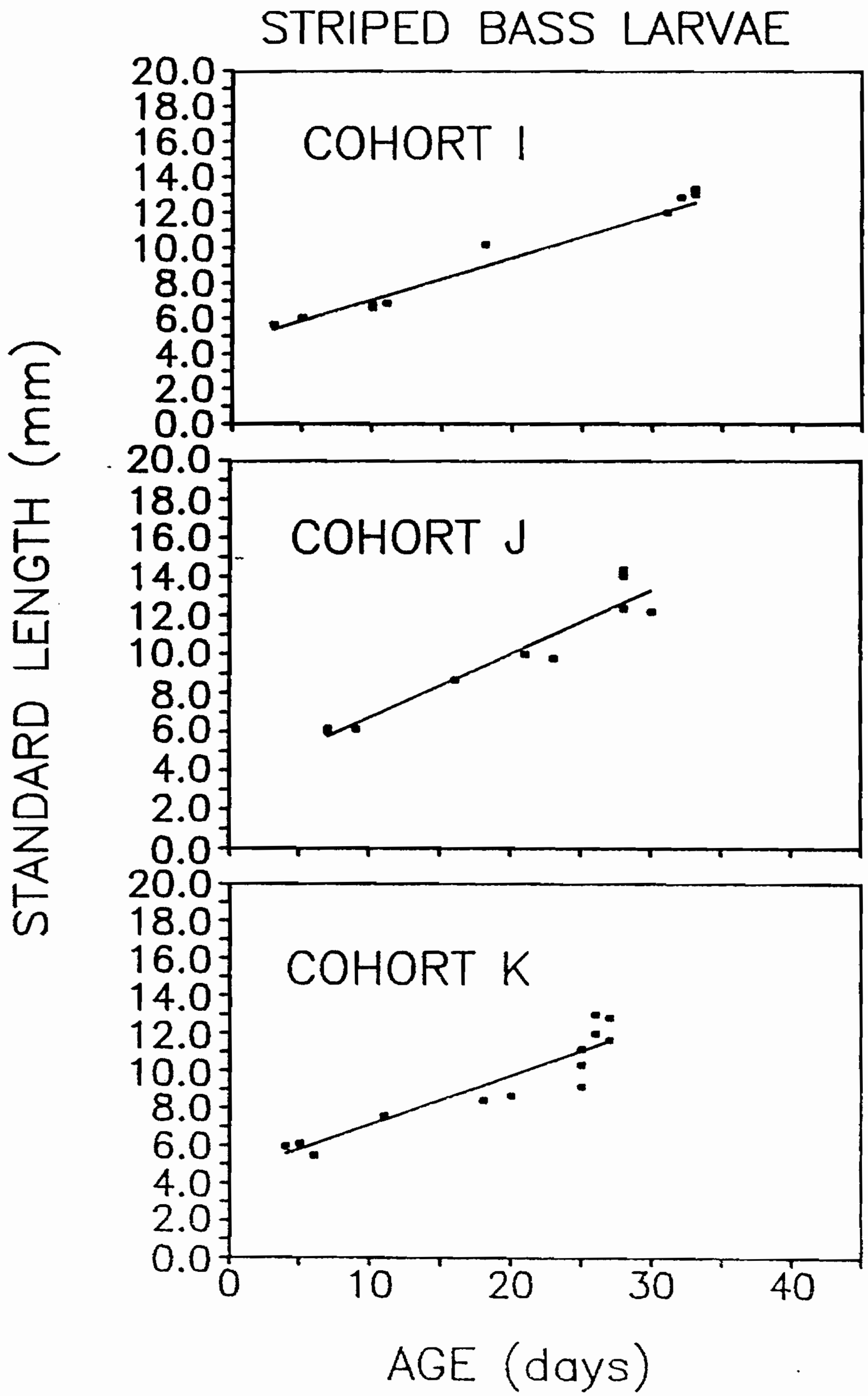


Figure 13. Growth of eight cohorts of striped bass based on otolith-aged larvae, Potomac River, 1987.



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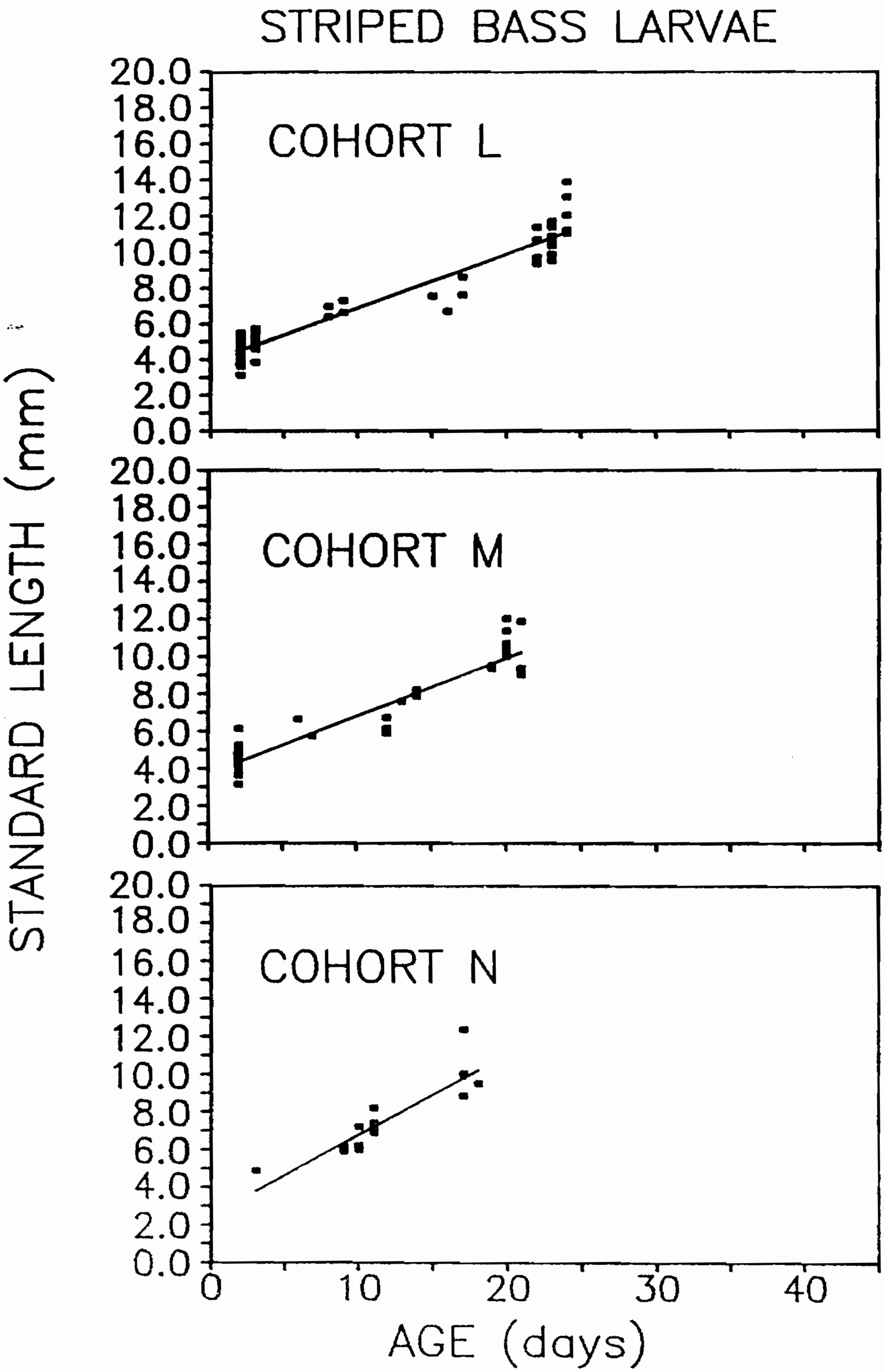

Fig. 13. Continued.

cohort rates differed significantly ($P<0.001$; ANCOVA[1]). Growth rates tended to increase as cohort hatching dates progressed seasonally. Differences in mean lengths-at-age between early-hatched and late-hatched cohorts became apparent when striped bass larvae were 12-14 days posthatch and older (Table 10A).

Predicted lengths at 30 days posthatch, from the cohort-specific regressions (Table 9A), ranged from 10.6 to 15.4 mm. Predicted ages of 15.0 mm larvae ranged from 29 to 55 days posthatch (Table 11A).

Cohort-specific growth rates of striped bass larvae also were calculated from their estimated lengths-at-age in the age-frequency distributions obtained on each cruise. These estimates, which were dependent on the age-length key and our ability to identify cohorts from one cruise to the next, ranged from 0.30 to 0.34 mm per day (Table 13). They were obtained from the linear regressions of estimated mean lengths on age for the eight cohorts. The relatively low among-cohort variability in growth rates estimated by this method resulted from an averaging effect that was induced by the age-length key.

Growth rates of striped bass larvae, termed "cruise-specific," ranged from 0.26 to 0.32 mm per day (Table 14). These rates were obtained from the linear regressions of estimated lengths-at-age on age of larvae represented in the age-frequency distribution on each cruise. Underlying assumptions of this method are that a stable age distribution and relatively constant environment are represented by the age-frequency distribution on each cruise. These assumptions are not correct for Potomac River striped bass in 1987. The method does not identify among-cohort variability in growth rates.

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[1]The variances among regression coefficients (i.e. growth rates) were not homogeneous. Thus, the conclusion of the statistical analysis is tentative.

Table 13. Striped bass. Cohort-specific linear regressions describing growth rates (mm/day) based on the estimated mean standard lengths of larvae from age-frequency distributions on each cruise date that a cohort occurred. Potomac River, 1987. Age and length data from Table 6.

HATCH DATES	COHORT	n	COHORT REGRESSIONS	S.E. SLOPE
4/24-4/26	F	3	L = 3.50 + 0.32(t)	0.010
4/27-4/29	G	4	L = 3.40 + 0.33(t)	0.006
4/30-5/2	H	5	L = 3.90 + 0.30(t)	0.011
5/3-5/5	I	5	L = 3.81 + 0.31(t)	0.007
5/6-5/8	J	5	L = 3.74 + 0.32(t)	0.015
5/9-5/11	K	3	L = 3.59 + 0.32(t)	0.016
5/12-5/14	L	4	L = 3.57 + 0.31(t)	0.019
5/15-5/17	M	4	L = 3.42 + 0.34(t)	0.002

mean slope = 0.32

Table 14. Striped bass. Cruise-specific regressions describing growth rates (mm/day) based on the estimated mean standard lengths of larvae present in each 3-day cohort on each cruise. Potomac River, 1987. Age and length data from Table 6.

CRUISE	n	COHORT REGRESSIONS	S.E. SLOPE
2	3	L = 3.51 + 0.31(t)	0.026
3	4	L = 4.09 + 0.26(t)	0.007
4	7	L = 3.60 + 0.31(t)	0.010
5	10	L = 3.68 + 0.32(t)	0.004
6	10	L = 4.01 + 0.29(t)	0.008
7	7	L = 4.05 + 0.30(t)	0.019

mean slope = 0.30

White Perch: The "average" growth rate, based on the entire sample of otolith-aged larvae (Figure 14), was 0.41 mm per day (S.E.=0.0081). This rate was derived from the linear regression

$$L = 2.82 + 0.41t$$

$$n = 202$$

$$r^2 = 0.93$$

where L = standard length, mm

t = age posthatch, days.

This estimate does not provide an estimate of among-cohort variability in growth rates. Individual variation in observed lengths-at-age of white perch larvae increases with age (Figure 14). At 30 days posthatch, observed larval lengths varied by approximately 5 mm. It is notable that the "average" white perch larval growth rate is faster than that of striped bass.

The cohort-specific growth rates of 11 white perch larval cohorts ranged from 0.29 to 0.69 mm per day (Table 15; Figure 15). The rates, which were obtained from linear regressions of length on age (Table 12A), could not be demonstrated to differ among cohorts (P=0.40; ANCOVA). The 0.69 mm/d estimate for cohort H (Tables 15 and 12A) probably is a poor one; the standard error of that estimate (0.16) was the highest that was obtained. The mean cohort-specific growth rate, excluding the 0.69 mm/d estimate, was 0.38 mm/d (S.E.=0.047). The variability in individual cohort growth rates, as judged by the standard errors, was higher on average for white perch than for striped bass (Tables 12 and 15).

