Final Report

A. Grant Number: NA96ED0076

B. Amount of Grant: Federal: $88,702 Match: $23,404 Total: $112,106

C. Project Title: Density-dependent growth and reproduction of Chesapeake Bay striped bass.

D. Grantee: University of Maryland Center for Environmental Science

E. Award Period: From 3/1/99 to 3/31/00 with unfunded extensions

F. Period covered by this report: March 1, 1999 – October 31, 2002

Prepared by: ____

Principal Investigator **Date**

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Density-dependent Growth and Reproduction of Chesapeake Bay Striped Bass

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The original objectives of this project were to examine evidence for density-dependence in growth and reproductive potential of Chesapeake Bay striped bass and to investigate the implications of density-dependence for biological reference points and overfishing thresholds. Our goals were to: (1) estimate age and year-class-specific growth rates of juveniles, pre-migrant subadults and migratory females, and examine evidence for density-dependence in growth, (2) estimate fecundity and age at first maturation for females of year-classes varying in initial abundance and test for density effects on these parameters and (3) evaluate the importance of density-dependence in these factors for calculation of biological reference points and overfishing thresholds. Difficulties and delays in accomplishing the first two objectives precluded our progressing to the third objective, therefore objective 3 is not addressed in this final report.

Density-dependent growth of post-juvenile striped bass

Methods

We looked for evidence of density-dependent growth of young-of-year striped bass by examining size of juveniles during their first growing season. We used data on young-of-year abundance and size (total length) collected by Maryland's Department of Natural Resources (MD DNR) during annual beach seine surveys. Replicate beach seine hauls are taken at 22 fixed station locations in the Choptank (4 stations), Nanticoke (4 stations), and Potomac Rivers (7 stations) and in the upper Bay (7 stations) (MD DNR 1995). A complete round of sampling is done three times each summer (July, August, September) for a total of 132 standard hauls each year. Each round of sampling is completed in about 10 days. At each station, a sub-sample of juvenile striped bass is measured. The survey has been conducted since 1954; however juvenile length sampling has become more consistent in recent years. We used data from 10 years in which samples were well balanced spatially and temporally (1982, 1984, 1989, 1991-1997). Fish lengths were measured for both of the replicate hauls done at each station, but were not recorded for each haul separately, thus we used mean length for combined replicate hauls as an index of YOY size and the sum of the numbers caught as an index of abundance at each station.

We used log-linear models (ANCOVA) to examine spatial and temporal variation in mean size and to test for possible density-dependent effects. Separate analyses were done for each monthly sampling period. The general form of the models was

$$\ln(\text{dependent}) = \ln(\text{number of YOY}) + \text{year effects} + \text{system effects} + \text{error}$$

We tested all 2-way interactions and dropped them from the model if they were not significant. Three dependent variables were examined: mean total length, variance in total length, and change in mean length between July and September.

None of the dependent variables (mean and variance in length, change in mean length from July to Sept.) were significantly affected by density of YOY striped bass. Year effects were significant in all the models and system effects were significant in several.

Density-dependent growth of post-juvenile striped bass

Methods

We looked for evidence of density-dependent effects on growth of immature pre-migrant fish (1989-1997 year-classes) and mature migratory females (1989-1994 year-classes) using back-calculation of scale annual increment data (DeVries and Frie 1996; Secor et al. 1995). For immature striped bass, we used archived scale samples collected during MD DNR's annual fall sampling of commercial pound net fisheries. The samples included the 1989 through 1996 year-classes. To examine growth of mature (migratory) females, scale samples were collected on the spawning grounds in conjunction with MD DNR's spring spawning stock survey.

Annual increment data were collected using pattern recognition software by Optimas. The number of samples read is shown in Table 1. We used three back-calculation methods to estimate length at age from the increment data: the Fraser-Lee formula, the scale-proportional formula and the body-proportional formula (Pierce et al. 1996). Estimates of length at age for each year-class were made for the Upper Bay, Middle Bay, Lower Bay, Choptank River, and Potomac River, as well as sampling locations combined.

Results

The scale length-body length relation for striped bass from all sampling locations is shown in Figure 1. A comparison of back-calculation methods for mean length at age for the 1989 year-class is shown in Figure 2. Divergence in the estimates was greatest at the youngest ages. Back-calculated mean length (mm) at age of striped bass by year-class for sampling locations combined using the Fraser-Lee formula is shown in Figure 3. There is some suggestion of slower growth by the 1989 year-class at ages 1-3.

II. Density-dependent fecundity

Methods

We collected gravid females during electro-shocking surveys conducted by the USFWS on the Choptank River spawning grounds in April of 2000 and 2001. In 2000, we sampled once a week for three weeks and collected a total of 40 females measuring 84-131 cm (total length). In 2001, we sampled 2-3 times a week for three weeks and collected a total of 102 females measuring 75-119 cm (total length). Scales and otoliths were removed from each fish for aging. Age was estimated from otoliths by Dr. David Secor's research group at the Chesapeake Biological Laboratory, University of Maryland. The fish were also aged using scales by Victor Vecchio of New York State Department of Environmental Conservation.

Sample Processing – 2000 Samples

Ovaries collected during 2000 were processed using four different methods so that we could compare estimates derived from several approaches. The methods were washed-out fresh eggs (Lowerre-Barbieri and Barbieri 1993), washed-out eggs preserved in formalin, intact ovarian samples preserved in formalin, and intact ovarian samples preserved in modified Gilson's solution. Eggs preserved in modified Gilson's solution degraded before we could process them and so were not included in our final methods comparison. The wash-out method caused hydration and extensive ova damage in striped bass, so we modified the method to wash out only a sample of ova to reduce the time that ova were exposed to water. We scanned a subsample of loose ova and stored the image for later enumeration using the pattern recognition system. After all subsamples were collected, the ovaries were stripped of remaining ova and the residual ovarian tissue was weighed. We used the pattern recognition system to count the eggs in the scanned images and estimated fecundity for each fish from the preserved samples. We replicated counts for 20 fish to compare estimates among methods. We also calculated fecundity estimates with and without remaining ovarian tissue (ovarian capsule plus villi) subtracted from ovary weight. We were able to do this because of having used the wash-out method; fecundity estimates based on intact samples do not explicitly account for ovarian capsule weight. Egg counts were expanded to the full ovary count using ovary weight/sample weight as the expansion factor.

Sample Processing – 2001 Samples

The ovaries and liver were removed from each fish and weighed. The wash-out method was not used this season because of biases introduced by water uptake (Table 2) and longer processing times. For each fish, five subsamples of intact ovarian tissue were weighed and placed in modified Gilson's solution. Two subsamples of intact ovarian tissue were weighed and placed in formalin. The samples preserved in Gilson's solution were watched closely to see when the ovarian tissue was sufficiently degraded for egg counts to be made (we expected approximately 40 days). However we discovered that when the first samples in the collection were ready, many of the samples collected later in the season had degraded too far, damaging the eggs. Therefore we were not able to use the Gilson's solution samples, but relied on the formalin-preserved ones. The samples preserved in formalin were teased apart and counted from scanned images using the Optimas pattern recognition system.

