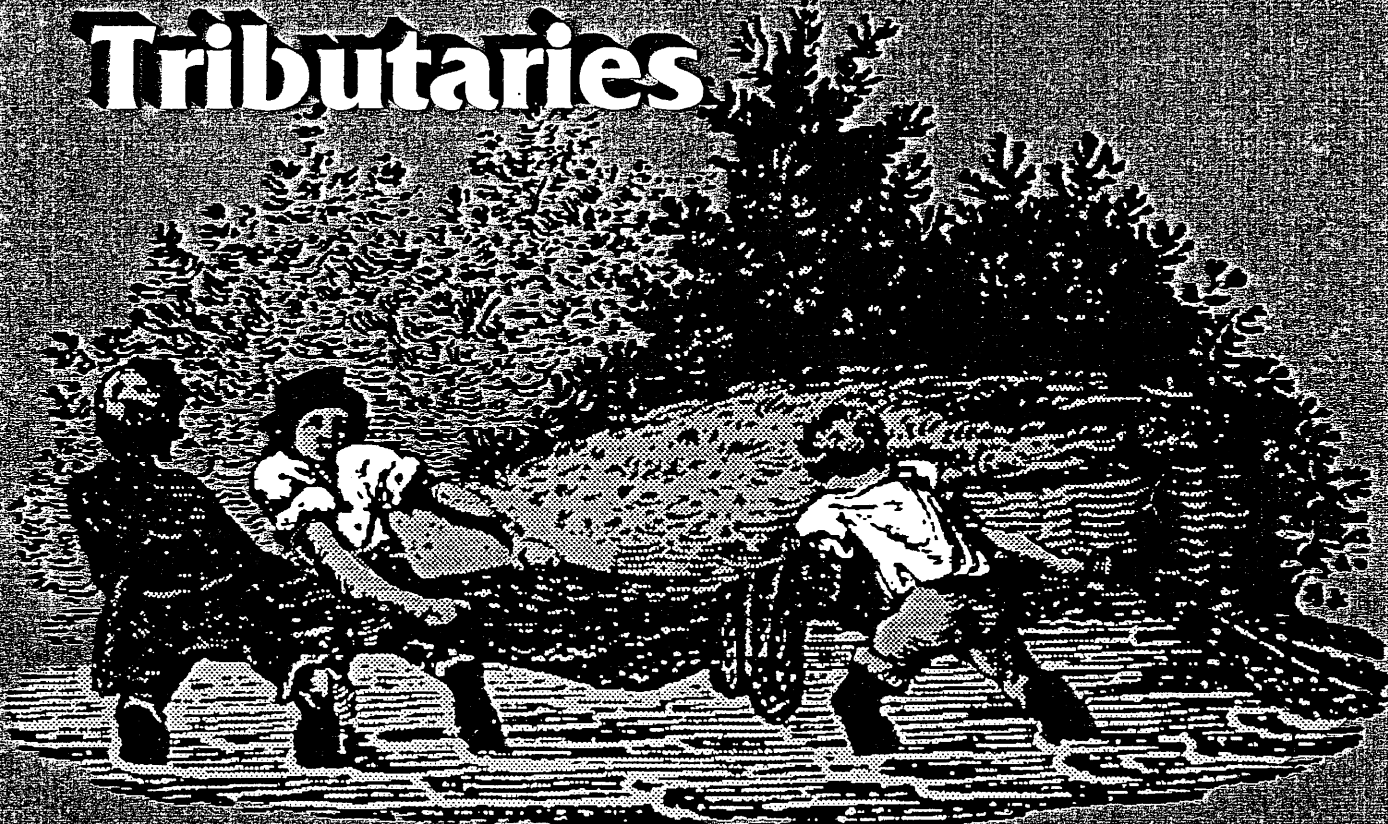
Fish Sampling in Eight Chesapeake Bay Tributaries



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CHESAPEAKE BAY RESEARCH AND MONITORING DIVISION

CBRM-HI-92-2

FISH ASSEMBLAGES AND DISSOLVED OXYGEN TRENDS

IN EIGHT CHESAPEAKE BAY TRIBUTARIES

DURING THE SUMMERS OF 1989 - 1991

A DATA REPORT

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TABLE OF CONTENTS

METHODS

Study Areas

Five Maryland tributaries on the western shore of the Chesapeake Bay were sampled during 1989. These tributaries included the South River, Severn River, Magothy River, Mattawoman Creek, and Wicomico River. Rock Creek and Curtis Creek, tributaries of the Patapsco River in the Baltimore area, and Fishing Bay on the eastern shore near Tangier Sound were added in 1990 (Figure 1). All eight tributaries were sampled again in 1991. These rivers were selected as representative of typical fish habitat, ecological conditions, and anthropogenic influences in many of the smaller tributaries of the Chesapeake Bay.

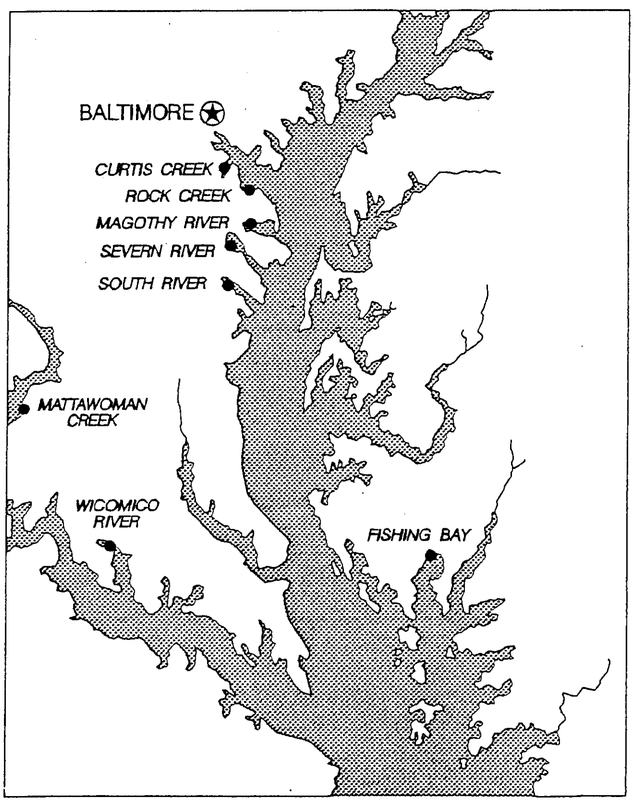


Figure 1. Location of Chesapeake Bay tributaries sampled for bioindex survey.

Fishing Bay, in Dorchester County (Figure 2), has the highest salinity of the study sites. The Fishing Bay watershed, composed mostly of forest and wetlands, is the least urbanized of the study areas. A portion of the Fishing Bay watershed is protected by the Blackwater Wildlife Refuge.

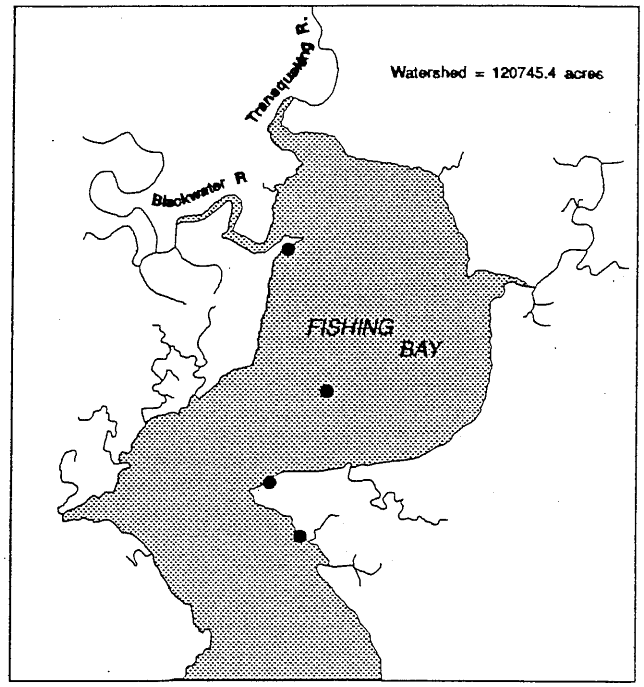


Figure 2. Location of Fishing Bay sampling stations, 1990 - 1991.

Mattawoman Creek is a tributary of the Potomac River located in Prince George's and Charles counties (Figure 3). It had the lowest salinity and little urban development. More than half the watershed is forested, with tree cover dominating the shoreline. A military testing installation (Indian Head Naval Surface Weapons Center) is found along both shores near the mouth of the creek.

The Wicomico River, another Potomac River tributary, is located between Charles and St. Mary's counties (Figure 4) and encompasses a broad range of salinity. This watershed contains the largest proportion of agricultural land of the studied tributaries and there is little urban development. The shoreline is mostly farm land and forest.

developed of the three, followed by the Severn River (Figure 7) and the South River watersheds (Figure 8). There are many houses and marinas along the shoreline of all three rivers.

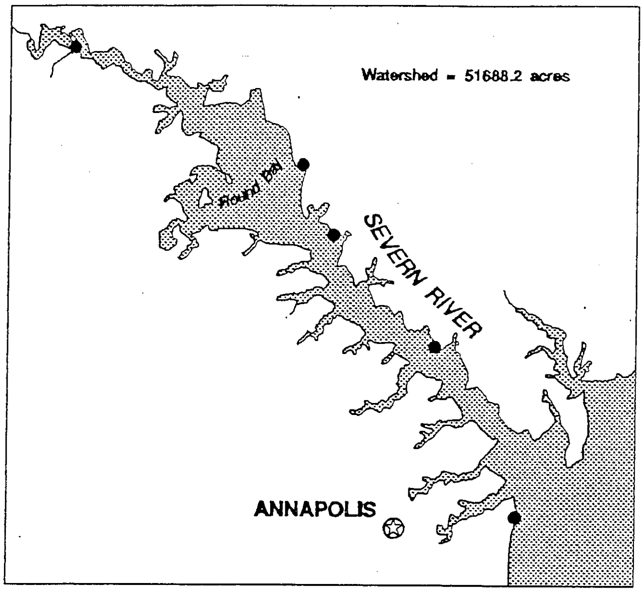


Figure 7. Sampling stations in Severn River, 1989 - 1991.

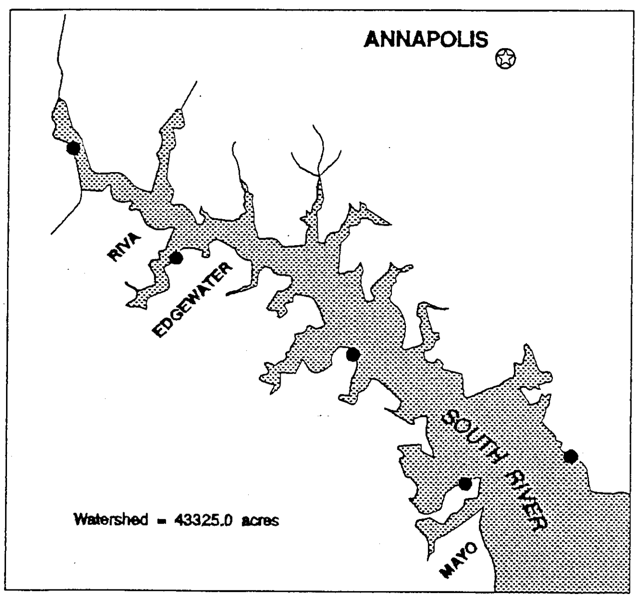


Figure 8. South River sampling stations, 1989 - 1991.

Fish Sampling

Under the original program design implemented in 1989, Mattawoman Creek was selected to represent a freshwater reference site (< 2 ppt salinity) and the Wicomico River was selected to represent a saltwater reference site (> 2 ppt). These selections were based on a pilot study and evaluation of land use in the watersheds of the proposed sample tributaries in 1988 (Uphoff 1988). The reference site selections were reinforced by analysis of water quality, number of fish species captured, and representation of what we considered the most "typical" fish community for Chesapeake Bay tributaries. The other sampled rivers, except Fishing Bay, are considered to be the urban stressed tributaries.

Tributaries were sampled once monthly in July, August and September during all three years. Sampling stations were located in tidal reaches. The study goal was to sample five stations in each tributary. Only four stations could be found in Fishing Bay, and only two stations in Curtis and Rock Creeks due to debris, unsuitable bottom substrate, excessive beach slope, bulkheading or steep banks. The stations are approximately one river mile apart starting from the mouth of the tributary and moving upstream. Summer months were selected to sample the seasonally-present populations of juvenile anadromous fish that may be important indicators of ecological health in estuarine systems and to sample fish assemblages during the season when they are most diverse. Sampling began during the first week of each month. An effort was made to sample tributaries in the following order each round: Severn, South, Magothy, and Wicomico Rivers, Mattawoman Creek, Fishing Bay, and Curtis and Rock Creeks.

The fish community was sampled by seining and trawling. Two seine hauls were made at each station, with a 30 minute interval between hauls to allow for repopulation. Seining gear consisted of a bagless 6.4mm mesh seine, 30.5m in length and 1.2m deep, with 1.5 meter poles attached to each end. One end of the seine was held on shore, while the other was pulled out perpendicular to shore until the seine was fully extended, and then pulled with the tide in an arc to the beach.

If depth allowed, three types of trawl tows were made at each station. Bottom tows were always kept in buckets and returned to the water once the second haul was completed. Every effort was made to return fish to the water unharmed. Specimens that could not be keyed in the field were preserved in 10% formalin for later identification in the laboratory.

Water Quality

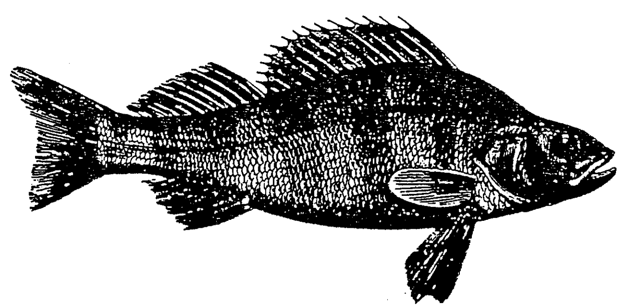
Water quality measurements and Secchi disc readings were taken at each station. A Hydrolab Surveyor II was used to measure water temperature, pH, dissolved oxygen (DO), conductivity, and salinity. Measurements were taken in the channel near the trawl station at the bottom, midwater, and surface. Water quality measurements were not taken at the seine stations. To ensure accuracy, the Hydrolab was calibrated each day before use.

Habitat Observations

Basic habitat observations such as maximum depth, bottom types, and presence of aquatic plants were recorded on the seine data sheets. A more detailed approach to habitat assessment began in September 1991, when a data sheet was developed to record habitat observations at each station. The intent was to get an overview of the riparian and upland areas of the sampled tributaries within each station, including information on bulkheading, bank slope, vegetation, in-stream structure, and nearby land use. Gathering such data for the large areas covered by the sample stations proved to be a time-consuming task not practical to our applications. Alternative data sheets were developed to record habitat conditions in the area immediately surrounding the seine stations, and were tested during sampling in 1992. Results of this experiment are forthcoming. Detailed information on watershed land use as of 1990 was obtained from the Map and Image Processing System (MIPS) computer database, by Mary Beamis, Maryland DNR, Tidewater Administration. These data were used to classify land usage in the watershed of each study tributary.

Catch Per Unit Effort

Catch per unit effort, or CPUE, was calculated for each method by dividing catch by effort. One unit of effort equaled one seine haul or one trawl tow.



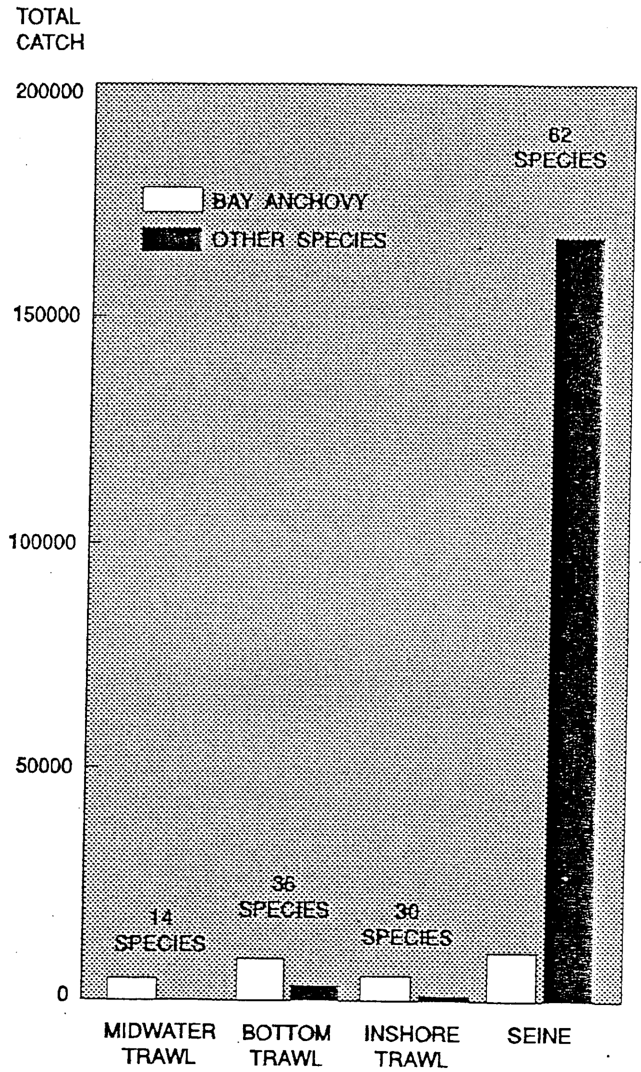


Figure 10. Total catch of bay anchovy versus catch of all other species for each sampling method.

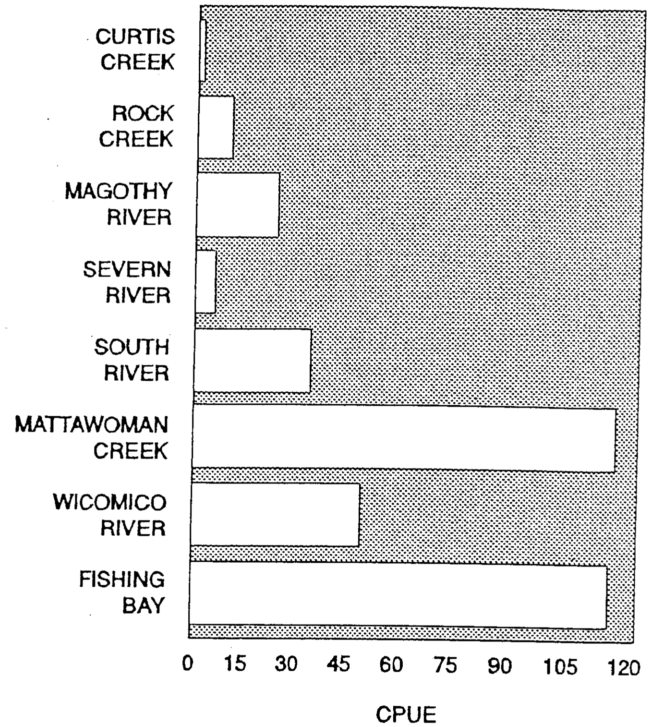


Figure 11. Overall mean bottom trawl CPUE for all years by tributary.

There was little variation among tributaries in the seine and trawl CPUE, except in Fishing Bay where trawling was much more effective. Trawling captured 65% of the Fishing Bay catch, but only 9% of the overall catch in the other tributaries. Catch per unit effort at Fishing Bay was 103 for trawling and 71 for seining, whereas the overall CPUE at all other stations during all three years was 37 for trawling and 364 for seining (Figure 12).

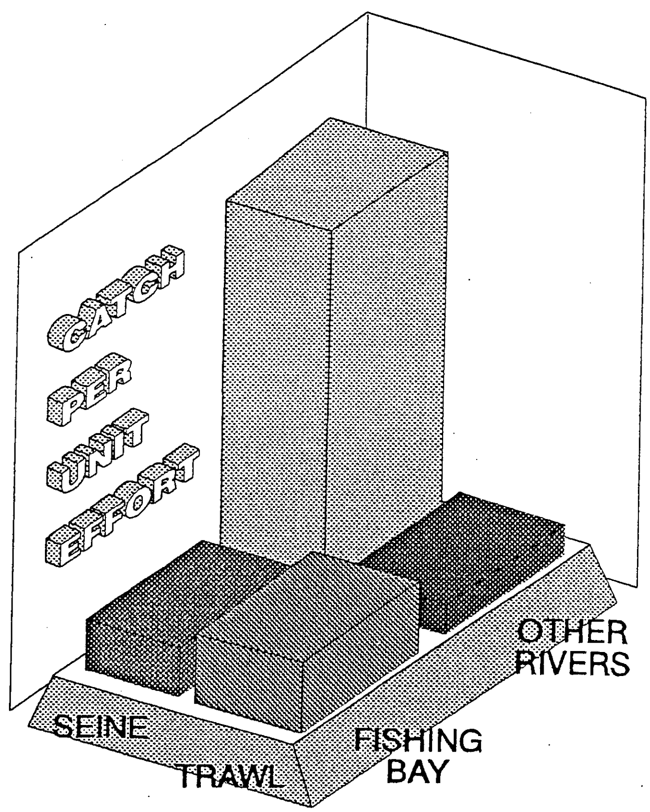


Figure 12. Comparison of overall mean seine and trawl CPUE between Fishing Bay and all other tributaries for all three years.

Comparisons to the Saltwater Reference Tributary

Histograms were developed to compare the fish

SPECIES	REFERENCE#	SPECIES	REFERENCE#
Atlantic silverside	1	American eel	33
Bay anchovy	2	Chain pickerel	34
Atlantic menhaden	3	Alewife	35
Striped killifish	4	Black crappie	36
Mummichog	5	Silvery minnow	37
Spot	6	Spottail shiner	38
Pumpkinseed	7	Weakfish	39
White perch	8	Golden shiner	40
Inland silverside	9	Goldfish	41
Atlantic needlefish	10	Green goby	42
Gizzard shad	11	Ladyfish	43
Striped bass	12	Largemouth bass	44
Hogchoker	13	Rainwater killifish	45
Atlantic croaker	14	Red drum	46
White catfish	15	Striped blenny	47
Striped anchovy	16	Winter flounder	48
Banded killifish	17	Channel catfish	49
Skilletfish	18	Fourspine stickleback	50
Bluegill	19	Inshore lizardfish	51
Northern pipefish	20	Atl. thread herring	52
Brown bullhead	21	American shad	53
Blueback herring	22	Oyster toadfish	54
Bluefish	23	Northern puffer	55
Sheepshead minnow	24	Offshore tonguefish	56
Carp	25	Redfin pickerel	57
Tessellated darter	26	Threespine stickleback	58
Harvestfish	27	Atlantic Spadefish	59
Yellow perch	28	Feather blenny	60
Rough silverside	29	Quillback	61
Spanish mackerel	30	Satinfin shiner	62
Summer flounder	31	Seaweed blenny	63
Naked goby	32	White sucker	64

Table 2. Reference numbers assigned to each species captured during the survey. These were used to create graphs to compare each tributary to the saltwater reference tributary, the Wicomico River.

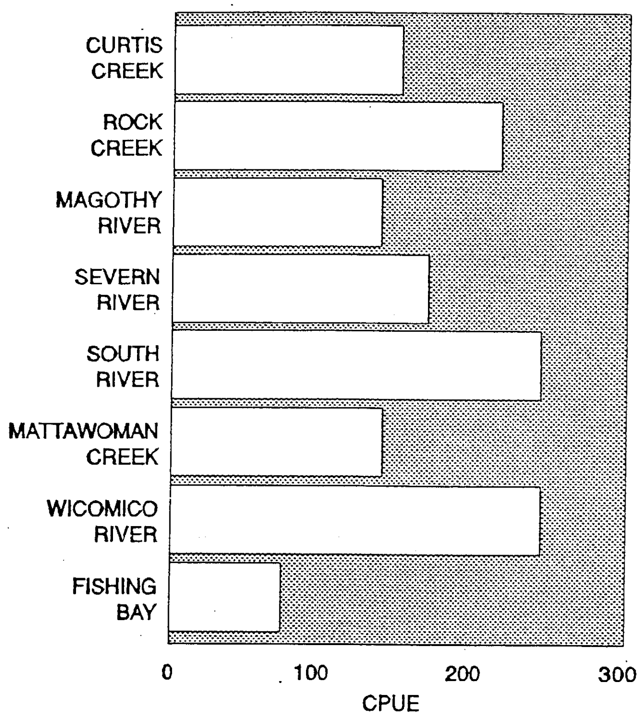


Figure 21. Three year overall mean CPUE of species classified as planktivores.

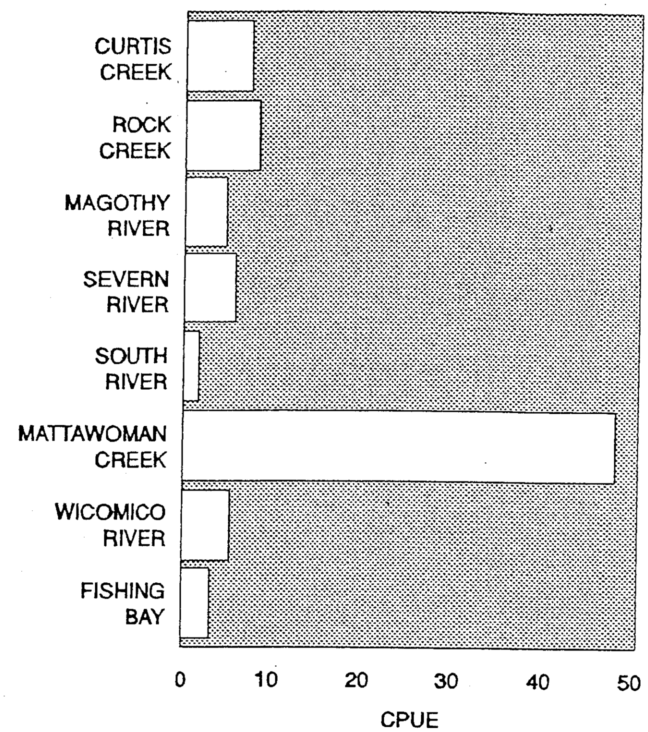


Figure 22. Three year overall mean CPUE of species classified as carnivores.

the other six tributaries. Carnivorous fish were most abundant in Mattawoman Creek with a CPUE of 48 fish per tow or seine, accounting for 26% of the total catch, but scarce in the other seven tributaries, representing only 2% to 4% of the catch (Figure 22). Overall, carnivores were slightly more common than benthic feeders. The average CPUE for carnivores over all tributaries was ten fish per seine or tow and the average CPUE for benthic feeders over all tributaries was six fish per seine or tow. Benthic feeders accounted for 2% to 8% of the catch (Figure 23).

Life History Strategy

All species were classified as marine, estuarine, freshwater, or anadromous spawners (Carlander 1969, 1977; Eddy and Underhill 1978; Lippson and Lippson 1984; Robins and Ray 1986) (Appendix I). We assigned species to each life history category based on the behavior of a species within the Chesapeake Bay. For example, white perch is generally considered to be a semi-anadromous species, but was classified as an anadromous fish for this analysis because it behaves as such within our study area.

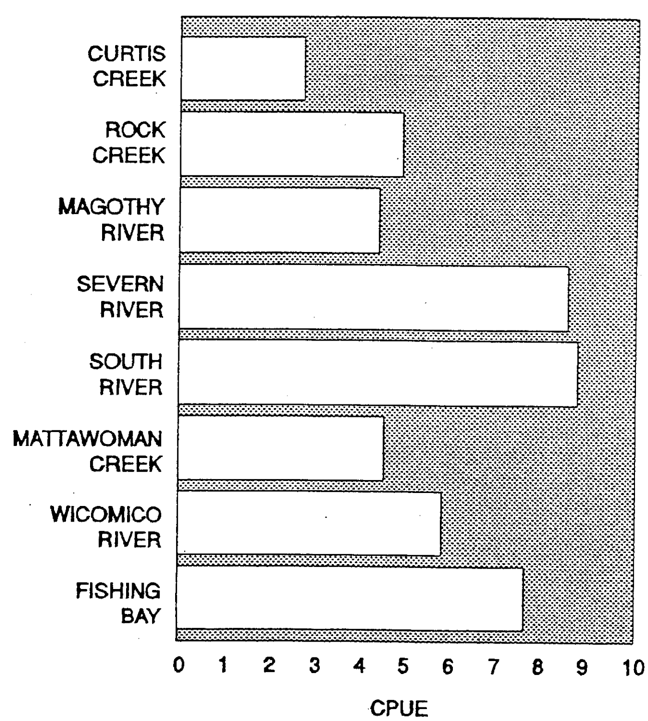


Figure 23. Three year overall mean CPUE of species classified as benthic feeders.

tributaries, this Eastern Shore site had a low overall mean CPUE of marine spawners, primarily due to a low catch of Atlantic menhaden. The differences among tributaries in catches of marine spawners was reduced when the Atlantic menhaden catch was removed (Figure 26). Marine spawners, especially Atlantic menhaden, were least common in Curtis Creek and Mattawoman Creek.