The growth rates of $\leq$20 day-old white perch larvae were lower than the rates that were calculated when $\geq$20 day-old larvae were included in the analysis (Table 15). For the four cohorts (I, J, K, L) that could be included

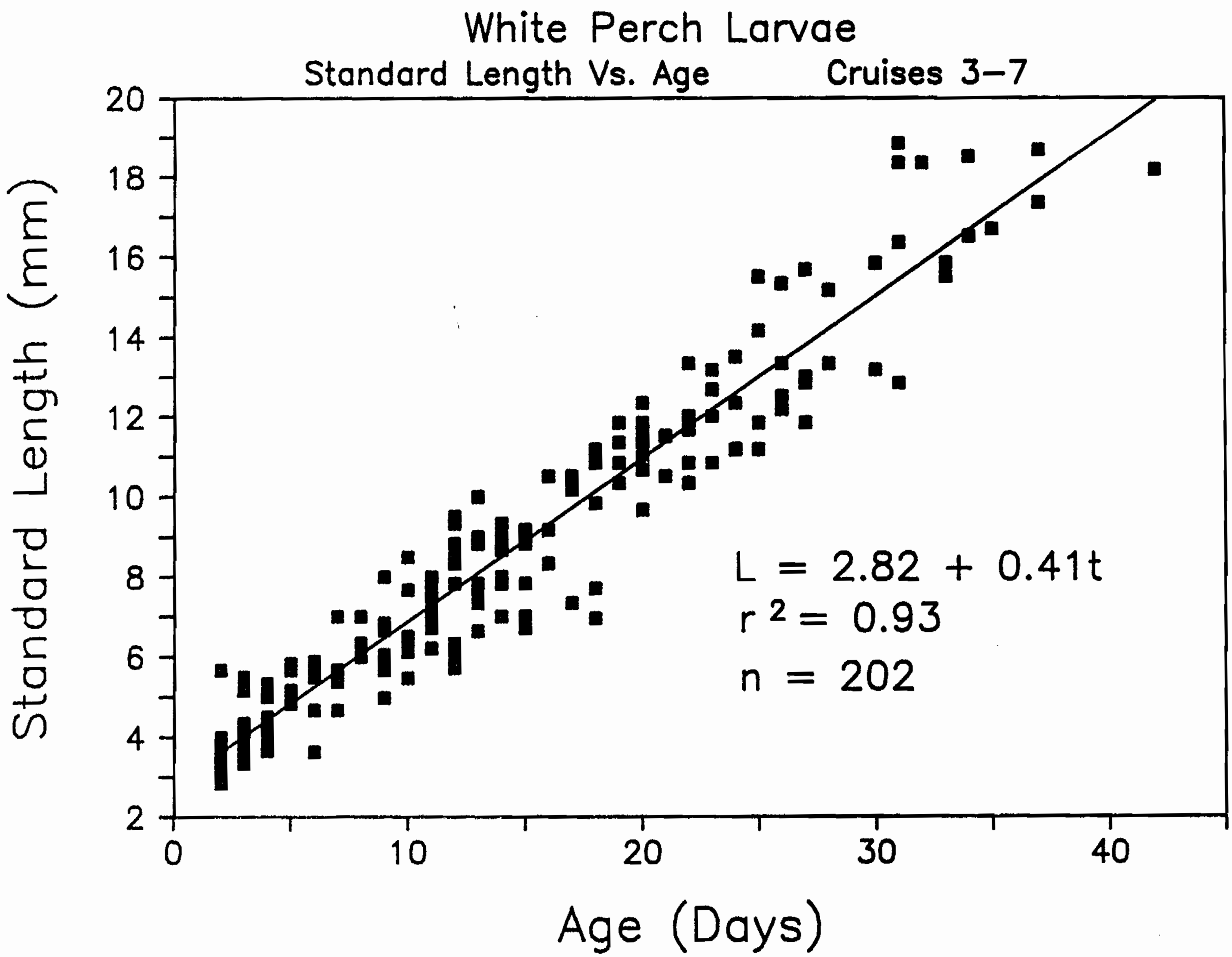


Figure 14. Growth of white perch based on the entire sample of otolith-aged larvae, Potomac River, 1987.

Table 15. White perch. Cohort-specific growth rates (mm/day) of 11 cohorts, based on otolith-aged larvae. Rates are given for all larvae that were aged and for larvae ≤20 days posthatch. Samples from cohorts G and H did not include larvae ≤20 days-old. Potomac River, 1987.

		All Larvae			Larvae ≤20 Days		
HATCH DATES	COHORT	n	Rate	S.E.	n	Rate	S.E.
4/27-29	G	3	0.404	0.043		-	-
4/30-5/2	H	6	0.693	0.156		-	-
5/3-5	I	33	0.419	0.019	21	0.348	0.052
5/6-8	J	28	0.397	0.017	16	0.391	0.040
5/9-11	K	21	0.375	0.039	14	0.328	0.049
5/12-14	L	14	0.359	0.059	6	0.147	0.186
5/15-17	M	25	0.350	0.049	25	0.350	0.049
5/18-20	N	19	0.320	0.063	19	0.320	0.063
5/21-23	O	24	0.393	0.054	24	0.393	0.054
5/24-26	P	19	0.286	0.046	19	0.286	0.046
5/27-29	Q	5	0.443	0.190	5	0.443	0.190
		MEAN	0.404		MEAN	0.334	

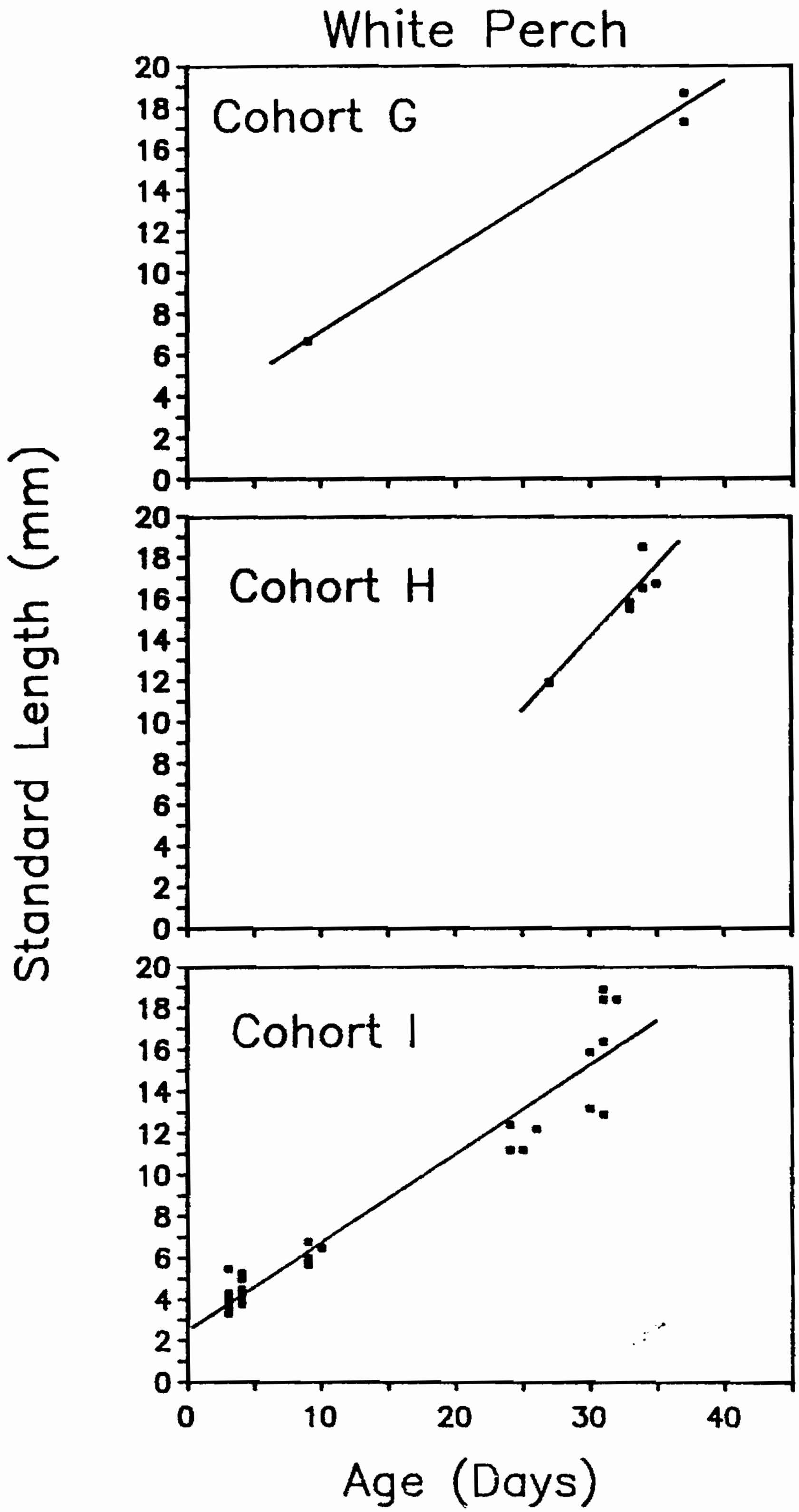
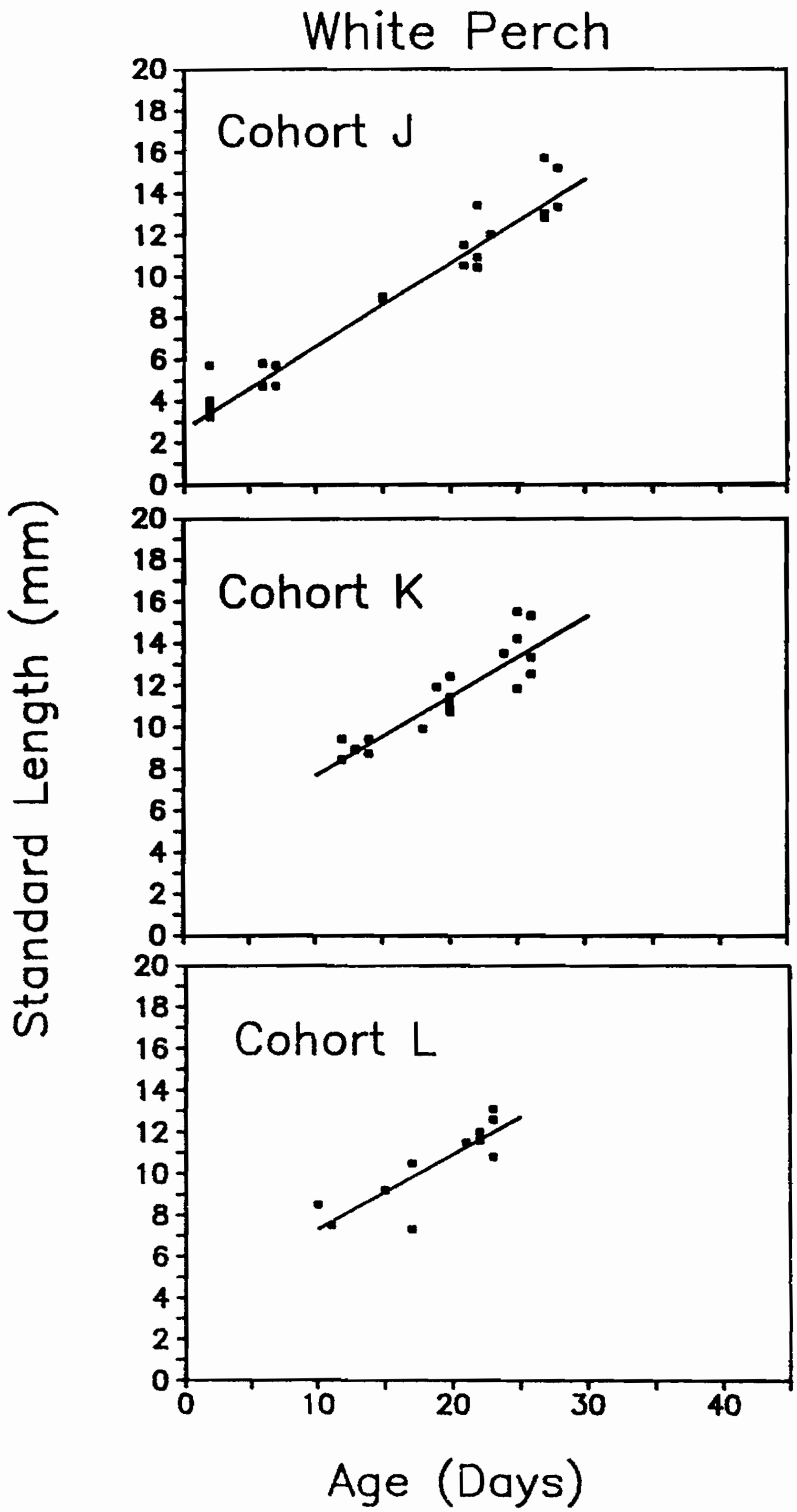


Figure 15. Growth of eleven cohorts of white perch based on otolith-aged larvae, Potomac River, 1987.