Results – 2000 Samples

Fecundity estimates obtained from fresh and preserved washed-out eggs were lower than those from preserved intact tissue (Figure 4). The lower estimate is probably due to water uptake by ova during the washing-out process. The effect of accounting for remaining ovarian tissue on estimates was smaller than the effect of washing eggs from the ovary (Figure 4, "intact" samples). The percent difference in fecundity estimates derived using different laboratory methods and calculation assumptions is summarized in Table 2.

Fecundity estimates for striped bass sampled during spring 2000 (Figures 5-7) were calculated from samples of washed-out eggs preserved in formalin, corrected for water uptake assuming a 24% underestimate (Table 2). This method was chosen over the other methods for the April 2000 samples for the following reasons:

1. Fresh washed-out samples were placed in water to get scanned images. These images were difficult to read using image analysis due to clumping of the eggs. Estimates were less accurate (poorer agreement between repeated counts on the same images) and only taken for one subsample per fish. Washed-out samples preserved in formalin were set in agarose instead of water. Agarose proved to be a better medium by coating and setting the eggs to keep them from clumping. All three subsamples were more clearly and quickly read per fish using this method.
2. Although intact ovarian subsamples preserved in formalin did not have to be corrected for water uptake, they took substantially more time to separate and process after preservation than the washed-out samples. Therefore, we only teased apart half of the samples to get an accurate correction factor and applied it to the washed-out preserved samples.
3. We could not use the intact ovarian samples preserved in modified Gilson's solution due to degradation of the eggs. However, this method may be preferred if samples are processed after approximately 40 days of preservation since we would have the advantages of fast preservation procedures and eggs separated from ovarian tissue.

Results – 2000 and 2001 Samples

Figures 8-13 show fecundity-length and fecundity-weight relations for sampling years combined. The fecundity estimates are similar to values previously reported for Chesapeake Bay (e.g. Westin and Rogers 1978; Mihursky et al. 1987). Figure 12 shows gonadosomatic indices (GSI, ovary weight/body weight*100) by year-class.

None of these measures show any apparent density-dependent effect, which might be expressed as lower relative fecundity, GSI, or H.S.I. for the 1989 and 1993 year-classes.

Figure 13 compares age estimates derived from scales and otoliths. The correlation between the estimates is fairly low ($r^2 = 0.61$) and estimates from scales become lower relative to otolith ages as fish age increases.

II. Density-dependent maturation rates

We looked for evidence of density-dependence in age and size at first maturity using CPUE-at-age data from MD Department of Natural Resources's spring spawner surveys in the Choptank River, Potomac River, and upper Chesapeake Bay. These surveys are conducted using an array of randomly-arranged drift gill net meshes (70 to 254 mm stretch mesh) fished five to seven days per week during the spawning season (MD DNR 1995); CPUE data were corrected for selectivity. Age was determined by reading scales (MD DNR); maturity was verified by expression of gonadal products.

Results

Mean length at age by year-class is shown for males and females in the Choptank River in Figures 14 and 15. CPUE at age up to age at full maturity for males and females in the Choptank River is shown in Figures 16 and 17. As anticipated, the data were quite noisy and we were not able to draw any inferences regarding density-dependent maturation rates.

Literature Cited

Lowerre-Barbieri, Susan K. and Luiz R. Barbieri. 1993. A new method of oocyte separation and preservation for fish reproduction studies. Fishery Bulletin 91(1):165-170.

Mihursky, J., H. Milsaps, and M. Wiley. 1987. Fecundity estimates for Maryland striped bass. *In* Characterization of Potomac River spawning stocks and fecundities of Maryland striped bass, Maryland DNR, Annapolis.

Pierce, Clay L., Joseph B. Rasmussen, William C. Leggett. 1996. Back-calculation of fish length from scales: empirical comparison of proportional methods. Transactions of the American Fisheries Society 125:889-898.

Westin, D.T. and B.A. Rogers. 1978. Synopsis of biological data on the striped bass, Morone saxatilis (Walbaum) 1792. Graduate School of Oceanography, University of Rhode Island Marine Technical Report 67.

Table 1. Number of scale samples of post-juvenile striped bass read for growth increment analysis.

Year Class	Location	Age	Number of fish
89	Upper Bay	3	30
	Lower Bay	3	30
	Upper Bay	6	30
	Middle Bay	6	30
	Lower Bay	6	30
	Potomac River	9	15
	Potomac River	10	7
	Choptank River	6	2
	Choptank River	7	28
90	Upper Bay	6	30
	Middle Bay	6	30
	Lower Bay	6	25
	Potomac River	8	5
	Potomac River	9	15
	Choptank River	6	17
91	Upper Bay	3	3
	Middle Bay	3	15
	Lower Bay	3	10
	Upper Bay	6	9
	Middle Bay	6	19
	Potomac River	7	11
	Choptank River	5	6
92	Upper Bay	3	7
	Middle Bay	3	15
	Lower Bay	3	17
	Upper Bay	6	19
	Middle Bay	6	21
	Lower Bay	6	10
	Potomac River	6	2
	Potomac River	7	6
93	Upper Bay	3	13
	Middle Bay	3	30
	Lower Bay	3	24
	Upper Bay	6	30
	Middle Bay	6	27
	Lower Bay	6	30
	Potomac River	6	2
94	Upper Bay	3	5
	Middle Bay	3	7
95	Upper Bay	3	8
	Middle Bay	3	8
	Lower Bay		13
96	Upper Bay	3	9
	Middle Bay	3	12
	Lower Bay	3	17
Total			729

Table 2. Percent difference in fecundity estimates derived using different laboratory methods and calculation assumptions.

A. Percent difference in fecundity estimate if weight of remaining ovarian tissue is not subtracted from ovary weight in expansion factor.
B. Effect of preservation on estimates from washed eggs.
C. Effect of washing eggs from ovarian tissue vs. collecting intact ovarian sample (both preserved in formalin).