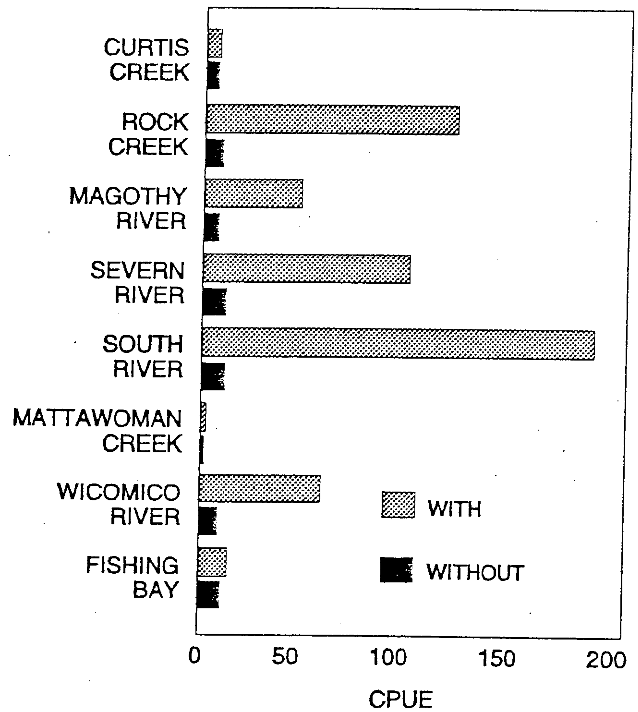


Figure 26. Three year overall mean CPUE of marine spawners with and without Atlantic menhaden catch.

Atlantic menhaden were an influential, though sporadic, component of the catch by this survey. While appearing in only 12.5% of the total seine hauls and trawl tows, they represented 36% of the total catch.

Anadromous and semi-anadromous species captured in the three year study were alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), blueback herring, striped bass (*Morone saxatilis*), and white perch. Mattawoman Creek, where all five species and 85% of the total anadromous catch was captured, ranked far above the other tributaries in this category (Figure 27). Fishing Bay was the only

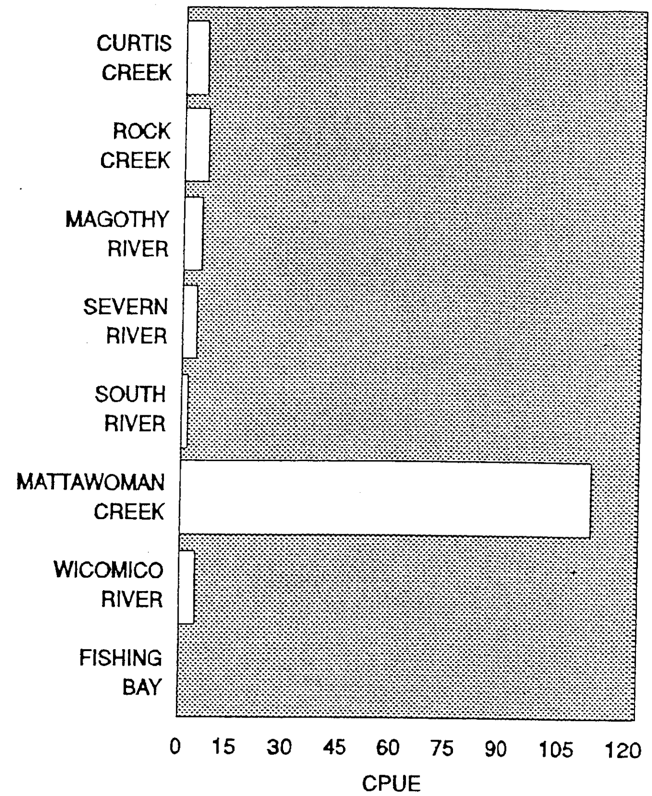


Figure 27. Three year overall mean CPUE of species classified as anadromous.

study area where no anadromous fish were captured. The striped bass catch was low in Mattawoman Creek; but in the other tributaries, striped bass was the most common anadromous species collected. Because sampling took place in summer, juveniles from spring spawning species were often captured (Figure 28). Eighty-six percent of the total anadromous fish catch by this survey was composed of juveniles.

The catch of anadromous species in Mattawoman Creek was dominated by blueback herring and white perch, which together represented 94% of the total anadromous species catch (Figure 29). Mattawoman Creek was the only sampled tributary where substantial numbers of blueback herring, white perch, or alewife were caught. American shad were only collected at Mattawoman Creek. The CPUE of anadromous juveniles in Mattawoman Creek was 40 times greater than in the other seven tributaries combined. Striped bass juveniles were common in upper western shore tributaries, which included the

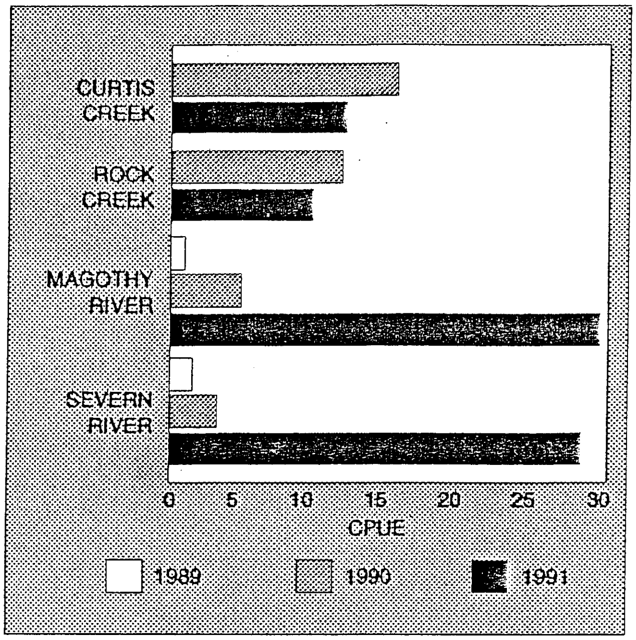


Figure 30. Mean CPUE of striped bass juveniles in upper bay tributaries. No data was collected for Rock Creek and Curtis Creek in 1989.

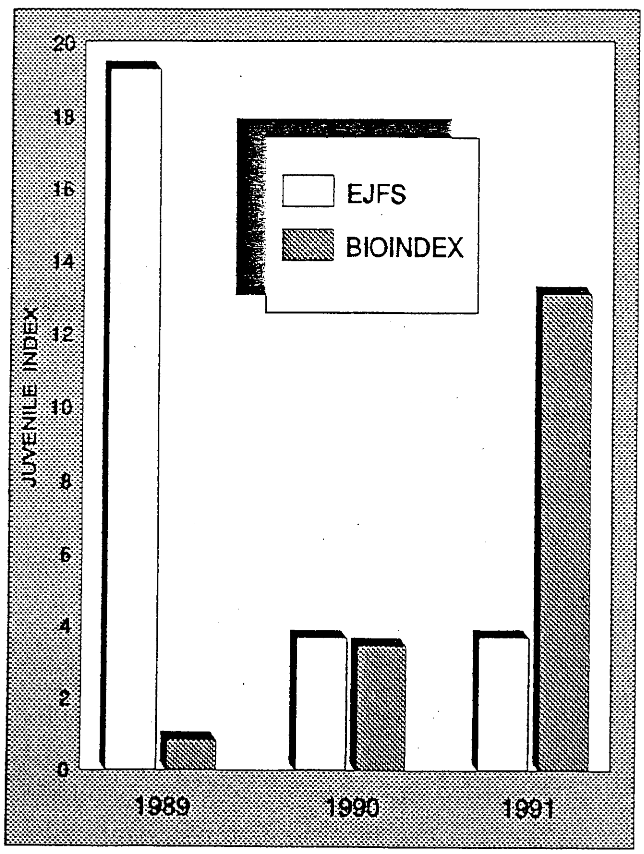


Figure 31. Comparison of striped bass juvenile index for the upper bay tributaries between the Maryland DNR Estuarine Juvenile Finfish Survey and this survey. Juvenile index = seine CPUE of juveniles.

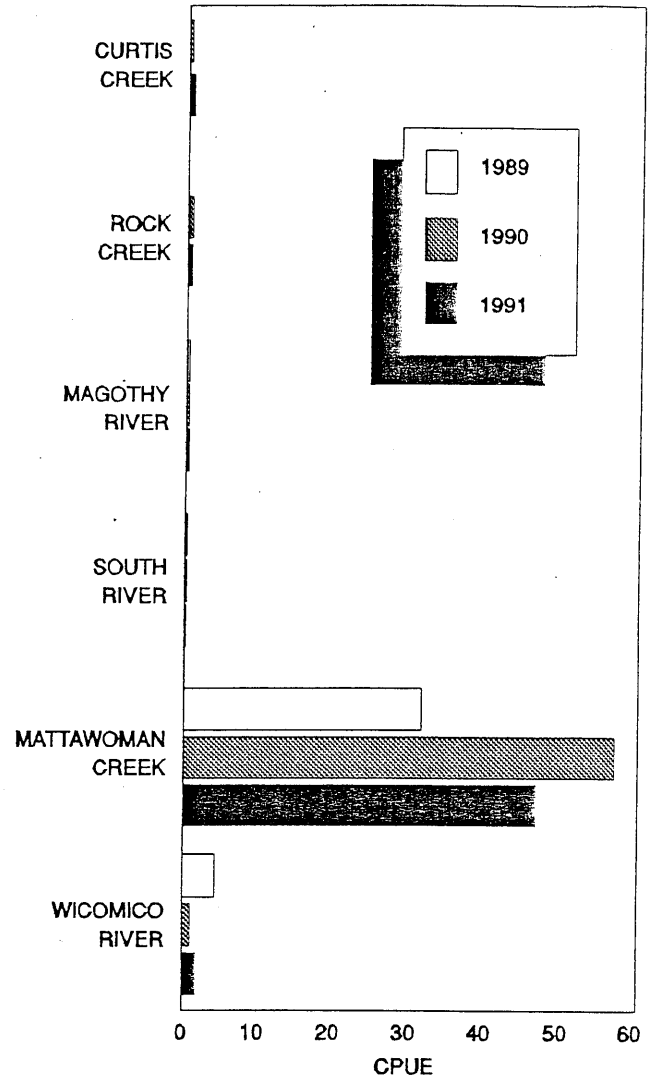


Figure 32. White perch CPUE by year and river. No white perch were captured in Fishing Bay and the Severn River. No data was collected for Rock Creek and Curtis Creek in 1989.

Species Richness

Three measures were used to interpret species richness at our sampling stations. One measure was the total number of species captured at a station. To compare tributaries, we calculated the mean number of species captured each year (Figure 33). The mean number of species captured per year was greatest in Mattawoman Creek, where means for each year ranged from 11.7 to 15.1. The Wicomico River had a slightly lower mean number of species, with values ranging from 11.2 to 13.3. The mean number of species captured each year in the other six tributaries ranged from 7.0 to 10.3. The Severn River, South this category, with the means for each year ranging from 7.9 to 12.4. The yearly means in the Wicomico River ranged from 4.9 to 8.3. The other six tributaries had yearly means ranging from 4.3 to 8.3. The Magothy River, Severn River, South River, Mattawoman Creek and Rock Creek showed increases in this measure over the sample period.

The quality of deep water habitat should be reflected in the number of fish species captured by the bottom trawl. The total number of species captured in bottom trawl tows was compiled for each year (Figure 35). Mattawoman Creek had the highest species numbers, with 14 to 19 species captured per year in bottom trawls from 1989 to 1991. Fishing Bay and the Wicomico River both had 8 to 13 species captured in bottom tows per year. The Magothy River declined from 11 species in 1989 to 2 species in 1990 and only 3 species in 1991. Rock Creek and Curtis Creek had the lowest species numbers in bottom trawl catches. Curtis Creek had 1 species in 1990 and 1991 and Rock Creek had 2 species in 1990 and 1 species in 1991. Between 1989 and 1991, the number of species captured in bottom trawl tows increased from 2 to 6 in the South River but decreased from 4 to 2 in the Severn River.

Resident versus non-resident species

Another way we examined the fish communities in the sampled tributaries was by comparing the CPUE of resident species to non-resident species (Figure 36, Appendix I) (Lippson and Lippson 1984). The Wicomico River had the highest CPUE of resident species. In Rock Creek, Severn River, South River, and Mattawoman Creek, the catch of non-resident species was greater than the catch of resident species.

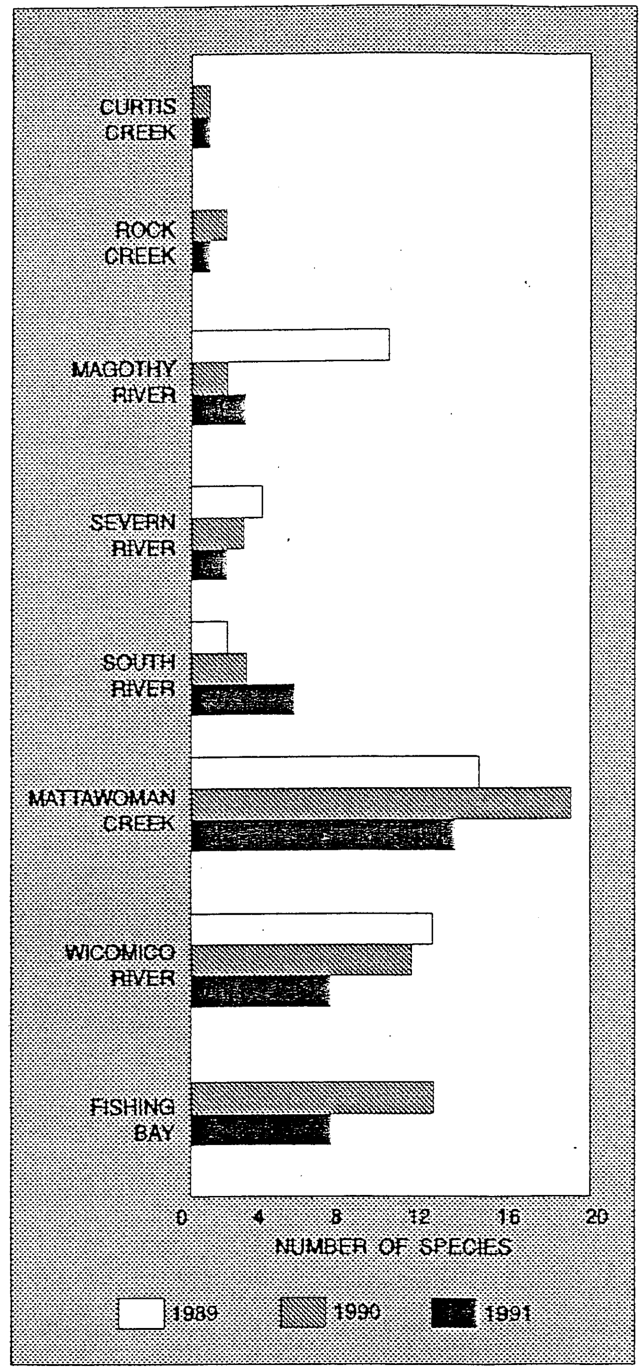


Figure 35. Mean number of species captured in bottom trawl tows by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989.

Target Species

The Chesapeake Bay Program identified local species that represent the various trophic levels and habitat types within the Bay (Funderburk et al. 1991). The CPUE effort for these species in our survey for each year was included in this report to serve as a reference for other Chesapeake Bay surveys. Atlantic menhaden was the most commonly captured target species, followed in decreasing abundance by bay anchovy, blueback herring, white perch, striped bass, spot, alewife, yellow perch and American shad. No hickory shad were captured in the sampled tributaries during the three year study period (Figure 37).

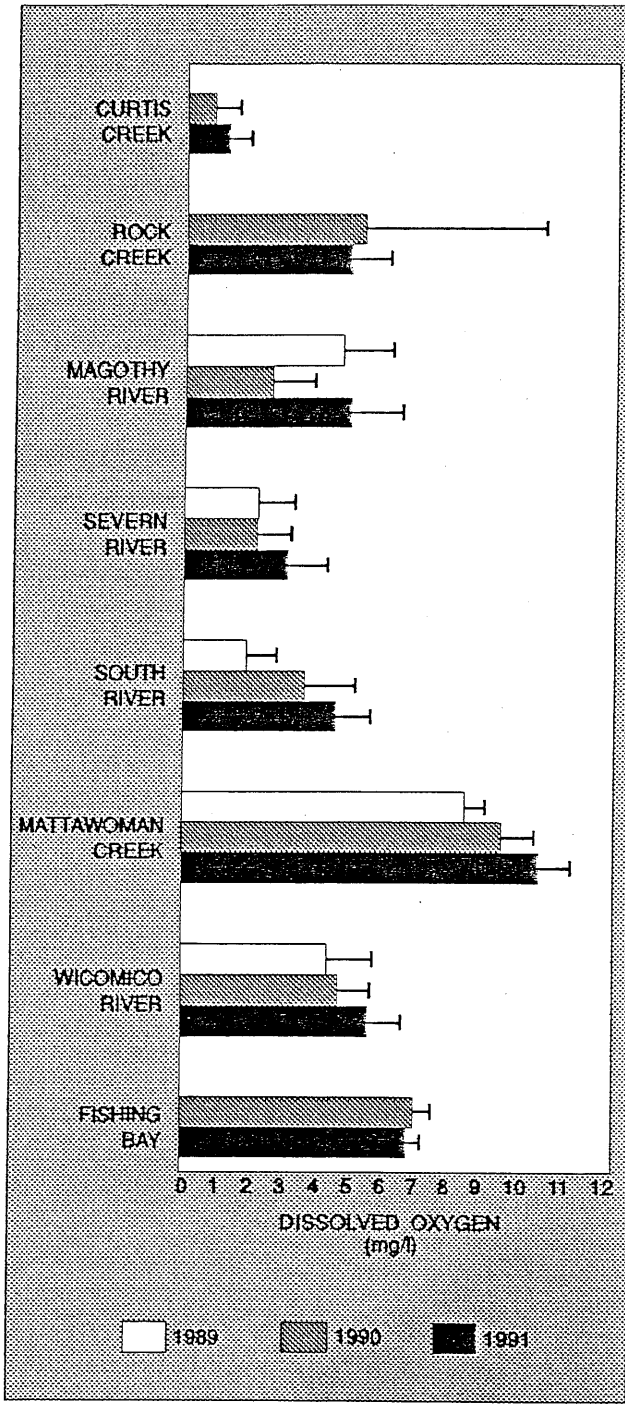


Figure 38. Mean bottom DO by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989. Bar extensions = 2 standard errors.

to the tributary itself (Figure 40). We categorized the Severn River, South River, Magothy River, and Rock Creek as urban-impacted. These rivers are characterized by urban development in their watersheds and

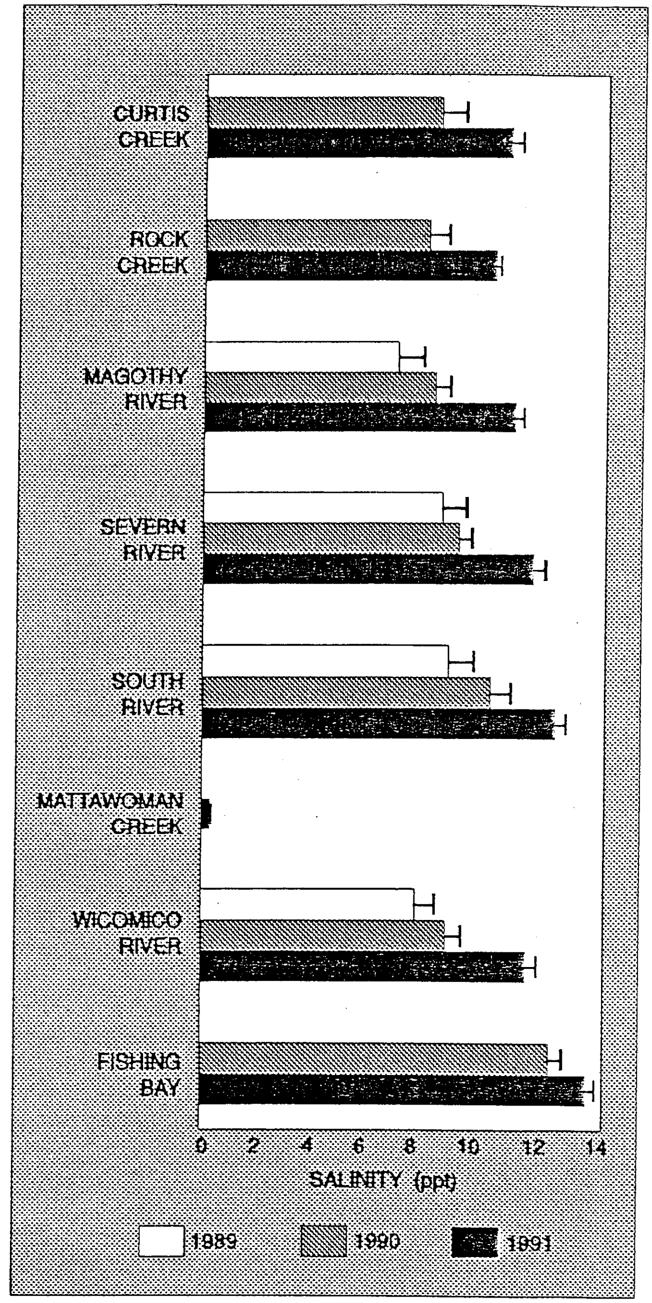


Figure 39. Overall mean salinity by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989. Bar extensions = 2 standard errors.

along their shorelines. The dominant land use in Rock Creek and the Magothy River is urban. Although total urban area is secondary to forested land in the Severn and South rivers, most of the development is along the shoreline in the tidal areas we sampled and therefore we feel it is more influential on the fish communities than the forested areas near the headwaters. Curtis Creek has industrial develop-

DISCUSSION

The fish communities of eight Chesapeake Bay tributaries were sampled with seines and trawls during the summers of 1989, 1990, and 1991. The data are being used to evaluate an index of biotic integrity, or bioindex, for tidal tributaries and subestuaries. The catches in all eight tributaries were dominated by Atlantic menhaden, Atlantic silverside, and bay anchovy. Planktivores were the dominant trophic group. The greatest catch of anadromous species occurred in Mattawoman Creek.

Previous studies have documented the effects of pollution and urbanization on individual species, fish assemblages, and aquatic habitat. Multi-species indices have been effective at indicating habitat conditions in small freshwater streams in the midwest (Karr et al. 1986, Karr 1987, Plafkin et al. 1989). It has also been shown that such indices are adaptable for use in other regions and habitats (Miller et al. 1988, Karr 1991, Hughes and Noss 1992). Fish communities in estuarine systems have been shown to respond to anthropogenic stress (Betchel and Copeland 1970, Vaas and Jordan 1991). Fish communities in estuarine systems should therefore be useful indicators of ecological stress, just as in freshwater streams. A bioindex based on estuarine fish assemblages appeared to respond to water quality conditions (Jordan et al. 1991).

Fish communities may respond to environmental stresses in many ways. Sensitive species may experience reduced survival and reproductive success, the proportion of trophic and habitat generalists may increase, the proportion of insensitive and tolerant species may increase, and there may be a resultant imbalance in species diversity (Betchel and Copeland 1970, Hughes and Noss 1992). Dissolved oxygen conditions in tidal and non-tidal waters also decline in response to urbanization (Limburg and Schmidt 1990).

The fish communities in the stressed tributaries we sampled appeared to reflect some of the changes expected of degraded habitat, such as an imbalance of species, changing trophic structure, decreased reproduction of sensitive species, and decreased species richness, suggesting that fish community assemblages hold promise as indicators of ecological health of subestuaries. By comparing various components of the fish assemblages in these tributaries to the predominant land use within their watersheds, we hope to establish a basis for quantifying the effects of anthropogenic influences upon the living resources of Chesapeake Bay tidal tributaries.

Changes in the trophic structure of a fish community may be another indicator of ecological stress. Mattawoman Creek appeared to have a more balanced trophic structure than the other tributaries, with planktivores being less dominant. However, some of the differences in Mattawoman Creek may be attributed to the lower salinity.

Because Atlantic menhaden are tolerant and trophic generalists (Peters and Lewis 1984, Jordan et al. 1991, Lippson 1991), a large catch of this species in a tributary could be an indication of stress. However, their low capture frequency and high catch percentage made it difficult to assess trends among the sampled tributaries, and their capture by this survey did not appear to accurately reflect any degree of habitat degradation. Atlantic menhaden can appear to be a dominant component of the fish assemblage in a tributary, while actually only being abundant but transient visitors. The dominance of Atlantic menhaden in this survey seems to reflect their schooling behavior. They represented the largest proportion of the effort.

Estuarine spawners possibly reflected habitat conditions within the sampled tributaries. When the catch of estuarine spawners was compared among tributaries, fewer species were found in the stressed tributaries. By comparison, the most species were found in the saltwater reference tributary, the Wicomico River.

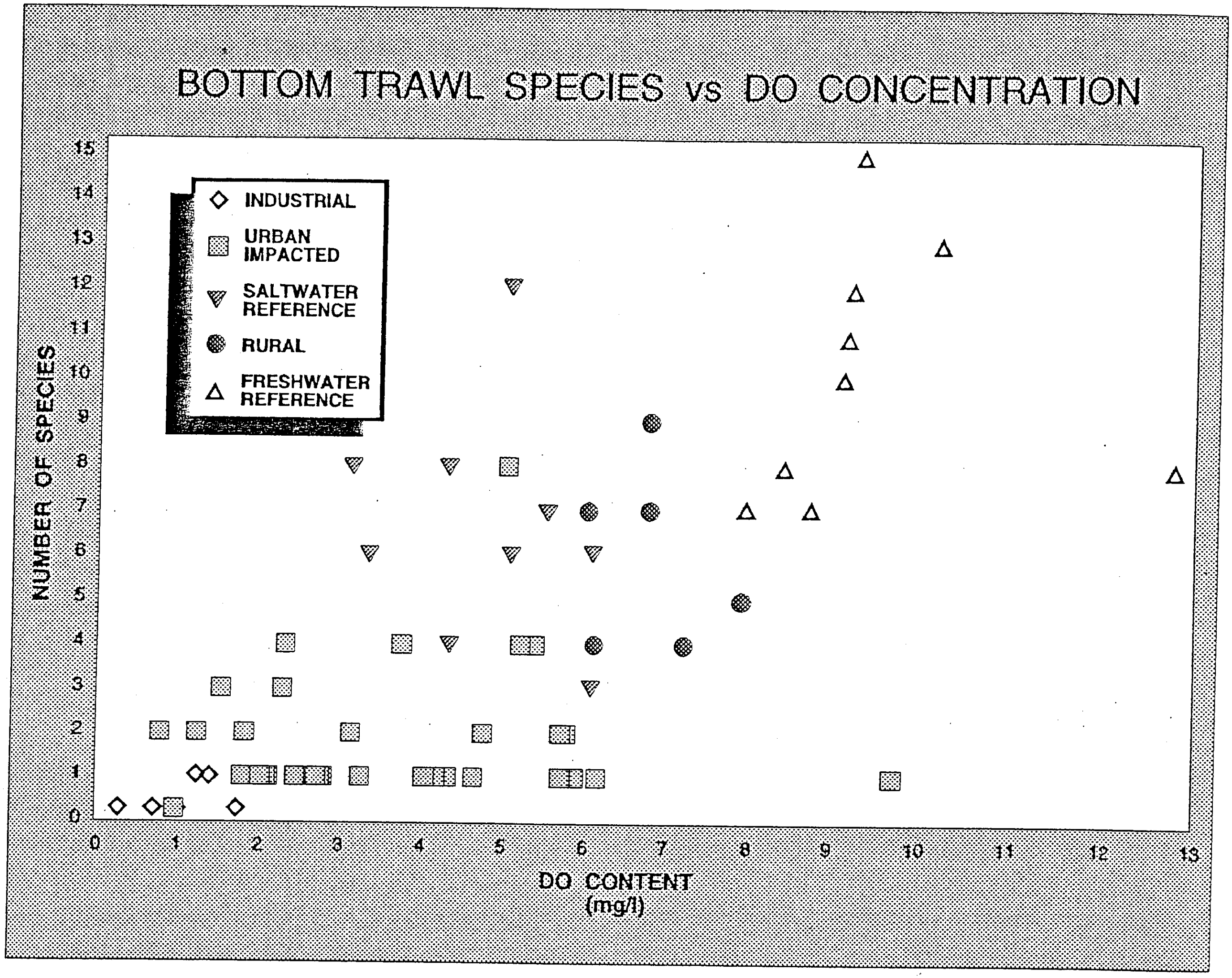


Figure 41. Number of species captured by bottom trawl tows in each sampling round plotted against mean bottom DO in each sampling round. Tributaries are grouped according to broad land use categorizations. Mattawoman Creek is a freshwater reference, Fishing Bay is classified as rural and the Wicomico River is a saltwater reference. The South River, Severn River, Magothy River and Rock Creek are grouped as urban-impacted. Curtis Creek is classified as industrial.