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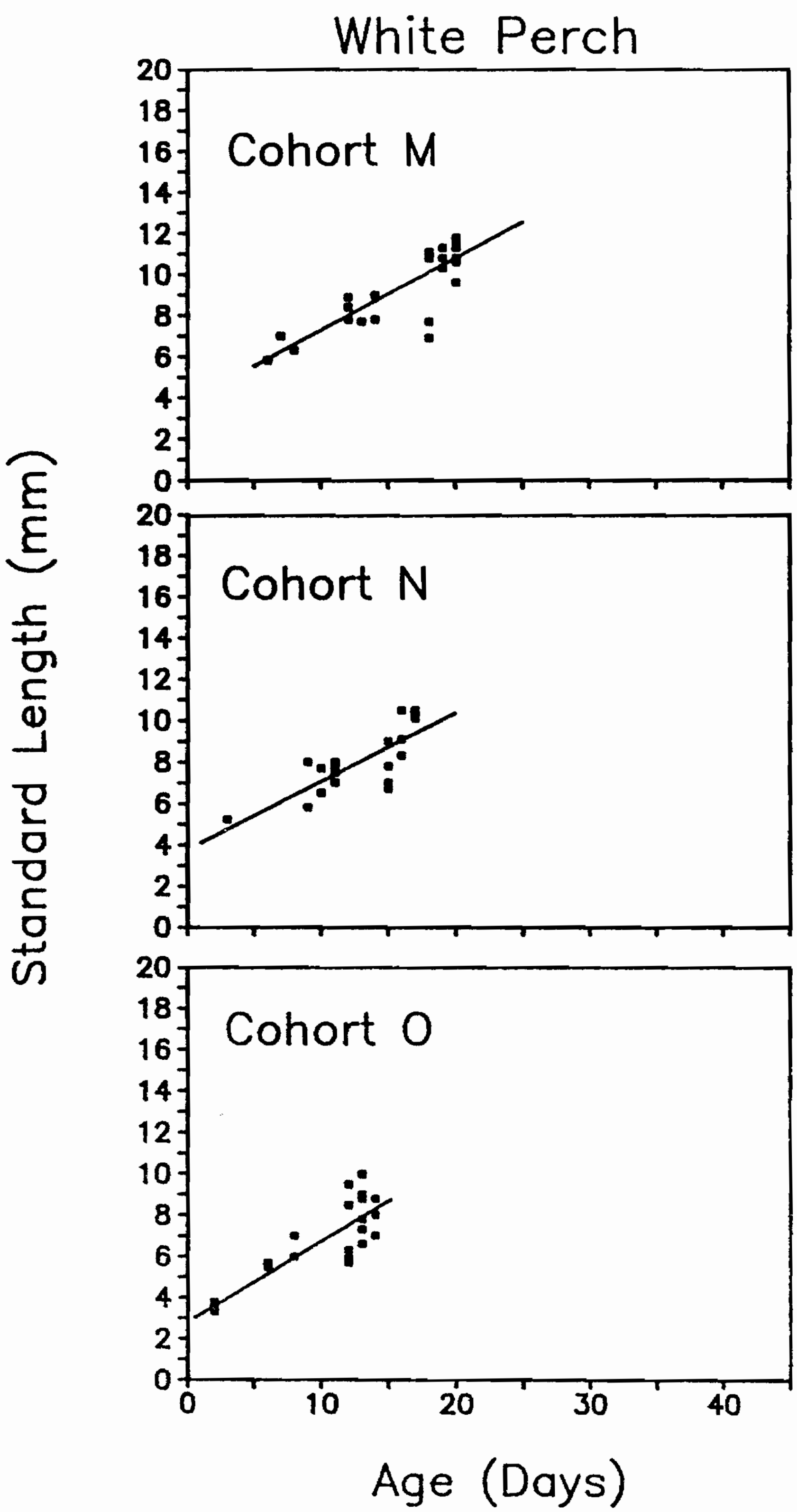

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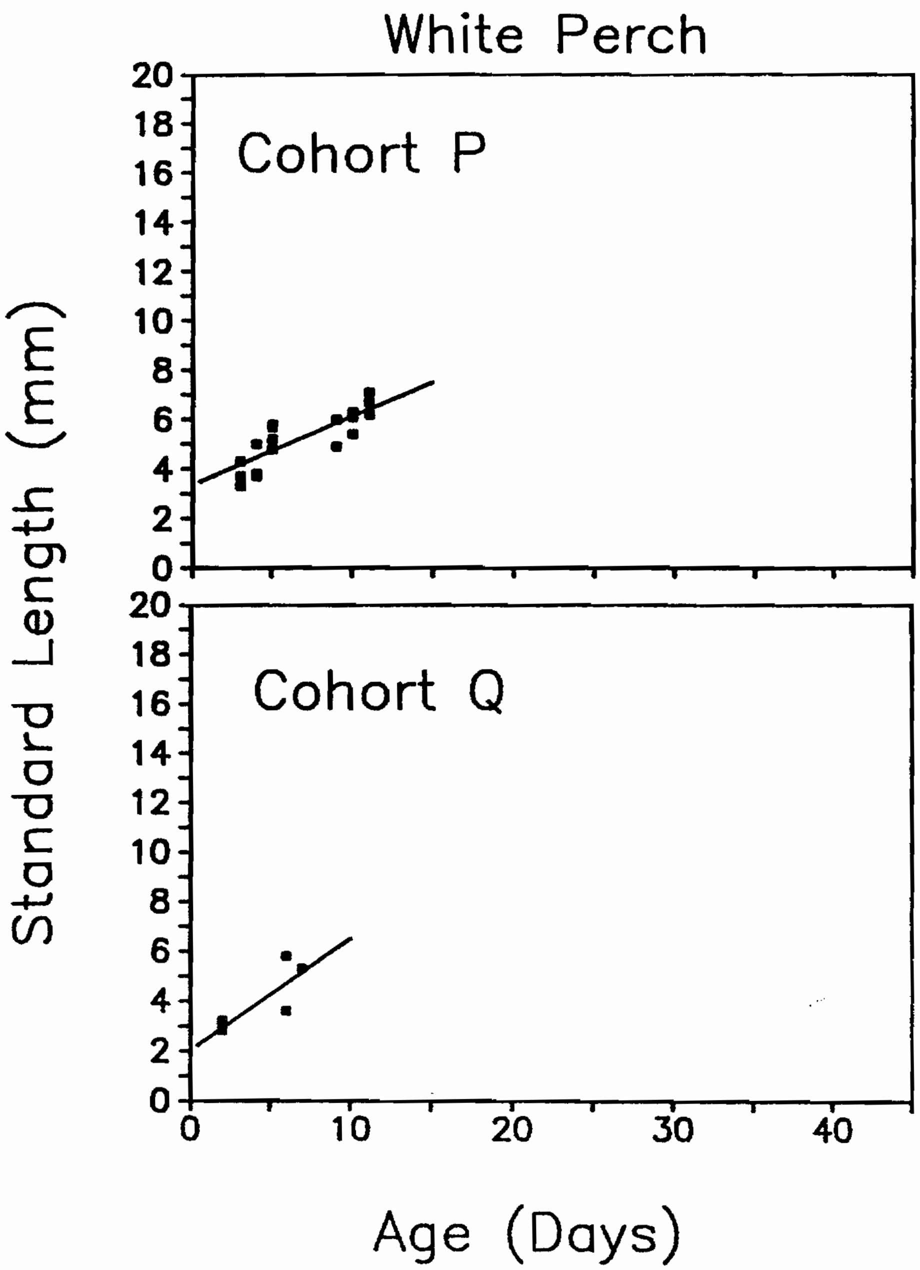

Fig. 15. Continued.

in the comparison, the mean difference in growth rate was 0.08 mm/d. Growth rates of larger larvae apparently were increasing in each case.

The white perch lengths-at-age, predicted from the cohort-specific growth equations (Table 13A), did not indicate any tendency to increase for the later-spawned cohorts. In fact, predicted lengths-at-age of the latest-hatched cohorts (i.e. N-Q) were smaller, on average, than those spawned earlier in the year. This result may be artifactual to the extent that the predictive regressions were influenced by the ages of larvae included in them. Because young white perch larvae grew slower than older larvae, those cohorts that consisted only of young larvae would be expected to have the smallest predicted lengths-at-age.

Predicted lengths of white perch larvae at 30 days posthatch from the individual cohorts ranged from 11.9 to 15.4 mm SL (Table 14A). The predicted ages of 15 mm larvae ranged from 29 to 41 days posthatch.

The cohort-specific growth rates of white perch larvae from the age-frequency distributions ranged from 0.41 to 0.48 mm per day (Table 16). The relatively low among-cohort variability in growth rates estimated by this method resulted from the averaging effect induced by use of the age-length key.

The "cruise-specific" growth rates of white perch larvae ranged from 0.37 to 0.43 mm per day (Table 17). As for striped bass, this method does not identify among-cohort variability in growth rates. An apparent increase in white perch growth rate as the season progressed, based on the "cruise-specific" estimates, may be an artifact. The higher rates may reflect a relative increase in growth rate of older white perch larvae that could only be seen when such individuals were included in the collections (e.g. Cruises 5, 6, and 7).

Table 16. White perch. Cohort-specific linear regressions describing growth rates (mm/day) based on the estimated mean standard lengths of larvae from age-frequency distributions on each cruise date that a cohort occurred. Potomac River, 1987. Age and length data from Table 7.

HATCH DATES	COHORT	n	COHORT REGRESSION	S.E. SLOPE
4/24-4/26	F	2	L = 2.23 + 0.43(t)	-
4/27-4/29	G	3	L = 2.73 + 0.42(t)	0.016
4/30-5/2	H	4	L = 2.11 + 0.44(t)	0.028
5/3-5/5	I	5	L = 2.47 + 0.43(t)	0.009
5/6-5/8	J	5	L = 2.86 + 0.42(t)	0.006
5/9-5/11	K	4	L = 2.54 + 0.43(t)	0.006
5/12-5/14	L	4	L = 2.85 + 0.41(t)	0.017
5/15-5/17	M	3	L = 2.18 + 0.48(t)	0.002
5/18-5/20	N	3	L = 2.14 + 0.46(t)	0.009
5/21-5/23	O	3	L = 2.60 + 0.42(t)	0.029
5/24-5/26	P	2	L = 2.19 + 0.43(t)	-
5/27-5/29	Q	2	L = 2.62 + 0.40(t)	-

Mean slope = 0.429

Table 17. White perch. Cruise-specific regressions describing growth rates (mm/day) based on the estimated mean standard lengths of larvae present in each 3-day cohort on each cruise. Potomac River, 1987. Age and length data from Table 7.

	n	COHORT REGRESSIONS	S.E. SLOPE
Cruise 1	3	L = 2.64 + 0.42(t)	0.107
Cruise 2	4	L = 2.99 + 0.37(t)	0.102
Cruise 3	4	L = 2.87 + 0.37(t)	0.025
Cruise 4	5	L = 3.18 + 0.37(t)	0.010
Cruise 5	7	L = 2.49 + 0.42(t)	0.010
Cruise 6	10	L = 2.57 + 0.42(t)	0.008
Cruise 7	14	L = 2.43 + 0.43(t)	0.004

Mean slope = 0.40

Hatch Date Frequencies: The distribution of hatch dates, based on otolith-aged larvae that had survived to >15 or >20 days posthatch, was examined to determine which cohorts and hatch dates were most likely to contribute to subsequent juvenile abundance. Three methods were used: 1) examination of larval hatch date frequencies in standard tows of the 60-cm sampler from the last three cruises; 2) examination of the estimated abundances of each 3-day cohort at 15 and 20 days posthatch from the mortality estimating models; 3) examination of larval hatch date frequency distributions from the $2m^2$ Tucker trawl on the last cruise in 1987 (4-5 June).

Striped Bass: Larvae ≥20 days posthatch, survivors of the earliest life stages, are potential recruits. Eight cohorts were represented on Cruises 5, 6 and 7 (Figure 16) in the standard tows of the 60-cm sampler. Cohorts I, K, and M (hatch dates of 3-5 May, 9-11 May, and 15-17 May) were most abundant. No cohorts hatched before 24 April were represented on Cruises 5-7, indicating that 1987 recruitment of striped bass in the Potomac depended on cohorts spawned later in the season.