Sample ID		A. Uncorrected ovary wt/ corrected ovary wt	B. Fresh washed/ formalin washed	C. Washed eggs/ intact sample (both preserved)
2		0.96	1.02	0.74
4		0.96	0.97	0.76
6		0.95	1.02	0.74
11		0.96	0.91	0.72
12		0.96	0.82	0.85
17		0.96	0.95	0.83
18		0.96	0.85	0.90
20		0.96	1.00	0.77
22		0.95	0.60	0.55
23		0.96	0.97	0.81
29		0.97	0.95	0.77
30		0.96	1.02	0.67
31		0.96	0.89	0.75
33		0.97	1.10	0.67
34		0.95	0.94	0.77
35		0.96	0.94	0.77
36		0.97	0.99	0.70
37		0.95	1.00	0.84
38		0.96	0.95	0.82
39		0.96	1.07	0.79
	Average	0.96	0.95	0.76
	Std Dev	0.00	0.11	0.08
	Cv	0.00	0.11	0.10

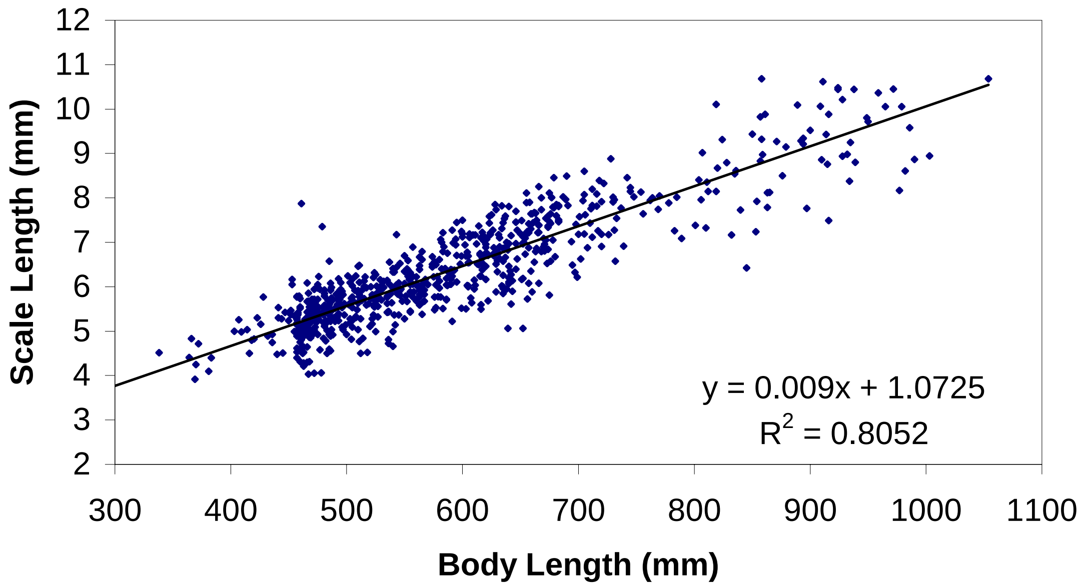


Figure 1. Regression of scale length on body length for striped bass from all sampling locations.

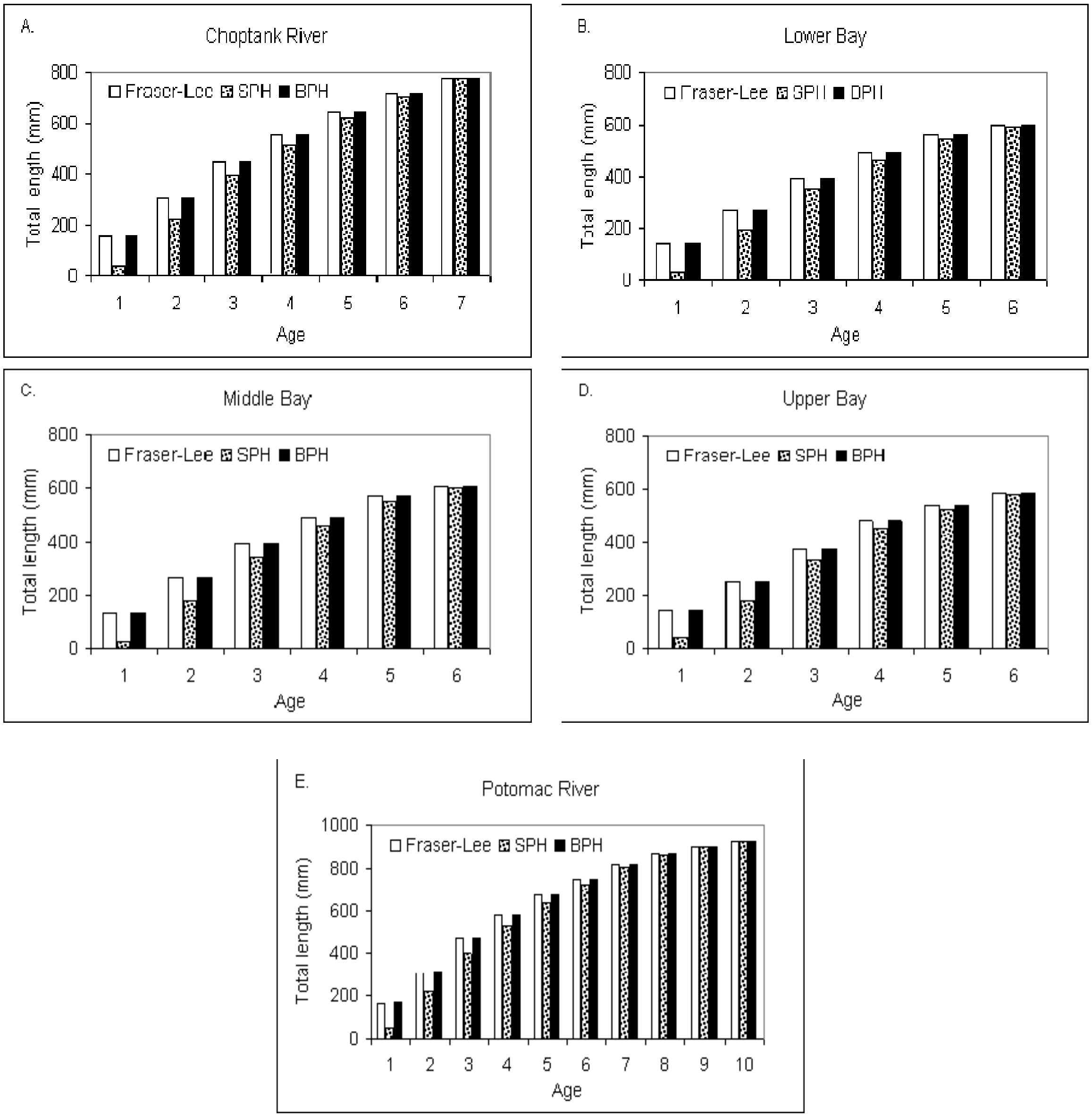


Figure 2. Total length (mm) at age for the 1989 yearclass estimated using three methods. Fraser –Lee, scale-proportional hypothesis (SPH), and body-proportional hypothesis (BPH). A. Choptank River, B. Lower Bay, C. Middle Bay, D. Upper Bay, E. Potomac River.