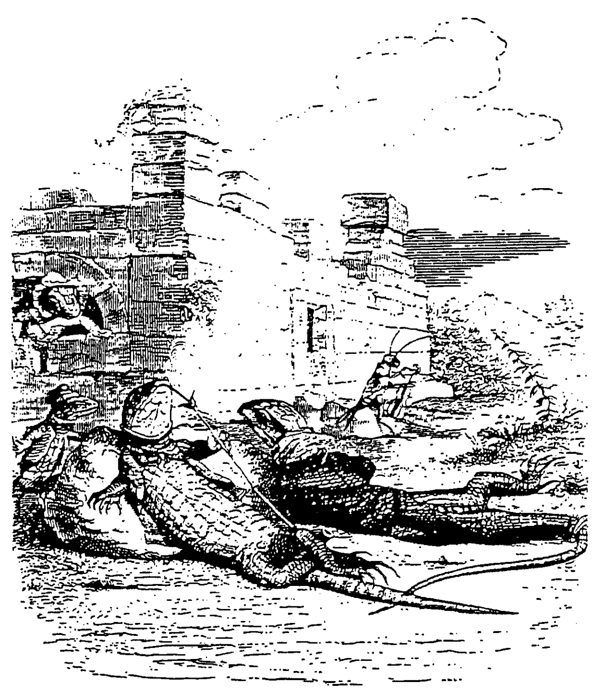
Mean salinity increased over the study period. This trend can possibly be explained by streamflow entering the Bay. The estimated Chesapeake Bay discharge decreased from 148.9 x $10^3 ft^3/s$ in 1989 to 64.6 x $10^3 ft^3/s$ in 1991 (Figure 42) (USGS 1989, 1990, 1991). Decreased discharge represents less freshwater entering the Bay and a corresponding increase in salinity.

The project was expanded in 1990 to sample a broader range of habitat conditions by adding Fishing Bay, Curtis Creek and Rock Creek, with some surprising results. Fishing Bay was added to the study because it was thought to be a relatively unspoiled environment. However, the fish community exhibited low species diversity and low overall catch, and no anadromous fish were captured. This suggests the presence of environmental stress in the system, but the extent and nature is not known at this time. Work in the future will more closely examine this system and its watershed for clues as to what has caused the apparent degradation of the fish community.

The bottom trawl was retained in future sampling for several reasons. This gear provides information about deep water habitats, often devoid of dissolved oxygen in the summer, that are important in the development of the bioindex procedures. The bottom trawl is deployable at all stations and, unlike the midwater trawl, can be deployed easily by inexperienced personnel.

This report is intended to be a data compilation and preliminary evaluation effort. Development and testing of the bioindex is continuing and this report supports those efforts. A detailed analysis of the bioindex will be presented in a future report slated for early 1993.

We hope to continue this project in the future to expand our knowledge of the relationship between land use and fish communities in Chesapeake Bay tributaries. We would like to better understand the apparent decline of the fish community in Fishing Bay, and the apparently healthy fish communities in Rock Creek and Curtis Creek. We would like to sample some degraded freshwater tributaries to compare to Mattawoman Creek. We would also like to conduct continuous water quality monitoring in the sampled tributaries to aid in interpreting our monthly water quality data.



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APPENDIX I

Resident Species Reference Table and Codes

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Atlantic Silverside *Menidia menidia*	Planktivore	ATH	Estuarine	45107	42.4337
Banded Killifish *Fundulus diaphanus*	Planktivore	CYD	Freshwater	1014	0.9539
Bay Anchovy *Anchoa mitchilli*	Planktivore	ENG	Estuarine	29394	27.6519
Black Crappie *Pomoxis nigromaculatus*	Carnivore	CEN	Freshwater	4	0.0038
Bluegill *Lepomis macrochirus*	Planktivore	CEN	Freshwater	938	0.8824
Brown Bullhead *Ictalurus nebulosus*	Benthic	ICT	Freshwater	279	0.2625
Carp *Cyprinus carpio*	Benthic	CYP	Freshwater	60	0.0564
Chain Pickerel *Esox niger*	Carnivore	ESO	Freshwater	53	0.0499
Channel Catfish *Ictalurus punctatus*	Benthic	ICT	Freshwater	67	0.0630
Feather Blenny *Hypsoblennius hentzi*	Benthic	BLE	Estuarine	1	0.0009
Fourspine Stickleback *Apeltes quadracus*	Planktivore	GAS	Estuarine	46	0.0433
Gizzard Shad *Dorosoma cepedianum*	Planktivore	CLU	Freshwater	2100	1.9755
Golden Shiner *Notemigonus crysoleucas*	Planktivore	CYP	Freshwater	40	0.0376
Goldfish *Carassius auratus*	Benthic	CYP	Freshwater	4	0.0038
Green Goby *Microgobius thalassinus*	Benthic	GOB	Estuarine	1	0.0009
Hogchoker *Trinectes maculatus*	Benthic	SOL	Estuarine	402	0.3782

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Spottail Shiner *Notropis hudsonius*	Planktivore	CYP	Freshwater	1634	1.5372
Striped Anchovy *Anchoa hepsetus*	Planktivore	ENG	Marine	224	0.2107
Striped Blenny *Chasmodes bosquianus*	Benthic	BLE	Estuarine	17	0.0160
Striped Killifish *Fundulus majalis*	Planktivore	CYD	Estuarine	9295	8.7441
Tessellated Darter *Etheostoma olmstedi*	Benthic	PED	Freshwater	425	0.3998
Threespine Stickleback *Gasterosteus aculeatus*	Planktivore	GAS	Estuarine	2	0.0019
White Catfish *Ictalurus catus*	Benthic	ICT	Freshwater	109	0.1025
White Sucker *Catostomus commersoni*	Benthic	CAT	Freshwater	1	0.0009
Yellow Perch *Perca flavescens*	Carnivore	PED	Freshwater	76	0.0715

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Spanish mackerel *Scomberomorus maculatus*	Planktivore	SCO	Marine	22	0.0207
Spot *Leiostomus xanthurus*	Benthic	SCI	Marine	2170	2.0414
Striped bass *Morone saxatilis*	Carnivore	PER	Anadromous	2430	2.2860
Summer flounder *Paralichthys dentatus*	Carnivore	BOT	Marine	33	0.0310
Weakfish *Cynoscion regalis*	Carnivore	SCI	Marine	44	0.0414
White perch *Morone americana*	Carnivore	PER	Anadromous	7294	6.8617
Winter flounder *Pseudopleuronectes americanus*	Benthic	PLE	Marine	33	0.0310

Family Codes Included in Resident and Non-resident Species Tables

ANG	ANGUILLIDAE	(eel)
ATH	ATHERINIDAE	(silverside)
BAT	BATRACHOIDIDAE	(toadfishes)
BEL	BELONIDAE	(needlefish)
BLE	BLENNIIDAE	(blennies)
BOT	BOTHIDAE	(lefteye flounder)
CAT	CATOSTOMIDAE	(sucker)
CEN	CENTRARCHIDAE	(sunfish)
CLU	CLUPEIDAE	(herring)
CYD	CYPRINODONTIDAE	(killifish)
CYN	CYNOGLOSSIDAE	(tonguefish)
CYP	CYPRINIDAE	(minnow)
ELO	ELOPIDAE	(ten-pounder)
ENG	ENGRAULIDAE	(anchovies)
EPH	EPHIPPIDAE	(spadefish)
ESO	ESOCIDAE	(pike)
GAS	GASTEROSTEIDAE	(stickleback)
GOB	GOBIIDAE	(gobies)
GOS	GOBIESOCIDAE	(clingfish)
ICT	ICTALURIDAE	(catfish)
PED	PERCIDAE	(perch)
PER	PERCICHTHYIDAE	(temperate bass)
PLE	PLEURONECTIDAE	(righteye flounder)
POM	POMATOMIDAE	(bluefish)
SCI	SCIAENIDAE	(drum)
SCO	SCOMBRIDAE	(mackerel)
SOL	SOLEIDAE	(sole)
STR	STROMATEIDAE	(butterfish)
SYD	SYNODONTIDAE	(lizardfish)
SYN	SYNGNATHIDAE	(pipefish)
TET	TETRAODONTIDAE	(puffer)

APPENDIX III Frequency of Capture and Total Catch for Each Species by River and Year

CURTIS CREEK	1989 FREQ.	1989 CATCH	1990 FREQ.	1990 CATCH	1991 FREQ.	1991 CATCH
ALEWIFE	NO DATA COLLECTED					
AMERICAN EEL						
AMERICAN SHAD						
ATLANTIC CROAKER			2	3	7	68
ATLANTIC MENHADEN			2	14	3	30
ATLANTIC NEEDLEFISH			1	41		
ATLANTIC SILVERSIDE			11	658	12	3236
ATLANTIC SPADEFISH						
ATL. THREAD HERRING						
BANDED KILLIFISH			3	21	6	101
BAY ANCHOVY			2	333	3	31
BLACK CRAPPIE						
BLUEBACK HERRING						
BLUEFISH			3	5	5	7
BLUEGILL						
BROWN BULLHEAD						
CARP						
CHAIN PICKERAL					2	3
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK						
GIZZARD SHAD					2	3
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH						
HOGCHOKER						
INLAND SILVERSIDE			12	336	11	173
INSHORE LIZARDFISH						
LADYFISH						
LARGEMOUTH BASS						
MUMMICHOG			9	281	10	296
NAKED GOBY					1	1
NORTHERN PIPEFISH			4	5	4	4
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED			7	149	6	166
QUILLBACK						
RAINWATER KILLIFISH						
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE					1	1
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW			1	6	2	3
SILVERY MINNOW						
SKILLETFISH						
SPANISH MACKEREL						
SPOT			8	17	6	27
SPOTTAIL SHINER						
STRIPED ANCHOVY						
STRIPED BASS			16	150	11	112
STRIPED BLENNY			2	2	2	2
STRIPED KILLIFISH			12	239	12	608
SUMMER FLOUNDER						
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH						
WHITE CATFISH						
WHITE PERCH			2	2	2	11
WHITE SUCKER						
WINTER FLOUNDER			2	4		
YELLOW PERCH			1	1		

MAGOTHY RIVER	1989		1990		1991	
	FREQ.	CATCH	FREQ.	CATCH	FREQ.	CATCH
ALEWIFE	1	4				
AMERICAN EEL	1	1			1	1
AMERICAN SHAD						
ATLANTIC CROAKER					17	307
ATLANTIC MENHADEN	6	1781	4	7602	4	34
ATLANTIC NEEDLEFISH	2	2	3	3	2	3
ATLANTIC SILVERSIDE	23	641	25	1698	25	3900
ATLANTIC SPADEFISH						
ATL. THREAD HERRING					1	6
BANDED KILLIFISH	14	93	7	23	8	192
BAY ANCHOVY	37	3681	11	336	9	317
BLACK CRAPPIE						
BLUEBACK HERRING	3	19				
BLUEFISH	9	11	10	32	3	5
BLUEGILL	4	88				
BROWN BULLHEAD	9	138	2	3	4	24
CARP			1	1	2	5
CHAIN PICKERAL	3	7	4	7	3	7
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK			2	9		
GIZZARD SHAD	1	1				
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH						
HOGCHOKER	6	6	1	2		
INLAND SILVERSIDE	27	589	27	941	25	327
INSHORE LIZARDFISH						
LADYFISH						
LARGEMOUTH BASS			1	1	4	10
MUMMICHOG	9	132	13	87	11	143
NAKED GOBY	1	1				
NORTHERN PIPEFISH	12	27	7	11	4	4
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED	9	174	7	36	6	124
QUILLBACK						
RAINWATER KILLIFISH	1	1	1	1		
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE	2	4	1	2		
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW	15	92	1	1	3	3
SILVERY MINNOW						
SKILLETFISH						
SPANISH MACKEREL						
SPOT	18	41	18	161	21	106
SPOTTAIL SHINER						
STRIPED ANCHOVY	2	4	5	5	3	9
STRIPED BASS	14	20	21	111	30	642
STRIPED BLENNY	1	1				
STRIPED KILLIFISH	28	621	21	535	19	662
SUMMER FLOUNDER			1	1	1	2
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH						
WHITE CATFISH			1	1		
WHITE PERCH	4	7	4	8	7	12
WHITE SUCKER						
WINTER FLOUNDER			2	3		
YELLOW PERCH			2	4		

SOUTH RIVER	1989		1990		1991	
	FREQ.	CATCH	FREQ.	CATCH	FREQ.	CATCH
ALEWIFE	2	12			1	1
AMERICAN EEL			1	1	2	2
AMERICAN SHAD						
ATLANTIC CROAKER			6	7	34	1183
ATLANTIC MENHADEN	8	3598	18	26567	5	2122
ATLANTIC NEEDLEFISH	3	7	2	12	4	13
ATLANTIC SILVERSIDE	28	1562	29	1068	30	2210
ATLANTIC SPADEFISH						
ATL. THREAD HERRING					1	27
BANDED KILLIFISH	3	9	1	3	1	1
BAY ANCHOVY	25	1303	35	1629	25	1088
BLACK CRAPPIE						
BLUEBACK HERRING						
BLUEFISH	9	16	7	8	4	5
BLUEGILL						
BROWN BULLHEAD						
CARP	2	3	6	12	4	8
CHAIN PICKERAL						
CHANNEL CATFISH						
FEATHER BLENNY	1	1				
FOURSPINE STICKLEBACK	2	7	1	1		
GIZZARD SHAD	2	5	2	4	2	2
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH			3	3		
HOGCHOKER	9	21	4	21	2	4
INLAND SILVERSIDE	23	673	25	385	22	225
INSHORE LIZARDFISH					4	7
LADYFISH						
LARGEMOUTH BASS						
MUMMICHOG	16	159	13	79	11	78
NAKED GOBY	3	5	3	4		
NORTHERN PIPEFISH	8	9	6	10	5	12
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED	2	2				
QUILLBACK						
RAINWATER KILLIFISH						
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE	1	1	1	7	1	1
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW			2	2	1	1
SILVERY MINNOW						
SKILLETFISH						
SPANISH MACKEREL			4	4	2	2
SPOT	19	63	32	109	23	87
SPOTTAIL SHINER						
STRIPED ANCHOVY			11	30	6	8
STRIPED BASS	15	47	11	23	13	75
STRIPED BLENNY			3	3	1	1
STRIPED KILLIFISH	30	506	16	234	18	409
SUMMER FLOUNDER			2	6	3	3
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH			2	2		
WHITE CATFISH						
WHITE PERCH	1	1	3	5	2	30
WHITE SUCKER						
WINTER FLOUNDER			4	7		
YELLOW PERCH						

WICOMICO RIVER	1989		1990		1991	
	FREQ.	CATCH	FREQ.	CATCH	FREQ.	CATCH
ALEWIFE					2	2
AMERICAN EEL	1	1	4	8		
AMERICAN SHAD						
ATLANTIC CROAKER					25	109
ATLANTIC MENHADEN	12	367	13	3186	19	6410
ATLANTIC NEEDLEFISH	12	165	11	32	9	20
ATLANTIC SILVERSIDE	27	4683	29	3223	33	10168
ATLANTIC SPADEFISH						
ATL. THREAD HERRING						
BANDED KILLIFISH	6	57	6	12	1	3
BAY ANCHOVY	36	5363	41	716	38	5395
BLACK CRAPPIE	1	2				
BLUEBACK HERRING	8	24	2	4		
BLUEFISH	10	16	3	7	2	3
BLUEGILL	3	45				
BROWN BULLHEAD	3	36				
CARP	8	19	2	4	1	1
CHAIN PICKERAL	2	4				
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK						
GIZZARD SHAD	12	104	3	23	5	16
GOLDEN SHINER	1	1				
GOLDFISH	1	1				
GREEN GOBY					1	1
HARVESTFISH			4	7	4	13
HOGCHOKER	12	26	7	71	9	16
INLAND SILVERSIDE	12	345	16	96	5	37
INSHORE LIZARDFISH						
LADYFISH					1	1
LARGEMOUTH BASS	1	1				
MUMMICHOG	22	548	21	938	18	517
NAKED GOBY	5	5	3	5	1	1
NORTHERN PIPEFISH	11	14	10	14	3	13
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED	15	436	11	52	2	3
QUILLBACK						
RAINWATER KILLIFISH			1	1		
RED DRUM					1	1
REDFIN PICKERAL						
ROUGH SILVERSIDE	1	2	5	7	3	5
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW	3	25			1	1
SILVERY MINNOW	1	2				
SKILLETFISH	3	4	3	14	7	35
SPANISH MACKEREL			4	4	3	9
SPOT	23	150	40	297	29	106
SPOTTAIL SHINER			1	2		
STRIPED ANCHOVY	3	4	9	71	1	2
STRIPED BASS	10	12	13	23	15	97
STRIPED BLENNY					1	1
STRIPED KILLIFISH	26	1047	30	631	26	733
SUMMER FLOUNDER			3	4	3	9
TESSELLATED DARTER	5	12	5	10		
THREESPINE STICKLEBACK						
WEAKFISH			2	2		
WHITE CATFISH	5	103	4	4		
WHITE PERCH	20	275	22	80	23	132
WHITE SUCKER						
WINTER FLOUNDER			1	1		
YELLOW PERCH	2	2	6	12	1	1

Fish Sampling in Eight Chesapeake Bay Tributaries

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Tidewater Administration

CHESAPEAKE BAY RESEARCH AND MONITORING DIVISION

CBRM-HI-92-2

FISH ASSEMBLAGES AND DISSOLVED OXYGEN TRENDS IN EIGHT CHESAPEAKE BAY TRIBUTARIES DURING THE SUMMERS OF 1989 - 1991

A DATA REPORT

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Brian M. Richardson
Margaret Roberts
Stephen J. Jordan

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Tidewater Administration
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Annapolis, Maryland 21401

November 1992

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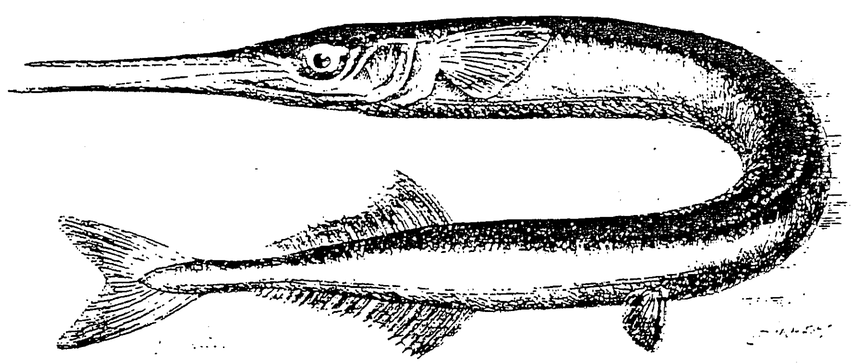
TABLE OF CONTENTS

INTRODUCTION

Ecological degradation within the Chesapeake Bay and many of its tributaries has been well documented (Carter 1982, Orth and Moore 1982, EPA 1983a, EPA 1983b, Lippson and Lippson 1984, NOAA 1990, Summers et al. 1990, Funderburk et al. 1991, Vaas and Jordan 1991, Rago 1992). Despite many investigations of living resources and water quality, it is difficult to link changes in ecosystem health to water quality and the effects of various land uses. Previous studies indicated that fish assemblages could be monitored as indicators of stress in aquatic systems (Karr 1991, Hughes and Noss 1992). An association between fish species diversity and pollution stress was demonstrated in estuarine systems (Betchel and Copeland 1970). In freshwater streams an index of biotic integrity was used to show ecological degradation from a variety of sources (Karr 1987), and adaptations of Karr's index have been used effectively in other environments (Miller et al. 1988). An indicator based on fish assemblages has shown promise in evaluating the stress of anthropogenic impacts on Chesapeake Bay tidal tributaries (Jordan et al. 1991).

In our project, data gathered from 1989 to 1991 from eight Chesapeake Bay tributaries is being used to further develop and fine tune a bioassessment procedure for tidal estuaries. We are trying to determine if a multimetric index of biotic integrity, or bioindex, based on fish assemblages, can be used to quantify urbanization and other land use effects on living resources in estuarine environments and document the effectiveness of ecological remediation efforts. This report compiles data collected from 1989 to 1991; evaluates capture methods; examines trends in the catch of fish species, fish assemblages and water quality; presents basic land use data for the sampled tributaries; and discusses some preliminary analysis on the use of dissolved oxygen and fish populations as indicators of anthropogenic stress.

This report serves as support for a future publication (early 1993) on the bioindex, and therefore includes detailed information about data collection methods, sample stations, and individual fish species.



METHODS

Study Areas

Five Maryland tributaries on the western shore of the Chesapeake Bay were sampled during 1989. These tributaries included the South River, Severn River, Magothy River, Mattawoman Creek, and Wicomico River. Rock Creek and Curtis Creek, tributaries of the Patapsco River in the Baltimore area, and Fishing Bay on the eastern shore near Tangier Sound were added in 1990 (Figure 1). All eight tributaries were sampled again in 1991. These rivers were selected as representative of typical fish habitat, ecological conditions, and anthropogenic influences in many of the smaller tributaries of the Chesapeake Bay.

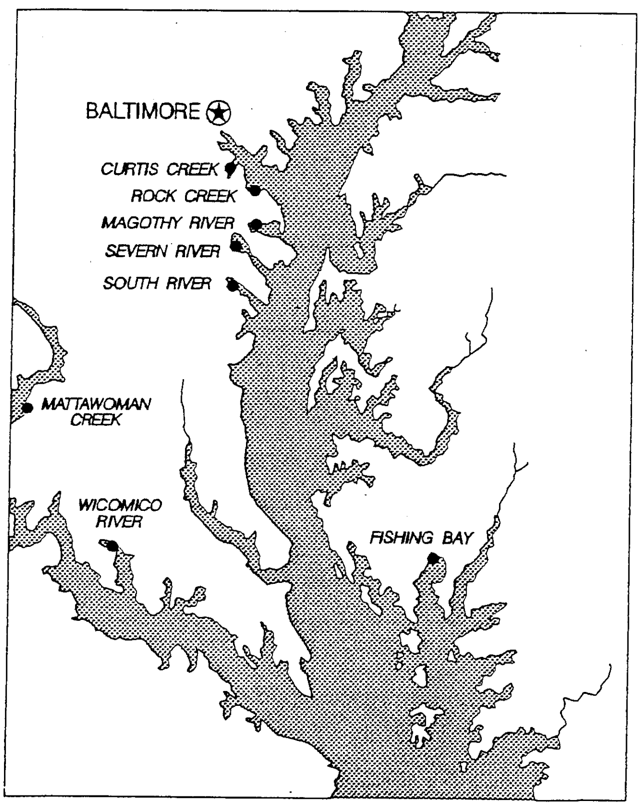


Figure 1. Location of Chesapeake Bay tributaries sampled for bioindex survey.

Fishing Bay, in Dorchester County (Figure 2), has the highest salinity of the study sites. The Fishing Bay watershed, composed mostly of forest and wetlands, is the least urbanized of the study areas. A portion of the Fishing Bay watershed is protected by the Blackwater Wildlife Refuge.

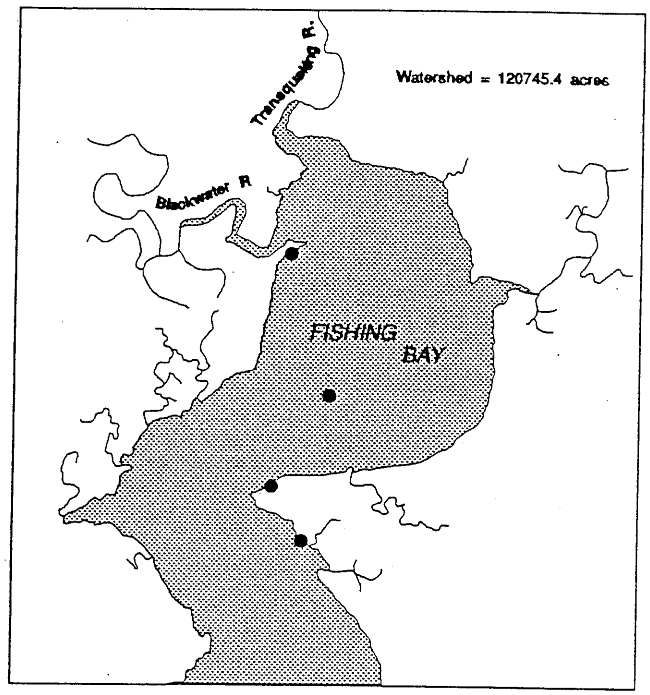


Figure 2. Location of Fishing Bay sampling stations, 1990 - 1991.

Mattawoman Creek is a tributary of the Potomac River located in Prince George's and Charles counties (Figure 3). It had the lowest salinity and little urban development. More than half the watershed is forested, with tree cover dominating the shoreline. A military testing installation (Indian Head Naval Surface Weapons Center) is found along both shores near the mouth of the creek.

The Wicomico River, another Potomac River tributary, is located between Charles and St. Mary's counties (Figure 4) and encompasses a broad range of salinity. This watershed contains the largest proportion of agricultural land of the studied tributaries and there is little urban development. The shoreline is mostly farm land and forest.

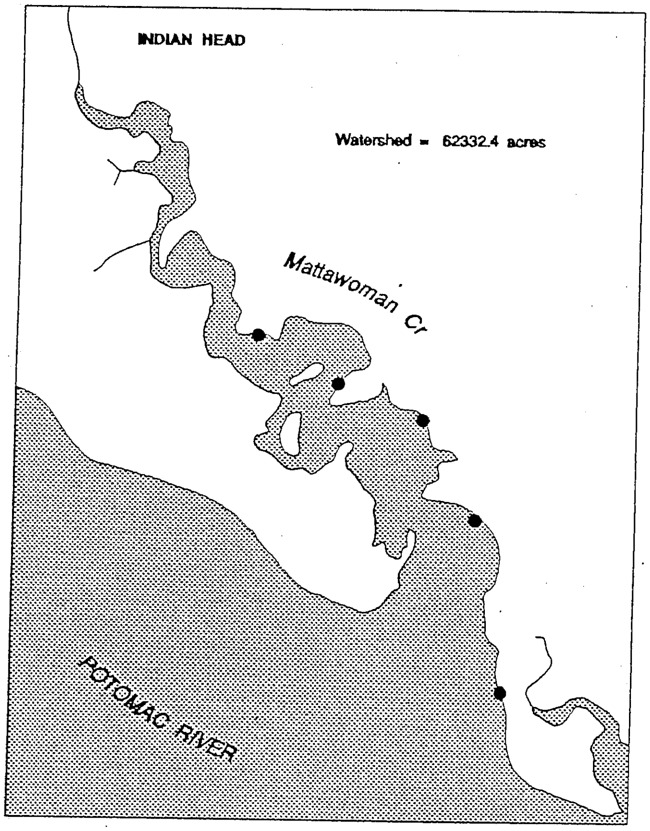


Figure 3. Mattawoman Creek sampling stations, 1989 - 1991.