Cohort survivorship at 15 and 20 days posthatch, respectively, estimated from the regression models used to calculate instantaneous mortality rates (Table 9), also indicated that no recruits were being derived from cohorts hatched prior to 24 April (Figure 17). From this analysis it is not clear that any of the nine cohorts hatched in the 24 April to 20 May period dominated potential contributions to recruitment. At 20 days posthatch, the eight cohorts had riverwide abundances that ranged from 2.7×10^6 to 18.7×10^6 larvae. Their summed abundance at 20 days posthatch was 91.3×10^6. Two cohorts (N and O), hatched from 18-23 May, potentially also could have made

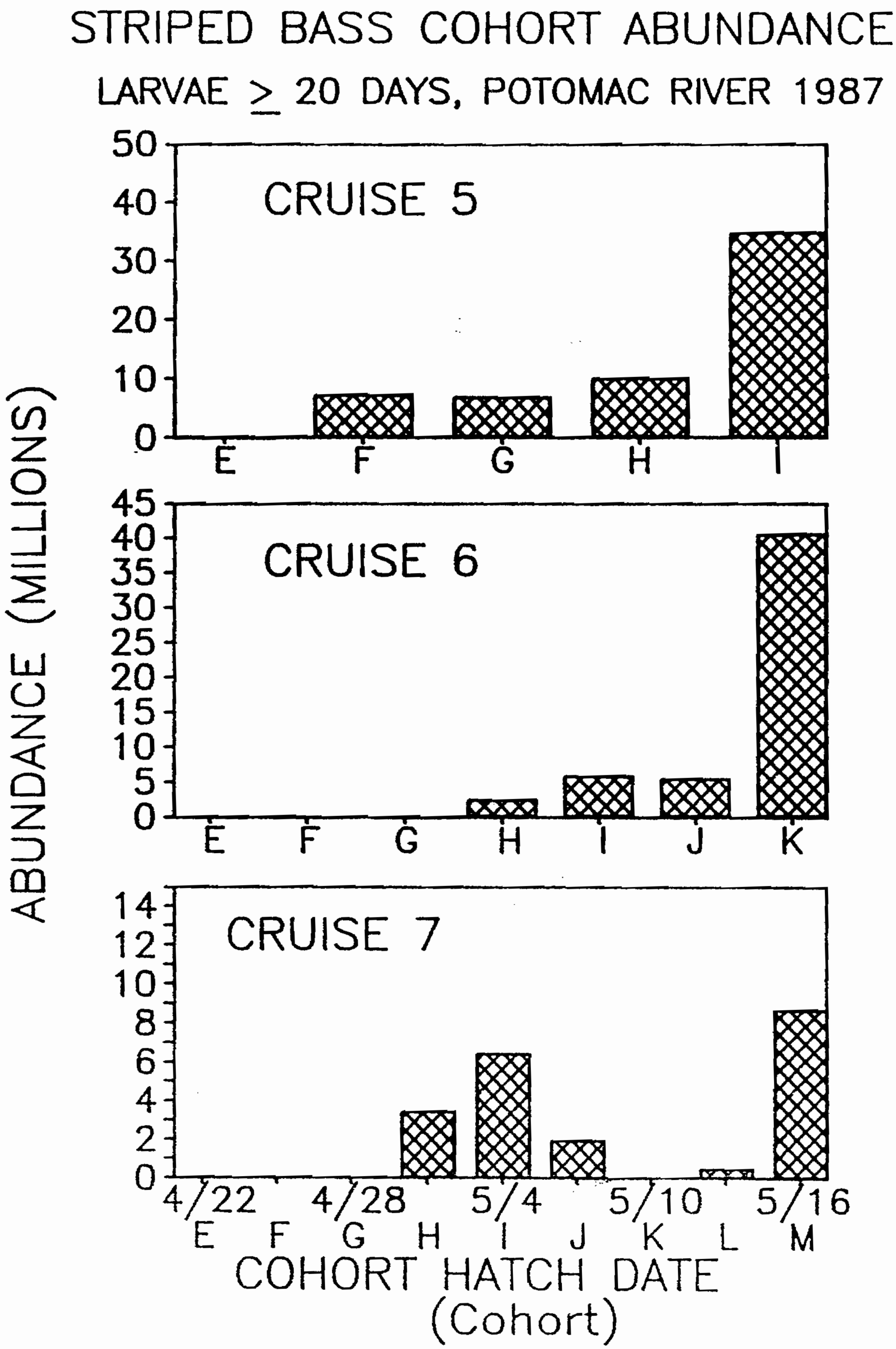

Figure 16. Estimated riverwide abundances of striped bass larvae ≥20 days posthatch and respective hatch dates on Cruises 5, 6, and 7 (21 May to 5 June period), Potomac River, 1987.

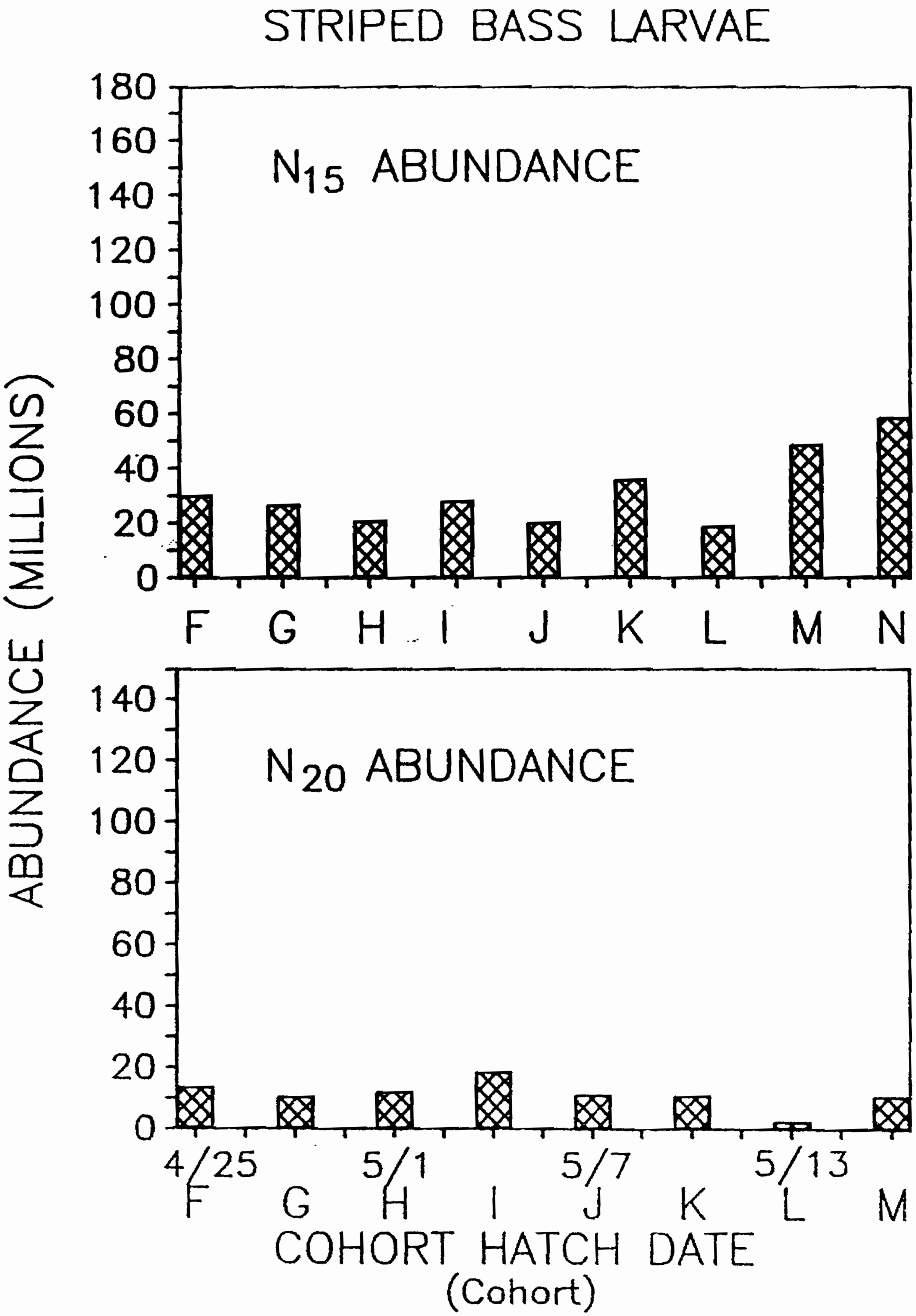

Figure 17. Estimated abundances of striped bass larvae at 15 and 20 days posthatch calculated from mortality estimation models (Table 9). Each cohort and its hatching date are indicated. Potomac River, 1987.

significant contributions to 1987 recruitment (Figure 10, Table 9).

Another indication of potential recruitment was obtained from examination of ≥20 days posthatch survivors in the Tucker trawl samples at Station 4 on Cruise 7 (4-5 June) (Figure 18). The relatively large Tucker trawl catches consisted of 127 striped bass larvae ≥20 days posthatch. The cohort-specific densities in Figure 18 were reconstructed by converting the length-frequency distribution to its corresponding age-frequency distribution, based on the otolith-aging analysis and our age-length key.

No striped bass larvae that were hatched before 24 April were represented in the Cruise 7 Tucker trawl catches. Potential recruits (≥20 days) were hatched in the period 24 April to 17 May. The observed high densities of striped bass in cohorts J, K, L, and M (Figure 18) are a consequence of their young ages rather than an indication of their relative recruitment potential. If each of the cohorts were suffering mortality equal to the mean instantaneous rate of 0.197 (Table 8), the survivorship at equivalent ages and the potential to recruit would be similar for cohorts F, K, J, and I. The potential for cohort G to contribute to recruitment was double that of (hatch date 27-29 April) cohorts F, K, J, and I. Cohorts L and M would be expected to contribute only 1/3 to 1/2 as many recruits as cohorts F, K, J, and I. recruits.

<u>White Perch</u>: The riverwide abundances of larvae ≥20 days posthatch, based on the last three cruises from collections in the 60-cm sampler, indicated that recruits would be derived from hatch dates after 24 April (Figure 19). The largest numbers of recruits likely would have hatched on dates between 7 and 15 May. Because white perch larvae continued to hatch in quite large numbers after 15 May (Figure 11), it is possible that late-hatched cohorts contributed

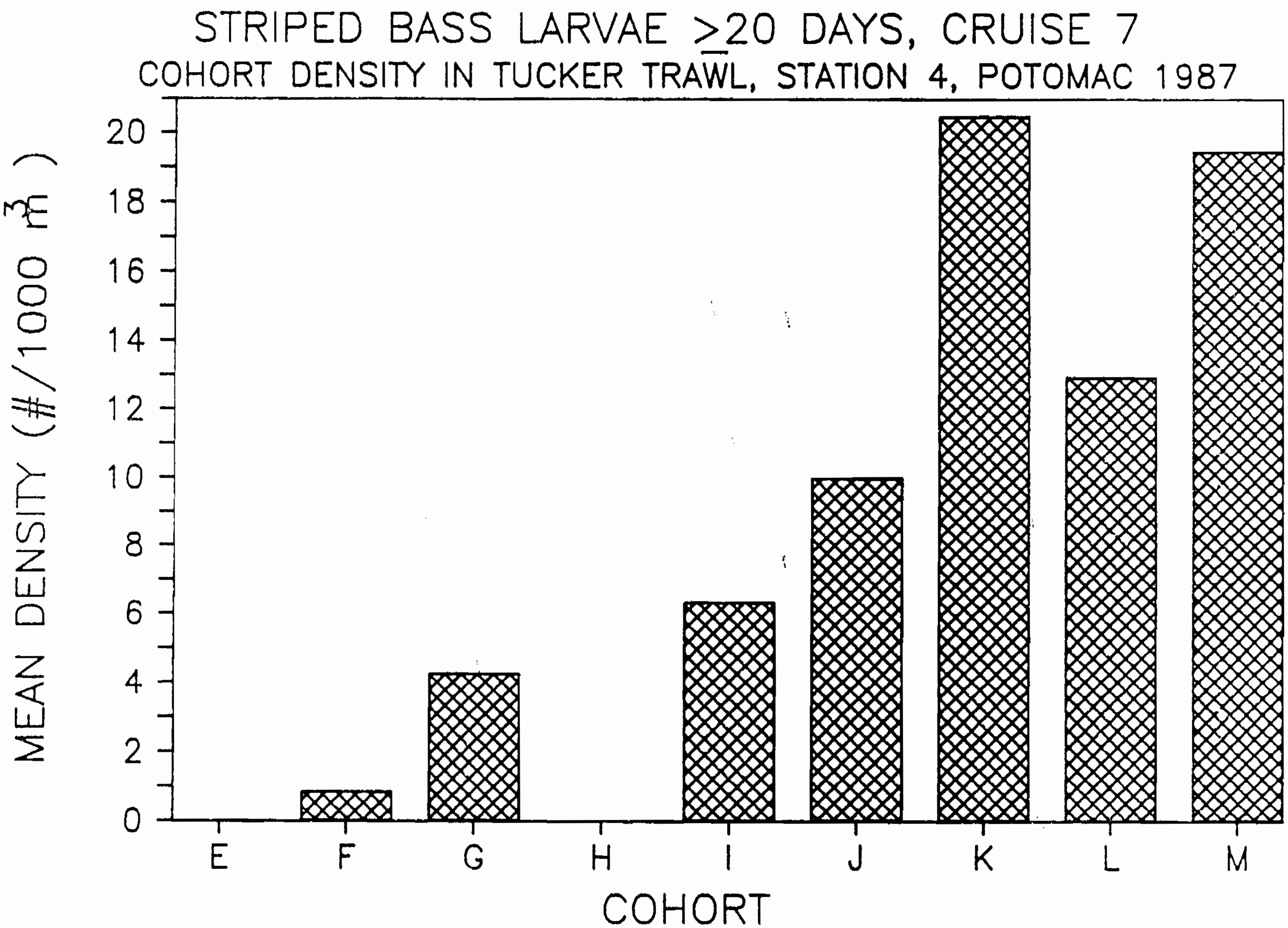

Figure 18. Densities (no. per m^3) of seven striped bass larval cohorts ≥20 days posthatch collected in the Tucker trawl at Sta. 4, Cruise 7, Potomac River, 1987. Cohort hatch dates are indicated.