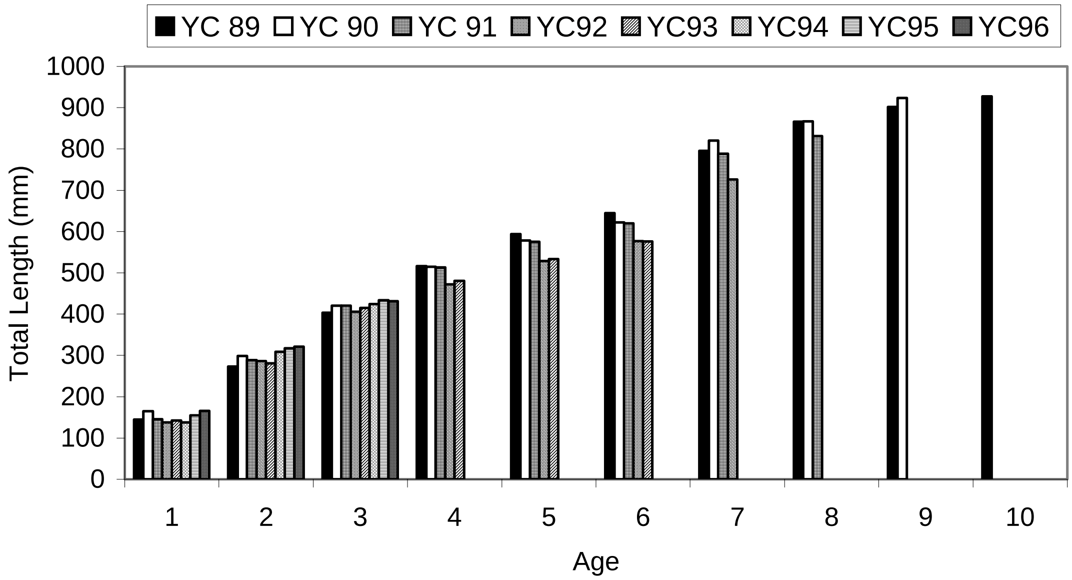


Figure 3. Mean length (mm) at age of striped bass by year-class, sampling locations

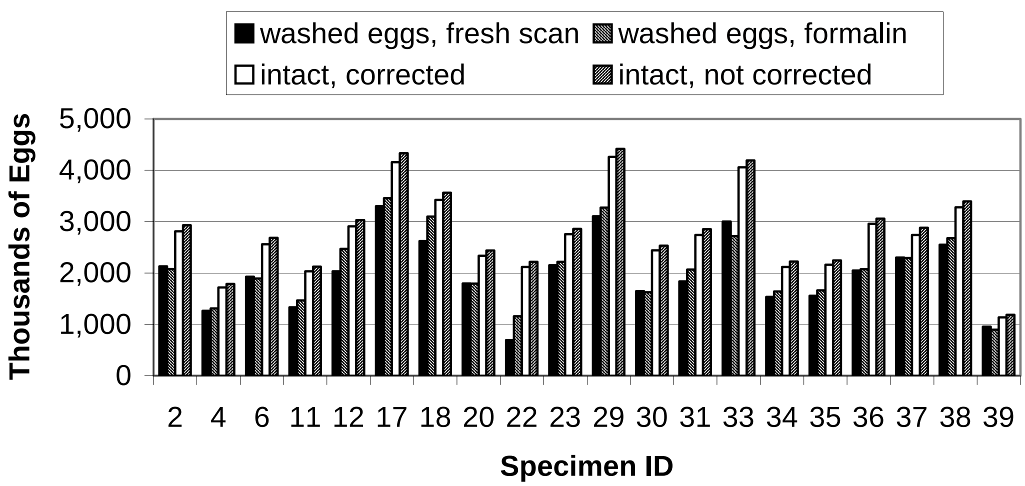


Figure 4. Comparison of methods for estimating fecundity using samples from spring 2000. Methods included fresh washed eggs, formalin-preserved washed eggs, intact ovarian sample preserved in formalin corrected for weight of ovarian capsule (“intact, corrected”), and not corrected for weight of ovarian capsule (“intact, not corrected”).

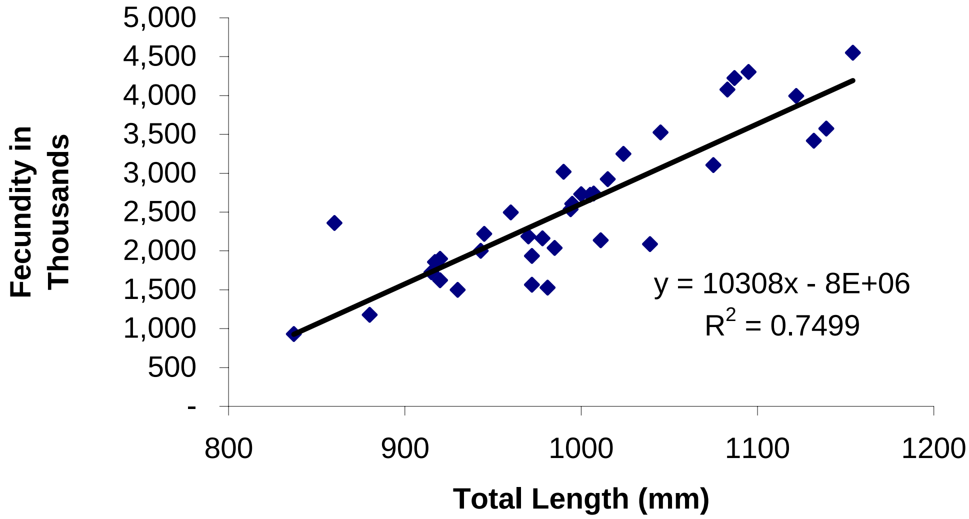


Figure 5. Fecundity (thousands of eggs) as a function of total length (mm) for striped bass sampled during spring 2000. Estimates are based on washed eggs corrected for water uptake.