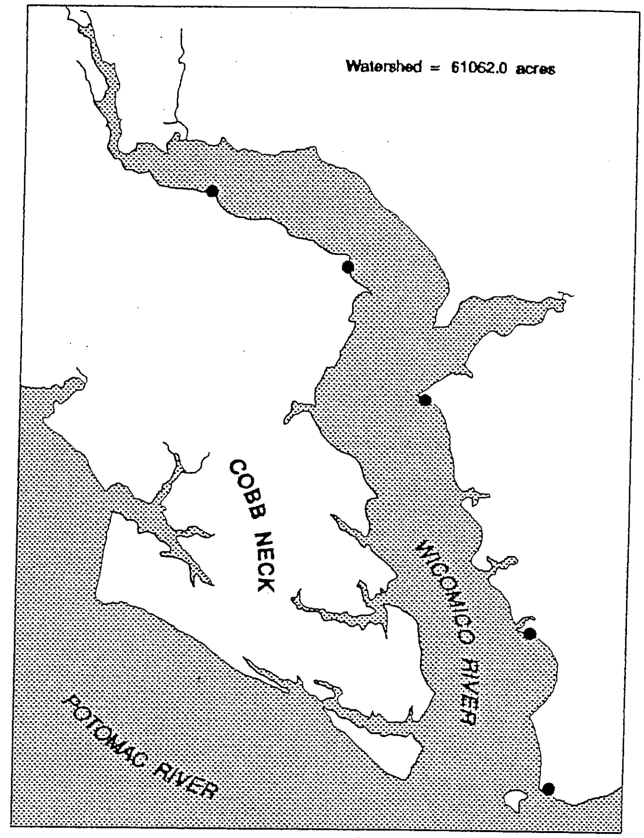


Figure 4. Reference tributary sampling stations, the Wicomico River, 1989 - 1991.

Rock Creek and Curtis Creek are Patapsco River tributaries in Anne Arundel county near Baltimore (Figure 5), located in densely populated and heavily industrialized areas. The Curtis Creek watershed has the largest proportion of industrial and commercial land of the study areas, and is heavily urbanized. The Rock Creek watershed encompasses the most urbanized land of the study areas, with houses and marinas located along much of the shoreline.

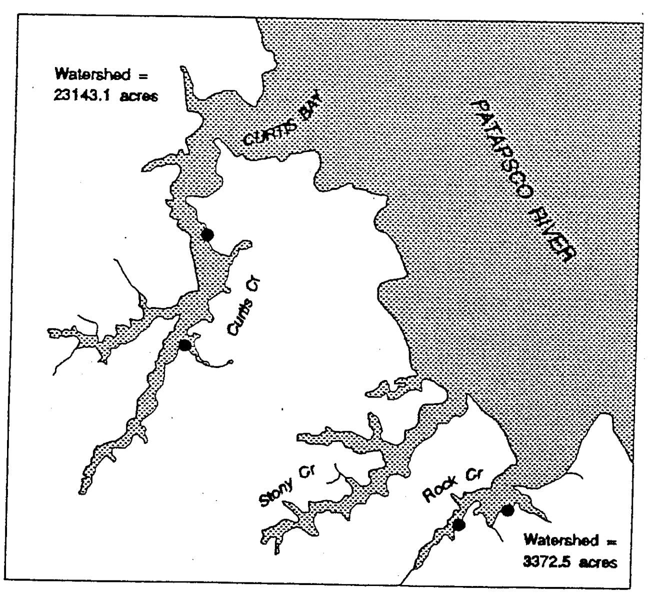


Figure 5. Curtis Creek and Rock Creek sampling stations, 1990 - 1991.

The South, Severn and Magothy rivers drain highly urbanized watersheds in the Annapolis area of Anne Arundel County. They are similar in salinity range. The Magothy River watershed (Figure 6) is the most

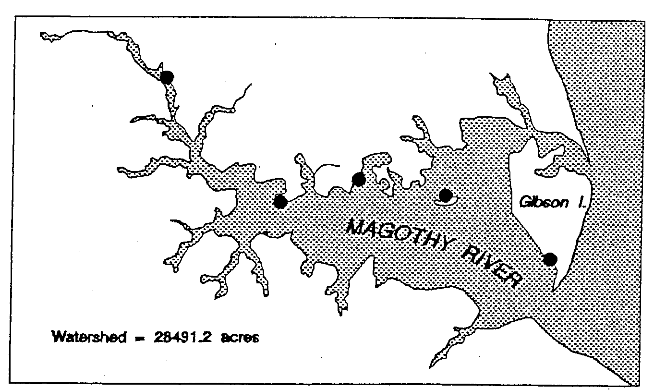


Figure 6. Location of Magothy River sampling stations, 1989 - 1991.

developed of the three, followed by the Severn River (Figure 7) and the South River watersheds (Figure 8). There are many houses and marinas along the shoreline of all three rivers.

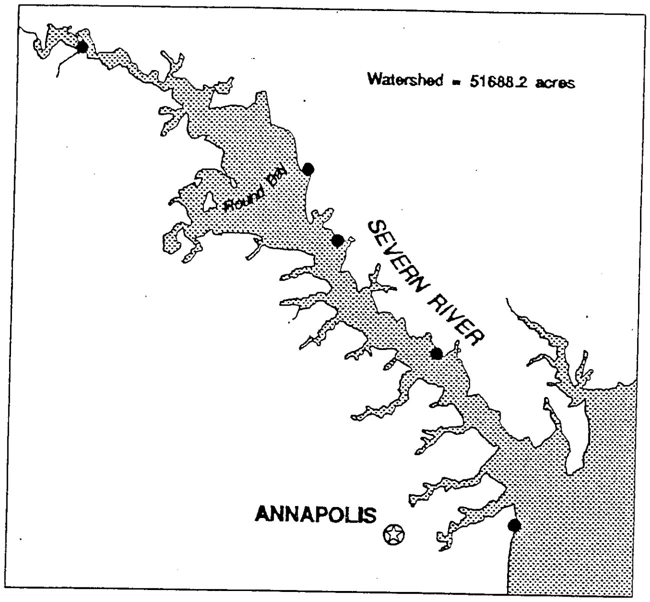


Figure 7. Sampling stations in Severn River, 1989 - 1991.

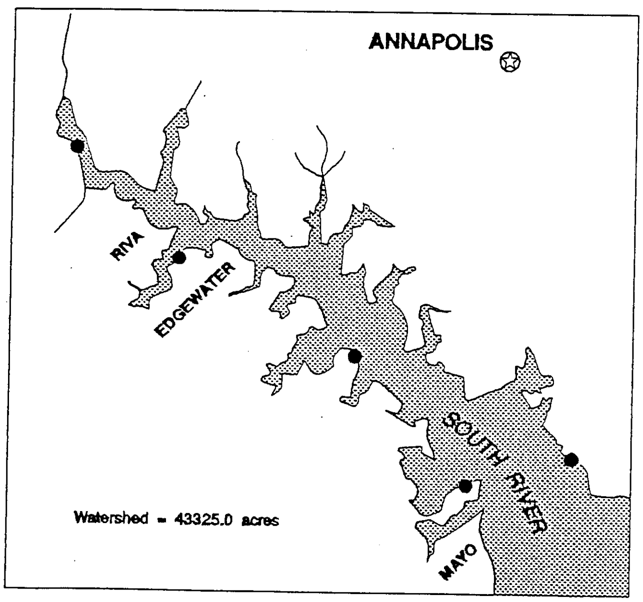


Figure 8. South River sampling stations, 1989 - 1991.

Fish Sampling

Under the original program design implemented in 1989, Mattawoman Creek was selected to represent a freshwater reference site (< 2 ppt salinity) and the Wicomico River was selected to represent a saltwater reference site (> 2 ppt). These selections were based on a pilot study and evaluation of land use in the watersheds of the proposed sample tributaries in 1988 (Uphoff 1988). The reference site selections were reinforced by analysis of water quality, number of fish species captured, and representation of what we considered the most "typical" fish community for Chesapeake Bay tributaries. The other sampled rivers, except Fishing Bay, are considered to be the urban stressed tributaries.

Tributaries were sampled once monthly in July, August and September during all three years. Sampling stations were located in tidal reaches. The study goal was to sample five stations in each tributary. Only four stations could be found in Fishing Bay, and only two stations in Curtis and Rock Creeks due to debris, unsuitable bottom substrate, excessive beach slope, bulkheading or steep banks. The stations are approximately one river mile apart starting from the mouth of the tributary and moving upstream. Summer months were selected to sample the seasonally-present populations of juvenile anadromous fish that may be important indicators of ecological health in estuarine systems and to sample fish assemblages during the season when they are most diverse. Sampling began during the first week of each month. An effort was made to sample tributaries in the following order each round: Severn, South, Magothy, and Wicomico Rivers, Mattawoman Creek, Fishing Bay, and Curtis and Rock Creeks.

The fish community was sampled by seining and trawling. Two seine hauls were made at each station, with a 30 minute interval between hauls to allow for repopulation. Seining gear consisted of a bagless 6.4mm mesh seine, 30.5m in length and 1.2m deep, with 1.5 meter poles attached to each end. One end of the seine was held on shore, while the other was pulled out perpendicular to shore until the seine was fully extended, and then pulled with the tide in an arc to the beach.

If depth allowed, three types of trawl tows were made at each station. Bottom tows were always made at each station, while inshore and midwater tows were made where possible (Table 1). A 3.1m otter or box trawl with 12.8mm stretch mesh, and 50.8cm x 25.4cm doors was used for inshore and bottom trawls. Inshore trawl stations were located in shoal waters as close to shore as possible, anywhere from 30-60m out and to one side of the seine station, in water 1-2m deep. Bottom and midwater trawl stations were located in deep channel areas off the seine station, with depths ranging from 1-12m. If water depth was not sufficient to allow separation between the areas sampled by the bottom and midwater tows, then only bottom tows were made. A midwater trawl 1.53 x 1.53m, with 12.8mm stretch mesh, and a 2.7m headrope was used for mid-depth tows in the channel. Super Krub doors (30.5 x 40.6cm) were attached 3.05m in front of the trawl, with two 3.8 liter floats on each door to keep the net shallow, and 12.7 x 20.3cm depressors were located at the ends of the footropes. We attempted to follow the same path in pulling both the bottom trawl and midwater trawl. All tows were made with the tide at a speed of 2 knots.

All fish collected in seines and trawls were identified to species (Eddy and Underhill 1978) and counted, maximum and minimum length measurements for each species taken, scales taken (where needed to distinguish young of year fish), and returned to the water. Fish from the first seine haul at a station were

		STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	TOTAL SEINES	TOTAL TRAWLS
CURTIS CREEK	1990	S B M	S B M				12	11
	1991	S B M	S B M				12	12
ROCK CREEK	1990	S B	S B				12	6
	1991	S B	S B				12	6
MAGOTHY RIVER	1989	S B	S B M I	S B M	S B M I	S B M I	30	34
	1990	S B	S B M I	S B M	S B M I	S B M I	30	31
	1991	S B	S B M I	S B M	S B M I	S B M I	30	36
SEVERN RIVER	1989	S B	S B M I	S B M I	S B M I	S B M I	30	36
	1990	S B	S B M I	S B M I	S B M I	S B M I	30	37
	1991	S B	S B M I	S B M I	S B M I	S B M I	30	39
SOUTH RIVER	1989	S B	S B M	S B M I	S B M I	S B M I	30	29
	1990	S B	S B M	S B M I	S B M I	S B M I	30	29
	1991	S B	S B M	S B M I	S B M I	S B M I	30	29
MATTAWOMAN CREEK	1989	S B	S B	S B	S B	S B M I	30	17
	1990	S B	S B	S B	S B	S B M I	30	19
	1991	S B	S B	S B	S B	S B M I	30	21
WICOMICO RIVER	1989	S B	S B	S B M I	S B M I	S B M I	30	31
	1990	S B	S B	S B M I	S B M I	S B M I	30	31
	1991	S B	S B	S B M I	S B M I	S B M I	30	30
FISHING BAY	1990	S B	S B M I	B	S B M I		18	24
	1991	S B	S B M I	B	S B M I		18	21

Table 1. Sampling methods and effort at each station; S=2 seine hauls, B=bottom trawl tow, I=inshore trawl tow, M=midwater trawl tow.

kept in buckets and returned to the water once the second haul was completed. Every effort was made to return fish to the water unharmed. Specimens that could not be keyed in the field were preserved in 10% formalin for later identification in the laboratory.

Water Quality

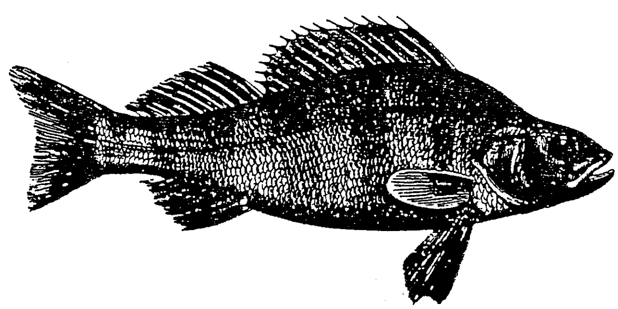
Water quality measurements and Secchi disc readings were taken at each station. A Hydrolab Surveyor II was used to measure water temperature, pH, dissolved oxygen (DO), conductivity, and salinity. Measurements were taken in the channel near the trawl station at the bottom, midwater, and surface. Water quality measurements were not taken at the seine stations. To ensure accuracy, the Hydrolab was calibrated each day before use.

Habitat Observations

Basic habitat observations such as maximum depth, bottom types, and presence of aquatic plants were recorded on the seine data sheets. A more detailed approach to habitat assessment began in September 1991, when a data sheet was developed to record habitat observations at each station. The intent was to get an overview of the riparian and upland areas of the sampled tributaries within each station, including information on bulkheading, bank slope, vegetation, in-stream structure, and nearby land use. Gathering such data for the large areas covered by the sample stations proved to be a time-consuming task not practical to our applications. Alternative data sheets were developed to record habitat conditions in the area immediately surrounding the seine stations, and were tested during sampling in 1992. Results of this experiment are forthcoming. Detailed information on watershed land use as of 1990 was obtained from the Map and Image Processing System (MIPS) computer database, by Mary Beamis, Maryland DNR, Tidewater Administration. These data were used to classify land usage in the watershed of each study tributary.

Catch Per Unit Effort

Catch per unit effort, or CPUE, was calculated for each method by dividing catch by effort. One unit of effort equaled one seine haul or one trawl tow.



RESULTS

This project gathered fish assemblage data used in evaluating the ecological health of eight tidal tributaries of the Chesapeake Bay. Therefore, much of the catch data is presented in terms of the ecological characteristics used in the bioindex calculations, such as spawning location, trophic function, and species richness. Also, comparisons were made between rivers considered to be urban-stressed (Severn, South, and Magothy Rivers, Curtis and Rock Creeks), and the other less impacted systems (Fishing Bay, Mattawoman Creek, and the Wicomico River). Catch data were included for important recreational and commercial species and Chesapeake Bay "target species" (Funderburk et al. 1991).

A total of 206,265 individuals was captured during the 1989-1991 surveys, representing 64 species and 31 families. The dominant species was Atlantic menhaden (*Brevoortia tyrannus*), accounting for 36.5% of the total catch. Eight species represented 90% of the overall catch. In descending abundance, these were Atlantic menhaden, Atlantic silverside (*Menidia menidia*), bay anchovy (*Anchoa mitchilli*), striped killifish (*Fundulus majalis*), blueback herring, white perch, inland silverside (*Menidia beryllina*), and mummichog (*Fundulus heteroclitus*). Seventeen species were represented by fewer than ten individuals, and thirteen species were represented by only one or two individuals.

Fish Collection

The effectiveness of each sampling method (seine, bottom trawl, midwater trawl and inshore trawl) was evaluated. The purpose of the project is to develop quick and efficient assessment procedures, thus, only methods that contribute significant information about fish assemblages are desired. The overall mean CPUE for seining at all stations in all tributaries during all years was 344 fish (Figure 9). Seining accounted for 89% of the total catch and collected 62 of 64 species. The green goby (*Microgobius thalassinus*) and the feather blenny (*Hypsoblennius hentzi*) were the only species captured by trawling alone. Once it was established that seining captured the majority of the fish, the next step was to determine if any of the trawling methods provided insights beyond that which could be learned from the seine collections.

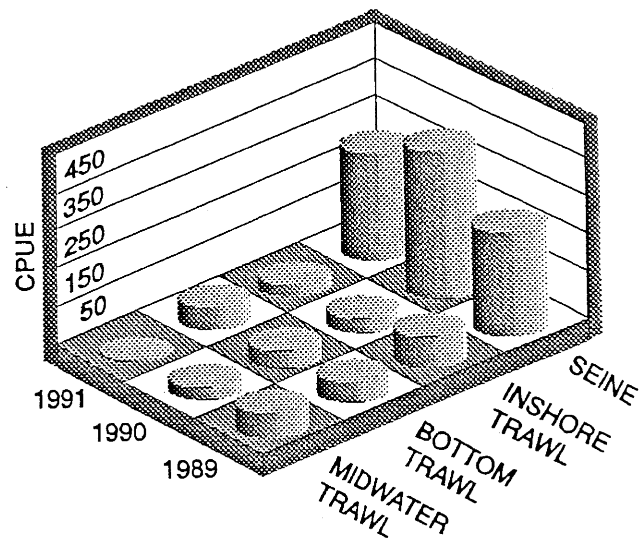


Figure 9. Overall mean CPUE for each sampling method by year.

The trawl catch was dominated by the bay anchovy (Figure 10). The bottom trawl provided more information about the fish assemblages than the inshore or midwater trawls (Figure 11), capturing 6% of the total catch (71% bay anchovy) and 36 species; 31% of the bottom trawl tows captured no fish. The overall mean bottom trawl CPUE for all stations in all tributaries during all three years was 49. The inshore trawl captured 30 species and only 2.6% of the total catch (88% bay anchovy); 19% of the tows resulted in no fish captured. The overall mean CPUE was 44. The midwater trawl conveyed the least information, capturing only 14 species and 2.4% of the total catch (95% bay anchovy); 68% of the tows resulted in no fish captured. The overall mean CPUE for the midwater trawl was 33.

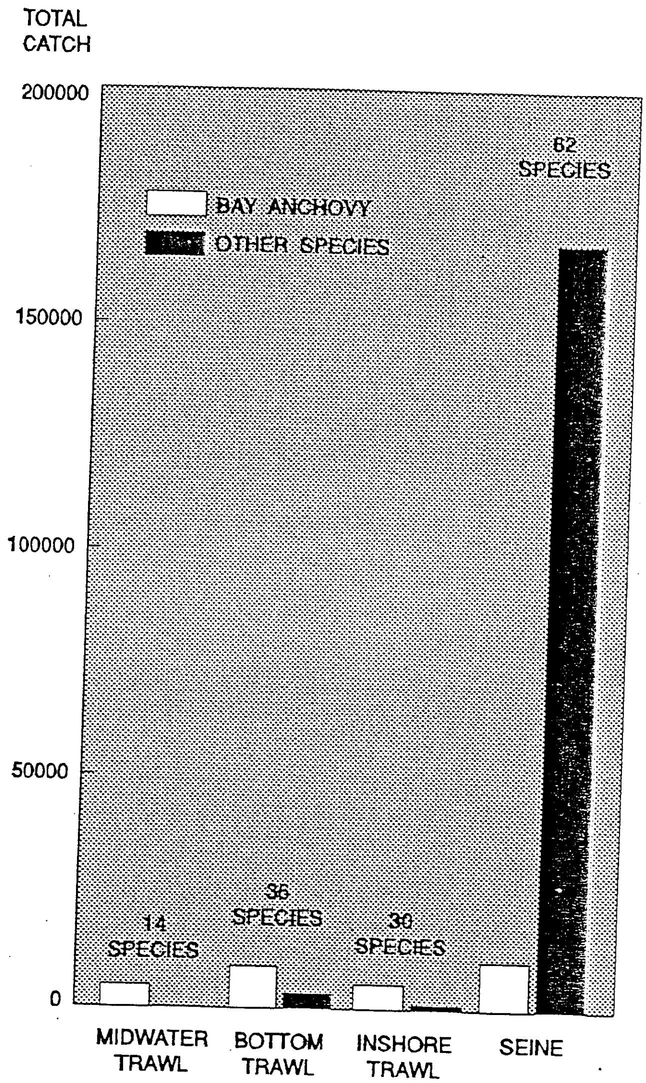


Figure 10. Total catch of bay anchovy versus catch of all other species for each sampling method.

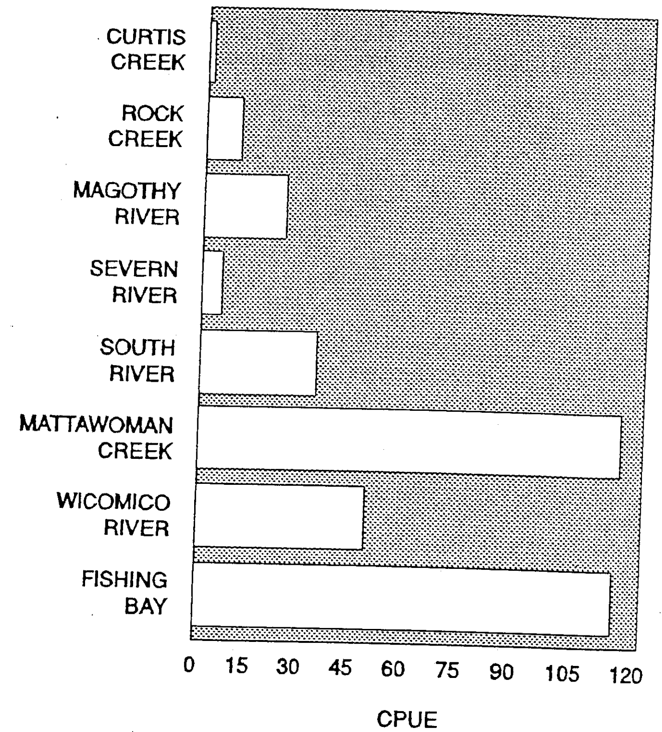


Figure 11. Overall mean bottom trawl CPUE for all years by tributary.

There was little variation among tributaries in the seine and trawl CPUE, except in Fishing Bay where trawling was much more effective. Trawling captured 65% of the Fishing Bay catch, but only 9% of the overall catch in the other tributaries. Catch per unit effort at Fishing Bay was 103 for trawling and 71 for seining, whereas the overall CPUE at all other stations during all three years was 37 for trawling and 364 for seining (Figure 12).

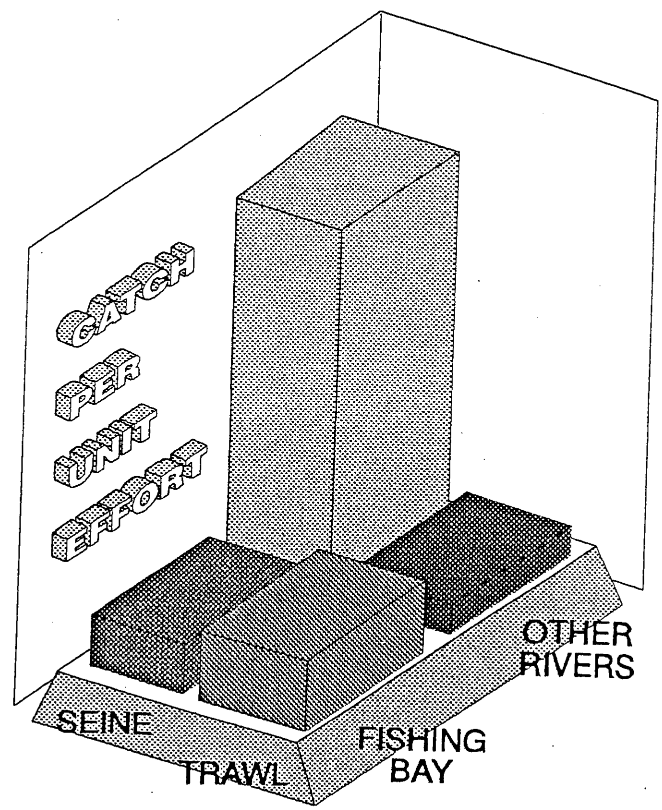


Figure 12. Comparison of overall mean seine and trawl CPUE between Fishing Bay and all other tributaries for all three years.

Comparisons to the Saltwater Reference Tributary

Histograms were developed to compare the fish species composition in each tributary to the saltwater reference tributary (Wicomico River). The 48 species captured in the Wicomico River were ranked by total catch of individuals over all three years (rankings 1-48) and the 16 additional species captured in the other tributaries were similarly ranked (49-64). Species having equal abundance were ranked alphabetically (Table 2). Species captured in each tributary were graphed by these rankings using $\log_{10}$ transformed catch data. By comparing each tributary to the saltwater reference tributary, the Wicomico River, changes in the fish community composition in the sampled tributaries can be easily seen. Also, similar patterns can be seen among some of the tributaries. These graphs are intended only to give a simple visual perception of fish community change in areas with less desirable habitat conditions. The reference site comparison graphs show the species imbalance that was expected in the fish assemblages of stressed tributaries. The Wicomico River (Figure 13) had the highest number of species, while Curtis and Rock Creeks (Figure 14 and 15) had the lowest number of species. The South River (Figure 16), Severn River (Figure 17), and Magothy River (Figure 18) showed the same assemblage patterns, reflecting similarities in the fish community structure in these tributaries. On the basis of fish species composition, Mattawoman Creek (Figure 19) was completely different from the other seven tributaries. We expect

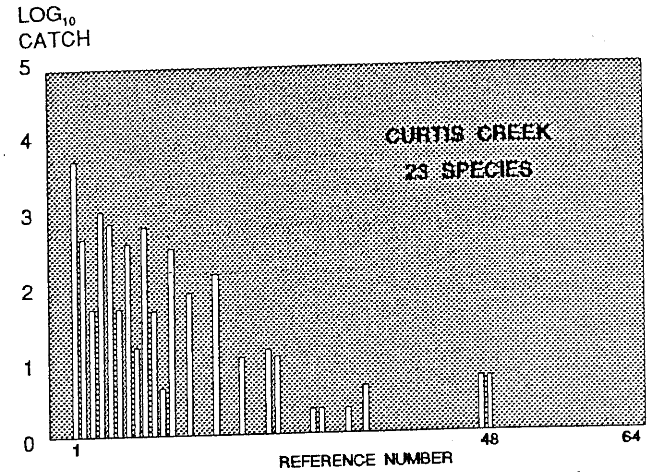


Figure 14. Curtis Creek $\log_{10}$ overall catch by species reference number.

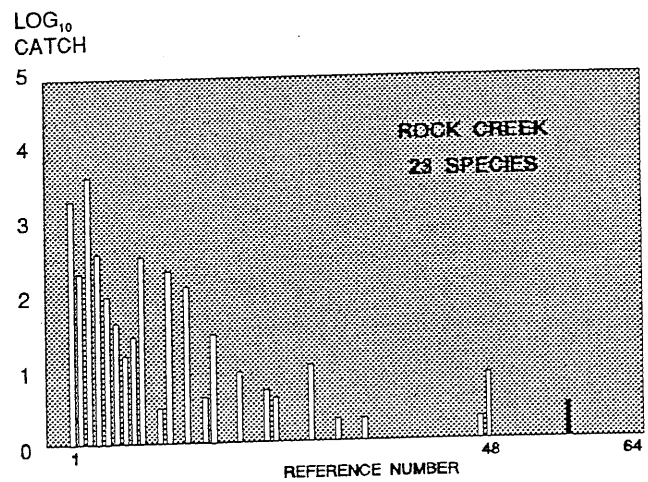


Figure 15. Rock Creek $\log_{10}$ overall catch by species reference number. Black bars represent species captured in Rock Creek that were not captured in the Wicomico River.