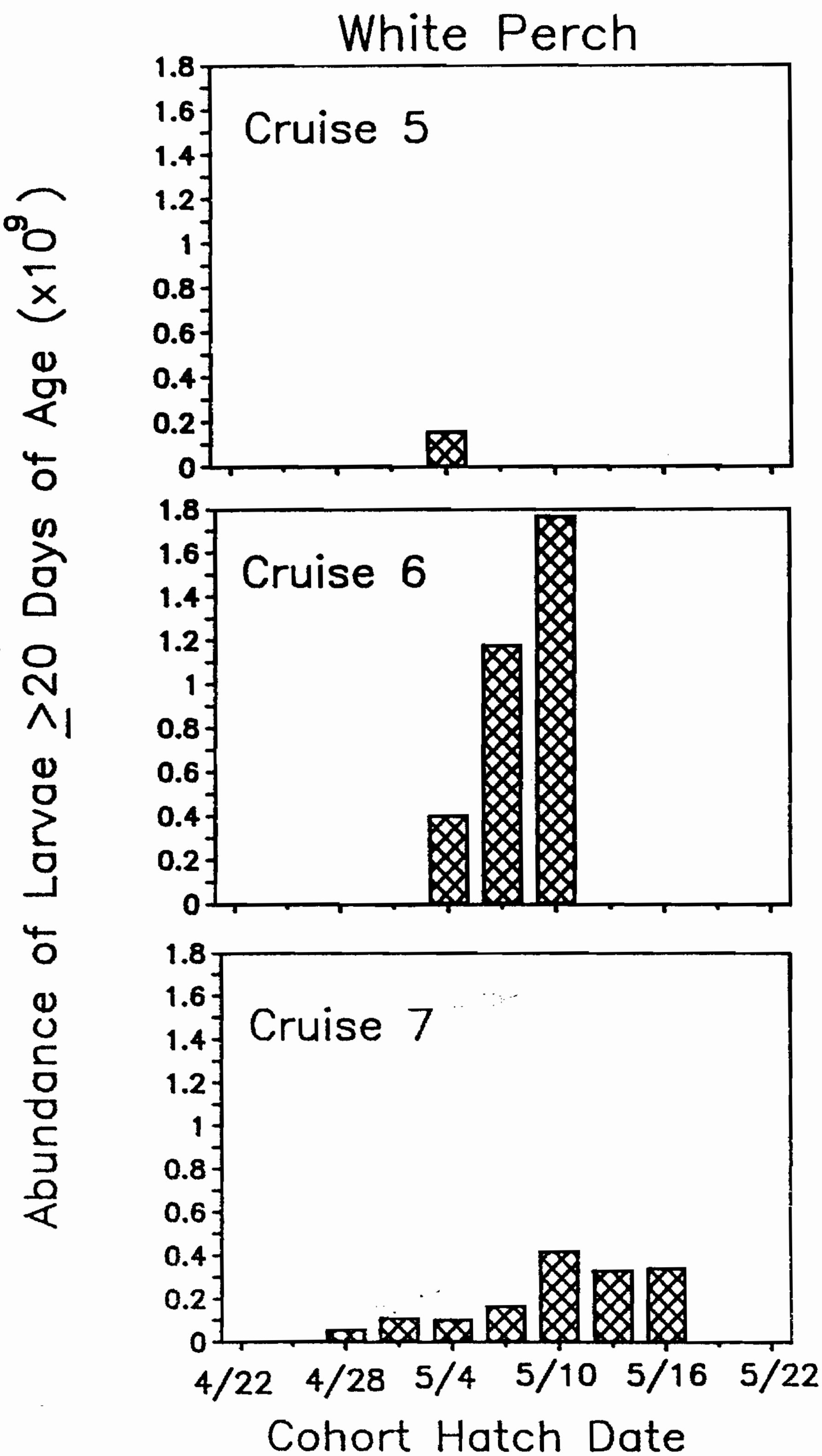

Figure 19. Estimated riverwide abundances of white perch larvae ≥20 days posthatch and respective hatch dates on Cruises 5, 6, and 7 (21 May to 5 June period), Potomac River, 1987.

significantly to recruitment, but we were unable to determine this from our collections which terminated on 5 June.

Cohort survivorship at 15 and 20 days of age, respectively, estimated from the regression models used to calculate instantaneous mortalities (Table 11), also indicated that white perch recruits would be derived from larvae hatched after 24 April (Figure 20), and they indicated that the largest recruitments would be derived from the 3 to 17 May hatch dates. We estimated that 3.2×10^9 and 2.2×10^9 larvae from hatches between 3 and 17 May survived to at least 15 and 20 days, respectively. We did not predict what contributions to recruitment might be made by white perch hatched after 17 May because we did not calculate abundances of cohorts beyond the age data that were represented in our regression models. We note, however, that only 350×10^6 white perch larvae $\leq$15 days posthatch were estimated to be present in the Potomac on 4-5 June 1987, compared to 1.9×10^9 older larvae (Figure 11g), suggesting that larvae hatched after 20 May 1987, were unlikely to have made a major contribution to white perch recruitment.

The Tucker trawl catches of white perch larvae on Cruise 7 also provide an indication of cohort-specific recruitment potential (Figure 21). A total of 11,798 white perch were collected in the Tucker trawl on that cruise. The densities of white perch larvae $\geq$20 days posthatch, derived from the age-length key based on otolith-aged larvae, include representatives from all cohort hatch dates between 24 April and 17 May.

Cohorts collected in the Tucker trawl that were hatched from 24 April to 16 May represent cohorts that ranged in age from 20 to 42 days posthatch. At equal age, these cohorts would be expected to have fourfold variability in recruitment potential if they suffered mean mortality of Z=0.082 (Table 10).

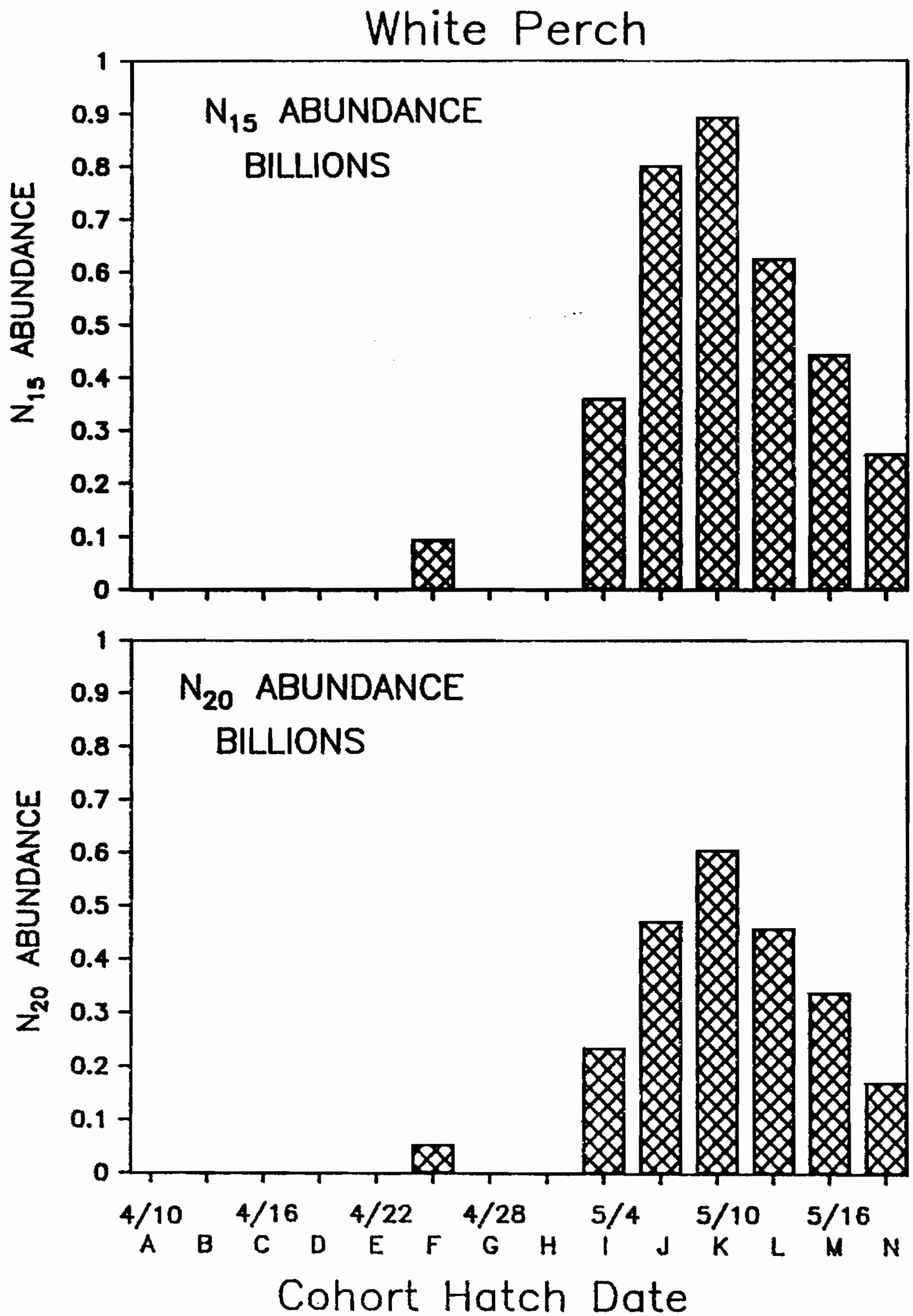

Figure 20. Estimated abundances of white perch larvae at 15 and 20 days posthatch calculated from mortality estimation models (Table 11). Each cohort and its hatching date are indicated. Potomac River, 1987.

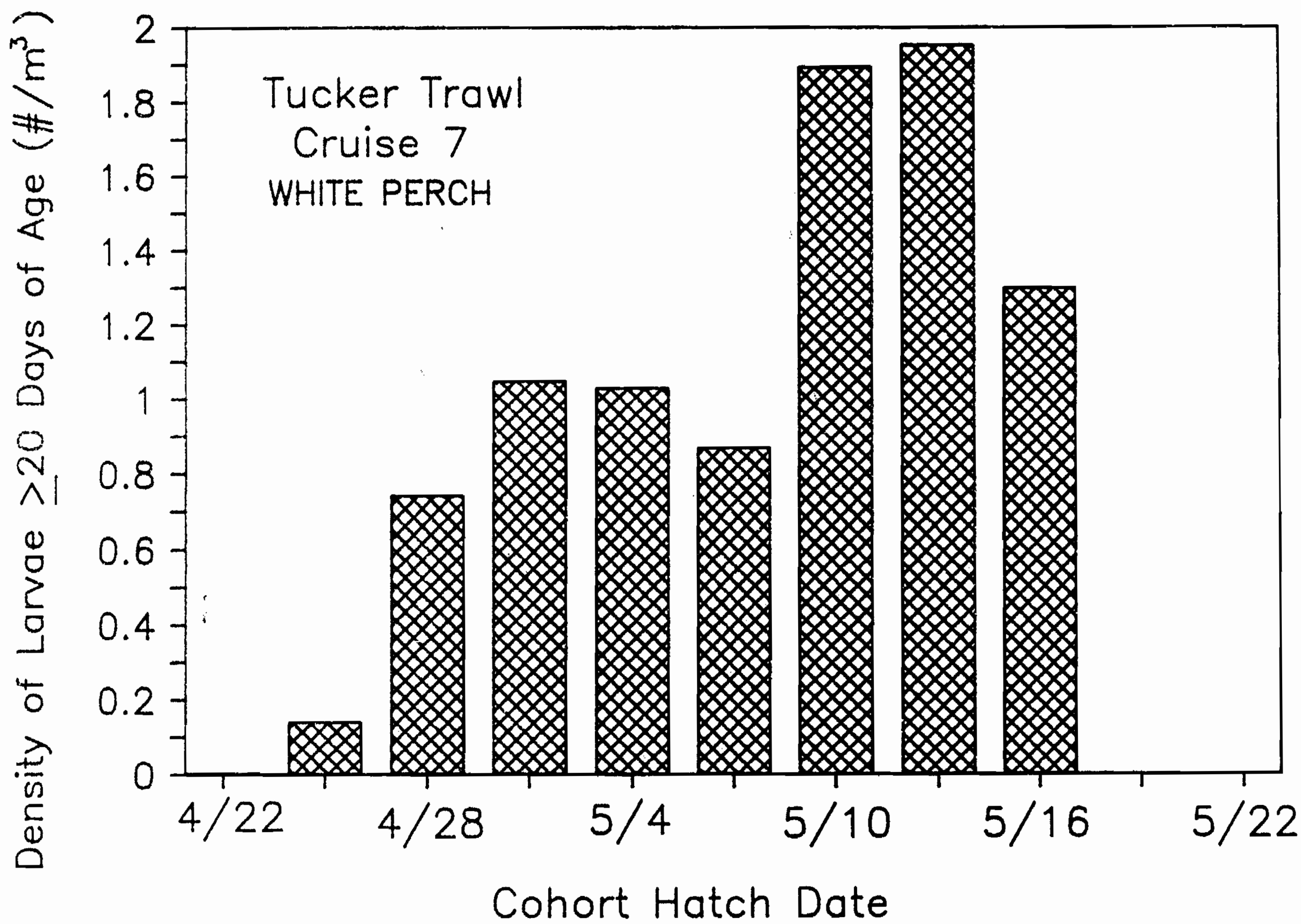

Figure 21. Densities (no. per m^3) of eight white perch larval cohorts $\geq$20 days posthatch collected in the Tucker trawl at Sta. 4, Cruise 7, Potomac River, 1987. Cohort hatch dates are indicated.