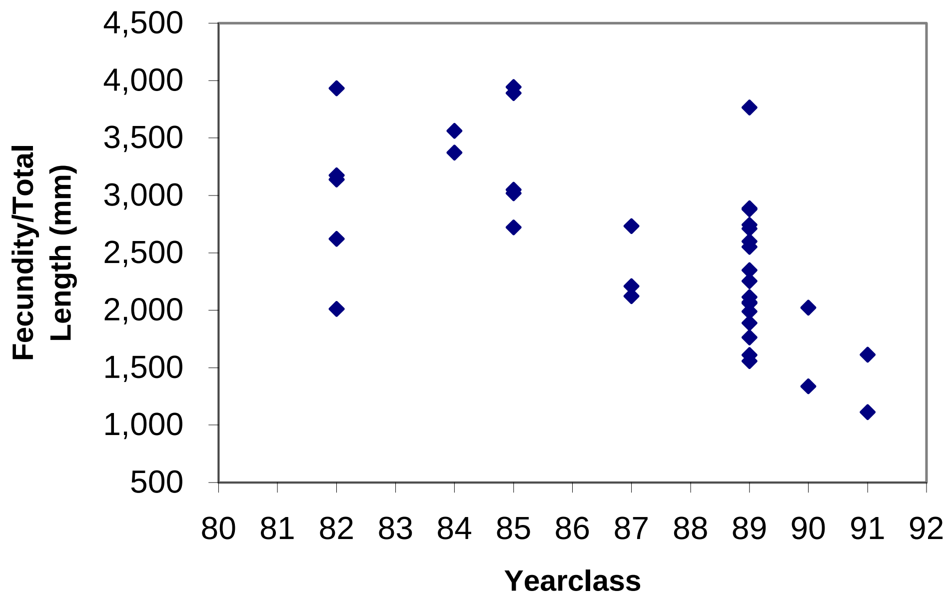


Figure 6. Length-specific fecundity (fecundity divided by total length) by yearclass, 2000 samples.

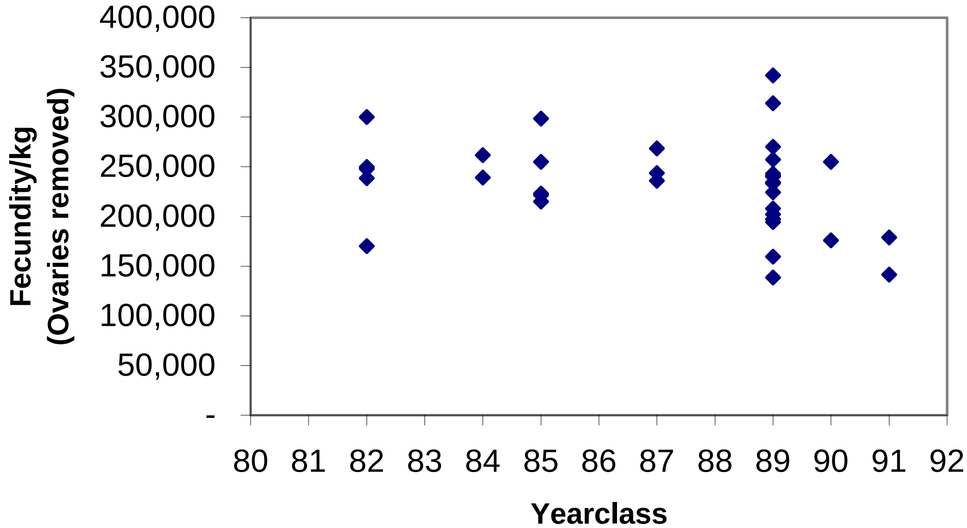


Figure 7. Weight-specific fecundity (fecundity divided by fish weight) by yearclass, 2000 samples.

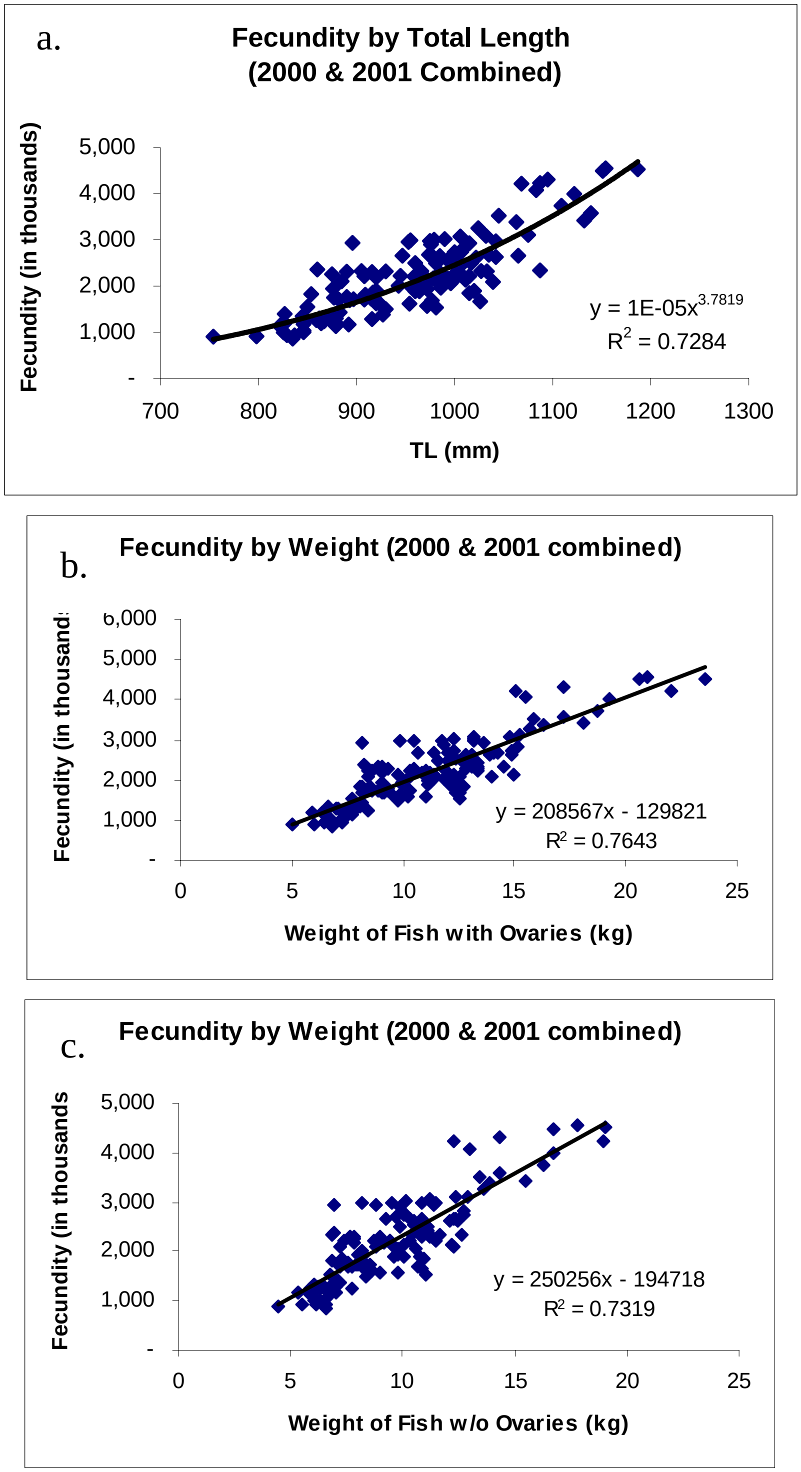


Figure 8. Fecundity estimates for striped bass collected during the 2000 and 2001 spawning seasons (2000 n=39; 2001 n=103). Fecundity is expressed as a function of (a) length, (b) whole weight of fish, and (c) weight of fish with ovaries removed.