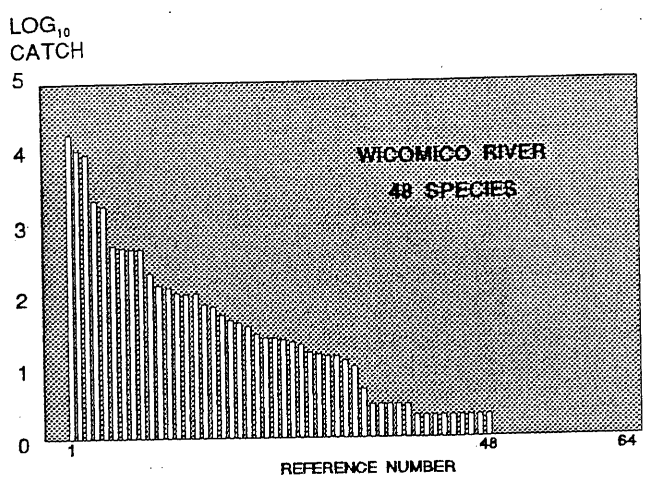


Figure 13. Graph of decreasing $\log_{10}$ overall catch by species reference number for saltwater reference tributary, the Wicomico River.

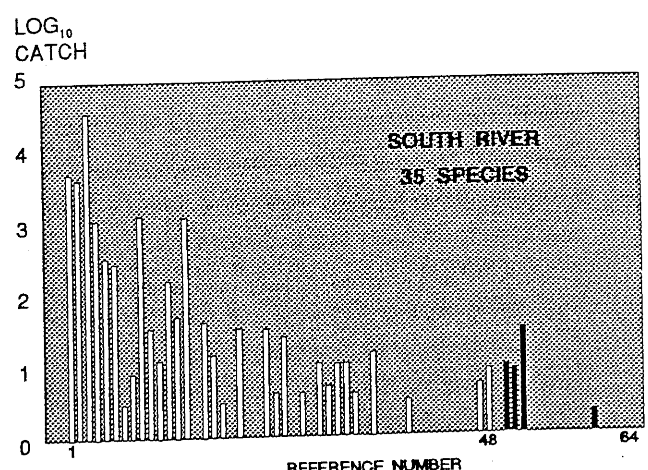


Figure 16. South River $\log_{10}$ overall catch by species reference number. Black bars represent species captured in the South River that were not captured in the Wicomico River.

SPECIES	REFERENCE#	SPECIES	REFERENCE#
Atlantic silverside	1	American eel	33
Bay anchovy	2	Chain pickerel	34
Atlantic menhaden	3	Alewife	35
Striped killifish	4	Black crappie	36
Mummichog	5	Silvery minnow	37
Spot	6	Spottail shiner	38
Pumpkinseed	7	Weakfish	39
White perch	8	Golden shiner	40
Inland silverside	9	Goldfish	41
Atlantic needlefish	10	Green goby	42
Gizzard shad	11	Ladyfish	43
Striped bass	12	Largemouth bass	44
Hogchoker	13	Rainwater killifish	45
Atlantic croaker	14	Red drum	46
White catfish	15	Striped blenny	47
Striped anchovy	16	Winter flounder	48
Banded killifish	17	Channel catfish	49
Skilletfish	18	Fourspine stickleback	50
Bluegill	19	Inshore lizardfish	51
Northern pipefish	20	Atl. thread herring	52
Brown bullhead	21	American shad	53
Blueback herring	22	Oyster toadfish	54
Bluefish	23	Northern puffer	55
Sheepshead minnow	24	Offshore tonguefish	56
Carp	25	Redfin pickerel	57
Tessellated darter	26	Threespine stickleback	58
Harvestfish	27	Atlantic Spadefish	59
Yellow perch	28	Feather blenny	60
Rough silverside	29	Quillback	61
Spanish mackerel	30	Satinfin shiner	62
Summer flounder	31	Seaweed blenny	63
Naked goby	32	White sucker	64

Table 2. Reference numbers assigned to each species captured during the survey. These were used to create graphs to compare each tributary to the saltwater reference tributary, the Wicomico River.

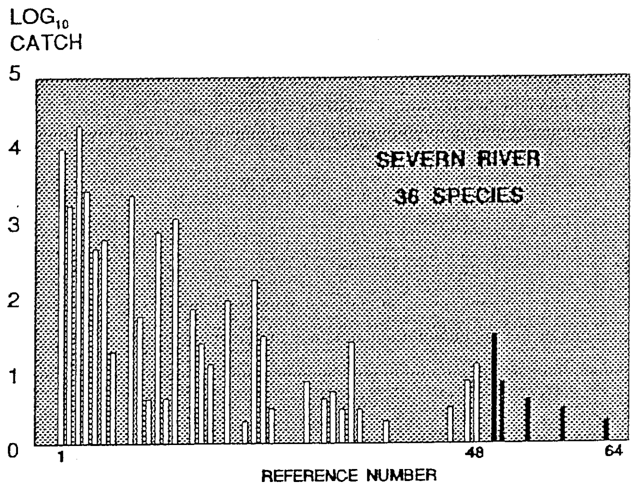


Figure 17. Severn River $\log_{10}$ overall catch by species reference number. Black bars represent species captured in the Severn River that were not captured in the Wicomico River.

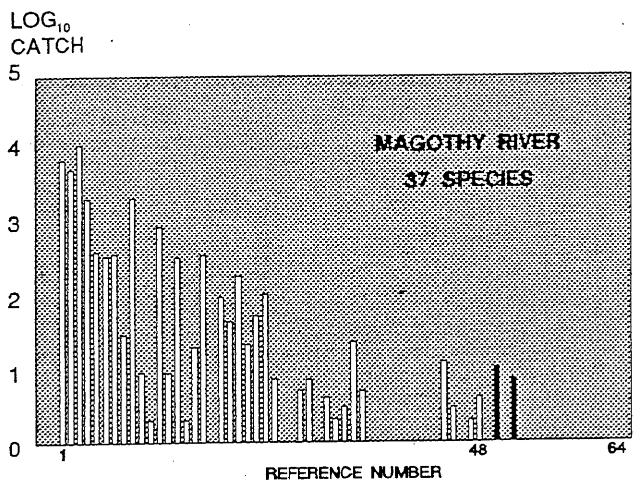


Figure 18. Magothy River $\log_{10}$ overall catch by species reference number. Black bars represent species captured in the Magothy River that were not captured in the Wicomico River.

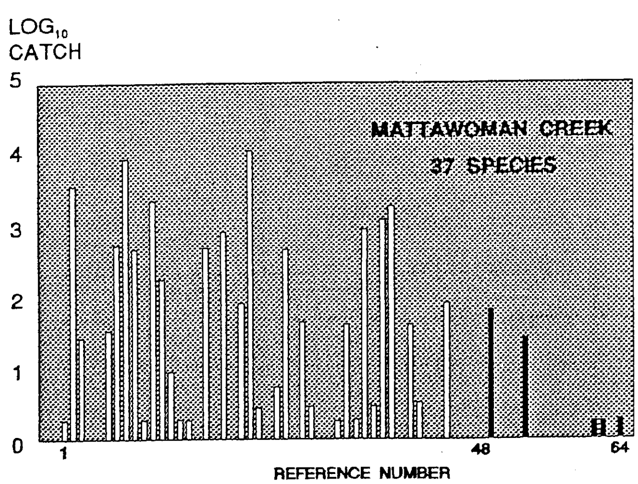


Figure 19. Mattawoman Creek $\log_{10}$ overall catch by species reference number. Black bars represent species captured in Mattawoman Creek that were not captured in the Wicomico River.

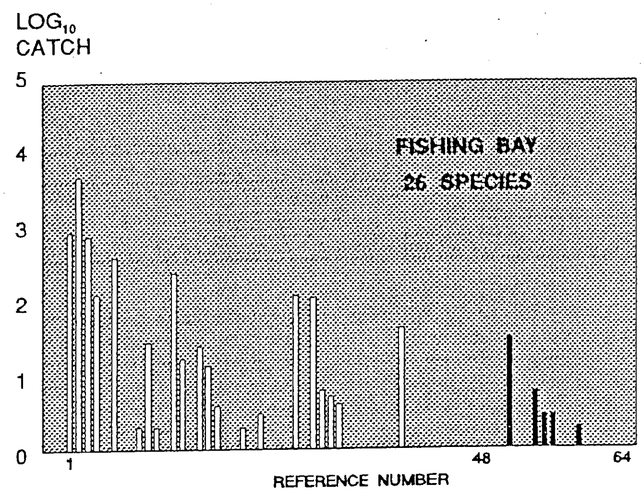


Figure 20. Fishing Bay $\log_{10}$ overall catch by species reference number. Black bars represent species captured in Fishing Bay that were not captured in the Wicomico River.

this is due to the lack of salinity in Mattawoman Creek. Therefore, Mattawoman Creek was viewed as a freshwater reference system, to which data gathered from stressed tidal freshwater systems will be compared in the future. The pattern in Fishing Bay was somewhat similar to the stressed tributaries (Figure 20).

Trophic Relationships

The trophic composition of the fish community in each tributary was examined. Species were loosely categorized as either planktivores, carnivores, or benthic feeders based on their prevalent adult habits (Carlander 1969, 1977; Eddy and Underhill 1978; Robins and Ray 1986) (Appendix I). Species primarily feeding on various forms of plankton were considered planktivores, those feeding primarily on other fish or invertebrates were considered carnivores, and primarily bottom dwelling and feeding species were grouped as benthic feeders.

Planktonic feeders were most abundant in all of the eight sampled tributaries with an average CPUE of 170 fish per tow or seine over all tributaries (Figure 21). However, planktivores represented a smaller percentage of the catch from Mattawoman Creek and Fishing Bay, accounting for 71% and 88% respectively, compared with 93% to 96% of the total catch in

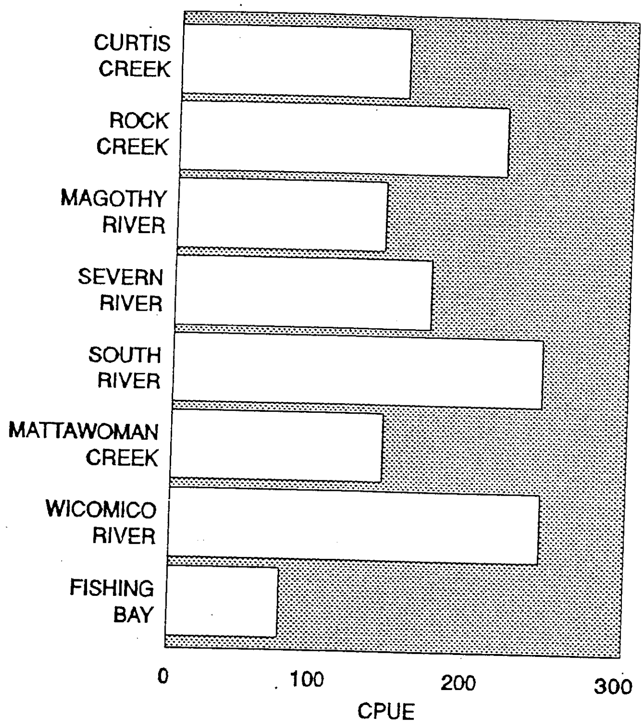


Figure 21. Three year overall mean CPUE of species classified as planktivores.

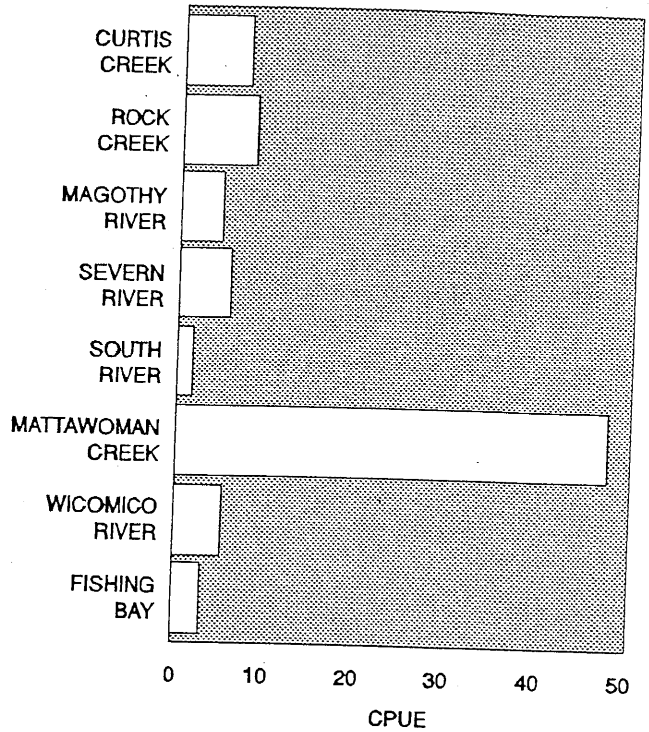


Figure 22. Three year overall mean CPUE of species classified as carnivores.

the other six tributaries. Carnivorous fish were most abundant in Mattawoman Creek with a CPUE of 48 fish per tow or seine, accounting for 26% of the total catch, but scarce in the other seven tributaries, representing only 2% to 4% of the catch (Figure 22). Overall, carnivores were slightly more common than benthic feeders. The average CPUE for carnivores over all tributaries was ten fish per seine or tow and the average CPUE for benthic feeders over all tributaries was six fish per seine or tow. Benthic feeders accounted for 2% to 8% of the catch (Figure 23).

Life History Strategy

All species were classified as marine, estuarine, freshwater, or anadromous spawners (Carlander 1969, 1977; Eddy and Underhill 1978; Lippson and Lippson 1984; Robins and Ray 1986) (Appendix I). We assigned species to each life history category based on the behavior of a species within the Chesapeake Bay. For example, white perch is generally considered to be a semi-anadromous species, but was classified as an anadromous fish for this analysis because it behaves as such within our study area.

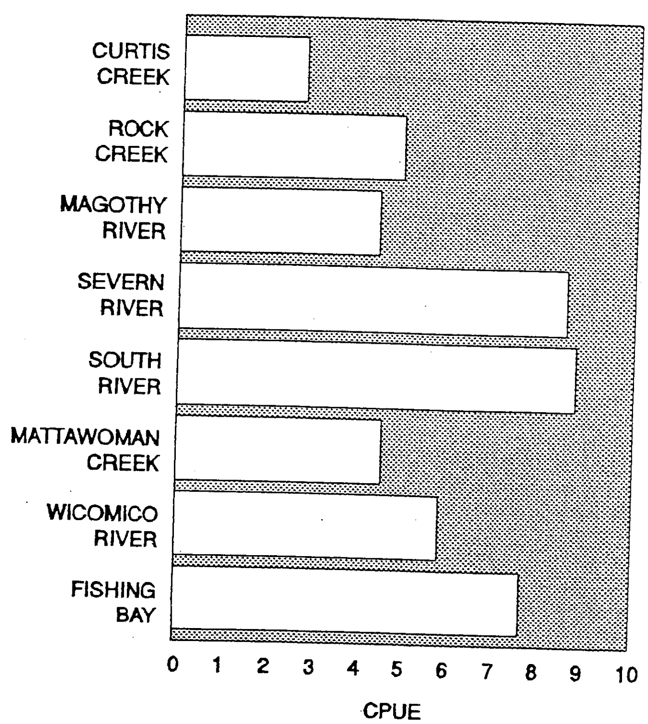


Figure 23. Three year overall mean CPUE of species classified as benthic feeders.

Freshwater spawners collected at our study sites included carp (*Cyprinus carpio*), redfin pickerel (*Esox americanus*), chain pickerel (*Esox niger*), spottail shiner (*Notropis hudsonius*), silvery minnow (*Hybognathus nuchalis*), brown bullhead (*Ictalurus nebulosus*), channel catfish (*Ictalurus punctatus*), white catfish (*Ictalurus catus*), black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis machrochirus*), pumpkinseed (*Lepomis gibbosus*), largemouth bass (*Micropterus salmoides*), and yellow perch (*Perca flavescens*). Freshwater spawners were most common in Curtis and Mattawoman creeks (Figure 24), but were also captured in most tributaries at the farthest upriver stations, presumably due to lower salinities in these areas.

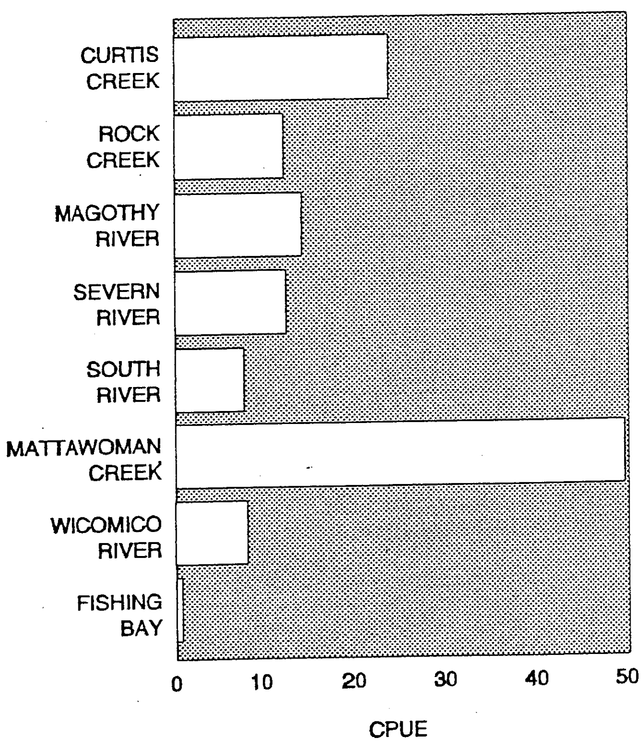


Figure 24. Three year overall mean CPUE of species classified as freshwater spawners.

Included among the estuarine spawners captured in this survey are three silversides (*Menidia menidia, Menidia beryllina, Membras martinica*), four killifish (*Fundulus heteroclitus, Fundulus majalis, Lucania parva, Cyprinodon variegatus*), three blennies (*Parablennius maromoreus, Chasmodes bosquianus, Hypsoblennius hentzi*), two gobies (*Microgobius thalassinus, Gobiosoma bosci*), northern pipefish (*Syngnathus fuscus*), two sticklebacks (*Apeltes quadracus, Gasterosteus aculeatus*), and bay anchovy. Estuarine spawners were most common in the Wicomico River and Curtis Creek (Figure 25). The fish assemblages of Rock Creek, Severn River, South River, Magothy River, Mattawoman Creek and Fishing Bay had comparatively fewer estuarine spawners.

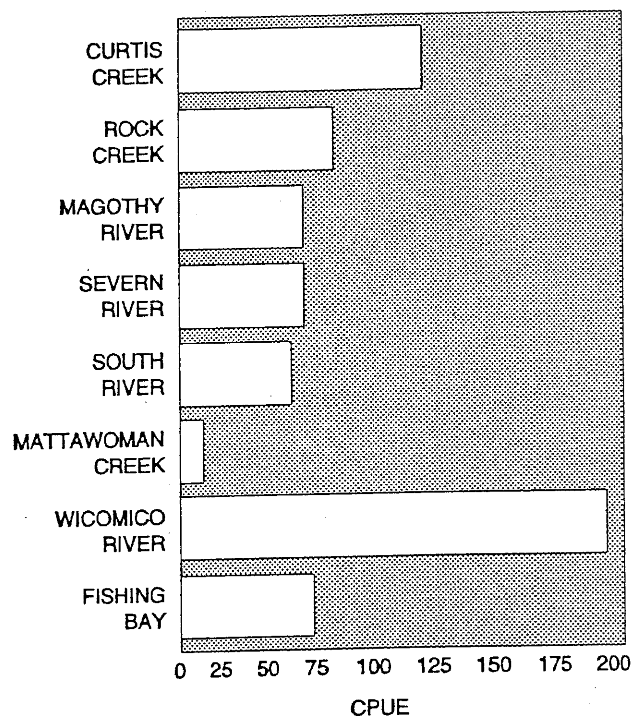


Figure 25. Three year overall mean CPUE of species classified as estuarine spawners.

Within the marine spawners category, we collected Atlantic needlefish (*Strongylura marina*), Atlantic menhaden, American eel (*Anguilla rostrata*), Atlantic croaker (*Micropogon undulatus*), spot (*Leiostomus xanthurus*), harvestfish (*Peprilus alepidotus*), inshore lizardfish (*Synodus foetens*), and two flounders (*Paralichthys dentatus, Pseudopleuronectes americanus*). The dominant member of this group was the Atlantic menhaden. Marine spawners were most common in the Severn River, South River, Magothy River, Wicomico River, and Rock Creek. Although Fishing Bay had the highest salinity of the eight study tributaries, this Eastern Shore site had a low overall mean CPUE of marine spawners, primarily due to a low catch of Atlantic menhaden. The differences among tributaries in catches of marine spawners was reduced when the Atlantic menhaden catch was removed (Figure 26). Marine spawners, especially Atlantic menhaden, were least common in Curtis Creek and Mattawoman Creek.

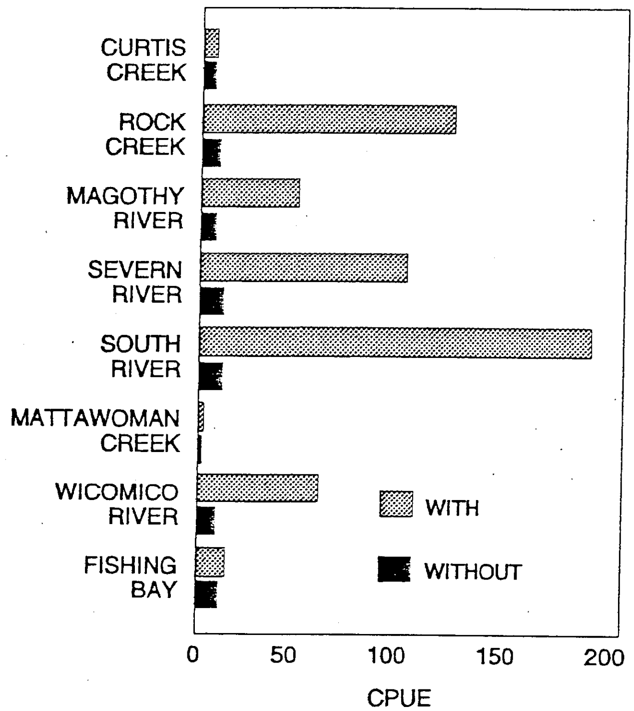


Figure 26. Three year overall mean CPUE of marine spawners with and without Atlantic menhaden catch.

Atlantic menhaden were an influential, though sporadic, component of the catch by this survey. While appearing in only 12.5% of the total seine hauls and trawl tows, they represented 36% of the total catch.

Anadromous and semi-anadromous species captured in the three year study were alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), blueback herring, striped bass (*Morone saxatilis*), and white perch. Mattawoman Creek, where all five species and 85% of the total anadromous catch was captured, ranked far above the other tributaries in this category (Figure 27). Fishing Bay was the only

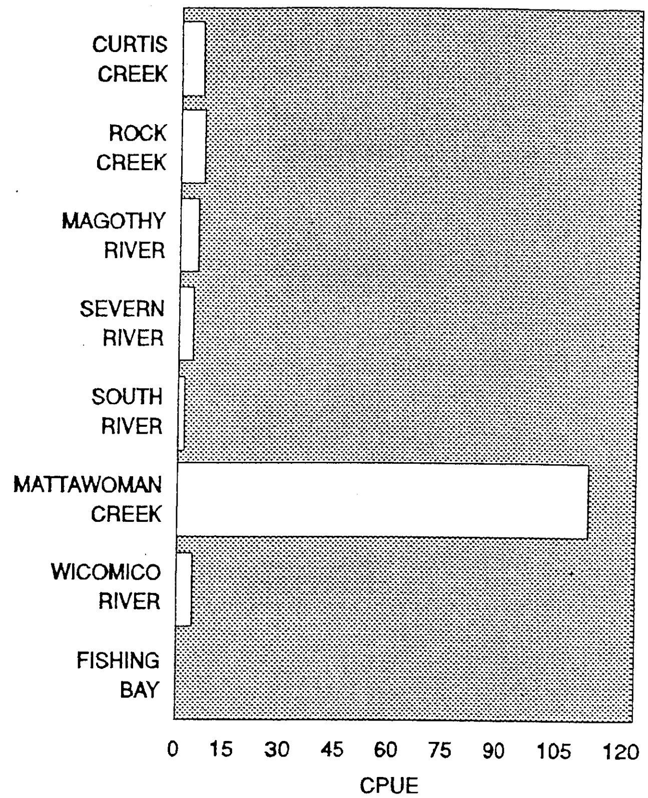


Figure 27. Three year overall mean CPUE of species classified as anadromous.

study area where no anadromous fish were captured. The striped bass catch was low in Mattawoman Creek; but in the other tributaries, striped bass was the most common anadromous species collected. Because sampling took place in summer, juveniles from spring spawning species were often captured (Figure 28). Eighty-six percent of the total anadromous fish catch by this survey was composed of juveniles.

The catch of anadromous species in Mattawoman Creek was dominated by blueback herring and white perch, which together represented 94% of the total anadromous species catch (Figure 29). Mattawoman Creek was the only sampled tributary where substantial numbers of blueback herring, white perch, or alewife were caught. American shad were only collected at Mattawoman Creek. The CPUE of anadromous juveniles in Mattawoman Creek was 40 times greater than in the other seven tributaries combined. Striped bass juveniles were common in upper western shore tributaries, which included the

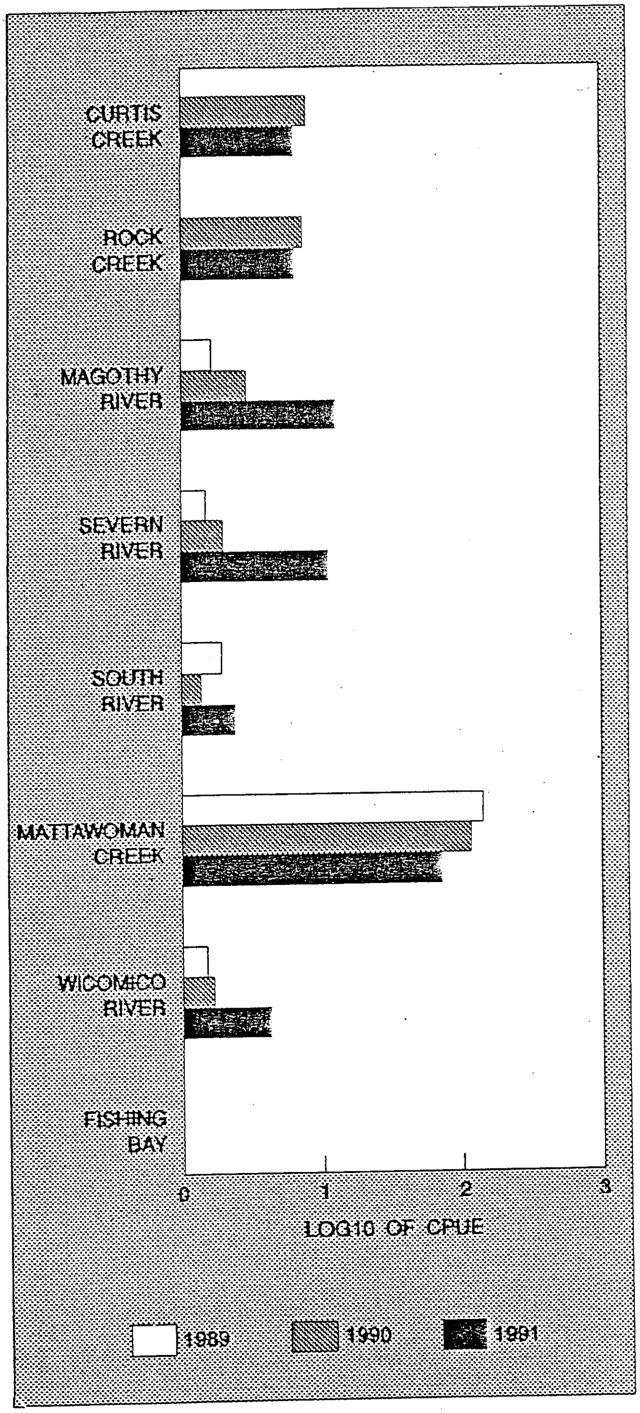


Figure 28. Mean $\log_{10}$ CPUE of anadromous species juveniles. No anadromous juveniles were captured in Fishing Bay over the sample period. Rock Creek, Curtis Creek and Fishing Bay were not sampled in 1989.