Cohort H (hatch date 3-5 May) would have had the highest potential while cohort F (hatch dates 24-26 April) would have had the lowest potential to contribute recruits. The potentials of other cohorts were approximately equal and only slightly less than that of cohort H.

The birthdate frequency analysis indicated that Potomac River recruitment patterns for striped bass and white perch were similar in 1987. Both species recruited from larvae that hatched on or after 24 April. The biggest contributions to recruitment probably will be from hatches that occurred between the last week of April and mid-May. White perch potential recruitment levels, based on ≥20 day posthatch abundances, appeared to be more than an order of magnitude higher than those for striped bass.

DISCUSSION

Successful spawning by Potomac River striped bass and white perch, defined as the production of larval cohorts that survived to at least 15-20 days posthatch, occurred during the one-month period, 24 April-24 May 1987. Spawning by white perch probably occurred for an extended period before our first cruise (16-17 April), but we collected no larvae that survived to ≥15 days posthatch that were hatched before 24 April. We also collected no striped bass larvae spawned before the 24 April hatch date that were potential survivors, although most egg production took place before that date (Houde et al. 1988). The first and major spawn that occurred between 14-22 April accounted for approximately 60% of the 1987 striped bass egg production, but no recruits were derived from it.

The combined evidence indicates that most larval production occurred from striped bass that hatched in the period 24 April-11 May, although significant contributions to advanced-stage larval production also occurred for hatch dates as late as 17 May. The sudden drop in river temperature (to below 10^{o}C), the storm, and the flood that followed intensive spawning on 15-17 April (Houde et al. 1988) were responsible for the probable near-complete loss of striped bass eggs and larvae before 24 April. A few larvae were collected on 27-28 April that hatched in the 21-23 April period (Table 6), but that cohort was not observed on any subsequent dates. Because we collected no striped bass larvae on our first cruise (16-17 April), and because river temperatures were <12^{o}C, we believe that no spawning of consequence had occurred before 14-15 April 1987.

The episodic loss of the 15-17 April striped bass spawn was the major event that occurred during the striped bass spawning season. Instantaneous mortality rates of larvae ranged from 0.08 to 0.39 for cohorts that were observed to produce 15 to 20-day posthatch survivors (7.7 to 32.3% per day mortality). Most of the 3-day cohorts hatched in the 24 April to 17 May period were estimated to have contributed $\geq 10 \times 10^6$ survivors to the 20-day posthatch population. No single cohort or group of cohorts could be identified as an exceptional contributor, nor could any of the cohorts be judged to have declined to extinction in the first 20 days posthatch.

The pattern of white perch successful spawning was similar to that for striped bass, even though the spawning period of white perch is more protracted. Most recruits were derived from hatches in the 24 April-20 May period, and the 3-17 May dates were estimated to have been particularly important. Individual white perch cohorts hatched in the 24 April-20 May period were estimated to have varied at least fourfold in their potential to provide recruits, judged by estimated survivorships at 20 days posthatch.

White perch larval abundances were higher than those for striped bass at all ages that we observed. Based on estimated abundances at 20-day posthatch, Potomac River white perch recruitment was estimated to be more than 30 times higher than that for striped bass in 1987.

Daily instantaneous mortality rates of 1987 striped bass larvae for which three or more cohorts were observed ranged from Z=0.08 to Z=0.39. The mean Z for these eight larval cohorts was Z=0.197. The precision of the estimates was low because the regression estimates were based on only 3-5 cohort observations. Coefficients of variation (s.e. divided by estimated Z) for the eight estimates (Table 8) ranged from 0.12 to 0.97, and averaged 0.52. There was a significant regression relationship ($P<0.025$) between instantaneous daily mortality rates and $\log_e$ egg abundances. The mortality rate declined by 0.10 per $\log_e$ unit increase in egg abundance. This result implies that survivorship of 1987 cohorts that were produced in the 24 April-17 May period was directly related to initial cohort egg abundance. Keep in mind that the largest egg production in 1987 produced no survivors and therefore could not be included in this analysis. When 1987 survival conditions were favorable, the mortality rates were lowest for cohorts that originated from the largest spawns.

Boynton et al. (1977) assumed a stable age distribution and calculated "average" survival for the 1974, 1975 and 1976 early life stages of striped bass in the Potomac River. We have recalculated their survival rates for yolk-sac larvae to postfinfold stage and expressed the mortalities as instantaneous rates. The estimates were: 1974, Z=0.14; 1975, Z=0.13; 1976, Z=0.13. Polgar (1977) estimated that larval mortality of the 1974 year-class in the Potomac was in the range 12-19% (Z=0.13 to 0.21). Dey (1981) dealt explicitly with the 1975 and 1976 year-classes of Hudson River striped bass and estimated Z=0.19

and Z=0.16, respectively, in those years. Annual mortalities, based on assumed stable age distribution, of Sacramento River striped bass larvae for seven years in the period 1968 to 1986 ranged from Z=0.21 to Z=0.32 (Low, 1986). Those values are higher than most of our cohort-specific estimates, but within the range of Z values observed in the Potomac in 1987.

Cohort-specific mortality rates of Potomac River white perch larvae also were obtained, but we have reasonable confidence in only three of the values (Table 10). The range of Z for cohorts I, J, and K was 0.08 to 0.11, mean=0.089. The coefficient of variation on those three estimates ranged from 0.19 to 0.21. No estimates of white perch instantaneous mortality rates exceeded 0.11 (Table 10). The white perch daily mortality rates apparently were considerably lower than those of striped bass in 1987. Only two of the eight striped bass larval cohorts with three or more observations (Table 8) had daily mortality rates as low as those estimated for white perch cohorts (Table 10).

Striped bass larval cohorts grew at a mean rate of 0.28 mm/day, based on the entire otolith-aged sample for 1987. The range in rates of 10 otolith-aged cohorts was 0.18 to 0.43 mm/day. The cohort-specific from age-frequencies method and cruise-specific method, gave estimates of 0.32 and 0.30 mm/day, respectively. These rates are higher than those reported for the Hudson River by Dey (1981), who gave a range of 0.10 to 0.20 mm/day for four years. Based on a stable age distribution assumption, Low (1986) estimated instantaneous growth rates of Sacramento River striped bass larvae. Expressed as absolute rates, they ranged from 0.29 to 0.46 mm/day for eight years in the period 1968-1986. Those rates are generally higher than we estimated for cohorts in the Potomac in 1987, although four Potomac cohorts had rates $\geq$0.31 mm/day

(Table 12). There was a weak regression relationship (P≅0.10) between growth rates and temperatures in the Potomac during 1987. Growth rate was observed to increase by 0.013 mm/day per degree increase in river temperature.

The considerable variability in growth observed among individual cohorts potentially could impact relative recruitments. Predicted sizes-at-age of striped bass larvae from several cohorts (Table 10A) indicated that cohorts hatched later in the season were attaining larger size-at-age because they grew faster. Striped bass larvae could vary by nearly 5 mm in length at 30-days posthatch as a consequence of among-cohort growth rate variation. More than 25-day variation in estimated age at 15.0 mm SL was possible given the growth-rate differences that we estimated among cohorts. However, a simple correlation analysis between estimated 20-day survivorship (Tables 8 and 9) and growth rates (Table 12) of eight cohorts did not detect any significant relationship between the two variables.

White perch larvae grew faster, on average, than striped bass larvae in 1987. The mean rate for all otolith-aged larvae was 0.41 mm/day. Cohort-specific rates ranged from 0.29 to 0.69 mm/day. The 0.69 mm/day rate is believed to be artifactual. It was based on a regression of only six data points (Table 15), two of which were anomalous. Not including that rate reduces the range to 0.29 to 0.44 mm/day. There was evidence that white perch larvae grew more slowly in their first 20 days posthatch than subsequently (Table 15). The observed variability in cohort-specific growth rates of white perch could lead to nearly 4 mm differences in length at 30 days posthatch and more than 10-day variation in the time that is required to grow to 15 mm standard length. White perch larval growth rates were not correlated with temperature, and there was no correlation between cohort-specific growth and mortality rates.

A detailed analysis of environmental effects on striped bass and white perch growth, mortality and survivorship in relation to environmental factors for the 1987 Potomac data is still to be completed. An environmental effects model is being developed that, when complete, will be submitted as part of future reports on larval striped bass and white perch dynamics. The conceptual model was outlined by Houde et al. (1988). The functional model will consider effects of light, turbidity, temperatures, and zooplankton abundance on larval survival and growth rates. It will be used to predict striped bass survivorship under variable river conditions.

In 1987, the most obvious environmental effect in the Potomac was the loss of >60% of striped bass egg production and newly-hatched larvae to falling river temperatures and flood conditions in the 17-20 April period. It is not certain if flood conditions at that time or at other dates contributed significantly to transport losses. The center of larval distributions remained relatively stable throughout the season (Houde et al. 1988). However, the highest discharge and river flow of the season were coincident with the sharp fall in temperature that occurred in the 17-20 April period. Discharge rates at Little Falls exceeded 100,000 ft^3 sec^{-1} at that time. Discharge never exceeded 37,000 ft^3 sec^{-1} and temperatures never dropped to lethal levels after 24 April, the date when we first began to observe potential recruits.

Despite the >60% loss to potential recruitment caused by the 17-20 April episodic mortality, relatively large numbers of striped bass larvae survived to $\geq$20 days posthatch. For cohorts observed at least three times that survived to $\geq$20 days, survivorship was 91.3×10^6 (Table 9). If the episodic loss had not occurred and cohorts hatched in the 15-22 April period had survived at rates equal to the cohorts that produced $\geq$20-day-old survivors, recruitment potential would have been enhanced by a factor of 2.5. The episodic loss was important, but it was not catastrophic. A 0.05 increase or decrease in the instantaneous daily mortality rate would have caused an even grater effect on potential recruitment than the 2.5-fold effect of the episodic loss. Such effects easily could arise from interannual variability in predation rates, starvation rates, persistent transport losses or contaminant-induced mortality.

Information reported here eventually will be linked to that collected in the Potomac River for Maryland's juvenile index surveys. Our larval survivorship and hatch-date analysis suggest that the period 24 April to 20 May provided most striped bass recruits in the Potomac during 1987. When Maryland DNR has completed its birthdate analysis on juvenile index specimens, it will be possible to determine if age-structured larval abundance data and cohort-specific vital rate estimates can be used to depict the subsequent recruitment pattern of juveniles and to define environmental conditions that lead to recruitment successes or failures.

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APPENDIX TABLES

Table 1A. Comparison of night and day catches of white perch larvae in oblique tows of the 505-um, 60-cm sampler at station 4, cruises 4-7, Potomac River, 1987.

Length Class (mm)	NIGHT Freq (No.)	NIGHT Density (No./1000m^3)	DAY Freq (No.)	DAY Density (No./1000m^3)
1.0	0.0	0.00	0.0	0.00
1.5	0.0	0.00	0.0	0.00
2.0	0.0	0.00	0.0	0.00
2.5	0.0	0.00	0.0	0.00
3.0	33.4	35.59	9.9	11.35
3.5	59.2	63.15	64.8	74.27
4.0	263.9	281.57	339.8	389.71
4.5	369.0	393.68	388.8	445.82
5.0	359.8	383.81	455.5	522.40
5.5	334.1	356.37	363.9	417.35
6.0	239.4	255.37	255.3	292.81
6.5	336.1	358.54	220.7	253.12
7.0	524.2	559.21	349.3	400.59
7.5	265.2	282.93	306.6	351.56
8.0	341.1	363.92	555.4	636.98
8.5	772.7	824.26	339.0	388.79
9.0	494.3	527.35	362.7	415.90
9.5	361.7	385.90	243.3	279.00
10.0	160.8	171.50	277.4	318.14
10.5	239.3	255.26	131.2	150.45
11.0	81.4	86.84	50.5	57.87
11.5	146.1	155.90	67.0	76.86
12.0	158.8	169.36	47.0	53.93
12.5	79.9	85.24	38.7	44.40
13.0	67.6	72.16	46.7	53.60
13.5	38.1	40.60	24.1	27.62
14.0	47.1	50.25	17.9	20.56
14.5	69.3	73.93	9.5	10.94
15.0	30.5	32.52	5.0	5.73
15.5	19.9	21.19	3.0	3.44
16.0	4.4	4.67	4.3	4.90
16.5	13.6	14.53	2.3	2.60
17.0	28.0	29.83	0.0	0.00
17.5	8.2	8.79	1.0	1.15
18.0	13.5	14.38	3.3	3.75
18.5	12.5	13.31	3.0	3.44
19.0	1.0	1.07	0.0	0.00
19.5	0.0	0.00	1.0	1.15
20.0	0.0	0.00	0.0	0.00
20.5	1.0	1.07	0.0	0.00
21.0	0.0	0.00	0.0	0.00

Table 2A. Comparison of densities of white perch larvae collected in oblique tows of the 60-cm sampler with paired 333 and 505-um mesh nets. Data from Sta. 4, Cruises 1-7, Potomac River, 1987.