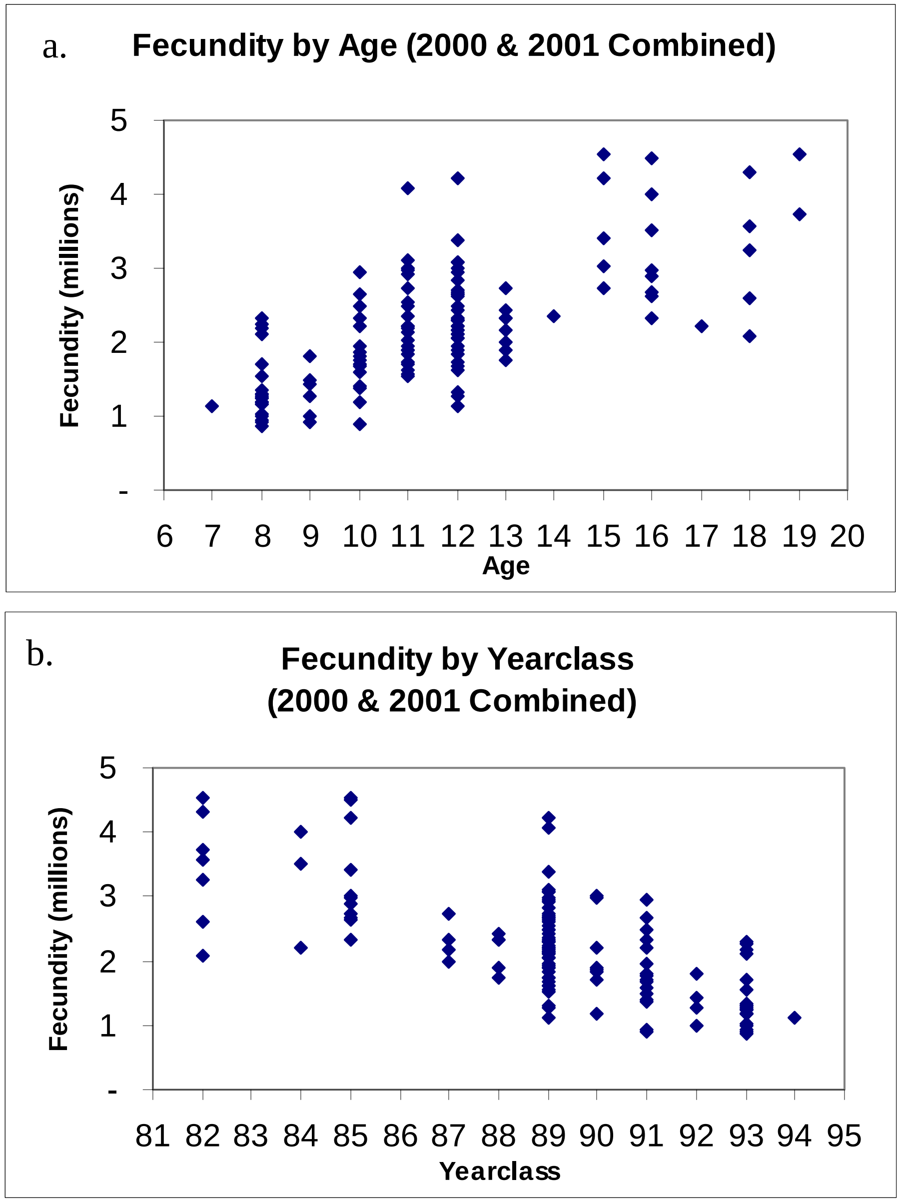
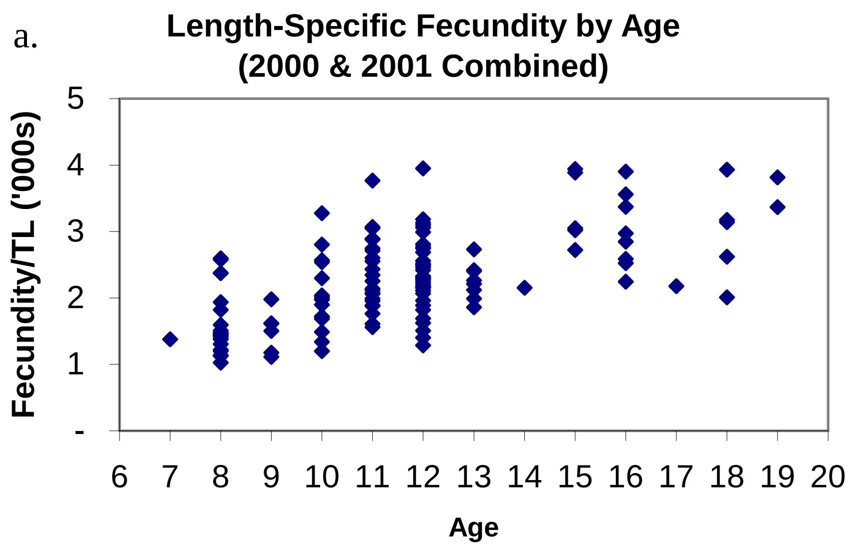


Figure 9. Fecundity estimates for striped bass collected during the 2000 and 2001 spawning seasons (2000 n=39; 2001 n=103). Fecundity is expressed as a function of (a) age and (b) yearclass.

a.



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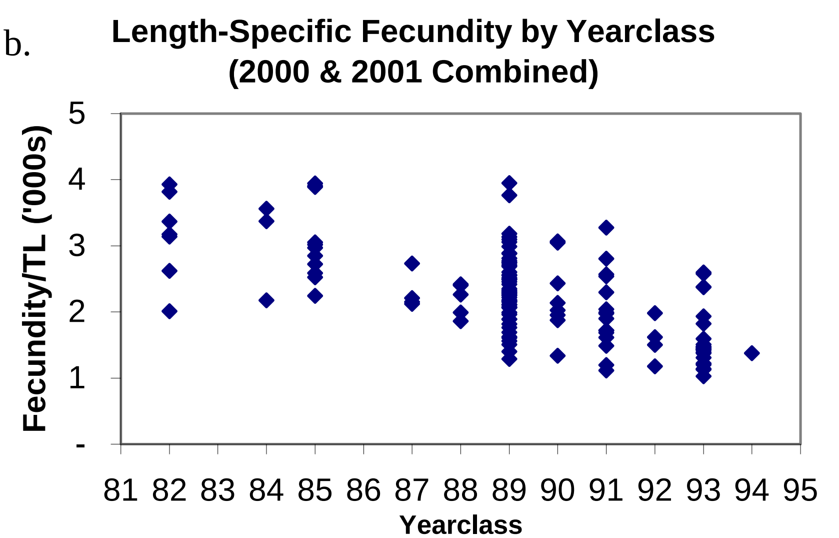

Figure 10. Length-specific fecundity (fecundity / total length (mm)) for striped bass collected during 2000 and 2001 spawning seasons. Length-specific fecundity is expressed as (a) function of age, (b) function of yearclass.