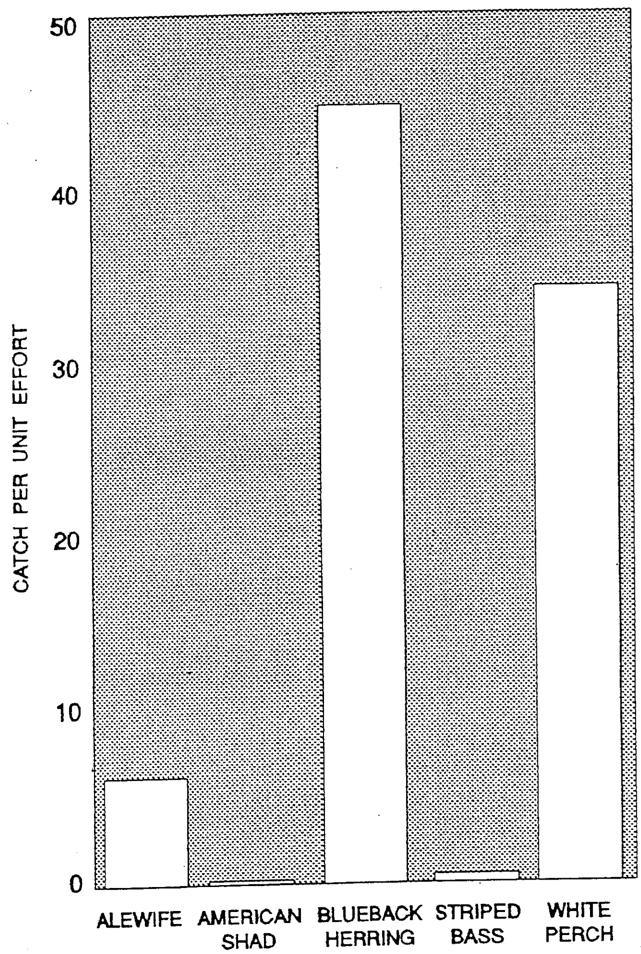


Figure 29. Mean CPUE of anadromous species juveniles captured in Mattawoman Creek, 1989 - 1991.

Severn River, Magothy River, Curtis Creek, and Rock Creek (Figure 30). We observed an increase in the CPUE of striped bass in the Severn River, Magothy River, and South River from 1989 to 1991. In comparisons between our upper bay tributary juvenile index for striped bass (the juvenile index is the seine CPUE of juveniles) and the upper bay juvenile index of the Maryland Estuarine Juvenile Finfish Survey, our rivers scored approximately the same in 1990 and much higher in 1991 (Figure 31) (personal communication: J. Uphoff, Maryland DNR Fisheries Division).

Like striped bass, the white perch is a recreationally and commercially important semi-anadromous fish. Few white perch were captured in any of our study areas except Mattawoman Creek (Figure 32). None were captured in Fishing Bay or the Severn River, which were both within the historic range of the species (unpublished data: Maryland DNR historical data).

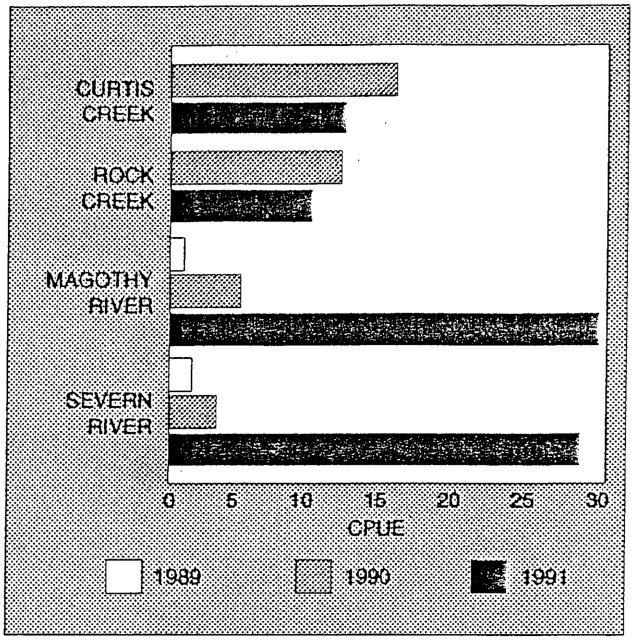


Figure 30. Mean CPUE of striped bass juveniles in upper bay tributaries. No data was collected for Rock Creek and Curtis Creek in 1989.

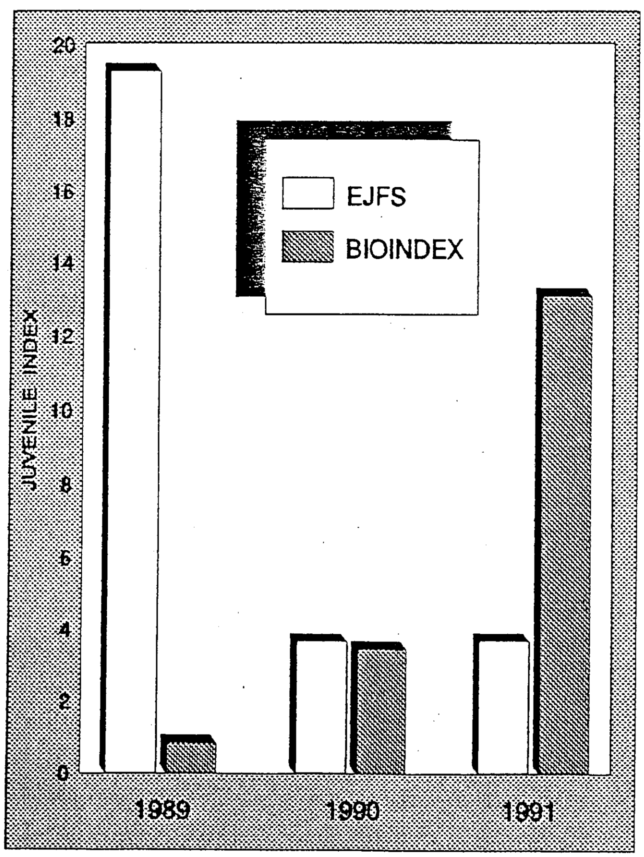


Figure 31. Comparison of striped bass juvenile index for the upper bay tributaries between the Maryland DNR Estuarine Juvenile Finfish Survey and this survey. Juvenile index = seine CPUE of juveniles.

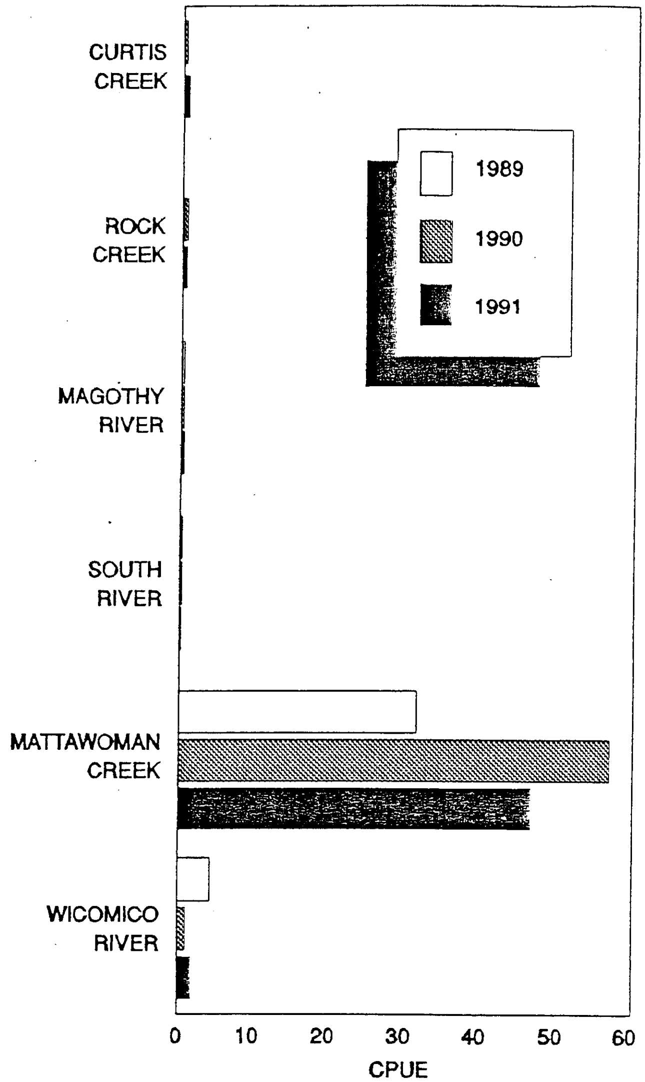


Figure 32. White perch CPUE by year and river. No white perch were captured in Fishing Bay and the Severn River. No data was collected for Rock Creek and Curtis Creek in 1989.

Species Richness

Three measures were used to interpret species richness at our sampling stations. One measure was the total number of species captured at a station. To compare tributaries, we calculated the mean number of species captured each year (Figure 33). The mean number of species captured per year was greatest in Mattawoman Creek, where means for each year ranged from 11.7 to 15.1. The Wicomico River had a slightly lower mean number of species, with values ranging from 11.2 to 13.3. The mean number of species captured each year in the other six tributaries ranged from 7.0 to 10.3. The Severn River, South

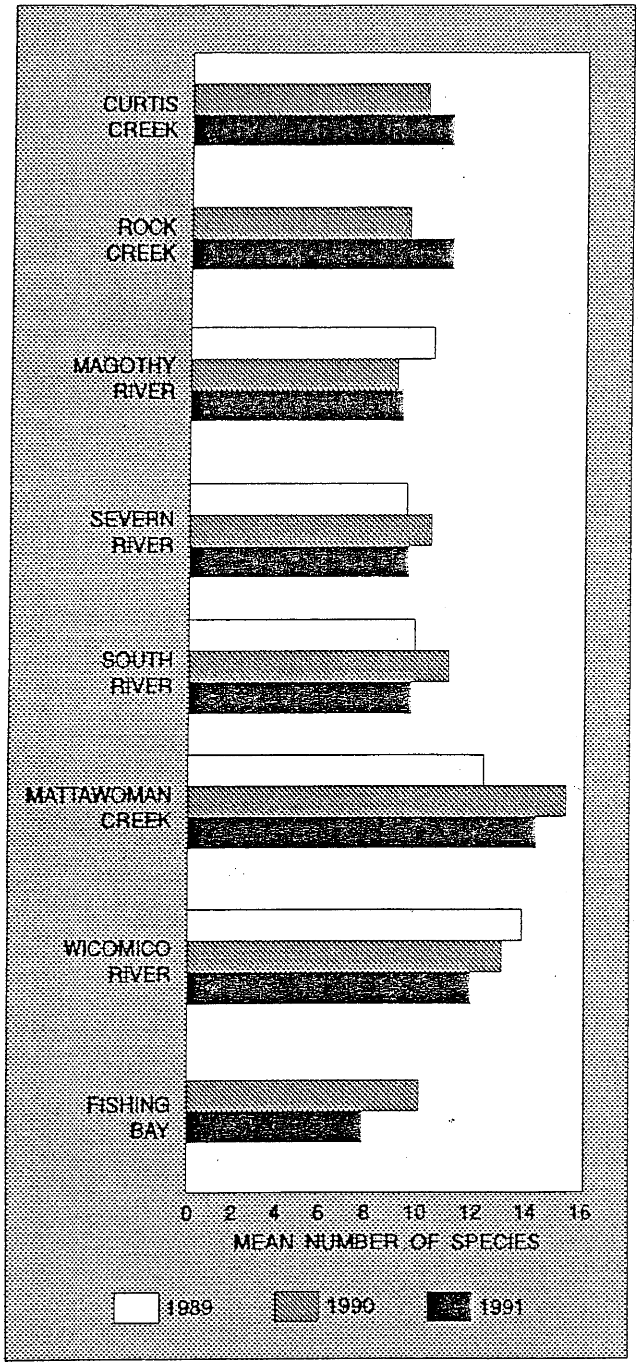


Figure 33. Mean number of species captured by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989.

River, and Mattawoman Creek showed slight increases in mean species number in 1990 and declines in 1991. The Wicomico River showed continued decrease in mean species number over the three years of sampling.

The number of species comprising 90% of the catch at a station is another indicator of species richness (Figure 34). Mattawoman Creek scored highest in

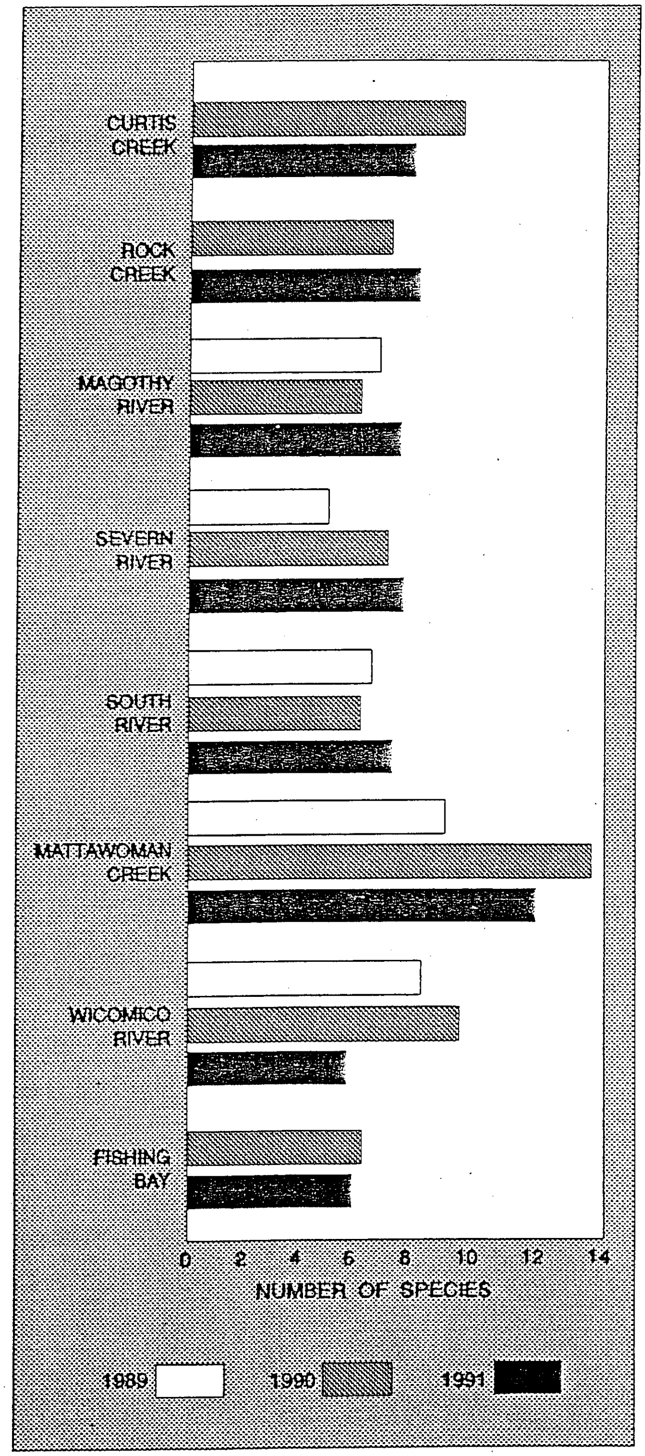


Figure 34. Mean number of species comprising 90% of the catch by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989.

this category, with the means for each year ranging from 7.9 to 12.4. The yearly means in the Wicomico River ranged from 4.9 to 8.3. The other six tributaries had yearly means ranging from 4.3 to 8.3. The Magothy River, Severn River, South River, Mattawoman Creek and Rock Creek showed increases in this measure over the sample period.

The quality of deep water habitat should be reflected in the number of fish species captured by the bottom trawl. The total number of species captured in bottom trawl tows was compiled for each year (Figure 35). Mattawoman Creek had the highest species numbers, with 14 to 19 species captured per year in bottom trawls from 1989 to 1991. Fishing Bay and the Wicomico River both had 8 to 13 species captured in bottom tows per year. The Magothy River declined from 11 species in 1989 to 2 species in 1990 and only 3 species in 1991. Rock Creek and Curtis Creek had the lowest species numbers in bottom trawl catches. Curtis Creek had 1 species in 1990 and 1991 and Rock Creek had 2 species in 1990 and 1 species in 1991. Between 1989 and 1991, the number of species captured in bottom trawl tows increased from 2 to 6 in the South River but decreased from 4 to 2 in the Severn River.

Resident versus non-resident species

Another way we examined the fish communities in the sampled tributaries was by comparing the CPUE of resident species to non-resident species (Figure 36, Appendix I) (Lippson and Lippson 1984). The Wicomico River had the highest CPUE of resident species. In Rock Creek, Severn River, South River, and Mattawoman Creek, the catch of non-resident species was greater than the catch of resident species.

Target Species

The Chesapeake Bay Program identified local species that represent the various trophic levels and habitat types within the Bay (Funderburk et al. 1991). The CPUE effort for these species in our survey for each year was included in this report to serve as a reference for other Chesapeake Bay surveys. Atlantic menhaden was the most commonly captured target species, followed in decreasing abundance by bay anchovy, blueback herring, white perch, striped bass, spot, alewife, yellow perch and American shad. No hickory shad were captured in the sampled tributaries during the three year study period (Figure 37).

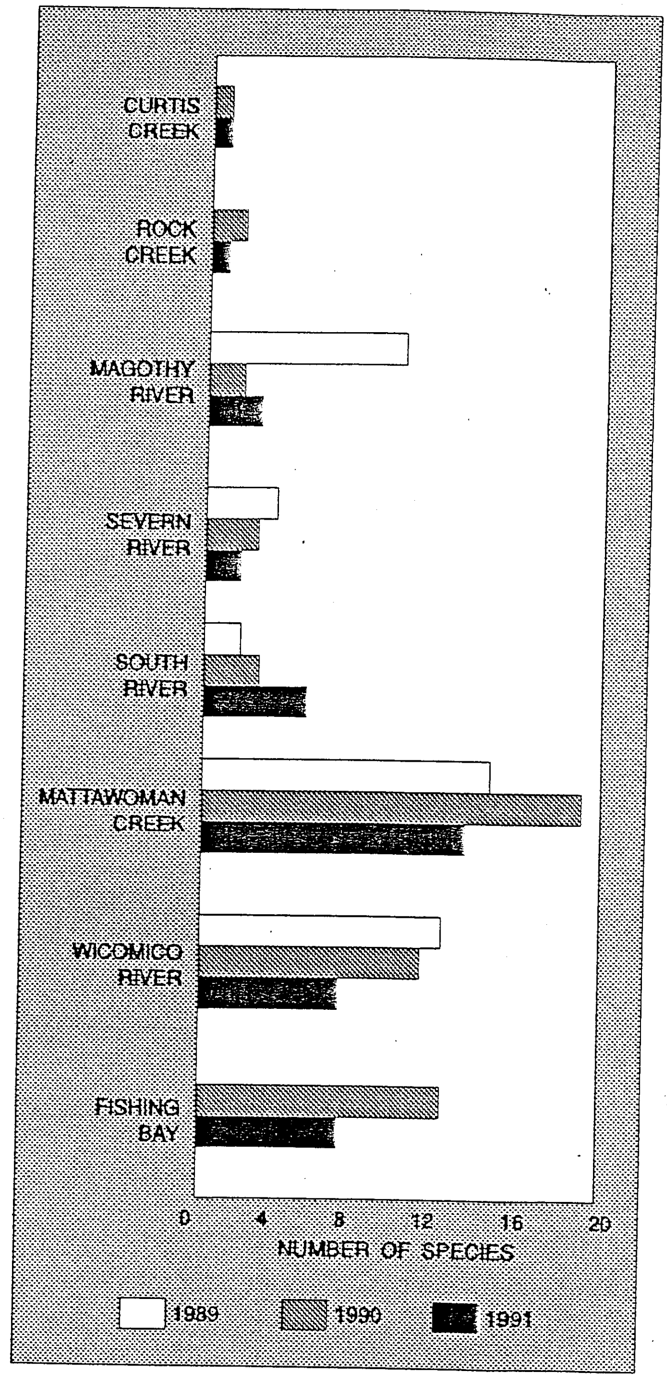


Figure 35. Mean number of species captured in bottom trawl tows by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989.

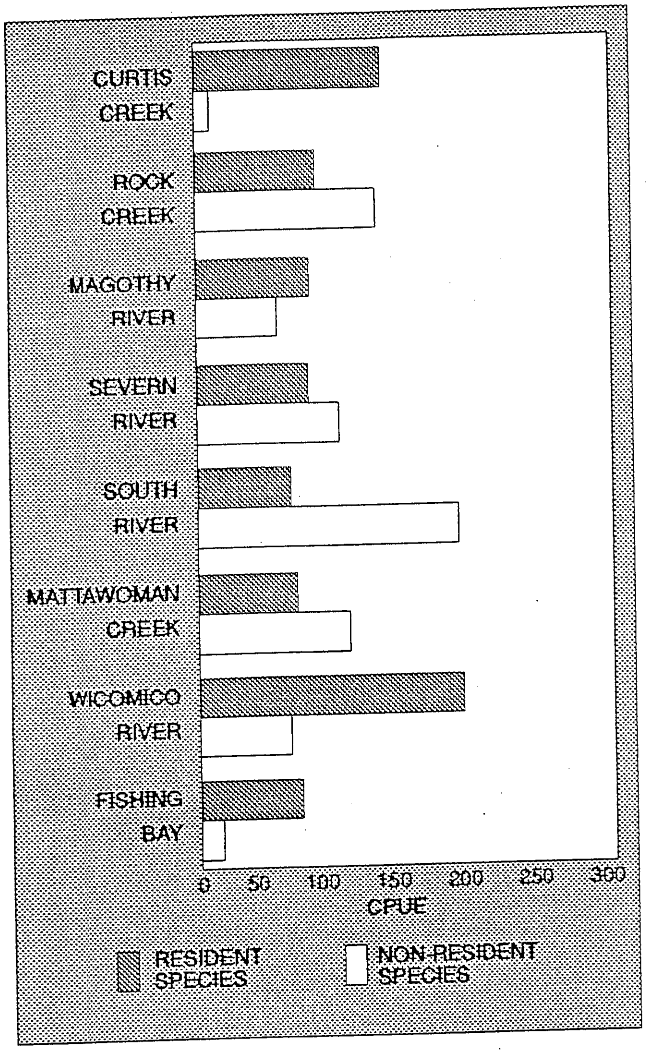


Figure 36. Comparison of overall mean CPUE between resident and non-resident species by river.

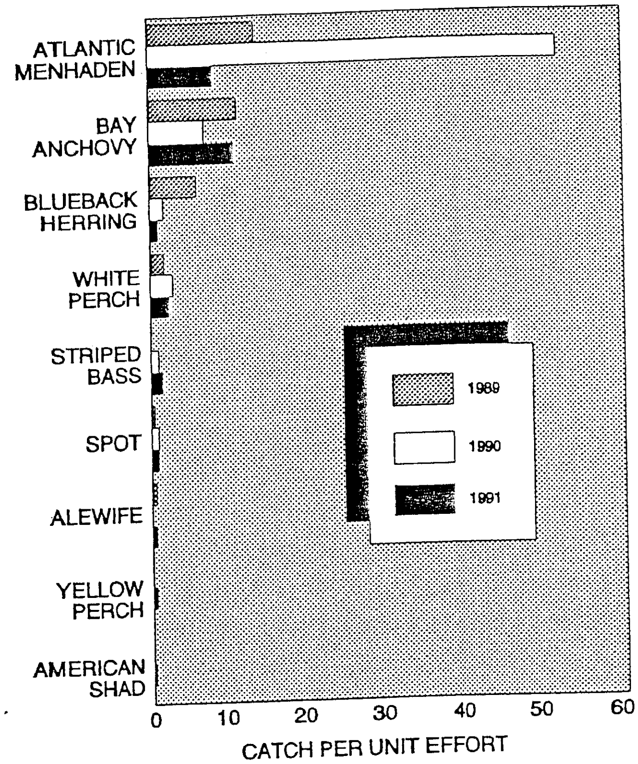


Figure 37. Mean CPUE for all sampled tributaries of Chesapeake Bay target species as identified by the Chesapeake Bay Program.

Unusual Catches

Unusual and interesting species occasionally were captured during this survey. Small numbers, usually just one or two individuals, of several species increased the overall species count. Among these unusual species were ladyfish (*Elops saurus*), Atlantic spadefish (*Chaetodipterus faber*), Northern puffer (*Sphaeroides maculatus*), offshore tonguefish (*Symphorus civitatus*), red drum (*Sciaenops ocellatus*), feather blenny, green goby, goldfish (*Carassius auratus*), quillback (*Carpiodes cyprinus*), and seaweed blenny (*Parablennius marmoreus*). A large cownose ray (*Rhinoptera bonasus*) with a wingspan possibly exceeding 1 meter was captured in a seine haul at station 4 in the Wicomico River in July 1991, but unfortunately proved to be too large and powerful for a beach landing.

Water Quality

There was indication of improving water quality conditions in some tributaries during the sample period, 1989 to 1991. Mean bottom dissolved oxygen values showed an increasing trend at many stations, and for all study stations in the Severn River, South River, Wicomico River, Curtis Creek and Mattawoman Creek (Figure 38). Mean salinity values increased in the tributaries between 1989 and 1991 (Figure 39).

Land Use

To begin relating changes in fish assemblages to land use, tributaries were categorized according to the dominant land use within each watershed, with special attention paid to areas immediately adjacent

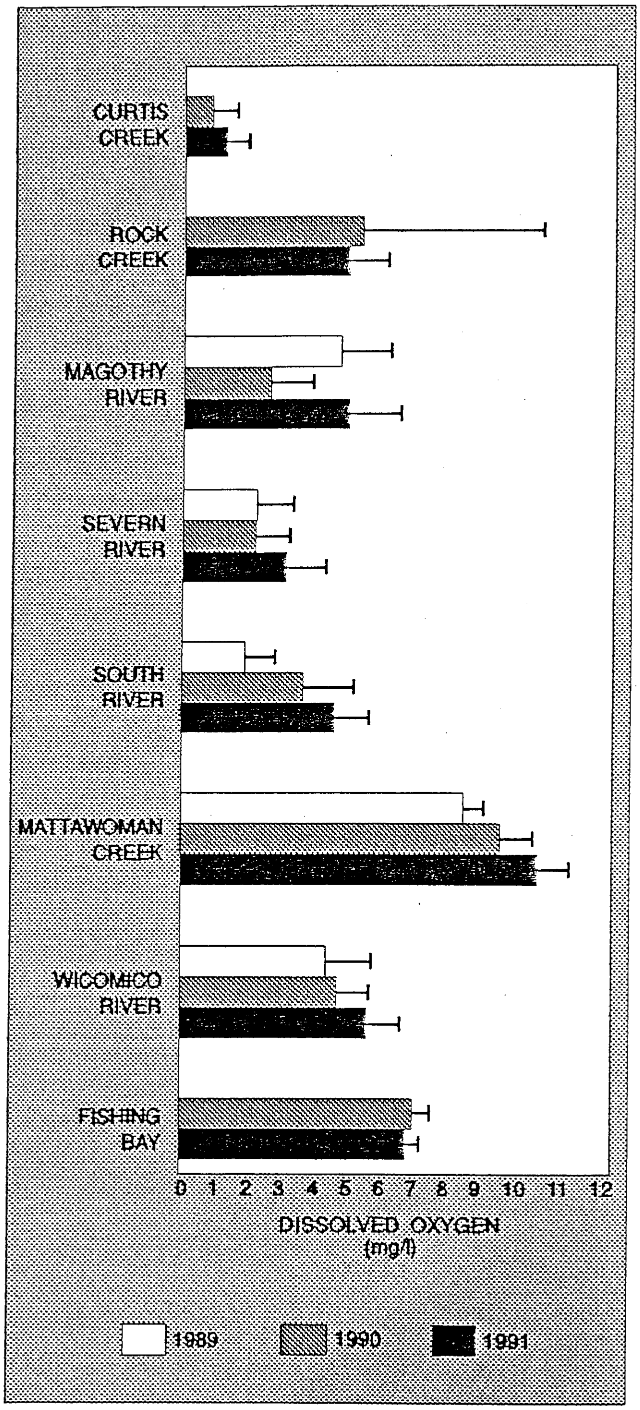


Figure 38. Mean bottom DO by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989. Bar extensions = 2 standard errors.