Length Class (mm)	333 um Freq. (no.)	333 um Density (No./1000m^3)	505 um Freq. (no.)	505 um Density (No./1000m^3)
1	0.0	0.00	0.0	0.00
2	1.0	1.35	1.0	1.12
3	170.8	230.28	108.5	122.05
4	743.5	1002.42	281.9	317.08
5	286.0	385.68	333.7	375.37
6	194.3	263.32	154.1	173.32
7	199.2	268.51	208.8	234.96
8	325.1	438.25	276.5	311.03
9	351.4	473.73	301.2	338.84
10	119.5	161.20	177.7	199.90
11	70.5	94.97	64.1	72.17
12	53.6	72.29	58.1	65.36
13	33.1	44.60	37.0	41.62
14	8.0	10.79	23.0	25.85
15	10.0	13.48	11.0	12.46
16	7.0	9.44	5.5	6.23
17	4.0	5.39	0.0	0.00
18	0.0	0.0	2.2	2.49
19	1.0	1.35	3.3	3.74
20	0.0	0.0	1.1	1.25

Table 3A. Comparison of catches of white perch larvae in the 505-um, 60-cm sampler and in the 700-um, $2m^2$ Tucker trawl. Data are from Sta. 4, Cruises 5-7, Potomac River, 1987.

Length Class (mm)	505 um Freq (No.)	505 um Density (No./1000m^3)	Tucker Freq (No.)	Tucker Density (No./1000m^3)
1.0	0.0	0.000	0.0	0.000
1.5	0.0	0.000	0.0	0.000
2.0	0.0	0.000	0.0	0.000
2.5	0.0	0.000	0.0	0.000
3.0	0.0	0.000	0.0	0.000
3.5	12.4	17.389	0.0	0.000
4.0	162.6	228.817	1.0	0.205
4.5	184.5	259.520	143.3	29.309
5.0	290.0	407.994	378.9	77.488
5.5	279.1	392.673	383.6	78.447
6.0	279.7	393.505	271.8	55.592
6.5	253.2	356.287	478.1	97.781
7.0	423.4	595.735	736.6	150.645
7.5	409.9	576.730	1619.7	331.269
8.0	562.2	790.943	1935.0	395.759
8.5	521.9	734.185	2067.7	422.901
9.0	600.7	845.045	2177.4	445.338
9.5	433.9	610.398	3156.2	645.522
10.0	529.3	744.621	3683.0	753.265
10.5	266.3	374.694	3495.6	714.929
11.0	109.1	153.503	3530.5	722.081
11.5	152.8	214.987	3619.3	740.243
12.0	113.8	160.075	3801.9	777.570
12.5	98.5	138.641	2426.8	496.340
13.0	125.3	176.280	2692.8	550.733
13.5	67.8	95.363	1013.1	207.203
14.0	52.8	74.298	808.9	165.448
14.5	29.4	41.423	308.0	62.990
15.0	16.1	22.693	385.1	78.772
15.5	10.1	14.196	44.9	9.183
16.0	15.0	21.083	128.4	26.257
16.5	8.3	11.669	731.7	149.652
17.0	0.0	0.000	0.0	0.000
17.5	3.9	5.543	301.7	61.697
18.0	13.4	18.816	558.4	114.212
18.5	12.7	17.897	346.6	70.881
19.0	0.0	0.000	301.7	61.697
19.5	4.5	6.379	0.0	0.000
20.0	0.0	0.000	0.0	0.000
20.5	0.0	0.000	128.4	26.257
21.0	0.0	0.000	0.0	0.000

Table 4A. Corrected riverwide abundances ($X10^{-6}$) of striped bass larvae from the 505-um, 60-cm sampler standard tows, Cruises 1-7, Potomac River, 1987.

Length Class	CRUISE 2			CRUISE 3			CRUISE 4		
(mm)	uncorr	corr N/D	corr 333/505	uncorr	corr N/D	corr 333/505	uncorr	corr N/D	corr 333/505
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.0	0.000	0.000	0.000	0.000	0.000	0.000	2.500	0.000	0.000
2.5	11.942	86.460	245.547	0.000	0.000	0.000	4.230	0.000	0.000
3.0	28.737	208.058	478.533	0.000	0.000	0.000	20.410	196.426	557.849
3.5	69.618	164.299	317.096	0.000	0.000	0.000	61.270	443.614	1020.313
4.0	110.243	188.516	311.051	1.436	3.390	6.542	136.570	322.310	622.058
4.5	41.693	60.872	87.046	3.692	6.313	10.416	242.870	415.316	685.271
5.0	15.582	32.722	41.230	4.772	6.967	9.963	248.860	363.335	519.569
5.5	0.000	0.000	0.000	4.591	9.641	12.147	145.820	306.221	385.839
6.0				6.293	14.223	14.223	83.870	189.547	189.547
6.5				2.703	6.540	6.540	59.550	144.114	144.114
7.0				0.000	0.000	0.000	22.960	59.232	59.232
7.5							15.740	42.974	42.974
8.0							9.160	26.386	26.386
8.5							5.850	21.061	21.061
9.0							2.870	10.845	10.845
9.5							1.430	4.791	4.791
10.0							0.000	0.000	0.000

Table 4A. Continued

Length Class (mm)	CRUISE 5			CRUISE 6			CRUISE 7		
	uncorr	corr N/D	corr 333/505	uncorr	corr N/D	corr 333/505	uncorr	corr N/D	corr 333/505
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.5	0.511	0.511	0.511	0.000	0.000	0.000	0.000	0.000	0.000
3.0	4.426	11.685	33.184	0.000	0.000	0.000	0.000	0.000	0.000
3.5	12.088	31.912	73.398	0.000	0.000	0.000	0.000	0.000	0.000
4.0	20.229	53.403	103.069	3.578	9.445	18.228	0.000	0.000	0.000
4.5	34.650	91.475	150.933	11.249	29.088	49.000	0.000	0.000	0.000
5.0	83.328	219.985	314.578	36.397	96.088	137.407	0.000	0.000	0.000
5.5	116.627	244.916	308.594	48.936	102.765	129.484	0.000	0.000	0.000
6.0	64.582	145.955	145.955	52.419	118.467	118.467	0.000	0.000	0.000
6.5	42.673	103.269	103.269	30.885	74.742	74.742	0.472	1.141	1.141
7.0	14.588	37.637	37.637	28.344	73.126	73.126	0.000	0.000	0.000
7.5	2.592	7.077	7.077	30.510	83.293	83.293	0.000	0.000	0.000
8.0	0.000	0.000	0.000	22.859	65.833	65.833	0.000	0.000	0.000
8.5	7.371	26.534	26.534	3.907	14.065	14.065	0.000	0.000	0.000
9.0	5.484	20.729	20.729	2.261	8.547	8.547	0.000	0.000	0.000
9.5	6.278	20.967	20.967	6.603	22.053	22.053	1.613	5.387	5.387
10.0	4.652	16.189	16.189	6.194	21.557	21.557	1.109	3.858	3.858
10.5	1.429	5.189	5.189	0.000	0.000	0.000	0.000	0.000	0.000
11.0	1.107	4.183	4.183	1.045	3.949	3.949	0.000	0.000	0.000
11.5	0.918	3.599	3.599	0.724	2.839	2.839	0.000	0.000	0.000
12.0	1.107	4.515	4.515	1.045	4.263	4.263	0.000	0.000	0.000
12.5	1.107	4.669	4.669	0.000	0.000	0.000	0.000	0.000	0.000
13.0	0.000	0.000	0.000				1.795	7.825	7.825
13.5							0.000	0.000	0.000
14.0							0.897	4.173	4.173
14.5							0.000	0.000	0.000

Table 5A. Corrected riverwide abundances (X10^6) of white perch larvae from the 505-um, 60-cm sampler standard tows, Cruises 1-7, Potomac River, 1987.

Length Class (mm)	CRUISE 1 uncorr	CRUISE 1 corr N/D	CRUISE 1 corr 333/505	CRUISE 1 corr Tuck/505	CRUISE 2 uncorr	CRUISE 2 corr N/D	CRUISE 2 corr 333/505	CRUISE 2 corr Tuck/505
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.5	0.454	0.454	0.454	0.454	3.208	3.208	3.208	3.208
3.0	10.679	10.679	10.679	10.679	18.516	18.516	18.516	18.516
3.5	26.304	26.304	26.304	26.304	65.414	65.414	65.414	65.414
4.0	23.271	23.271	36.770	36.770	171.739	171.739	271.368	271.368
4.5	10.085	10.085	15.444	15.444	56.199	56.199	86.067	86.067
5.0	0.000	0.000	0.000	0.000	0.641	0.641	0.955	0.955
5.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.0	1.069	1.069	1.517	1.517	0.000	0.000	0.000	0.000
6.5	0.000	0.000	0.000	0.000	0.652	0.652	0.906	0.906
7.0					0.000	0.000	0.000	0.000
7.5								
8.0								

Length Class (mm)	CRUISE 3 uncorr	CRUISE 3 corr N/D	CRUISE 3 corr 333/505	CRUISE 3 corr Tuck/505	CRUISE 4 uncorr	CRUISE 4 corr N/D	CRUISE 4 corr 333/505	CRUISE 4 corr Tuck/505
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.5	1.311	1.311	1.311	1.311	2.051	2.051	2.051	2.051
3.0	57.406	57.406	57.406	57.406	46.377	46.377	46.377	46.377
3.5	219.733	219.733	219.733	219.733	273.878	273.878	273.878	273.878
4.0	289.386	289.386	457.265	457.265	549.578	549.578	868.399	868.399
4.5	289.883	289.883	443.947	443.947	551.876	551.876	845.181	845.181
5.0	90.376	90.376	134.590	134.590	428.250	428.250	637.758	637.758
5.5	23.371	23.371	33.935	33.935	443.395	443.395	643.812	643.812
6.0	0.000	0.000	0.000	0.000	321.813	321.813	456.602	456.602
6.5	1.350	1.350	1.875	1.875	369.663	369.663	513.464	513.464
7.0	0.717	0.717	0.977	0.977	305.546	305.546	416.136	416.136
7.5	0.000	0.000	0.000	0.000	131.860	131.860	176.326	176.326
8.0					38.682	29.785	39.153	39.153
8.5					7.328	8.720	11.280	11.280
9.0					0.000	0.000	0.000	0.000
9.5								
10.0								

Table 5A. Continued.

Length Class (mm)	CRUISE 5 uncorr	CRUISE 5 corr N/D	CRUISE 5 corr 333/505	CRUISE 5 corr Tuck/505	CRUISE 6 uncorr	CRUISE 6 corr N/D	CRUISE 6 corr 333/505	CRUISE 6 corr Tuck/505	CRUISE 7 uncorr	CRUISE 7 corr N/D	CRUISE 7 corr 333/505	CRUISE 7 corr Tuck/505
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.5	1.423	1.423	1.423	1.423	0.494	0.494	0.494	0.494	1.711	1.711	1.711	1.711
3.0	36.922	36.922	36.922	36.922	35.932	35.932	35.932	35.932	6.417	6.417	6.417	6.417
3.5	145.315	145.315	145.315	145.315	54.704	54.704	54.704	54.704	13.000	13.000	13.000	13.000
4.0	194.000	194.000	306.544	306.544	110.492	110.492	174.591	174.591	17.248	17.248	27.255	27.255
4.5	115.222	115.222	176.459	176.459	106.674	106.674	163.368	163.368	16.963	16.963	25.978	25.978
5.0	151.968	151.968	226.313	226.313	133.123	133.123	198.250	198.250	15.238	15.238	22.693	22.693
5.5	185.894	185.894	269.918	269.918	181.256	181.256	263.185	263.185	29.111	29.111	42.269	42.269
6.0	159.757	159.757	226.670	226.670	171.893	171.893	243.889	243.889	36.263	36.263	51.451	51.451
6.5	175.322	175.322	243.524	243.524	159.781	159.781	221.937	221.937	31.593	31.593	43.883	43.883
7.0	255.142	255.142	347.488	347.488	266.563	266.563	363.044	363.044	35.440	35.440	48.267	48.267
7.5	234.761	234.761	313.927	313.927	252.106	252.106	337.121	337.121	14.328	14.328	19.160	19.160
8.0	294.064	226.429	297.642	297.642	443.566	341.546	448.962	448.962	19.510	15.023	19.748	19.748
8.5	256.613	305.370	394.999	394.999	237.783	282.962	366.014	366.014	18.149	21.598	27.937	27.937
9.0	215.098	279.628	356.253	356.253	359.082	466.806	594.724	594.724	57.170	74.321	94.686	94.686
9.5	140.177	199.052	249.983	209.023	154.041	218.739	274.707	229.697	19.415	27.570	34.624	28.951
10.0	127.077	195.699	242.447	376.324	174.568	268.835	333.054	516.963	47.082	72.507	89.827	139.429
10.5	30.844	51.201	62.615	128.647	120.826	200.571	245.286	503.955	34.289	56.919	69.609	143.015
11.0	6.866	12.289	14.845	32.714	164.463	294.390	355.599	783.660	32.340	57.888	69.924	154.098
11.5	0.000	0.000	0.000	0.000	113.257	216.320	258.232	608.514	12.104	23.119	27.598	65.034
12.0					121.954	250.005	295.089	741.427	31.840	65.273	77.044	193.576
12.5					30.562	66.626	77.793	207.862	17.684	38.552	45.014	120.275
13.0					46.677	108.292	125.132	354.709	30.977	71.866	83.042	235.397
13.5					17.180	42.263	48.349	145.073	11.674	28.719	32.855	98.582
14.0					1.723	4.480	5.075	16.087	17.514	45.535	51.592	163.525
14.5					0.000	0.000	0.000	0.000	8.560	23.539	26.423	88.298
15.0									4.487	13.012	14.475	50.908
15.5									3.801	11.593	12.784	47.238
16.0									4.940	15.857	17.340	67.213
16.5									2.036	6.863	7.443	30.221
17.0									0.000	0.000	0.000	0.000
17.5									3.115	11.493	12.273	54.450
18.0									2.934	11.324	12.002	55.559
18.5									2.692	10.849	11.416	55.071
19.0									0.000	0.000	0.000	0.000
19.5									0.897	3.922	4.069	21.250
20.0												