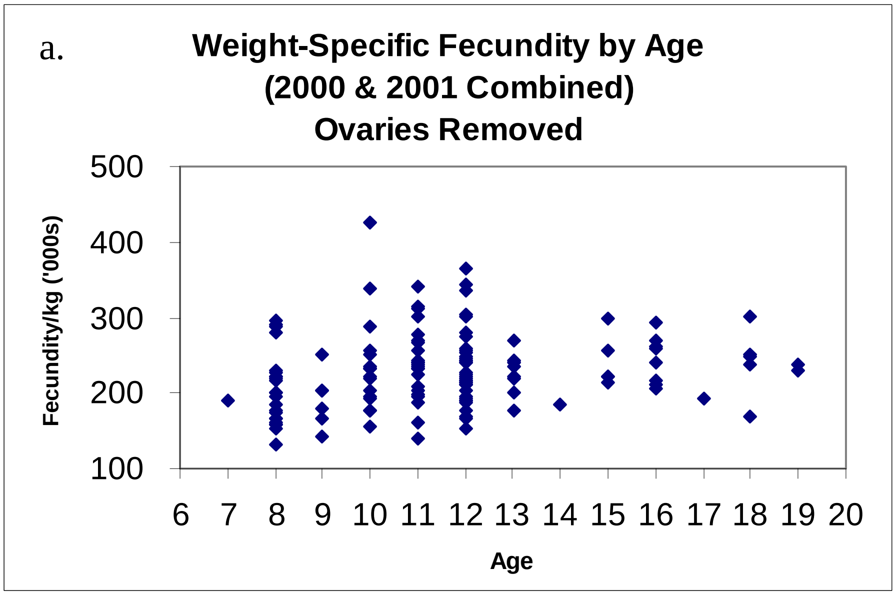

Figure 11. Weight-specific fecundity (fecundity / weight (kg) with ovaries removed) for striped bass collected during 2000 and 2001 spawning seasons.

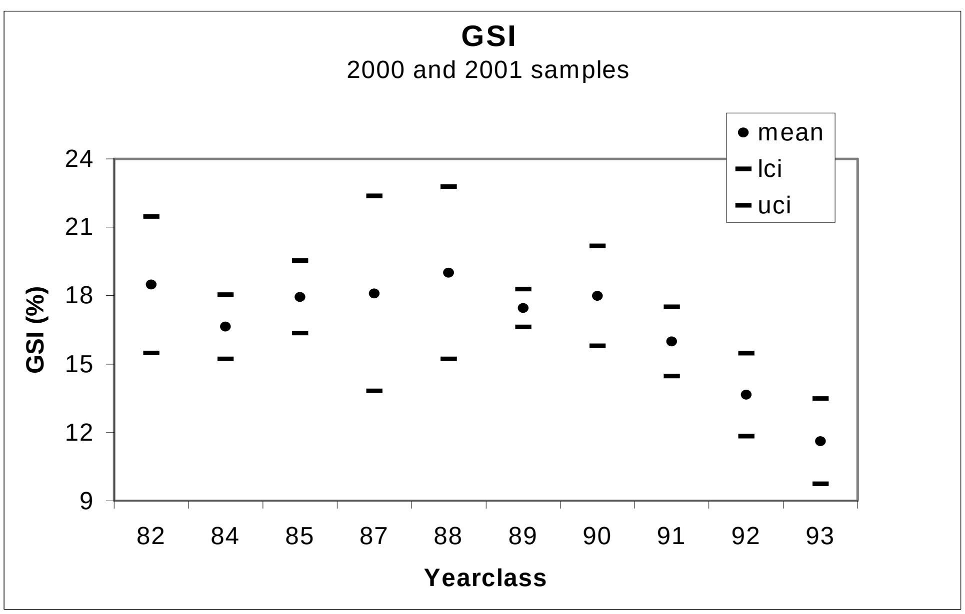

Figure 12. Mean GSI (%) and 95% confidence intervals for striped bass collected during 2000-2001 spawning seasons.

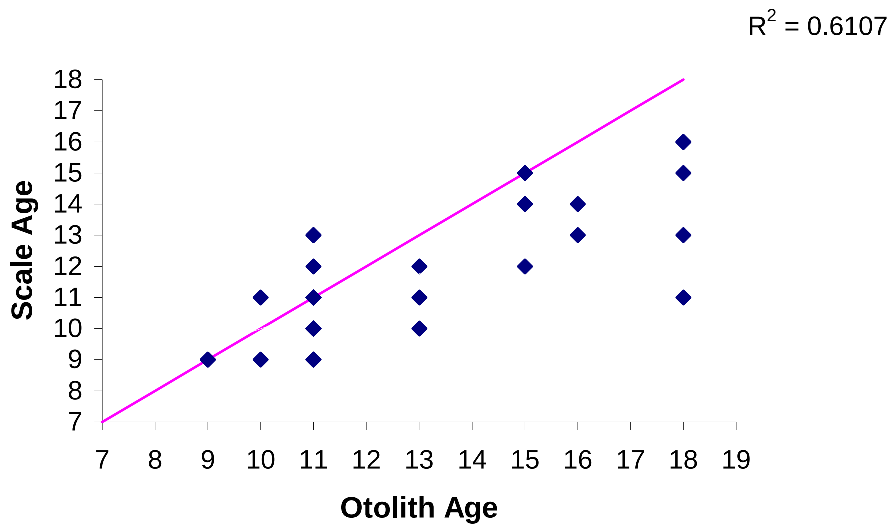

Figure 13. Scale age versus otolith age for female striped bass sampled during spring 2000. Line represents a 1:1 relationship.