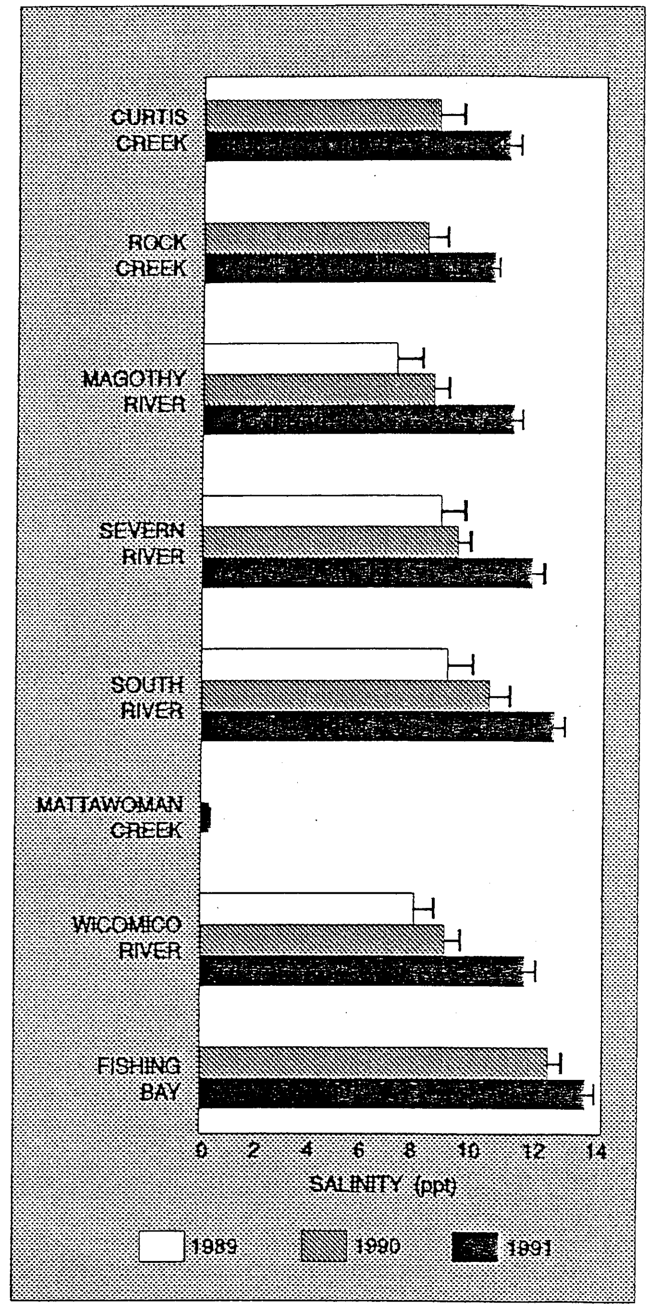


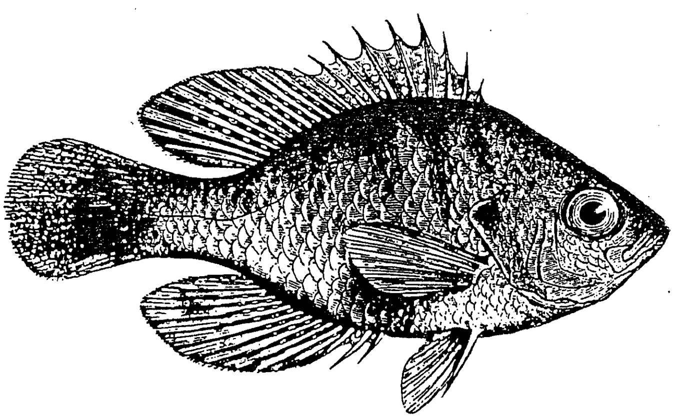
Figure 39. Overall mean salinity by river and year. No data was collected for Rock Creek, Curtis Creek and Fishing Bay in 1989. Bar extensions = 2 standard errors.

to the tributary itself (Figure 40). We categorized the Severn River, South River, Magothy River, and Rock Creek as urban-impacted. These rivers are characterized by urban development in their watersheds and along their shorelines. The dominant land use in Rock Creek and the Magothy River is urban. Although total urban area is secondary to forested land in the Severn and South rivers, most of the development is along the shoreline in the tidal areas we sampled and therefore we feel it is more influential on the fish communities than the forested areas near the headwaters. Curtis Creek has industrial develop-

	URBAN	FOREST	AGRICULTURE	COMMERCIAL	WATER	WETLANDS
CURTIS CREEK	43.30	28.65	4.29	17.45	4.21	0.25
ROCK CREEK	45.22	29.26	3.47	4.02	18.02	0.0
MAGOTHY RIVER	43.13	28.29	5.18	3.11	19.86	0.0
SEVERN RIVER	33.43	36.86	9.68	4.09	15.02	0.12
SOUTH RIVER	21.80	44.10	17.20	2.04	13.74	0.41
MATTAWOMAN CREEK	15.77	64.10	13.65	1.82	3.02	1.12
WICOMICO RIVER	6.08	41.24	29.98	0.20	18.73	3.62
FISHING BAY	0.57	37.12	6.25	0.08	22.94	33.00

Figure 40. Percent of watershed acreage for each general land use classification by tributary. Industrial acreage is included in the commercial classification. Barren land, less than 2% at all tributaries, is omitted from this figure.

ment along much of its lower shoreline and the largest proportion of industrial land of the study areas, so we classified it as industrial-impacted. The Wicomico River watershed has sparse residential development and farmland occasionally reaching the shoreline. It was classified as the saltwater reference site. Tree cover dominates the shoreline of Mattawoman Creek and the watershed has little urban or commercial development, so was classified as the freshwater reference site. Fishing Bay is located in a lightly developed area of the Eastern shore. The watershed contains a large wildlife refuge and shoreline development is sparse. The major influence upon the watershed appears to be the forests and wetlands that account for over 70% of the land area, so Fishing Bay was classified as low density/rural-impacted.



DISCUSSION

The fish communities of eight Chesapeake Bay tributaries were sampled with seines and trawls during the summers of 1989, 1990, and 1991. The data are being used to evaluate an index of biotic integrity, or bioindex, for tidal tributaries and subestuaries. The catches in all eight tributaries were dominated by Atlantic menhaden, Atlantic silverside, and bay anchovy. Planktivores were the dominant trophic group. The greatest catch of anadromous species occurred in Mattawoman Creek.

Previous studies have documented the effects of pollution and urbanization on individual species, fish assemblages, and aquatic habitat. Multi-species indices have been effective at indicating habitat conditions in small freshwater streams in the midwest (Karr et al. 1986, Karr 1987, Plafkin et al. 1989). It has also been shown that such indices are adaptable for use in other regions and habitats (Miller et al. 1988, Karr 1991, Hughes and Noss 1992). Fish communities in estuarine systems have been shown to respond to anthropogenic stress (Betchel and Copeland 1970, Vaas and Jordan 1991). Fish communities in estuarine systems should therefore be useful indicators of ecological stress, just as in freshwater streams. A bioindex based on estuarine fish assemblages appeared to respond to water quality conditions (Jordan et al. 1991).

Fish communities may respond to environmental stresses in many ways. Sensitive species may experience reduced survival and reproductive success, the proportion of trophic and habitat generalists may increase, the proportion of insensitive and tolerant species may increase, and there may be a resultant imbalance in species diversity (Betchel and Copeland 1970, Hughes and Noss 1992). Dissolved oxygen conditions in tidal and non-tidal waters also decline in response to urbanization (Limburg and Schmidt 1990).

The fish communities in the stressed tributaries we sampled appeared to reflect some of the changes expected of degraded habitat, such as an imbalance of species, changing trophic structure, decreased reproduction of sensitive species, and decreased species richness, suggesting that fish community assemblages hold promise as indicators of ecological health of subestuaries. By comparing various components of the fish assemblages in these tributaries to the predominant land use within their watersheds, we hope to establish a basis for quantifying the effects of anthropogenic influences upon the living resources of Chesapeake Bay tidal tributaries.

Changes in the trophic structure of a fish community may be another indicator of ecological stress. Mattawoman Creek appeared to have a more balanced trophic structure than the other tributaries, with planktivores being less dominant. However, some of the differences in Mattawoman Creek may be attributed to the lower salinity.

Because Atlantic menhaden are tolerant and trophic generalists (Peters and Lewis 1984, Jordan et al. 1991, Lippson 1991), a large catch of this species in a tributary could be an indication of stress. However, their low capture frequency and high catch percentage made it difficult to assess trends among the sampled tributaries, and their capture by this survey did not appear to accurately reflect any degree of habitat degradation. Atlantic menhaden can appear to be a dominant component of the fish assemblage in a tributary, while actually only being abundant but transient visitors. The dominance of Atlantic menhaden in this survey seems to reflect their schooling behavior. They represented the largest proportion of the effort.

Estuarine spawners possibly reflected habitat conditions within the sampled tributaries. When the catch of estuarine spawners was compared among tributaries, fewer species were found in the stressed tributaries. By comparison, the most species were found in the saltwater reference tributary, the Wicomico River.

These fish live year-round in the tributaries and must adapt to existing habitat conditions to survive. The poor habitat conditions in our study tributaries classified as stressed may make year-round survival difficult. Mattawoman Creek ranked low, probably reflecting more the lack of salinity than poor habitat conditions.

The anadromous species of the Chesapeake Bay are sensitive to anthropogenic stresses, and the decline in their stocks can be associated with the actions of man, through fishing mortality and loss or degradation of habitat (Speir 1987, Funderburk et al. 1991, Jordan et al. 1991). The low anadromous catches we recorded in the stressed tributaries may be a response to increased anthropogenic influences. The low catches in the saltwater reference tributary, the Wicomico River, probably reflected its location as a tributary of the lower Potomac River and not habitat degradation. Generally, the pre-spawning adults of anadromous species would be expected to travel farther upriver, until they find less saline water that will trigger them to move into a tributary or subtributary. The high salinity at the mouth of the Wicomico River would likely make it less desirable than a tributary located further upstream such as Mattawoman Creek, where freshwater is found at the mouth.

Mattawoman Creek catches possibly reflected the predominant forested land use and lower levels of urbanization in the watershed. Mattawoman Creek is considered to be one of the most important fish spawning and nursery tributaries on the Potomac River. Mattawoman Creek is also designated an area of Critical State Concern by the Maryland Department of State Planning, due to the large numbers of wildlife, and diverse bird, plant, and animal life located within the watershed (Charles County 1990).

The juvenile striped bass catch in the upper western shore tributaries are a positive sign, both for the species and the tributaries. Although these tributaries show signs of degradation, they are still playing an important role in the reproductive success of at least one Chesapeake Bay anadromous fish species.

No anadromous fish were captured in Fishing Bay in 1990 or 1991 by this survey. Historical records from unpublished Maryland DNR data from 1959 and 1960 show the presence of striped bass, white perch, blueback herring and alewife. Undocumented fishing reports have indicated recent spring (1992) catches of white perch in the Blackwater River, a tributary of Fishing Bay. Because seining was shown to be effective at capturing juvenile anadromous species in our other study tributaries, it seems likely that few anadromous species are reproducing successfully in the Fishing Bay watershed. However, it is also possible that these fish were not as vulnerable to capture on the shallow flats of our Fishing Bay seine stations. Their absence may also be due to unknown influences within the watershed.

Dissolved oxygen (DO) is important to living resources and responsive to urbanization within watersheds. Therefore, one goal of this study was to investigate the relationship between fish assemblages and DO in the eight sampled tributaries. Bottom trawl catches were most strongly associated with DO. Strong groupings among tributaries with similar land usage in their watersheds were evident when the number of fish species captured by bottom trawls was plotted against bottom DO (Figure 41). Each data point on this graph represents the total number of species captured by the bottom trawl in each tributary, each sampling round; plotted against average bottom DO for each tributary, each sampling round. For example, there is one point that represents the total number of species captured for stations one through five on the Severn River in July of 1991 versus the average bottom DO value for those stations in July of 1991. Stations in Mattawoman Creek (freshwater reference), Wicomico River (saltwater reference) and Fishing Bay (rural) had high DO and a correspondingly high number of fish species captured in the bottom trawl. The Severn, South, and Magothy Rivers, and Rock Creek (urban-impacted), as a group, had lower DO and fewer species. Curtis Creek (industrial) had low numbers of species captured in the bottom trawl regardless of DO.

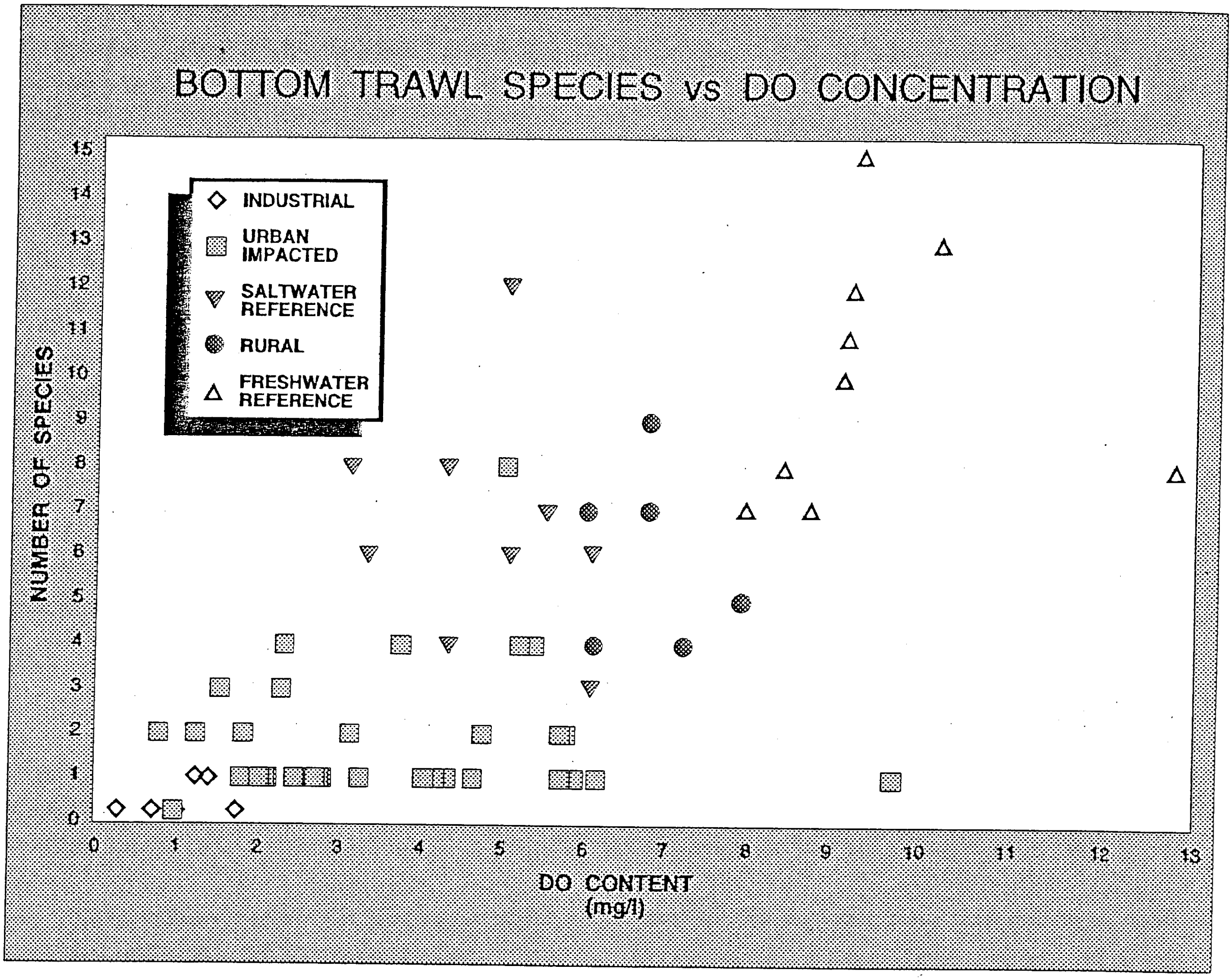


Figure 41. Number of species captured by bottom trawl tows in each sampling round plotted against mean bottom DO in each sampling round. Tributaries are grouped according to broad land use categorizations. Mattawoman Creek is a freshwater reference, Fishing Bay is classified as rural and the Wicomico River is a saltwater reference. The South River, Severn River, Magothy River and Rock Creek are grouped as urban-impacted. Curtis Creek is classified as industrial.

Mean salinity increased over the study period. This trend can possibly be explained by streamflow entering the Bay. The estimated Chesapeake Bay discharge decreased from 148.9 x $10^3ft^3/s$ in 1989 to 64.6 x $10^3ft^3/s$ in 1991 (Figure 42) (USGS 1989, 1990, 1991). Decreased discharge represents less freshwater entering the Bay and a corresponding increase in salinity.

The project was expanded in 1990 to sample a broader range of habitat conditions by adding Fishing Bay, Curtis Creek and Rock Creek, with some surprising results. Fishing Bay was added to the study because it was thought to be a relatively unspoiled environment. However, the fish community exhibited low species diversity and low overall catch, and no anadromous fish were captured. This suggests the presence of environmental stress in the system, but the extent and nature is not known at this time. Work in the future will more closely examine this system and its watershed for clues as to what has caused the apparent degradation of the fish community.

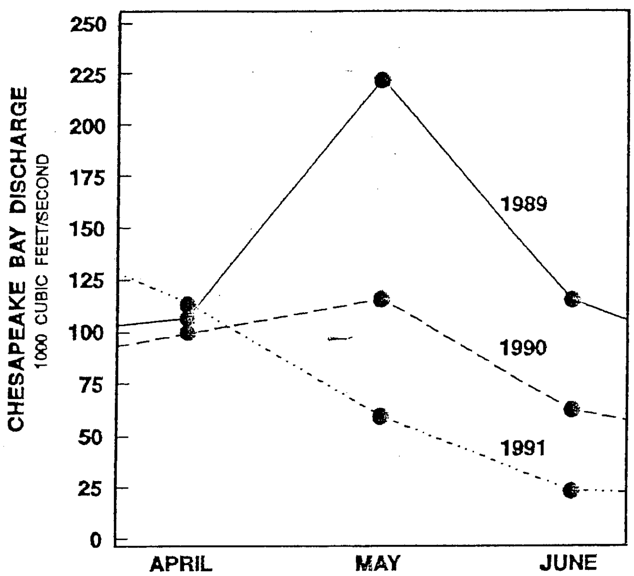


Figure 42. Estimated USGS Chesapeake Bay spring discharge rates by year.

Conversely, Curtis Creek and Rock Creek had better fish communities than was expected based on land usage in the watersheds. These are the most urbanized and industrially impacted tributaries sampled, so low catch and low species diversity were expected. Instead, many samples compared favorably to other less impacted tributaries, especially with respect to juvenile striped bass. These areas appear to be striped bass nurseries for the upper bay spawning stocks.

While we consider the design and results of our sampling program to be valid, further investigation has revealed potential shortcomings. Most obvious is that sampling is limited to summer months. Summer was chosen because we assumed it was the season when the most complete fish assemblage would be present. We hope to conduct some fall and spring sampling in the future to address the question of seasonal variations in the fish communities of the sampled tributaries.

There has been some difficulty in interpreting DO data, largely because of the monthly sampling frequency. To obtain better information on the diurnal variation in DO values, we plan to deploy a continuous sampling buoy in the Wicomico River and a Hydrolab field data logger in the South River in spring of 1993. The buoy is on loan from the US Environmental Protection Agency's Chesapeake Bay Program. Data from continuous sampling of dissolved oxygen will be used to generate time series graphs of water quality conditions and provide a better understanding of the monthly sampling data. The catch data may also be somewhat influenced by selection of seining stations. In some instances, we chose stations where a seine could be successfully worked, but that are not necessarily representative of habitat in a tributary. For example, in some heavily bulkheaded areas, we were forced by the logistics of seining to sample the only available sandy beach, and may therefore have captured more fish as a result. Fewer stations were sampled in those tributaries added in 1990, either because of their small size (Curtis Creek and Rock Creek), or because of a lack of seineable stations (Fishing Bay).

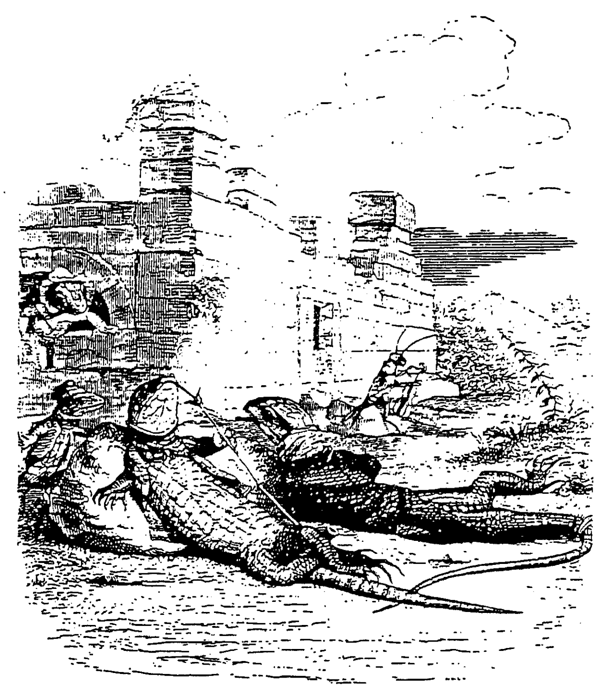
In spite of these shortcomings and the difficulty in fully sampling large subestuaries, this project appears to be accomplishing the goal of developing indices of biotic integrity, or bioindices, for estuarine tributaries. Analysis of the fish communities in these eight tributaries of the Chesapeake Bay suggests that fish assemblages can be used as indicators of habitat degradation, just as is done in small freshwater systems. There appear to be differences in the fish community structure among the sampled tributaries that can be detected with the relatively inexpensive sampling procedures described in this report.

The project was continued in 1992 with some modifications to increase sampling efficiency. The midwater and inshore trawls were dropped from sampling after 1991, based on the low numbers of species and individuals captured, the dominance of the catch by anchovies, and the high percentage of tows capturing no fish. This decision also was influenced by the fact that midwater and inshore tows cannot be made at some stations due to a lack of suitable sampling areas.

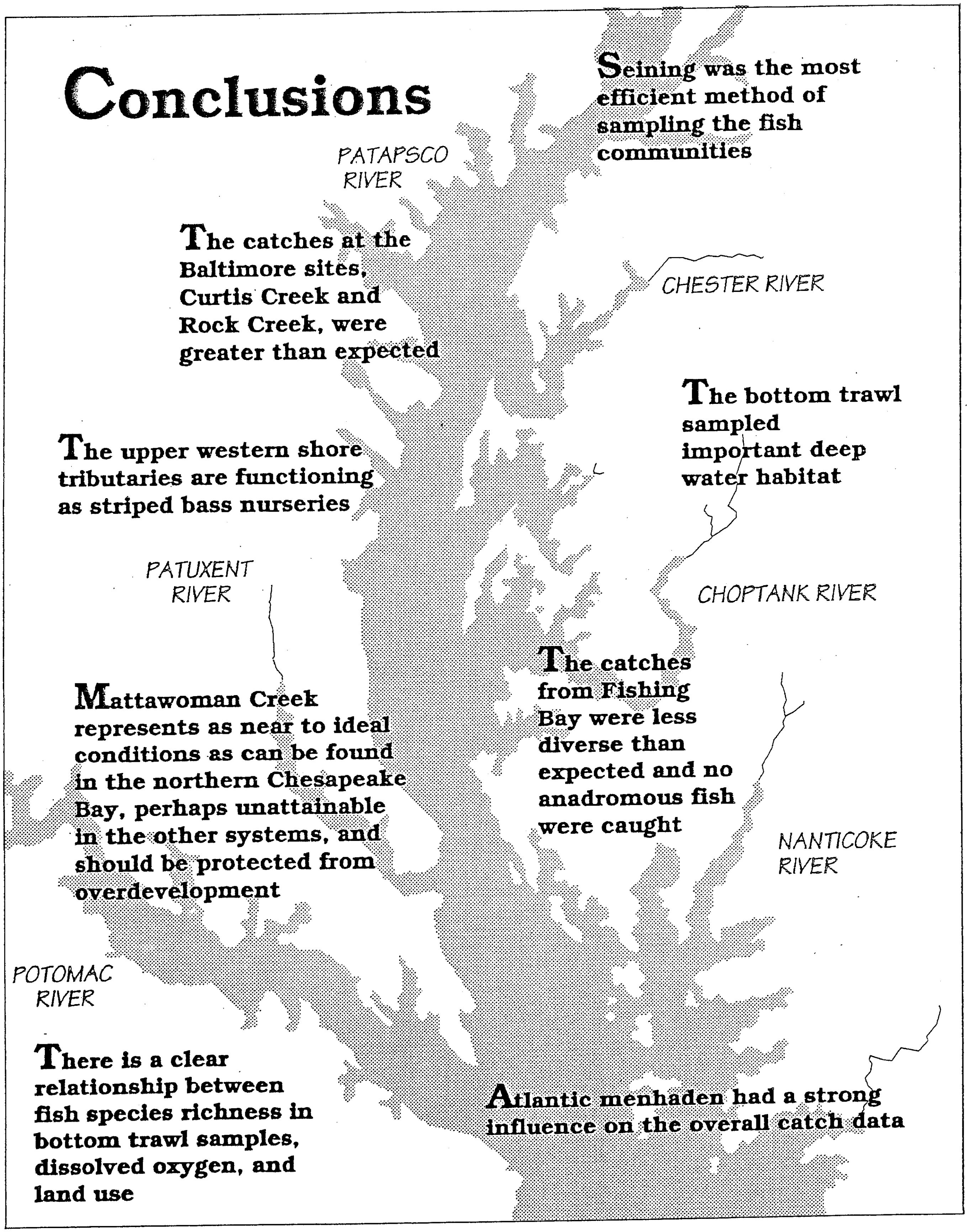
The bottom trawl was retained in future sampling for several reasons. This gear provides information about deep water habitats, often devoid of dissolved oxygen in the summer, that are important in the development of the bioindex procedures. The bottom trawl is deployable at all stations and, unlike the midwater trawl, can be deployed easily by inexperienced personnel.

This report is intended to be a data compilation and preliminary evaluation effort. Development and testing of the bioindex is continuing and this report supports those efforts. A detailed analysis of the bioindex will be presented in a future report slated for early 1993.

We hope to continue this project in the future to expand our knowledge of the relationship between land use and fish communities in Chesapeake Bay tributaries. We would like to better understand the apparent decline of the fish community in Fishing Bay, and the apparently healthy fish communities in Rock Creek and Curtis Creek. We would like to sample some degraded freshwater tributaries to compare to Mattawoman Creek. We would also like to conduct continuous water quality monitoring in the sampled tributaries to aid in interpreting our monthly water quality data.