Table 6A. Age-length key based on otolith-aged striped bass larvae collected in the Potomac River, 1987. The body of the table contains probabilities that larvae in the 0.5 mm length-classes will be included in 3-day age-groups.

LENGTH (mm SL)	AGE CLASS (days) 0-2.99	3-5.99	6-8.99	9-11.99	12-14.99	15-17.99	18-20.99	21-23.99	24-26.99	27-29.99	30-32.99	33-35.99	36-38.99	39-41.99	42-44.99
3	1														
3.5	1														
4	1														
4.5	0.5319	0.4681													
5		1													
5.5		0.2709	0.7291												
6			1												
6.5			0.0668	0.9332											
7				1											
7.5					1										
8					1										
8.5						1									
9						1									
9.5							1								
10							0.8554	0.1446							
10.5								1							
11								0.6293	0.3707						
11.5									1						
12									0.4052	0.5948					
12.5										1					
13										0.2578	0.7422				
13.5											1				
14											0.1666	0.8334			
14.5												0.9265	0.0765		
15												0.117	0.883		
15.5													0.8315	0.1685	
16													0.0838	0.9162	
16.5														0.7157	0.2843
17														0.063	0.937

Table 7A. Age-length key based on otolith-aged white perch larvae collected in the Potomac River on Cruises 1-4, 1987. The body of the table contains probabilities that larvae in the 0.5 mm length-classes will be included in 3-day age-groups.

Standard Length (mm)	AGE CLASS (days)					
	0-2.99	3-5.99	6-8.99	9-11.99	12-14.99	15-17.99
2.5	1.0000					
3	1.0000					
3.5	1.0000					
4	0.2177	0.7823				
4.5		1.0000				
5		1.0000				
5.5		0.1170	0.8830			
6			1.0000			
6.5			0.8238	0.1762		
7			0.1841	0.8159		
7.5				0.9713	0.0287	
8				0.6480	0.3520	

Table 8A. Age-length key based on otolith-aged white perch larvae collected in the Potomac River on Cruises 5-7, 1987. The body of the table contains probabilities that larvae in the 0.5 mm length-classes will be included in 3-day age-groups.

Standard Length (mm)	AGE (days)															
	0-2.99	3-5.99	6-8.99	9-11.99	12-14.99	15-17.99	18-20.99	21-23.99	24-26.99	27-29.99	30-32.99	33-35.99	36-38.99	39-41.99	42-44.99	45-47.99
2.5	1.0000															
3	1.0000															
3.5	0.5438	0.4562														
4		1.0000														
4.5		1.0000														
5		0.1762	0.8238													
5.5			1.0000													
6			0.9099	0.0901												
6.5				1.0000												
7				1.0000												
7.5				0.6915	0.3085											
8					1.0000											
8.5					1.0000											
9					0.1423	0.8577										
9.5						1.0000										
10						1.0000										
10.5							1.0000									
11							1.0000									
11.5							0.7939	0.2061								
12								1.0000								
12.5								1.0000								
13								0.3050	0.6950							
13.5									1.0000							
14									0.9719	0.0281						
14.5									0.0764	0.9236						
15										1.0000						
15.5										0.7549	0.2451					
16											1.0000					
16.5																

Table 8A. Continued.

Standard Length (mm)	AGE (days)															
	0-2.99	3-5.99	6-8.99	9-11.99	12-14.99	15-17.99	18-20.99	21-23.99	24-26.99	27-29.99	30-32.99	33-35.99	36-38.99	39-41.99	42-44.99	45-47.99
17											0.4404	0.5596				
17.5												1.0000				
18												0.9115	0.0885			
18.5												0.2177	0.7823			
19													1.0000			
19.5													0.7190	0.2810		
20													0.1075	0.8925		
20.5														0.9591	0.0409	
21														0.5000	0.5000	
21.5														0.0537	0.9463	
22															0.8577	0.1423

Table 9A. Growth equations describing growth-in-length for eight cohorts of striped bass larvae, Potomac River, 1987.

COHORT HATCH DATE	COHORT	N	R2	COHORT REGRESSIONS	s.e. (slope)	MEAN AGE
4/24-4/26	F	4	0.958	L = 3.19 + .30(t)	0.04	41
4/27-4/29	G	27	0.961	L = 3.62 + .28(t)	0.01	38
4/30-5/2	H	8	0.925	L = 5.34 + .18(t)	0.02	36
5/3-5/5	I	11	0.926	L = 4.72 + .24(t)	0.02	33
5/6-5/8	J	11	0.918	L = 3.48 + .33(t)	0.03	30
5/9-5/11	K	14	0.877	L = 4.51 + .26(t)	0.03	27
5/12-5/14	L	63	0.913	L = 3.93 + .30(t)	0.01	24
5/15-5/17	M	38	0.902	L = 3.74 + .31(t)	0.02	21
5/18-5/20	N	15	0.780	L = 2.53 + .43(t)	0.06	18
5/21-5/23	O	4	0.910	L = 3.69 + .32(t)	0.07	15

Table 10A. Matrix of predicted lengths-at-age for striped bass larvae in eight cohorts for which regression equations describing growth were available (see Table 9A).

Cohort		MEAN AGE (days) 1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5	31.5	34.5	37.5	40.5
F	mean	3.64	4.52	5.41	6.30	7.19	8.08	8.96	9.85	10.74	11.63	12.52	13.40	14.29	15.18
	s.e.	1.83	1.79	1.76	1.72	1.69	1.66	1.62	1.59	1.56	1.52	1.49	1.46	1.43	1.40
G	mean	4.03	4.86	5.68	6.51	7.34	8.17	9.00	9.82	10.65	11.48	12.31	13.14	13.96	
	s.e.	0.40	0.40	0.39	0.38	0.37	0.36	0.35	0.34	0.34	0.33	0.32	0.31	0.30	
H	mean	5.60	6.13	6.66	7.19	7.72	8.25	8.78	9.30	9.83	10.36	10.89	11.42	11.95	12.48
	s.e.	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.51	0.50
I	mean	5.08	5.79	6.51	7.22	7.94	8.65	9.37	10.08	10.80	11.51	12.23			
	s.e.	0.68	0.67	0.65	0.64	0.62	0.61	0.60	0.58	0.57	0.55	0.54			
J	mean	3.97	4.95	5.94	6.92	7.91	8.89	9.87	10.86	11.84	12.83				
	s.e.	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.66	0.63				
K	mean	4.90	5.69	6.48	7.27	8.07	8.86	9.65	10.44	11.23					
	s.e.	0.68	0.66	0.64	0.62	0.60	0.58	0.56	0.54	0.52					
L	mean	4.38	5.27	6.17	7.06	7.96	8.85	9.75	10.65						
	s.e.	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19						
M	mean	4.21	5.15	6.10	7.04	7.98	8.92	9.87							
	s.e.	0.36	0.34	0.33	0.31	0.30	0.28	0.26							
N	mean	3.17	4.46	5.75	7.04	8.34	9.63								
	s.e.	0.90	0.82	0.75	0.68	0.61	0.54								

Table 11A. Striped bass. Predicted lengths at 30 days posthatch and predicted ages at 15 mm SL for 10 cohorts, Potomac River, 1987.

Cohort	Length at 30d	Age at 15 mm
F	12.07	39.9
G	11.89	41.2
H	10.63	54.8
I	11.87	43.1
J	13.32	35.1
K	12.41	39.8
L	12.89	37.1
M	13.04	36.3
N	15.42	29.0
O	13.22	35.6

Table 12A. Growth equations describing growth-in-length for 11 cohorts of white perch larvae, Potomac River, 1987.

Cohort Hatch Dates	Cohort	Equation	# Obs	r^2
4/27-29	G	y = .404x + 3.068	3	0.99
4/30-5/2	H	y = .693x - 6.813	6	0.83
5/3-5	I	y = .419x + 2.640	33	0.94
5/6-8	J	y = .397x + 2.830	28	0.96
5/9-11	K	y = .375x + 4.122	21	0.83
5/12-14	L	y = .359x + 3.800	14	0.75
5/15-17	M	y = .350x + 3.826	25	0.68
5/18-20	N	y = .320x + 3.936	19	0.60
5/21-23	O	y = .393x + 2.940	24	0.71
5/24-26	P	y = .286x + 3.273	19	0.70
5/27-29	Q	y = .443x + 2.102	5	0.64

Table 13A. Matrix of predicted lengths-at-age for white perch larvae in 11 cohorts for which regression equations describing growth were available (see Table 12A).

Cohort		Age (Days) 1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5	31.5	34.5	37.5
G	Mean	3.67	4.88	6.09	7.31	8.52	9.73	10.94	12.15	13.36	14.57	15.78	16.99	18.20
	S.E.	1.27	1.15	1.04	0.94	0.84	0.75	0.67	0.61	0.58	0.57	0.60	0.64	0.71
H	Mean	-5.77	-3.70	-1.62	0.46	2.54	4.62	6.70	8.77	10.85	12.93	15.01	17.09	
	S.E.	4.90	4.43	3.96	3.49	3.03	2.56	2.10	1.64	1.19	0.77	0.45	0.50	
I	Mean	3.27	4.53	5.79	7.04	8.30	9.55	10.81	12.07	13.32	14.58	15.83		
	S.E.	0.32	0.28	0.25	0.23	0.23	0.24	0.26	0.29	0.33	0.38	0.42		
J	Mean	3.46	4.65	5.84	7.03	8.22	9.41	10.60	11.79	12.98	14.17			
	S.E.	0.26	0.22	0.20	0.18	0.17	0.18	0.20	0.23	0.27	0.31			
K	Mean	4.68	5.81	6.93	8.06	9.18	10.31	11.43	12.56	13.68				
	S.E.	0.70	0.59	0.49	0.38	0.29	0.23	0.21	0.25	0.33				
L	Mean	4.34	5.42	6.49	7.57	8.65	9.72	10.80	11.88					
	S.E.	1.06	0.89	0.72	0.56	0.41	0.30	0.27	0.34					
M	Mean	4.35	5.40	6.45	7.50	8.55	9.60	10.65						
	S.E.	0.75	0.61	0.48	0.35	0.25	0.22	0.27						
N	Mean	4.42	5.37	6.33	7.29	8.25	9.21							
	S.E.	0.75	0.57	0.41	0.27	0.23	0.33							
O	Mean	3.53	4.71	5.89	7.07	8.25								
	S.E.	0.50	0.37	0.26	0.24	0.31								
P	Mean	3.70	4.56	5.42	6.27									
	S.E.	0.29	0.18	0.15	0.22									
Q	Mean	2.77	4.10	5.42										
	S.E.	0.72	0.41	0.69										

Table 14A. White perch. Predicted lengths at 30 days posthatch and predicted ages at 15 mm SL for 11 cohorts, Potomac River, 1987.

Cohort	Length at 30d	Age at 15 mm
G	15.18	29.6
H	13.98	31.5
I	15.21	29.5
J	14.77	30.6
K	15.37	29.0
L	14.57	31.2
M	14.32	31.9
N	13.53	34.6
O	14.74	30.7
P	11.85	41.0
Q	15.39	29.1