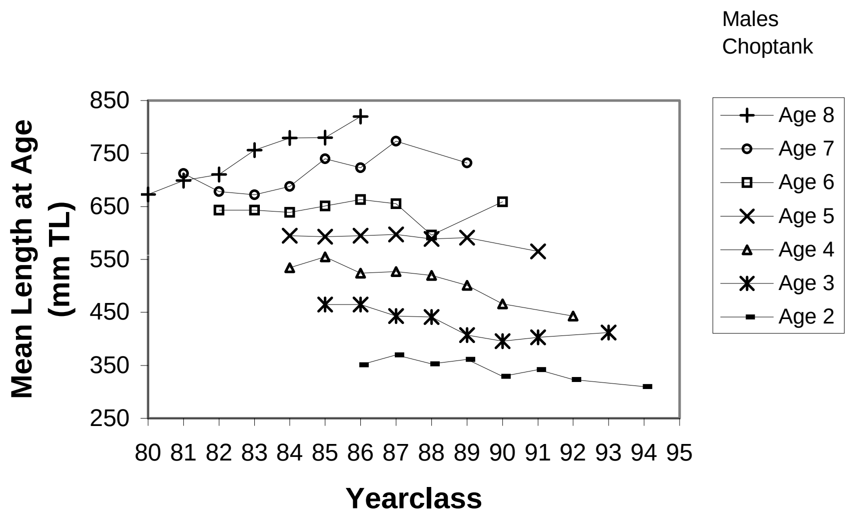

Figure 14. Mean length at age by yearclass for males in the Choptank River from gillnet sampling by MD DNR during the spawning season, 1980-1994.

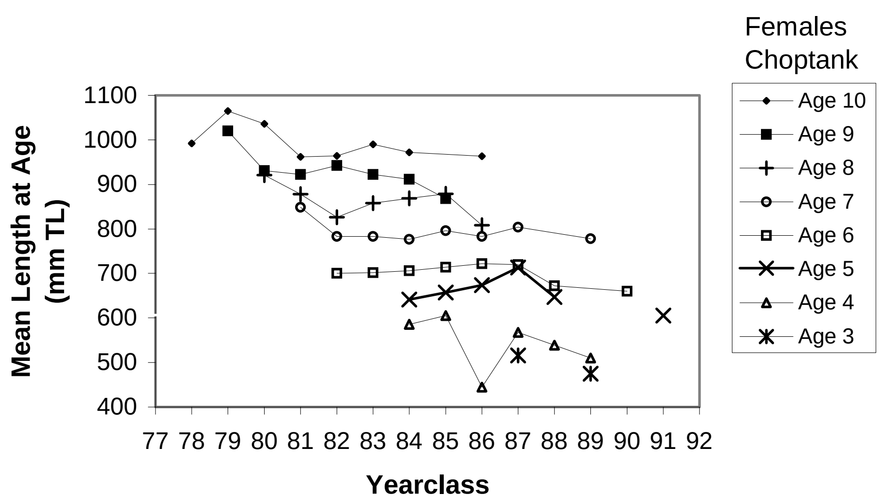

Figure 15. Mean length at age by yearclass for females in the Choptank River from gillnet sampling by MD DNR during the spawning season, 1978-1991.

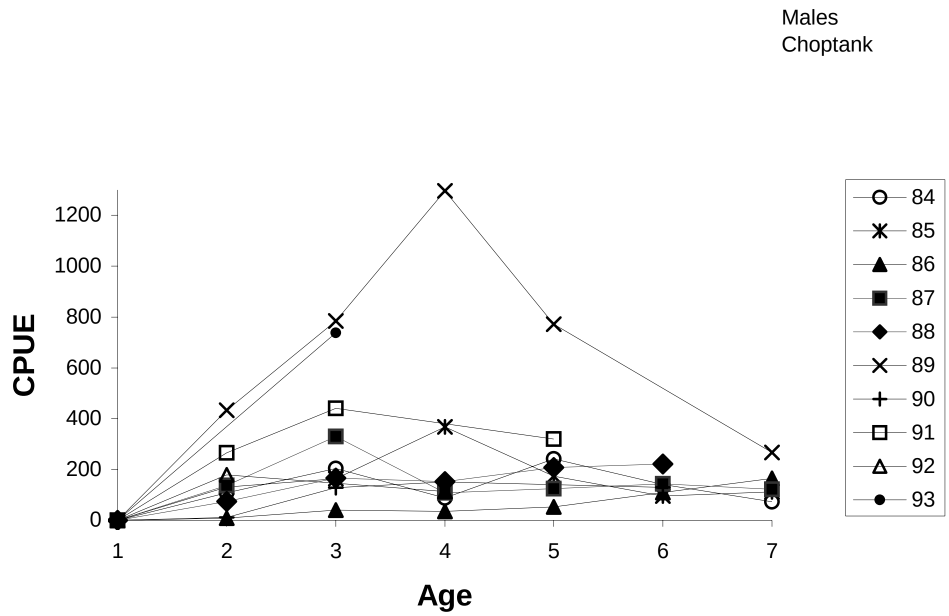

Figure 16. Catch per unit effort (CPUE) up to age at full maturity for males in the Choptank River by yearclass. Data collected from MD DNR gillnet surveys from 1985-1996.

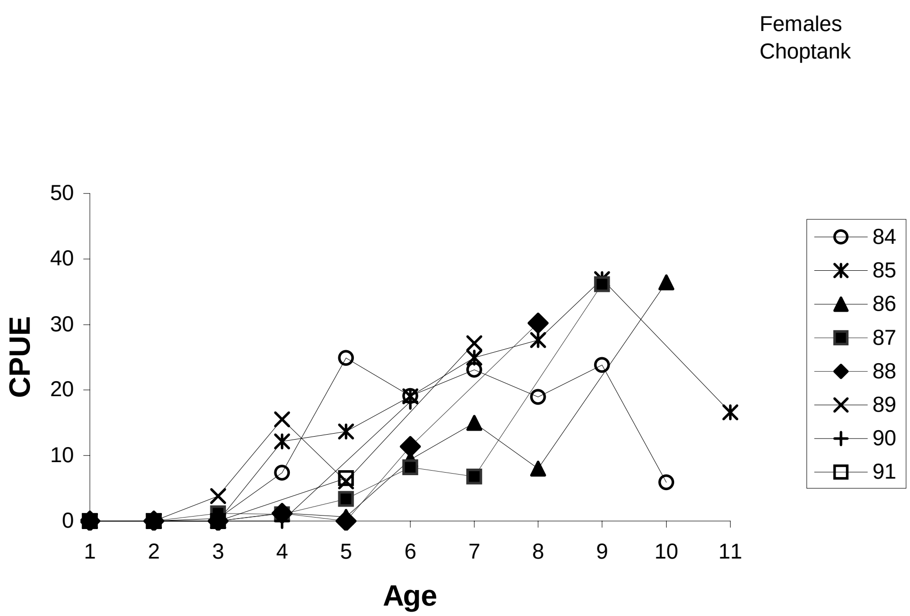

Figure 17. Catch per unit effort (CPUE) up to age at full maturity for females in the Choptank River by yearclass. Data collected from MD DNR gillnet surveys from 1985-1996.