Conclusions



Seining was the most efficient method of sampling the fish communities

The catches at the Baltimore sites, Curtis Creek and Rock Creek, were greater than expected

The bottom trawl sampled important deep water habitat

The upper western shore tributaries are functioning as striped bass nurseries

Mattawoman Creek represents as near to ideal conditions as can be found in the northern Chesapeake Bay, perhaps unattainable in the other systems, and should be protected from overdevelopment

The catches from Fishing Bay were less diverse than expected and no anadromous fish were caught

There is a clear relationship between fish species richness in bottom trawl samples, dissolved oxygen, and land use

Atlantic menhaden had a strong influence on the overall catch data

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APPENDIX I

Resident Species Reference Table and Codes

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Atlantic Silverside *Menidia menidia*	Planktivore	ATH	Estuarine	45107	42.4337
Banded Killifish *Fundulus diaphanus*	Planktivore	CYD	Freshwater	1014	0.9539
Bay Anchovy *Anchoa mitchilli*	Planktivore	ENG	Estuarine	29394	27.6519
Black Crappie *Pomoxis nigromaculatus*	Carnivore	CEN	Freshwater	4	0.0038
Bluegill *Lepomis macrochirus*	Planktivore	CEN	Freshwater	938	0.8824
Brown Bullhead *Ictalurus nebulosus*	Benthic	ICT	Freshwater	279	0.2625
Carp *Cyprinus carpio*	Benthic	CYP	Freshwater	60	0.0564
Chain Pickerel *Esox niger*	Carnivore	ESO	Freshwater	53	0.0499
Channel Catfish *Ictalurus punctatus*	Benthic	ICT	Freshwater	67	0.0630
Feather Blenny *Hypsoblennius hentzi*	Benthic	BLE	Estuarine	1	0.0009
Fourspine Stickleback *Apeltes quadracus*	Planktivore	GAS	Estuarine	46	0.0433
Gizzard Shad *Dorosoma cepedianum*	Planktivore	CLU	Freshwater	2100	1.9755
Golden Shiner *Notemigonus crysoleucas*	Planktivore	CYP	Freshwater	40	0.0376
Goldfish *Carassius auratus*	Benthic	CYP	Freshwater	4	0.0038
Green Goby *Microgobius thalassinus*	Benthic	GOB	Estuarine	1	0.0009
Hogchoker *Trinectes maculatus*	Benthic	SOL	Estuarine	402	0.3782

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Inland Silverside *Menidia beryllina*	Planktivore	ATH	Freshwater	7077	6.6576
Largemouth Bass *Micropterus salmoides*	Carnivore	CEN	Freshwater	94	0.0884
Mummichog *Fundulus heteroclitus*	PLanktivore	CYD	Estuarine	3779	3.5550
Naked Goby *Gobiosoma bosci*	Benthic	GOB	Estuarine	30	0.0282
Northern Pipefish *Syngnathus fuscus*	Planktivore	SYN	Estuarine	215	0.2023
Oyster Toadfish *Opsanus tau*	Benthic	BAT	Estuarine	8	0.0075
Pumpkinseed *Lepomis gibbosus*	Planktivore	CEN	Freshwater	1675	1.5757
Quillback *Carpiodes cyprinus*	Benthic	CAT	Freshwater	1	0.0009
Rainwater Killifish *Lucania parva*	Planktivore	CYD	Estuarine	5	0.0047
Redfin Pickerel *Esox americanus*	Carnivore	ESO	Freshwater	2	0.0019
Rough Silverside *Membras martinica*	Planktivore	ATH	Estuarine	142	0.1336
Satinfin Shiner *Notropis analostanus*	Planktivore	CYP	Freshwater	1	0.0009
Seaweed Blenny *Parablennius marmoreus*	Benthic	BLE	Estuarine	1	0.0009
Sheepshead Minnow *Cyprinodon variegatus*	Planktivore	CYD	Estuarine	165	0.1552
Silvery Minnow *Hybognathus nuchalis*	Planktivore	CYP	Freshwater	1035	0.9737
Skillet Fish *Gobiesox strumosus*	Benthic	GOS	Estuarine	69	0.0649

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Spottail Shiner *Notropis hudsonius*	Planktivore	CYP	Freshwater	1634	1.5372
Striped Anchovy *Anchoa hepsetus*	Planktivore	ENG	Marine	224	0.2107
Striped Blenny *Chasmodes bosquianus*	Benthic	BLE	Estuarine	17	0.0160
Striped Killifish *Fundulus majalis*	Planktivore	CYD	Estuarine	9295	8.7441
Tessellated Darter *Etheostoma olmstedi*	Benthic	PED	Freshwater	425	0.3998
Threespine Stickleback *Gasterosteus aculeatus*	Planktivore	GAS	Estuarine	2	0.0019
White Catfish *Ictalurus catus*	Benthic	ICT	Freshwater	109	0.1025
White Sucker *Catostomus commersoni*	Benthic	CAT	Freshwater	1	0.0009
Yellow Perch *Perca flavescens*	Carnivore	PED	Freshwater	76	0.0715

Non-resident Species Reference Table and Codes

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Alewife *Alosa pseudoharengus*	Planktivore	CLU	Anadromous	830	0.7808
American eel *Anguilla rostrata*	Benthic	ANG	Marine	58	0.0546
American shad *Alosa sapidissima*	Planktivore	CLU	Anadromous	29	0.0273
Atlantic thread herring *Opistonema oglinum*	Planktivore	CLU	Marine	33	0.0310
Atlantic croaker *Micropogonias undulatus*	Benthic	SCI	Marine	2940	2.7658
Atlantic menhaden *Brevoortia tyrannus*	Planktivore	CLU	Marine	75232	70.7733
Atlantic needlefish *Strongylura marina*	Carnivore	BEL	Marine	376	0.3537
Atlantic spadefish *Chaetodipterus faber*	Benthic	EPH	Marine	1	0.0009
Blueback herring *Alosa aestivalis*	Planktivore	CLU	Anadromous	8688	8.1731
Bluefish *Pomatomus saltatrix*	Carnivore	POM	Marine	276	0.2596
Harvestfish *Peprilus alepidotus*	Carnivore	STR	Marine	134	0.1261
Inshore lizardfish *Synodus foetens*	Carnivore	SYD	Marine	44	0.0414
Ladyfish *Elops saurus*	Carnivore	ELO	Marine	1	0.0009
Northern puffer *Sphoeroides maculatus*	Benthic	TET	Marine	2	0.0019
Offshore tonguefish *Symphorus civitatus*	Planktivore	CYN	Marine	2	0.0019
Red drum *Sciaenops ocellatus*	Benthic	SCI	Marine	1	0.0009

SPECIES NAME	TROPHIC LEVEL	FAMILY	SPAWN LOCATION	CATCH	CPUE
Spanish mackerel *Scomberomorus maculatus*	Planktivore	SCO	Marine	22	0.0207
Spot *Leiostomus xanthurus*	Benthic	SCI	Marine	2170	2.0414
Striped bass *Morone saxatilis*	Carnivore	PER	Anadromous	2430	2.2860
Summer flounder *Paralichthys dentatus*	Carnivore	BOT	Marine	33	0.0310
Weakfish *Cynoscion regalis*	Carnivore	SCI	Marine	44	0.0414
White perch *Morone americana*	Carnivore	PER	Anadromous	7294	6.8617
Winter flounder *Pseudopleuronectes americanus*	Benthic	PLE	Marine	33	0.0310

Family Codes Included in Resident and Non-resident Species Tables

ANG	ANGUILLIDAE	(eel)
ATH	ATHERINIDAE	(silverside)
BAT	BATRACHOIDIDAE	(toadfishes)
BEL	BELONIDAE	(needlefish)
BLE	BLENNIIDAE	(blennies)
BOT	BOTHIDAE	(lefteye flounder)
CAT	CATOSTOMIDAE	(sucker)
CEN	CENTRARCHIDAE	(sunfish)
CLU	CLUPEIDAE	(herring)
CYD	CYPRINODONTIDAE	(killifish)
CYN	CYNOGLOSSIDAE	(tonguefish)
CYP	CYPRINIDAE	(minnow)
ELO	ELOPIDAE	(ten-pounder)
ENG	ENGRAULIDAE	(anchovies)
EPH	EPHIPPIDAE	(spadefish)
ESO	ESOCIDAE	(pike)
GAS	GASTEROSTEIDAE	(stickleback)
GOB	GOBIIDAE	(gobies)
GOS	GOBIESOCIDAE	(clingfish)
ICT	ICTALURIDAE	(catfish)
PED	PERCIDAE	(perch)
PER	PERCICHTHYIDAE	(temperate bass)
PLE	PLEURONECTIDAE	(righteye flounder)
POM	POMATOMIDAE	(bluefish)
SCI	SCIAENIDAE	(drum)
SCO	SCOMBRIDAE	(mackerel)
SOL	SOLEIDAE	(sole)
STR	STROMATEIDAE	(butterfish)
SYD	SYNODONTIDAE	(lizardfish)
SYN	SYNGNATHIDAE	(pipefish)
TET	TETRAODONTIDAE	(puffer)

APPENDIX II

Percentage of Watershed Acreage by Land Use Classification

LAND USE CATEGORY	ROCK CREEK	CURTIS CREEK	MAGOTHY RIVER	SEVERN RIVER	SOUTH RIVER	MATTAWOMAN CREEK	WICOMICO RIVER	FISHING BAY
LOW DENSITY SUBDIVISION	6.90	2.79	10.10	15.57	10.79	9.68	5.44	0.37
MEDIUM DENSITY SUBDIVISION	23.19	27.88	29.50	11.86	8.60	3.52	0.07	0.04
HIGH DENSITY SUBDIVISION	10.83	4.06	0.68	2.46	0.79	0.63	0.0	0.0002
COMMERCIAL	4.02	14.78	2.79	4.05	1.92	1.62	0.20	0.06
INDUSTRIAL	0.0	2.67	0.08	0.04	0.06	0.15	0.0	0.0
AGRICULTURE	3.47	4.29	5.13	9.68	17.23	13.65	29.98	6.25
FOREST	29.26	28.65	28.29	36.86	44.09	64.10	41.24	37.12
WATER	18.02	4.21	19.96	15.02	13.74	3.02	18.73	22.94
WETLAND	0.0	0.25	0.0	0.12	0.41	1.12	3.62	33.00
BARE	0.0	1.89	0.46	0.81	0.57	0.53	0.08	0.02
EXTRACTIVE	0.0	0.0	0.24	0.0	0.06	0.05	0.0	0.02
INSTITUTIONAL	1.95	5.80	2.12	2.12	0.96	1.57	0.005	0.11
OPEN URBAN	2.25	2.77	0.73	1.42	0.74	0.37	0.56	0.05

APPENDIX III Frequency of Capture and Total Catch for Each Species by River and Year

CURTIS CREEK

CURTIS CREEK	1989 FREQ.	1989 CATCH	1990 FREQ.	1990 CATCH	1991 FREQ.	1991 CATCH
	NO DATA COLLECTED					
ALEWIFE						
AMERICAN EEL						
AMERICAN SHAD						
ATLANTIC CROAKER						
ATLANTIC MENHADEN			2	3	7	68
ATLANTIC NEEDLEFISH			2	14	3	30
ATLANTIC SILVERSIDE			1	41		
ATLANTIC SPADEFISH			11	658	12	3236
ATL. THREAD HERRING						
BANDED KILLIFISH						
BAY ANCHOVY			3	21	6	101
BLACK CRAPPIE			2	333	3	31
BLUEBACK HERRING						
BLUEFISH						
BLUEGILL			3	5	5	7
BROWN BULLHEAD						
CARP						
CHAIN PICKERAL						
CHANNEL CATFISH					2	3
FEATHER BLENNY						
FOURSPINE STICKLEBACK						
GIZZARD SHAD						
GOLDEN SHINER					2	3
GOLDFISH						
GREEN GOBY						
HARVESTFISH						
HOGCHOKER						
INLAND SILVERSIDE						
INSHORE LIZARDFISH			12	336	11	173
LADYFISH						
LARGEMOUTH BASS						
MUMMICHOG						
NAKED GOBY			9	281	10	296
NORTHERN PIPEFISH					1	1
NORTHERN PUFFER			4	5	4	4
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED						
QUILLBACK			7	149	6	166
RAINWATER KILLIFISH						
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE						
SATINFIN SHINER					1	1
SEAWEED BLENNY						
SHEEPSHEAD MINNOW						
SILVERY MINNOW			1	6	2	3
SKILLETFISH						
SPANISH MACKEREL						
SPOT						
SPOTTAIL SHINER			8	17	6	27
STRIPED ANCHOVY						
STRIPED BASS						
STRIPED BLENNY			16	150	11	112
STRIPED KILLIFISH			2	2	2	2
SUMMER FLOUNDER			12	239	12	608
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH						
WHITE CATFISH						
WHITE PERCH						
WHITE SUCKER			2	2	2	11
WINTER FLOUNDER						
YELLOW PERCH			2	4		
			1	1		

1989 NO DATA COLLECTED

ROCK CREEK	1989 FREQ.	1989 CATCH	1990 FREQ.	1990 CATCH	1991 FREQ.	1991 CATCH
ALEWIFE						
AMERICAN EEL						
AMERICAN SHAD			1	1	9	125
ATLANTIC CROAKER			3	4247	2	81
ATLANTIC MENHADEN						
ATLANTIC NEEDLEFISH			12	533	12	1577
ATLANTIC SILVERSIDE						
ATLANTIC SPADEFISH						
ATL. THREAD HERRING			6	18	4	10
BANDED KILLIFISH			5	180	4	23
BAY ANCHOVY						
BLACK CRAPPIE						
BLUEBACK HERRING			2	2	2	2
BLUEFISH						
BLUEGILL						
BROWN BULLHEAD						
CARP					1	1
CHAIN PICKERAL						
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK					2	2
GIZZARD SHAD						
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH						
HOGCHOKER			11	270	9	72
INLAND SILVERSIDE						
INSHORE LIZARDFISH						
LADYFISH						
LARGEMOUTH BASS			3	21	7	77
MUMMICHOG						
NAKED GOBY			2	6	2	2
NORTHERN PIPEFISH						
NORTHERN PUFFER						
OFFSHORE TONGUEFISH					6	14
OYSTER TOADFISH						
PUMPKINSEED						
QUILLBACK						
RAINWATER KILLIFISH						
RED DRUM					1	2
REDFIN PICKERAL						
ROUGH SILVERSIDE						
SATINFIN SHINER						
SEAWEED BLENNY					2	3
SHEEPSHEAD MINNOW						
SILVERY MINNOW						
SKILLETFISH						
SPANISH MACKEREL			12	29	4	13
SPOT						
SPOTTAIL SHINER			1	3		
STRIPED ANCHOVY			15	128	13	90
STRIPED BASS					1	1
STRIPED BLENNY			11	50	12	336
STRIPED KILLIFISH					1	1
SUMMER FLOUNDER						
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH						
WHITE CATFISH			7	14	8	12
WHITE PERCH						
WHITE SUCKER			3	7		
WINTER FLOUNDER			2	7	2	3
YELLOW PERCH						

MAGOTHY RIVER	1989		1990		1991	
	FREQ.	CATCH	FREQ.	CATCH	FREQ.	CATCH
ALEWIFE	1	4				
AMERICAN EEL	1	1			1	1
AMERICAN SHAD						
ATLANTIC CROAKER					17	307
ATLANTIC MENHADEN	6	1781	4	7602	4	34
ATLANTIC NEEDLEFISH	2	2	3	3	2	3
ATLANTIC SILVERSIDE	23	641	25	1698	25	3900
ATLANTIC SPADEFISH						
ATL. THREAD HERRING					1	6
BANDED KILLIFISH	14	93	7	23	8	192
BAY ANCHOVY	37	3681	11	336	9	317
BLACK CRAPPIE						
BLUEBACK HERRING	3	19				
BLUEFISH	9	11	10	32	3	5
BLUEGILL	4	88				
BROWN BULLHEAD	9	138	2	3	4	24
CARP			1	1	2	5
CHAIN PICKERAL	3	7	4	7	3	7
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK			2	9		
GIZZARD SHAD	1	1				
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH						
HOGCHOKER	6	6	1	2		
INLAND SILVERSIDE	27	589	27	941	25	327
INSHORE LIZARDFISH						
LADYFISH						
LARGEMOUTH BASS			1	1	4	10
MUMMICHOG	9	132	13	87	11	143
NAKED GOBY	1	1				
NORTHERN PIPEFISH	12	27	7	11	4	4
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED	9	174	7	36	6	124
QUILLBACK						
RAINWATER KILLIFISH	1	1	1	1		
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE	2	4	1	2		
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW	15	92	1	1	3	3
SILVERY MINNOW						
SKILLETFISH						
SPANISH MACKEREL						
SPOT	18	41	18	161	21	106
SPOTTAIL SHINER						
STRIPED ANCHOVY	2	4	5	5	3	9
STRIPED BASS	14	20	21	111	30	642
STRIPED BLENNY	1	1				
STRIPED KILLIFISH	28	621	21	535	19	662
SUMMER FLOUNDER			1	1	1	2
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH						
WHITE CATFISH			1	1		
WHITE PERCH	4	7	4	8	7	12
WHITE SUCKER						
WINTER FLOUNDER			2	3		
YELLOW PERCH			2	4		

SEVERN RIVER	1989 FREQ.	1989 CATCH	1990 FREQ.	1990 CATCH	1991 FREQ.	1991 CATCH
ALEWIFE	1	1	1	1		
AMERICAN EEL	1	1	1	1		
AMERICAN SHAD						
ATLANTIC CROAKER	2	2	1	1	25	1089
ATLANTIC MENHADEN	7	7913	7	10573	1	1
ATLANTIC NEEDLEFISH	7	11	9	25	6	14
ATLANTIC SILVERSIDE	30	3348	31	2939	29	2871
ATLANTIC SPADEFISH						
ATL. THREAD HERRING						
BANDED KILLIFISH	3	21				
BAY ANCHOVY	18	992	16	448	15	146
BLACK CRAPPIE						
BLUEBACK HERRING	1	1				
BLUEFISH	13	221	8	26	4	4
BLUEGILL						
BROWN BULLHEAD						
CARP			2	2		
CHAIN PICKERAL					3	23
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK			6	11	2	18
GIZZARD SHAD	1	1	2	2		
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH						
HOGCHOKER	1	2	1	1		
INLAND SILVERSIDE	25	729	27	1113	23	324
INSHORE LIZARDFISH					4	6
LADYFISH						
LARGEMOUTH BASS						
MUMMICHOG	10	198	11	200	11	25
NAKED GOBY			2	4		
NORTHERN PIPEFISH	6	7	12	23	7	54
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH			1	2	1	1
PUMPKINSEED	3	8	7	7	1	1
QUILLBACK						
RAINWATER KILLIFISH			2	2		
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE	1	3	3	3		
SATINFIN SHINER						
SEAWEED BLENNY	1	1				
SHEEPSHEAD MINNOW	3	12	3	16		
SILVERY MINNOW						
SKILLETFISH	1	1			6	10
SPANISH MACKEREL						
SPOT	19	37	27	165	29	378
SPOTTAIL SHINER			1	1		
STRIPED ANCHOVY	1	1	12	53	3	11
STRIPED BASS	15	38	18	66	19	623
STRIPED BLENNY	1	2			4	4
STRIPED KILLIFISH	28	1214	27	805	29	552
SUMMER FLOUNDER	1	1			2	2
TESSELLATED DARTER						
THREESPINE STICKLEBACK	1	2				
WEAKFISH						
WHITE CATFISH						
WHITE PERCH						
WHITE SUCKER						
WINTER FLOUNDER			3	11		
YELLOW PERCH						

SOUTH RIVER	1989		1990		1991	
	FREQ.	CATCH	FREQ.	CATCH	FREQ.	CATCH
ALEWIFE	2	12			1	1
AMERICAN EEL			1	1	2	2
AMERICAN SHAD						
ATLANTIC CROAKER			6	7	34	1183
ATLANTIC MENHADEN	8	3598	18	26567	5	2122
ATLANTIC NEEDLEFISH	3	7	2	12	4	13
ATLANTIC SILVERSIDE	28	1562	29	1068	30	2210
ATLANTIC SPADEFISH						
ATL. THREAD HERRING					1	27
BANDED KILLIFISH	3	9	1	3	1	1
BAY ANCHOVY	25	1303	35	1629	25	1088
BLACK CRAPPIE						
BLUEBACK HERRING						
BLUEFISH	9	16	7	8	4	5
BLUEGILL						
BROWN BULLHEAD						
CARP	2	3	6	12	4	8
CHAIN PICKERAL						
CHANNEL CATFISH						
FEATHER BLENNY	1	1				
FOURSPINE STICKLEBACK	2	7	1	1		
GIZZARD SHAD	2	5	2	4	2	2
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH			3	3		
HOGCHOKER	9	21	4	21	2	4
INLAND SILVERSIDE	23	673	25	385	22	225
INSHORE LIZARDFISH					4	7
LADYFISH						
LARGEMOUTH BASS						
MUMMICHOG	16	159	13	79	11	78
NAKED GOBY	3	5	3	4		
NORTHERN PIPEFISH	8	9	6	10	5	12
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED	2	2				
QUILLBACK						
RAINWATER KILLIFISH						
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE	1	1	1	7	1	1
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW			2	2	1	1
SILVERY MINNOW						
SKILLETFISH					2	2
SPANISH MACKEREL			4	4		
SPOT	19	63	32	109	23	87
SPOTTAIL SHINER						
STRIPED ANCHOVY			11	30	6	8
STRIPED BASS	15	47	11	23	13	75
STRIPED BLENNY			3	3	1	1
STRIPED KILLIFISH	30	506	16	234	18	409
SUMMER FLOUNDER			2	6	3	3
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH			2	2		
WHITE CATFISH						
WHITE PERCH	1	1	3	5	2	30
WHITE SUCKER						
WINTER FLOUNDER			4	7		
YELLOW PERCH						

MATTAWOMAN CREEK	1989 FREQ.	1989 CATCH	1990 FREQ.	1990 CATCH	1991 FREQ.	1991 CATCH
ALEWIFE	26	295	21	191	18	323
AMERICAN EEL	5	7	5	7	5	28
AMERICAN SHAD	7	24	3	5		
ATLANTIC CROAKER					1	1
ATLANTIC MENHADEN	1	3	4	14	4	8
ATLANTIC NEEDLEFISH			1	1		
ATLANTIC SILVERSIDE	1	1				
ATLANTIC SPADEFISH						
ATL. THREAD HERRING						
BANDED KILLIFISH	20	74	27	171	21	193
BAY ANCHOVY	5	40	13	400	31	2302
BLACK CRAPPIE			1	2		
BLUEBACK HERRING	35	5734	32	1913	23	993
BLUEFISH					1	2
BLUEGILL	11	33	8	45	24	727
BROWN BULLHEAD	11	18	8	37	6	22
CARP			1	1	4	4
CHAIN PICKERAL			1	1		
CHANNEL CATFISH	4	11	14	56		
FEATHER BLENNY						
FOURSPINE STICKLEBACK						
GIZZARD SHAD	15	371	23	334	28	1231
GOLDEN SHINER	6	12	8	22	3	5
GOLDFISH	1	1			2	2
GREEN GOBY						
HARVESTFISH						
HOGCHOKER	3	3	2	2	2	3
INLAND SILVERSIDE	14	35	24	234	21	172
INSHORE LIZARDFISH						
LADYFISH						
LARGEMOUTH BASS			21	36	17	46
MUMMICHOG						
NAKED GOBY					1	1
NORTHERN PIPEFISH						
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED	38	145	29	151	27	207
QUILLBACK			1	1		
RAINWATER KILLIFISH						
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE			1	2		
SATINFIN SHINER					1	1
SEAWEED BLENNY						
SHEEPSHEAD MINNOW						
SILVERY MINNOW	14	114	24	557	16	362
SKILLETFISH						
SPANISH MACKEREL						
SPOT			9	17	5	14
SPOTTAIL SHINER	29	411	37	568	36	652
STRIPED ANCHOVY						
STRIPED BASS	11	27	22	113	9	33
STRIPED BLENNY						
STRIPED KILLIFISH						
SUMMER FLOUNDER						
TESSELLATED DARTER	26	141	28	110	24	152
THREESPINE STICKLEBACK						
WEAKFISH						
WHITE CATFISH			1	1		
WHITE PERCH	71	1493	82	2835	81	2406
WHITE SUCKER			1	1		
WINTER FLOUNDER						
YELLOW PERCH	10	13	11	16	11	17

WICOMICO RIVER	1989		1990		1991	
	FREQ.	CATCH	FREQ.	CATCH	FREQ.	CATCH
ALEWIFE					2	2
AMERICAN EEL	1	1	4	8		
AMERICAN SHAD						
ATLANTIC CROAKER					25	109
ATLANTIC MENHADEN	12	367	13	3186	19	6410
ATLANTIC NEEDLEFISH	12	165	11	32	9	20
ATLANTIC SILVERSIDE	27	4683	29	3223	33	10168
ATLANTIC SPADEFISH						
ATL. THREAD HERRING						
BANDED KILLIFISH	6	57	6	12	1	3
BAY ANCHOVY	36	5363	41	716	38	5395
BLACK CRAPPIE	1	2				
BLUEBACK HERRING	8	24	2	4		
BLUEFISH	10	16	3	7	2	3
BLUEGILL	3	45				
BROWN BULLHEAD	3	36				
CARP	8	19	2	4	1	1
CHAIN PICKERAL	2	4				
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK						
GIZZARD SHAD	12	104	3	23	5	16
GOLDEN SHINER	1	1				
GOLDFISH	1	1				
GREEN GOBY					1	1
HARVESTFISH			4	7	4	13
HOGCHOKER	12	26	7	71	9	16
INLAND SILVERSIDE	12	345	16	96	5	37
INSHORE LIZARDFISH						
LADYFISH					1	1
LARGEMOUTH BASS	1	1				
MUMMICHOG	22	548	21	938	18	517
NAKED GOBY	5	5	3	5	1	1
NORTHERN PIPEFISH	11	14	10	14	3	13
NORTHERN PUFFER						
OFFSHORE TONGUEFISH						
OYSTER TOADFISH						
PUMPKINSEED	15	436	11	52	2	3
QUILLBACK						
RAINWATER KILLIFISH			1	1		
RED DRUM					1	1
REDFIN PICKERAL						
ROUGH SILVERSIDE	1	2	5	7	3	5
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW	3	25			1	1
SILVERY MINNOW	1	2				
SKILLETFISH	3	4	3	14	7	35
SPANISH MACKEREL			4	4	3	9
SPOT	23	150	40	297	29	106
SPOTTAIL SHINER			1	2		
STRIPED ANCHOVY	3	4	9	71	1	2
STRIPED BASS	10	12	13	23	15	97
STRIPED BLENNY					1	1
STRIPED KILLIFISH	26	1047	30	631	26	733
SUMMER FLOUNDER			3	4	3	9
TESSELLATED DARTER	5	12	5	10		
THREESPINE STICKLEBACK						
WEAKFISH			2	2		
WHITE CATFISH	5	103	4	4		
WHITE PERCH	20	275	22	80	23	132
WHITE SUCKER						
WINTER FLOUNDER			1	1		
YELLOW PERCH	2	2	6	12	1	1

FISHING BAY	1989		1990		1991	
	FREQ.	CATCH	FREQ.	CATCH	FREQ.	CATCH
ALEWIFE	NO DATA COLLECTED					
AMERICAN EEL						
AMERICAN SHAD						
ATLANTIC CROAKER			1	8	4	7
ATLANTIC MENHADEN			9	680	1	1
ATLANTIC NEEDLEFISH			6	9	7	18
ATLANTIC SILVERSIDE			19	528	19	263
ATLANTIC SPADEFISH					1	1
ATL. THREAD HERRING						
BANDED KILLIFISH			1	12		
BAY ANCHOVY			31	2919	26	1752
BLACK CRAPPIE						
BLUEBACK HERRING						
BLUEFISH			2	2		
BLUEGILL						
BROWN BULLHEAD			1	1		
CARP						
CHAIN PICKERAL						
CHANNEL CATFISH						
FEATHER BLENNY						
FOURSPINE STICKLEBACK						
GIZZARD SHAD			1	1		
GOLDEN SHINER						
GOLDFISH						
GREEN GOBY						
HARVESTFISH			12	104	2	7
HOGCHOKER			9	46	13	178
INLAND SILVERSIDE			1	1		
INSHORE LIZARDFISH			8	14	10	17
LADYFISH						
LARGEMOUTH BASS						
MUMMICHOG						
NAKED GOBY			2	3		
NORTHERN PIPEFISH						
NORTHERN PUFFER			1	1	1	1
OFFSHORE TONGUEFISH					2	2
OYSTER TOADFISH			4	5		
PUMPKINSEED						
QUILLBACK						
RAINWATER KILLIFISH						
RED DRUM						
REDFIN PICKERAL						
ROUGH SILVERSIDE			9	85	2	19
SATINFIN SHINER						
SEAWEED BLENNY						
SHEEPSHEAD MINNOW						
SILVERY MINNOW						
SKILLETFISH					2	3
SPANISH MACKEREL			4	4	1	1
SPOT			21	134	24	219
SPOTTAIL SHINER						
STRIPED ANCHOVY			11	23		
STRIPED BASS						
STRIPED BLENNY						
STRIPED KILLIFISH			11	72	6	41
SUMMER FLOUNDER			1	3	1	1
TESSELLATED DARTER						
THREESPINE STICKLEBACK						
WEAKFISH			13	33	7	7
WHITE CATFISH						
WHITE PERCH						
WHITE SUCKER						
WINTER FLOUNDER						
YELLOW PERCH						